
**GREENHOUSE GAS EMISSIONS
INVENTORY OF SPAIN
1990-2007**

COMMUNICATION TO THE EUROPEAN COMISIÓN

(Decisions 2004/280/EC and 2005/166/EC)

**Ministry of Environment
and Rural and Marine Affairs**

Secretariat of State for Climate Change

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Assessment**

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EXECUTIVE SUMMARY

ES.1.- Base information on greenhouse gases and climate change inventories

The present document is the 2009 edition of the National Inventory Report (NIR) on greenhouse gases (GHG) 1990-2007 submitted by Spain to the Commission of the European Union, in accordance with the provisions of the Decisions of the European Parliament and Council 280/2004/EC and 2005/166/EC. The submission of the inventories is effected in line with the reporting guidelines reflected in document FCCC/SBSTA/2006/9 from the Secretariat for the Framework Convention on Climate Change (UNFCCC) to which Spain must also submit the NIR in accordance with the international commitments undertaken vis-à-vis that body. The presentation in electronic format of the inventory tables accompanying this report has been prepared using the software (CRF Reporter, version 3.2) designated for the purpose of completing the Common Reporting Format (CRF).

The information included in the CRF tables is given both in units of mass for each gas and carbon dioxide equivalents (CO₂-eq) for each of the substances considered in Appendix A to the Kyoto Protocol, which includes the following six direct greenhouse gases or groups of gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC); perfluorocarbons (PFC), and sulphur hexafluoride (SF₆). In addition, the tables show the estimated emissions of the following three indirect greenhouse gases: nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC), as well as the estimated emissions of sulphur oxides (SO_x), in terms of mass of each gas. Removals by sinks have been estimated with reference to CO₂ fixed as carbon in forests and grazing lands, also including emissions from forest fires.

This edition of the inventory updates (after review) some estimates given for the period 1990-2006 in the previous edition and also extends the time series to the year 2007. Where necessary, the review of the estimates of certain inventory items is the result of several factors, including: the revision of the underlying statistics and data, changes in estimating methodologies (selection of methods, factors and algorithms) as a result of an improved knowledge of emission-generating processes and, where necessary, the correction of detected errors.

The report is organized as a series of chapters and appendices. Following this initial chapter, the Executive Summary, are Chapters 1 to 8, Chapter 10¹ and Appendices 1 to 8. Chapter 1, "Introduction," offers a general overview of the objectives, elaboration procedures and the most relevant characteristics of the inventory. Chapter 2, "Greenhouse Gas Emission Trends", shows a general panorama of the evolution of emissions during the 1990-2007 inventory periods. The subsequent Chapters 3 to 8 of this Report contain a detailed presentation of each of the sectors in which the activities potentially emitting greenhouse

¹ The report does not include any chapter 9 "Others", as there is no specific content for such a chapter.

gases are grouped together: thus, Chapter 3 deals with Energy Sector sources, Chapter 4 with Industrial Processes (excluding combustion processes), Chapter 5 covers Solvent and Other Product Use sources, Chapter 6 Agriculture, Chapter 7 compiles information regarding emissions through source and absorption by sinks, categories related with Land Use, Land Use Change and Forestry, and Chapter 8 deals with Waste. Chapter 9, reserved for Other Activities, does not form part of this inventory as all the activities included there are covered in preceding chapters. The final chapter, Chapter 10, follows these sector chapters, and deals with the implementation of the inventory's New Calculations and Improvement Plans. Appendices 1 to 8 complement the report by compiling additional information and providing details not featured in the previous chapters. Specifically, Appendix 1 presents the methodology used for the assessment of key inventory sources. Appendix 2 refers to a detailed examination of the methodology and data for the CO₂ emissions estimates originating from fossil fuel combustion, though it refers to the corresponding sector chapters for a detailed explanation. Appendix 3 provides details of other methodological descriptions of individual category sources or sinks not included in Chapters 3 to 8. A comparison of the reference and sector approaches to CO₂ emissions estimates for fuels is presented in Appendix 4, as well as pertinent information on the national energy balance. Appendix 5 summarizes an assessment of the inventory's exhaustiveness with reference to the source categories not included in the estimates. Appendix 6 compiles additional information that should be considered part of the NIR submission, or which can serve as a useful reference. Appendix 7 presents an evaluation of the uncertainty of inventory emissions estimates, as well as a description of the methodology used for the same. Finally, Appendix 8, reserved for the purpose of highlighting other pertinent or voluntary information, contains for reference purposes the inventory's default information on CO₂ emission factors and lower heating values of fuels used in the absence of other more adequate specific information available in each case, for application of the Directive on Emissions Trading.

Sub-headings ES.2, ES.3 and ES.4 in this Executive Summary contain the following:
a) aggregated trends of emissions and absorptions, b) gas and sector emissions trends, and
c) other indirect greenhouse gas trends.

ES.2.- Summary of aggregate emission and absorption trends

To evaluate the impact greenhouse gas emissions (and absorptions) can have on global warming, emissions estimates are expressed as CO₂-equivalent, weighting those corresponding to each gas with the respective coefficients assigned for a time horizon of 100 years, in the Second Evaluation Report (1995) drafted by the Intergovernmental Panel on Climate Change (IPCC)². The period of years inventoried in this edition extends from 1990 to 2007. This period becomes the reference number (base year number) to examine the evolution over time of aggregated emissions (without taking into account those emissions/absorptions from "Land Use, Land Use Change and Forestry") becomes the officially approved number that is the basis for the calculation of the Assigned Amount in

² IPCC has published in 2001 and 2007 its Third and Fourth Evaluation Report on Climate Change, respectively. In these reports the estimation of the warming potential of greenhouse gases has been updated, although this update has not influenced the assessment of the commitments regarding the reduction of emissions by the countries that have already ratified the Kyoto Protocol.

Spain for assessing the fulfilment of the Kyoto Protocol³. The base year number was established after the verification (in 2007) of the Spanish inventory from the edition of 2006 (series 1990-2004), conducted by the team appointed by the FCCC Secretariat⁴.

Table ES.2.1 shows, both in absolute terms (gigagrammes of CO₂-eq) and as a time-based index (100 in the base year), the values corresponding to the total gross emissions (except for the "Land Use, Land Use Change and Forestry" section which are computed separately). Figures ES.2.1 and ES.2.2 show the graphic representation of the time index, illustrating the variation over time and the percentages of interannual variation of aggregate inventory emissions. As can be seen, the total emissions in 2007 are 52.6% higher than in the base year, a value that reduces to 48.6% when comparing the average of the last five years, 2003-2007, with the same base year⁵. Overall, the index has been marked by sustained growth in the period inventoried, except for the years 1993, 1996 and 2006 when reductions were recorded in comparison with the previous year.

Table ES.2.1.- Aggregate Emissions Evolution

Absolute values (Gg CO ₂ -eq)							
PK base year	1990	1995	2003	2004	2005	2006	2007
289,773.21	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56

Annual evolution index (base year = 100)								
PK base year	1990	1995	2003	2004	2005	2006	2007	Lustrum 2003-2007
100	99.4	110.1	14.6	147.0	152.2	149.5	152.6	148.6

³ The exact number chosen for the calculation of the assigned amount in the base year (PK base year) was 289,773,205.032 tonnes of CO₂-eq; and the assigned amount for the fulfilment of the commitment to the Kyoto Protocol for the 2008-2012 period is 1,666,195,929 tonnes of CO₂-eq.

⁴ For the estimation of the base year number, 1990 was taken as reference for CO₂, CH₄ and N₂O and 1995 for fluorinated gases such as HFC, PFC and SF₆. For this reason the base year is itself a hybrid of these two years and does not correspond to a specific calendar year.

⁵ The comparison of the 2002-2006 five-year average with the base year is similar to what will have to be done in the period 2008-2012 taking 2010 as the representative value for comparison with the base year.

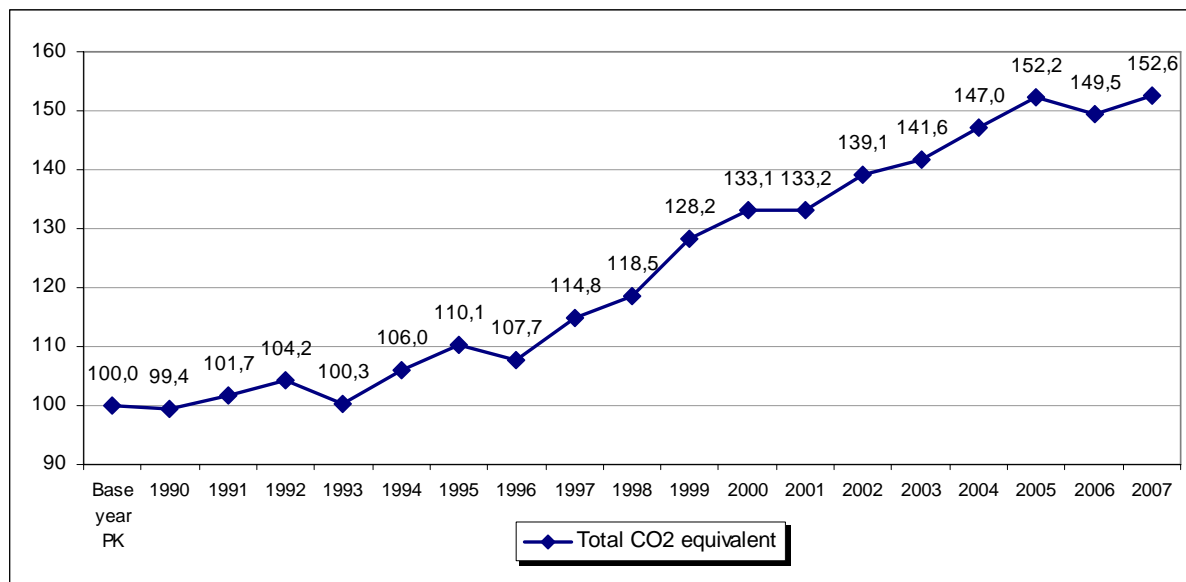
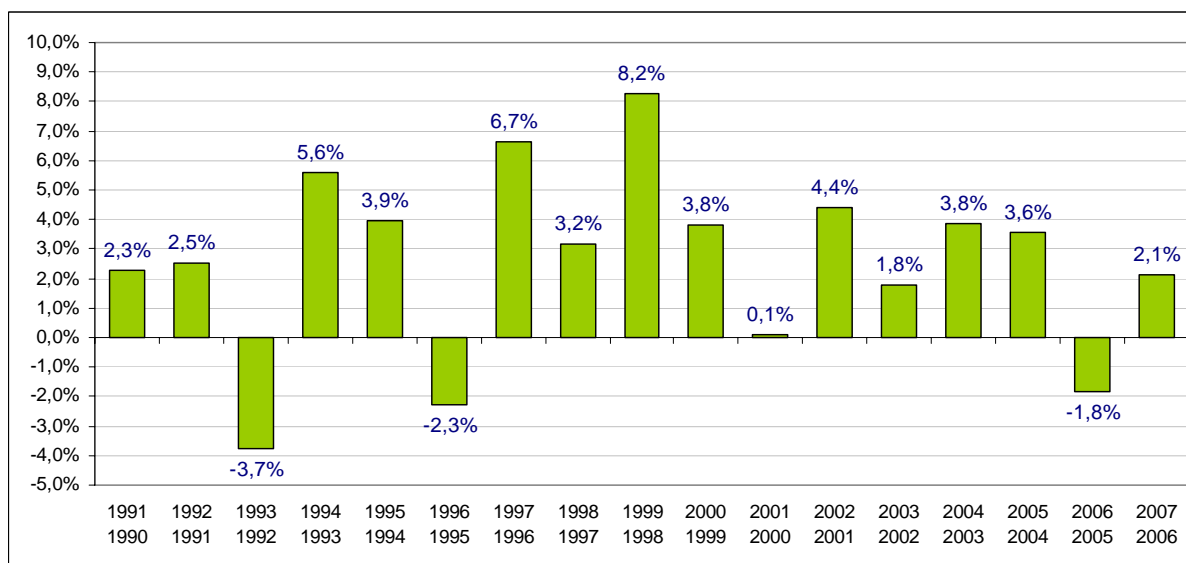
Figure ES.2.1.- Aggregate emissions evolution index**Figure ES.2.2.- Interannual variation (percentage)**

Table ES.2.2 shows, in the upper block, the values corresponding to net carbon absorptions, expressed in Gg of CO₂ (shown with negative signs) arising from “Land Use, Land Use Change and Forestry” activities; and, in the lower block, the time-based index for these absorptions using 1990 as the base year. Figure ES.2.3 shows the table for this latter index concerning all the years of the inventory period. By observing previous data, it is concluded that CO₂ net absorptions in 2007 vary by 30.5% over the year 1990 as opposed to the 28.9% of the average of the last quinquennium (2003-2007). Overall, the index’s evolution presents three differentiated periods: one corresponding to the years 1990-1993

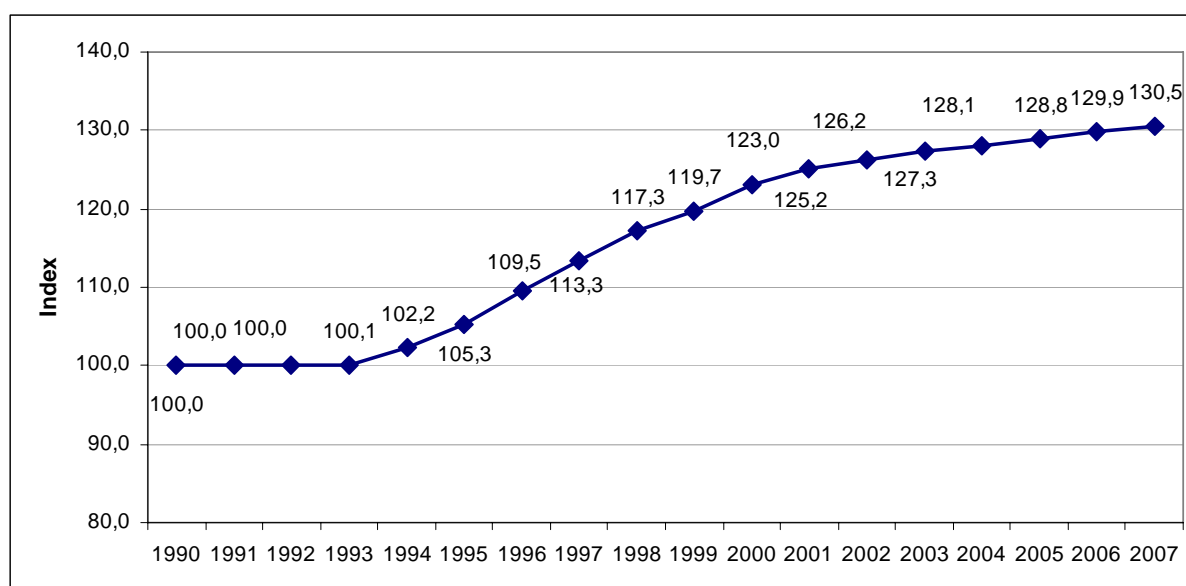
with a constant annual absorption determined by the forest land that historically remains forest land; another corresponding to the years 1994-2001, where a significant contribution of croplands that have been reforested and a much smaller contribution (but arithmetically increasing) of croplands converted to grasslands is added to the previous component; and the period from 2002 to 2007, when the absorption growth rate of croplands converted to grasslands is maintained while the more important contribution of croplands converted to forests is tempered.

Table ES.2.2.- Trends in net absorptions

Absolute values (Gg CO ₂ -eq)						
1990	1995	2003	2004	2005	2006	2007
21,479	22,615	27,346	27,518	27,675	27,908	28,035

Annual evolution index (base year = 100)							
1990	1995	2003	2004	2005	2006	2007	Lustrum 2003-2007
100.0	105.3	127.3	128.1	128.8	129.9	130.5	128.9

Figure ES.2.3.- Evolution index of net absorptions



ES.3.- Summary of emissions trends by gas and sector

Table ES.3.1 compiles emissions estimates by type of gas (except for those emissions/absorptions corresponding to the "Land Use, Land Use Change and Forestry" section since these are assessed separately) for the six groups or gases already indicated as having a direct effect on global warming: CO₂, CH₄, N₂O, HFC, PFC and SF₆. The upper part of the table illustrates emissions in absolute terms (Gg CO₂-eq); in the centre, the percentage contribution to gross total CO₂-eq emissions in the inventory as a whole; and in the lower

section, the evolution in time index terms (100 in 1990 for CO₂, CH₄ and N₂O; 1995 = 100 for fluorinated gases).

Table ES.3.1. Emissions evolution by type of gas

Amounts in Gg CO ₂ -eq							
GAS	1990	1995	2003	2004	2005	2006	2007
CO ₂	228,446.83	255,255.70	334,020.63	351,384.17	367,996.87	358,418.06	366,366.37
CH ₄	28,587.41	31,819.76	38,336.36	38,071.42	37,944.16	38,510.51	39,058.70
N ₂ O	27,747.40	26,504.20	32,392.92	31,356.97	29,687.34	30,020.30	30,470.38
HFC	2,403.18	4,645.44	5,032.78	4,679.87	5,006.09	5,549.63	5,837.02
PFC	882.92	832.51	267.31	272.04	244.41	247.63	249.12
SF ₆	66.92	108.34	207.66	254.00	271.63	323.62	339.97
TOTAL GASES	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56

Percentage of the total CO ₂ -eq in the inventory							
GAS	1990	1995	2003	2004	2005	2006	2007
CO ₂	79.28	79.98	81.42	82.48	83.42	82.76	82.83
CH ₄	9.92	9.97	9.34	8.94	8.60	8.89	8.83
N ₂ O	9.63	8.30	7.90	7.36	6.73	6.93	6.89
HFC	0.83	1.46	1.23	1.10	1.13	1.28	1.32
PFC	0.31	0.26	0.07	0.06	0.06	0.06	0.06
SF ₆	0.02	0.03	0.05	0.06	0.06	0.07	0.08
TOTAL GASES	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Annual evolution index (1990 = 100)							
GAS	1990	1995	2003	2004	2005	2006	2007
CO ₂	100.0	111.7	146.2	153.8	161.1	156.9	160.4
CH ₄	100.0	111.3	134.1	133.2	132.7	134.7	136.6
N ₂ O	100.0	95.5	116.7	113.0	107.0	108.2	109.8
HFC	51.7	100.0	108.3	100.7	107.8	119.5	125.7
PFC	106.1	100.0	32.1	32.7	29.4	29.7	29.9
SF ₆	61.8	100.0	191.7	234.4	250.7	298.7	313.8

On examining the types of gas, Table ES.3.1, it is noteworthy that carbon dioxide stood out as the dominant component, contributing approximately 80% (range between 79.3 and 82.8). The gases occupying the next two positions are methane and nitrous oxide, with contributions relatively similar but generally larger for methane, which goes from 9.9% to 8.8% from 1990 to 2007, while nitrous oxide slips from 9.6% to 6.9% over the same period. Taken together, fluorinated gases appear with a range of between 1.0% (1991) and 2.3% (2000) for the whole inventoried period.

Table ES.3.2 shows the emission estimates by activity sector, distinguishing the following groups from the IPCC nomenclature: Energy, Industrial Processes, Use of Solvents and Other Products, Agriculture, and Waste. The calculation of the emissions/absorptions⁶ in Section 5 "Land Use, Land Use Change and Forestry" are not included here, as reflected in heading ES.2. The upper part of the table illustrates emissions in absolute terms (Gg CO₂-

⁶ The negative pro-memoria values indicated for the Land Use, Land Use Change and Forestry group correspond to net absorptions of CO₂-eq (absorptions of CO₂ by carbon fixing minus CH₄ and N₂O emissions in forest fires) for this group.

eq); in the centre, the percentage contribution of gross total CO₂-eq emissions, and in the lower section, the evolution in time index terms (100 in the base year) for each group considered.

Table ES.3.2.- Emissions evolution by activity sector

Absolute values (Gg CO ₂ -equivalent)							
SECTOR	1990	1995	2003	2004	2005	2006	2007
1. Energy processing	212,465.02	240,705.53	314,441.60	331,500.24	347,308.80	337,170.02	345,391.32
2. Industrial processes	26,314.29	27,411.17	32,722.32	32,860.15	34,321.67	35,007.86	34,852.48
3. Use of solvents and other products	1,387.85	1,343.58	1,596.23	1,517.91	1,481.74	1,517.27	1,674.20
4. Agriculture	40,330.18	39,877.02	48,323.12	47,191.80	44,878.13	45,817.68	46,425.65
6. Waste treatment and disposal	7,637.31	9,828.64	13,174.38	12,948.35	13,160.16	13,556.93	13,977.90
TOTAL SECTORS	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56
5. Land Use Change and Forestry	-21,290.92	-22,456.81	-27,190.82	-27,392.72	-27,415.09	-27,344.98	-27,996.96

Contribution to the total CO ₂ -eq of the inventory							
SECTOR	1990	1995	2003	2004	2005	2006	2007
1. Energy processing	73.7	75.4	76.6	77.8	78.7	77.9	78.1
2. Industrial processes	9.1	8.6	8.0	7.7	7.8	8.1	7.9
3. Use of solvents and other products	0.5	0.4	0.4	0.4	0.3	0.4	0.4
4. Agriculture	14.0	12.5	11.8	11.1	10.2	10.6	10.5
6. Waste treatment and disposal	2.7	3.1	3.2	3.0	3.0	3.1	3.2
TOTAL SECTORS	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Annual evolution index (1990 = 100)							
SECTOR	1990	1995	2003	2004	2005	2006	2007
1. Energy processing	100.0	113.3	148.0	156.0	163.5	158.7	162.6
2. Industrial processes	100.0	104.2	124.4	124.9	130.4	133.0	132.4
3. Use of solvents and other products	100.0	96.8	115.0	109.4	106.8	109.3	120.6
4. Agriculture	100.0	98.9	119.8	117.0	111.3	113.6	115.1
6. Waste treatment and disposal	100.0	128.7	172.5	169.5	172.3	177.5	183.0
TOTAL SECTORS	100,0	110,8	140,0	142,6	148,1	153,3	150,6

Examining the results by activity sector, the dominant contribution of the Energy group stands out in first place, ranging between 73.7% in 1990 and 78.1% in 2007. It should be remembered that this group, apart from the emissions from fixed and mobile combustion sources, contains the evaporation emissions from fuel mining, transport and distribution activities, which are also relevant for gases other than CO₂, such as CH₄. In second place and at quite a distance from the previous group sits the Agriculture group, with quotas varying between 14.0% for 1990 and 10.5% in 2007. Third place is held by Industrial Processes (excluding combustion activities that are included in the Energy section), whose contribution declines from 9.1% in 1990 to 7.9% in 2007. The Waste group shows an overall upward trend, albeit with variations, ranging between 2.7% in 1990 and 3.2% in 2007, with slightly higher levels in intermediate years. Finally, the Use of Solvents and Other Products section presents a marginal contribution of between 0.3% and 0.5% of the total.

ES.4.- Evolution of other indirect GHG and aerosol formation

Table ES.4.1 illustrates the emissions' estimates of four gases (NO_x, CO, NMVOC and SO₂), each expressed in the top portion of the table in Gg for the corresponding gas, and in the lower section as a time index (1990 = 100).

Table ES.4.1.- Evolution of NO_x, CO, NMVOC and SO₂ emissions

Absolute values (Gg)							
GAS	1990	1995	2002	2003	2004	2005	2006
NO _x	1,231.39	1,333.80	1,480.42	1,482.69	1,513.41	1,514.63	1,466.08
CO	3,882.79	3,475.37	2,738.79	2,821.44	2,716.57	2,530.46	2,432.83
NMVOC	1,094.42	1,030.35	1,022.43	1,038.82	1,027.25	989.94	964.61
SO ₂	2,168.72	1,786.16	1,535.65	1,269.79	1,312.34	1,264.45	1,169.66

Annual evolution index (1990 = 100)							
GAS	1990	1995	2002	2003	2004	2005	2006
NO _x	100.0	108.3	120.2	120.4	122.9	123.0	119.1
CO	100.0	89.5	70.5	72.7	70.0	65.2	62.7
NMVOC	100.0	94.1	93.4	94.9	93.9	90.5	88.1
SO ₂	100.0	82.4	70.8	58.6	60.5	58.3	53.9

1.- INTRODUCTION

1.1.- Base information regarding greenhouse gas inventories and climate change

The present document is the edition corresponding to 2009 of the National Inventory Report (NIR) 1990-2007 on Greenhouse Gases (GHG) submitted by Spain to the Commission of the European Union, in accordance with the stipulations contained in Decisions 280/2004/EC and 2005/166/EC of the European Parliament and the European Council. The submission of the inventories is effected in line with the reporting guidelines reflected in document FCCC/SBSTA/2006/9 from the Secretariat for the Framework Convention on Climate Change (UNFCCC) to which Spain must also submit the NIR in accordance with the international commitments undertaken vis-à-vis that body. The presentation in electronic format of the inventory tables accompanying this report has been prepared using the software (CRF Reporter) designated for the purpose of completing the Common Reporting Format (CRF).

On the other hand, bearing in mind that Spain must report on the same subject to both the EU Commission and the Secretariat for the Framework Convention on Climate Change, there is an obvious need to ensure that the format and contents of the information contained in the inventories is shared by submissions to both international authorities, an assurance given by the common structure adopted in the Spanish inventory to be submitted to both institutions. This common format is established in the aforementioned UNFCCC document and includes the NIR and CRF tables.

The Directorate-General for Environmental Quality and Evaluation is the National Authority for the Air Pollutant Emissions Inventory System in accordance with Ministerial Order MAM/1444/2006 dated May 9th, 2006. Moreover, Article 27.4 of Rule 34/2007 dated November 15th, 2007, for Air Quality and Environmental Protection stipulates that, for the preparation and periodical updating of the inventory, the Government must enact the regulations for a National Inventory System in accordance with the existing international guidelines. Within the Directorate-General for Environmental Quality and Environmental Assessment, the Sub-Directorate-General for Air Quality and Industrial Environment is the department assigned to elaborate the inventory and to process the information collected from different sources.

With regard to the substances covered by the inventory, information included in the CRF tables is given both in units of mass for each gas and carbon dioxide equivalents (CO₂-e) for each of the substances considered in Appendix A to the Kyoto Protocol, which includes the following six direct greenhouse gases or groups of gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide, (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulfur hexafluoride (SF₆). In addition, the tables show the estimated emissions of the following three indirect greenhouse gases: nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC), as well as the estimated emissions of sulphur oxides (SO_x), in terms of mass of each gas for these four substances. Absorption emissions by sinks have been estimated within category 5 of IPCC's "Land Use, Land-use Change and

Forestry”, with respect to the CO₂ fixed as carbon by forest systems and the grasslands, including also in this category 5 of the IPCC, the CH₄, N₂O, NO_x and CO emissions from forest fires.

This edition of the inventory updates, revising where necessary, the estimates given for the period 1990-2006 in the previous edition, at the same time as it extends the time series to the year 2007. If necessary, revision of the estimates for certain inventory items is the result of several factors, including: a) revision of the underlying statistics and data, b) changes in estimating methodologies (selection of methods, factors and algorithms) as a result of an improved knowledge of emission-generating processes, and c) where necessary, the correction of detected errors.

The periodical preparation of air pollutant emission inventories began in Spain two decades ago in order to comply with information commitments agreed to in the European Union within the framework of several International Conventions, as well as to serve as an essential source of information for an awareness of the status of the environment and the design and review of environmental policies and measures, particularly those referring to the atmosphere. They also provide background information for the preparation of the National Statistics Institute’s environmental accounts and the Inventory is integrated within the National Statistical Plan with a specifically assigned statistical operation number.

Today, data from the national inventory allow the country to meet information obligations and needs resulting from the international commitments summarized in Chart 1.1.1:

Chart 1.1.1.- Summary of international information commitments regarding emission inventories

- | |
|--|
| <ul style="list-style-type: none"> - Geneva Convention on Long-Range Transboundary Air Pollution and its Protocols. Annual report and estimate of acidifying pollutant and ozone precursor emissions, heavy metals, particles and persistent organic pollutants. - United Nations Framework Convention on Climate Change and Kyoto Protocol. Annual report and estimate of greenhouse gas emissions. - European Union: <ul style="list-style-type: none"> o Directive 2001/81/EC of the European Parliament and of the Council dated October 23rd, 2001, on national emission ceilings for certain air pollutants. Annual report and estimate of sulphur dioxide, nitrogen oxide, volatile organic compound and ammonia emissions. o Decision 280/2004/EC (and Decision 2005/166/CE on the procedures for its application) of the European Parliament and of the Council dated February 11th, 2004, concerning a mechanism for monitoring greenhouse gas emissions in the EU and for implementing the Kyoto Protocol. Annual report and emissions estimates. |
|--|

In order to meet these obligations, one fundamental condition that must be respected is that inventories be prepared at all times in accordance with the required criteria. This makes it necessary to subject inventories and their preparation procedure to a continuous process of improvement and readjustment as new guidelines and methodologies develop in each case.

As provided for in the Kyoto Protocol, Article 5.1 and in accordance with Decision 280/2004/EC, of the European Parliament and the Council regarding a mechanism for monitoring the emissions of greenhouse gases in the Community and for application of Article 4.4 of the Kyoto Protocol, the Member States must establish, by December 31st, 2005, at the latest, a National Inventory System for the estimation of anthropogenic emissions of greenhouse gases by sources and the absorption of carbon dioxide by sinks.

Spain has set up the needed legal framework to implement all the institutional, legal and procedural arrangements necessary to be able to comply with the functions described in the regulatory guidelines so as to ensure transparency, consistency, comparability, completeness, and accuracy of inventories and has allocated the necessary resources for the timely performance of all these functions. This legal framework (detailed in section 1.2) can be resumed, as already stated in previous paragraphs, in the approval, in the last few years, of the following instruments: Law 34/2007 for Air Quality and Environmental Protection (which establish the obligation to prepare and periodically update a National Inventory System), the Ministerial Order MAM/1444/2006 where the Directorate-General for Environmental Quality and Evaluation is designated as the National Authority of the National Air Pollutant Emissions Inventory System and the Government's Delegated Committee for Economic Affairs (February 2007) where the mechanism to obtain the information to implement in Spain the National Inventory System for Pollutant Emissions into the Atmosphere are established.

In addition, although the requirements set for the preparation of the NIS on greenhouse gases are stricter than those applied for the rest of the air emissions inventories, Spain has not limited itself to applying the NIS solely to the drafting of the inventories regarding the Kyoto Protocol but rather, for reasons of consistency, optimization of resources and efficacy, it has opted to develop an NIS that covers all the obligations mentioned in Chart 1.1.1. Therefore, all of the institutional, legal and procedural arrangements referred to in this document must be understood as applicable to the preparation of all pollutant emission inventories listed in Chart 1.1.1.

1.2.- Description of the institutional arrangements adopted to prepare the inventory

1.2.1.- Regulatory framework

The air pollutant emissions inventories are considered to be statistics for State purposes and as such, in accordance with article 149.1.31 of the Spanish Constitution, are performed on the basis of the exclusive responsibility of the State for the preparation of statistics for State purposes. In this sense, the regulatory frame of reference is provided by the Spanish Public Statistical Function Act (Law 12 dated May 9th, 1989) and by the 2005-2008 National Statistical Plan, approved by Royal Decree 1911 dated September 17th, 2004. The National Statistical Plan for 2005-2008 includes, within the environment sector and under statistical operation number 4710, the "Inventory of Air Pollution Emissions". The inclusion of the air pollutants emissions inventory entails as a statistical operation: the obligation to provide the NIS with the information required for its compilation, with the

protection of statistical secrecy and guarantee of continuity of the NIS itself within the framework of the National Statistical Plan.¹

With regard to data collection, the aforesaid Law 12/1989 establishes two different regimes for the regulation of statistics depending on whether data are demanded in a compulsory manner or individuals are free to provide information voluntarily. Since they form part of the National Statistical Plan and their preparation represents an obligation for the Spanish State, among other reasons, in accordance with the international commitments undertaken and particularly those affecting the European Union, emissions inventories fall into the first of these two regimes, i.e., the submission of data by individuals is compulsory.

The Directorate-General for Environmental Quality and Evaluation requests the Ministerial Departments and public bodies with sectoral authority over activities generating air pollutant emissions, to provide the necessary information in accordance with the procedure set out in that resolution. To this end, the Directorate-General for Environmental Quality has prepared a Guide to Institutional Information Requirements (hereinafter Guide) specifying the kind of data to be requested from the different Departments and bodies, so that they can incorporate the pertinent procedures into their respective Statistical Plans in order to have this information available. This Guide will be updated on a regular basis, particularly when there are changes in the methodology for drawing up the Inventory or in the levels of detail required to update the data time series in order to remain consistent over time.

1.2.2.- Single national entity

In accordance with the provisions of NIS guidelines, each State must designate a single national entity with overall responsibility for the inventory. Although Spain already had an executive centre in charge of preparing inventories, and in accordance with that already stated in the previous paragraph, in order to comply specifically with the NIS requirements, the Ministry of the Environment order MAM/1444/2006, dated May 9th, 2006, designated the Directorate-General for Environmental Quality and Evaluation at the Ministry of the Environment as the National Authority for the National Air Pollutant Emissions Inventory System.

1.2.3.-Institutional arrangements

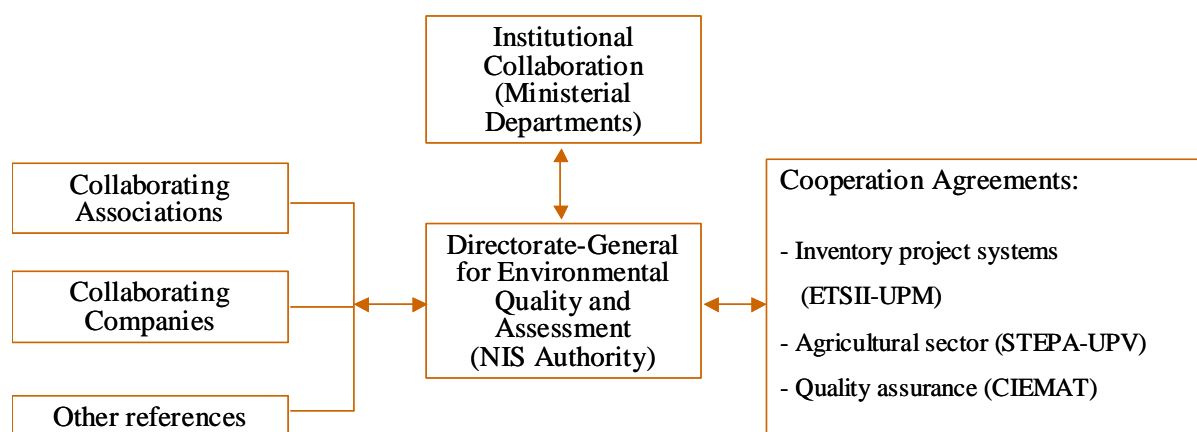
While the existence of an entity assuming overall responsibility for the inventory is indispensable, it is evident that, given the high number and complexity of tasks involved in inventory preparation, the participation of many different offices is also essential in its planning, development and approval.

The Directorate-General for Environmental Quality and Evaluation is the National Authority for the National Air Pollutant Emissions Inventory System (Ministerial Order

¹ The continuity of the Inventory, as an integral part of the National Statistical Plan, has been already included in Royal Decree 1663/2008 approving the 2009-2012 National Statistical Plan and allocating statistical operation number 5713 to the Inventory.

MAM/1444/2006). To develop these functions, the Directorate-General for Environmental Quality and Evaluation relies on the Technical Assistance of AED-NDS-TWOBE to supply technical support in the execution tasks and in the general development of the Inventory. To support the development and implementation of NIS, the DGCEA has also established that cooperation agreements with different entities, principally, research institutes and university departments, among them: ETSII-UPM² for Inventory project systems; STEPA-UPV³ for the agricultural sector; and CIEMAT⁴ for quality control procedures and especially in the energy sector⁵. Figure 1.2.1 presents the core of coordinating resources used by DGCEA for the NIS.

Figure 1.2.1.-DGCEA's coordinating resources for NIS



Furthermore, in the various thematic contexts, working groups have been set up with different bodies. The most significant working groups and meeting fora in Figure 1.2.2 are as follows:

- For Agriculture and Livestock (GT-INV-AG) to address specific aspects of these two sub-sectors and composed of representatives from the Ministry of Environment and Rural and Marine Environment, and the co-operation of experts in the field.
- Land Uses and Climatic Change (GT-USCC) for the improvement of estimations in the sector-equivalent CRF (Land Use, Land Use Change and Forestry) with the co-operation of the Ministry of the Environment and Rural and Marine Affairs, and the Ministry of Public Works, with the co-operation of experts in the field.
- The co-ordination of technical aspects with the Regions regarding methodological elements and base information for the inventories.

² Industrial Engineering Technical School -Polytechnic University in Madrid

³ Systems and Technology of Animal Production – Valencia Polytechnic University

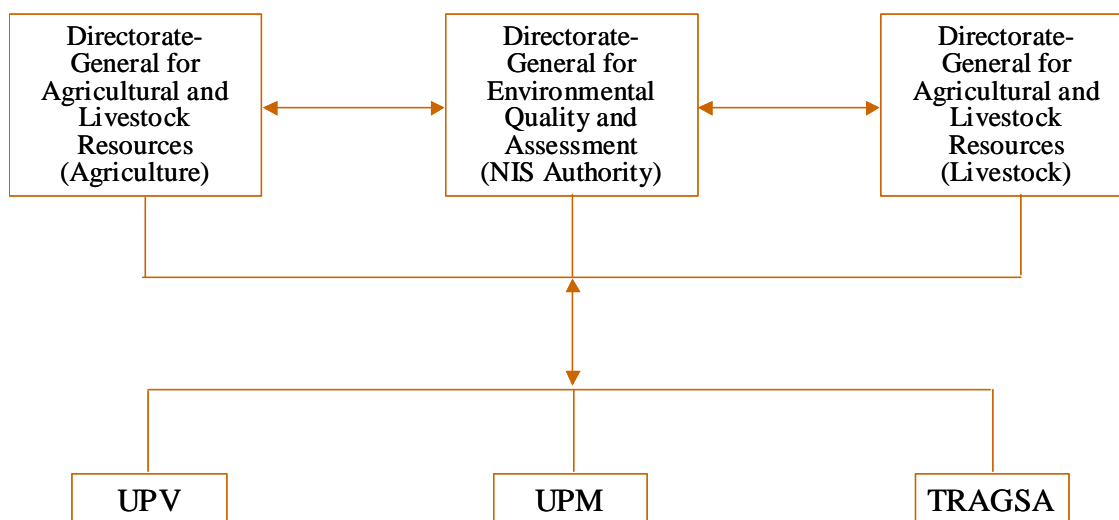
⁴ CIEMAT (Research Centre for Energy, Environment and Technology).

⁵ Collaboration contract with CIEMAT for the years 2007 and 2008.

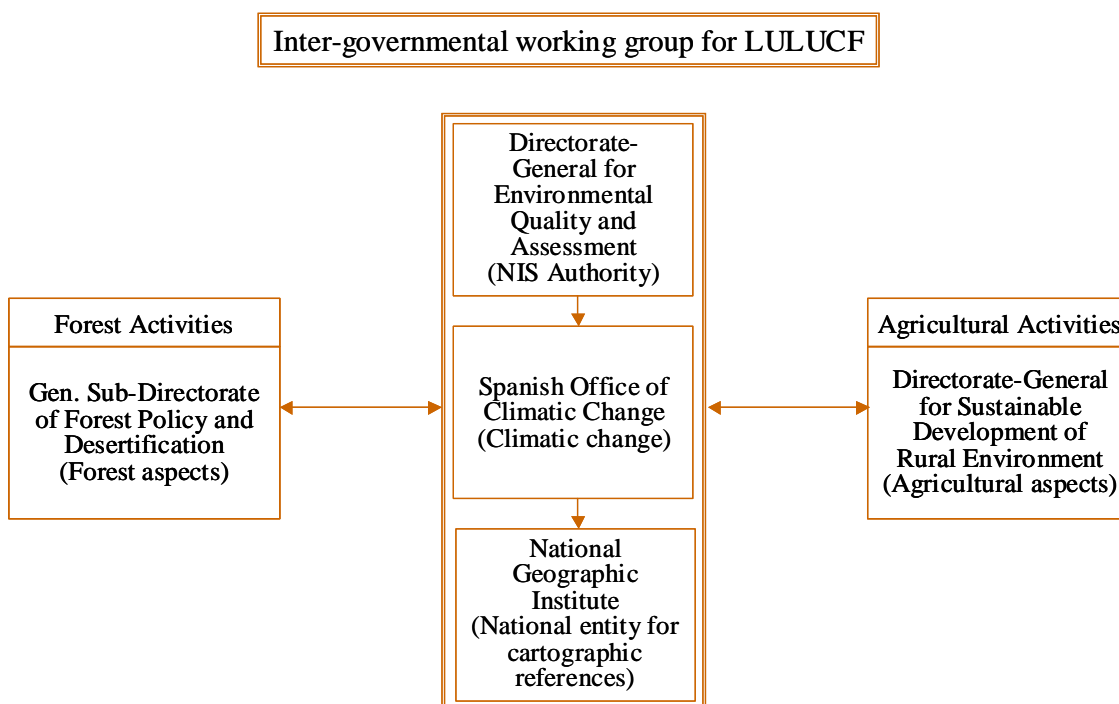
- The forum newly created in 2008 to contrast disaggregation issues in the National Inventory by Regions holds sectoral meetings (to deal with specific subjects in a particular sector) as well as bilateral meetings (to deal with subjects relating to a specific Region). These meetings are attended by the inventory team as well as by representatives from the Inventories area of the Regional Governments.

Figure 1.2.2.-Working groups

Inter-governmental working group for Agriculture-Livestock



Inter-governmental working group for “Land-use changes”



```
graph LR; A["DGCEA  
National Inventory"] <--> B["GT  
- Coordinator  
- Andalucía government  
- Members of the  
working group"]; B <--> C["GT  
Regional  
Inventories"]
```

The diagram illustrates the relationship between three entities:

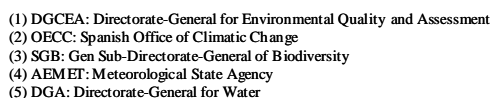
- DGCEA National Inventory** (left box)
- GT** (middle box), which includes:
 - Coordinator
 - Andalucía government
 - Members of the working group
- GT Regional Inventories** (right box)

Double-headed arrows indicate a reciprocal relationship between DGCEA National Inventory and the GT entity, and between the GT entity and GT Regional Inventories.

```
graph LR; DGCEA[DGCEA  
National Inventory  
with economic  
disaggregation] <--> Forum[Forum Contrasting  
Disaggregation by  
Autonomous Community of  
the National Inventory vs  
Autonomous Community  
Inventories]; Forum <--> CCAA[CCAA  
Autonomous  
Community  
Inventories];
```

The diagram illustrates the relationship between three entities: DGCEA, Forum Contrasting Disaggregation, and CCAA. DGCEA is represented by a box containing the text "DGCEA" and "National Inventory with economic disaggregation". The Forum is represented by a box containing the text "Forum Contrasting Disaggregation by Autonomous Community of the National Inventory vs Autonomous Community Inventories". CCAA is represented by a box containing the text "CCAA" and "Autonomous Community Inventories". Double-headed arrows connect DGCEA to the Forum, and the Forum to CCAA, indicating a reciprocal relationship between them.

Figure 1.2.3.-Participation of ministerial departments in the NIS



1.3.- Inventory drafting process

The national emissions inventory is conceived as a single inventory that can be presented in a variety of output formats. One of these formats corresponds to the presentation of greenhouse gas emissions for both the European Commission and the Framework Convention on Climate Change Secretariat.

The inventory drafting process takes place over the course of a series of stages which include: Identification of key categories, selection methods, the compilation of data, information processing, results presentation and uncertainty analysis, and Inventory validation. These stages are described in the subparagraphs below.

1.3.1.- Identification of key categories

The primary objective in this stage is to establish the relative priority of the source and sink categories in terms of their contribution to the emissions and absorptions for the whole Inventory. An ulterior objective is the assistance in optimizing resource allocation to improve accuracy and precision of the Inventory by means of identifying and prioritizing efforts to improve the estimation of those categories, designated *key categories*⁶; focusing on the Inventory's absolute level or estimated emissions trends, weighting, when possible said level or trend by the emission's estimation uncertainty of the corresponding category.

The following Section 1.5 of this chapter gives specific details on this process and the results of identifying key categories.

1.3.2.- Selection methods for estimating emissions

The objective of this phase is selecting which estimation methods will be employed in the Inventory for each source and sink category. This stage includes the initial selection of a category not previously considered, as well as the selection of the revised method for those categories where a methodological change is introduced to an existing method. The deciding factors in this process include: the preliminary feasibility analysis on all the available methodologies (availability of required information, effective practice of estimation algorithm), and the cost-effective analysis of the required resources (development, implementation and maintenance resources) and the benefits, in terms of forecast and accuracy, associated to this methodology-category for the entire Inventory.

Selection method criteria

The estimation method for emissions depends on the nature of the activity considered, and in this aspect, particularly whether or not it is considered a key category and the availability of the base information. The selection method is aimed at determining the most

⁶ IPCC Good Practices Guidance 2000 defines a key category if it (emission source or sink) can exert a major influence in the Inventory's global estimation, whether by absolute value or series trend.

exact and accurate results of the emissions for each case activity studied with a long-term improvement plan of going to increasingly advanced tiers.

For the selection of emissions estimation methods, the principal sources of general reference are used, such as the IPCC Guides, EMEP-CORINAIR Handbook, the EPA's AP-42 Guide, other secondary resource references, and of course, the country's methodologies (country-specific advanced tiers) which are given greater priority than those in the general references.

Types of methods

The selection of methodology conforms to some of the following types of established classification methods.

- I) Methods based on observed emission data.
 - a. On-going measurement.
 - b. Measurements at regular intervals.
- II) Methods based on calculation procedures
 - a. Balance of materials
 - b. Modelling/correlation
 - c. Emission factor

Review of methodologies

An examination is conducted, focusing on those methodologies associated with major categories as the main targets for improved approaches (tier advance). For non-key categories a rotating examination is established such that on a tri-annual basis an analysis on methodology improvements is conducted on all of them.

1.3.3.- Data compilation

The objective of this phase is the compilation of data required on activity parameters and variables, algorithm information and emission factors, and if necessary on measured or estimated emissions; and, in general, pertinent information on the selected methods per activity.

The starting point for the compilation of activity data is:

- The nomenclature for activities and pollutants and the selection method of emission estimation.
- The identification of entities or sources of information related with each nomenclature activity.

A content request covering activity variables and parameters, and where appropriate the specifications of the methods used for emissions estimates are associated with each body furnishing information.

The information compilation process is carried out with the following steps:

- Identification of the information providers per activity
- Verification and revision if necessary of contact information
- Definition of requests
- Issuance and follow-up of requests
- Receipt of response to requests.

Identification of the information providers

The first step is to update the data obtained from previous editions of the Inventory from information providers categorized by SNAP group. Institutions with expertise in the subject matter of each activity are requested to report on new entries, eliminations or changes in the bodies, businesses, manufacturing plants, etc. pertaining or linked to each institution.

Verification of data

Once the list of information providers is obtained, the contact information for these providers is verified by telephone follow-up in order to confirm the details (contact person(s), email, postal address) of the Inventory's information providers.

The contact information data are keyed into the auxiliary database "Inventory Document Source Status" (EFDI in its Spanish acronym). In this database, historical data is collected, changes experienced by businesses, associations and public offices are recorded and noted; the information corresponding to the Inventory's previous editions is maintained to ensure its monitoring, which is the principle that the data collection system is based on.

Definition of requests

Once the list of Inventory information providers and their contact information is updated, an analysis is prepared on the documentation to be requested from each information provider (questionnaire to be completed, special publication).

For those providers who participated in the Inventory's previous edition, the information requests sent previously are revised, implementing in each case the relevant changes. For new information providers, the information to be requested is analyzed and a new form is prepared if the content of the information to be requested is not covered by any of the pre-existing forms.

The information request generally consists of a letter (explaining the contents of the mailing and requesting the provider's cooperation) and of one or various attachments (questionnaire to be completed, information gathering application), usually formatted with EXCEL or Word. In other cases, requests are made in the same letter (without attachment) for data or official publications which address the information requested.

Issuance and follow-up of requests

Once the entities and the information to be requested from each one are identified the information requests are processed.

These requests are sent to the contact persons identified in the verification of contact information stage, preparing a double mailing for each request by postal mail (sending an official letter of request signed by the DGCEA director) and by email (sending of letter and attachments for the information requested to provide greater flexibility and efficiency for the recipient in preparing the answers to the request and in subsequent processing by the DGCEA).

The EFDI database contains a list with the information requested by date sent, the deadline for returning the answers, by SNAP activity, and for each Inventory edition.

On-going monitoring of the status of the request with assistance by the EFDI database is carried out; by means of an alerting system, reminders are issued if certain dates have lapsed and finally the management of the petition processing is closed by appropriately designating them as "Completed" or "Pending".

In case that within the period indicated in the letter of request the information has not been received from the information provider, a reminder is issued by telephone and email of the necessity to provide said information, underlining the "obligation" of the office, association, business, etc. of remitting the information as soon as possible.

Receipt of the requests

A formal third-party examination is carried out on the mailings received to detect any possible omissions, incompleteness which could cause a loop in the request issuance system and to correct these problems. Next, the input of the information is prepared. The entities providing information are given confirmation of receipt and notified that a preliminary verification of the data provided is under way, which will be complemented by the tests provided previously during the data processing stage. Alternatively, those bodies that have not provided the information requested within the deadline are notified that their data have not been provided for processing in the current edition.

The EFDI database processes all the mailing and receipt of requests for each edition of the Inventory ensuring its traceability.

Archiving the documentation

All documentation generated throughout the inventory is gathered together in a register reporting the operations carried out and the results obtained. This register is stored in electronic or hard copy format in order to prevent its manipulation, deterioration or loss.

A standardized procedure is followed that includes:

- Organisation and circulation of documentation as it is generated by the project.
- Classification and maintenance of documents containing substantive information in a structured archive.
- Description of documentation, contents and key words to facilitate consultation at a later date.
- Physical installation that ensures easy recovery and preservation.

Therefore the archive is made up of base data and associated documentation, all based on the relationships between SNAP categories, entities and documents, grouped together to form chronological series of documents. It also includes the different reports sent and the database of the inventory itself.

This database along with the most important data are duplicated for practical work organisation and backup reasons at the Directorate-General for Environmental Quality and Evaluation (Ministry of the Environment) and at the company providing specific technical assistance.

The aim of this entire information management system is to comply with the goals of information protection and to provide fast, accurate access to the data.

1.3.4.- Data processing

The objective of this phase is the development, implementation and maintenance of the emissions estimation algorithms in compliance with the methods chosen and the activity and parameter variables information and other procedural specifications gathered in the compilation of data.

This phase incorporates the integration of data with the emission estimate methods in order to apply the calculation procedures of said emissions.

The activity data, the emission factors and calculation procedure are implemented on the ORACLE database of the Inventory where data processing is managed and emission estimates are generated. Previous calculation procedures determined in modules outside the

database and that are predominantly supported by spreadsheets and auxiliary database⁷ do, however, exist.

This phase also incorporates data processing that entails reinstatement of methodologies and new calculations.

In order to process the information, a combination of approaches is used: both bottom-up (from the detailed level to the aggregate level) and top-down (from the aggregate level to the detailed level). In general, the bottom-up approach uses, if available, information contrasted at the most disaggregated levels of the sectoral hierarchies of the nomenclature for potentially pollutant-emitting activities that are the basis of the inventory (SNAP nomenclature) and territorial activities (NUTS nomenclature of EUROSTAT). On the basis of this initial information, estimates for the higher levels can then be obtained by successive aggregation until the maximum level is reached.

This first approach is used for large point sources and a good number of area sources (for example, emissions from mining industries, agricultural crops and livestock). The second approach, the top-down approach, is used for the remaining area sources.

Database: Information content

The information base obtained by the providers is illustrated and filed in the Inventory's ORACLE database using the following procedures.

- Accurate expansion of the relational model with the representation of the new clusters of data received.
- Verification and integration of data into the database.
 - Application of the internal consistency criteria of the data for each data block. Missing information is identified, anomalous data pointed out (erroneous or suspect of error), and communication is established with the provider in order to obtain the missing information and to analyze the anomalous data and correct errors in the same.
 - Consistency criteria for data aggregates supplied by different providers are applied. Potentially incompatible data aggregates are identified and communicated to the providers in order to resolve apparent contradictions.
 - Database integration of the validated information.

⁷ In the practical application the most frequently used are EXCEL spreadsheets and ACCESS database.

Database: Calculating algorithms

The algorithms for emission estimates are stored in the Inventory's ORACLE database by way of references and procedures that call upon the variables, parameters, emission factors chosen during the selection and development of methods phase.

Emissions estimation

Before the final estimation of emissions, a preliminary estimation of annual emissions by sectors and sub-sectors by activity and substance (gas) category is prepared. Annual comparisons for the period inventoried are compared against the preliminary estimates of contributions by sector/sub-sector to the emission totals of each substance and for each sector/sub-sector the inter-annual variation rates; carried out with the goal of detecting possible anomalies.

If anomalies are detected, their origin is investigated and any errors identified are resolved.

Once the errors identified have been resolved, a final estimation of emissions is prepared according to the different activity nomenclatures and in all the presentation formats required by the Inventory, SNAP base format, CRF Format, NFR Format.

Identification and record of new calculations

The identification and registration of new calculations and/or reinstatement of methodologies is executed in the auxiliary application, *Methodology Revisions and New Calculations*, designed toward this effect.

In the process of preparing the Inventory, during the selection of method phase, the methodology used in the Inventory's previous edition is revised. This revision could lead to the reinstatement of the methodology used for some of the Inventory's activity. The reinstatement of methodologies could create the execution of new calculations that could affect all or part of the time series. On the other hand, the database update (new available information or correction of errors) may give way to new calculations.

In the above-mentioned application, reinstatement as well as methodologies that give way to new calculations are recorded as new calculations themselves - to be executed over the emission data for the affected time series, indicating the origin of the proposal (internal verification or external notice), motive (error correction, change of methodology, emission/algorithm factor change, activity variable change, source category change), the argument for accepting or denying the implementation of the new calculation, the formulated reinstatement, the affected aspects, horizontal aspects, group(s), subgroup(s) or SNAP activities affected), affected substances, affected item (activity variable, estimation algorithm, emissions) and years affected.

Chapter 10 of the NIR "10.-New calculations and improvement" describes the new calculations applied in the national inventory of emissions. Said chapter examines the following themes:

- Explanation and justification of recalculations.
- Implications on emission levels.
- Implications on emission trends.
- Execution of new calculations and foreseen improvements in the Inventory (analysis by affected categories).

1.3.5.- Preparation of results tables and reports

The objective of this phase is the preparation of reports and results tables of air pollutant emissions, required by a variety of forums that the NIS reports to in order to find the best balance between accuracy and precision on one end and available resources on the other, in accordance with the format, content and deadline criteria.

Every type of report generated is conveniently recorded and filed according to its particular specifications.

The description of reports and results tables generated follows:

A) Report on greenhouse gas emissions:

- Annual report to the European Union commission
- Annual report to the Framework Convention on Climate Change

These reports contain:

- Anthropogenic emissions of CO₂, CH₄, N₂O, HFC, PFC, and SF₆ (year x-2)
- Provisional data CO, SO₂, NO_x and NMVOC (year x-2 and constants x-3)
- Emissions and absorptions of use and changes in land-use (year x-2)
- Description of methodologies and data sources used (Appendix I Decision. 2005/166/CE)
- Information on the quality assurance and quality control plan
- Uncertainty evaluation
- Description and interpretation of trends
- Measures to improve estimations
- Information on indicators
- National system changes

- Data presentation CRF (Common Reporting Format) + NIR (National Inventory Report)

B) Report for Directive on national emission ceilings:

- Annual communication to the European Union commission
 - Anthropogenic emissions of SO_x, NO_x, NMVOC and NH₃
 - EMEP/CORINAIR methodology
 - Data presentation of NFR (Nomenclature for Reporting) tables with sectoral and territorial specifications.

C) Report to Geneva Convention and EMEP program

- Annual report to Economic Commission for European UN EMEP program:
 - Anthropogenic emissions of SO_x, NO_x, NMVOC, NH₃, CO, particulate matter, heavy metals and persistent pollutants Breakdown by point sources and disaggregation by EMEP grid
 - EMEP/CORINAIR methodology
 - Presentation of data in NFR tables

This phase carries out the monitoring of database interfaces with the tables and reports presentation forms, and are compared to the variations originating from the methodological revisions and new recalculations effected in the Inventory's successive editions.

1.3.6.- Inventory approval

With respect to the inventory's approval, according to the previously cited, Government's Delegated Committee for Economic Affairs, each year the Ministry of the Environment must present the inventory proposal to said Committee for its approval.

Once the Inventory on air pollutant emissions, its reports and data on the required presentation forms, is approved, they are published and sent to international bodies by means of the respective countries focal points before the secretaries of the different relevant international conventions, just as it is done for the European Commission by means of Spain's Permanent Representation before the European Union.

1.4.- General description of the methodologies and data sources used

1.4.1.- Inventory development principles

The following section deals with the development given in this 2009 edition of the principles that must be taken into account during the preparation of inventories as established in the document FCCC/SBSTA/2006/9 of the Framework Convention on Climate Change Secretariat.

Time-series consistency

One important characteristic of the inventory preparation process has been the emphasis placed on guaranteeing, as far as possible, that the 1990-2007 time series was consistent over the years with the updated methodology from the 1996 IPCC *"Revised guidelines for national greenhouse gas inventories"* (1996 IPCC Reference Manual) and with the 2000 IPCC revised *"Good practice guidance for preparing Inventories"* (2000 IPCC Good practice guidance) and the 2003 revised *IPCC Good practice guidance for emission and absorption estimations related to Land Use, Land-Use Change and Forestry*, (2003 IPCC *Good practice guidance* for LULUCF). The emissions and absorptions now estimated by type of gas have been expressed in terms of CO₂-equivalent with the global warming potential weighting factors (over a 100-year horizon) from the revised IPCC 1995 edition.

New calculations performed

The aforementioned purpose of time-series consistency has led to the recalculation of the series sent with the 2008 submission covering the period 1990-2006. This revision, whose quantification is presented in Chapter 10 of this report (NIR) and in Table 8(a) and 8(b) of CRF Reporter, has undoubtedly contributed to a significant improvement in the reliability of emission figures and time trends derived from such figures. Basic information for the year 2007 is partly provisional (preliminary figures in some sectors) and therefore it is anticipated that estimations made for this year will probably be recalculated when the final data are available.

Consistency

Consistency in the estimation of CO₂ emissions from combustion activities has been especially taken into account throughout the entire process dealing with fossil fuel-using activities. The amount of fuels used for energy purposes, and that, consequently, affects to the estimated fuel consumption used with no energy purpose in the "Industrial Processes" sector, has been compared with the information of the available years of the National Energy Balance as shown on EUROSTAT "Energy Balance Sheets" and in the International Energy Agency "Energy Statistics" publications and in addition has been reviewed with specific information at individual plant on large point sources (mainly chemical sector). CO₂ emissions from biomass combustion are summarized in the Memo items although, in line with IPCC methodology, these are not included in the national total of CO₂ emissions total.

The *reference approach*, shown in Tables 1.A(b) and 1.A(c) of the CRF, can in this sense, be considered a consistency test for the estimation of CO₂ emission from combustion processes.

Furthermore, some changes have been implemented, while also maintaining the principle of consistency over time, in the “Agriculture” sector, in what concerns the crops surfaces and the numbers of animals, and in the “Waste” sector with respect to the amounts of waste deposited in landfills, and the biogas generated and captured, at those landfills where the biogas is captured.

These and other aspects related to the consistency of the activities and their estimated emissions are covered in detail in the corresponding sectoral chapters (3 to 8) in this report.

Completeness

Completeness has been evaluated according to the types of estimate status recommended in the IPCC methodology: *NO* (not occurring); *NE* (not estimated); *NA* (not applicable); *IE* (included elsewhere), *C* (confidential); *0* (less than half of the unit used). As a general evaluation, it may be said that the objective of completeness has been satisfactorily attained, with the following exceptions: i) although the complete time series for surface and surface change among land-use categories has been estimated for the “Land use, land-use change and forestry” category, the emission and absorption flow have not been successfully estimated for all subcategories within categories 5B to 5E, and ii) the potential emissions for the fluorinated gases, (HFC, PFC, SF₆) have not been estimated due to a lack of specific information regarding the flows in foreign trade (imports and imports) by type of gas.

Uncertainty/quality of the estimate

Uncertainty has been assessed by following the Tier 1 approach according to the methodology given in the document “IPCC Good Practice Guidance”. This approach is shown in detail in Appendix 7 of this report.

Transparency

From a formal point of view, the completion of the base tables (background) in CRF Reporter including activity variables, estimated emissions and implied emission factors as well as complementary information, if any, appearing in these tables represents the most significant step towards achieving relevant transparency in inventory preparation. In addition, transparency requirements are complied with through the documentation and archiving of base data sources that, besides what may logically be reflected in the base tables, have been used to prepare inventories.

1.4.2.- General methodology

Data shown in the CRF Reporter tables for this edition contain all relevant information regarding direct and indirect greenhouse gas emissions/uptakes produced in Spain during the period 1990-2007.

The following section gives a brief description of the work undertaken to prepare the GHG inventory and, more especially, a description of how the CRF Reporter tables have been completed using information from the National Inventory System.

The emission estimation approaches recommended in both the “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories” and the “IPCC Good Practice and Uncertainty Management Handbook for National Greenhouse Gas Inventories”, published in 2000 as well as in the “IPCC Good Practice Handbook for emission and absorption estimations related to Land Use, Land-Use Change and Forestry”, published in 2003, were adopted for all those activities for which these approaches were considered most suitable, taking into account available resources and data. Whenever a national approach was available and considered more appropriate than the alternative IPCC approach, this national approach was adopted in compliance with IPCC’s own recommendations. Therefore, with regards to gas type and emission source cross-tabs, the approaches indicated in the following section have been adopted.

Methodologies applied by IPCC activity category

Energy: Combustion processes

In order to estimate CO₂ emissions, the carbon mass balance has been applied, provided that information has been available, taking for the characteristics of the fuels the most specific national parameters, provided either by the emission sources themselves, in the case of Large Point Sources, or derived from standard fuel specifications.

For all other pollutants, the following have been used:

- CH₄ and N₂O emission factors, for stationary combustion sources and mobile sources (except road traffic), taken almost completely from the references in the IPCC, EMEP/CORINAIR, CITEPA and API (American Petroleum Institute) Compendium.
- NMVOC and CO emission factors, for stationary combustion sources and mobile sources (except road traffic), were taken almost completely from EMEP/CORINAIR.
- Emission factors and estimation algorithms, for road traffic, were taken from COPERT III for all inventoried pollutants from this form of transport.
- Available estimates based on direct measurements, mainly cases of SO₂ and NO_x from Large Point Sources.
- Estimates based on mass balance, mainly for SO₂ in emissions from mobile sources and from stationary sources without desulphurisation technologies.

Energy: Fugitive Emissions

For this activity category, national methods have been used when, as in the following cases, the information available on processes, emission factors or estimation algorithms has been considered to be more appropriate to the sector’s activity in Spain:

- CO₂ emissions in (non-combustion) fuel transformation processes, mainly in coke ovens and oil refining.
- CH₄ emissions in coal mining and carbon usage.
- CH₄, NMVOC and CO₂ emissions in transportation and distribution of natural gas and other gaseous fuels (methane-air, propane-air, propane, factory gas).

For all other activities in this sector, IPCC or EMEP/CORINAIR emission factors have been used, depending on which was considered more representative. The following examples belong to this category:

- CH₄ and NMVOC emissions generated in domestic oil and natural gas production activities as well as fugitive emissions of both pollutants generated in crude oil and petroleum product loading-unloading and storage operations at sea terminals.

Industrial processes

Emissions from the three main greenhouse gases, (CO₂, CH₄, N₂O) resulting from activities in this sector have been estimated by following the IPCC methodology. In the important case of CO₂ emissions generated in decarbonising processes, the type of carbonate has determined the factors used, provided that a quantification of the different carbonates contained in the input-output of material in the corresponding processes was available. In cases where this information was not available by type of carbonate, factors referring to the total carbonated material treated in the process have been used according to information available in each sector.

For indirect greenhouse gases and sulphur oxides, a combination of national methods has been followed, completed, in the absence of such information, with EMEP/CORINAIR emission factors.

In order to estimate fluorinated gas emissions (HFC, PFC and SF₆), the IPCC methodology called actual approach was adopted. The complementary *potential approach* was not considered viable as at the maximum level of disaggregation of the foreign trade nomenclature, commercial transactions cannot be identified by individual gas (and it is also extremely complicated to do this in the chain of importers-distributors-exporters itself). Such individual gases include:

- HFC-23; HFC-32; HFC-125; HFC-134a; HFC-143a; HFC-152a; HFC-227ea, HFC-236fa inside the HFC group;
- CF₄; C₂F₆; C₃F₈; C₄F₁₀ inside the PFC group, and
- SF₆

Use of Solvents and Other Products

In this group, where the IPCC methodology itself refers to EMEP/CORINAIR for a great many activities, the national methods used have been complemented with factors from EMEP/CORINAIR, EGTEI-CLRTAP/EMEP and IIASA-RAINS.

Agriculture

In the group of agricultural activities, the methodological treatment must be differentiated by sub-sectors and, if applicable, by type of gas. Therefore:

- To estimate CH₄ emissions from enteric fermentation in livestock, the IPCC methodology has been followed, with advanced approach (Tier 2) for cattle and sheep, and simple approach (Tier 1) for all other animals.
- To estimate CH₄ and N₂O emissions from manure management, the IPCC methodology has been followed, supported by national estimations on the distribution of manure management systems. A similar treatment, IPCC methodology supported by national emission factors, has been followed to estimate CH₄ emissions in rice cultivation.
- In the case of N₂O emissions from agricultural soils, the IPCC methodology has been used with support, as regards the determination of parameters and basic activity variables, from the national study results.
- Pollutant emissions generated in the burning of agricultural stubble have been estimated: For CH₄, CO, N₂O, and NO_x, using the IPCC methodology; and b) for SO_x and NMVOC using the IPCC methodology for the calculation of carbon content in the plant and EMEP/CORINAIR emission factor.
- To estimate NO_x emissions from soils, the EMEP/CORINAIR methodology has been used since there is no IPCC alternative available.

Land use, land-use change and forestry

The estimation of CO₂ net captures by the forest systems, contained in category 5A of the FCI, has been made by following the IPCC 2003 Good Practice Guidelines methodology, with the base information essentially taken from the Second and Third National Forestry Inventory and the Maps of Crops and Exploitations, Regional Maps and the National Forestry Map. The estimates made included the following sub-categories: i) forests which remain forests, and ii) cropland turned into forests. Emissions for different gases originating from CO₂ in forest fires have been included in category 5A as well. At category 5C "Grassland" the carbon uptakes by the croplands converted to grassland has been estimated. With regard to the choice of parameters required by the estimation algorithms, the national values have been used when specific verified national information has been available; if not, the default values recommended in the IPCC 2003 Good Practices Guidance have been used.

For the estimation of the time series for surfaces categorized by land use and surface changes among categories, the CORINR-LANDCOVER information base has been used (reference years 1990 and 2000) as well as Spain's Forestry Map, scale 50.000 (EMF-50). The relevant geographical information system tools were employed for this information base.

Waste

The CH₄ and N₂O emissions from waste treatment and disposal activities have been estimated following IPCC methodology. The most relevant activity in the emissions has been

the landfill disposal of urban solid waste, differentiating between managed and unmanaged landfill sites. Methane emissions arising from the anaerobic degradation of the organic part of waste have been estimated by following the IPCC first-order kinetic equation. In the case of controlled landfills capturing biogas, the information, collected by means of individualised questionnaires, and processed at plant level⁸. With regard to urban and industrial wastewater treatment activities, IPCC guidelines have also been followed to estimate CH₄ emissions in water treatment lines and sludge treatment lines. Other estimation sources in the sector are related to N₂O emissions from human consumption of proteins, which is estimated according to IPCC, and waste incineration, where emissions have been estimated according to EMEP/CORINAIR⁹ guidelines.

Treatment of the carbon stored in fuel products

The consumption of fuel products for non-energy use is included in the fuel balance under the item with the same name. The amounts of each type of fuel included in this item are incorporated into the *reference approach* analysis with each one being split conveniently into two fractions: a) the fraction stored in products; and b) the fraction that is presumably released in the short term resulting in the corresponding CO₂ emissions according to the aforementioned *reference approach*.

Treatment of international bunker fuels

To estimate the Memo item (not included in the national total) of emissions corresponding to international shipping and aviation, the fuel consumption figures assigned to the respective international traffic in energy balances have been taken as activity variables: international maritime bunkers and international aviation.

1.5.- Brief description of key categories

In order to optimize resource allocation to improve the accuracy and precision of emission inventory estimates, it is necessary to prioritize quality monitoring and assurance procedures for activities that, from the point of view of their contribution to the uncertainty of inventory estimates, are revealed as key or priority categories.

The identifying of key sources has been carried out, first for all inventory categories with the exception of those corresponding to the "Land use, land-use change and forestry sector, (UTCUTS in Spanish, LULUCF in English); secondly, LULUCF¹⁰ activities have been considered as well but apart from the previously mentioned key categories.

⁸ When the captured biogas in landfills is energy-valued, the emissions estimate is included in IPCC 1A1 of the "Energy" sector.

⁹ When the incinerated waste is energy-valued, the emissions estimate is included in IPCC 1A1 of the "Energy" sector.

¹⁰ In the 2003 IPCC Good Practice Guidance is defined the difference between "key category" and "key source". The first is more comprehensive than the second, as it includes both "sources" and

In this sense, the IPCC Good Practice Handbook defines an category as a key source if that source or sink may have a significant influence on the estimate in terms of the absolute value or trend of the total inventory estimate.

From an operational point of view, the aforementioned handbook establishes two approaches or tiers to tackle the identification of key sources. The Tier 1 approach is aimed at determining the influence, whether in terms of the absolute value or trend of the series, that an emission source can have on the uncertainty of the total inventory estimate but without needing to resort to formal uncertainty analysis procedures. The Tier 2 approach is similar but takes into account prior information obtained from a formal uncertainty analysis. In the current edition of the inventory, key categories have been identified with the Tier 1 approach.

When this first approach is used, a distinction must be made between the identification of a source as a key source in terms of the absolute value or the trend or both. To identify the source in terms of the absolute value, a threshold is first set (usually 95%) for the accumulated distribution function of emissions according to inventory activities, with these having been placed in order of decreasing contribution (in terms of CO₂-eq emissions). It can be considered that the set of activities included in the accumulated distribution function within that threshold allows a percentage of around 90% of the overall inventory uncertainty¹¹ to be guaranteed. For identification in terms of trend, the Tier 1 approach also sets a threshold of 95% but in this case established on activities' contribution to trend metrics¹². In the identification of categories in the LULUCF sector, the specifications established in the 2003

"sinks", whereas the second only refers to the emitting sources. This distinction is maintained in the 2006 IPCC Guidance, but it did not appear on the previous IPCC Guidances.

¹¹ Studies conducted and published in "Methodological Choice in Inventory Preparation. Suggestions for Good Practice Guidance" (Flugsrud, 1999), comparing the accumulated fractions of level/trend assessments with the fractions of uncertainty in inventories from different countries, showed that a reasonable approximation to 90% of the overall uncertainty of the inventory was covered by selecting a threshold of 95% in assessments.

¹² The respective metrics for the absolute value and trend correspond to Formulas (1) and (2) below:

$$(1) \quad L_{x,t} = \frac{E_{x,t}}{E_t}$$

$$(2) \quad T_{x,t} = L_{x,t} * \left| \frac{(E_{x,t} - E_{x,0})}{E_{x,t}} - \frac{(E_t - E_0)}{E_t} \right|$$

where:

$L_{x,t}$ is the valuation level for the category x in the year t

$L_{x,t}$ is the valuation level for the category x in the year t

$E_{x,t}$ and $E_{x,0}$ are the emissions estimates for the category x in the year t and the year 0, respectively.

0 is the "reference year 90/95" (i.e. 1995 for fluorinated compounds and 1990 for all other pollutants in the current inventory edition). The term "base year" is reserved for the reference year 90/95 of the 2006 edition, series 1990-2004, from the inventory edition verified in 2007 by the appointed team by the SCMCC. In this last edition an Assigned Amount was established, and it will be taken as reference to assess the compliance of Spain of its commitment with the Kyoto Protocol during the 2008-2012 period.

IPCC Good Practice Guidance, relative to the absolute value and trend metrics (equations 5.4.1 to 5.4.3).

Besides the classification, where applicable, of a category as key in terms of absolute value and/or trend, in quantitative terms, qualitative judgments with regard to those categories are also of interest in some cases and, in addition to level and/or trend criteria, deserve attention for other possible reasons as candidates likely to have a significant influence on overall inventory estimates. In this case we find the following categories, among others:

- the use of HFC in the cooling and refrigeration activities where scarce information is provided over the activity variable and also where it is presumable that future expansion will be recorded as HFCs replace the use of other classes of gas, such as, CFC and HCFC, as the utilization of these other gases is phased out.
- traffic emissions of N₂O where it has been a wide variability of emission factors have been determined in comparisons among countries; and given that the quantity of these emissions depends, as makes sense, on the estimated breakdown of the fleet of vehicles according to the vehicle categories and technologies (age);
- The allocation of fuel consumption in military activities and the chart of said consumption within the fuel balance of the national inventory.
- the determining of the air and sea transport contribution in the domestic sector in relation to total traffic (domestic times international), given that in the case of the Spanish inventory the fuel percentage of domestic air transport is notably higher than the percentage estimated using traffic models, as with the PAGODA model developed by EUROCONTROL.

These two activities will be subjected to special research in future editions of the inventory.

Going back to the quantitative identification of key categories, it can be said that criteria adopted in this edition respond to principles established in the 2000 IPCC Good Practice Guidance, which in all cases leaves a wide margin to incorporate national considerations. Among the specifically national elements, the following are considered relevant for the identification of key categories with the objective of allowing a more detailed analysis of significant inventory activities:

- CO₂ emissions per combustion within the Energy sector (excluding ones of transport origin) has been broken down by crossing the type of fuel according to classification of major categories: solids, liquids, gases and others, with the following sub-categories: thermal power plants (1A1a), oil refineries (1A1b), solid fuel transformation (1A1c), industrial sector (1A2) and other sources (1A4). Similarly, CH₄ and N₂O emissions have been differentiated by fuel group and emission activity source, and establishing the following sub-categories for this case: energy generation and fuel transformation (1A1), industrial sector (1A2), and other sources (1A4).

- Within the road traffic sub-category, CO₂ emissions have been disaggregated depending on the type of fuel, analyzing separately the emissions associated with diesel vehicles and emissions corresponding to gasoline vehicles.
- With regard to fugitive emissions in the Energy sector, emissions for each of its sub-categories, solid fuels (1B1) and petroleum products and gas (1B2), have been differentiated by type of pollutant, CO₂ and CH₄.
- In order to ensure a complete inventory analysis, the list of categories given in Table 7.1 of the 2000 IPCC Good Practice Guidance has been extended by adapting it to the list of national pollutant emission sources with global warming potential. It is important to highlight the presence of activities identified as key sources due to their absolute value and/or trend in the set of new categories identified for this purpose, including:
 - Limestone and dolomite production (2A3) due to CO₂
 - Other industrial processes due to CO₂, excluding the production of cement (2A1), lime (2A2), limestone and dolomite (2A3), and iron and steel (2C1)
 - Halocarbon and SF₆ consumption (2F) due to HFC and PFC gases
 - Use of solvents and other products (3) due to CO₂
 - Agricultural soil emissions associated with animal production (4D2) by N₂O

After presenting the analysis approach and commenting on the level of disaggregation, the following tables illustrate the synthesis of the results obtained in the identification of key categories either by trend or by level: Table 1.5.1.a with corresponding LULUCF exclusion, and Table 1.5.1.b for activities in the LULUCF sector. The table indicates, by IPCC sectors, first, all the IPCC code and the description of the activity, second the associated fuel in the case of a combustion activity, and finally the associated gas that makes this activity a key category for the inventory emissions. The most substantial part of the table contains the identification as key category according to its contribution to the emission level, trend or both. The information in the table is complemented by the comments column.

Finally, it is interesting to note that the contents of the sectoral chapters (chapter 3 “Energy”, chapter 4 “Industrial Processes”, chapter 5 “Uses of solvents and other products”, chapter 6 “Agriculture” and chapter 8 “Waste”) in the inventory includes the analysis of all key sources identified herein and that there is a general presentation in Appendix 1 to this report.

Table 1.5.1.a.- Summary of the activities contribution of the Inventory (excluding LULUCF)

IPCC SOURCE CATEGORIES		Fuel	Gas	Key Source Category	Criterion (1)		Comments	
					Level	Trend		
ENERGY								
1A1a	Public electricity and heat production	Gaseous	CO ₂	YES	YES	YES	Level in 1997-2007	Trend in 1993-1995, 1997-2007
1A1a	Public electricity and heat production	Solid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1994, 1996-2007
1A1a	Public electricity and heat production	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1992, 1994-2007
1A1a	Public electricity and heat production	Other	CO ₂					
1A1b	Petroleum refining	Gaseous	CO ₂	YES		YES		Trend in 1997-2000, 2002-2007
1A1b	Petroleum refining	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1992, 1994-1996, 1998-2007
1A1c	Manufacture of solid fuels	Gaseous	CO ₂	YES		YES		Trend in 1991, 1996
1A1c	Manufacture of solid fuels	Solid	CO ₂	YES	YES	YES	Level in 1990-1994	Trend in 1992-2007
1A1c	Manufacture of solid fuels	Liquid	CO ₂	YES		YES		Trend in 1994-2000
1A1	Combustion – Energy sector		CH ₄					
1A1	Combustion – Energy sector		N ₂ O					
1A2	Combustion – Energy sector	Gaseous	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990, 1992-2007
1A2	Combustion – Energy sector	Solid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A2	Combustion – Energy sector	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A2	Combustion – Industrial sector	Other	CO ₂					
1A2	Combustion – Industrial sector		CH ₄					
1A2	Combustion – Industrial sector		N ₂ O					
1A3a	Civil Aviation		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1997, 2007
1A3a	Civil Aviation		CH ₄					
1A3a	Civil Aviation		N ₂ O					
1A3b	Road transport	Gasoline	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A3b	Road transport	Gas-oil	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A3b	Road transport		CH ₄					
1A3b	Road transport		N ₂ O	YES	YES	YES	Level in 1997-2007	Trend in 1993-2007
1A3d	National naval navigation		CO ₂	YES	YES	YES	Level in 1990-1996,1999-2007	Trend in 1993-1994, 1997-1998
1A3d	National naval navigation		CH ₄					
1A3d	National naval navigation		N ₂ O					
1A3c+1A3e	Other transport		CO ₂					
1A3c+1A3e	Other transport		CH ₄					
1A3c+1A3e	Other transport		N ₂ O					
1A4	Combustion - Other sectors–	Gaseous	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1991-2007
1A4	Combustion - Other sectors	Solid	CO ₂	YES	YES	YES	Level in 1990-1996	Trend in 1991-1992, 1994-2007
1A4	Combustion - Other sectors	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1994, 1996-2007
1A4	Combustion - Other sectors		CH ₄	YES		YES		Trend in 1995, 1999
1A4	Combustion - Other sectors		N ₂ O					
1B1	Fugitive emissions - Solid fuels		CO ₂					
1B1	Fugitive emissions - Solid fuels		CH ₄	YES	YES	YES	Level in 1990-1998	Trend in 1991-2007
1B2	Fugitive emissions - Oil and natural gas		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1991, 1993-1994
1B2	Fugitive emissions - Oil and natural gas		CH ₄	YES		YES		Trend in 1991-1992

(1). Identification of the criterion (level, trend) by which the emission source is considered a key source.

Table 1.5.1.a.- Summary of the activities contribution of the Inventory (excluding LULUCF) (Continued)

IPCC SOURCE CATEGORIES		Fuel	Gas	Key Source Category	Criterion (1) Level Trend		Comments	
INDUSTRIAL PROCESSES								
2A1	Cement production		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
2A2	Lime Production		CO ₂					
2A3	Limestone and dolomite use		CO ₂	YES	YES	YES	Level in 1996-2007	Trend in 1991-1993
2C1	Iron and steel production		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1991-1992, 1994-2007
2-2A1-2A2-2A3-2C1	Other industrial processes		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990, 1992-1994
2	Industrial processes		CH ₄					
2B2	Nitric acid production		N ₂ O	YES	YES	YES	Level in 1990-2003	Trend in 1990-2007
2C3	Aluminium production		PFC	YES		YES		Trend in 1990, 1999-2003, 2005-2006
2E1	Production of HCFC-22 (HFC-23 emission)		HFC	YES	YES	YES	Level in 1990-2001	Trend in 1990-1995, 1997-1998, 2001-2007
2E2+2E3	Production of halocarbons and SF6 (except HCFC-22)		HFC&PFC					
2F	Consumption of halocarbons and SF ₆		HFC&PFC	YES	YES	YES	Level in 2000-2007	Trend in 1997-2007
2F7	Electrical equipment		SF ₆	YES		YES		Trend in 1990
USE OF SOLVENTS AND OTHER PRODUCTS								
3	Solvent and other product use		CO ₂	YES		YES		Trend in 1994-1995
3	Solvent and other product use		N ₂ O					
AGRICULTURE								
4A	Enteric Fermentation in Domestic Livestock		CH ₄	YES	YES	YES	Level in 1990-2007	Trend in 1990, 1992, 1994-2007
4B	Manure management		CH ₄	YES	YES	YES	Level in 1990-2007	Trend in 1990-1998
4B	Manure management		N ₂ O	YES	YES		Level in 1990-2007	
4C	Rice cultivation		CH ₄					
4D1	Agricultural Soils - Direct Emissions		N ₂ O	YES	YES	YES	Level in 1990-2007	Trend in 1990-1995, 1997-2007
4D2	Agricultural Soils - Animal Production		N ₂ O	YES	YES	YES	Level in 1990-1992, 1995-1999	Trend in 1992
4D3	Agricultural Soils - Indirect Emissions		N ₂ O	YES	YES	YES	Level in 1990-2007	Trend in 1990-1995, 1997-2007
4D4	Agricultural soils – Others		N ₂ O					
4F	Field burning of agricultural wastes		CH ₄					
4F	Field burning of agricultural wastes		N ₂ O					
WASTE								
6A	Waste Disposal in Landfills		CO ₂					
6A	Waste Disposal in Landfills		CH ₄	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
6B	Waste-water handling		CH ₄	YES	YES		Level in 1993-1999, 2002-2007	
6B	Waste-water handling		N ₂ O					
6C	Waste Incineration		CO ₂					
6C	Waste Incineration		CH ₄					
6C	Waste Incineration		N ₂ O					

(1). Identification of the criterion (level, trend) by which the emission source is considered a key source.

Table 1.5.1.b Summary of contributions for LULUCF activities

IPCC Categories		Fuel	Gas	Key Category	Criterion (1)		Comments
					Level	Trend	
LULUCF							
5A	Carbon fixing in forestry systems		CO ₂	YES	YES	YES	Level in 1990-2007
5A	Fires in forest systems		CH ₄ & N ₂ O	YES		YES	Trend in 1990-1992, 1994-1995, 1997-2007
							Trend in 1991, 1994

(1). Identification of the criterion (level, trend) by which the category is considered a key source.

1.6.- Information on the quality assurance and quality control plan

1.6.1.- Approach

The quality assurance and quality control plan focuses on following generally-accepted good practice principles so that the Inventory meets the following requirements: Timely presentation, completeness (with respect to activities and pollutants covered), consistency (transversal and in time series), comparability (with other inventories), accuracy and precision, transparency, and ongoing improvements.

The quality assurance and quality control plan is an essential part of the system for quality assurance and quality control (QA/QC) and verification activities. It lists the verification and QA/QC activities and the composition of the team which will execute them with allocation of responsibilities to its members.

The quality assurance and quality control plan is conceived as an internal document to organize the verification and QA/QC activities to ensure the Inventory's ongoing improvement and so is able to complete its objectives. It is for this reason that the plan is conceived as an active element, which, although it initially serves as a reference point for specifications for the next inventory edition, it is periodically reviewed at least once a year, to compile the changes occurring in activities and inventory processes detected by the inventory's working group, as well as receiving recommendations from external review teams. This periodic revision of the quality assurance and quality control plan, to adapt it to recommended procedural changes, is an important element in ensuring the plan's contribution to the QA/QC system's ongoing improvement. The quality assurance and quality control plan affects all stages of the inventory's development.

1.6.2.- Objectives

An essential element of the quality assurance and quality control plan is setting its objectives with regard to the inventory's quality. These objectives, which relate to the basic principles in drafting the inventory, must be established in a realistic manner and be suitable to the final objective of improving the inventory's quality. Setting these objectives facilitates the inventory's evaluation when a review is conducted. The objectives established in the quality assurance and quality control plan for the Spanish inventory are specified below:

a) Compliance with deadline for availability and distribution of the questionnaire

A timeline of individual tasks has been developed to achieve this objective. Checkpoints have been established for the times when different stages take place. The satisfactory completion of the deadlines for these stages constitutes the best control for the completion of global terms for the inventory's availability. Additionally, in case the deadline is not met for in one part of a stage, a notice is generated to try and correct the delay in the long run of the pending stages. One special control factor is the deadline for the stage

dealing with the collection of answers to the questionnaire set before the information providers¹³.

b) Completeness

This principle refers to the objective of achieving an Inventory as complete as possible with the inclusion of emissions estimated for all activity-pollutant cross-tabs producing emissions, complemented by the appropriate label (NO = not occurring; NA = not applicable; IE = Inappropriate activity estimate; and NE = not estimated) for cases in which an affirmative estimate is not given (emission or absorption).

To bring this principle into operation, an exhaustive analysis is done of the Inventory's SNAP base nomenclature (which corresponds to the nomenclatures used in the rest of the Inventory formats), all the cross-tab activities with pollutants for which references for emission estimates are provided, and with reference to these methods, an analysis is made and the base data necessary for the application of selected estimation method is collected. The operational monitoring of this objective is carried out with the help of the "Completeness check" quality control procedure.

c) Consistency (transversal and time series)

The objective of the consistency transversal refers to the use of the same variable or parameter in all the Inventory categories that share it. This objective is ensured by introducing this variable or parameter into the database a single time and ensuring general access to it by any algorithms or procedural modules requiring its use.

The objective of time series consistency refers to the assurance of a homogeneous pattern over time for the variables indexed against time, in an effort to avoid spurious patterns. This objective is addressed with: i) quality control of primary data, and ii) atypical control to identify possible false patterns with incorrect values. The operational control of this objective is executed with QC over the variables entered and methods for detection for atypicals in time series.

d) Comparability

The completion of this objective, which attempts to attain the highest standard of Inventory comparability with inventories developed for other countries and geographic areas, and potentially, in the longer term, with different time periods, is addressed with the systematic use of definitions for generally used terms and nomenclature for activities and pollutants maintained over time. These requirements are met through the Spanish inventory's use of definitions and nomenclatures (and associated correspondence) in the SNAP base format and in NFR (air pollution substances) and CRF formats (greenhouse gases).

¹³ Produced in the inventory's 2008 edition, despite a delay in the delivery to the EU Commission; basically due to a delay in essential data on the energetic balance. However, the appropriate quality assurance and control plan mechanisms have been applied resulting in minimizing the delay.

e) Accuracy and precision

The term accuracy calls for achieving an unbiased estimator (not deviating upward or downward) with respect to the central value of the emissions estimation; whereas precision calls for reaching the minimal uncertainty (confidence interval close to the central value with a particular degree of probability, conventionally 95%). To attain this double objective, analysis and revisions of methods are undertaken, as necessary, over determined key categories which, because they are susceptible to clear improvement in their methodological approach (going to more advanced tiers), are considered priorities; and complemented with a sample selection of non-key categories. In this improvement plan the recommendations from bodies that develop quality control procedures are used as needed.

f) Transparency

The objective of transparency is directed toward guaranteeing the reproducibility of the Inventory results by external teams using the base data and documentation of the estimation algorithms. To this end in the base report in the Inventory's SNAP format. Vol. 2 "Analysis by SNAP activities" documents: the description of the processes generated from emissions, the activity variables used and the originating sources, the algorithms and emission factors used, and the estimated emissions themselves. Complementarily, the information on the final activity variables, emission algorithms/factors, and emissions estimates are consulted from the Inventory's ORACLE database.

g) Inventory improvement

All previous objectives lead to this final objective of Inventory improvement, and as such contribute to the same, with all the quality assurance and control elements mentioned.

1.6.3.- Responsible bodies

The Directorate-General for Environmental Quality and Evaluation (DGCEA) of the Ministry of Environment and Rural and Marine Affairs, as the Single National Authority of the National Inventory System for Pollutant Emissions into the Atmosphere (Ministerial Order MAM/1444/2006), is the body responsible for the Inventory's quality assurance and control system and counts with the support of the named specific technical assistance for the execution of tasks that this system has, support that has clearly defined responsibilities and tasks and counts with specific qualified personnel dedicated to the implementation of the quality assurance and control system.

The main responsibilities concerning the quality assurance and control plan are:

- Coordinate QA/QC activities for the national Inventory.
- Gather and reference the internal procedures for QA/QC, the information providers and other organizations which cooperate with NIS, develop.
- Ensure the development and application of the QA/QC plan.

The coordination of resources by DGCEA as required for the implementation of the National Inventory System (NIS), including coordination of the contribution of different participating bodies to the QA/QC plan is shown in Figures 1.2.1, 1.2.2 and 1.2.3 of section 1.2 of the this document, where the Institutional and Legal Arrangements are addressed.

1.6.4.-Quality control and records of the Inventory development stages

Selection methods for estimating emissions

The objective of this block is to equip the Inventory with the records of its methodological approach, which are essentially included in the following:

- Registration of design plan: where all the phases for executing the Inventory are contained, the participants of each phase and the tasks required as well as implemented changes.
- Registration of the methodology revisions plan: which includes for each source category, the current methodological approach, and whether or not said approach is to be revised.
- Registration of the references used Document references about the methodologies used in each edition of the Inventory are kept in the EFDI database, where the documentation employed is gathered for the Inventory, Also, for each one of the activities considered by the Inventory can be consulted in the "National Inventory base report" in SNAP format: Vol. 2. "Analysis by SNAP activities" which is prepared with each Inventory edition; the record of references used for emissions estimates. This series publication allows access to historical information on methodologies employed in the Inventory's successive editions.

Data compilation

a) Quality controls

This phase of the project carries out the following QC procedures related to the Quality Control of Tier 1 activities.

Completeness check

The completeness check is carried out operationally over the SNAP base nomenclature for Inventory activities and pollutants, the identification of information providers stage. In each new edition of the Inventory, an investigation is carried out before sending out the request for information to compare the highs and lows of the bodies and plants per activity.

The gaps in coverage, normally due to missing base information, are documented in the NIR and in the CRF corresponding tables.

Verification of providers' contact information

This QC is carried out in the verification stage of contact information, once the list of information providers is obtained.

This verification is effected by telephone follow-up in order to confirm contact information (contact person(s), email, postal address) for the Inventory's information providers.

Requests' follow-up

The status of the request is subject to on-going monitoring through the EFDI database; by means of an alert system, reminders are issued if certain dates have lapsed and finally the processing of the request is closed by appropriately designating them as "Completed" or "Pending".

If no information has been received from the provider within this time period, the reminder is sent, by telephone and email, stating the need to receive said information.

Verification of the integrity of the base documentation received

Verifications on the integrity of the archives with the providers of information data are carried out during the receipt phase.

A formal third-party examination is carried out on the mailings received to detect any possible omissions, incompleteness which could cause a loop in the request issuance system and to correct such errors.

For the entities that have not provided the information requested within the deadline, a notice of missing information is prepared to be processed during the course of the edition

b) Records generated

The information providers' data is recorded along with the contact information, issuance, follow-up and reception of request requested.

The documentation received is registered with EFDI and the bodies that have complied with the requirements are informed in the same way as if the data provided was to be processed. All this feedback is filed in the projects corresponding folder according to the established documentation and archive system.

The notices of missing information are also registered accordingly. The register of general quality controls (tier 1) is done following an ABC criteria from greater to lesser relevance, on the "major" anomalies detected and established as such, in the *QC Register Tier 1 and Tier 2*.

Data processing

a) Quality controls (Tier 1)

This phase of the project carries out the following QC procedures related to the general quality control activities (Tier 1).

Verification of transcription errors on data entry

Currently the recording of data is reduced to a minimal amount of data, generally small.

Depending on the format in which the information is received, different controls are performed.

If the information is provided in protected PDF files or in paper, then:

- If the quantity of information is small, it is manually recorded in the database. On the information manually recorded the following controls are performed:
 - For the activity variables with disaggregation (sectoral/geographic) in the original source, the control is applied on the aggregate(s) to verify coincidence between data in the original source and in the database. In case of discrepancy, an investigation is performed by successive levels of disaggregation until the level where the discrepancy is identified.
 - For activity variables that are presented on the aggregate level (generally small), a control is performed on the second recording.
- If there is a large amount of information, it is scanned. In the process of scanning, possible errors are checked, such as swapping "0" for "O", displacement of lists or columns (tend to occur during changes in order of magnitude, identified with atypical controls). Alternatively, a second scan is performed with greater resolution to resolve any possible remaining anomalies.

Verification that the estimation algorithms are operating correctly

The following controls are performed:

- For the algorithms of low or medium complexity, replicas in spreadsheets for representative cases are used.
- For highly complex algorithms, simplified replicas are submitted of the more complex modules or subroutines.
- Investigation of anomalies reported by users of information, processed and provided to the Inventory or on the quality assurance updates.

Verification of correctness of the units in which variables and parameters are expressed

Unit conversion is performed when data are keyed into the Inventory's ORACLE database which provides automatic unit conversion mechanisms.

The errors in units where variables and parameters are expressed are commonly identified by tests of order of magnitude or atypical tests in data in cross-tab sections or time-series which is noted below. If any anomalies are detected, their basis is investigated, and the possible identified errors resolved.

Verification of the integrity of the database structure

Various built-in quality controls exist in the Inventory's ORACLE database that assure the consistency of the information contained therein, such as:

- Control for uniqueness of facts recorded in the tables.
- Reference integrity (over existing classes).
- Control for minimum attributes for information required for registration.
- Control of integrity restrictions in the attribute domains and of the relationships between different attributes whether or not they are from the same relationship.

Verification of the consistency of information shared by different sources

This control is operational by means of the restrictions on integrity reference established in the Inventory's ORACLE database.

Verification of data flow correction in the various stages of the process

The formal consistency of hierarchal disaggregation (top-down) is ensured by the "domain restriction" of the proxy variables (in absolute figures or unit sum fractions).

The formal consistency of the hierarchical aggregation (bottom-up) is ensured by the formal structure itself of the hierarchy established in the Inventory's ORACLE database dictionary.

For the horizontal flow of data, the verification procedures of the functional relations (regression models, other attribution mechanisms) in line with what is noted above in the control "Verification that the estimation algorithms operate correctly".

Verification of methodological changes or of data requiring recalculation

Methodological changes and new calculations are registered in the "Revision of methodologies and new calculations.mdb" designed for such effect. Its implementation is prepared applying the revision or new calculation homogeneously across to all temporal intervals inventoried. These changes are noted in Chapter 10 of the NIR report and proposed for inclusion in all corresponding CRF tables.

Verification of time series homogeneity

For the control of homogeneity in the time series data, those methods considered most appropriate from those highlighted in the following table have been developed and applied. Visual, observation, inter-annual variation rate, and robust regression, Thiel-Sen type.

Method	Trend	Atypical	Comments	Adaptation
Visual observation	Subjective	Subjective	Subjective overview	X☺
Inter-annual rate	Inter-annual variation mean	Largest and smallest remainder values (with sign)	Simple overview	X☺
MCS regression	Pending coefficient	Largest and smallest remainder values (with sign)	Not robust, too generalized	X
Thiel-Sen regression	Pending coefficient	Specific formula for identification	Robust	☺

Note: "X" means the method may be applied taking into account its limitations.

Verification of homogeneity in transversal cut

Additionally, methods have been established for the identification of atypical data, using the procedures noted below on the spill-over for MCS regression or preferably Thiel-Sen. The following tables show the relationships of the methods considered more relevant and that coincide with the tests selected in the guide to good practices for the identification of atypical data in cross-section analysis (not time series).

Method	Centre	Dispersion	Comments	Adaptation
Median and box plot	Median	Whiskers	Asymmetric consideration	☺
Trimmed median and winsorized 2-Sigma	Trimmed median	2 SD _w	Intuitive, robust, simple	☺
Median and absolute deviation normalized	Median	2 MADN	Robust, simple	☺
Huber's M and absolute deviation normalized	Estimator M	2 MADN	Precise, less intuitive, computational load	☺
Empirical likelihood adjustment of Huber's M estimator	M estimator optimized	2 MADN optimized	Precise, less intuitive, computational load	☺

Comparison with estimates from the previous year

In relation to the changed in common years (1a, n-1) of the two editions, a comparison on the methodological revisions and new calculation is performed.

As far as the promotion control in the last edition of the Inventory. Estimation of the "n" year in regards to "n-1", is realized with the support of "completeness check" and with the external information on the activity variable evolution.

b) Quality monitoring by type of source (level 2)

They are oriented towards specific data types used in the estimation methods for individual sources, especially:

- Main categories (key sources) of sources and sinks
- Categories that have undergone methodological revisions.
- Categories that employ advanced estimation methods.

Although some of these controls may be share by various sources, other demonstrate sectoral specificity. This is the reason why in general they are specified by sectors.

Within the controls (ranges and evolution indices) applied, the following are highlighted:

- On the product ratios/input (or their reverse)
 - In the transformation of energy
 - In industrial combustion
 - In industrial processes (without combustion)
 - In the agricultural or livestock production
 - In the generation and treatment of wastes
- On the composition of material / combustibles.
 - Material / products:
Physical-chemical properties: Density (liquids), carbonate contents, VOC contents
 - Combustibles:
Physical-chemical properties: Molar gases composition, dry carbon base composition, petroleum products composition, carbon contents, heating value
Evolution of combustible mix (relative price dependency)
Balance of materials, especially of carbon in industrial processes

c) Records generated

The calculation methods that are used in external models on the Inventory's ORACLE database are registered.

The methodological reinstatement and new calculations to be used are registered. In this manner the verification of the results and sensitivity analysis of the same before in the applied calculations methods are carried out.

The register of general quality controls (tier 1) is done following an ABC criteria from greater to lesser relevance, on the "greater" anomalies detected and established as such, in the *QC Register Tier 1 and Tier 2* application.

The registration of methodological reinstatements and new calculation is executed in the *Methodology Revisions and New Calculations* application.

Preparation of results tables and reports

a) Quality controls:

The verification of each chapter is assured by means of a reading by a person independent of the technical expert that has executed it; and the outgoing original copy is checked for conformity against what was planned.

b) Records generated:

The results tables and reports are considered System Records and are filed and controlled as such in the EFDI document control application.

1.6.5.- Quality assurance system

The inventory's quality assurance is based on its objective revision by personnel unconnected to the team preparing the inventory with the aim of evaluating its quality as well as the fulfilment of the proposed quality control specifications and taking advantage of this process to identify the areas for improvement within a process of continuous optimization of the inventory.

The programme is mainly materialized through the following methods:

- Institutes/technical experts are specifically dedicated to revision and quality monitoring, focusing on the main source categories or those that have undergone alterations in data or estimation methods.
- Systematic commissions to specialist institutes to perform quality assurance work on specific activities or substances in the inventory and related to the corporate purpose of these institutions.

- In addition, in-depth revisions are made by experts participating in inventory organizations in similar countries, reference work groups for the major source categories or the Secretariats or Panels of the Conventions or Protocols in question.

In this section, deserves special mention the “Quality assurance program of the national inventory of air pollutant emissions” which was commissioned to CIEMAT¹⁴ (Research Centre for Energy, Environment and Technology) This work about the inventory quality assurance (QA) was made by CIEMAT during 2007 and 2008.¹⁵

The CIEMAT report is composed by two parts: i) general aspects of the inventory; and ii) aspects related to the energy sector.

In this section the main conclusions about the inventory general aspects are summarised, while at chapter 3 of the NIR (National Inventory Report) the energy referred aspects are commented. The followings general conclusions/recommendations to improve the inventory should be pointed out:

a) Structure and responsibility

Search for an increased transparency in the responsibilities allocation to perform the tasks between the Directorate-General for Environmental Quality and Assessment and the Technical Assistance team.

b) Sources of information

Verification of the active emission sources database together with the Autonomous Communities. To insist in the need that the information providers must document their QC/QA procedures.

c) Data retrieval procedures.

Increased systematic and automatic procedures for individual technical questionnaires processing referred to plants and business associations.

d) Emission estimation methods.

Improvement in the documentation procedure for the methods used and in the procedure carried out to choose the methods. A more advanced exploitation of the quantification of uncertainty results.

e) Quality assurance and control system.

To specifically develop certain parts of the quality system: records, goals and quality manual.

¹⁴ In this sense see reference to CIEMAT under heading 1.2.3 of this chapter.

¹⁵ The CIEMAT report can be accessed at the NIS archives.

f) Documentation, archive and custody.

Specific designation of the maximum responsible of this function at the Directorate-General for Environmental Quality and Assessment

g) Availability and access to the inventory information.

Clearing the access procedures to the information and among them the WEB query. Inventory information return to its content providers, for evaluation and quality assurance of the data processed.

1.6.6.- Confidentiality handling

The air pollutant emissions inventories are considered to be statistics for State purposes within statistical operation 4710 of the 2005-2008 Statistical Plan and, as such, in accordance with article 149.1.31 of the Spanish Constitution, they are performed on the basis of the exclusive responsibility of the State for the preparation of statistics for State purposes. In this sense, the regulatory frame of reference is provided by the Spanish Public Statistical Function Act (Law 12/1989 of May 9th, 1989) and by the 2005-2008 National Statistical Plan, approved by Royal Decree 1911/2004 on September 17th, 2004.

In this context, the information requested for the inventory follows the rules of statistical secrecy in accordance with the provisions of the 2005-2008 National Statistical Plan.

1.7.- General evaluation of uncertainty

The results presented in the Executive Summary chapter and those presented later in chapter 2 on Emissions Trends and in the sectoral chapters 3 to 8 of this report refer in the first place to estimates of the central emissions values by cross-tabbing activities and pollutants. The aggregation of emissions, weighted according to the global warming potentials of each gas considered, is reflected in the estimation of the central value of the overall emission in the inventory. The central value is, however, only an indicator of the level of the random variable that is the estimated emission of each pollutant source and gas.

To characterize the accuracy of the estimation, it is of interest to establish methods to determine the uncertainty of that estimation. The IPCC Good Practice Guidance offers two approaches for quantifying the uncertainty in each activity and gas, as well as for the determination of the uncertainty of the emission considered in the inventory. The tier 1 approach, which has been adopted to estimate the uncertainty in this edition of the inventory, determines the uncertainty by using two-stage error propagation equations.

In the first stage, the uncertainty of the emission from a source category and gas is approximately estimated taking into account the fact that such emission can be given as the result of an activity variable multiplied by an emission factor and taking into account the combination of the uncertainties in these two factors as expressed in the following equation:

$$U_E = \sqrt{U_A^2 + U_F^2} \quad [1.7.1]$$

where:

U_E represents the uncertainty associated with the emission

U_A represents the uncertainty associated with the activity variable

U_F represents the uncertainty associated with the emission factor

and where U_E , U_A and U_F express, as a percentage, the ratios (uncertainty coefficients) with one half of the 95% confidence interval for the variable considered as the numerator and the expected value of the variable as the denominator.

In the second stage, the uncertainty of an aggregate is approximately estimated from the uncertainties of the components, activity sources by pollutant, making up the inventory. This estimation of uncertainty is performed in terms of level and in terms of trend, differentiates between the emissions in the reference year and the base year, as expressed in equation [1.7.2].

$$U_{E_{total}} = \frac{\sqrt{(U_{E_1} \cdot E_1)^2 + (U_{E_2} \cdot E_2)^2 + \dots + (U_{E_n} \cdot E_n)^2}}{E_1 + E_2 + \dots + E_n} \quad [1.7.2]$$

where:

$U_{E_{total}}$ represents the uncertainty associated with the aggregate emissions

U_{E_i} represents the uncertainty associated with each component emission

E_i represents the expected value of each component emission

and where $U_{E_{total}}$ and U_{E_i} express, as a percentage, the ratios (uncertainty coefficients) with one half of the 95% confidence interval for the variable considered as the numerator and the expected value of the variable as the denominator.

To estimate the uncertainty in the trend (the difference between emissions in the reference year and base year), two types of sensitivity have been defined to evaluate these differences:

- Type A sensitivity.

This represents the change in the difference in inventory emissions between the base year and the reference year, expressed as a percentage, resulting from a 1% increase in emissions of a given source and gas in both the base year and the reference year.

- Type B sensitivity.

This represents the change in the difference in inventory emissions between the base year and the reference year, expressed as a percentage, resulting from a 1% increase in emissions of a given source and gas in the reference year only.

Conceptually, type A sensitivities arise from uncertainties equally affecting the base year and reference year while type B sensitivities arise from uncertainties that only affect the reference year. The uncertainties that correlate over the years are normally associated with type A sensitivity, whereas those that do not correlate over the years are associated with type B sensitivity. These two types of sensitivities simplify the analysis of the correlation. To make the algorithm work, it is assumed, by default, that the emission factor uncertainties correspond to type A sensitivity and are normally correlated between years. However, activity variables correspond to type B sensitivities and are not correlated between years, except where otherwise mentioned, as seen below in the application of the algorithm for this inventory. Once the uncertainties in the emissions have been calculated according to each of the two types of sensitivity indicated, they can be weighted and added using the error propagation equation to obtain the total uncertainty in the trend.

The Tier 1 procedure was applied according to the definition and relations between variables (columns) of Table 6.1, Section 6.3.2 of the IPCC Good Practices Guidance implemented on a worksheet, reproduced in Appendix 6 of this report.

In order to illustrate the uncertainty estimation, the years 2005 and 2006 were selected as representative, that is, the most recent years in the series of the period inventoried, 1990-2006, excluding its last year, 2007, for which part of the base information is provisional and causes an increase in the uncertainty associated with the estimation of its emissions. Table 1.7.1 summarizes the results of the quantification of uncertainty, and the following conclusions can be drawn from its analysis:

- a) The 95% confidence range for the emissions level of the aggregate of the inventory is in the order of 16% around the central value of the reference year 1990/1995; and 10.9% for 2005, and 11.4% for 2006.
- b) The 95% confidence interval for the emissions evolution index with regards to the reference year 1990/1995 is in the order of 6.4% for 2005 and in the order of 5.7% for 2006.

Table 1.7.1. 95% confidence intervals for the inventory emissions level and trend

Year	Absolute values (Gg CO ₂ -e)					Evolution index for reference year 1990/1995=100				
	Central value	Lower limit		Upper limit		Central value	Lower limit		Upper limit	
		Value	%	Value	%		Value	%	Value	%
Reference year 1990/1995	290,368	242,665	-16.4	338,071	-16.4	100	NA	NA	NA	NA
2005	441,150	392,850	-10.9	489,451	-10.9	151.93	142.25	-6.4	161.60	6.4
2006	433,070	383,601	-11.4	482,539	-11.4	149.15	140.64	-5.7	157.65	5.7

1.8.- General evaluation of completeness

Completeness has been evaluated according to the types of estimate status recommended in the IPCC methodology: *NO* (not occurring); *NE* (not estimated); *NA* (not applicable); *IE* (included elsewhere), *C* (confidential); *O* (less than half of the unit used).

In the evaluation of the completeness by activities, a conservative criterion has been followed in the assigning of labels *NE* (not estimated) in relation to the alternative assignments *NO* (not occurring) and *NA* (not applicable). Thus, *NO* has been assigned only when it is certain that the activity does not occur in national territory, and *NA* has been reserved for cases where there is well-founded knowledge that there is no emission in the selected cross-tab of the emitting activity and gas emitted; in the remaining cases where no estimate has been made and no other labels were assigned, reference was made to this situation by the label *NE*, although in a large number of these cases there may be no positive emission (in general these are cases where there is no information regarding factors or emission estimation algorithms).

For a detailed presentation of the status labels by activities and gases, please refer to the corresponding tables in the CRF Reporter.

As a general evaluation, it may be said that the objective of completeness has been satisfactorily attained, with the following qualifications. Although the complete time series for surface and surface change has been estimated for the “Land use, land-use change and forestry” category between land-use categories, the emission and absorption flow have not been successfully estimated from categories 5B to 5F, but it has been estimated the CO₂ uptakes of the forestry systems (forest that continues to be a forest and land converted to forest) and croplands converted to grasslands, as well as forest fire emissions. For fluorinated gases (HFC, PFC, SF₆), it has not been possible to estimate the potential emissions due to lack of specific detailed information on foreign trade flows (imports and exports) by gas type. In the case of fuel consumption in military activities, it has not been possible to establish its position within the fuel balance sheet in the national inventory. Appendix 5 “Evaluation of completeness” to this report contains detailed tables of these exceptions to the completeness of the coverage in the inventory.

2.- EMISSION TRENDS

2.1.- Description and interpretation of aggregated emission trends

This sub-section first examines the trends in aggregated emissions without disregarding the net absorptions originated in the sector related to “Land Use, Land Use Change and Forestry” (LULUCF), and secondly, it presents the information on net absorptions that result from the balance of sink flows and carbon sources, and therefore CO₂ emissions, and non-CO₂ gases emissions in this sector.

In order to assess the consequences of the emissions (and absorptions) of greenhouse gases on general atmospheric warming, the estimated emissions figures are given in terms of CO₂-equivalent (CO₂-eq), with the values corresponding to each gas weighted by the respective coefficients assigned in the Second Evaluation Report on Climate Change (1995) prepared by the Inter-governmental Panel on Climate Change (IPCC)¹. The interval of years inventoried in this edition extends from 1990 to 2007. This period provides the reference number (base year number) in order to examine the evolution over time of aggregated emissions (without taking into account those from LULUCF). It was officially approved as the base number for the calculation of the Assigned Amount in Spain for assessing the fulfilment of the commitment to the Kyoto Protocol². The base year number was established after verification (in 2007) of the Spanish inventory for the 2006 edition (series 1990-2004), conducted by the team appointed by FCCCS³.

2.1.1.- Emissions

Table 2.1.1 shows, both in absolute terms (gigagrammes of CO₂-eq) and a time-based index (100 in the base year), the values corresponding to the total gross emissions (except for the “Land Use, Land Use Change and Forestry” sector which are computed separately). Figures 2.1.1 and 2.1.2 show the graphic representation of the time index, which represent the time variation index and the percentages of interannual variation of aggregate inventory emissions. It can be seen that the total emissions in 2007 are 52.6% higher than the base year, a value that reduces to 48.6% when comparing the average of the last five years, 2003-

¹ IPCC has published in 2001 and 2007 its Third and Fourth Evaluation Report on Climate Change, respectively. In these reports the estimation of the warming potential of Greenhouse gases has been updated, although this update has not influenced the assessment of the commitments regarding the reduction of emissions by the countries that have already ratified the Kyoto Protocol.

² The exact number of the base year chosen for the calculation of the assigned amount (PK base year) was 289,773,205.032 tonnes of CO₂-eq; and the assigned amount for the fulfilment of the commitment to the Kyoto Protocol for the 2008-2012 period is 1,666,195,929 tonnes of CO₂-eq.

³ For the estimation of the base year number, the year 1990 was taken as reference for CO₂, CH₄ and N₂O and the year 1995 for fluorinated gases such as HFC, PFC and SF₆. For this reason the base year is itself a hybrid of these two earlier years and does not correspond to a specific calendar year.

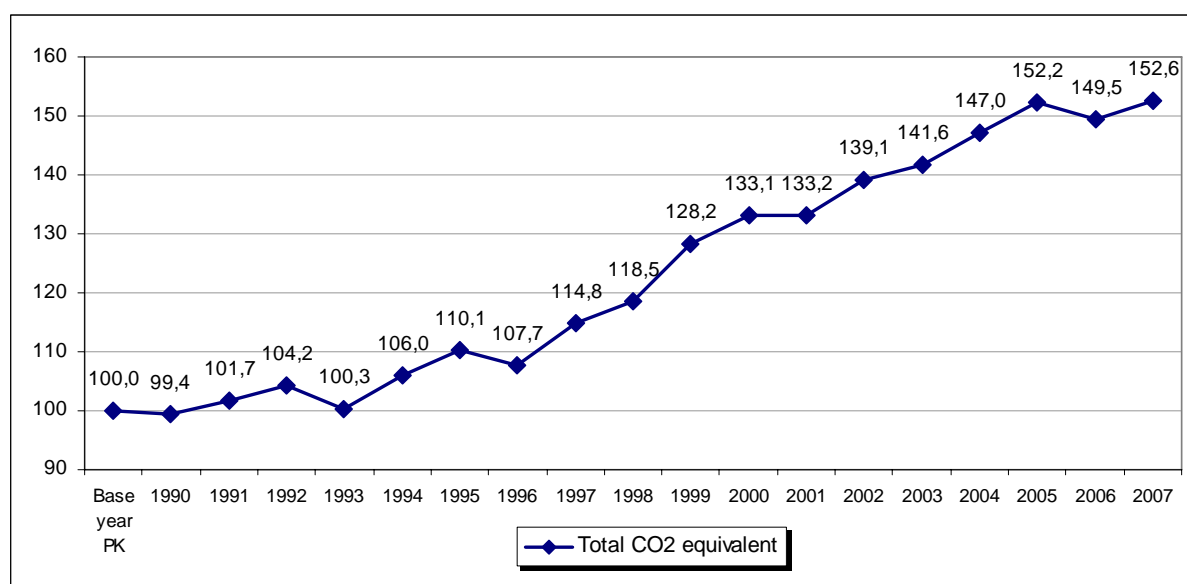
2007, with the same base year⁴. Overall, the index has been marked by sustained growth in the period inventoried, except for the years 1993, 1996 and 2006 when reductions were recorded with respect to the previous year. In terms of growth curves, the 1990-1996 period is characterized by a more moderate growth than that corresponding to 1996-2007. This variability in evolution appears to be related to the year's rainfall (annual peaks/troughs) and its implication for the generation of electricity through heat-fired power stations, although another series of additional factors such as the general expansion in fuel consumption and economic activity are at the core of the change in slope observed between the time subintervals 1990-1996 and 1996-2007 indicated above.

Table 2.1.1.- Evolution of aggregate emissions

Absolute values (Gg CO ₂ -eq)							
PK base year	1990	1995	2003	2004	2005	2006	2007
289,773.21	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56

Annual evolution index (base year = 100)								
PK base year	1990	1995	2003	2004	2005	2006	2007	Quinquennium 2003-2007
100	99.4	110.1	141.6	147.0	152.2	149.5	152.6	148.6

Figure 2.1.1. - Annual evolution index



⁴ The comparison of the five-year average 2003-2007 with the base year is similar to what will have to be done in the period 2008-2012 taking 2010 as the representative value for comparison with the base year.

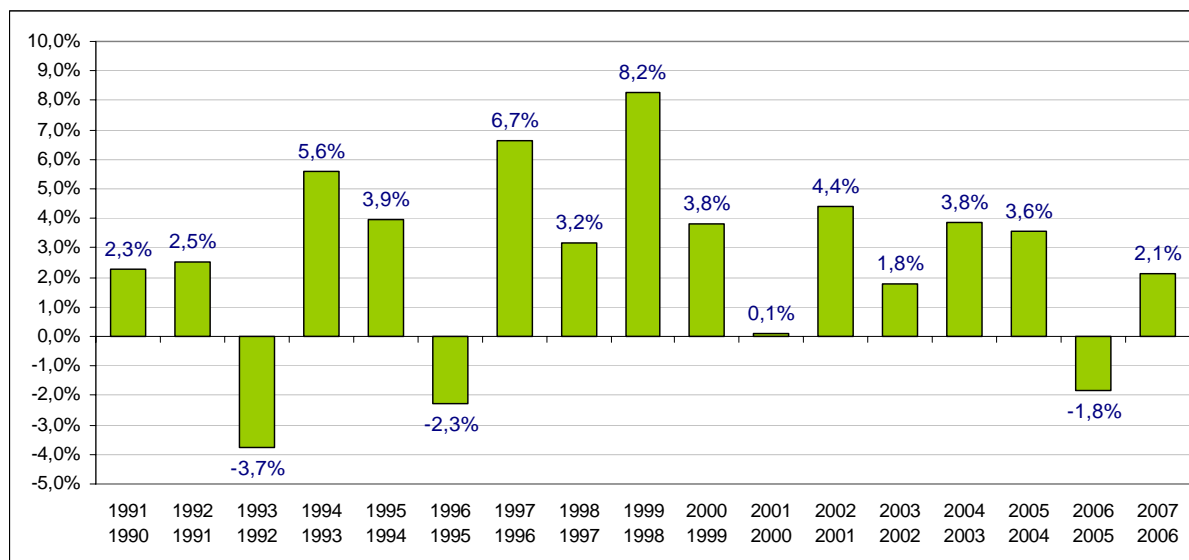
Figure 2.1.2.- Interannual variation (percentage)

Table 2.1.2.a (absolute values) and Table 2.1.2.b (percentage values) illustrate the contributions of the different sectors and categories of activities, always expressed in terms of CO₂-eq, in order to provide a panoramic view of the evolution of the aggregate inventory emissions over time. As can be seen, Energy is the dominant sector and throughout the whole period inventoried its relative participation increases vis-à-vis the total. The Energy sector is followed, at a great distance, by the Agriculture and Industrial Processes sectors (excluding industrial combustion, which is calculated within Energy). These sectors show a decline in their weighting vis-à-vis the total (more pronounced in the Agriculture than in Industrial Processes) but in general terms they maintain their relative positions. Since 1990, the Waste Treatment sector, once more at a distance regarding the contributions from the other two sectors, shows a growth in terms of its relative weight in the total, although this weight has stabilized in recent years. Meanwhile, the activities pertaining to the Use of Solvents and Other Products make a marginal contribution to the total. All this information can be seen in greater detail (with a breakdown by activity sector and gas) in Appendix 6 of this report.

Table 2.1.2.a.- Emissions of CO₂ equivalent (Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emissions)	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56
1. Energy processing	212,465.02	240,705.53	314,441.60	331,500.24	347,308.80	337,170.02	345,391.32
A. Combustion activities	208,238.44	236,503.10	310,719.22	327,426.00	343,222.11	333,217.17	341,370.89
1. Energy industries	77,694.33	86,812.83	106,527.96	115,937.68	126,075.05	117,080.64	123,035.49
2. Manufacturing and construction industries	46,660.84	53,314.58	68,625.76	70,744.03	71,518.09	69,737.08	68,329.69
3. Transport	57,483.20	66,983.36	97,471.78	101,290.31	105,547.66	108,611.49	112,268.53
4. Other sectors	26,400.07	29,392.34	38,093.71	39,453.98	40,081.32	37,787.96	37,737.18
5. Other							
B. Fugitive emissions from fuels	4,226.58	4,202.42	3,722.38	4,074.25	4,086.69	3,952.85	4,020.43
1. Solid fuels	1,835.17	1,482.64	1,115.18	1,064.42	1,028.78	1,054.63	977.80
2. Oil and natural gas	2,391.41	2,719.78	2,607.20	3,009.82	3,057.91	2,898.21	3,042.63
2. Industrial processes	26,314.29	27,411.17	32,722.32	32,860.15	34,321.67	35,007.86	34,852.48
A. Mineral products	15,659.31	16,114.21	21,123.32	21,606.05	22,224.41	22,616.89	22,344.97
B. Chemical industry	3,767.76	3,238.91	2,779.90	2,551.33	2,642.00	2,307.02	2,151.65
C. Metal production	4,417.13	3,303.93	3,501.46	3,679.71	4,076.32	4,097.44	4,053.52
D. Other industries							
E. Production of halocarbons and SF ₆	2,403.18	4,637.88	1,749.17	786.53	680.93	863.42	707.20
F. Consumption of halocarbons and SF ₆	66.92	116.24	3,568.47	4,236.53	4,698.01	5,123.09	5,595.13
G. Other							
3. Solvent and other product use	1,387.85	1,343.58	1,596.23	1,517.91	1,481.74	1,517.27	1,674.20
4. Agriculture	40,330.18	39,877.02	48,323.12	47,191.80	44,878.13	45,817.68	46,425.65
A. Enteric fermentation	11,779.63	12,043.91	14,005.24	13,696.07	13,485.88	13,331.53	13,559.54
B. Manure management	8,695.38	9,781.38	11,588.63	11,983.76	11,871.24	12,356.46	12,438.81
C. Rice cultivation	227.45	137.22	297.89	309.03	300.26	268.47	268.47
D. Agricultural soils	19,089.69	17,403.76	21,884.72	20,757.85	18,890.99	19,437.03	19,734.65
E. Prescribed burning of grassland							
F. Field burning of agricultural residues	538.03	510.76	546.64	445.08	329.76	424.20	424.20
G. Other							
5. Land use change and forestry							
6. Waste treatment and elimination	7,637.31	9,828.64	13,174.38	12,948.35	13,160.16	13,556.93	13,977.90
A. Solid waste disposal in landfills	4,976.12	6,895.78	9,371.01	9,059.55	9,226.21	9,506.10	9,761.07
B. Waste water treatment	2,312.54	2,491.99	3,168.78	3,268.64	3,330.63	3,397.20	3,541.60
C. Waste incineration	94.77	35.80	18.19	9.43	9.31	9.57	10.05
D. Other	253.88	405.08	616.40	610.74	594.02	644.06	665.18
7. Other							

Table 2.1.2.b.- Percentage distribution by sector of emissions of CO₂ equivalent

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emissions)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1. Energy processing	73.74	75.42	76.64	77.81	78.73	77.86	78.09
A. Combustion activities	72.27	74.10	75.74	76.86	77.80	76.94	77.18
1. Energy industries	26.96	27.20	25.97	27.21	28.58	27.04	27.82
2. Manufacturing and construction industries	16.19	16.70	16.73	16.61	16.21	16.10	15.45
3. Transport	19.95	20.99	23.76	23.78	23.93	25.08	25.38
4. Other sectors	9.16	9.21	9.29	9.26	9.09	8.73	8.53
5. Other							
B. Fugitive emissions from fuels	1.47	1.32	0.91	0.96	0.93	0.91	0.91
1. Solid fuels	0.64	0.46	0.27	0.25	0.23	0.24	0.22
2. Oil and natural gas	0.83	0.85	0.64	0.71	0.69	0.67	0.69
2. Industrial processes	9.13	8.59	7.98	7.71	7.78	8.08	7.88
A. Mineral products	5.43	5.05	5.15	5.07	5.04	5.22	5.05
B. Chemical industry	1.31	1.01	0.68	0.60	0.60	0.53	0.49
C. Metal production	1.53	1.04	0.85	0.86	0.92	0.95	0.92
D. Other industries							
E. Production of halocarbons and SF ₆	0.83	1.45	0.43	0.18	0.15	0.20	0.16
F. Consumption of halocarbons and SF ₆	0.02	0.04	0.87	0.99	1.06	1.18	1.26
G. Other							
3. Solvent and other product use	0.48	0.42	0.39	0.36	0.34	0.35	0.38
4. Agriculture	14.00	12.49	11.78	11.08	10.17	10.58	10.50
A. Enteric fermentation	4.09	3.77	3.41	3.21	3.06	3.08	3.07
B. Manure management	3.02	3.06	2.82	2.81	2.69	2.85	2.81
C. Rice cultivation	0.08	0.04	0.07	0.07	0.07	0.06	0.06
D. Agricultural soils	6.63	5.45	5.33	4.87	4.28	4.49	4.46
E. Prescribed burning of grassland							
F. Field burning of agricultural residues	0.19	0.16	0.13	0.10	0.07	0.10	0.10
G. Other							
5. Land use change and forestry							
6. Waste treatment and elimination	2.65	3.08	3.21	3.04	2.98	3.13	3.16
A. Solid waste disposal in landfills	1.73	2.16	2.28	2.13	2.09	2.20	2.21
B. Waste water treatment	0.80	0.78	0.77	0.77	0.75	0.78	0.80
C. Waste incineration	0.03	0.01	0.00	0.00	0.00	0.00	0.00
D. Other	0.09	0.13	0.15	0.14	0.13	0.15	0.15
7. Other							

2.1.2.- Absorptions and emissions in LULUCF

Table 2.1.3 shows, in the first two blocks, the values corresponding to net carbon absorptions (shown with negative signs) expressed in Gg of C and Gg of CO₂ respectively, arising from LULUCF activities. The absorptions (the first block in the table) are in turn subdivided by origin, distinguishing among the following three types of sink: forests which remain as forests (FF), cropland turned into forests but without reaching its level of maturity as a forest system (CF), and grazing land turned into forest (CG). The third block in the table and Figure 2.1.3 respectively show the net absorption values and the graphical representation of the time index (base 100 in 1990). By observing previous data, it is concluded that CO₂ net absorptions in 2007 vary by 30.5% over the year 1990 opposed to 28.9% variation in the average of the last quinquennium (2003-2007) also concerning the year 1990. Overall, the index's evolution presents three differentiated periods: i) one corresponding to the years 1990-1993 with a constant annual absorption determined by the

forest land that historically remains forest land; ii) one corresponding to the years 1994-2001, where a significant contribution of croplands that have been reforested and a much smaller contribution (but arithmetically increasing) of croplands converted to grasslands is added to the previous component; and iii) the 2002-2007 period, which maintains the absorption growth rate of croplands converted to grasslands while tempering the more important contribution of croplands converted to forests.

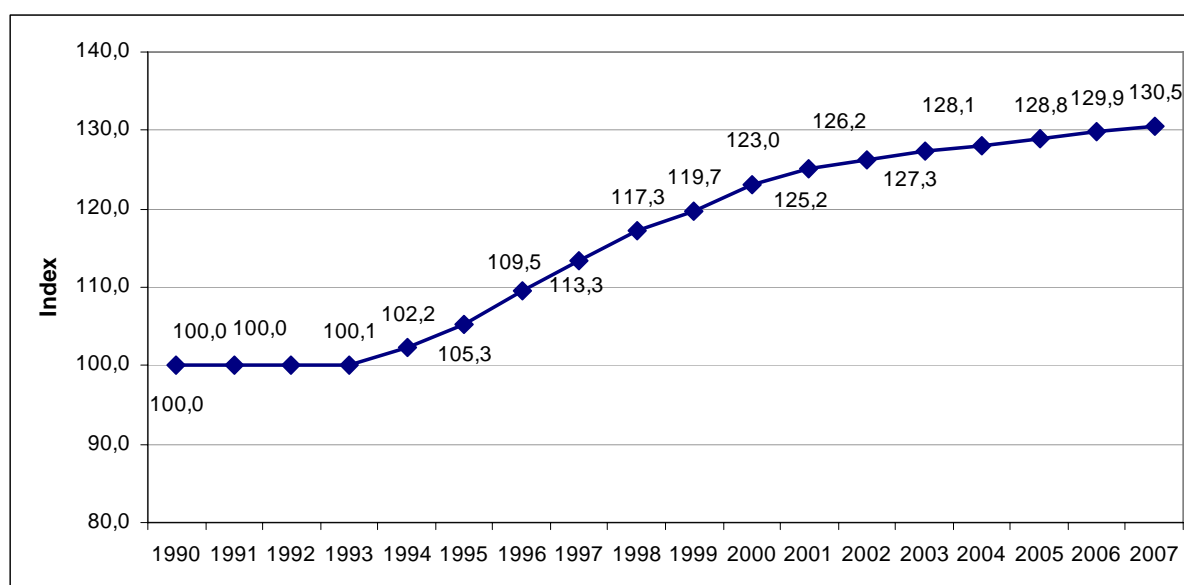
Table 2.1.3 - Evolution of net absorptions

Net absorptions (Gg of C)							
Sinks	1990	1995	2003	2004	2005	2006	2007
FIRE FIGHTING	-5,857	-5,857	-5,857	-5,857	-5,857	-5,857	-5,857
CF		-303	-1,581	-1,627	-1,668	-1,730	-1,763
CG	-1	-9	-20	-22	-23	-25	-26
Total	-5,858	-6,168	-7,458	-7,505	-7,548	-7,611	-7,646

Net Absorptions (Gg of CO ₂ -eq)						
1990	1995	2003	2004	2005	2006	2007
-21,479	-22,615	-27,346	-27,518	-27,675	-27,908	-28,035

Evolution index for net absorptions(1990 = 100)							
1990	1995	2003	2004	2005	2006	2007	Quinquennium 2003-2007
100.0	105.3	127.3	128.1	128.8	129.9	130.5	128.9

Figure 2.1.3.- Evolution index of net absorptions



The LULUCF sector, apart from carbon absorptions in forests, also records CO₂ gas emissions resulting from forest fires. In table 2.1.4 the upper panel shows (in terms of CO₂-

eq) the contribution of emissions from other gases with a direct warming effect (CH₄ and N₂O) created by these fires and the lower panel shows the evolution in the proportion of these emissions.

Table 2.1.4.- Emissions of greenhouse gases other than CO₂ from forest fires

Absolute figures (Gg CO ₂ -eq)						
1990	1995	2003	2004	2005	2006	2007
188	158	156	125	260	563	38

Evolution index (1990 = 100)						
1990	1995	2003	2004	2005	2006	2007
100.0	84.1	82.7	66.5	138.1	298.9	20.2
						Quinquennium - 2003-2007
						129.2

2.2.- Description and interpretation of emission trends by gas

Table 2.2.1 shows the emission estimates, by type of gas, for the six groups or types of gas with a direct effect on global warming: CO₂, CH₄, N₂O, HFC, PFC and SF₆⁵. The upper part of the table shows emissions in absolute amounts (Gg CO₂-eq); the middle part shows the contributions (as a percentage) to the total CO₂-eq emissions in the inventory total, and the bottom part shows the trend in terms of the time index (1990 = 100 for CO₂, CH₄ and N₂O; 1995 = 100 for fluorinated gases).

Table 2.2.1. - Evolution of emissions by type of gas

Amounts in Gg CO ₂ -eq							
GAS	1990	1995	2003	2004	2005	2006	2007
CO ₂	228,446.83	255,255.70	334,020.63	351,384.17	367,996.87	358,418.06	366,366.37
CH ₄	28,587.41	31,819.76	38,336.36	38,071.42	37,944.16	38,510.51	39,058.70
N ₂ O	27,747.40	26,504.20	32,392.92	31,356.97	29,687.34	30,020.30	30,470.38
HFC	2,403.18	4,645.44	5,032.78	4,679.87	5,006.09	5,549.63	5,837.02
PFC	882.92	832.51	267.31	272.04	244.41	247.63	249.12
SF ₆	66.92	108.34	207.66	254.00	271.63	323.62	339.97
TOTAL GASES	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56

Percentage of the total CO ₂ -eq in the inventory							
GAS	1990	1995	2003	2004	2005	2006	2007
CO ₂	79.28	79.98	81.42	82.48	83.42	82.76	82.83
CH ₄	9.92	9.97	9.34	8.94	8.60	8.89	8.83
N ₂ O	9.63	8.30	7.90	7.36	6.73	6.93	6.89
HFC	0.83	1.46	1.23	1.10	1.13	1.28	1.32
PFC	0.31	0.26	0.07	0.06	0.06	0.06	0.06
SF ₆	0.02	0.03	0.05	0.06	0.06	0.07	0.08
TOTAL GASES	100.00	100.00	100.00	100.00	100.00	100.00	100.00

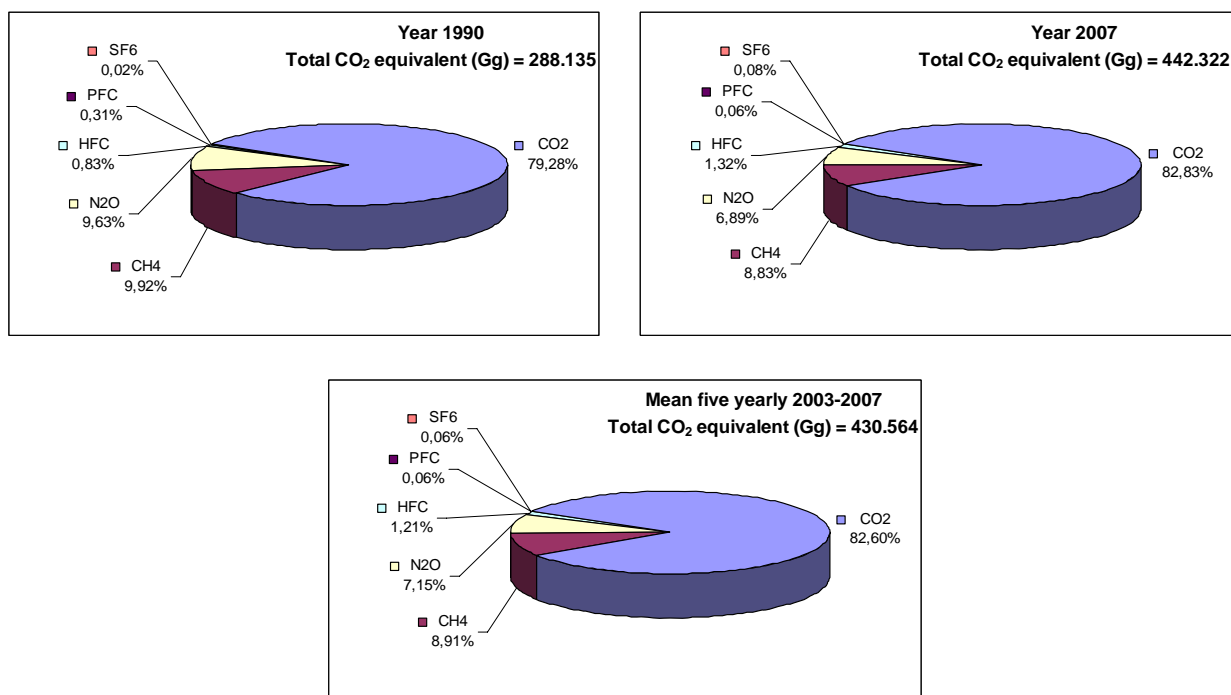
Annual evolution index (1990 = 100; 1995 = 100 for fluorinated gases)							
GAS	1990	1995	2003	2004	2005	2006	2007
CO ₂	100.0	111.7	146.2	153.8	161.1	156.9	160.4
CH ₄	100.0	111.3	134.1	133.2	132.7	134.7	136.6
N ₂ O	100.0	95.5	116.7	113.0	107.0	108.2	109.8
HFC	51.7	100.0	108.3	100.7	107.8	119.5	125.7
PFC	106.1	100.0	32.1	32.7	29.4	29.7	29.9
SF ₆	61.8	100.0	191.7	234.4	250.7	298.7	313.8
TOTAL GASES	100.0	110.8	140.0	142.6	148.1	153.3	150.6

⁵ The emissions/absorptions corresponding to the "Land Use, Land Use Changes and Forestry" sector are not calculated.

As we can see in table 2.2.1, carbon dioxide stands out as the dominant gas, with a weighting of around 80% throughout the inventory period (79.3% in 1990 and reaching 82.8% in 2007). The gases occupying the next two positions are methane and nitrous oxide, with relatively similar contributions but generally larger for methane, which goes from 9.9% to 8.8% between 1990 and 2007, while nitrous oxide slips from 9.6% to 6.9% over the same period. Taken together, fluorinated gases appear with a range between 1.0% (1991) and 2.3% (2000) for the whole period inventoried.

The changes in these relative contributions over time are shown in Figure 2.2.1 for the following three time periods: 1990, 2007 and the average for the quinquennium of 2003-2007. Comparing the three panels in this figure, it is possible to see how CO₂ increases its relative participation by almost 3.5 per cent when 1990 is compared with 2007, with this year also being 0.2% higher than the average for the last five years. In contrast, a small variation can be seen in CH₄, with a -1.1% fluctuation between the extremes in those time periods as its range for this period varies from 9.9% from 1990 to 8.8% from 2007. N₂O reflects a larger percentage fall than CH₄, from 9.6% in 1990 to 6.9% in 2007, with an intermediate value of 7.2% in the last five years. With respect to the fluorinated gases, differences are observed between the individual gases (HFC, PFC and SF₆), but overall, their participation increases until the second half of the 90s, and then drops, remaining at 1.5% in 2007 and 1.3% for the average for the last five years. In any case, fluorinated gases have maintained a low level of contributions to the total emissions over the inventory period.

Figure 2.2.1. - Contribution to emissions by gas type

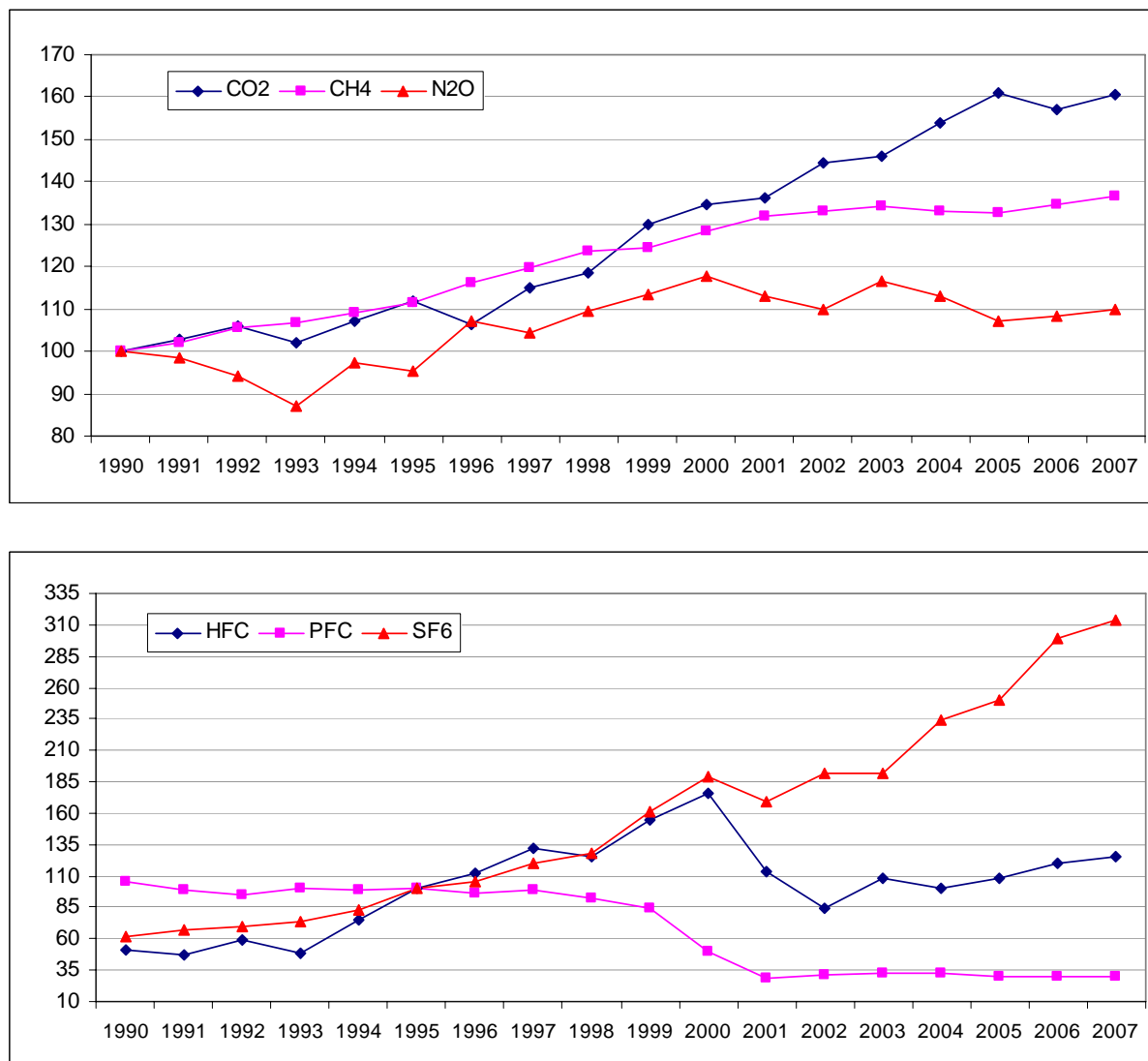


The evolution of the time indices for emissions of the different gases, shown in the lower part of Table 2.2.1, is illustrated in Figure 2.2.2 below. The upper panel of the same table shows the indices for the emissions of CO₂, CH₄ and N₂O, taking 100 for the year 1990. In the bottom panel, there is an index of the evolution for the groups or types of fluorinated gases, HFC, PFC and SF₆, taking 100 in this case for the base year 1995. With respect to the evolution of CO₂, it is possible to see the lowest values corresponding to 1993 and 1996, and the increase in the slope as it passes from the subinterval for 1990-1996 to 1996-2007. These movements reflect to a large extent the evolution of the aggregated index discussed above and finally settle in 2007 at 60.4% above the year 1990. The evolution of CH₄ shows a more uniform trend throughout the period, finally arriving at 36.6% above the 1990 level. N₂ follows a different pattern compared to the two gases mentioned earlier, with a medium reduction in the subinterval 1990-1995, growing in the following years till 2000, after which the time series shows a mean reduction to 9.8% above 1990 in 2007.

With respect to the fluorinated gases, for which the graphical representation is given at the bottom of Figure 2.2.2, there are differences in the evolution of the various gases. PFCs present a stable evolution, slightly decreasing between 1990 and 1999, with a significant reduction between 1999 and 2001, and with stability between 2001 and 2007, with its 2007 level being 70.1% lower than in 1995. This pattern is determined by the evolution of PFC emissions in the manufacturing of primary aluminium, basically due to the replacement (and subsequent elimination) at one plant from 1999 onwards of a production line using side pin prebaked-anode technology by a central pin with greater process efficiency (smaller number of anode effects per vat and day), with a consequent reduction in PFC emissions.

On the other hand, the evolutions of HFC and SF₆ emissions show, after a convergence period in 1990-1994 and a parallel evolution between 1995 and 2000, a later divergence between 2001 and 2007, with a sustained increase for SF₆ and an abrupt fall (2000-2002) in HFC, with the former ending up in the last year with an increase of 213.8% with respect to 1995, while HFC increased in 2007 by 25.7% with respect to the same year of 1995. The decrease in HFC in 2000-2002 is due to the construction and commissioning at one of the HCFC-22 manufacturing plants of a facility to reduce HFC-23 emissions by means of their compression, condensation, liquefaction and storage for subsequent delivery to an external waste manager for processing.

Nonetheless, please refer to Chapters 3 to 8 to see the causes behind the evolution of the trends for the different gases, which offer a detailed explanation of activities with potential emission of greenhouse gases, and Appendix 6, which offers a breakdown of the figures by gas and sector for emissions in 1990, 1995 and 2003-2007.

Figure 2.2.2. - Time indices for emissions by gas

2.3.- Description and interpretation of emission trends by sectors

Table 2.3.1 shows the emission estimates by activity sector, distinguishing the following groups from the IPCC nomenclature: Energy, Industrial Processes, Use of Solvents and Other Products, Agriculture, and Waste. A *pro memoria* review is given for Land Use, Land Use Change and Forestry, without including these figures in the gross emission calculation⁶. The upper part of the table shows emissions as absolute values (Gg CO₂-eq), the centre shows contributions (percentage) to total CO₂-eq inventory emissions and the lower part shows evolution in terms of time index (year 1990 = 100).

Table 2.3.1. - Emission evolution by activity sector

Absolute values (Gg CO ₂ -equivalent)							
SECTOR	1990	1995	2003	2004	2005	2006	2007
1. Energy processing	212,465.02	240,705.53	314,441.60	331,500.24	347,308.80	337,170.02	345,391.32
2. Industrial processes	26,314.29	27,411.17	32,722.32	32,860.15	34,321.67	35,007.86	34,852.48
3. Use of solvents and other products	1,387.85	1,343.58	1,596.23	1,517.91	1,481.74	1,517.27	1,674.20
4. Agriculture	40,330.18	39,877.02	48,323.12	47,191.80	44,878.13	45,817.68	46,425.65
6. Waste treatment and disposal	7,637.31	9,828.64	13,174.38	12,948.35	13,160.16	13,556.93	13,977.90
TOTAL SECTORS	288,134.66	319,165.94	410,257.65	426,018.47	441,150.50	433,069.76	442,321.56
5. Land Use Change and Forestry	-21,290.92	-22,456.81	-27,190.82	-27,392.72	-27,415.09	-27,344.98	-27,996.96

Contribution to the total CO ₂ -eq of the inventory							
SECTOR	1990	1995	2003	2004	2005	2006	2007
1. Energy processing	73.7	75.4	76.6	77.8	78.7	77.9	78.1
2. Industrial processes	9.1	8.6	8.0	7.7	7.8	8.1	7.9
3. Use of solvents and other products	0.5	0.4	0.4	0.4	0.3	0.4	0.4
4. Agriculture	14.0	12.5	11.8	11.1	10.2	10.6	10.5
6. Waste treatment and disposal	2.7	3.1	3.2	3.0	3.0	3.1	3.2
TOTAL SECTORS	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Annual evolution index (1990 = 100)							
SECTOR	1990	1995	2003	2004	2005	2006	2007
1. Energy processing	100.0	113.3	148.0	156.0	163.5	158.7	162.6
2. Industrial processes	100.0	104.2	124.4	124.9	130.4	133.0	132.4
3. Use of solvents and other products	100.0	96.8	115.0	109.4	106.8	109.3	120.6
4. Agriculture	100.0	98.9	119.8	117.0	111.3	113.6	115.1
6. Waste treatment and disposal	100.0	128.7	172.5	169.5	172.3	177.5	183.0

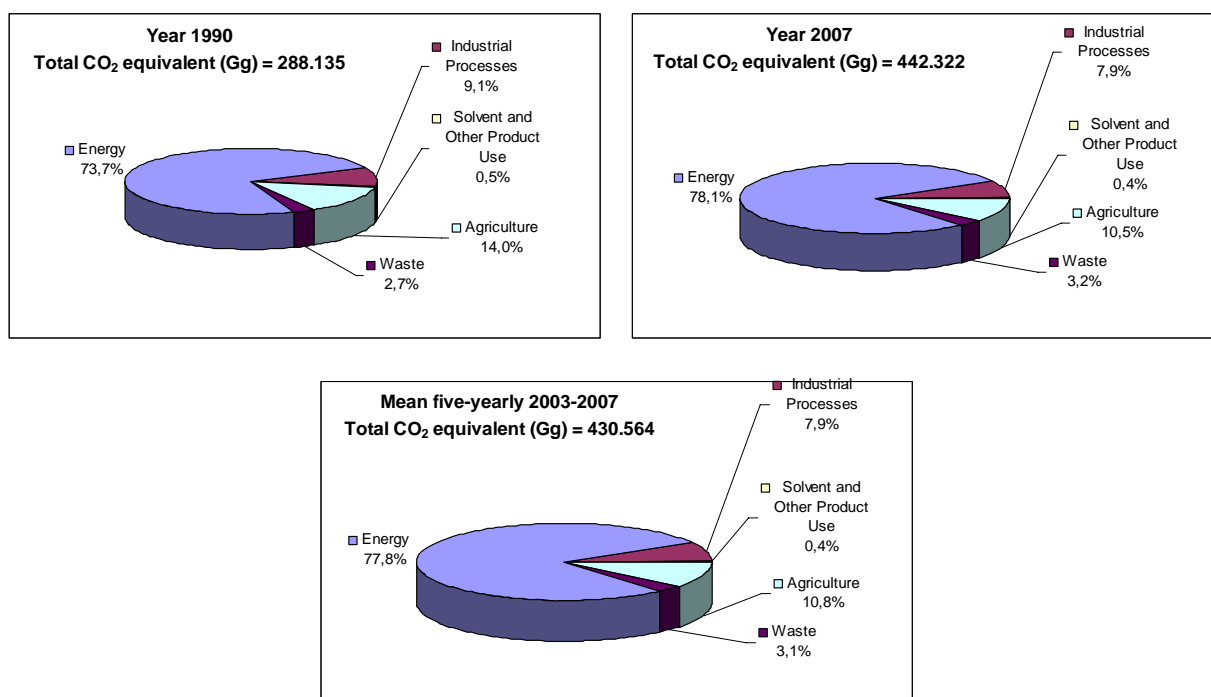
Examining the results by activity sector, the dominant contribution of the Energy group stands out in first place, ranging between 73.7% in 1990 and 78.1% in 2007. It should be remembered that this group, apart from the emissions from fixed and mobile combustion sources, contains the evaporation emissions from fuel mining, transport and distribution activities, which are also relevant for gases other than CO₂, such as CH₄. In second place and at quite a distance from the previous group sits the Agriculture group, with quotas

⁶ The negative values in the Memo entry for the "Land Use, Land Use Change and Forestry" sector correspond to net CO₂-eq (absorptions of CO₂ by fixing of carbon minus emissions of CH₄ and N₂O in forest fires) in this group.

varying between 14.0% for 1990 and 10.5% in 2007. Third place is held by Industrial Processes (excluding combustion activities that are included in the Energy sector), whose contribution declines from 9.1% in 1990 to 7.9% in 2007. The Waste group shows an increasing trend overall, albeit with variations), with a contribution varying between 2.7% in 1990 and 3.2% in 2007, reaching slightly higher levels in intermediate years. Finally, the Use of Solvents and Other Products sector presents a marginal contribution of between 0.3% and 0.5% of the total.

The changes in these relative contributions over time are shown in Figure 2.3.1 for the following three time periods: 1990, 2007 and the mean for the five-year period from 2003 to 2007. Comparing the three panels in this figure, it is possible to see how the Energy sector increases its relative participation by 4.1 percentage points when 1990 is compared with the average for the five-year period from 2003 to 2007, and it later increases by 0.2 additional points from the level of the five-year average for 2003-2007 to the level for 2007. With respect to the Agriculture sector, its relative contribution descends by 3.5 percentage points between 1990 and 2007, bringing it 0.3 points below the average for the latest five-year period. The Industrial Processes group also shows a relative reduction of around 1.3% between 1990 and 2007, and practically the same figure for the average over the last five years and in the last year of the period. The Waste sector maintains a relatively stable level with an increase of 0.5 per cent between 1990 and 2007, and a slight increase of 0.1 per cent between the mean of the last five years and 2007. With respect to the Use of Solvents sector, its contribution has fallen by 0.1% between the first and last years in the inventory period.

Figure 2.3.1. - Contribution to emissions by activity sector

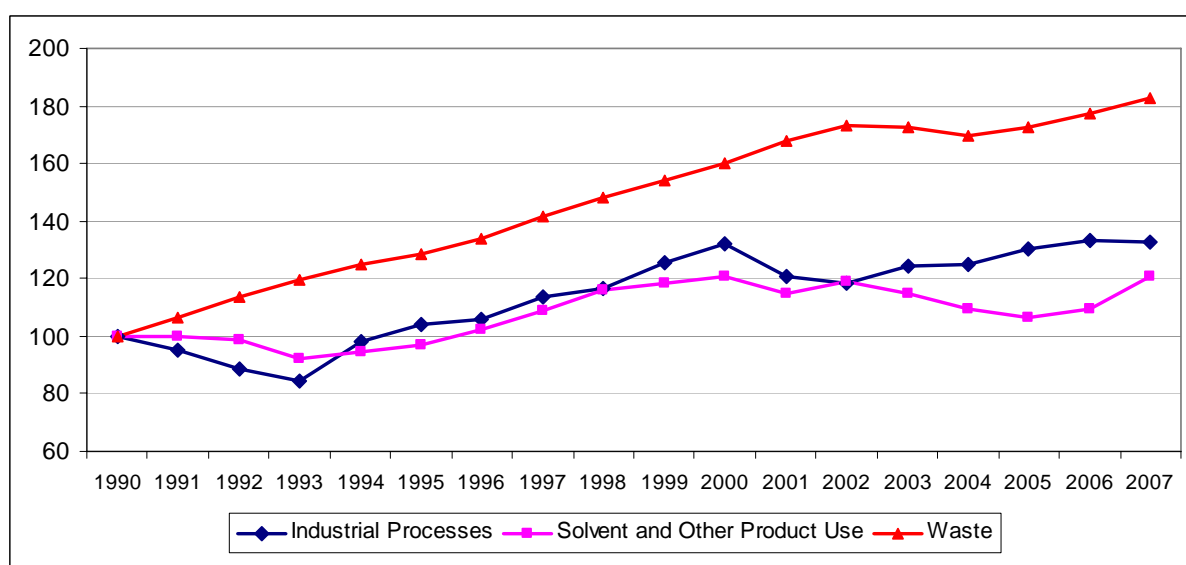
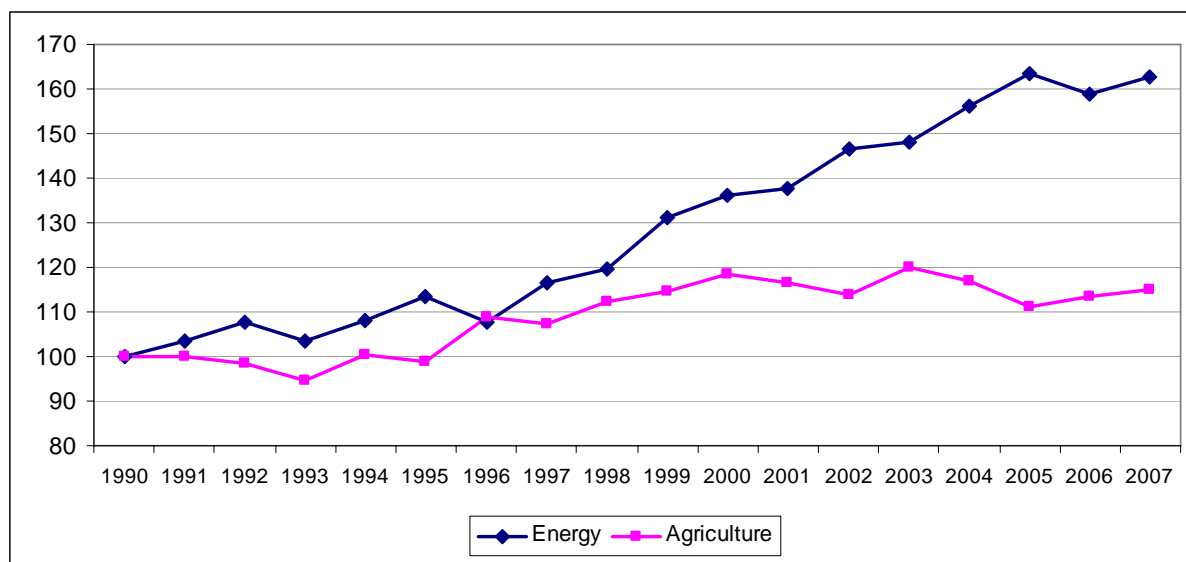


The evolution of the time indices for emissions of the different sectors, shown in the lower part of Table 2.3.1, is illustrated in Figure 2.3.2 below. The upper panel of the figure

shows the indices for emissions in the Energy and Agriculture sectors, and the lower panel includes the sectors of Industrial Processes, Use of Solvents and Other Products, and Waste; all of these take 1990 as reference 100. With respect to the Energy sector, the profiles reproduce to a large extent those mentioned above for the aggregate emissions (Figure 2.1.1) and CO₂ (Figure 2.2.2); this is justified by the close relationship between CO₂ emissions and the Energy sector and between both of these and the aggregate emissions. In the Agriculture sector there is stability between 1990 and 1995, followed by a period of sustained growth from 1997 to 2000, which is followed by a period from 2000-2007 with fluctuations though generally characterized by a slight decrease. The evolution of this sector is basically determined by CH₄ emissions deriving from enteral fermentation and N₂O from agricultural soils, and in this latter activity the fluctuations are associated with interannual variations in the amount of synthetic nitrogenized fertilizers applied to crops. The Waste sector shows the most intense and uniform upward trend over the period inventoried, 1990-2007, basically dominated by the evolution of CH₄ emissions in landfills. On the other hand, in the evolution of Industrial Processes there is a reduction in the initial years, 1990-1993, the main cause being the decline in the economic cycle which is particularly reflected in the fall of cement production; this is followed by a period of sustained growth from 1993 to 2000, and a downturn and final recovery from 2001 to 2007 caused by the evolution of PFC and HFC emissions in this period, as already discussed in section 2.2. Lastly, the Use of Solvents and Other Products sector shows, after a stable phase in the years 1990-1992, a sustained increase between 1993-2000, a moderate reduction in the level in subsequent years finishing with a significant increase in the year-on-year rate in the years 2006 and 2007, associated with the use of N₂, although its very low absolute level makes it irrelevant with respect to the evolution of the aggregate.

In conclusion, it is possible to distinguish, on the one hand, the evolution of the Waste Treatment and Energy Processing sectors, both with very high emission growth rates of 83% and 62.6% respectively if the level for 2007 is compared with the reference year of 1990 and, on the other hand, more moderate evolution for the Industrial Processes and Agriculture sectors, whose growth rates are similar at 32.4% and 15.1%. The Use of Solvents and Other Products sector has a variation of 20.6% between the start and end of the inventoried period but, as has been stated above, there is almost no impact on the variation in the aggregate.

In any case, to see with greater details the causes affecting the evolution in the different sectors, please refer to chapters 3 to 8 where a detailed description is given of the activities potentially emitting greenhouse gases, as well as the emission figures broken down by gas and sector for the years 1990, 1995 and 2003-2007 in Appendix 6.

Figure 2.3.2. - Time indices for emissions by activity sector

2.4.- Description and interpretation of trends for gases with an indirect greenhouse effect

Table 2.4.1 shows the evolution of greenhouse gases in absolute values expressed in gigagrammes of each gas (upper part of the table) and as time evolution indices (1990 = 100; lower part of the table), and the variation in these indices is illustrated in Figure 2.4.1.

With respect to NO_x emissions, these are primarily the result of combustion processes from stationary or mobile sources, with industrial processes and agriculture coming in a distant second. In spite of the technological advances experienced in the major sources generating this gas (power generation, transport vehicles, etc.) and the reduction brought about in the emission standards (emissions per unit of product), the growth in activity sectors such as energy and transport have counteracted the effect of technological gains and absolute emissions grew by 20.2% between 1990 and 2007.

CO emissions originate from the incomplete oxidation of fuels in combustion processes and their emissions come primarily from the energy sector (which of course includes combustion in transport). The Transport sector is where it has been possible to achieve marked reductions in emission levels due to the penetration of new technologies (catalytic converters) in petrol-driven vehicles and also the relative increase of diesel vehicles versus petrol. The emissions of this gas have decreased by 34.2% between the start and end of the period inventoried.

NM VOC emissions mainly originate from the Energy and Use of Solvents sectors, and secondarily from Industrial Processes and the other sectors. Throughout the period inventoried, the energy sector has demonstrated a reduction in its relative contribution, fundamentally due to the reduction in automobile emission levels (introduction of catalytic converters) and also due to the relative increase in diesel vehicles compared to petrol-driven ones. Major improvements have also been recorded in the use of solvents, through a reduction in the volatile organic components in the products used as well as through improvements in product application and waste management. Overall, the emissions of this gas have been reduced to 13.5% between 1990 and 2007.

The energy sector absolutely dominates the generation of SO₂ emissions, with percentages of around 99% during the course of the period inventoried. The main reduction in this sector has been achieved by introducing an important change towards the use of fuels with minimal sulphur content. Hence, the reduction in the emissions of this gas, the largest among the four gases considered in this sub-section, was 46.6% between 1990 and 2007.

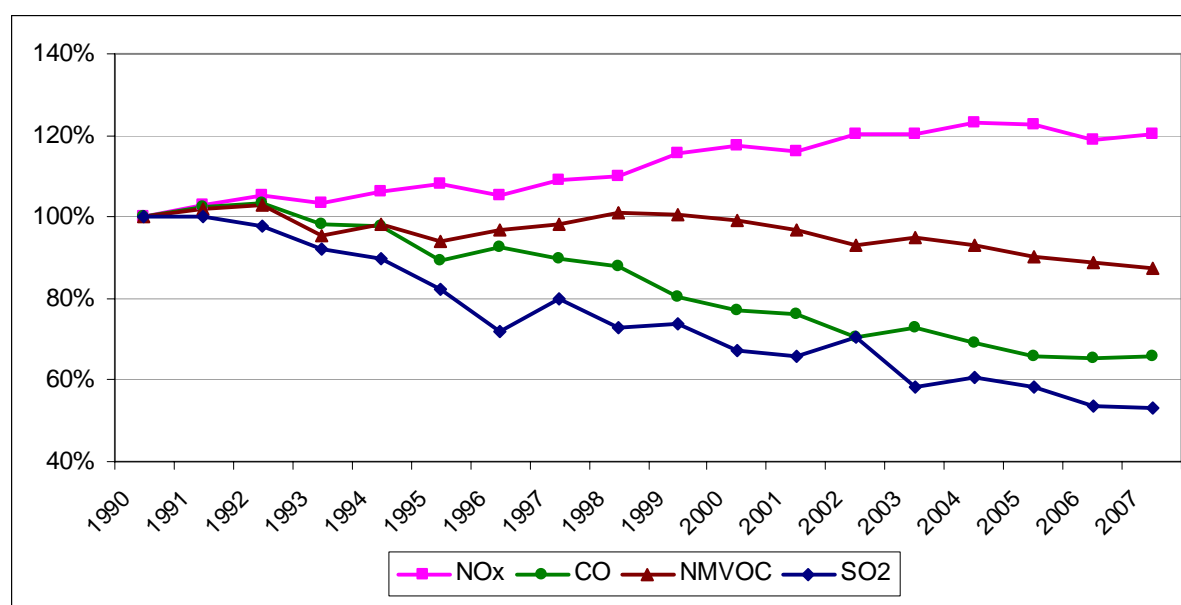
All this information can be seen in greater detail (with a breakdown by activity sector and gas) in Appendix 6 of this report.

Table 2.4.1. - Evolution of emissions of NO_x, CO, NMVOC and SO₂**Absolute values (Gigagrammes)**

GAS	1990	1995	2003	2004	2005	2006	2007
NO _x	1,246.38	1,347.15	1,501.35	1,531.65	1,530.25	1,481.35	1,498.46
CO	3,884.78	3,477.20	2,831.58	2,693.71	2,556.76	2,538.32	2,555.24
NMVOC	1,095.24	1,031.11	1,039.94	1,020.02	990.45	973.63	958.22
SO ₂	2,166.84	1,781.91	1,266.80	1,309.89	1,265.93	1,161.52	1,156.03

Annual evolution index (1990 = 100)

GAS	1990	1995	2003	2004	2005	2006	2007
NO _x	100.0	108.1	120.5	122.9	122.8	118.9	120.2
CO	100.0	89.5	72.9	69.3	65.8	65.3	65.8
NMVOC	100.0	94.1	95.0	93.1	90.4	88.9	87.5
SO ₂	100.0	82.2	58.5	60.5	58.4	53.6	53.4

Figure 2.4.1. - Time indices for emissions of NO_x, CO, NMVOC and SO₂

3.- ENERGY

3.1.- Sector panorama

The energy emissions in 2007 represented 78.09% of the total inventory emissions of CO₂equivalent (CO₂-eq), implying an increase in its contribution with regard to 1990, in which they represented 73.74% of the total. Therefore, a 62.6% increase in this sector's CO₂-eq emissions has been recorded within the 1990-2007 inventory period. CO₂-eq went from 212,465 (Gg) in 1990 to 345,391 Gg in 2007. Table 3.1.1 described the energy sector emissions in terms of CO₂-eq and itemized by component categories according to the CRF nomenclature. A distinction is made between fuel combustion activities (1A1 to 1A4 categories) and fugitive emissions from fuels (1B1 and 1B2 categories).

Table 3.1.1.– CO₂ Equivalent Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
1.A Combustion activities	208,238	236,503	310,719	327,426	343,222	333,217	341,371
1.A.1 Energy sector industries	77,694	86,813	106,528	115,938	126,075	117,081	123,035
1.A.2 Manufacturing industries and construction	46,661	53,315	68,626	70,744	71,518	69,737	68,330
1.A.3 Transport	57,483	66,983	97,472	101,290	105,548	108,611	112,269
1.A.4 Other sectors	26,400	29,392	38,094	39,454	40,081	37,788	37,737
1.B Fugitive emissions from fuels	4,227	4,202	3,722	4,074	4,087	3,953	4,020
1.B.1 Solid fuels	1,835	1,483	1,115	1,064	1,029	1,055	978
1.B.2 Oil and natural gas	2,391	2,720	2,607	3,010	3,058	2,898	3,043
Total Energy	212,465	240,706	314,442	331,500	347,309	337,170	345,391

As can be observed, the majority of the emissions of this sector come from combustion activities (over 98%), with fugitive emissions constituting a lesser source of emissions not only in the sector but in the total inventory. For this reason the evolution of emissions in the sector is determined by combustion activities. Figure 3.1.1 shows the evolution of the sector's CO₂-equivalent emissions, broken down into each of their categories.

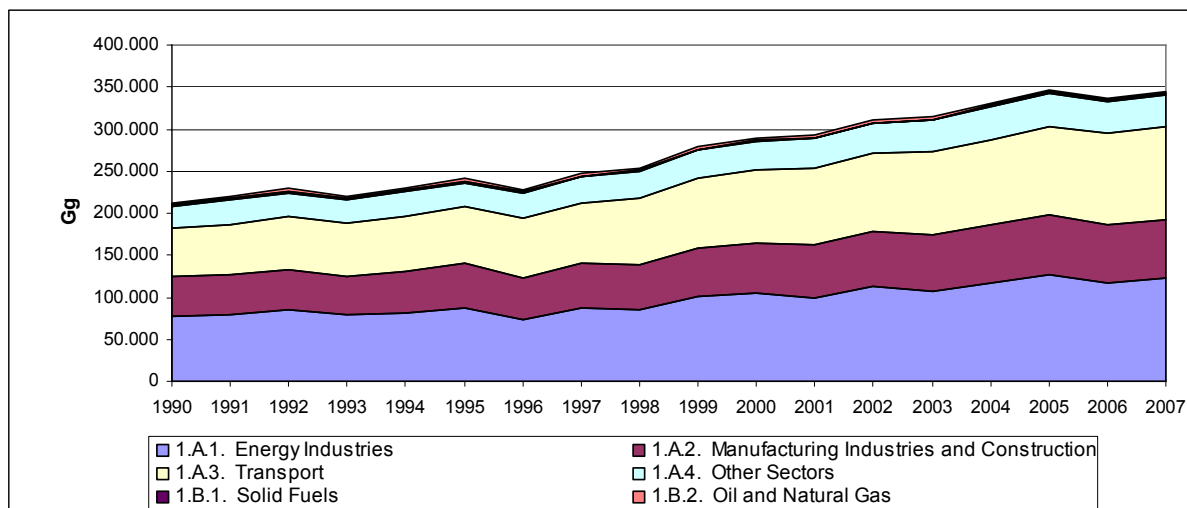
Figure 3.1.1.– Evolution of CO₂-equivalent emissions

Figure 3.1.2 shows the contribution of the various source categories in the energy sector to the total emissions of CO₂-eq during the period 1990-2007. As can be seen, the combined contribution of the sector is greater than 70% of the total emissions, with its highest quota (78.7%) being reached in 2005.

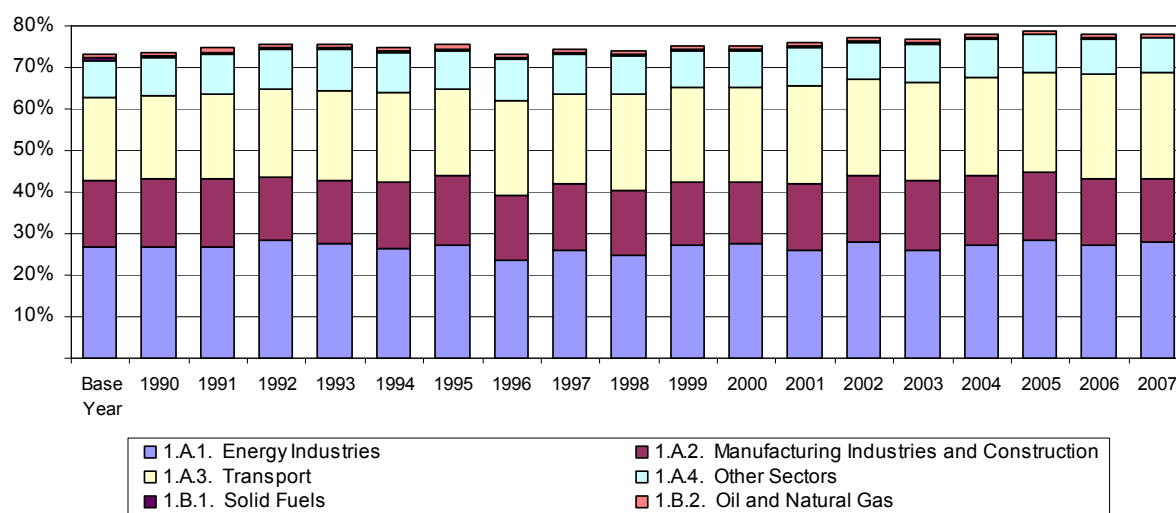
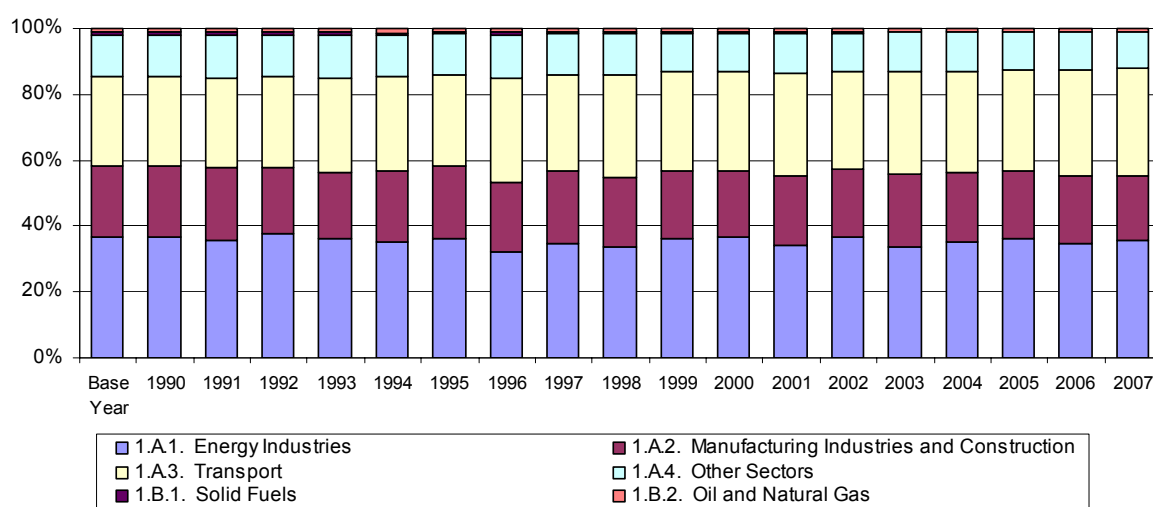
Figure 3.1.2.- Percentage of CO₂-eq emissions by category in relation to the total of the inventory

Figure 3.1.3 shows the distribution by source category of CO₂-equivalent emissions in the energy sector. As illustrated in the figure, the main categories that contribute to these sector's emissions are those belonging to the energy sector (power plants, oil refineries, conversion of fuels) and to transport (35.6 and 32.5%, respectively for 2007), followed by

manufacturing industries and construction (19.8% for 2007) and combustion in other sectors (10.9% for 2007). As mentioned before, emissions from the combustibles fugitive emissions category are of less relevance (less than 1.2% for 2007) within the sector. However, it is worth mentioning the decreasing contribution of solid fuels emissions compared to the increasing evolution of the liquid and gas fuel, this being a reflection of the increase in the consumption of natural gas and petroleum fuels compared to the consumption of carbons.

Figure 3.1.3.- Percentage of CO₂-eq emissions by category in relation to the sector's total



a) Primary Information Sources (Activity Variables, Algorithms, and Emission Factors)

The most relevant activity variables for this sector are the consumption of fuels and the assignment of these to different categories in the sector.

Throughout the inventory, a principle of consistency with the national fuel balance is adopted, regarding the totals of each type of fuel, in the EUROSTAT and International Energy Agency (IEA) versions, up to the penultimate year of the inventory period, and in the MITYC's (Ministry of Industry, Trade and Tourism) version of the international energy questionnaires for the last year of the inventory period¹. Notwithstanding the aforementioned, in itemizing the sector, information for the inventory is drawn, mostly, from the direct information cases from the plants belonging to those sectors to which individual questionnaires have been sent. When the information has been obtained through this manner and completely covers a particular sector, preference is given to this information source over other alternate sources. However,

¹ This source availability (IEA and EUROSTAT energetic balances on one end and international energy questionnaires on the other) should be considered throughout this chapter whenever reference sources on energy data are mentioned.

when the information received from an individual source does not wholly cover a particular sector, the complementary information from the information source most aggregated is used to obtain the total consumption estimate of the corresponding sector. Furthermore, for some other sectors, an estimation is made of the fuel consumption from specific consumption ratios, taking into account the information provided on their activity variables (including the consumption of the national fishery fleet or agricultural and forestry machinery).

As for fuel types, these are taken from the EMEP/CORINAIR's NAPFUE nomenclature, complemented where necessary by the IPCC. Additionally, for certain fuels that are particularly relevant to the computation of CO₂ emissions, an individualized analysis is reached by plants from the energy and industrial sectors, allowing them to effect the estimation of the emissions by means of a carbon balance.

As for the emissions estimation algorithms, these start, as far as possible, from the carbon balance to estimate CO₂ emissions (the IPCC methodology based on the fuel's carbon content and an oxidation factor for turning carbon to CO₂) although, when this information is not available for a fuel, an approximation is taken for the final CO₂ factor, based on the standard characteristics of the fuels (essentially the net heating value). For CH₄ and N₂O, where the mass balance methodology is not operational, emission factors have been taken from bibliographic references, among which it is fitting to emphasize the 1996 IPCC Reference Manual, the IPCC Good Practices Guidance, the EMEP/CORINAIR Handbook, and other sectoral sources (American Petroleum Institute, API) or institutions (CITEPA = Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique).

Specific information sources for the key activities in this sector are mentioned below in the presentation of each of the particular activities.

b) Completeness, transparency and consistency over time

The estimated emissions of the three main gases with a direct global warming effect (CO₂, CH₄ and N₂O) cover the immense majority of the CRF categories in the energy sector. In this sector, the emissions from municipal solid waste incineration plants and from biogas combustion from landfills are included whenever energy recovery of incinerated waste and biogas is undertaken in these activities. Nevertheless, the failure to include the differentiated emissions corresponding to military use of energy, the CO₂ emissions coming from the extraction and manipulation of coals, the emissions (venting and flaring) coming from the production of petroleum and natural gas and the emissions from the incineration of industrial waste, (although the emissions for part of this kind of waste are accounted for in the plants which recover the energy from the same) could be considered as a limitation in applying the completeness principle.

In the energy sector, intensive use is made of information gathered via individualized questionnaire addressed to the plants considered to be large point sources, including those in the following sectors: public power plants, incineration plants and large municipal solid waste landfills, oil refineries, transformation of solid fuels (coke ovens in integrated iron and steel industry), integrated iron and steel industry plants, alumina and primary aluminium production,

paper pulp mills and glass manufacture². For these plants the base information is used to allow a detailed analysis of the fuel consumption and their composition in terms of carbon content and heating values. This information is traceable, after the lifting of the confidentiality requirements by some sectors for the revision of the national inventories. For the sectors and activities in which the information has been processed using sources that are not individualized by plant, in most of the relevant cases sectorial and provincial (NUTS3) breakdowns are available, allowing a detailed analysis of the information in line with the *bottom-up* approach.

The key sources in the energy sector are examined in detail below. For the period 1990-2007, the following key sources have been identified:

- Public service heat and power plants (1A1a) for CO₂ emissions. For solid and liquid fuels due to their emission level throughout the 1990-2007 period and for gas fuels due to their level for the 1997-2007 period. Due to the trend, for solid fuels through the years 1990-1994 and 1996-2007, for liquid fuels through the years 1990-1992, 1994-2007, and for gas fuels through the years 1993-1995 and 1997-2007.
- Oil refineries (1A1b) for CO₂ emissions. For liquid fuels by their emission level throughout the whole period 1990-2007 and by their trend in 1990-1992, 1994-1996 and 1998-2007; and for gas fuels by their trend in 1997-2000 and 2002-2007.
- Transformation of solid fuels and other energy industries (1A1c) for CO₂ emissions. For solid fuels by their emission levels in the years 1990-1994 and by their trend in the period 1992-2007; for liquid fuels by their trend in 1994-2000; and for gas fuels by their trend in the year 1996.
- Stationary combustion in the industrial sector (1A2) for CO₂ emissions. Due to the emission level throughout the 1990-2007 period of solid, liquid and gas fuels. Due to the trend of solid and liquid fuels throughout the 1990-2007 period and for gas fuels due to their trend in the years 1990 and 1992-2007.
- National air traffic (1A3a) by its CO₂ emission level throughout the period 1990-2007 and by its trend in 1990-1997 and 2007.
- Road transport (1A3b): for CO₂ by its emission level and by its trend throughout the period 1990-2007 in both gasoline and diesel; and for N₂O by its level in 1997-2007 and by its trend in 1993-2007.
- National navigation (1A3d) by its CO₂ emission level in 1990-1996, and 1999-2007 and by its trend in 1993-1994 and 1997-1998.
- Stationary combustion in "Other Sectors" (1A4). Due to the CO₂ emission level throughout the 1990-2007 period for liquid and gas fuels, and in the 1990-1996 period for solid fuels. Due to the trend in CO₂ emissions, for solid fuels in the years 1991-1992

² Regarding the glass manufacture plants, the information by means of individualized questionnaires is available starting from year 2003.

and 1994-2007, for liquid fuels in the years 1990-1994 and 1996-2007, and for gas fuels in the 1991-2007 period. Regarding CH₄ emissions, this activity is a key source due to its trend in the years 1995 and 1999 for all of the fuels.

- Fugitive emissions – solid fuels (1B1): for CH₄ by its emission level in 1990-1998, and by its trend in the period 1991-2007.
- Fugitive emissions – oil and natural gas (1B2): for CO₂ by its level in all the years in the period 1990-2007, and by its trend in 1991, 1993 and 1994; and for CH₄ by its trend in 1991 and 1992.

As a summary of the foregoing information Table 3.1.2 below presents, for the key categories in this sector, the contribution of the emissions to the level and trend, and the category's ranking in relation to the key sources³, as well as the absolute values in terms of CO₂-eq, all referred to 2007.

Table 3.1.2.- Key sources: Level and Evolution

IPCC Activity		Gas	CO ₂ -eq (Gg) (2007)	Level Assessment (2007)			Contribution Trend (2007)		
Code	Description			%	Key source	Rank	%	Key source	Rank
1A1	Combustion in energy sector	N ₂ O	739	0.17	NO	37	0.14	NO	40
1A1a	Public electricity and heat production - Solid	CO ₂	71,082	16.07	YES	2	7.46	YES	5
1A1a	Public electricity and heat production – Liquid	CO ₂	9,706	2.19	YES	14	0.24	NO	31
1A1a	Public electricity and heat production - Gaseous	CO ₂	25,880	5.85	YES	4	11.10	YES	2
1A1b	Oil refining – Liquid	CO ₂	11,372	2.57	YES	10	2.28	YES	13
1A1b	Oil refining – Gaseous	CO ₂	1,478	0.33	NO	30	0.62	YES	24
1A1c	Manufacture of solid fuels and other energy industries – Solid	CO ₂	945	0.21	NO	34	0.82	YES	20
1A1c	Manufacture of solid fuels and other energy industries – Liquid	CO ₂	780	0.18	NO	36	0.31	NO	29
1A1c	Manufacture of solid fuels and other energy industries – Gaseous	CO ₂	197	0.04	NO	53	0.05	NO	50
1A2	Stationary combustion in industry – Solid	CO ₂	5,694	1.29	YES	18	6.37	YES	6
1A2	Stationary combustion in industry – Liquid	CO ₂	25,750	5.82	YES	5	5.10	YES	7
1A2	Stationary combustion in industry – Gaseous	CO ₂	35,621	8.05	YES	3	10.02	YES	3
1A3a	Domestic civil aviation	CO ₂	7,582	1.71	YES	17	0.57	YES	25
1A3b	Road transportation - Gasoline	CO ₂	76,542	17.30	YES	1	17.30	YES	1
1A3b	Road transportation – Gasoil	CO ₂	21,185	4.79	YES	7	8.06	YES	4
1A3b	Road transport	N ₂ O	2,851	0.64	YES	23	0.80	YES	21
1A3d	National navigation	CO ₂	3,260	0.74	YES	21	0.43	NO	27
1A4	Stationary combustion in other sectors – Solid	CO ₂	553	0.13	NO	42	1.29	YES	17
1A4	Stationary combustion in other sectors – Liquid	CO ₂	24,910	5.63	YES	6	3.57	YES	9
1A4	Stationary combustion in other sectors – Gaseous	CO ₂	11,283	2.55	YES	11	4.08	YES	8
1A4	Stationary combustion in other sectors	CH ₄	658	0.15	NO	39	0.26	NO	30
1B1	Fugitive emissions – Solid fuels	CH ₄	884	0.20	NO	35	0.83	YES	19
1B2	Fugitive emissions – Oil and natural gas	CO ₂	2,482	0.56	YES	24	0.09	NO	44
1B2	Fugitive emissions – Oil and natural gas	CH ₄	560	0.13	NO	41	0.18	NO	37

³ Ranking determined by the contribution of the emissions in the category to the level or the trend.

c) Explanation of the trend

The emissions in this category are clearly dominated by those from combustion activities, as these represent between 98% and 99% of the category, with totally marginal fugitive emissions.

The main activity group comprises the energy industries sector (category 1A1, including power plants, oil refineries, fuel manufacturing), as these represent between 32% and 38% of the emissions in the category. Due to its relative weight, it is important to highlight in this aggregate, on the one hand, the evolution of power plants and, on the other hand, the oil refining industry, as the solid fuel transformation sub-sector has a tiny weighting inside the whole group. In the trend emissions of power plants two sub-intervals large gaps can be clearly distinguished. The period 1990-1998 relatively stable with moderate growth, and the period 1998-2007 with a significant rate increase in line with the electric energy necessity caused by economic growth. Regarding this general trend pattern, the emissions appear modulated by peaks and troughs mainly due to the impact of the hydrological year on electricity generation. The noted trough years are 1996, 2001, 2003 and 2006, and relative peak years 1995, 2002 and 2005. Regarding the oil refineries, the evolution of emission is basically noted by its volume of crude oil refined, as well as the expansion in co-generation activities within this industry; and in the last few years by the extension of particular processes (hydrogen manufacturing plants), intensive fuel consumption. The total CO₂-eq emissions for category 1A1 have increased more than 58% when compared the level in 2007 to 1990.

For industrial combustion (category 1A2), the emission continue in the general trend and fluctuation of the country's economic activity, with a decrease in 1990-1993, a fluctuation period between 1993-1997 and a period of late growth, with a downturn in 2006 and 2007. The change in the fuel mix toward composition with less carbon content per energy unit has also played an important role in the evolution of emissions. The CO₂-eq emissions in category 1A2 experience a variation greater than 46% in 2007 versus 1990.

Emission contributions within the transport activities category vary from 27% to 33% inside the period studied, with road transport as the predominant emphasis, with CO₂-eq emissions between 89%-92% for transport in the period inventoried. Showing as well elevated interannual rate, with an exception in 1993 of a decrease and practically stable in 1995. A long way from road transport is air traffic (between 4.4%-7.3% CO₂-eq emissions of transport) which after the period 1990-1994 of decrease in activity and consequently emissions, experienced a significant increase in activity level, with a parenthetical exception made in 2000-2003 during the relative crisis in the sector within the international political context. Finally, maritime transport, starting from a position of little weight in relation to the whole of transport (between 1.6% and 2.9% in the inventoried period) experienced sustained growth from 1998. Other transportation modes (railroad, pipeline, etc.) have a marginal contribution. The total of CO₂-eq emissions for all transport activities present an increase over 95% of 2007 versus 1990.

As for the combustion in "Other sectors" (category 1A4, where the combustion in residential, commercial and institutional sector is included, as well as the use of fuels in agricultural and forestry machinery and fishery fleet), there can be distinguished the 1990-1997 period, of relative stability or moderate growth, and the 1997-2005 period, of sustained growth followed by 2006, with a downward inflection, and the year 2007 which has practically

the same level as 2006. Part of the profile is caused by the evolution of activity level and economic income but with peaks and troughs less strident than those presented in industrial combustion. The emission contribution of this category oscillates between 11-13% in the period studied, with a variation in CO₂-eq emissions between the year 2007 and 1990 of 42.9%.

d) Quality assurance program

As already stated in heading 1.6.5 of chapter 1, during 2007-2008 the "Quality assurance program of the national inventory of air pollutant emissions" was developed, which was commissioned to CIEMAT⁴ (Research Centre for Energy, Environment and Technology). In the stated program, two of the main areas are covered, one referred to the inventory general aspects and a second one specific to the Energy sector which is the one reported hereinafter.

As a summary of the main conclusions about the aspects related to the energy the following ones must be pointed out:

a) Input data

Improvement in the emission factors documentation, mainly in those cases related to very singular fuel or processes.

b) List of emission sources

To homogenize the data processing in the waste treatment plants where energy recovery is in place, in which presently the incinerators and landfills are included.

Harmonization of the sources identification to cover the Large Combustion Plants (LCP) (Directive 2001/80/EC and Royal Decree 430/2004).

c) Questionnaires

Questionnaires design improvements to avoid possible ambiguities in the information requirements that could lead to interpretation misunderstandings of the data supplied. Consequently fulfilment norms of the questionnaires must be adopted to facilitate and clarify to the centres responsible persons what are the needed requirements.

d) Quality controls

Intensification of the quality controls applied to the information provided in the questionnaires, it could be in the questionnaires itself or in the following information processing by means of auxiliary tools or in the database itself. Specifically, special attention must be given to the data provided about measured emissions (SO₂, NO_x, particulate matter), declared fuel characteristics, as well as to avoid the lack of information in the data provided.

⁴ See in this sense reference to CIEMAT in Heading 1.2.3.

e) Generated documentation

Improvement of the generated documentation, expanding the explanations about the controls carried out, criteria used in the assignation of the various nomenclature (specially for what concern the fuels), and the data modification applied.

f) Database (structure and content)

Improvement of the transparency regarding the auxiliary tools of the main database.

g) Traceability

Improvement of the traceability of the database modified information, by means of intrinsic mechanism of the database itself or through references in the elaborated reports.

h) Emissions data (data processing)

Extension of the contrast development between emission estimates based upon measures and those based upon calculations.

i) Reports

Improvement in the elaborated reports by including a more detailed information about the fuels consumed, estimate methodology used and references to the additional information and documents used.

The remaining headings in this chapter examine the activities (by IPCC category) or group of activities (combinations of more than one IPCC category) in the energy sector, having taken into account for this grouping the identification of key sources given above; in some cases two or more key sources have been grouped together for ease of presentation and, in any case, the final heading also provides a single presentation (albeit more summarized) of the non-key sources for the sector.

3.2.- Production of public service heat and power (1A1a)

3.2.1.- Description of the activity

Public service heat and power generation plants are included here, where they constitute one of the main contributions to the emissions in the inventory as a whole. It should be noted that conventional power plants are included here alongside municipal solid waste plants and municipal solid waste landfills carrying out energy recovery (electricity generation).

In the power plants, the dominant type of installation is boilers, and, among these, those with power ratings in excess of 300 MWt. Besides boilers, installations of engines and gas turbines are also significant.

Table 3.2.1 shows greenhouse gas emissions by type of fuel, with CO₂ making this a key source. Table 3.2.2 complements the previous information expressing the combined emissions

of the three gases (CO₂, CH₄ and N₂O) in terms of CO₂-eq. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector. CO₂ emissions caused by burning biomass do not appear in these tables since, according to IPCC methodology, these must not be counted in the inventory, although they have been estimated as a Memo item and reflected as such in the CRF Reporter.

Table 3.2.1.- Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO₂							
Liquid	6,007	7,880	10,995	11,886	12,964	11,293	9,706
Solid	57,787	63,397	71,666	75,246	75,996	65,583	71,082
Gases	427	135	7,860	11,881	20,375	23,857	25,880
Biomass							
Other	120	221	561	632	712	687	697
Total	64,341	71,633	91,082	99,645	110,047	101,420	107,365
CH₄							
Liquid	0.10	0.13	0.24	0.27	0.32	0.31	0.31
Solid	0.35	0.39	0.44	0.46	0.47	0.40	0.44
Gases	0.00	0.00	0.42	0.69	1.21	1.56	1.73
Biomass	0.00	0.14	1.49	2.47	2.59	2.92	3.06
Other	0.00	0.00	0.02	0.01	0.01	0.01	0.01
Total	0.45	0.66	2.62	3.90	4.61	5.22	5.54
N₂O							
Liquid	0.12	0.16	0.23	0.25	0.28	0.24	0.21
Solid	0.47	1.21	1.24	1.18	1.13	0.97	0.99
Gases	0.01	0.00	0.17	0.26	0.45	0.54	0.60
Biomass	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Other	0.04	0.07	0.17	0.17	0.18	0.19	0.19
Total	0.64	1.44	1.82	1.88	2.04	1.96	2.01

Table 3.2.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	64,548	72,094	91,701	100,310	110,778	102,137	108,104
CO ₂ -eq Index	100.0	111.7	142.1	155.4	171.6	158.2	167.5
% of CO ₂ -eq over total inventory	22.40	22.59	22.35	23.55	25.11	23.58	24.44
% CO ₂ -eq on energy	30.38	29.95	29.16	30.26	31.90	30.29	31.30

3.2.2.- Methodology

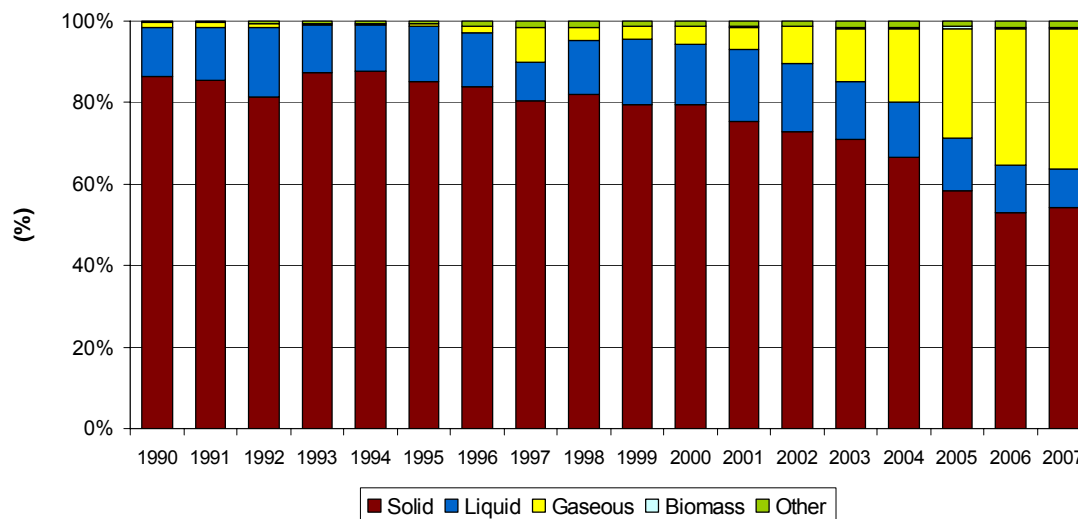
Table 3.2.3 shows the activity variable and fuel consumption, expressed in energy terms (terajoules of lower heating value, TJ_{LHV}). This is derived information calculated from the consumption in physical units (tonnes or m³N) and the corresponding heating values. The information about fuel characteristics and consumption obtained via the individualized questionnaires to thermal power stations includes their composition and, among their characteristics, apart from the LHV parameter cited above, the contents in carbon, sulphur, ash, etc. determined by means of analytical methods. These results provide the annual mean values of these parameters. In reference to the municipal solid waste incinerators and landfills that recover energy, the information about the quantities of waste and biogas burned has been

obtained in the same way: by means of individualized questionnaires to each incineration plant and large landfill, soliciting from each one the composition of waste and biogas, as well as other parameters required for the application of estimation emission algorithms.

Table 3.2.3.- Fuel consumption (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Liquid	79,772	103,438	144,673	156,421	170,276	148,370	127,138
Diesel	6,947	9,307	27,469	34,238	43,470	47,231	50,154
Residual oil	72,825	94,131	117,204	121,003	126,747	101,084	76,951
Petroleum coke				1,134			
Other liquid fuels				46	59	55	33
Solid	581,243	645,835	727,941	767,240	778,218	670,057	724,436
Hard coal	401,954	460,387	606,215	643,058	656,325	559,634	614,122
Sub-bituminous coal	53,162	104,118	42,678	46,932	47,585	42,556	41,995
Brown coal	114,539	75,380	67,273	65,080	61,976	57,032	56,385
Coke							
Brown coal briquettes	5,860						
Coke oven gas	944	591	2,500	2,732	2,410	2,327	1,834
Blast furnace gas	4,784	5,359	9,274	9,438	9,922	8,508	10,099
Gases	7,337	2,638	134,009	205,808	357,841	420,963	457,565
Natural gas	7,337	2,638	125,635	198,270	351,374	414,317	450,826
Other gaseous fuels			8,374	7,538	6,466	6,645	6,739
Biomass	4	242	3,560	5,499	5,896	6,494	6,199
Wood/Wood wastes			146	405	352	266	268
Other solid biomass			767	719	1,080	1,209	612
Biogas	4	242	2,647	4,375	4,464	5,019	5,319
Other	3,103	5,708	15,483	17,423	17,978	19,189	19,845
MSW	3,103	5,708	15,277	15,423	15,598	17,461	18,532
Industrial wastes			206	2,000	2,379	1,728	1,313
Total	671,459	757,862	1,025,666	1,152,391	1,330,208	1,265,073	1,335,183

With regard to fuels, there is a clear predominance of solid fuels (domestic and imported coal) and by classes of fuel, coals and anthracites are followed by brown lignite and of sub-bituminous coal, and to a lesser extent gases derived from primary solid fuels (gas from coke ovens and furnaces). The main consumption among liquid fuels corresponds to residual oil with a complementary contribution of gas-oil, although from 2006 it can be observed an appreciable drop in the residual oil consumption due to the shutdown of the plants that used this fuel). As for gaseous fuels, the increase in natural gas consumption is clear especially since 2002 as a consequence of the commissioning of the new combined cycle thermal power stations that mostly use this fuel. Finally, in the group of other combustibles, the consumption due to solid municipal waste in incineration and biogas in landfills which recover said waste and biogas, is included. Figure 3.2.1 shows the distribution of consumption in terms of energy by type of fuel during the inventory period.

Figure 3.2.1.- Distribution of fuel consumption, based on TJ_{lhv} 

For the estimation of CO₂ emissions, preference is given to the calculation procedure starting from the carbon content in each fuel used, and the stoichiometric calculation elevated to mass of CO₂ is complemented with the inclusion of the oxidation factor. Specifically, the following estimation algorithm is applied:

$$FE_{CO_2} [kg / GJ] = \frac{44}{12} \cdot C_{comb} \cdot \varepsilon \cdot \frac{1}{H_U} \cdot 10^6 \quad [3.2.1]$$

where

EF_{CO_2} : specified emission factor

C_{comb} : the fuel's carbon ratio (kg of C/kg of fuel)

ε : fraction of oxidized carbon

H_U : the lower heating value (in MJ per kg of fuel)

The values of CC_{comb} and H_U should be taken as specific for each type of fuel used. The default values for the oxidized carbon fraction (ε) are in line with the 1996 IPCC Reference Manual, namely:

Solid fuels : 0.980

Liquid Fuels: 0.990

Gaseous Fuels: 0.995

Where it was not possible to use the specific characteristics of the fuels (in particular with regard to their carbon content) the default emission factors have been used on the basis of the standard characteristics of the fuels.

For the estimation (as a Memo item) of CO₂ from biomass, the emission factors applied have been inferred from the proposed carbon contents appearing in the 1996 IPCC Reference Manual.

With regard to the estimation of CH₄ and N₂O emissions, the factors applied are selected from the different methodological guides (EMEP/CORINAIR, IPCC), and also from sectorial and institutional sources (API, CITEPA) for the energy activity variable (GJ) in terms of LHV. This same procedure is followed for the estimation of other pollutants considered in the CRF (NMVOC and CO), while for SO₂ and NO_x, preference is given to the measured emissions provided by the plants themselves.

Tables 3.2.4 to 3.2.6 show the emission factors by type of installation used in the estimation of the emissions, although in the case of CO₂ the factors indicated are those used by default when the specific characteristics of the fuel are not available.

Table 3.2.4.- Emission factors. Boilers

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	0.03	0.7
Residual oil	76	0.7	1.5
Petroleum coke	98.3	0.3	2.5
Other liquid fuels	73 (1) 92.9-93.3 (2) (5)	0.7 (3)	1.5 (3)
Hard coal	101	0.6	0.8 96 (4)
Sub-bituminous coal	99.42	0.6	0.8 96 (4)
Brown coal	100.2	0.6	0.8
Coke	99.8	1.3	3
Brown coal briquettes	98	0.6	0.8
Coke oven gas	37.5 – 45.2 (5)	2.5	1.75
Blast furnace gas	267.1 – 279.9 (5)	0.3	1.75
Natural gas	55-56 (6)	0.1	0.9
Wood/Wood wastes	110	32	4
Agricultural wastes	110	32	4
Biogas	112	2.5	1.75
Industrial wastes (7)	67-79 (5)	2.9	1.4
Industrial wastes (8)	43.7-51.4 (5)	2.5	1.75

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 111, table 27 and Chapter 112, Table 7.

1996 IPCC Reference Manual, Table 1-1, for CO₂ from biomass

API Compendium for N₂O from residual oil, gas oil and natural gas ("Uncontrolled boilers and heaters")

CITEPA, for the N₂O from coke, petroleum coke, coke oven gas, furnace gas and biogas.

IPCC Reference Manual, Table 1-15, for the N₂O in coal and black lignite in the case of combustion in fluidized bed.

1996 IPCC Reference Manual, Table 1-8, for the N₂O in wood, wood waste and agricultural waste.

- (1) Used oil.
- (2) The emission factor corresponds to a residual fuel in the chemical industry, composed basically of benzene, toluene, p-xylene, undecane and other heavy components. This emission factor has been obtained by mass balance from the characteristics provided for this fuel.
- (3) Assimilated to the residual oil emission factor
- (4) Combustion in fluidized bed
- (5) The indicated range of CO₂ factors has been obtained by mass balance from the characteristics provided for the fuels in question in the period inventoried.
- (6) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.
- (7) This is shredded rubber. The range of CO₂ factors has been obtained by mass balance starting from the characteristics provided in the period inventoried.
- (8) This takes into account the case of a residual gas for the chemistry industry (resulting from dehydrogenation of propane in the process of producing propylene), after assimilating the emission factors for CH₄ and N₂O to that of coke oven gas for their contents in hydrogen and methane. In the case of CO₂ the factor has been obtained by mass balance from the specific characteristics (carbon content, LHV) provided for the gas in question.

Table 3.2.5.- Emission factors. Gas turbines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	4	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	4	1.3
Other gaseous fuels (2)	117.8 – 126.3	3	2.5
Industrial wastes (2)	43.7-51.4	2.5	1.75

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 111, table 27 and Chapter 112, Table 7.

API Compendium for N₂O in natural gas ("Uncontrolled turbines") and in diesel fuel, assimilating the emission factor in these cases to that of stationary engines.

CITEPA, for the N₂O in residual oil and other gaseous fuels.

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

(2) This is synthetic gas obtained as a result of the coal gasification process. For CO₂ the range of variation is shown for the whole of the period inventoried. For CH₄, the emission factor applied by the Inventory Working Party has been assimilated to that of natural gas, using an intermediate value within the range proposed by the EMEP/CORINAIR Guidebook for this fuel (2.5-4 g/GJ).

(3) The term industrial waste fuels includes a residual gas from the chemistry industry (resulting from dehydrogenation of propane in the process of producing propylene), after assimilating the emission factors for CH₄ and N₂O to that of coke oven gas for their contents in hydrogen and methane. In the case of CO₂ the factor has been obtained by mass balance from the specific characteristics (carbon content, LHV) provided for the gas in question, presenting the range of variation throughout the period inventory.

Table 3.2.6.- Emission factors. Stationary engines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1.5 (Gas-oil) 3.5 (Diesel)	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	50	1.3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 111, table 27 and Chapter 112, Table 7.

API Compendium for the N₂O in residual oil ("Large bore diesel engine")

CITEPA, for N₂O in residual oil.

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

With regard to municipal solid waste incinerators, the emission factors used for the estimation of greenhouse gas emissions have been taken from Tables A1.1 to A1.6 in Appendix I of chapter B-921 of the EMEP/CORINAIR Guidebook, Third Edition. In the case of VOCs, we have assumed 95% of NMVOCs and 5% of CH₄. For CO₂, the emission factor assumed is 324 kg/tonne of waste, calculated on the basis that 36% of this CO₂ is of fossil origin and 64% of biogenic origin, and taking into account that the overall factor (fossil + biogenic) for CO₂ per tonne of waste is 900 kg/tonne. The values indicated for CO₂ have been derived by the Inventory Working Team from data on waste composition. Table 3.2.7 shows the default emission factors used for the estimation of emissions. It is worth noting that in a certain specific case, CH₄ and CO₂ stack emission measurements have been available, although in this latter case the fact that only the part of the said emissions coming from fossil fuels should only be computed according to the IPCC methodology should be taken into consideration.

Table 3.2.7.- Incineration of M.S.W. Emission factors

	CO ₂ (t/t)	CH ₄ (kg/t)	N ₂ O (kg/t)
MSW	0.324	0.001	0.1

The emissions of pollutants from the methane burned in the biogas captured in managed SWDS have been calculated by multiplying tonnes of methane burned by the corresponding

emission factors over the methane burned pertaining to boilers, engines and turbines (see Table 3.2.8). For CH₄ the emission factors have been derived from the information on efficiency percentages in the burning of hydrocarbons taken from Table 2.4-3 of section 2.4 “Municipal Solid Waste Landfill” in the EPA AP-42 5th Ed.; assuming that the complementary efficiency units in the burn constitute the fractions of the methane escaped. The N₂O factor has been derived by the Inventory Working Team on the basis of the value N₂O/GJ_{LHV} for biogas, referred to in the CITEPA publication, “Facteurs d’émission du protoxide d’azote pour les installations de combustion et les procédés industriels”.

Table 3.2.8.- Managed landfills with biogas capture. Emission factors

	Boilers	Engines	Turbines	Unit
CH ₄	20,000	28,000	56,000	g CH ₄ /t CH ₄
N ₂ O	90	90	90	g CH ₂ /t CH ₄

3.2.3.- Uncertainty and consistency over time

The five types of fuels considered in this category correspond to solid, liquid, gaseous, biomass and other fuels; of these, the first three are those with a significant relevance in CO₂ emissions, since with respect to this gas the emissions of each of these three types of fuel, separately, constitute a key source in the inventory.

For the activity variables, and following consultations with representatives of the main electricity generation companies, uncertainty values have been reached for the consumption (mass) of fuels: 2% for solid fuels, 1.5% for liquid fuels and 1.75% for gaseous fuels.

The uncertainty of the emission factors is in turn determined by the carbon contained in the fuel (mass of carbon/mass of fuel) and the oxidation factor for turning carbon into CO₂. As a result of the combination of these uncertainties, it is estimated that the uncertainty corresponding to the emission factors is around 4% for the solid fuels, 2% for liquid fuels and 1.5% for gas fuels.

The activity variables and the emission factors are, in general, considered to have a high degree of consistency over time, as the information comes directly from the electric power stations themselves. However, it is worth mentioning that for the first years in the series (1990-1993), since the collection of information by individualized questionnaire was not used, it was necessary to resort to the statistics provided by the Electric Energy Compensations Office (OFICO)⁵, considered to be a highly reliable source which has made it possible to establish a homogenous link between the series of activity variables and emissions.

⁵ This body, no longer existing, provided data on activity variables until 1994, as well as emissions of CO₂ until 1996.

3.2.4.- Quality assurance and verification

Among the quality assurance tasks in this category emphasis must be placed on the monitoring of the fuel characteristics used in thermal power stations, with special stress on the characteristics of the coals in view of their great variability and their contribution to CO₂ emissions. From the information provided, the corresponding values are checked against the elemental analysis to confirm that the sum of the components in this analysis is equal to 100. In the case of shortcomings in this information or if atypical values arise, the plants are investigated to detect the causes of the anomalies in order to obtain the necessary corrections or justifications of the corresponding parameters. Table 3.2.8 presents the information request model for the characteristics of fuels used in thermal power stations.

Table 3.2.8.- Information requested regarding fuel characteristics

					ELEMENTAL ANALYSIS DRY BASE (% in mass)							Sum of element analysis
FUEL	LHV		PHI %	H ₂ O %	CARBON %	H %	SULPHUR		N %	O %	ASHES %	
	kcal/kg	GJ/t					%	Y/N				

PHI: Coefficient for sulphur retention in slag and ashes.

Sulphur: "Y/N" Indicate whether the sulphur percentage includes the ashes retained.

Furthermore, given the penetration that the combined cycle installations have had over the last few years in the electricity generation sector, the thermal power stations have begun to be requested to provide molar compositions of the natural gas used at each plant, as this is the fuel used in most installations of this kind. From these compositions, the carbon content and the gas density are obtained, allowing the verification of the information provided against the standard values for the gas's characteristics.

Another additional verification, in this case related to the activity variable, is the checking of the consumption levels provided by the thermal power stations against the statistics existing in the different sectors. This comparison permits detection of possible errors or omissions in the fuel consumptions provided; any discrepancies that may appear are investigated with the power stations or with those responsible for the sectorial statistics. In addition, it has been carried out the verification of the homogeneity in power stations (even by facilities) of the ratio of the produced electric power (alternator terminals) with regard to the thermal input energy (in terms of lower heating values) consumed by the power plant (or facility). This control, that is considered of great interest, and that was also recommended in the quality assurance program of the inventory, particularly in the energy sector, developed by CIEMAT, allowed the detection and correction of certain atypical values about fuel consumption.

3.2.5.- New calculations

The main changes made in this activity category with regard to estimates given in the previous edition are described below.

- In the years 2005 and 2006 the CO₂ emission factors in a thermal power plant have been corrected after a mass balance error has been detected. This modification means an increase of 4.7 Gg in emissions of CO₂ in 2005 and 3.5 Gg in 2006.
- It has been revised the lower heating values of the residual oil used in a power plant in 2005, which affects the consumption of the stated fuel expressed in energy units (TJ). This modification in terms of CO₂-eq means a practically negligible drop in the emissions (lower than 0.002Gg).
- For 2005 and 2006 the information regarding the fuel consumption of low-power electricity generation plants operating under the ordinary regime has been revised in accordance with the data appearing in Annex V of the Statistics on Electrical Power (prepared by the Ministry of Industry, Tourism and Trade, MITYC), which were not available at the time of the previous edition of the inventory for 2006, while it has been provided a revised edition for 2005. This update resulted in an increase of CO₂-eq emission of 0.04 Gg in 2005 and 60 Gg in 2006.
- It has been eliminated the biogas consumptions in years 2002 to 2005 from a power plant shown on the stated Annex V of the Statistic on Electrical Power after it has been detected a double accounting of the stated consumption. This update means a minimal drop in the CO₂-eq emissions lower than 0.01 Gg in each year of the 2002-2005 period.

Figure 3.2.2 shows the comparative development of absolute values of the CO₂-eq emissions between the results of the current edition, and the results of the previous edition, while Figure 3.2.3 presents the percentage difference in these emissions between both inventory editions. As can be seen in the latter figure, the relative variation of CO₂ equivalent emissions as a result of the new calculations in this activity is practically negligible in this category, whereas larger variation is seen in 2006 with an increase of 0.07%.

Figure 3.2.2.– CO₂-eq emissions. Comparison of 2009 and 2008 editions

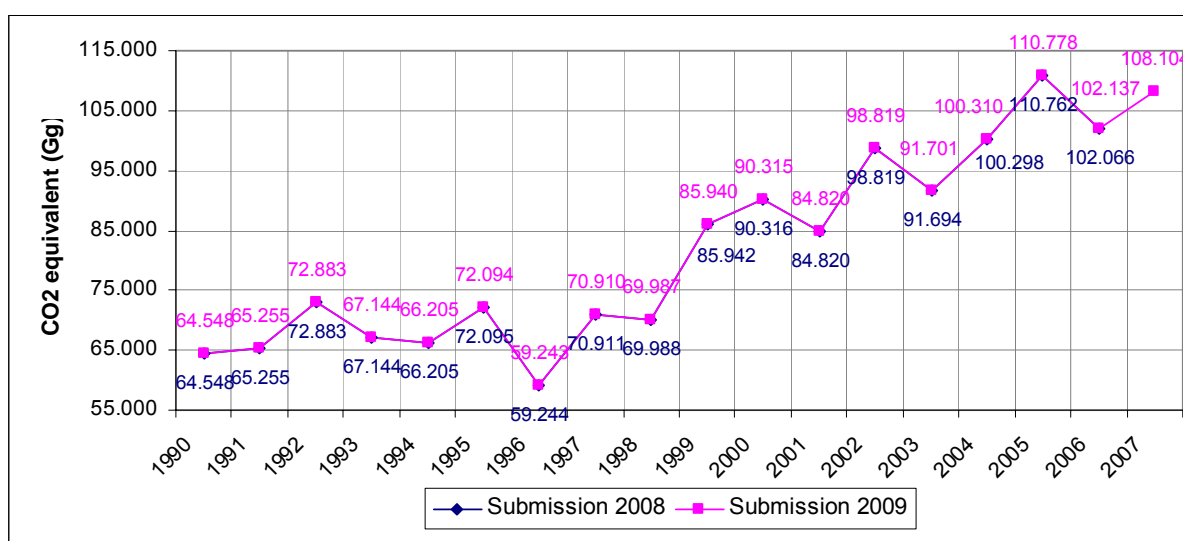
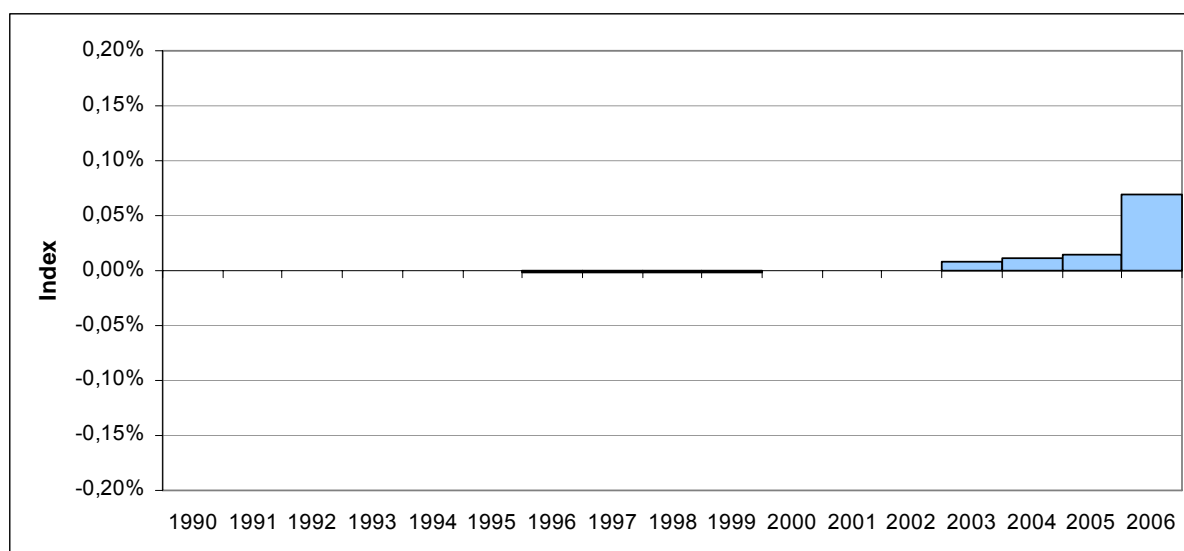


Figure 3.2.3.– CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions

3.2.6.- Improvement Plans

In view of this sector's relevance, intensifying the monitoring of the fuel characteristics in order to have greater control over the atypical values occasionally reported by some power stations is planned. It is also foreseen the continuation and extension of the individual analysis of large landfills, specially the ones that perform biogas recovery.

3.3.- Oil refineries (1A1b)

3.3.1.- Description of the activity

Of the group of activities performed by refineries, those corresponding to combustion processes are dealt with here. Processes to be distinguished include boilers, gas turbines, stationary engines and non-contact process furnaces. The purpose of the first three types of installation is the generation of electricity, steam or heat according to the refineries' requirements and they do not present any special characteristics in comparison to installations of this type in other sectors. However, process furnaces are specific to this sector and are used to perform a series of physical-chemical reactions on crude oil, including distillation, catalytic reforming, hydrotreating, catalytic cracking, alkylation, hydrocracking, etc., which lead to the separation of crude oil into fractions. No contact is produced in these furnaces between the flame or combustion gases and the crude oil or its resulting fractions. Notably, emissions generated by these furnaces during non-combustion processes fall into category 1B2a. Emissions from flare stacks do not fall into this category either but instead come under category 1B2c.

Table 3.3.1 shows greenhouse gas emissions by type of fuel, with CO₂ making this a key source. Table 3.2.2 further supplements the previous information by expressing the overall

emissions in CO₂-equivalent terms. This same table presents the variation over time index (base 100 in 1990) for CO₂-eq equivalent emissions, the contributions of this category's CO₂-eq equivalent emissions to the totals for the inventory and the Energy sector, as well as the CO₂-eq-equivalent emission ratio as a function of the crude oil processed.

Table 3.3.1.- CO₂ Equivalent Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO₂							
Liquid	10,861	12,301	11,655	12,057	11,622	11,683	11,372
Gases	45	61	1,053	1,341	1,470	1,232	1,478
Total	10,906	12,361	12,709	13,398	13,092	12,916	12,850
CH₄							
Liquid	0.20	0.29	0.28	0.29	0.28	0.29	0.28
Gases	0.001	0.003	0.064	0.076	0.079	0.067	0.084
Total	0.20	0.29	0.35	0.36	0.36	0.35	0.36
N₂O							
Liquid	0.24	0.32	0.31	0.32	0.30	0.31	0.30
Gases	0.001	0.001	0.022	0.029	0.028	0.024	0.030
Total	0.24	0.32	0.33	0.34	0.33	0.34	0.33

Table 3.2.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	10,986	12,466	12,818	13,512	13,203	13,027	12,960
CO ₂ -eq Index	100.0	113.5	116.7	123.0	120.2	118.6	118.0
% of CO ₂ -eq over total inventory	3.81	3.91	3.12	3.17	2.99	3.01	2.93
% CO ₂ -eq on energy	5.17	5.18	4.08	4.08	3.80	3.86	3.75

	1990	1995	2003	2004	2005	2006	2007
Crude oil processed (Gg)	53,556	55,754	58,765	61,734	61,986	62,341	61,435
Gg CO ₂ -eq / Gg crude oil	0.205	0.224	0.218	0.219	0.213	0.209	0.211

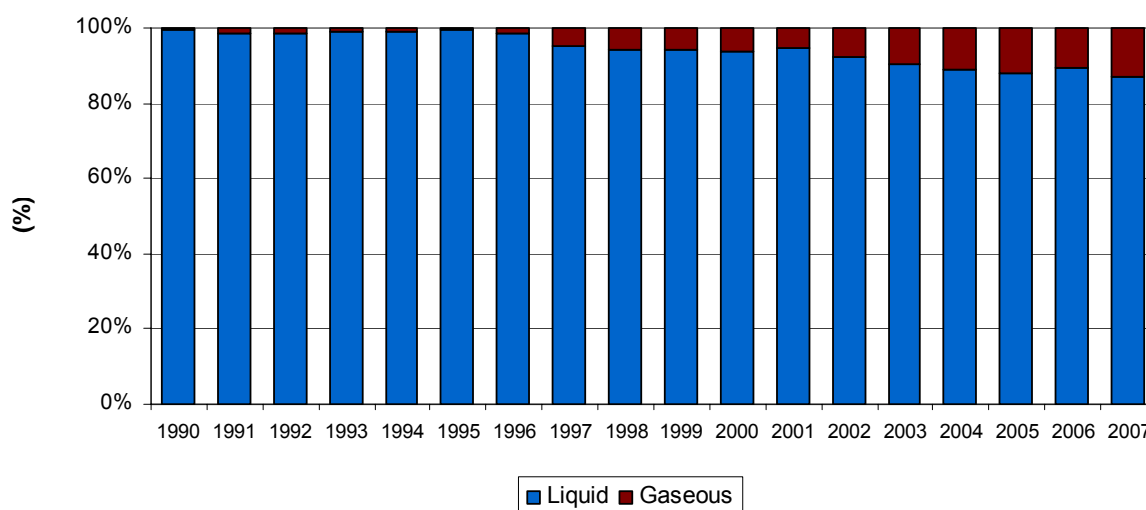
3.3.2.- Methodology

Table 3.3.3 shows fuel consumptions, expressed in terms of energy (TJ of lower heating value), used as the activity variable in the estimation of emissions. Information on this consumption, as well as their characteristics, has been gathered through individualized questionnaires sent to each of the ten existing refineries. The main fuels consumed in this category are residual oil and refinery gas, with slightly lower amounts of gas-oil and natural gas and practically marginal amounts of LPG and naphtha.

Table 3.3.3- Fuel Consumption (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Liquid	155,424	181,155	174,770	183,203	176,194	178,379	176,060
Kerosene			172	129	22	2	36
Diesel	369	8,119	4,722	1,971	1,981	2,449	252
Residual oil	75,469	80,980	78,124	80,871	73,867	73,496	74,086
L.P.G.		3,799	143	54	172	206	512
Naphtha	195	900					
Refinery gas	79,392	87,357	91,609	100,177	100,152	102,226	101,174
Gases	820	1,084	18,792	23,027	24,563	21,048	25,820
Natural gas	820	1,084	18,399	22,346	23,259	20,016	24,757
Other gaseous fuels			394	681	1,304	1,032	1,062
Total	156,244	182,239	193,563	206,230	200,757	199,428	201,880

Figure 3.3.1 shows the distribution of the consumption by type of fuel over the inventory period. The increase seen in gas fuel consumption (natural gas) is due to the progressive commissioning of co-generation facilities at refineries.

Figure 3.3.1.- Fuel consumption distribution, based on TJ_{LHV} 

To estimate CO_2 emissions, providing that all pertinent information has been made available, preference is given to the calculation procedure based on the carbon content of each fuel used and the stoichiometric calculation raised to the mass of CO_2 is complemented by including the oxidation factor (see equation [3.2.1] and the explanation for the algorithm in heading 3.2.2). Default emission factors from standard fuel characteristics are used when the necessary data have not been available to apply the algorithm above. In the case of refinery gas, the variation in characteristics provided by refineries cause the range of CO_2 emission factors to be very broad, sometimes varying from 47 kg CO_2 /GJ to 72 kg CO_2 /GJ.

In terms of estimating CH_4 and N_2O emissions, factors selected from different methodological guidelines (EMEP/CORINAIR, IPCC) and sectoral and institutional sources (API, CITEPA) are applied to the activity variable energy (GJ) in terms of LHV. This same procedure is used to estimate other pollutants considered in the CRF (NO_x , NMVOC and CO)

while for SO₂, preference is given to the estimated emissions provided by plants (normally by mass balance).

Tables 3.3.4 to 3.3.6 show the emission factors by type of installation used in the estimation of the emissions, although in the case of CO₂ the factors indicated are those used by default when the specific characteristics of the fuel are not available.

Table 3.3.4.- Emission Factors. Boilers

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1.7	0.7
Residual oil	76	0.7	1.5
L.P.G.	65	0.9	2.5
Naphtha	72.6	3	2.5
Refinery gas	60	1	1.5
Natural gas	55-56 (1)	1.4	0.9

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 111, Tables 24 - 30 and Chapter 112, Table 10.

API Compendium for N₂O from residual oil and gas oil ("Uncontrolled boilers and heaters")

CITEPA for N₂O from LPG and naphtha (assimilated in this case to the default value for other oil-based products)

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.3.5.- Emission factors. Gas turbines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Kerosene	71.5	1	2.5
Diesel	73	4	1.85
Residual oil	76	3	1.75
L.P.G.	65	1	2.5
Refinery gas	60	2	3
Natural gas	55-56 (1)	4	1.3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 111, Tables 24 - 30, and Chapter 112, Tables 5-8 and 10.

API Compendium for N₂O from gas oil (assimilated to the stationary engine emission factor) and natural gas ("Uncontrolled Turbines").

CITEPA for N₂O from residual oil, LPG and kerosene (assimilated in this case to the default value for other oil-based products)

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.3.6.- Emission Factors. Process furnaces

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1.7	0.7
Residual oil	76	1.75	1.75
L.P.G.	65	6	2.5
Refinery gas	60	1.5	1.5
Natural gas	55-56 (1)	1.4	2.5
Other gaseous fuels			

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 136. Table 6.

API Compendium for N₂O from gas oil (assimilated to the boiler emission factor).

CITEPA for N₂O from residual oil, LPG and natural gas.

The factors of other gas fuels (purge gas obtained from hydrogen manufacturing plants) are pending identification in terms of the precise characterization of the composition of this type of fuel.

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

3.3.3.- Uncertainty and consistency over time

With regard to activity variables and those liquid fuels that give this activity its key source nature, and given that fuel consumptions have been obtained directly from individualized questionnaires sent to refining plants, it is considered that the uncertainty is around 3.5%. For CO₂ emission factors, it can be assumed that the average uncertainty is around 2.7%.

In general it is considered that the series of activity variables (fuel consumption) present a high degree of consistency over time since the information comes from the refineries themselves. The series of emission factors presents an acceptable degree of consistency over time although explicit information has not always been available on the characteristics of the fuels used. Therefore, in these cases, default characteristics have been used to obtain the factors applied to estimate emissions.

3.3.4.- Quality assurance and verification

Due to the large number of installations at the refineries and given that information is requested for each refinery installation by installation in order to differentiate consumptions and emissions between boilers, turbines and furnaces, one of the main quality assurance tasks to be performed is the verification that the total fuel consumptions of all installations corresponds to the total given for the whole refinery, thereby detecting possible errors or omissions in figures corresponding to a particular installation. This breakdown of the information collected allows individualized monitoring of the operation of the combustion installations and of their life cycle by revealing data concerning the creation or dismantling of the installations.

Another task performed in this category refers to monitoring the characteristics of the fuels used, with special attention paid to the heating value and their sulphur and carbon contents. The fuels most often used are residual oil and refinery gas (see table 3.3.3). Since their characteristics are not the same as those of standard commercial fuels and they can vary greatly from one refinery to another (especially refinery gas⁶), values that are considered atypical are compared with the plants' own values in order to justify the origin of such values or, if appropriate, to correct possible errors in the information provided.

In addition, consumption and emission ratios are obtained per tonne of crude oil treated. These can be used to carry out monitoring procedures on the information provided at each refinery over the inventory period, although it is worth mentioning that when making comparisons between refineries, the complexity of their installations must be taken into account.

⁶ For this fuel, for example, the variability of characteristics is in some cases determined by the extent to which the fuel is enriched with hydrogen.

3.3.5.- New calculations

The variations originated by the new calculations in this activity stem from the correction of a database error as it was detected the omission of the CH₄ and N₂O emissions in 2006 at a refinery. This review means an increase in emissions of 16.1 Gg of CO₂-eq in 2006.

Figure 3.3.2 shows the comparative development of absolute values of the CO₂-eq emissions between the results of the current edition and the results of the previous edition, while Figure 3.3.3 presents the percentage difference in these emissions between both inventory editions. As illustrated in the last figure, the relative variation of CO₂-eq emissions as a consequence of the new calculations carried out indicates an increase of 0.12% in 2006.

Figura 3.3.2.- CO₂-eq emissions. Comparison of 2009 and 2008 editions

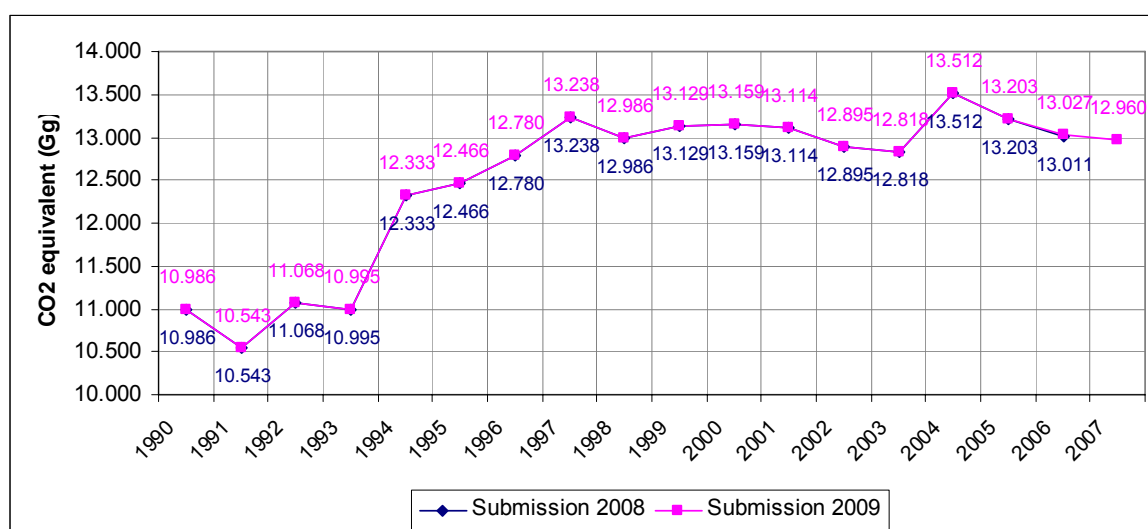
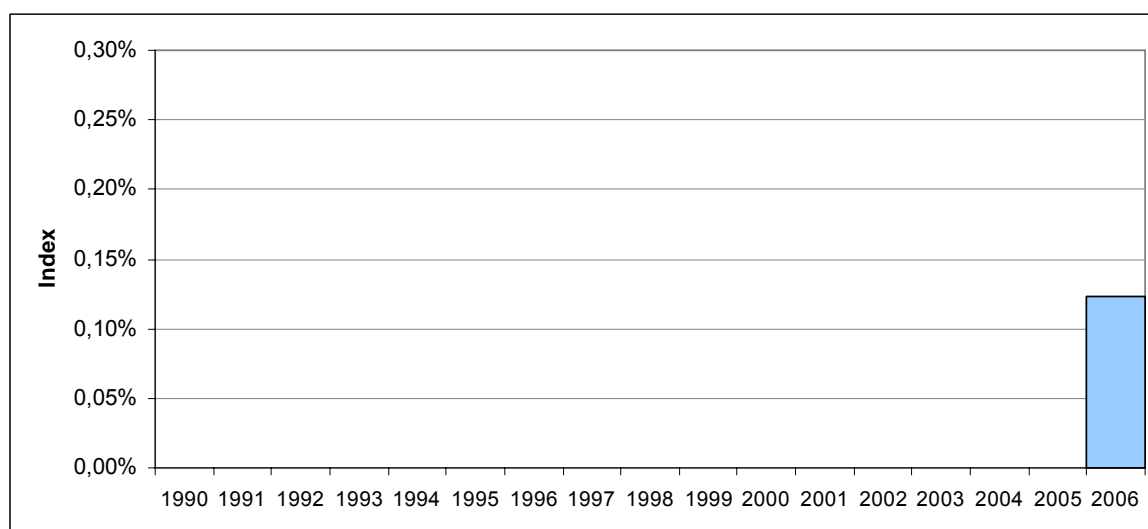


Figura 3.3.3.- CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions



3.3.6.- Improvement plans

For the future, emphasis will still be placed on data collection by questionnaire regarding the full provision of the characteristics of the fuels used, which in the past have not always been supplied.

3.4.- Solid fuel transformation and other energy industries (1A1c)

3.4.1.- Description of the activity

This category deals with emissions generated in the transformation of solid fuels (coke ovens, coal gasification) as well as emissions generated at non-specific combustion installations both in this fuel transformation sector and in other energy industries (coal mining, oil and natural gas production).

Table 3.4.1 shows greenhouse gas emissions by type of fuel, with CO₂ making this a key source. Table 3.4.2 further supplements the previous information by expressing the overall emissions in CO₂-equivalent terms. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector.

Table 3.4.1.- Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO₂							
Liquid	57	826	671	708	790	767	780
Solid	1,847	1,127	1,079	1,105	943	888	945
Gases	205	253	213	251	307	209	197
Total	2,110	2,207	1,963	2,064	2,039	1,864	1,923
CH₄							
Liquid	0.001	0.031	0.002	0.002	0.003	0.002	0.003
Solid	1.946	1.579	1.532	1.790	1.968	1.883	1.676
Gases	0.011	0.009	0.005	0.006	0.008	0.005	0.005
Total	1.958	1.620	1.539	1.798	1.979	1.890	1.684
N₂O							
Liquid	0.002	0.017	0.017	0.018	0.020	0.019	0.020
Solid	0.026	0.017	0.021	0.022	0.019	0.020	0.019
Gases	0.004	0.004	0.003	0.004	0.005	0.003	0.003
Total	0.032	0.038	0.042	0.044	0.044	0.042	0.042

Table 3.4.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	2,161	2,253	2,008	2,116	2,095	1,916	1,971
CO ₂ -eq Index	100.0	104.3	93.0	97.9	96.9	88.7	91.2
% of CO ₂ -eq over total inventory	0.75	0.71	0.49	0.50	0.47	0.44	0.45
% CO ₂ -eq on energy	1.02	0.94	0.64	0.64	0.60	0.57	0.57

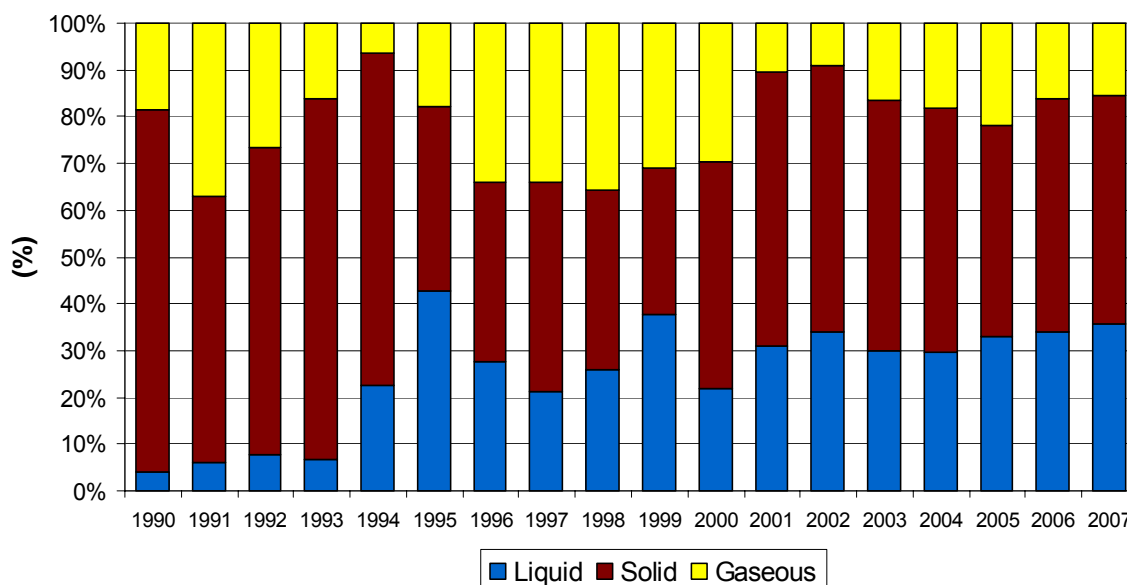
3.4.2.- Methodology

Fuel consumption is used as the basic activity variable to estimate emissions. In the cases of coke ovens located at integrated iron and steel plants and coal gasification, information has been gathered from individualized questionnaires sent to plants where these processes are conducted. For all other activities in this category, including coke ovens not contemplated above, information has been based on IEA and EUROSTAT data. The main fuels used in this category are coke oven gas and blast furnace gas (solid fuels), residual oil and gas oil (liquid fuels), and natural gas (gaseous fuels). Table 3.4.3 shows fuel consumptions expressed in terms of energy (TJ of net heating value). It can be seen that for some fuels (especially coking coal and liquid fuels) there are important interruptions (even complete absence in some years) over the series.

Table 3.4.3.- Fuel consumption (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Liquid	822	10,880	6,974	7,274	8,179	7,826	8,187
Diesel	243	127					
Residual oil	132	10,753					
L.P.G.	448				9		
Petroleum coke			6,974	7,274	8,170	7,826	81,87
Solid	15,776	9,984	12,502	12,940	11,245	11,452	11,123
Coking coal							
Hard coal	4,102	513	1,864	1,869	624	433	484
Sub-bituminous coal	13						
Gas works gas	10	5					
Coke oven gas	7,534	6,611	8,672	9,139	8,694	9,284	8,624
Blast furnace gas	4,116	2,856	1,967	1,932	1,927	1,735	2,015
Gases	3,734	4,525	3,802	4,476	5,480	3,727	3,522
Natural gas	3,734	4,525	3,802	4,476	5,480	3,727	3,522
Total	20,333	25,389	23,278	24,690	24,905	23,005	22,833

Figure 3.4.1 shows consumption distribution by type of fuel over the inventory period. This distribution reflects the interruptions in the consumption data indicated in the previous table.

Figure 3.4.1.- Fuel consumption distribution, based on TJ_{LHV} 

The CO₂ emissions corresponding to coke ovens are estimated by mass balance from the carbon content of the fuels consumed each year (in the case of integrated iron and steel plants, fuel characteristics vary for each plant and year while for all other plants, some common characteristics have been used in all years). With regard to CH₄ and N₂O, emissions have been estimated using default emission factors. It is worth noting that from 2003 on, measured emissions of CH₄ at integrated iron and steel plants were available. Nevertheless, the huge variability in emissions obtained means that, for the time being, these measurements have not been considered in the inventory as this would create a lack of consistency in the emission time series. For all other pollutants considered in the CRF (SO₂, NO_x, NMVOC and CO), default emission factors have also been used, with the exception of those cases where the plants themselves have provided measured emissions.

Table 3.4.4 shows the emission factors used for coke oven estimates. In the case of CO₂, ranges of variation are shown for the emission factors according to the characteristics of the fuels used over the inventory period.

Table 3.4.4.- Emission factors. Coke ovens

	CO ₂ (t/TJ)	CH ₄ (kg/kt coke)	N ₂ O (kg/TJ)
Coke oven gas	41.3 – 45	405	1.75
Blast furnace gas	242.9 – 293.5		1.75

Source: CO₂: Factors obtained from information provided in the questionnaires.
 CH₄: CORINAIR Manual (Appendix to part 7, heading 13)
 N₂O: CITEPA. Default values for the fuels considered.

In order to estimate emissions in the coal gasification process, the part that has not been considered as solid fuel transformation to gas, according to the carbon balance between process inputs and outputs, has been calculated from the total coal and petroleum coke

consumptions. The complementary part of inputs to this process is assigned to combustion (category 1A1a) and coincides with the consumption in this activity of gas obtained in the gasification process. It is important to point out that this assignment process guarantees that the energy balance between inputs and outputs is balanced in carbon terms.

It is therefore necessary to separate those emissions that are attributable to the gasification process mentioned here from those that correspond to the combustion processes of gas obtained in the gas turbines. This breakdown is done by taking the carbon ratio between the gas obtained in the gasification process and the carbon from the solid input fuels as a reference, thereby obtaining the CO₂ emissions that are attributable to the gasification process. For CH₄ and N₂O, emissions have been estimated by using default emission factors taken from the EMEP/CORINAIR Guidebook and from CITEPA (in the case of N₂O for petroleum coke). For all other pollutants considered in the CRF (SO₂, NO_x, NMVOC and CO), the plant itself has provided measured emissions.

Table 3.4.5.- Emission factors. Coal gasification

	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Petroleum coke	0.3	2.5
Coal	0.6	0.8

For the other combustion installations in this category, emissions have been estimated by using default emission factors taken from different methodological guidelines (EMEP/CORINAIR, IPCC) and from sectorial and institutional sources (API, CITEPA) regarding the activity variable energy (GJ) in terms of LHV. Tables 3.4.6 to 3.4.8 show, by type of installation, the emission factors used to estimate emissions.

Table 3.4.6.- Emission factors. Boilers

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1.7	0.7
Residual oil	76	2.9	1.5
L.P.G.	65	0.9	2.5
Petroleum coke	98.3	0.3	2.5
Coking coal	94	3	0.8
Hard coal	112	3	1.4
Sub-bituminous coal	99.42	3	1.4
Gas works gas	52	1.4	2.5
Natural gas	55-56 (1)	1.4	0.9

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10, and Chapter 111, Tables 27, 29 and 30.

1996 IPCC Reference Manual (Table 1-8) for N₂O from coal and anthracite and black lignite.

CITEPA, for N₂O from petroleum coke, LPG and gas works gas (in this case assimilated to other gaseous fuels).

API Compendium for N₂O from residual oil, gas oil and natural gas ("Uncontrolled boilers and heaters")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.4.7.– Emission factors. Gas turbines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	4	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	4	1.3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10.

CITEPA, for N₂O in residual oil.

API Compendium for N₂O from gas oil (assimilated to the stationary engine emission factor) and natural gas ("Uncontrolled turbines")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.4.8.- Emission factors. Stationary engines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1,5	1,85
Residual oil	76	3	1,75
Natural gas	55-56 (1)	5	1,3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10.

CITEPA, for N₂O in residual oil.

API Compendium for N₂O from gas oil ("Large Bore Diesel Engine") and for natural gas ("4 Cycle – Lean Burn Engine")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

3.4.3.- Uncertainty and consistency over time

The dominant activity in this category in terms of emissions is combustion in coke ovens and more specifically those located at integrated iron and steel plants. For these plants, information obtained from individualized questionnaires is considered to have a reduced uncertainty. The coal gasification activity has a similar or greater level of accuracy. The greatest uncertainty is associated with coke ovens not located at integrated iron and steel plants and other non-specific sources of combustion (mining, oil and gas extraction) where information does not come directly from the plants. As a whole, the estimated uncertainty for the activity variable can be placed at around 5%. Taking into account the mixture of fuels used in this category, it is estimated that the uncertainty for emission factors is also around 5%.

The series are generally considered to be consistent over time although changes in activity variable and emissions reflect, to a good extent, the disappearance of an integrated iron and steel plant in the mid-nineties along with the emergence of the coal gasification process from 1997. On the other hand, and as has already been explained, consistency is conditioned by information on national energy balances published by the IEA and EUROSTAT, which, for this category, show notable fluctuations in some fuels.

3.4.4.- Quality control and verification

Quality assurance tasks in this category that must be highlighted include the monitoring of the characteristics of iron and steel gases used in coke ovens at the integrated iron and steel plants due to the greater variability in characteristics of these fuels between plants and years, which particularly affects CO₂ emissions. From the information provided per plant and year, values corresponding to the molar composition of each gas are compared, checking that

the sum of the components of this composition is equal to 100 and deriving, from the components' molecular weights and heating values (combustion enthalpies), the carbon content, sulphur content, density and heating value (net and gross) characteristics of the iron and steel gas in question (in the case of the last two parameters, the derived values are compared with those provided directly by the plant). In the case of gaps in information or atypical values, the causes of these anomalies are investigated in conjunction with the plants themselves in order to obtain the necessary corrections or justification of the corresponding values. Table 3.4.9 shows the model to request information on the characteristics of the coke oven gas and blast furnace gas.

Table 3.4.9.- Characteristics of iron and steel gases. Information requested

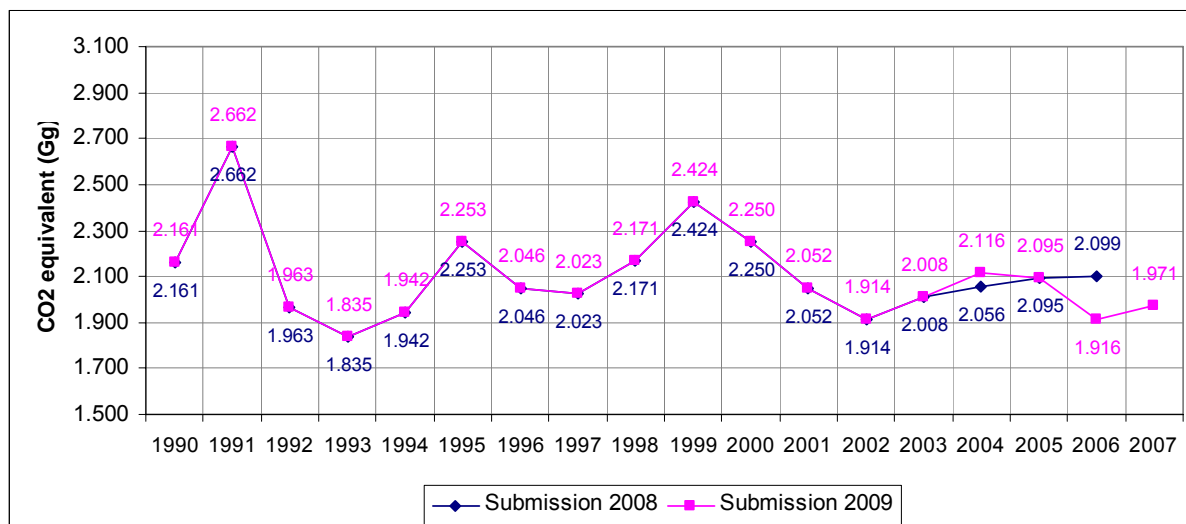
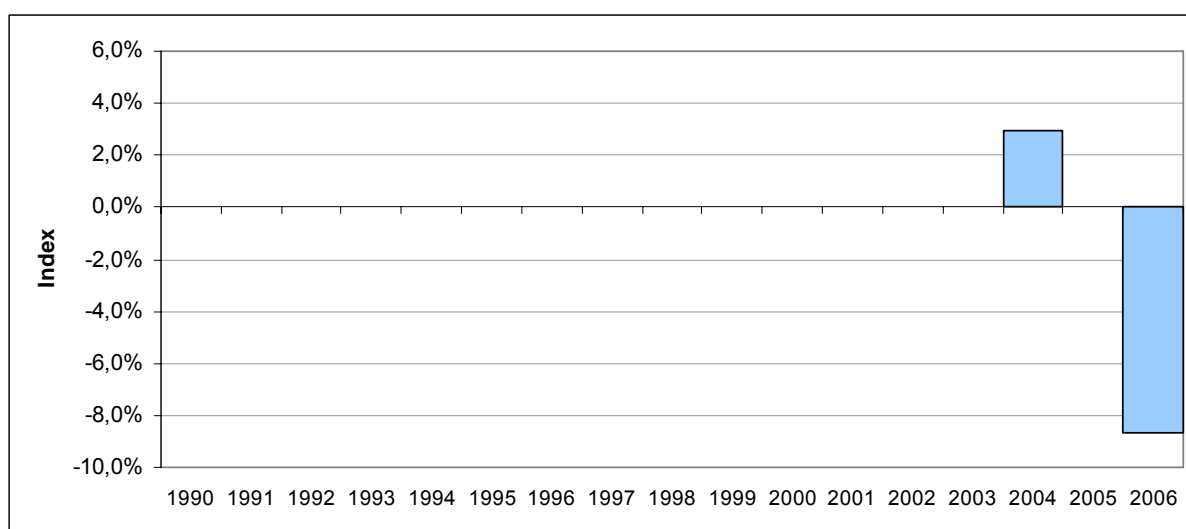
COKE OVEN GAS			BLAST FURNACE GAS		
CO ₂		%	CO ₂		%
C _n H _m		%	O ₂		%
O ₂		%	CO		%
CO		%	H ₂		%
H ₂		%	CH ₄		%
CH ₄		%	N ₂		%
C _n H _{2n+2}		%	LHV		kcal/Nm ³
N ₂		%	Density		kg/Nm ³
C ₆ H ₆		g/Nm ³			
NH ₃		g/Nm ³			
C ₁₀ H ₈		g/Nm ³			
SH ₂		g/Nm ³			
LHV		kcal/Nm ³			
Density		kg/Nm ³			

According to indications from iron and steel plants, C_nH_m could be characterized by the compound C₃H₈ while C_nH_{2n+2} could be characterized by the compound C₂H₆.

3.4.5.- New calculations

In this category, the new calculations made are the consequence of the revision of natural gas consumption (non-specific combustion) in 2004 and 2006, which means an increase of 60 Gg of CO₂-eq emissions in 2004 and a decrease of 183 Gg in 2006.

Figure 3.4.2 shows the comparative development of absolute values of the CO₂ emissions between the results of the current edition, and the results of the previous edition, while Figure 3.4.3 presents the percentage difference in these emissions between both inventory editions. As can be seen in the latter figure, the relative variation of CO₂ equivalent emissions as a result of the new calculations in this activity represents an increase in 2004 of 2.9% while in 2006 there was a decline of 8.7%.

Figure 3.4.2.- CO₂-eq emissions. Comparison of 2009 and 2008 editions**Figure 3.4.3.- CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions**

3.4.6.- Improvement plans

One promising action for improvement in this sector is the plan to collect individualized information on coke ovens not located at integrated iron and steel plants. This approach is expected that could be applied according to the information supplied at plant level that reports certified CO₂ emissions within the framework of the Directive on Emissions Trading. Following this approach, it is expected to gather individual plant information both on emissions generated in coke ovens and on national coke and coke oven gas productions with specifications of the characteristics of these fuels.

3.5.- Combustion in industry (1A2)

3.5.1.- Description of the activity

This category, which is a key source in CO₂ emissions for solid, liquid, and gas fuels for all inventoried periods, includes a wide variety of combustion processes performed in industry sector (category 1A2).

Table 3.5.1 shows greenhouse gas emissions by type of fuel, with CO₂ making this a key source. Table 3.2.2 further supplements the previous information by expressing the overall emissions in CO₂-equivalent terms. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector. CO₂ emissions caused by burning biomass do not appear in these tables since, according to IPCC methodology, these must not be counted in the inventory, although they have been estimated as a Memo item and reflected as such in the CRF Reporter.

Table 3.5.1.- Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO₂							
Liquid	24,520	28,942	27,902	28,118	27,368	26,743	25,750
Solid	13,238	10,104	5,697	5,365	5,099	4,683	5,694
Gases	8,439	13,737	33,979	36,169	37,877	37,139	35,621
Biomass							
Other			297	311	377	378	478
Total	46,196	52,782	67,874	69,964	70,721	68,944	67,543
CH₄							
Liquid	0.8	0.9	0.7	0.7	0.7	0.6	0.6
Solid	0.7	0.6	0.9	1.0	1.0	1.0	1.0
Gases	0.5	1.2	4.7	5.2	5.7	5.7	5.7
Biomass	1.1	1.1	1.0	1.0	1.0	1.1	1.1
Other			0.0	0.0	0.0	0.0	0.0
Total	3.1	3.7	7.4	8.0	8.5	8.4	8.4
N₂O							
Liquid	0.6	0.7	0.7	0.7	0.6	0.6	0.6
Solid	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Gases	0.2	0.4	0.9	0.9	1.0	1.0	0.9
Biomass	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Other			0.0	0.0	0.0	0.0	0.0
Total	1.3	1.5	1.9	2.0	2.0	2.0	2.0

Table 3.2.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	46,661	53,315	68,626	70,744	71,518	69,737	68,330
CO ₂ -eq Index	100.0	114.3	147.1	151.6	153.3	149.5	146.4
% of CO ₂ -eq over total inventory	16.19	16.70	16.73	16.61	16.21	16.10	15.45
% CO ₂ -eq on energy	21.96	22.15	21.82	21.34	20.59	20.68	19.78

3.5.2.- Methodology

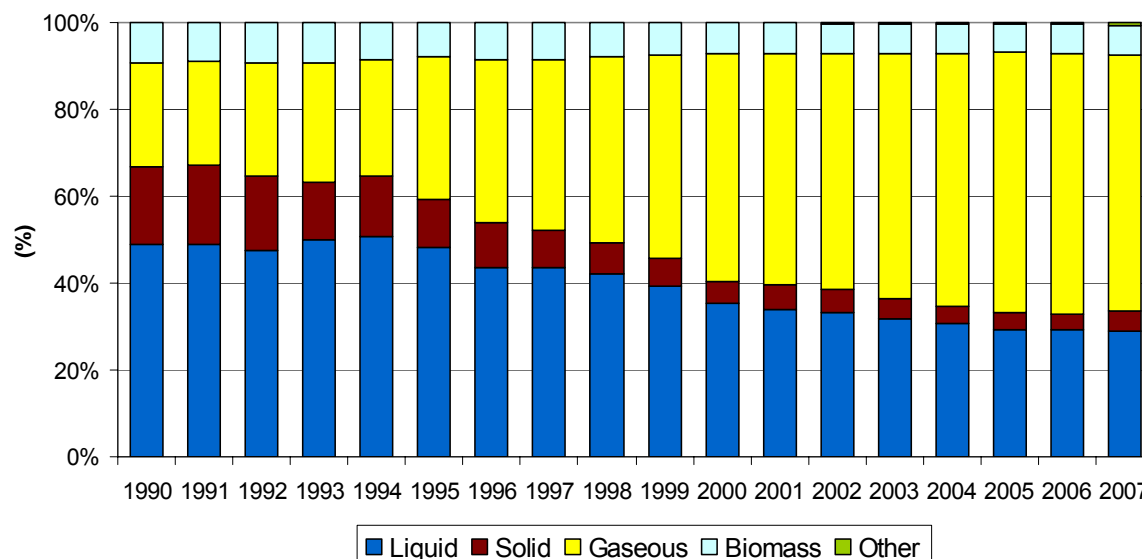
For industrial combustion, the basic information sources for the activity variables (fuel consumption) have been the national fuel balance, supplemented with information from principal sectoral associations (among them: Union of Iron and Steel Companies (UNESID); Spanish Cement Association (OFICEMEN); National Association of Lime and Derivatives Manufacturers of Spain (ANCADE); Vidrio España; National Association of Manufacturers of Glass Frits, Enamels and Ceramic Colours (ANFFECC); Spanish Association of Manufacturers of Baked Clay Bricks and Roof Tiles (HISPALYT); Spanish Association of Manufacturers of Tiles, Pavements and Ceramic Tiles (ASCER); Association of Spanish Pulp and Paper Manufacturers (ASPAPPEL); and direct information from the individual facility's questionnaires.

Table 3.5.3 shows estimated fuel consumptions for this key source expressed in terms of energy (lower heating value TJ_{LHV}).

Table 3.5.3.- Fuel Consumption (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Liquid	311,602	362,552	339,662	341,821	331,661	322,608	312,188
Crude oil							248
Diesel	70,857	57,226	110,153	118,211	118,140	116,407	107,715
Residual oil	170,032	207,911	92,050	83,623	74,614	65,707	72,198
L.P.G.	13,113	17,120	18,050	18,498	18,289	16,841	16,426
Petroleum coke	55,664	78,205	119,408	121,489	120,618	123,653	115,603
Refinery gas	1,937	2,090					
Solid	112,500	85,111	48,088	43,895	40,950	39,182	48,614
Coking coal							
Hard coal	60,830	24,332	15,451	14,546	14,460	14,655	20,867
Sub-bituminous coal	1,004						
Coke	18,184	33,323	15,345	12,728	8,844	8,231	9,010
Gas works gas	82						
Coke oven gas	15,057	14,389	8,502	7,928	8,064	8,193	9,834
Blast furnace gas	16,612	11,661	7,833	8,187	8,189	6,932	7,699
Other coal & derived fuels	732	1,405	958	505	1,393	1,171	1,204
Gases	153,009	245,683	606,504	645,554	676,071	663,212	636,002
Natural gas	153,009	245,683	606,504	645,554	676,071	663,212	636,002
Biomass	58,937	59,788	70,210	72,882	73,081	74,271	75,707
Wood/Wood wastes	23,502	22,670	22,768	22,710	23,109	23,906	24,594
Other solid biomass	13,633	13,252	13,814	14,039	14,541	14,678	14,828
Black liquor	18,217	20,428	30,392	32,880	32,106	32,389	32,923
Biogas	3,585	3,438	3,237	3,253	3,325	3,298	3,361
Other			4,239	4,497	5,225	5,274	6,466
Industrial wastes			4,239	4,497	5,225	5,274	6,466
Total	635,795	753,134	1,068,704	1,108,649	1,126,988	1,104,547	1,078,977

Figure 3.5.1 shows the distribution of the consumption by type of fuel over the inventory period. As can be seen, there is substantial increase in natural gas consumption, which in relative terms has a 58.9% contribution in 2007, with a decrease in the liquid fuel participation (of 49% in 1990 and 28.9% in 2007); moreover, in solid fuels (of 17.7% in 1990 and 4.5% in 2007) as a consequence of the progressive replacement of fuels used in the industry.

Figure 3.5.1.- Fuel consumption distribution, based on TJ_{LHV} 

To estimate CO₂ emissions, providing that all pertinent information has been made available⁷, preference is given to the calculation procedure based on the carbon content of each fuel used and the stoichiometric calculation raised to the mass of CO₂ is complemented by including the oxidation factor (see equation [3.2.1] and the explanation for the algorithm in heading 3.2.2). Default emission factors from standard fuel characteristics are used when the necessary data has not been available to apply the previous algorithm. For estimating CH₄ and N₂O emissions, factors selected from different methodological guidelines (EMEP/CORINAIR, IPCC) and sectoral and institutional sources (API, CITEPA) are applied to the activity variable energy (GJ) in terms of LHV. This same procedure is used to estimate other pollutants considered in the CRF (SO₂, NO_x, NMVOC and CO) with the exception of those cases where the plants themselves have provided measured emissions.

The Tables 3.5.4 to 3.5.8 show the emission factors by type of installation used in the estimation of the emissions, although in the case of CO₂ the factors indicated are those used by default when the specific characteristics of the fuel are not available. On the other hand, in the case of furnaces, and due to the great variety of emission factors given in the references depending on the process performed and operating conditions, ranges of factors are given, especially for CH₄.

⁷ This is the case, among others, of the industrial sectors of integrated iron and steelworks, paper pulp manufacture and aluminum manufacture, in which this information is made available through individualized questionnaires sent to plants.

Table 3.5.4.- Emission factors. Boilers

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1.7	0.7
Residual oil	76	2.9	1.5
L.P.G.	65	0.9	2.5
Petroleum coke	98.3	0.3	2.5
Refinery gas	55	2.5	1.5
Coking coal	94	3	3
Hard coal	101	15 (1) 3 (2)	1.6
Sub-bituminous coal	99.42	15 (1) 3 (2)	1.6
Coke	105	15 (1) 1.3 (2)	3
Gas works gas	52	1.4	2.5
Coke oven gas	41.3-45 (3)	2.5	1.75
Blast furnace gas	242.9-293.5 (3)	0.3	1.75
Steel furnace gas	181.3-184.4 (3)	0.3	2.5
Natural gas	55-56 (4)	1.4	0.9
Wood/Wood wastes	110	16.7 (5) 18 (1) (6) 32 (2) (6)	4
Agricultural wastes	110	30	4
Black liquor	73	1	4
Biogas	112	2.5	1.75

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10, and Chapter 111, Tables 27, 29 and 30

1996 IPCC Reference Manual, Table 1-1, for CO₂ from biomass

1996 IPCC Reference Manual, Table 1-8, for N₂O from pit-coal and anthracite, black lignite, wood and wood waste, charcoal, agricultural waste and black liquor (assimilated in this case by the biomass content).

CITEPA, for N₂O from petroleum coke, LPG, iron and steel gases, gas works gas (in this case assimilated to other gaseous fuels) and biogas.

API Compendium for N₂O from residual oil, gas oil and natural gas ("Uncontrolled boilers and heaters")

(1) Boilers with rated heating power between 50 and 300 MWt.

(2) Boilers with rated heating power < 50 MWt.

(3) The indicated range of CO₂ factors has been obtained by mass balance from the characteristics provided for the fuels in question in the period inventoried.

(4) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

(5) Wood

(6) Wood waste

Table 3.5.5.- Emission factors. Gas turbines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	4	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	4	1.3
Propane	63.8	1	2.5
Steel furnace gas	186.5 (2)	0.3 (3)	2.5

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 111, Tables 24-30 and Chapter 112, Tables 5-10.

CITEPA, for N₂O from residual oil, LPG and steel gas.

API Compendium for N₂O from gas oil (assimilated to the stationary engine emission factor) and natural gas ("Uncontrolled turbines")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

(2) Obtained by mass balance from the characteristics provided for the fuel in question in the period inventoried.

(3) Assimilated to the boiler emission factor.

Table 3.5.6.- Emission factors. Stationary engines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	1.5	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	50	1.3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10.

CITEPA, for N₂O in residual oil.

API Compendium for N₂O from gas oil ("*Large Bore Diesel Engine*") and for natural gas ("*4 Cycle – Lean Burn Engine*")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.5.7.- Emission factors. Furnaces

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Crude oil	72.6	5	1.75
Diesel	73	1.5 – 4	1.5
Residual oil	76	0.7 – 5	1.75
L.P.G.	65	0.9 – 1	2.5
Petroleum coke	98.3	0.3 – 1.5	2.5
Refinery gas	54.1	2.5	1.75
Hard coal	99.42 101	1 – 3	1.4 – 3
		15 (5)	
		50 (6)	
Coke	105	0.5 - 1.5	1.4 – 3
		15 (5)	
		50 (6)	
Coke oven gas	41.3-45 (1)	2.5	1.75
		257 (6)	
Blast furnace gas	242.9-293.5 (1)	0.3	1.75
		257 (6)	
Steel furnace gas	181.3-184.4 (1)	0.3	2.5
Natural gas	55-56 (2)	1 - 4	2.5
		14 (6)	
Wood/Wood wastes	110	0.2 - 32	4
Animal meal	110	0.2	4
Industrial wastes	84 (3)	1	2.5
	73 (4)		
Sewage sludge	-	30 (7)	4
Other wastes	80 (8)	30 (7)	2.5

Source: EMEP/CORINAIR Guidebook. Part B. Chapters 323 to 3323; Chapter 112, Tables 7, 9 and 10, and Chapter 111, Tables 27, 29 and 30

1996 IPCC Reference Manual, Table 1-1, for CO₂ from biomass

CITEPA, for N₂O except biomass fuels.

1996 IPCC Reference Manual, Table 1-8, for N₂O from biomass.

1996 IPCC Reference Manual, Table 1-17, for CH₄ from cement and lime furnaces (except biomass).

(1) The indicated range of CO₂ factors has been obtained by mass balance from the characteristics provided for the fuels in question in the period inventoried.

(2) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

(3) Tires and residual solvents

(4) Used oils

(5) Plaster furnaces. EMEP/CORINAIR Guidebook. Chapter 324. Table 2

(6) Sintering furnaces. EMEP/CORINAIR Guidebook. Chapter 331. Table 8.2a.

(7) 1996 IPCC Reference Manual, Table 1-7.

(8) "The Cement CO₂ Protocol: CO₂ Emissions Monitoring and Reporting Protocol for the European Emissions Reduction & Trading System". Guide to the Protocol. May 22, 2003

Table 3.5.8.- Emission factors. Industrial machinery

	CO ₂ (t/t)	CH ₄ (kg/t)	N ₂ O (kg/t)
Diesel	3.138	0.170	0.0864

Source: CO₂: EMEP/CORINAIR Guidebook. Part B. Chapter 810, equation (2).

CH₄: EMEP/CORINAIR Guidebook. Part B. Chapter 810, Table 8.1.

N₂O: CORINAIR Manual, part 9, for gas oil (2 g/GJ is indicated with a LHV of 43.2 GJ/t)

3.5.3.- Uncertainty and consistency over time

One of the traits that most merits emphasis when characterizing the uncertainty of this key source is the heterogeneity of activities and types of fuel. Each one has its own uncertainties that must be suitably weighted in order to estimate the uncertainty as a whole, both of the activity variable and emission factors. As far as CO₂ emission factors, the uncertainty is derived by taking into account the uncertainty of the fuel carbon content and the oxidation factor.

For solid fuels, the uncertainty activity variable estimated is around 5% in the upper limits of the range proposed by the 2006 IPCC Guidance (Table 2.15) for the cross-tab *well-developed statistical system* and *extrapolation* (range: 3%-5%), since although consumption is located in a relatively small number of sectors, and some of them in large facilities from which information is obtained by direct questionnaire; the information must be supplemented with extrapolations to estimate the rest of the consumption (other subsectors and facilities). The uncertainty of the emission factor is calculated as a combination of uncertainty components of 1.5% for the oxidation factor and 15% for the carbon content; this last component is estimated in turn as an average of uncertainties, relatively reduced, associated with the characteristics of this kind of fuels consumed at point sources that is provided by direct information from the facilities, along with their notably less accurate area sources.

For the variable activity of liquid fuels, the compilation of information (direct questionnaires to large facilities supplemented with extrapolation of other facilities and sectors) is included, with respect to the classification given in Table 2.15 of the 2006 IPCC Guidance within *well-developed statistical system* with *extrapolation*. Consequently, the uncertainty associated with the consumption of this fuel type has been quantified to an upper limit of about 10% of the range proposed by the Guidance for this type of general industry system (range: 5%-10%). Regarding the emission factor, the associated uncertainty incorporates the uncertainty itself in the carbon content, estimated at 3% according to the variability in the characteristics and in the oxidation factor of around 1%.

Regarding gaseous fuels, insofar as natural gas, the reference information for the activity variable, categorized by sectoral segments and by quantity in terms of rate types, is included in a practically complete "well-developed statistical system" existing, however, a certain lack of clarity in the combination of the consumption attributable to co-generated electricity and the rest of sectoral activity consumption. Taking this into consideration, an uncertainty with an upper limit of 5% is attributed to natural gas as suggested in Table 2.15 of the 2006 IPCC Guidance of well-developed systems based on surveys (range: 3-5%). The uncertainty in the CO₂ emission factor is 1.5% in accordance with the high level of accuracy in

the carbon content, calculated at some 1.4% from the annual molar composition provided by gas transport company, with a 0.5% oxidation factor for this fuel.

Due to the variety of fuels considered in the group “Other fuels”, along with the lower general development observed in the information gathering systems and the extrapolation application, it is estimated an uncertainty in the activity variable of 17.5%, inside the range included in the table 2.15 of the 2006 IPCC Guidance for this system and data source crossing (range: 15-20%). On the basis of this heterogeneity, the global uncertainty of the CO₂ emission factor is estimated at 5%, just as it appears in the 2006 IPCC Guidance (Table 2.13).

As far as the time-series consistency of the activity variable is concerned, it is assumed that the dominant part of industrial combustion is associated with a high degree of consistency since information on fuel consumption comes from consistent sources with a high degree of sectoral coverage and even from individual plants. Finally, the part corresponding to mobile machinery, which has been determined with the support of activity patterns (see section 3.5.2), is also considered to benefit from a good level of consistency over time.

3.5.4.- Quality assurance and verification

The scope of quality assurance activities includes the verification of information on activity variables, both in sectors where information is obtained via individualized questionnaire (integrated iron and steel, primary aluminium manufacture, paper pulp production) and in those sectors where information provided by relevant business associations is broken down according to province (for example, cement, lime, bricks and tiles). For the first sectors, data regarding amounts of fuels consumed and regarding the specific characteristics of these fuels are analyzed for each plant; while for the latter sectors, special emphasis is placed on consumption series consistency, with possible atypical values being studied. In addition, for certain activities, especially in the metallurgical industry, energy requirements have been checked by unit of manufactured product as mentioned in the literature (IPPC BREFs, EMEP/CORINAIR) against the empirical ratios resulting from exploitation of the inventory's base information, and if there have been notable discrepancies, potential causes have been investigated and, eventually, energy consumption series have been revised.

3.5.5.- New calculations

Main modifications made in the estimation of the emissions of these key source categories in comparison to the previous edition of the inventory are described in detail below.

- The most relevant change in scope is the systematic revision of the fuel balance that is specifically used for the emissions inventory. It should be underlined here that in the last year of each inventory only international energy questionnaires are provided, and of these only in advance which generally implies that in the following year's edition the figures taken for said questionnaires of the previous year must be revised once the correct energetic balance information is obtained from IEA and EUROSTAT.
- For what concern the years 2004-2006, it has been carried out a reallocation of natural gas consumptions in the non integrated iron and steel plants among the different types of plants. This modification does not affect the CO₂ emissions as the total quantities are

the same, but affect the CH₄ and N₂O emissions as the emission factors applied are different. Nevertheless, the variation in terms of CO₂-eq is very small (between 0.8 Gg and 1.3 Gg).

- In the secondary lead production the fuel consumptions estimate for 2004 and 2006 has been revised following the availability of updated information from the Ministry of Industry, Tourism and Trade (MITYC) concerning production data and being this data the one used to estimate the consumptions. This modification means an increase of 1 Gg of CO₂-eq in 2004 and a decrease of 0.7 Gg of CO₂-eq in 2006.
- The information regarding one plant of the chemistry sector has been updated with the new information provided for this inventory edition. In particular the specific characteristic of the coal used in this plant was available, therefore the own emission factors could be applied instead of applying generic emission factors.
- In a plant of paper pulp production the characteristics of the natural gas (heating value and density) have been revised for the years 1997-2003, according to the new information supplied by the plant. This modification implies a variation of the CO₂-eq emissions that, in the stated period, range between a decrease of 2.7 Gg (2003) and an increase of 4.3 Gg (2002).
- In addition, in another paper pulp production plant the omission of the residual oil consumption in one boiler during 2006 has been corrected. This modification means an increase of 0.2 Gg in terms of CO₂-eq.
- The fuel consumption in three automobile manufacturing plants for 2006 has been updated with the revised information supplied by the plants for this inventory edition. These updates entail a decrease of 2.9 Gg of CO₂-eq emissions during 2006 compared to the previous inventory edition.
- The plaster furnaces fuel consumption estimate for the years 2005 and 2006 has been modified following the detection of incorrect estimated figures in the previous inventory edition. This modification means an increase of 186.1 Gg in terms of CO₂-eq during 2005 and 257.2 Gg during 2006.
- In lime production corrections have been made to the biomass consumption figure for the years 2005 and 2006, after it has been detected an incorrect input in the database of the units expressing those consumptions. In addition, the characteristics of the different petroleum cokes consumed during 2006 have been revised. These modifications means an 0.2 Gg increment in terms of CO₂-eq in 2005 and a 11.8 Gg decrease during 2006.
- In the production of fine ceramic materials (wall and floor tiles) the liquid fuel consumption estimate has been revised for the years 2000-2006 due to the base information update (floor tile production) provided by the Spanish Association of Manufacturers of Tiles, Pavements and Ceramic Tiles (ASCER). In addition, an error in the natural gas consumption related to 2004 has been corrected in accordance with the information provided by ASCER. This data update means a decrease in CO₂-eq emissions during 2000-2006 period comprised between 16.7 Gg (year 2000) and 422.9 (year 2003).

A comparison of the CO₂-eq emissions in this key source between this and the previous edition of the inventory is shown in terms of absolute values in figure 3.5.2 and in relative terms (percent difference) in figure 3.5.3. As illustrated in the last figure, the relative variation of CO₂-eq emission as a consequence of new calculations effected in this category fluctuates between 0.08% in 1996 and 1.28% in 2006, with an exception in 1998, 1999 and 2004 where the revision in estimates resulted in a relative variation between 0.04% and 0.2%.

Figure 3.5.2.- CO₂-eq. emissions. Comparison of 2009 and 2008 editions

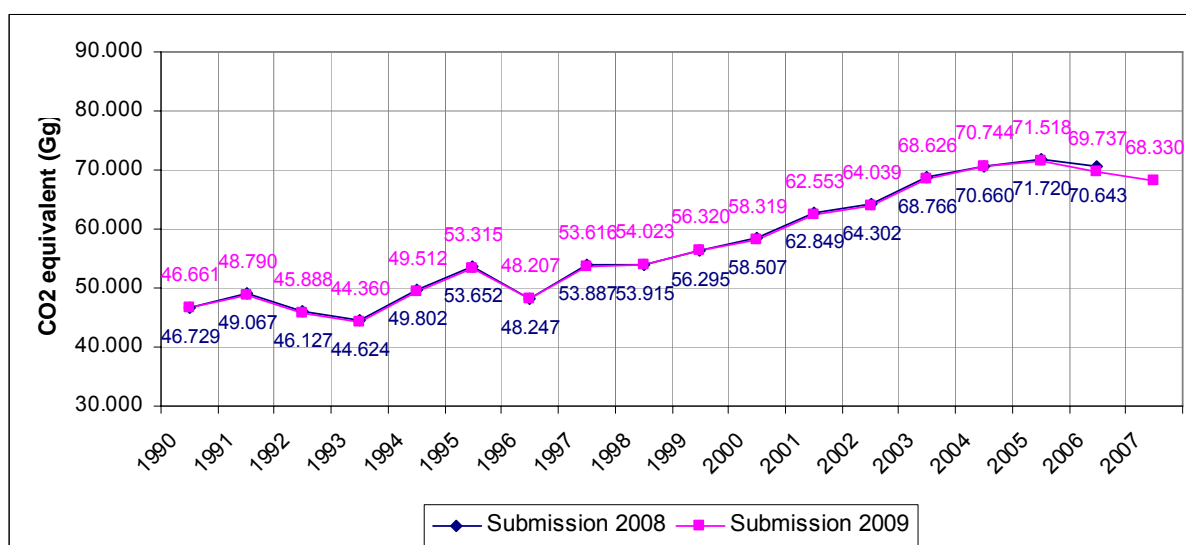
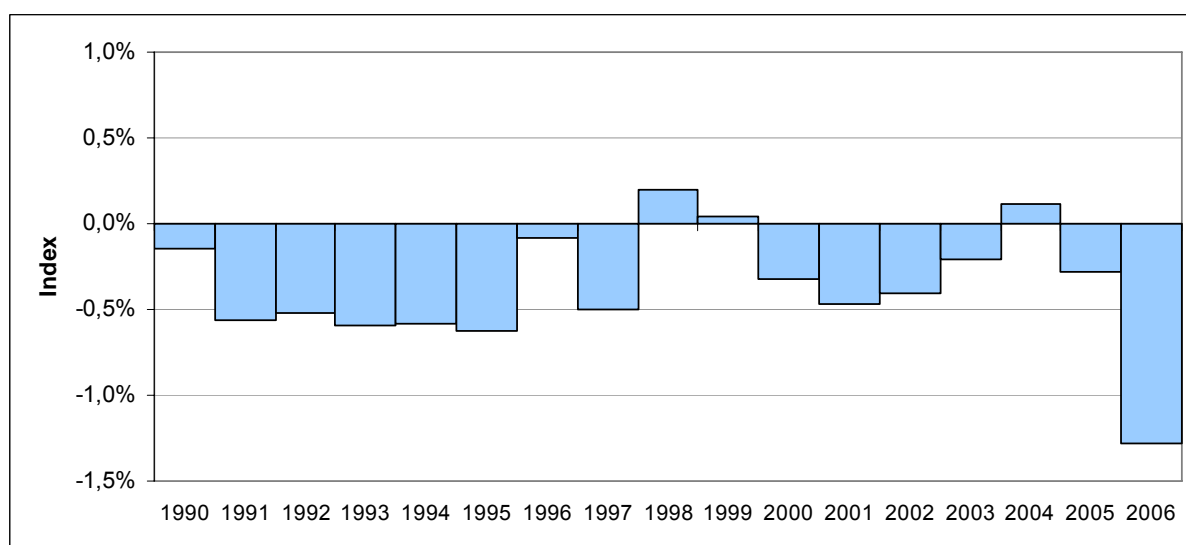


Figure 3.5.3.- CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions



3.5.6.- Improvement plans

A first line of action in the improvement plans is to continue and improve access to individualized information per plant in certain non-ferrous metallurgical sectors where the number of plants in existence is low and therefore there is a positive cost/benefit relationship for having information on a per plant basis (this includes secondary lead and secondary copper manufacturing activities, where individualized information is available for some of the production plants). This approach is intended to apply to iron foundries.

Another line of improvement is to explore potential industrial sub-sectors that perform captive lime production operations that have not yet been investigated (sugar refineries, copper works, calcium carbide) and that could imply, by not being considered in commercial circuits, that fuel consumptions and emissions associated with this activity are being undervalued.

Finally, although these plans will require more time, it is hoped that the basic information on biomass consumption as well as standardization of its classes can be improved as this is relevant to determine the characteristics of calorific values and emission factors.

3.6.- Domestic air traffic (1A3a)

3.6.1.- Description of the activity

This category includes transportation activities carried out by aircrafts nationwide. Two types of operations are highlighted: a) landing and take-off cycles (LTO) at airports and b) cruise phase of flights. LTO also include landing operations (flying at below 1000 m), taxiing by the plane to reach the point of disembarkation, taxiing by the plane from the boarding point to the end of the runway and take-off (again until reaching an altitude of 1000 m).

Table 3.6.1 shows CO₂ emissions with this gas making this a key source. Table 3.6.2 complements this information by including CH₄ and N₂O emissions associated with combustion and by expressing the total emissions of the three gases in terms of CO₂-equivalent. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector.

Table 3.6.1.- CO₂ emissions (Amounts in Gg)

1990	1995	2003	2004	2005	2006	2007
4,130	3,301	5,311	5,881	6,854	7,204	7,582

Table 3.6.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	4,171	3,335	5,365	5,941	6,924	7,277	7,659
CO ₂ -eq Index	100.0	79.9	128.6	142.4	166.0	174.5	183.6
% of CO ₂ -eq over total inventory	1.45	1.04	1.31	1.39	1.57	1.68	1.73
% CO ₂ -eq on energy	1.96	1.39	1.71	1.79	1.99	2.16	2.22

3.6.2.- Methodology

In order to estimate emissions in this category, the IPCC⁸ Tier 2a approach has been applied. To choose the method, criteria given in the 2000 IPCC Good Practice Guidance, figure 2.8, have been followed, according to which the availability of aggregate information on aeroplane movements determines the selection of this tier. This information is published in air traffic statistics compiled by the Ministry of Public Works⁹ for each airport and segment, both domestic and international¹⁰.

In order to estimate fuel consumptions by type of operation and segment, data provided in international questionnaires on oil-derived products sent by the Ministry of the Economy to the international organisations IEA and EUROSTAT¹¹ have been used as a starting point. Starting from this base information, where a distinction is made between the domestic and international segment, fuel consumption in landing and take-off operations is estimated, with the cruise phase of flight being assigned the remainder.

Consumptions attributable to LTO are calculated by determining a mean annual consumption factor for each national civil airport (total volume of fuel consumed per LTO) derived from a distribution of existing traffic by type of plane.

For the period between 1996 and 1998, the public business entity in charge of running civil airports and controlling air navigation, AENA¹², developed an exhaustive study on the types of planes landing and taking off from each airport, separating them according to their domestic or international nature. In order to assign consumption ratios to the various LTO operations, the database designed by ICAO¹³ regarding exhaust emissions and consumptions by type of engine was consulted. The Fleet Planning and Environment Unit of the IBERIA airline company provided considerable assistance in the task of integrating information from both sources, national and international, which allowed a representative aircraft class identified by ICAO¹⁴ made up of an IATA code and an engine configuration (number, models and representation in the class) to be established for each denomination of plane considered by AENA.

⁸ "IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories", heading 2.5.

⁹ "Tráfico comercial en los aeropuertos españoles", Dirección General de Aviación Civil (DGAC), Ministerio de Fomento.

¹⁰ Military, state, private and air work traffic is not included.

¹¹ The national organisation responsible for monitoring oil-derived product questionnaires does not divide consumption into socio-economic activities as of the reference year 2001. Therefore, information available in energy balances from the IEA has been adopted for 2001-2004.

¹² AENA (Aeropuertos Españoles y Navegación Aérea – Spanish Airports and Air Navigation)

¹³ "Engine Exhaust Emissions Data Bank". 1995 edition. ICAO (International Civil Aviation Organization)

¹⁴ Combination of data included in "ICAO Aircraft Type Designators" and in "ICAO Engine Exhaust Emissions Data Bank"

For the remaining years of the period inventoried, information gathering by AENA was unviable given the volume of information requested. For this reason, it has been decided that mean factors per airport inferred for the nearest available year should be assumed in the appropriate reference year. Therefore, by taking into account the consumption ratios per LTO and airport, the aggregate amount of fuel attributable to landing and take-off operations is estimated using the following formula:

$$Comb_{CAD,A}^t = NCAD_A^t \cdot FC_{CAD,A}^{t'} \quad \text{donde}$$

$$FC_{CAD,A}^{t'} = \sum_i \left(\frac{NLanding_i^{t'} \cdot FC_{I,Landing}^{t'} + NTake-off_i^{t'} \cdot FC_{I,Take-off}^{t'}}{NLanding_i^{t'} + NTake-off_i^{t'}} \right)$$

where:

- A = domestic civil airport
- t = reference year
- t' = year covered by the study that is closest to the reference year (i.e. 1996 if t ≤ 1996; 1997 if t = 1997; 1998 if t ≥ 1998)
- i, l = type of plane (AENA denomination) and representative class of the type of plane, respectively
- NCAD = N° of LTO
- NLanding = N° of landing operations
- NTake-off = N° of take-off operations
- FC = consumption factor

As has been commented before, fuel consumption for cruise phase of flight, either for domestic or international traffic, has been inferred by subtracting the estimated LTO values from the international questionnaire figure. Table 3.6.3 shows fuel consumptions in terms of energy, differentiated by type of segment (TJ (LHV)).

Table 3.6.3.- Fuel consumption (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Aviation gasoline from which			477	434	434	434	477
LTO			85	75	70	70	78
Cruise			392	359	364	364	399
Kerosene ⁽¹⁾ from which	56,845	45,441	72,628	80,520	93,918	98,731	103,891
LTO	6,413	8,299	12,908	13,849	15,136	15,913	16,898
Cruise	50,432	37,142	59,720	66,671	78,782	82,818	86,993
Total	56,845	45,441	73,105	80,953	94,351	99,164	104,368

(1) Includes, through the years, aviation kerosene times gasoline type jet fuel.

Although a difference is shown for aviation use between aviation gasoline and kerosene in the fuel balance for the national inventory, and in Table 3.6.3, in the emissions calculation of the CRF Reporter, total consumption of both fuels has been included in a single type of fuel (kerosene) for the period 1990-1996 given the very slight relevance of aviation gasoline with

regard to the total. Also, for this fuel, missing data can be detected in the original source of the IEA and EUROSTAT energy balance for 1994 and 1995, leading to conclude that aviation gasoline might have been included under kerosene in these years.

In order to select the emission factors applied, a distinction has been made as to whether consumption is made in the cruise phase of flight or by LTO and/or by pollutant. In the specific case of CO₂, the default factor of 3.15 tonnes of CO₂ per tonne of fuel proposed in the 1996 IPCC Reference Manual, Table 1-52, has been applied.

3.6.3.- Uncertainty and consistency over time

Uncertainty in domestic fuel consumption has been estimated to be around 35% from information published in the UNFCCC document on aviation, FCCC/TP/2003/3 (14 Nov 2003). This value is derived from the percentage variation observed between the data obtained by modelling, model AERO (32,642 TJ_{LHV}), and the consumption estimate given by the inventory (50,168 TJTJ_{LHV}) for 1992, taking this rate to be the range limit determining the 95% confidence interval. The qualitative factors that have determined this uncertainty are the uncertainty itself in distinguishing the fraction attributable to domestic traffic¹⁵, from the total amount associated with aviation, the nature of the socio-economic data provided in the questionnaires (sales or consumption), or the list of activities considered (inclusion or exclusion of military traffic).

For the CO₂ emission factor, the associated uncertainty has been evaluated to be 5% by following the considerations contemplated in chapter 2, section 2.5.1.6, of the 2000 IPCC Good Practice Guidance.

With regard to the consistency over time, it must be indicated that the fuel consumption assigned to LTO is calculated for the entire inventory period using the same estimation procedure. Consumption attributed to the cruise phase of flight is determined by the aggregate data available in national or international statistics, which are assumed to be consistent.

3.6.4.- Quality assurance and verification

While following-up in the movement of aircraft, operations were identified at four new airports starting in 2004 operations (Albacete, Ceuta, Logroño and Torrejón), which did not appear in the 1990-2003 statistics used in the inventory's previous edition. The presence of these airports does not affect the global calculation of CO₂ or N₂O emissions but does slightly change the emissions estimations of CH₄. In future inventory editions, these new airports will be included in the breakdown of airport and navigation activity operations.

¹⁵ Table 1 of the above-mentioned UNFCCC report on aviation shows that, in the comparison of figures regarding total fuel consumption (sum of domestic and international) estimated by the inventory and those estimated by modelling corresponding to 1992, the percentage difference is significantly reduced to 9%.

3.6.5.- New calculations update

In the current inventory edition no methodological modifications or updates have been made to the base information that concerns the greenhouse gases emissions estimated in the previous edition.

3.6.6.- Improvement plans

A collaboration project between different national bodies (DGCEA , National Aviation Safety Agency -AESA- and the Services and Studies for Air Navigation and Aeronautical Safety Enterprise -SENASA-) and international organizations (EUROCONTROL) is currently in progress to implement a methodology and model development of traffic and air traffic emissions (MECETA model). In future editions, the plan is to introduce methodological aspects and information from this programme into the national inventory.

3.7- Road transport (1A3b)

3.7.1.- Description of the activity

This category contemplates pollutant emissions due to vehicle traffic whose main purpose is the transportation of passengers or merchandise. The category does not include those groups of self-propelled vehicles that, despite performing or being able to perform a transportation service, are classified and used instead as industrial or agricultural-forestry machinery (these vehicles are dealt with in categories 1A2 and 1A4, respectively).

The pollutant emission source of this category is fuel consumption: leaded or unleaded petrol, diesel fuel and liquefied petroleum gas. Table 3.7.1 shows this category's greenhouse gas emissions by type of gas, while table 3.7.2 complements this information by expressing all emissions in terms of CO₂-eq equivalent. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector.

Table 3.7.1.- Emissions by type of gas (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO ₂	50,442	60,341	86,592	89,704	92,666	95,141	97,848
CH ₄	11.32	11.22	9.42	8.88	8.65	8.50	7.79
N ₂ O	2.19	3.57	7.51	7.97	8.43	8.85	9.20

Table 3.7.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	51,360	61,684	89,118	92,362	95,461	98,062	100,863
CO ₂ -eq Index	100.0	120.1	173.5	179.8	185.9	190.9	196.4
% of CO ₂ -eq over total inventory	17.82	19.33	21.72	21.68	21.64	22.64	22.80
% CO ₂ -eq on energy	24.17	25.63	28.34	27.86	27.49	29.08	29.20

3.7.2.- Methodology

ACTIVITY VARIABLES

There are three main activity variables used to calculate road traffic emissions:

1. Fuel consumption figures prepared by the inventories' working groups, based on information from the following sources:

"Energy Statistics of OECD Countries" by the International Energy Agency

"Energy Balance Sheets" by EUROSTAT, and

"Oil-derived Product Consumption Statistics" by the Sub-Directorate-General for Hydrocarbons at the Spanish Ministry of Industry, Tourism and Commerce.

2. Official figures on registered vehicles, distributed by category, age, cubic capacity and useful load, published in the *Statistical Yearbook* of the Directorate-General for Traffic at the Ministry of the Interior.
3. Figures regarding journeys, broken down into categories of vehicles and the interurban and rural road networks travelled on, including: the State Road Network (RCE), Regional Community networks and Provincial networks. These figures are provided by the Directorate-General for Roads at the Ministry for Public Works.

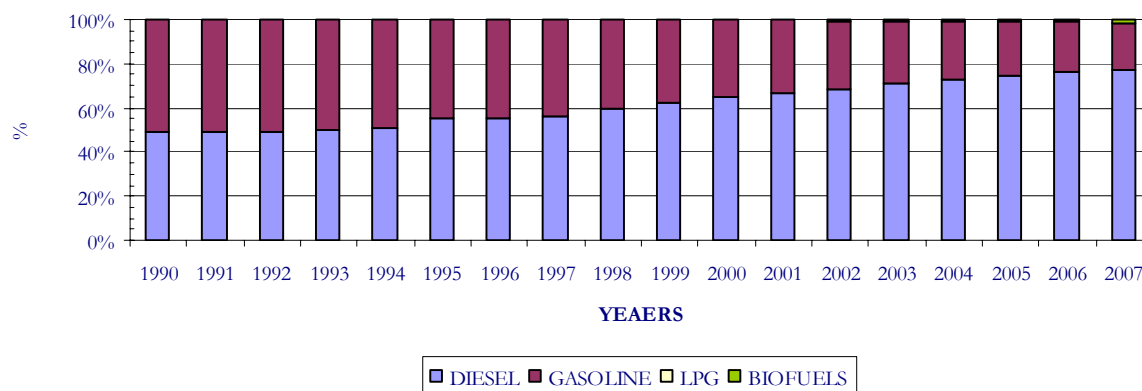
FUEL CONSUMPTION

The most outstanding facet is the sustained growth in fuel consumption as a result of interannual increases in vehicle use. At the same time, making a distinction by type of fuel, the steady growth in diesel consumption is highlighted against the evolution of gasoline consumption which, after a growth in the initial years was followed by stability in the intermediate years, shows a decreasing pattern from 1998. The evolution in figures for gasoline ranges between 8,000 to 9,000 kt until 2003, steadily descending to 6,655 kt in 2007; while diesel has shot from 7,788 kt in 1990 to 24,395 kt in 2007 (consumption of liquefied gases is marginal). This has led to a modification in the relative distribution of consumption between petrol and diesel fuel, starting with a practically equal distribution in 1990 and reaching a situation where diesel fuel represents almost three-quarters the total consumption in 2007, as can be seen in figure 3.7.1.

With reference to the renewable fractions of diesel fuel (pure biodiesel) and gasoline (ethanol) these have grown in the last years, being in 2007 around 1,2% in the case of biodiesel in comparison with the diesel fuel total, and around 2,9% in the case of ethane in comparison with the petrol total. The presentation of the fossil and renewable part of the liquids fuels contributions used in road transportation is shown in the excel spreadsheets elaborated by the CRF in the following way: the CH₄ and N₂O emissions have been included totally within the fossil liquid fuels, this is indicated in the stated pollutant emissions for the biomass with the label "IE" (estimated elsewhere); while for the CO₂ each part (fossil and

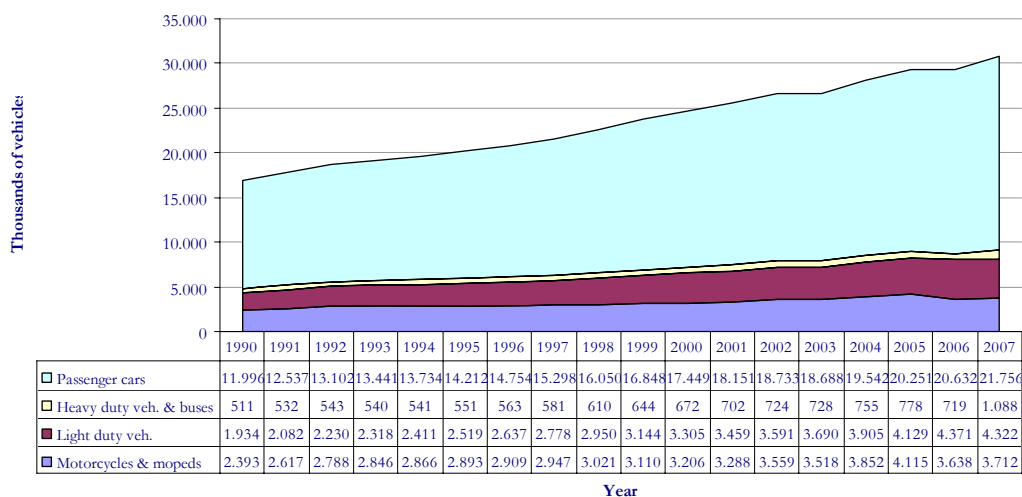
renewable) has its own emission, reflecting the associated to the renewable part as *Memo* concept only.

3.7.1.- Gasoline and diesel fuel consumption (Amounts in kt)



FLEET OF VEHICLES

The fleet of registered vehicles has experienced a notable growth between 1990 and 2007. As can be seen in figure 3.7.2, it has grown between 55% and 123% depending on the category of vehicles being considered: motorcycles and mopeds 55%, light duty vehicles 123%, heavy duty vehicles 113% and passenger cars 81%.

Figure 3.7.2.- Fleet of vehicle

If we look at the distribution by type of fuel for each class of vehicle, the evolution of private cars shows a large degree of disparity. Although considerable at around 7%, the growth in gasoline-driven passenger cars does not compare with the growth in diesel cars, near to 740%. This disparity is consequently shown in the distribution of the vehicles by age, an aspect that is very important in terms of emission calculations, giving rise to newer diesel-powered passenger cars in comparison with gasoline-driven ones (the average age for diesel passenger cars is between 5 and 6 years while for petrol it is over 13 years). This is clearly consistent with the trend to progressively replace gasoline with diesel fuel as experienced over recent years (both the evolution of all passenger cars according to fuel and the distribution by age for 2007 can be seen in figures 3.7.3 and 3.7.4 below).

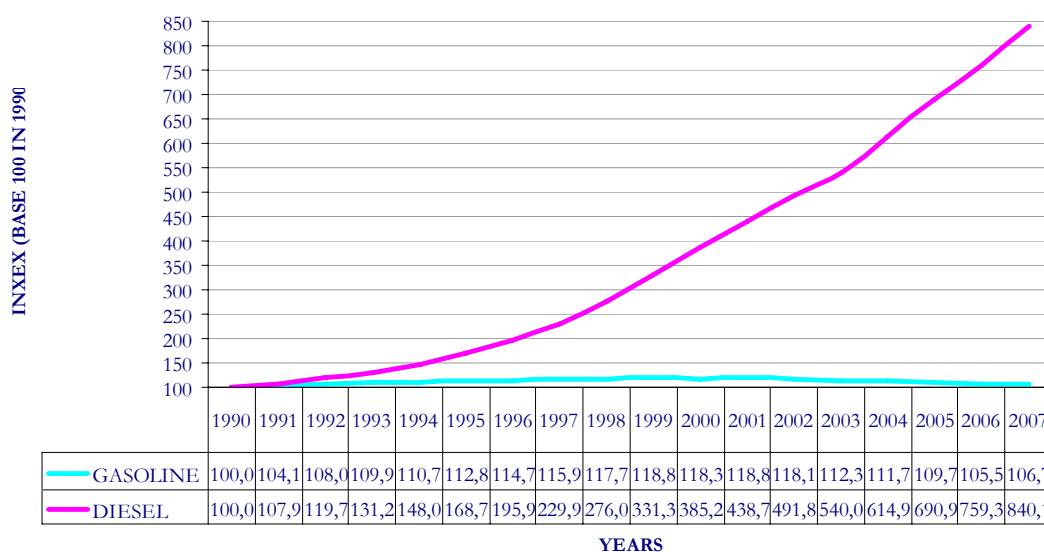
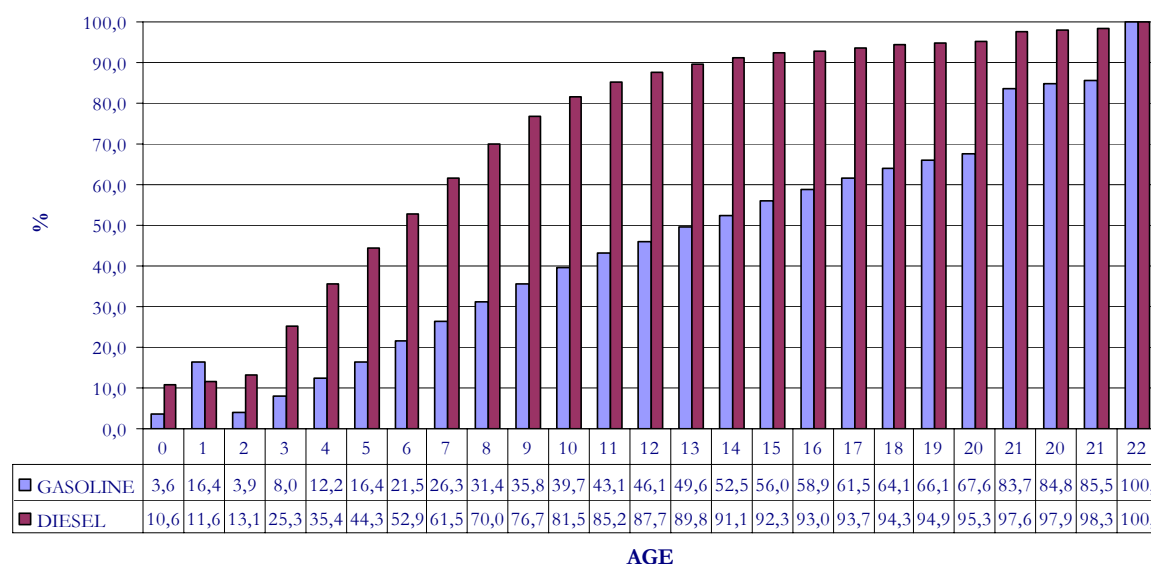
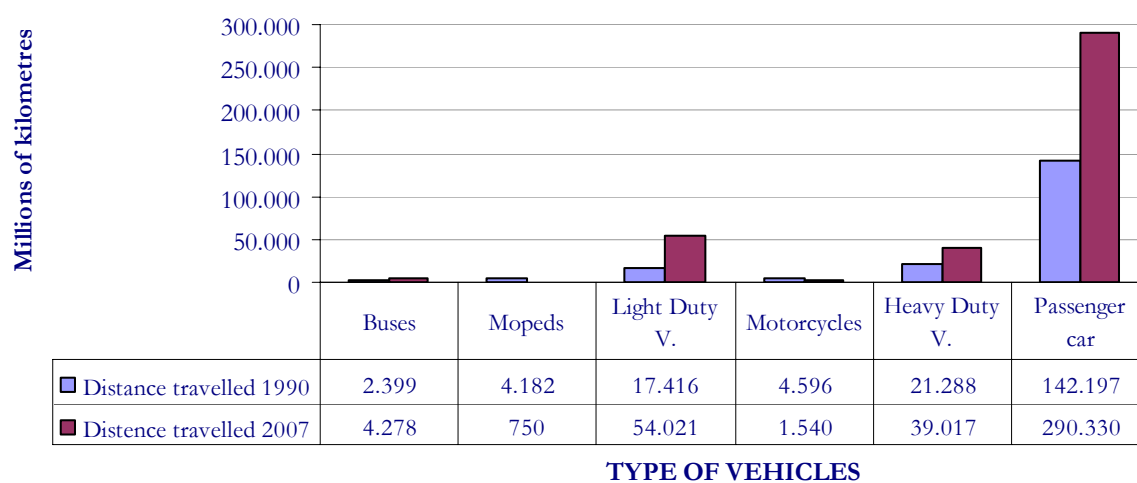
Figure 3.7.3.- Evolution of passenger cars fleet by used fuel type

Figure 3.7.4.- Age of passenger cars fleet in 2007

DISTANCES TRAVELLED

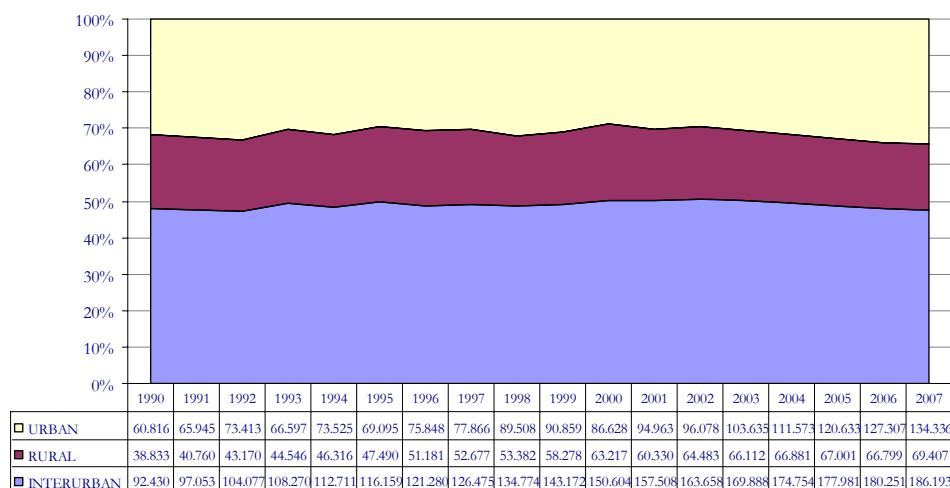
Between 1990 and 2007, there has been a sustained growth in distances travelled in any of the three types of driving patterns considered, interurban, rural and urban, increasing from a total of 192,078 million kilometres in 1990 to 389,936 in 2007, representing an increase of approximately 103% in eighteen years. According to type of vehicle, the biggest increase corresponds to light duty vehicles with 210%, followed by passenger cars with 104% and heavy duty vehicles with 83%, as can be seen in figure 3.7.5 below.

Figure 3.7.5.- Distances travelled by type of vehicle

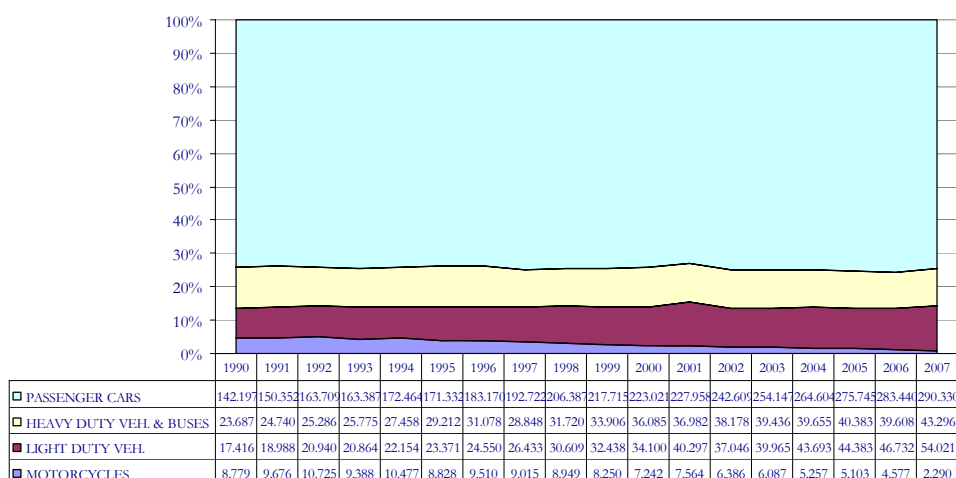
With regard to the distribution of distances travelled according to the driving patterns, it can be said that stability is shown over the years in the inventoried period, with interurban driving representing between 47.2% and 50.5% of the total mileage, rural driving between 17.8% and 21.0% and urban driving between 28.8% and 34.5% whilst, in the course of the years, it is apparent an increase of the urban driving pattern and a corresponding decrease of the interurban and rural driving patterns. In what concerns the distribution of mileage according to vehicle category it can be observed that the main categories show very little variation: passenger cars range between 74.0% of the total in 1990 and 74.5% in 2007 while heavy duty vehicles, whether for freight or passenger transport, vary between 12.33% in 1990 and 11.10% in 2007. Figure 3.7.6 below shows both distributions (the distances travelled are expressed in millions of kilometres).

Figure 3.7.6.- Distribution of distances travelled

a) By driving patterns



b) By type of vehicle



EMISSION FACTORS

The calculation of emission factors and CO₂, N₂O, and CH₄ emissions has been based on the publications and documents of the CORINE AIRE project working group, or more specifically on the methodology explained in the European Environment Agency technical report “*COPERT III Computer Programme to Calculate Emissions from Road Transport*”.

The CO₂ emission factors have been calculated from the characteristics of the fuels (their carbon content) so as to obtain the final emissions, in other words under the assumption that in the end the fuel's entire carbon content will end up mixing with oxygen to form CO₂. The calculation formula used is:

$$E_{f,CO_2}^F = 44,011 \frac{Q_f}{12,011 + 1,008 r_{H/C}}$$

where:

$$E_{f,CO_2}^F$$

Are the final CO₂ emissions produced by consumption of fuel f

$$Q_f$$

Is the total consumption of fuel f

$$r_{H/C}$$

Is the ratio between the number of hydrogen and carbon atoms in fuel f (1.8 for gasoline, 2.0 for diesel fuel and approximately 2.53 for LPG)

Application of the above formula gives the following CO₂ emission factors per unit of mass for each of the three types of fuel considered: gasoline (fossil fraction), 3.183, diesel fuel (fossil fraction), 3.138 and liquefied petroleum gases, 3.023 (all three expressed in kg of CO₂/kg of fuel)¹⁶.

N₂O y de CH₄ emission factors per kilometre travelled have in turn been calculated as functions of the type of vehicles and the representative speeds of the roads and categories of vehicles considered, i.e.:

$$e_{i,j}^T = f(v)$$

¹⁶ The gasoline and diesel fuel renewable fractions contribution has been estimated as follows: for gasoline, based on the ethanol stoichiometric composition, gives a value of 52.2% of carbon mass to ethanol mass; and for biodiesel, it has been set as methyl ester with oleic fatty acid the molecular formula C₂₀ H₃₇ O₄, that gives a value of 70.4% of carbon mass over the stated ester mass. Therefore, the final emission factor of CO₂ is 1,914 kg of CO₂/kg of fuel for ethanol and 2,581 kg of CO₂/kg of fuel for biodiesel.

where:

$$e_{i,j}^T = f(v)$$

Is a function of the speed that gives the mass of pollutant j (N_2O or CH_4) emitted by vehicles in class i per unit of distance travelled.

In order to apply the methodology, the speeds given in Table 3.7.3 below have been considered.

Table 3.7.3.- Driving patterns

		Inter-urban	Rural	Urban
PASSENGER CARS	Range	80 - 130	40 – 80	10 - 40
	Represented by	105	65	25
LIGHT WEIGHT VEHICLES	Range	80 - 130	40 – 80	10 - 40
	Represented by	100	65	25
HEAVY WEIGHT VEHICLES	Range	80 - 100	40 – 80	10 - 40
	Represented by	95	60	25
BUSES AND COACHES	Range	80 - 105	40 – 80	10 - 40
	Represented by	95	60	25
MOTORCYCLES	Range	80 - 130	40 – 80	10 - 40
	Represented by	105	65	25
MOPEDS	Range		40 – 50	10 - 40
	Represented by		45	25

Figures 3.7.7 below show the emission functions of nitrous oxide and methane for the main categories of vehicles.

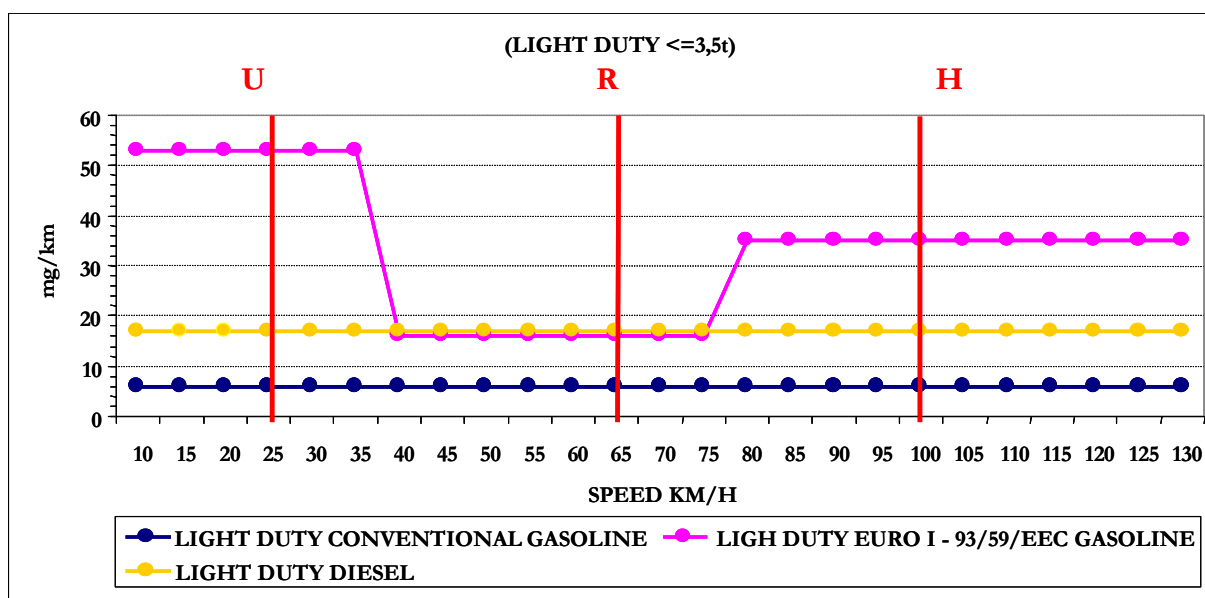
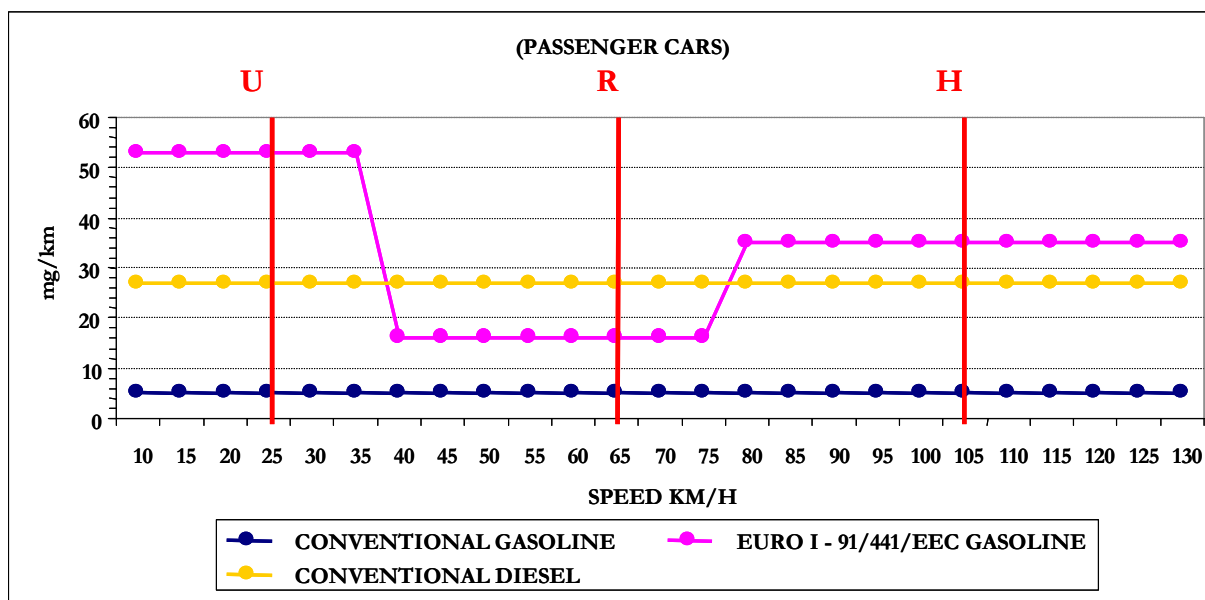
Figure 3.7.7.- N₂O emission functions

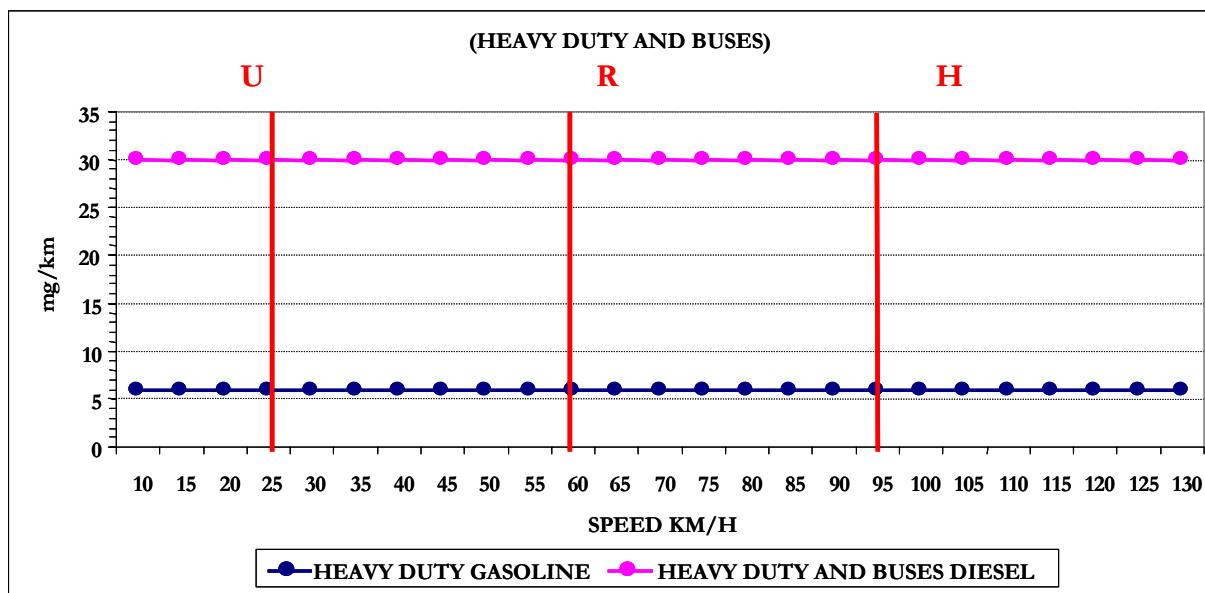
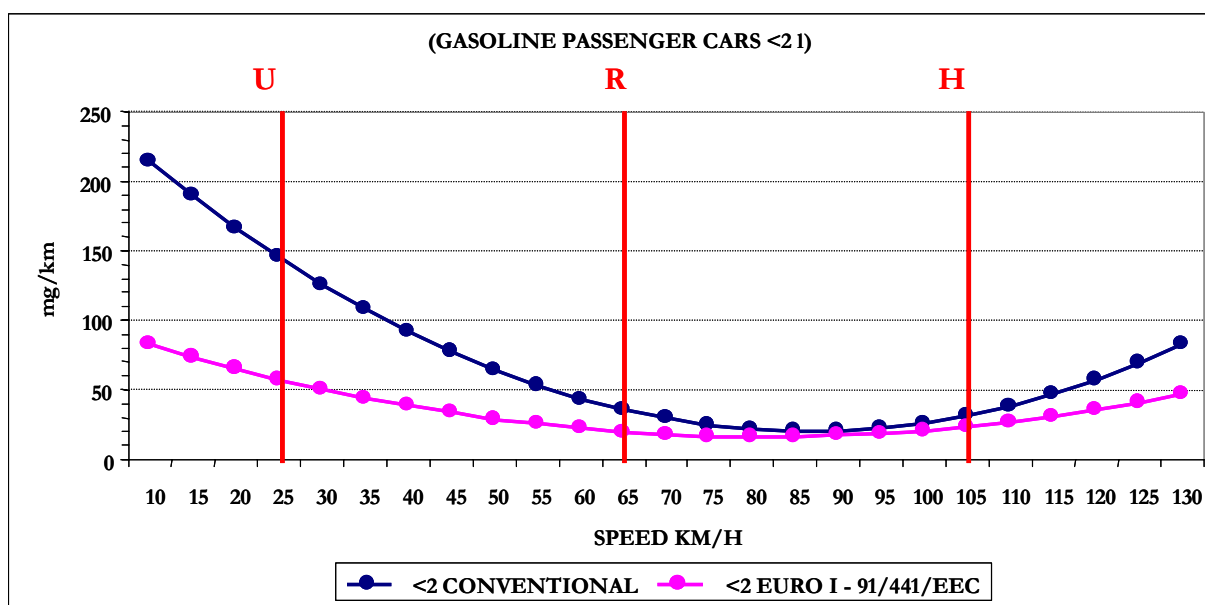
Figure 3.7.7 (continued).- N_2O emission functionsFigure 3.7.7 (continued).- CH_4 emission functions

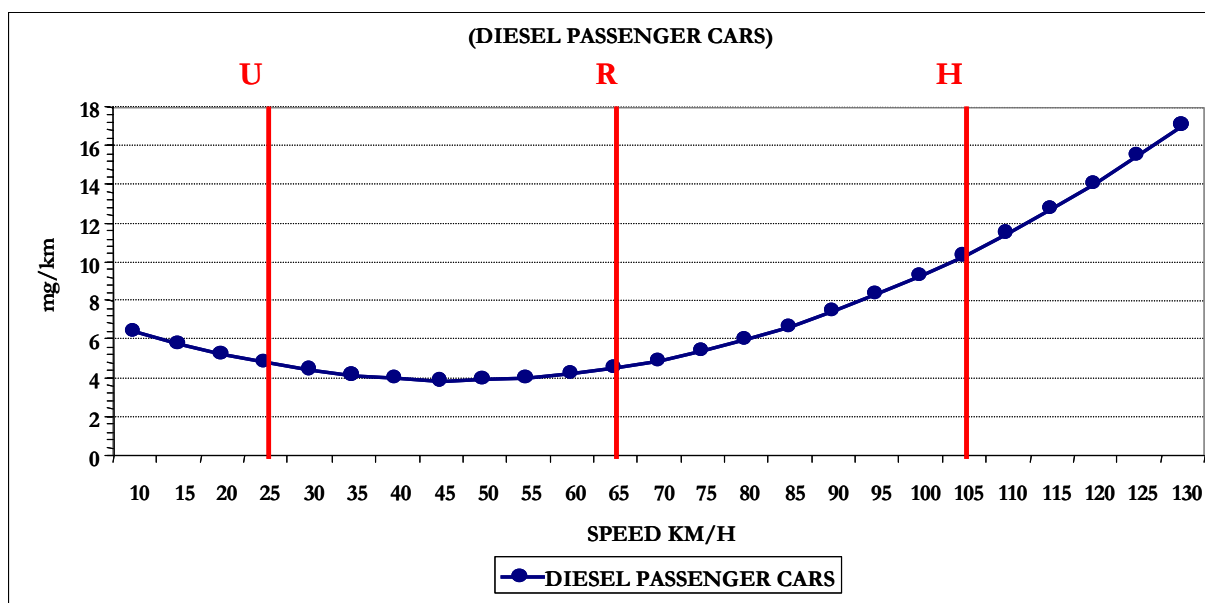
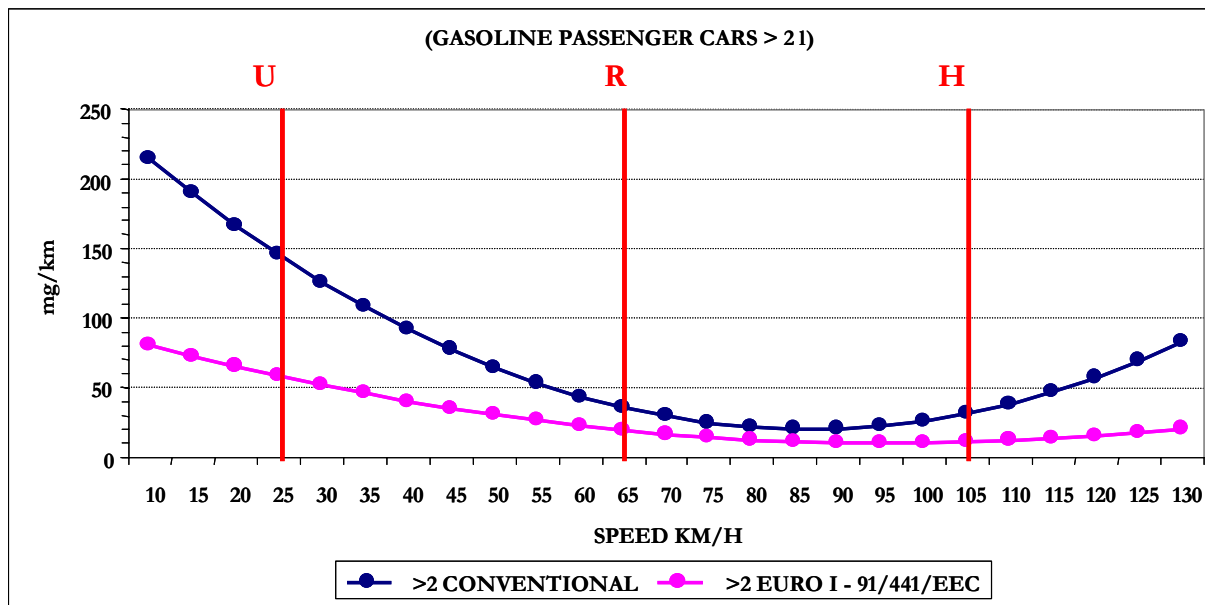
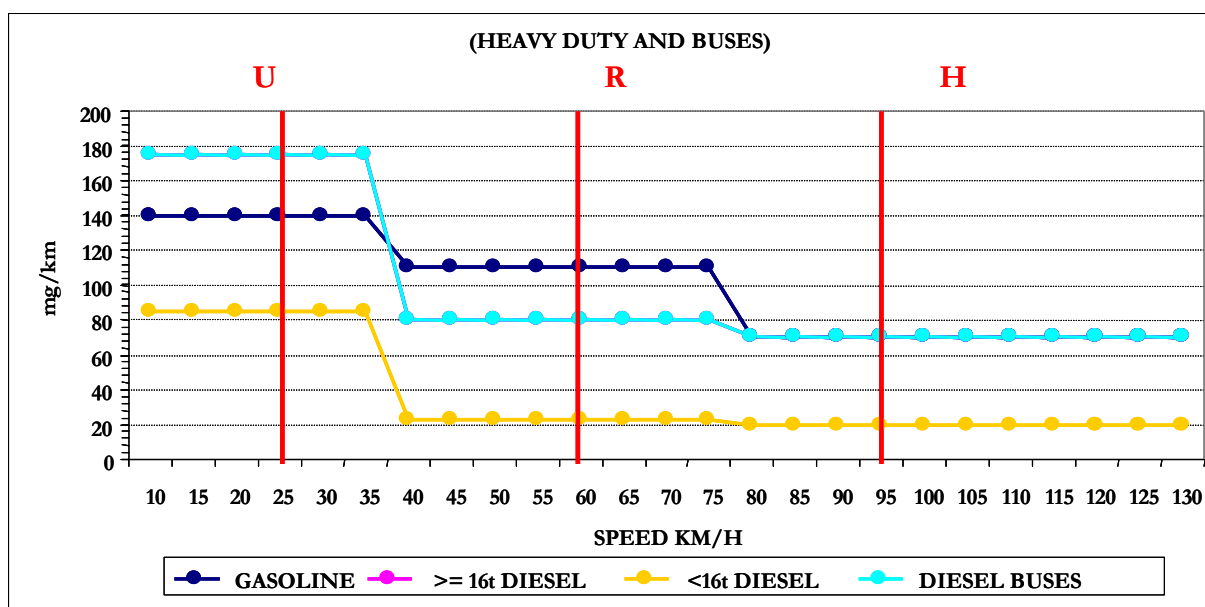
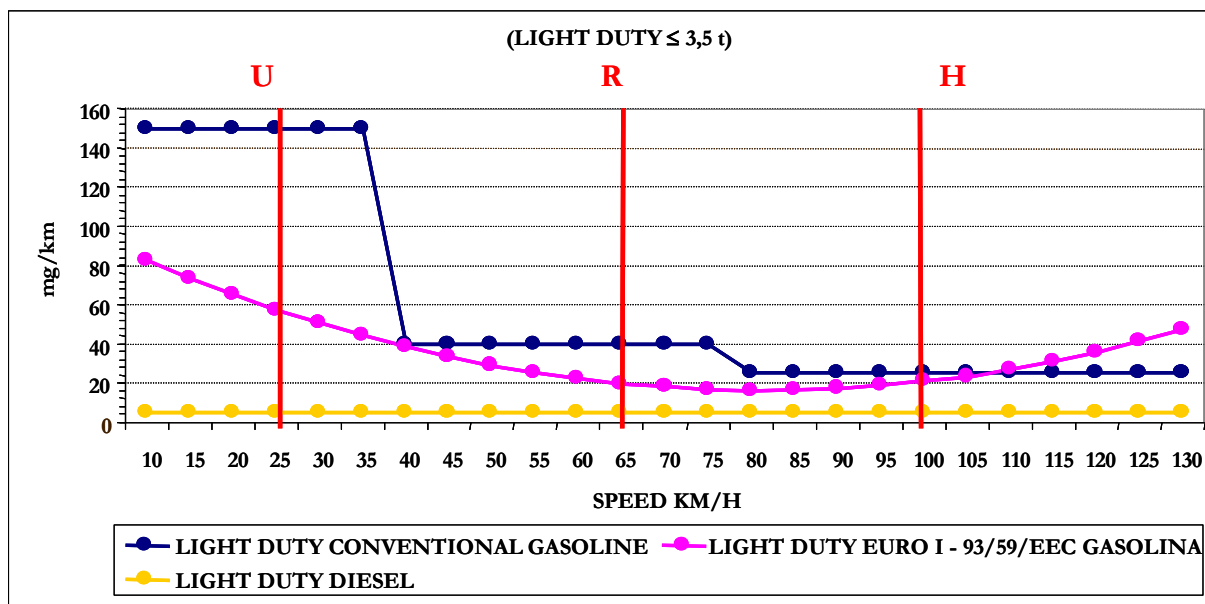
Figure 3.7.7 (continued).- CH₄ emission functions

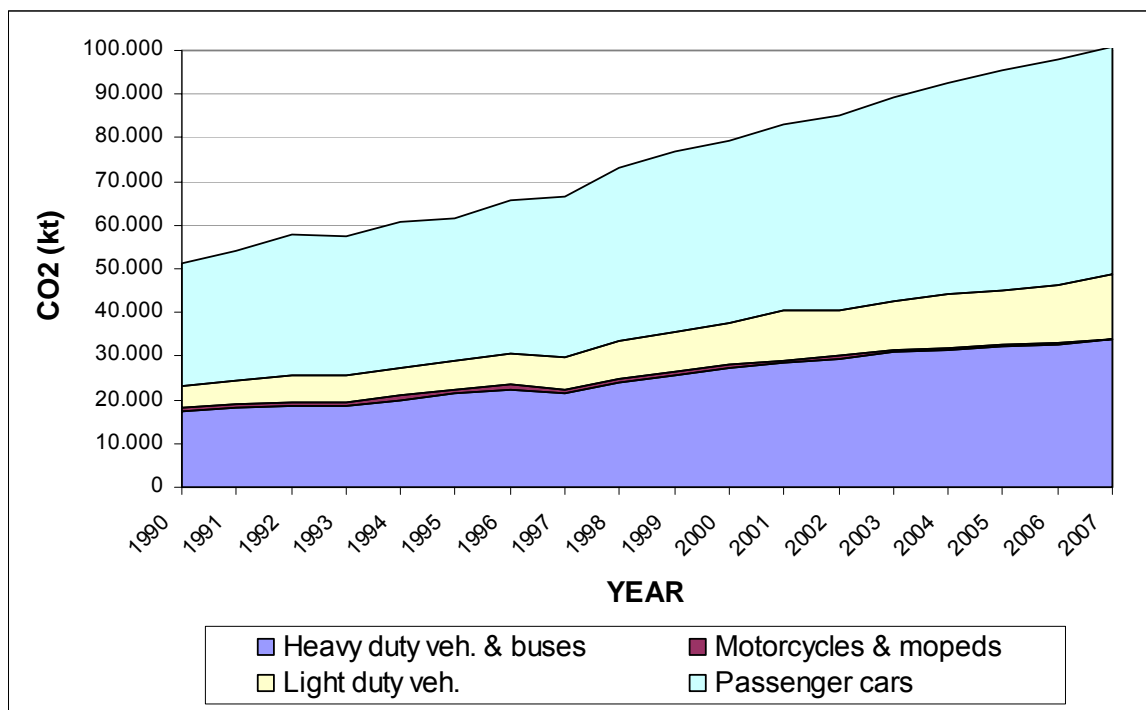
Figure 3.7.7 (continued).- CH₄ emission functions

EMISSIONS

Emissions calculated by applying the COPERT III methodology to the activity variables indicated above (distances travelled, fuel consumptions and fleet of vehicles) are shown in table 3.7.4 and figure 3.7.8 below, broken down by vehicle category.

Table 3.7.4.- CO₂-eq equivalent emissions by vehicle category (Gg)

YEAR	HEAVY DUTY VEHICLES	MOTORCYCLES	LIGHT VEHICLES	PASSENGER CARS	TOTAL
1990	17,185	894	4,972	28,308	51,360
1991	17,993	991	5,463	29,872	54,318
1992	18,407	1,101	6,061	32,476	58,045
1993	18,654	967	5,987	31,983	57,591
1994	19,868	1,080	6,367	33,488	60,803
1995	21,289	914	6,679	32,802	61,684
1996	22,513	981	7,011	35,243	65,748
1997	21,387	933	7,521	36,666	66,508
1998	23,873	927	8,764	39,404	72,969
1999	25,639	835	9,219	41,147	76,839
2000	27,319	720	9,560	41,551	79,148
2001	28,385	723	11,223	42,758	83,089
2002	29,510	538	10,391	44,590	85,029
2003	30,880	510	11,198	46,530	89,118
2004	31,420	429	12,223	48,290	92,362
2005	32,169	426	12,497	50,369	95,461
2006	32,782	354	13,114	51,811	98,062
2007	33,854	201	14,629	52,179	100,863

Figure 3.7.8.- CO₂ equivalent emissions by vehicle category (Gg)

3.7.3.- Uncertainty and consistency over time

With regard to the activity variable (fuel consumption: gasoline and diesel), the uncertainty is estimated to be 3% for gasoline and 5% for diesel given that gasoline is specifically used exclusively for this activity while for diesel, the amount attributable to mobile machinery must be deducted from the statistical base figure in order to obtain the effective consumption assigned to road transportation, which has the effect of increasing the uncertainty associated with this fuel.

To calculate the uncertainty of the CO₂ emission factors, contributions due to the fuel carbon content and the fraction of carbon oxidized to CO₂ have been combined, resulting in some uncertainties of 2.1% for petrol and 2.2% for diesel.

As for N₂O, the uncertainty of the activity variable (distances travelled by class of vehicle and representative speed) is estimated to be around 10% while that corresponding to emission factors is estimated to be 50%.

With regard to the time-series consistency, it is considered that the degree of consistency is high in terms of both the background information (fuel consumption and distances travelled by category of vehicle according to speed) and the representative nature of the emission factors that include the penetration of new technologies incorporated into the successive series of vehicle fleets.

3.7.4.- Quality assurance and verification

The quality assurance task performed in this category is a comparison between the original source of distances travelled in certain provinces for traffic on roads that are the responsibility of different administrative bodies (state, regional and provincial roads).

3.7.5.- New calculations

The main change carried out has been the fossil and renewable fraction breakdown, for petrol as well as for diesel fuel, that since 2002 comprise the incorporation of renewable fractions for these fuels.

In terms of CO₂-eq, the modifications carried out mean upward variations in the years 2000 (9.1 Gg), 2005 (27.9 Gg) and 2006 (33.9 Gg), while downward variations occur in the years 2002 (356,5 Gg), 2003 (504.0 Gg) and 2004 (818.9 Gg), which in relative terms results in variations that range between -0.88% in 2005 and 0.03% in 2006.

Figure 3.7.9 shows the comparative development of absolute values of the CO₂ emissions between the results of the current edition, and the results of the previous edition, while figure 3.7.10 presents the percentage difference in these emissions between both inventory editions.

Figure 3.7.9.- CO₂-eq emissions. Comparison of 2009 and 2008 editions

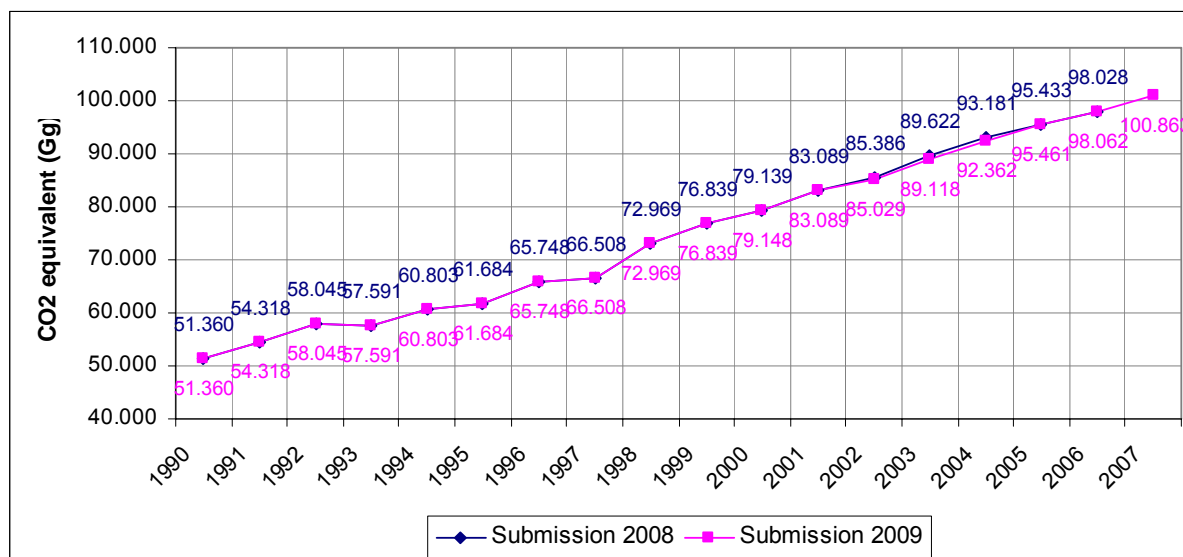
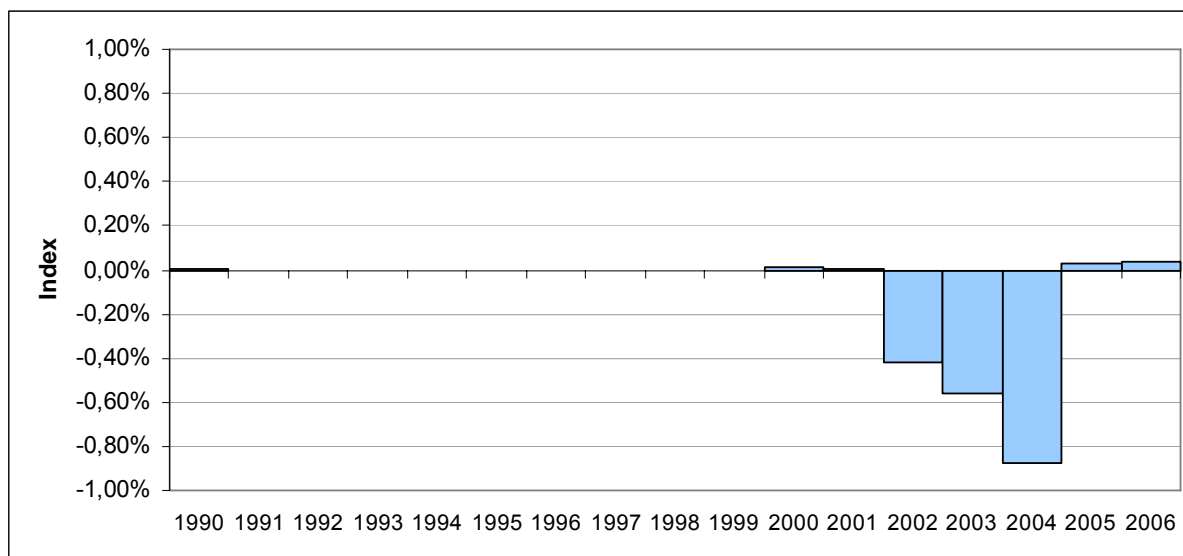


Figure 3.7.10.- CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions

3.7.6.- Improvement plans

With a view to the future, the estimation procedure will continue to evolve in parallel with new developments arising in the COPERT methodology (the next incorporation of the COPERT IV version) and with the revised composition of the country's fleet of vehicles. Regarding the vehicles, and in collaboration with the Directorate-General for Roads at the Ministry of Public Works and the Directorate-General for Road Traffic of the Ministry of the Interior, it is proposed to advance the estimation of the effective fleet of vehicles travelling on main roads (interurban and rural traffic). This estimate can obviously not be done on an individual basis but instead will be done in groups, which are considered statistically representative. The final effect is expected to be a "rejuvenation" of the operative fleet for the emissions model, which in short will improve the representative nature of the model. On a long-term it is also planned to directly collect information from traffic indicators in urban centres.

3.8.- Domestic sea traffic (1A3d)

3.8.1.- Description of the activity

This category includes emissions from merchant sea traffic on routes with Spanish ports of origin and destination, regardless of whether the ship's flag or nationality of the shipping company is national or foreign. Emissions from sea fishing are not included here as these come under activity 1A4c.

Table 3.8.1 shows greenhouse gas emissions by type of fuel, with CO₂ making this a key source. Table 3.8.2 complements this information by expressing all emissions of the three gases in terms of CO₂-eq. The same table gives the time evolution index (100 in base year

1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector.

Table 3.8.1.- Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO₂							
Residual oil	1,234	1,259	1,661	1,693	1,768	1,944	2,294
Diesel	266	307	712	726	745	819	966
Total	1,500	1,565	2,374	2,419	2,513	2,763	3,260
CH₄							
Residual oil	0.07	0.07	0.09	0.10	0.10	0.11	0.13
Diesel	0.01	0.01	0.02	0.02	0.02	0.02	0.03
Total	0.08	0.08	0.12	0.12	0.12	0.14	0.16
N₂O							
Residual oil	0.03	0.03	0.04	0.04	0.05	0.05	0.06
Diesel	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Total	0.04	0.04	0.06	0.06	0.06	0.07	0.08

Table 3.8.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	1,513	1,580	2,395	2,440	2,536	2,788	3,290
CO ₂ -eq Index	100.0	104.4	158.3	161.3	167.6	184.2	217.4
% of CO ₂ -eq over total inventory	0.53	0.49	0.58	0.57	0.57	0.64	0.74
% CO ₂ -eq on energy	0.71	0.66	0.76	0.74	0.73	0.83	0.95

3.8.2.- Methodology

To estimate fuel consumption in this activity, national energy balances¹⁷ and information provided by the Spanish Ship-owners Association (ANAVE) have been considered. The following sub-periods are presented with regards to information available from ANAVE insofar as the handling of that information:

- the base information for 1993-2002 is derived from the statistical analysis developed at the time of the survey issued by the association "State Ports" to marine companies associated with ANAVE;
- the previous sub-series was completed and extended to preceding year (1990-1992) projecting the available consumption data;
- for 2002-2004, since no survey was available, the information added by type of fuel was provided directly from ANAVE; and
- from 2005, since no information was available from ANAVE, the fuel consumption was estimated from a mean consumption factor per Gross Registered Tonnage unit (GRT). The consumption factor has been derived from the energy consumption series for this

¹⁷ Please refer to the IEA publication "Energy Statistics of OECD Countries".

activity and from the information published in the Yearbook from the Ministry of Public Works regarding the figures for merchant navy vessels engaged in coastal shipping.

The breakdown of fuel type has been processed by sub-periods as indicated in continuation:

- For 1990-2004, the consumption figure for diesel provided by ANAVE was used as a reference, and following estimates made by ANAVE experts, it has been estimated that some 70% corresponds to domestic traffic (the remaining 30% is considered by ANAVE technicians to correspond to international traffic consumption); with regards to residual oil, the greater of the energetic balance value and the 65% consumption provided by ANAVE (the expert's estimated percentage corresponding to domestic traffic) was used. This solution is obviously a compromise between the two reference sources.
- From 2005 the breakdown by fuel type has been estimated applying the gas-oil and residual oil contribution mean over the total energy calculated according to the breakdown in previous years.

Table 3.8.3 shows estimated fuel consumptions for this activity expressed in terms of energy (TJ (lower heating value)).

Table 3.8.3.- Fuel consumption (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Residual oil	16,072	16,393	21,638	22,048	23,033	25,323	29,879
Diesel	3,659	4,223	9,806	9,992	10,256	11,276	13,304
Total	19,731	20,617	31,444	32,040	33,289	36,599	43,183

To estimate CO₂ emissions, an emission factor derived from the fuel's carbon content has been used. For CH₄ emissions, it has been assumed that these emissions represent 5% of total VOC emissions, while for N₂O, factors selected from EMEP/CORINAIR have been used. For NO_x, NMVOC and CO, information from the study *"Marine Exhaust Emissions Research Programme"* by Lloyds Register has been used while for SO₂, the emission factors, variable according to the year, have been derived by mass balance as a function of the sulphur content of the fuels. Table 3.8.4 shows the emission factors used to estimate the greenhouse gas emissions.

Table 3.8.4.- Emission factors

	CO ₂ (t/t)	CH ₄ (kg/t)	N ₂ O (kg/t)
Residual oil	3.085	0.175	0.08
Diesel	3.138	0.095	0.08

3.8.3.- Uncertainty and consistency over time

The uncertainty associated with the variable has been estimated to be 50%. In order to determine this, the percentage difference between residual oil consumptions in navigation as declared in the IEA's energy balances and the amounts provided by the national association has been evaluated. The difference in diesel figures presented by both sources has been

removed from the calculation as it is considered that the IEA's balance has overestimated navigation consumptions by including the diesel consumed in sea fishing.

The uncertainty of the carbon dioxide factor is derived from the uncertainties associated with the carbon content of the fuels used and the oxidation factor, arriving at an uncertainty of 2.7%.

With regard to the consistency over time, it is worth mentioning that information on fuel consumptions provided by ANAVE was obtained until 2002 by gathering information for each ship belonging to the ship-owners association. Since 2003, however, fuel consumptions have had to be estimated by extrapolation as a discontinuity was recorded in the previous information system. On the other hand, it is important to point out that the procedure used to estimate residual oil and diesel consumption is conducted by combining two sources and, although considered a reasonable procedure, it would be better to have a procedure to gather and compare information directly, to this end contacts are being established with the relevant agencies involved in maritime traffic.

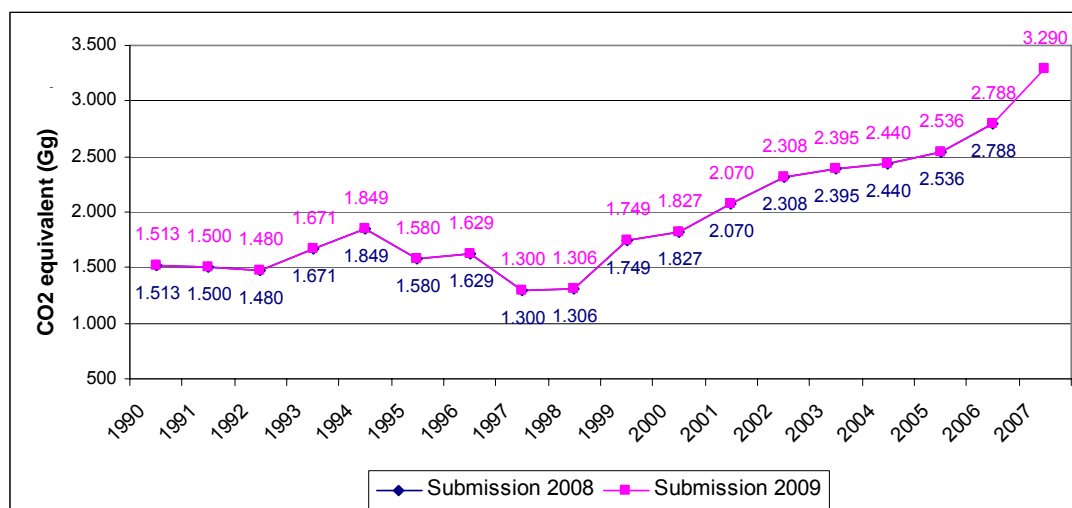
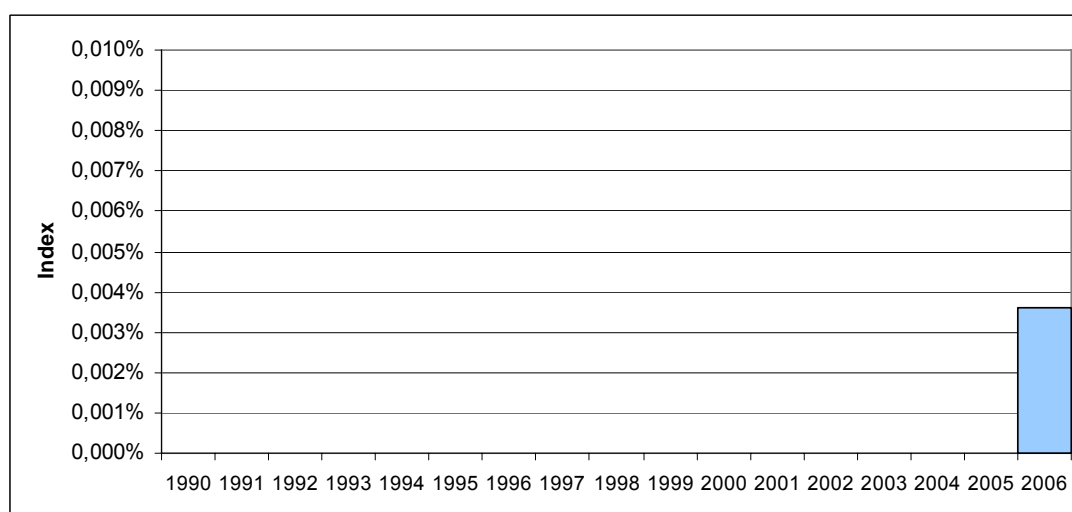
3.8.4.- Quality assurance and verification

Due to the difficulties of trying to reconcile the two sources of information mentioned above with inconsistent evolutions, the combined estimation procedure described before had to be adopted for the fuels used. Although this procedure does not strictly represent quality assurance, it is considered to produce more reasonable results than those obtained from using either of the two sources separately. For what concerns the abovementioned, priority will be given to the base data control and verification in coordination with the relevant entities involved in the maritime traffic.

3.8.5.- New calculations

The fuel consumption attributed to maritime traffic for 2006 has been changed in this edition as a result of the revision in the consulted reference source - Yearbook from the Ministry of Public Works - of the extensive variable (GRT units) for that year. The changes in the estimated figures for 2006 consumption caused an increase of 0.1 Gg (less than 0.01%) in CO₂-eq emissions for maritime traffic compared with the previous edition.

Figure 3.8.1 shows the comparative development of absolute values of the CO₂ emissions between the results of the current edition, and the results of the previous edition, while figure 3.8.2 presents the percentage difference in these emissions between both inventory editions.

Figure 3.8.1.- CO₂-eq emissions. Comparison of 2009 and 2008 editions**Figure 3.8.2.- CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions**

3.8.6.- Improvement plans

Having recognized the uncertainty currently associated with the consumption of diesel and residual oil, the putting into effect of a new collaboration project, presently at the initial stages, with the General Directorate of the Merchant Navy, the State Ports body and with ANAVE, in order to access and process information corresponding to fuel consumption in domestic sea traffic, and even corresponding to sea routes followed by this traffic.

3.9.- Combustion in other sectors (1A4)

3.9.1.- Description of the activity

Category 1A4 compiles the emissions generated from combustion in the non industrial sector, included among them, commercial, institutional, residential, as well as agriculture, forestry and fishing.

Table 3.9.1 show greenhouse emission gases by fuel type, with CO₂ (in the three major classes of fossil fuels, solids, liquids, and gases) and CH₄, (for aggregate consumption), the key sources (see heading 3.1 in this chapter). Table 3.9.2 further supplements the previous information by expressing the overall emissions in CO₂-equivalent terms. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category over the totals for the inventory and the energy sector. CO₂ emissions caused by burning biomass do not appear in these tables since, according to IPCC methodology, these must not be counted in the inventory, although they have been estimated as a Memo item and reflected as such in the CRF Reporter.¹⁸

Table 3.9.1.- Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO₂							
Liquid	21,680	23,939	27,470	27,893	27,688	25,875	24,910
Solid	2,282	1,440	536	544	552	545	553
Gases	1,319	2,982	9,098	10,019	10,839	10,378	11,283
Biomass	10,096	9,398	9,223	9,204	9,204	9,204	9,227
Total	25,281	28,360	37,104	38,456	39,079	36,798	36,747
CH₄							
Liquid	1.03	1.21	1.35	1.36	1.35	1.26	1.19
Solid	7.49	5.75	2.06	2.06	2.06	2.06	2.06
Gases	0.06	0.14	0.53	0.60	0.68	0.70	0.77
Biomass	30.44	27.75	27.30	27.30	27.30	27.30	27.30
Total	39.02	34.85	31.24	31.32	31.38	31.32	31.32
N₂O							
Liquid	0.55	0.57	0.59	0.60	0.60	0.57	0.55
Solid	0.05	0.03	0.01	0.01	0.01	0.01	0.01
Gases	0.02	0.05	0.15	0.16	0.18	0.17	0.19
Biomass	0.34	0.33	0.32	0.32	0.32	0.32	0.32
Total	0.97	0.97	1.08	1.10	1.11	1.07	1.07

Table 3.9.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	26,400	29,392	38,094	39,454	40,081	37,788	37,737
CO ₂ -eq Index	100.0	111.3	144.3	149.4	151.8	143.1	142.9
% of CO ₂ -eq over total inventory	9.16	9.21	9.29	9.26	9.09	8.73	8.53
% CO ₂ -eq on energy	12.43	12.21	12.11	11.90	11.54	11.21	10.93

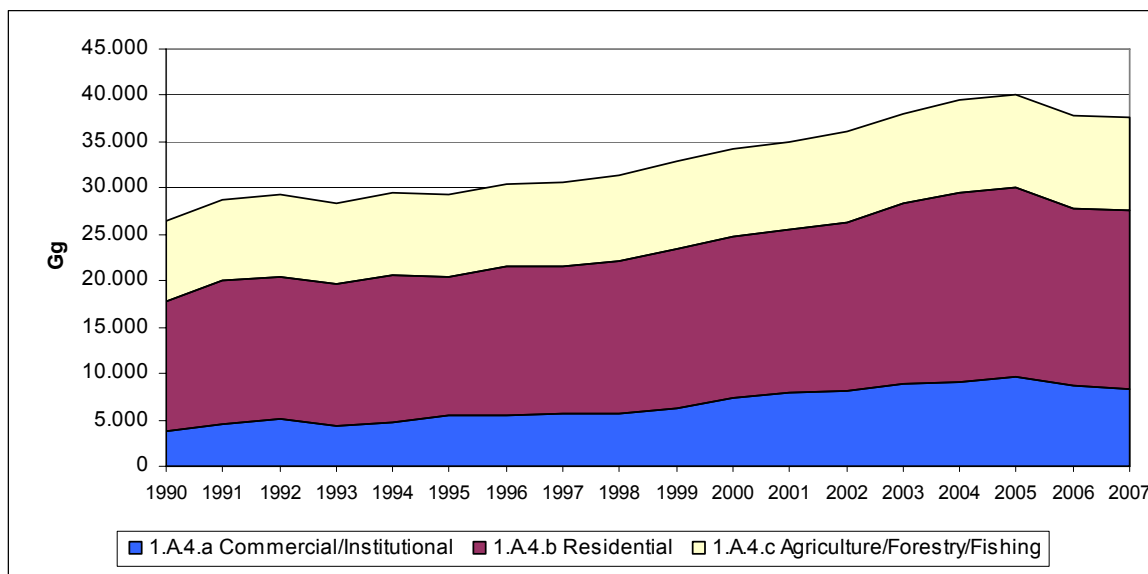
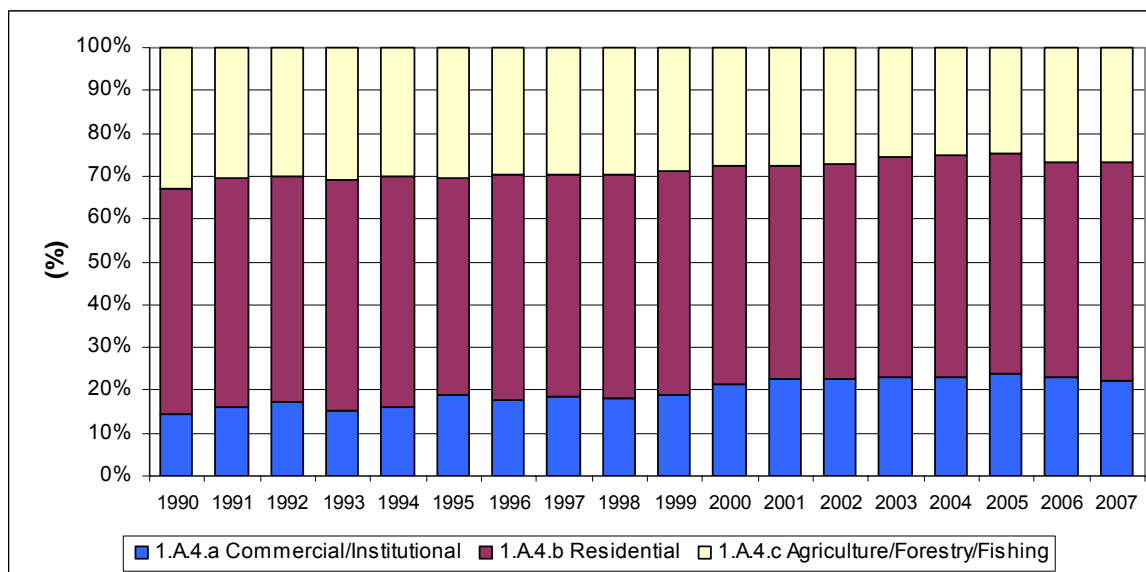
¹⁸ During the elaboration phase of this report an error in the determination of the final consumption in the commercial and institutional sector and biomass consumption in co-generation has been detected. This fault has been registered and will be corrected in the next edition of the inventory.

Table 3.9.3 illustrates the CO₂-eq emissions for each sector that makes up this category (1A4a Commercial and Institutional; 1A4b Residential; and 1A4c Agriculture, Forestry and Fishing). Similarly, the time development index (1990 as reference year) for CO₂-eq emissions, the CO₂-eq emission contribution for the total inventory, as well as the emission contributions of each sector total in category 1A4.

Table 3.9.3.- CO₂-eq Emissions per sector: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
1.A.4.a Commercial and institutional							
CO ₂ -eq (Gg)	3,787	5,513	8,801	9,166	9,613	8,776	8,305
CO ₂ -eq Index	100.0	145.6	232.4	242.0	253.8	231.7	219.3
% of CO ₂ -eq over total inventory	1.3%	1.7%	2.1%	2.2%	2.2%	2.0%	1.9%
% CO ₂ -eq of 1.A.4	14.3%	18.8%	23.1%	23.2%	24.0%	23.2%	22.1%
1.A.4.b Residential							
CO ₂ -eq (Gg)	13,961	14,916	19,497	20,340	20,503	18,931	19,255
CO ₂ -eq Index	100.0	106.8	139.7	145.7	146.9	135.6	137.9
% of CO ₂ -eq over total inventory	4.8%	4.7%	4.8%	4.8%	4.6%	4.4%	4.4%
% CO ₂ -eq of 1.A.4	52.9%	50.7%	51.2%	51.6%	51.2%	50.1%	51.2%
1.A.4.c Agriculture, forestry and fishing							
CO ₂ -eq (Gg)	8,652	8,963	9,795	9,947	9,962	10,076	10,076
CO ₂ -eq Index	100.0	103.6	113.2	115.0	115.1	116.5	116.5
% of CO ₂ -eq over total inventory	3.0%	2.8%	2.4%	2.3%	2.3%	2.3%	2.3%
% CO ₂ -eq of 1.A.4	32.8%	30.5%	25.7%	25.2%	24.9%	26.7%	26.8%

Figures 3.9.1 and 3.9.2 show the graphic representation of the previous table's information. Figure 3.9.1 presents the evolution of CO₂-eq emissions for each sector that in the category 1A4 during the inventory period; figure 3.9.2 shows the contribution of each sector total in 1A4.

Figure 3.9.1.- Evolution of CO₂-equivalent emissions**Figure 3.9.2.- Percentage of CO₂-eq emissions by category of 1.A.4 sector total**

3.9.2.- Methodology

The basic sources of information on activity variables (fuel consumption) have been:

- For the commercial, institutional and residential sectors (categories 1A4a and 1A4b), information has essentially been taken from the national fuel balance for fossil fuels while consumptions for biomass have been estimated from information provided by the IDAE.

- For the agriculture, forestry and fishing sector (category 1A4c), estimates have been taken from knowledge of activity patterns and the energy requirements associated with such activity, assuming that practically all fuel used is diesel fuel. With regard to information on sub-sector activity patterns (sea fishing, agricultural and forestry machinery), information has been gathered as follows:
 - * Sea fishing: the data contains information on the power of the fishing fleet provided by the Subdirectorate-General for the Fishing Fleet and values for parameters referring to specific average fuel consumption per work unit, number of days operation a year, hours of operation per day and frequency and duration of stays in port, which have been compared by experts from the sector.
 - * Agricultural and forestry machinery: for agricultural machinery, information has been based on that provided by the Sub-Directorate-General for Means of Agricultural Production at the Ministry of Agriculture, Fisheries and Food (MAPA) to evaluate power installed in active vehicles by type of machinery (tractors, combine harvesters or rotovators). Other parameters that play a part in the calculation of fuel consumptions are the number of effective hours/year of each type of machinery and energy requirements per standard hour of operation and per unit of rated power.

In order to estimate consumptions corresponding to forestry machinery, a similar procedure has been followed. In this case, socio-economic data relating to forestry, such as reforested surface area or the volume of wood harvested, have been selected as base information. These data have been compiled into the publication "Yearbook of Food and Agricultural Statistics" prepared by the MAPA and have been complemented by experts from the sector for years when the aforementioned publication was not available. These experts have also directly specified such data for other complementary, basic activity variables such as the length of repaired forest tracks and the surface area of firebreaks. These experts have also provided supplementary information regarding the characteristics of machinery by class of operation, such as number of units, mean installed capacity of each unit, pulling or loading performance and specific average fuel consumption, from which the total installed capacity and/or hours of operation by class of operation have been derived.

- * Finally, for stationary combustion in the agricultural sector (engines and other installations), the information considered is that appearing in the national fuel balance, with the exception of diesel, for which consumption is estimated that is in proportion to the value given for mobile agricultural machinery. The different treatment adopted for stationary combustion in agricultural irrigation engines is worth mentioning as this is based on both diesel consumption ratios per hectare of irrigation as taken from the document "Energy Saving and Efficiency Strategy – E4" for the agricultural sector¹⁹ and the irrigation surface area that appears in the "Yearbook of Food and Agricultural Statistics" by MAPA.

¹⁹ Working Document drawn up for the Energy Saving and Efficiency Strategy 2004-2012 of the Agriculture and Fisheries Sector, July 2003 edition.

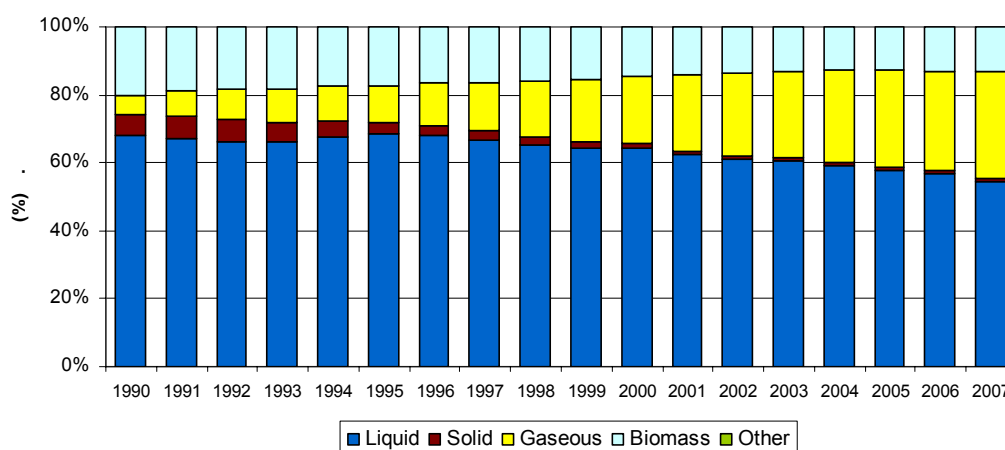
Table 3.9.4 shows estimated fuel consumptions for this key source expressed in terms of energy (lower heating value TJ_{LHV}).

Table 3.9.4.- Fuel consumption: combustion in other sectors (Amounts in TJ_{LHV})

Type	1990	1995	2003	2004	2005	2006	2007
Liquid	307,894	337,310	385,451	391,541	388,508	363,078	350,047
Gasoline	262	264	227	212	224	224	224
Kerosene	4,791	2,298	43				
Diesel	190,683	217,145	281,442	289,938	289,239	272,953	267,043
Residual oil	11,035	25,632	19,899	15,998	15,799	13,108	6,900
L.P.G.	100,576	90,859	80,573	82,391	80,420	74,019	73,088
Petroleum coke	488	520	390	390	358	358	325
Refinery gas	59	592	2,876	2,611	2,468	2,416	2,466
Solid	28,353	15,685	6,017	6,182	6,322	6,199	6,356
Hard coal	15,443	12,743	4,551	4,551	4,551	4,551	4,551
Sub-bituminous coal	924						
Patent fuels	152						
Gas works gas	11,834	2,943	1,466	1,631	1,771	1,648	1,805
Gases	23,974	53,243	162,468	178,906	193,558	185,314	201,477
Natural gas	23,974	53,243	162,468	178,906	193,558	185,314	201,477
Biomass	91,783	85,421	83,845	83,674	83,674	83,674	83,881
Wood/Wood wastes	82,455	79,191	78,672	78,672	78,672	78,672	78,672
Charcoal	8,209	4,735	4,035	4,035	4,035	4,035	4,035
Other solid biomass	1,118	859	968	968	968	968	968
Biogas	0	636	170				207
Total	452,003	491,659	637,781	660,303	672,062	638,265	641,760

Figure 3.9.3 shows the distribution of the consumption by type of fuel over the inventory period. As is seen a notable increase is produced in the consumption of natural gas, whose relative contribute went from 5.3% in 1990 to 31.4% in 2007, however, liquid fuels still predominate in the energy consumption (over 54.5% in 2007).²⁰

Figure 3.9.3.- Fuel consumption distribution, based on TJ_{LHV}



²⁰ this participation of the liquid fuels, the consumption of the fisheries activities and of the mobile agricultural and forestry machinery is being computed.

For the CO₂ emission estimation, default emission factors have been applied from the standard fuel characteristics. In terms of estimating CH₄ and N₂O emissions, factors selected from different methodological guidelines (EMEP/CORINAIR, IPCC) and sectoral and institutional sources (API, CITEPA) are applied to the activity variable energy (GJ) in terms of LHV. This same procedure has been followed for the estimation of the other pollutants mentioned in the CRF (SO₂, NO_x, NMVOC, and CO).

Tables 3.9.5 to 3.9.9 show, by type of installation, the emission factors used to estimate emissions.

Table 3.9.5.- Emission factors. Boilers

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	3.5	0.7
Residual oil	76	7	1.5
L.P.G.	65	1.5	2.5
Petroleum coke	98.3	225	2.5
Refinery gas	55	2.5	1.5
Hard coal	101	450	1.4
Sub-bituminous coal	99.42	450	1.4
Patent fuels	101	450	3
Gas works gas	52	5	2.5
Natural gas	55-56 (1)	2.5	0.9
Wood/Wood wastes	110	320	4
Charcoal	110	450	1
Agricultural wastes	110	320	4
Biogas	112	2.5	1.75

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10, and Chapter 111, Tables 27, 29 and 30
1996 IPCC Reference Manual, Table 1-1, for CO₂ from biomass

IPCC Reference Manual (Table 1-8) for N₂O from pit-coal and anthracite, black lignite, wood and wood waste, charcoal and agricultural waste.

CITEPA, for N₂O from petroleum coke, LPG, gas works gas (in this case assimilated to other gaseous fuels) and biogas.

API Compendium for N₂O from residual oil, gas oil and natural gas ("Uncontrolled boilers and heaters")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.9.5.- Emission factors. Gas turbines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Diesel	73	4	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	4	1.3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10.

CITEPA, for N₂O in residual oil.

API Compendium for N₂O from gas oil (assimilated to the stationary engine emission factor) and natural gas ("Table C1 – Uncontrolled turbines")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.9.7.- Emission factors. Stationary engines

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
Kerosene	73	4	2
Diesel	73	1.5	1.85
Residual oil	76	3	1.75
Natural gas	55-56 (1)	50	1.3

Source: EMEP/CORINAIR Guidebook. Part B. Chapter 112, Tables 7, 9 and 10.

CITEPA, for N₂O in residual oil.

API Compendium for N₂O from gas oil (Table C1. *Large Bore Diesel Engine*) and natural gas ("Table C1. 4 Cycle – Lean Burn")

(1) 1990 and 1991, 55 kg CO₂/GJ; 1992 and thereafter: 56 kg CO₂/GJ.

Table 3.9.8.- Emission factors. Agricultural and forestry machinery

	CO ₂ (t/t)	CH ₄ (kg/t)	N ₂ O (kg/t)
Gasoline	3.183	6.170	0.0781
Diesel	3.138	0.170	0.0864

Source: CO₂: EMEP/CORINAIR Guidebook. Part B. Chapter 810, equation (2).

CH₄: EMEP/CORINAIR Guidebook. Part B. Chapter 810, Tables 8.1 and 8.2.

N₂O: CORINAIR Manual, part 9, for diesel (2 g/GJ is indicated with a LHV of 43.2 GJ/t); for petrol, the emission factor has been assimilated to the implicit factor for road traffic in 1990 (1.76 g/GJ, with an LHV of 44.37 GJ/t)

Table 3.9.9.- Emission factors. Sea fishing

	CO ₂ (t/t)	CH ₄ (kg/t)	N ₂ O (kg/t)
Diesel	3.138	0.095	0.080

Source: CO₂: EMEP/CORINAIR Guidebook. Part B. Chapter 810, equation (2).

CH₄: "Marine Exhaust Emissions Research Programme" Study, assuming a methane content of 5% for VOC.

N₂O: EMEP/CORINAIR Guidebook (August 2002 edition). Part B, Chapter 842, Table 8.2

3.9.3.- Uncertainty and consistency over time

Regarding the activity variable (fuel consumption), the access to information tends to be heterogeneous insofar as the different fuel types, with limited analysis in the case of carbons and petroleum products and with greater completeness and reliability in relation to natural gas.

For carbon and petroleum product consumption, the information base provided by coal storage and importers statistics and from data provided by the operators and distributors of petroleum products, is complemented by the inventory working team by energy requirement estimates by cross-tab with type of facility (stationary combustion in commercial-institutional, residential, agriculture, forestry and fishing). In the case of carbons, the estimation procedure also includes an evaluation of the evolution of combustibles combined for each sub-sector. In conclusion, and looking at the classification provided in the 2006 IPCC Guidance (Table 2.15), it is considered that the estimated consumption of these two fuel classes is derived from a "less developed system" intersected by "extrapolation"; in this regard, an uncertainty coefficient of 20% has been applied to carbons and 15% for petroleum products, mean value and lower limit, respectively, of the range proposed in the Guidance for this recovery system (range: 15%-25%).

As far as natural gas consumption, the information compiled by sectoral segments and by quantity with respect to rate class is used; it is considered a practically complete "well

developed statistical system”, although a certain lack of clarity in the combination of the consumption attributable to co-generated electricity and the rest of sectoral activity consumption does exist. That is why the uncertainty coefficient of 5% maximum limit of the range reflected in the 2006 IPCC Guidance for this type of system cross-tabbed with *survey* (range: 3-5%).

The uncertainty in fossil fuel consumption, expressed in energy for this category is estimated at 10%, considering a weighted mean of the value proposed for fossil fuels consumed in the category (25% for solids, 15% for liquids, and 5% for gases.) With reference to the biomass, the inaccuracy of the activity variable sources leads to an uncertainty estimate of 100% according to the information presented in Table 2.15 of the 2006 IPCC Guidance for the cross-tab "less developed statistical system" with "extrapolation".

The uncertainty associated with the CO₂ factors is a result of the estimated coefficients for carbon content and for the carbon oxidation fraction to CO₂. Likewise, the uncertainties in the emission factors for carbon are 15.1%, from 15% in carbon content to 1.5% for the oxidation factor. For liquid fuels, with diesel predominating the category, the coefficient is quantified from 2.2%, as a result of taking the 2% carbon content value and 1% oxidation value. Finally, natural gas has been assigned a 1.4% uncertainty for carbon content, a figure deducted from the molar composition provided by the main gas company, and a 0.5% uncertainty oxidation factor, as a result of said combination with a 1.5% coefficient in the emission factor.

The CH₄ uncertainty emission factor is estimated at 100%, using the proposed range (-50% to 150%) from Table 2.12 of the 2006 IPCC Guidance as reference.

Although the consumption data for stationary combustion as far as temporal consistency is concerned is provided by the energy balances published in the IEA and EUROSTAT, complemented with national statistics about production and consumptions in co-generation provided by the Energy Saving and Diversification Institute (IDAE) the erratic pattern shown in the energy balances series, has not always been adequately explained (this erratic pattern is not reflected in the activity variable associated with mobile machinery, determined with assistance with activity patterns (see section 3.9.2). With the aim to minimize non justified discrepancies between the fuel consumption trends and the evolution of the determining socioeconomic variables in each sub-sector, all the series of consumed energy, total and by fuel type, related to each sector have been revised by checking the figures from the balances.

3.9.4.- Quality assurance and verification

Quality assurance and verification applied in this category to agricultural / forestry and maritime fishing machinery, are based on activity rates (annual hours of operation); for the algorithm estimation parameters for consumption (coefficients from registered fleets to fleets in effect and consumption ratios specific (per (g/HPh) by expert judgements, and in general without comparative statistics.

For the remainder of the activities (stationary combustion), the activity variables have been derived from energetic balances and from supplementary statistical information for the sectors for irrigation motors and co-generation in the services sub-sector. As already stated in the previous section, for what concerns the final consumption non assigned to power

generation, the energy consumption series have been analyzed by sub-sector, assessing its affinity with the trend of their representative socioeconomic variables.

3.9.5.- New calculations update

The main variations carried out in this category on the present edition versus the previous edition are described below.

Stationary combustion in the institutional-commercial sector. The revision of the time-series consistency of the 1990-2007 series of published consumptions in the balances has led to modifications of the figures related to the final consumptions assigned to this sector in the previous inventory edition.

Another modification in the consumption series has been the consequence of a revision of the estimate of fuels used in the co-generation. In the last edition, the information about the national co-generation statistic related to the consumption assignable to power production was combined with the final consumption figures published on the national balance sheet. While on the actual edition, the national co-generation statistic has been adopted as unique source of information for what concerns co-generation (total consumption in co-generation, assignable to power as well as heat), where the rest of the final consumption is estimated by deducting the section assigned to the unsold heat generation. This change has led to upward variations in those fuels that, even if they are being reported in the statistic, do not appear considered in the national balance sheets within the sector²¹ final consumption.

In the stated last modification, there is a revision of the distribution of the co-generation consumption by type of non specific installation. This new division entails a pollutant emission variation which their emission levels depend, not only on the type of fuel, but also on the installation class that consume it, as the methane and the nitrous oxide.

- Stationary combustion in the agricultural sector: The type of diesel fuel consumed by this sector has been revised and therefore certain characteristics of the fuel as the heating value. Estimated the consumption in fixed installations, excluding the irrigation engines, proportionally to the mass of fuel assigned to the mobile agricultural machinery, a variation of its heating value propagates to the diesel fuel energy consumption in the stated installations, activity variable taken into consideration in the emissions calculations, and therefore, to the emissions for the whole period 1990-2007.

Irrigation engines: The estimated diesel fuel for 2006 has been revised as the base information (irrigation surfaces) related to that year is available in the MAPA's Food and Agriculture Statistics 2007 Yearbook, that was published during the process of this inventory edition.

²¹ As was already explained in Heading 3.9.1 (see footnote 18), during the elaboration phase of this report, an error in the fuel consumption estimate in this sector was detected for years 1990-2007, whose amount varies in percentage terms between -3% and 2% with regard to total energy sectoral consumption, and consequently of a similar level for the associated CO₂-eq emissions.

- Agricultural machinery: It has been corrected a transcription error in the 2005 estimates that reproduces in the non for cereal crops harvesters calculation procedures, the power figures related to 2004.
- Mobile forestry machinery It has been modified the fuel consumption of units devoted to felling and dragging operations of wood estimated for the years 2005 and 2006, as the base information (volume of wood harvested published in the MAPA's Food and Agriculture Statistics Yearbook) related to the year 2005 is available in this edition and propagates to the following years.

In addition, it has been revised for this activity the emission factors applied to the petrol units. While in previous editions, the petrol operated machinery devoted to forestry works was incorporated to the petrol operated industrial mobile machinery, by adopting the proposed factors of the EMEP/CORINAIR Guidebook for this machinery, in the present edition it was considered more suitable to apply the suggested factors of that source of information for the forestry activity on the base of the technical characteristics (power) of those units. This rectification affected mainly to the estimates of indirect gases (NMVOC, NO_x and CO) for all the years related to the period 1990-2006.

A comparison of the CO₂-eq emissions in this key source between this and the previous edition of the inventory is shown in terms of absolute values in figure 3.9.4 and in relative terms (percent difference) in figure 3.9.5. As can be seen in the last figure the relative variation as a result of new calculations effected on this activity is between -0.29% (year 2006) and 0.43 (year 2000).

Figure 3.9.4.- CO₂-eq emissions. Comparison of 2009 and 2008 editions

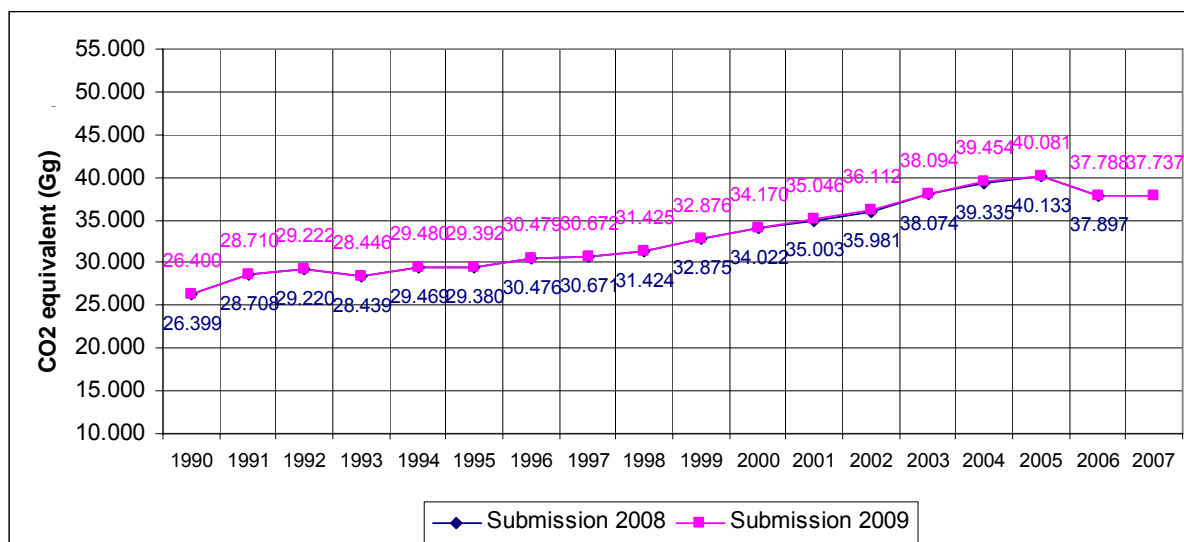
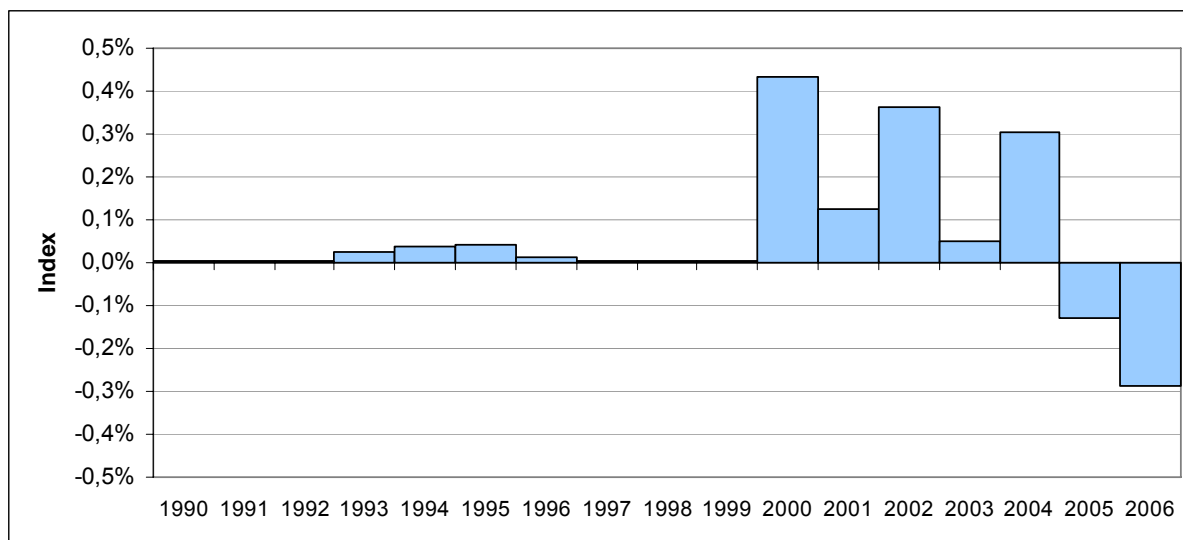


Figure 3.9.5.- CO₂-eq emissions Percentage difference of 2009 vs. 2008 editions

3.9.6.- Improvement plans

For future editions of the inventory a review will be carried out - one specially involving mobile agricultural-forestry machinery - concerning the methodology (integrating information about energy requirements standards and other relevant parameters for the estimation algorithms of emissions) in which it is considered the progressive renewal and consequent introduction of technologies destined towards the limitation of emissions in this kind of machinery, according to applied legislation. This line of work, undertaken in the present edition with the collaboration of the Directorate General for Agriculture of the Ministry of Agriculture, Fisheries and Food, that is presently under development.

3.10.- Fugitive emissions – solid fuels (1B1)

3.10.1.- Description of the activity

This category includes emissions generated in solid fuel (coal) extraction, storage and handling processes but not those emissions generated by combustion activities to generate energy to be used in those processes, even though they may use coal.

Activities identified and for which methane and/or carbon dioxide emissions have been estimated are: a) coal mining; b) pre-treatment of coal; c) coal storage; and d) coke ovens (door leakage and extinction)²².

²² Processes to transform coal into coke and solid semicoke are included among coal handling activities. This latter process is not contemplated in the list of activities as it is not performed in Spain.

Gross coal production from mining has experienced a practically linear sustained decline, going from 43,120 kt in 2006 to 20,000 kt in 2007 (a 53.6% drop in comparison to 1990). With this evolution, underground mining has experienced an even greater drop than open-cast mining and this, as will be seen later on, has had an effect on the evolution of emissions given that underground mining has relatively greater emission factors than those corresponding to open-cast mining.

As for the production of coal coke, the series reflects a general downward trend until 1999, when a partial recovery begins in the domestic production activity and it returns to levels close to those achieved in 1992. The comparison with the estimated figures for 1990 gives a reduction of 14.6% in 2006, with the value going from 3,211 kt in 1990 to 2,742 kt in 2007.

The main pollutant emitted by these activities to be highlighted, see table 3.10.1, is methane. It is this pollutant that identifies this IPCC category as a key source both due to its level of emissions until 1998 and due to its trend over the entire inventory period, 1991-2007. The other gas with direct global warming impact is carbon dioxide, whose emissions correspond to the opening of coke oven doors and the extinguishing of furnaces.

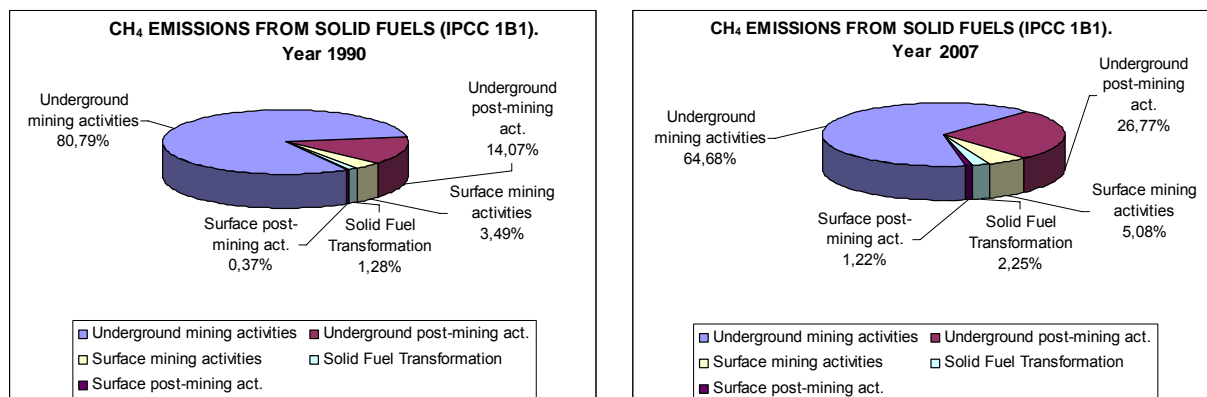
Table 3.10.1.- Emissions by pollutant (Amounts in Gigagrams of CO₂-eq)

	1990	1995	2003	2004	2005	2006	2007
CO ₂	17.63	13.38	72.03	72.80	89.91	124.94	93.53
CH ₄	1,817.54	1,469.26	1,043.15	991.62	938.87	929.69	884.27
Total CO₂-eq	1,835.17	1,482.64	1,115.18	1,064.42	1,028.78	1,054.63	977.80

Coal mining is the predominant source of CH₄. This activity is responsible for over 97,7% of this pollutant's estimations in IPCC category 1B1. Due to the mining technique used, and despite observing a gradual decline in this activity over recent years, the high contribution of emissions from underground mining during both the mining phase and the first post-mining treatment is worth highlighting (please refer to table 3.10.2 and figure 3.10.1). Thus, CH₄ emissions in this category have dropped by 51.8% in 2007 in comparison to 1990 due mainly to the same degree of decline in underground mining (53.1%). The remaining sources, except post-mining treatments in open-cast mining, which has very little impact on total emissions, also show reductions in emissions: 20.7% for open-cast mining and 14.6% for solid fuel transformation.

Table 3.10.2.- CH₄ emissions (Amounts in Gigagrams of CO₂-eq)

IPCC category	1990	1995	2003	2004	2005	2006	2007
1B1a.i Underground Mines of which	1,724.03	1,380.09	962.04	905.10	859.18	852.42	808.73
Mining Activities	1,468.32	1,135.52	717.45	664.81	625.96	619.66	571.99
Post-mining Activities	255.71	244.58	244.60	240.29	233.22	232.77	236.74
1B1a.ii Surface Mines of which	70.25	71.50	61.46	65.95	59.83	56.69	55.68
Mining Activities	63.46	63.20	51.74	54.69	48.92	47.33	44.90
Post-mining Activities	6.78	8.30	9.72	11.27	10.91	9.36	10.77
1B1b Solid Fuel Transformation	23.26	17.66	19.64	20.57	19.86	20.58	19.87
1B1 Solid Fuels	1,817.54	1,469.26	1,043.15	991.62	938.87	929.69	884.27

Figure 3.10.1.- Main CH₄ emitting activities

3.10.2.- Methodological aspects

This section focuses fundamentally on the methodology applied to estimate methane emissions as it is considered a key source in the national inventory. At the end of this section there is a sub-section dedicated to other pollutants emitted in this IPCC category with specific methodological information.

3.10.2.1.- CH₄ EMISSIONS

Each of the sources responsible for emissions as described in the previous section, i.e. mining, post-mining, coal storage and coke oven door leakage and extinction, has been dealt with individually, assigning all methane estimates obtained to IPCC category 1B1. This section covers the methodology, emission factors and activity variables applied for each source of emissions.

a) Coal production, first treatment and storage: The methodology used is specific to the country, adopting the IPCC²³ tier 2 approach. This choice of methodology aims to replace default factors associated with the Tier 1²⁴ approach with factors derived from nationally available information on methane contents per type of coal.

National information has been used for the emission factors per tonne of product, making a distinction according to the type of mining (underground or open-cast) and the type of coal (other bituminous coal, anthracite, black lignite or brown coal). The (mean) values of these factors are based on firedamp concentration measurements per tonne of coal in

²³ Please refer to 1996 IPCC Reference Manual, equation 1 (section 1.7.2.2) and equation 3 (section 1.7.2.3).

²⁴ The 1996 IPCC Reference Manual does not propose a default value for the Tier 1 approach but instead proposes a broad range for each type of mining as a function of the level of methane content.

different Spanish coal-mining basins, as gathered in a sectorial study conducted by the AITEMIN²⁵ Available information was complemented by expert opinions regarding:

- the composition of the firedamp, assuming that the gas is essentially made up of methane²⁶;
- the characterization of coals and mining techniques in each coal-mining basin analyzed in the study, at the time of assessing the representative nature of methane contents obtained;
- the completeness of the information, by establishing assumptions on methane contents in coal from open-cast mining (*in-situ gas content*) that were not explicitly identified in the reference source consulted. After examining the values given in the report and the ranges proposed by IPCC²⁷, it has been assumed that the values of open-cast mining factors are one order of magnitude lower than their underground mining counterparts;
- emissions from adjacent strata in open-cast mining (*assumed emission factor for surrounding strata*). Experts do not consider the emissions associated with this source to be significant and therefore it is assumed valid to remove this component from the equation associated with IPCC Tier 2 approach for open-cast mining;
- the fraction of gas emitted during storage and first treatment of coal. Based on expert opinion, it has been established that 20% of the *in situ* methane content in coal from both underground mining and open-cast mining is emitted during the first treatment and storage. Given that emissions are estimated separately, a percentage of 10% has been assigned to each of the two activities mentioned.

Table 3.10.4 shows the emission factors derived from information gathered and expert opinions.

²⁵ AITEMIN (Asociación de Investigación Tecnológica de Equipos Mineros – Technological Mining Equipment Research Association), “Measurement of the concentration of stratum firedamp in different Spanish coal-mining basins”, 1989.

²⁶ In the EMEP/CORINAIR Guidebook (ed. 2005), chapter B511, section 9, a species of firedamp is reported with a methane content of between 80% and 95% (Williams 1993). According to this same source, carbon dioxide concentrations are lower than 6% and the nitrogen content does not exceed 8%.

²⁷ Ranges suggested in the 1996 IPCC Reference Manual for the Tier 1 methodology are 10-25 m³ CH₄/tonne of coal extracted for underground mining (equation 1, section 1.7.2.2) and 0.3-2 m³ CH₄/tonne for open-cast mining (equation 2, section 1.7.2.3.)

Table 3.10.4.- Mean CH₄ content and emission factors by type of coal and activity

	CH ₄ Emission factors				
	Other bituminous coal	Anthracite	Sub-bituminous coal	Brown coal	Units
EXTRACTION					
CH ₄ Content (Open-cast)	0.7	0.1	0.5	0.1	m ³ CH ₄ /t coal
EF (Open-cast)	469	67	335	67	g CH ₄ /t gross production
CH ₄ Content (Underground)	7	1	5	NA	m ³ CH ₄ /t coal
EF (Underground)	4,690	670	3,350	NA	g CH ₄ /t gross production
TREATMENT					
EF (Open-cast)	46.9	6.7	33.5	6.7	g CH ₄ /t consumed
EF (Underground)	469	67	335	NA	g CH ₄ /t consumed
STORAGE					
EF	469	67	335	6.7	g CH ₄ /t stored

The factors in the above table have been applied to estimate methane by assuming that all the gas released in mining activities is emitted, given that no information was available regarding the installation of degasification systems in underground mining or the amount of methane recovered to be used later for energy or flaring. Due to this lack of information, it has not been possible to evaluate potential emissions in abandoned mines either²⁸.

In the above table of factors (see units column), different activity variables have been noted, differentiated by the type of coal and/or mining technique, as a function of the emitting activity:

- For extraction, gross coal production has been selected. The data, available on a provincial level by class of coal and type of mining, are provided by the Subdirectorate-General for Mines at the Ministry of Industry, Tourism and Commerce.
- With regard to the first treatment of coal, *domestic supply* has been adopted as the variable in accordance with the recommendations of experts, who ensured that practically all the coal consumed is treated before its final use.

The main information sources are the energetic balances from the International Energy Agency, supplemented by the international questionnaire on carbons given in MITYC. Data collected here do not differentiate between the type of mining and the coal classification does not coincide with that determined in the emission factors as pit coal and anthracite entries are given as an aggregate until 2003. In order to then prepare the information to correct limitations in the level of breakdown provided, the following criteria were adopted: application of percentages corresponding to the gross domestic production to differentiate by type of mining, and application of the ratios obtained in the

²⁸ It is noted that the CH₄ emission factors appearing in the CRF Reporter and associated with mining correspond to factors weighted by the amounts of each type of coal extracted in each type of mining. The different behaviours they present as a function of type of activity (extraction or first treatment) and type of mining (underground or open-cast) are based on the different percentage participation of types of coals with a high methane content (pit coal and black lignite) in the coal extracted.

2004 international coal questionnaire to estimate separately the amounts of pit coal and anthracite assigned to the period 1990-2003.

- For storage, the amount in stock at the end of the year in four categories of basic locations is taken as the activity variable: coal-fired thermal power plant storage facilities, storage facilities at the minehead, iron and steel plant storage facilities and others. The information comes from the following sources: CARBUNION²⁹, Red Eléctrica Española (the Spanish Power Grid)³⁰ and national coal statistics prepared by the Ministry of Industry, Tourism and Commerce³¹. However, as none of the sources mentioned provides a breakdown by type of mining, it has been assumed that all coal is extracted using underground mining, with the exception of brown lignite, which comes from an exclusively domestic source so it is known to be extracted using open-cast mining.

b) Coke oven door leakage and extinction: The procedure suggested by the EMEP/CORINAIR Guidebook, based on coke production, has been chosen as the method to estimate methane emissions as this is suitable for calculation using the available activity information. With regard to the emission factor, the default value proposed in the EMEP/CORINAIR Guidebook (345 g CH₄/t coke)³² has been taken.

Coke production fundamentally occurs at integrated iron and steel plants³³, where associated information has been collected via questionnaires sent to plants. Data in other sectors, analyzed on an area source level, are obtained after subtracting the aggregate amount obtained via these questionnaires from the figures reflected in the coal questionnaires sent to the International Energy Agency and EUROSTAT or in national statistics, "Statistics on Coking Paste Manufacture, Coke Ovens and Blast Furnace Gas".

3.10.2.2.- CO₂ EMISSIONS

Although fugitive CO₂ emissions in category 1B1, "solid fuels", do not represent a key source for the inventory, they are mentioned here as they were dealt with using a specific, national methodology. With regard to coverage of this methodology, this has been limited in this edition of the inventory to coke oven opening and extinction activities due to a lack of information regarding potential CO₂ emissions in mining activities³⁴ See Appendix 3 for a description of methodological aspects.

²⁹ Carbunion (National federation of coal mining companies) provides global data on small amounts stored at iron and steel plants and 'Others' until 1996. From that year on, figures are replicated, assuming stability in the series. The stored coal is assumed to correspond entirely to pit coal.

³⁰ The Spanish Power Grid, in its statistics entitled "Report on the Electricity System", publishes stocks at thermal power plants by type of coal and plant.

³¹ The Ministry of Industry, Tourism and Commerce provides data on stocks at mines by type of coal.

³² EMEP/CORINAIR Guidebook (ed. 1996), chapter B146, Table 4, reference [6] (Poland, 1992).

³³ At present, there are 2 coke ovens located in the iron and steel sector in Spain.

³⁴ CO₂ in seam gas, coal fires, combustion and oxidation of coal waste and other carbonaceous materials (please refer to IPCC Good Practice Guidance, section 2.6.1.4)

3.10.3.- Uncertainty and consistency over time

The uncertainty associated with coal mining activity variables (gross production, domestic supply and coal stock) is estimated to be around 5%³⁵.

Distinction by type of coal, in the case of the breakdown between coal and anthracite in gross domestic supply, or by type of mining, in the case of coal stores or gross domestic supply, would increase the uncertainty initially assigned to aggregate activity data. These elements have been incorporated, with regard to quantifying the uncertainty, in the methane factors that, together with the ratio of established assumptions (see methodological aspects), have resulted in estimating the uncertainties associated with such factors at around 100% for open-cast mining, 50% for underground mining and also 50% for post-mining activities. When evaluating these percentages, the order of magnitude and/or ranges indicated for the Tier 2 approach in the table of uncertainties given in the IPCC Good Practice Guidance (Table 2.14, section 2.6.1.6)³⁶ have been taken into account.

To calculate the uncertainty associated with metallurgical coke production, the uncertainties of production at coke ovens located at iron and steel plants and all other coke ovens are combined. A propagated uncertainty close to that estimated for coke ovens at iron and steel plants, has been assumed as this socio-economic sector represents the main national producer of coke and the other sectors' contribution is considered to be in the minority. Experts from the sector have estimated that the uncertainty corresponding to production in the iron and steel sector could be around 2% given that the information has been reported by the companies and directly provided by the plants via questionnaire. On the other hand, the methane emission factor associated with category 1B1b is accompanied by an uncertainty of 85%, derived from the upper and lower limits of the different ranges proposed by the EMEP/CORINAIR Guidebook³⁷.

With regard to the consistency over time, it is noted that methane emission factors, at the level at which they are applied³⁸, have remained constant over the inventory period. On the other hand, to determine the activity variables associated with mining, the base information has been sought from the same reference sources and has been treated consistently over the years. As far as the activity variable for coke production is concerned, information has been

³⁵ This estimate is in keeping with the indications of the IPCC Good Practice Guidance, section 2.6.1.6, by evaluating an uncertainty to be in the range of 1-2% with the possibility of increasing to 5% or even 10% according to the activity variable chosen (saleable production) or the national mining policy (existence of unregulated mines).

³⁶ Open-cast mining: factor of 2; underground mining: range from 50 to 75%; and post-mining activities: 50%.

³⁷ EMEP/CORINAIR Guidebook (ed. 2005), chapter B146, Table 8.2 and 9. Mean methane and VOC factors and ranges have been taken from Table 8.2 for coking processes (without combustion) with the upper central value having been discarded due to its being considered anomalous. The data analyzed have been derived by applying, in the case of VOC factors, the methane content reflected in Table 9.1 corresponding to the source in question.

³⁸ In the specific case of mining, first treatment and storage, estimates are made by type of coal and type of mining.

gathered from two basic sources: a) the Coal Questionnaire sent to the International Energy Agency and EUROSTAT, and b) the Statistics on Coking Paste Manufacture, Coke Ovens and Blast Furnace Gas. On a year-to-year basis, the source considered to have data more in keeping with the iron and steel industry's requirements has been chosen.

3.10.4.- Quality assurance and verification

In this category, the main monitoring procedures performed have been based on the prior examination of the socio-economic data by analyzing evolution of the series during the inventory period.

It is worth mentioning that, for the gross coal production, it is requested that base information be broken down into provinces by type of mining and type of coal. This territorial breakdown of the base information makes it easier for anomalous values and incorrect amount calculations to be detected upon individual analysis of the provincial series and standardization of coal mining and the types of coal extracted by province.

3.10.5.- New calculations update

No new calculations have been performed on this activity) in the current edition (1990-2007) with respect to the past edition (1990-2006).

3.10.6.- Improvement plans

It was taken into consideration the introduction in the inventory of individualized information per plant of the coke ovens non located in integral iron and steel plants, this will be done with the questionnaire that these plants, submitted to the Directive on Emissions Trading regime, will provide to the Central Administration through their own autonomous communities. It is considered that this development will enable a substantial improvement in the reliability of domestic coke production data, the activity variable used for solid fuel manufacture. This approach may also improve the accuracy of iron and steel gas estimates from the fuel balance of the inventory (also see heading 3.4.6).

3.11.- Fugitive emissions – oil and natural gas (1B2)

3.11.1.- Description of the activity

This category includes emissions generated during the extraction, storage, transmission, processing or disposal of fuels derived from oil or natural gas that are not used for energy purposes. Therefore, one of the activities included, among others, is the flaring of oil or natural

gas but combustion activities destined to provide energy during the extraction or transformation³⁹ processes are not included.

The estimated emission flows for this category's activities are as follows:

- a) Evaporation and losses of organic compounds at production platforms during extraction, first treatment and loading for subsequent transmission, with a distinction being made between natural gas and crude oil.
- b) Leaks at crude oil sea terminals (this includes loading-unloading operations of tankers, handling and storage in tanks located at the terminals).
- c) Leaks in gaseous fuel supply systems, with a distinction being made between transmission and distribution networks.
- d) Losses during the processing of oil-derived products and natural gas⁴⁰, with a distinction being made by operation and type of fuel.
- e) Intentional gas emissions, for safety reasons, at processing plants and in natural gas supply systems using direct venting of gas or flaring⁴¹.

After the crude oil refining process, the resulting products contain insignificant amounts of methane and therefore emissions of this pollutant are not estimated. However, in later phases of the refining process, there are NMVOC emissions that are estimated to be those associated with oil-derived product distribution, with individualized treatment of the gasoline and storage of oil-derived products.

This IPCC category has been identified as a key source due to its level of CO₂ emissions over the period inventoried, its CO₂ emission trend in 1991 and 1993-1994 and the methane trend in 1991-1992. Another greenhouse gas emitted is N₂O, whose emission levels, significantly lower in terms of CO₂-eq, are estimated exclusively at gas flares. Table 3.11.1 shows greenhouse gas emissions by pollutant.

Table 3.11.1.- CO₂ Equivalent Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
CO ₂	1,760.36	1,902.09	1,917.79	2,180.58	2,151.79	2,279.56	2,279.56
CH ₄	631.02	817.67	689.34	829.21	906.04	618.55	618.55
N ₂ O	0.0313	0.0203	0.0695	0.0356	0.0743	0.1017	0.1017

³⁹ It is important to clarify that oil flaring refers to the productive activity of the oil industry but not flaring in the chemical industry or in the steel and iron industry since emissions from these latter two industries fall into category 2C1.

⁴⁰ Natural gas treatment processes, such as sulphur recovery, have been estimated as a whole along with losses in extraction, first treatment and loading.

⁴¹ For natural gas, available flaring information refers exclusively to regasification plants and underground storage.

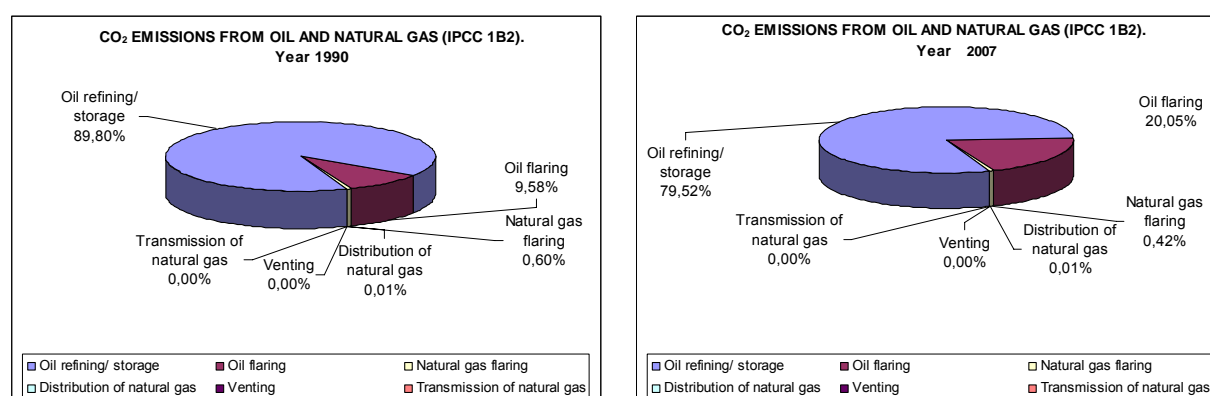
CO₂-eq	2,391.41	2,719.78	2,607.20	3,009.82	3,057.91	2,898.21	2,898.21
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The main sources of CO₂ in oil and natural gas are processes in the oil refining industry (IPCC category 1B2a.iv Refining/Storage). The fluid catalytic cracking, in spite of the declining of its emissions contribution, constitutes the main emission source, representing 60.0% in 2007 of the estimated emissions in 1B2 category. Far from these percentages other petroleum products processing⁴² can be found, with a relative participation of 19,5% in 2007, and the flaring in oil refinery plants, that significantly increase its contribution in the last year of the period reaching up to 20.5% of the emissions⁴³ Therefore, as shown in Table 3.11.2, CO₂ emissions in category 1B2 show an increase of 41.0% in 2007 in comparison to 1990 due to the observed increase in refining and product storage, estimated at 24.9%, and the great increase in flaring, which has been estimated at 183.5%, (a slight decrease of -0.3% for flaring in oil refineries and an increase of 195.1% for gas flares). Figure 3.11.1 complements this information - showing the contributions of each of the sources as a part of the total CO₂ emissions in IPCC category 1B2.

Table 3.11.2.- CO₂ emissions (Amounts in Gigagrams)

IPCC category	1990	1995	2003	2004	2005	2006	2007
1B2a.iv Oil refining/storage	1,580.79	1,710.92	1,740.41	1,969.92	1,934.03	2,018.04	1,973.98
1B2b.iii Gas transmission	0.00	0.00	0.01	0.01	0.01	0.01	0.00
1B2b.iv Gas distribution	0.21	0.01	0.25	0.29	0.20	0.27	0.17
1B2c.ii Venting gas	0.07	0.00	0.13	0.20	0.18	0.05	0.01
1B2c.i Oil flaring	168.70	184.47	153.78	198.26	192.71	227.69	497.78
1B2c.ii Gas flaring	10.58	6.69	23.21	11.89	24.66	33.49	10.55
1B2 Oil and natural gas	1,760.36	1,902.09	1,917.79	2,180.58	2,151.79	2,279.56	2,482.49

Figure 3.11.1.- Main CO₂emitting activities



⁴² The category of other petroleum products processing contains estimates of CO₂ emissions generated in coke calcination and hydrogen production.

⁴³ Pending on a future checking, the emissions increase seems to be related to a improvement of the estimating method, that was previously referred to crude oil processed and, since recently specific information on volumes and composition of the burned gases in flares is becoming available (this information improvement sets a challenge for its correct extrapolation to the past with the aim of guaranteeing full time-series consistency).

Crude oil processing at the 10 existing refineries in Spain, with practically all of the crude oil coming from foreign sources, has experienced a general upward trend, with moderate variations, going from 53,556 kt in 1990 to 61,374 kt in 2007, which represents a 14.6% increase.

It must be mentioned that the evolution of emissions at oil flares in the early period shows a high correlation with the processed crude oil series since, although their operation is for safety reasons and therefore the volume flared and emitted is related to more complex determinants, such as the type of gas, the existence of shutdown periods at the refinery or excess production, the estimation procedure applied by default takes that amount as the activity variable value (please refer to *Methodological aspects* for more details). The increased availability of specific information in the oil refining sector regarding the flares emissions has determined the evolution shown by the emissions series in the last years of the period, where it can be observed the erratic pattern specific of this activity variable

The second most important pollutant, representing approximately a third of CO₂-eq emissions estimated for this IPCC category (ranging from 18% to 32% of total emissions), is methane. Emissions of this pollutant are given as 560 Gg of CO₂-eq for 2007, which represents a decrease of 11.2% in comparison to the estimated 631 Gg for 1990. The main contributions are in the form of natural gas leakages in the distribution networks, with an estimated global methane contribution for this category of 86.3% in 2007, or venting in the transmission system, with 4.8% in 2007. The heterogeneous evolution of this latter emission source, together with the more uniform evolution (initial drop followed by a period of growth) observed in gas distribution emissions, determines the profile of the global emissions.

3.11.2.- Methodological aspects

This section focuses on explaining the methodology applied to estimate carbon dioxide and methane emissions since these are the two pollutants that make this activity category a key source.

In order to provide a preliminary vision of the emission sources, it is highlighted that the activity called "oil-derived product processing" also includes different emission sources that have been dealt with individually. For its part, natural gas supply systems are broken down by type of installation or nature of the losses. Tables 3.11.3 (oil-derived product processing) and 3.11.4 (natural gas supply) below show the list of estimated sources in these activities and their correspondence with IPCC categories.

Table 3.11.3.- Oil-derived product processing

IPCC category	Emission source ^(a)		Pollutant	
	Process Category	Description	CO ₂	CH ₄
1B2a.iv Oil Refining/Storage	Separation	Vacuum distillation		√
		Delayed coking		NE ^(c)
	Conversion	Coke calcining	√	
		Fluid catalytic cracking ^(b)	√	√ ^(d)
		Hydrotreating	√	
	Treating	Steam reforming	√	
		Hydrosulphurisation	√	

Note: For the other processing activities performed at refineries, such as atmospheric distillation or distillate sweetening, no emission factors are available although they are assumed to be very little representative.

- a) Direct process emissions
- b) Emissions in the catalyst regenerator
- c) No emission factor has been found in the literature
- d) Significant emissions if the fluid catalytic cracking unit does not have electrostatic filters (EMEP/CORINAIR Guidebook, ed. 2005, chapter B411, Table 8.1). In Spain, installations have this abatement technique.

Table 3.11.4.- Natural gas supply systems

IPCC category	Emission Source		Pollutant	
	Network Type/facility	Description	CO ₂	CH ₄
1B2b.iii Transmission	Transmission	Gas pipelines	√	√
1B2b.iv Gas distribution	Distribution	Pipelines, connections and regulating and metering stations (RMS)	√	√
1B2c.ii Venting	Transmission	Compression stations	√	√
	Transmission	Regasification plants	√	√
	Transmission	Underground stores	√	√
1B2c.ii Gas flaring	Transmission	Regasification plants	√	√
	Transmission	Underground stores	√	√

Each emission source has been analyzed individually in order to select methodological procedures by evaluating the methodology and the most appropriate emission factor in view of the availability of associated socio-economic variables and their contribution to total emissions in this category.

3.11.2.1.- CO₂ EMISSIONS

CO₂ emissions from category 1B2 have been calculated by grouping the estimations done for each potential emission source highlighted in the previous section. The methodological aspects of each estimate are described below:

a) Coke calcination: In order to estimate emissions at this emission source a carbon mass balance in coke has been applied (loss of carbon during green coke calcination). According to the classification given in the 1996 IPCC Reference Manual, section 1.5, this procedure is considered a Tier 2 methodological approach since fuel consumption, in this case for non-energy use, is identified for a sufficiently homogeneous class of installation.

With a carbon content in green coke of 91.8% and a loss of mass from green coke to calcined coke of 30%, an emission factor of 1,009.8 kg CO₂ per tonne of green coke is arrived at ($1,009.8 = (44/12) \cdot 0,918 \cdot 0,30 \cdot 1000$ where the ratio (44/12) is the factor to raise the content to carbon dioxide mass). The parameters used were taken from the publication “Oil refining, natural gas and petrochemical”^{44 45}, hereinafter referred to as “Refining”. In the factor calculation, it is assumed that the mass lost corresponds entirely to carbon.

⁴⁴ “Oil refining, natural gas and petrochemical”. Fundación Fomento Innovación Industrial (Foundation for the Promotion of Industrial Innovation). 1997.

⁴⁵ Please refer to Table 7.3 (Typical elementary composition of coke) and page 265 (“Loss of weight from coke during the calcination process reaches 28-30% of the original”) in the above publication.

Data regarding the mass of green coke processed by the coking units is provided directly by the plant as this was requested in the questionnaires sent to the refineries.

b) Catalyst regenerator in fluid catalytic cracking (FCC): Since de-activated FCC catalysts are regenerated by burning off retained coke, emissions have been estimated according to a mass balance to calculate the carbon contained in this coke⁴⁶ According to the classification given in the 1996 IPCC Reference Manual, section 1.5, this procedure is considered a Tier 2 methodological approach since fuel consumption, in this case for non-energy use, is identified for a sufficiently homogeneous class of installation.

To calculate emissions, a fixed emission factor of 3,366 kg CO₂ per tonne of coke retained in the catalyst is applied, which is derived from a mean carbon content in green coke of 91.8% ($3,366 = (44/12) \cdot 0.918 \cdot 1000$ where the ratio (44/12) is the factor used to raise the content to carbon dioxide mass). To determine the mean coke composition, Table 7.3 of the "Refining" publication has been consulted.

Data regarding the mass of coke retained in the FCC unit catalysts come directly from the plant as this information was requested in the questionnaires sent to the plants.

c) Hydrogen plants, steam reforming and sulphur recovery plants: Through questionnaires, refineries provide estimated emissions by type of installation, with these emissions being based on the fuels and process characteristics.

d) Oil refinery flares: Flares can burn a great variety of gaseous fuels such as refinery gas, purge gas, sour gas or residual gases from sulphur recovery plants. Composition and energy capacity are extremely variable characteristics depending on both the type of gas and the refinery itself, which makes it impossible to establish general default factors. Given the deficient quality of information per plant on the amounts and compositions of gases burned at flares, the Tier 1 methodological approach proposed in the 2000 IPCC Good Practice Guidance, section 2.7.1.1, was adopted by default, which was then complemented with CO₂ emission statements from the refineries themselves.

The emission factor used is 3.15 kg CO₂ per tonne of crude oil processed, derived from a mean carbon content in crude oil and a fraction of carbon emitted at flares. By taking an average value of 86%C in crude oil and 0.1% of the total carbon of crude oil⁴⁷, the factor is obtained according to the following equation: ($3,15 = (44/12) \cdot 0.86 \cdot 0.001 \cdot 1000$). In order to establish an average composition of crude oil, the reference "Refining"⁴⁸ has been consulted.

⁴⁶ Refineries do not provide information on cracking unit steam generators or gas turbines that harness the heat generated by burning residual carbon monoxide resulting from catalyst regeneration. Therefore, there are no problems related with taking these figures into account twice.

⁴⁷ Assessment of fraction of carbon emitted provided by experts from the EMEP/CORINAIR programme.

⁴⁸ "The composition of oil is extremely varied... Predominant elements are carbon (84-87% in weight).." (page 30).

Data regarding the amount of crude oil processed come directly from the plant as this was requested in the questionnaires sent to the refineries. As has already been mentioned, some refineries attach flare CO₂ emission estimates to the previous information thereby giving preference to these emissions provided as they are calculated from concrete information on both the volume of gas and the average composition of the mixture incinerated.

e) Natural gas transmission network (including gas pipelines, compression stations, underground stores and regasification plants): In order to estimate emissions through leaks and venting, a country-specific methodology is applied. With regard to flares, according to the classification given in the 1996 IPCC Reference Manual, section 1.5, the estimation procedure is considered a Tier 2 methodological approach 2 since fuel consumption, in this case for non-energy use, is specified for a sufficiently homogeneous class of installation.

The information compiled from the questionnaires of the companies consulted regarding the different network installation, includes annual volumes of natural gas emitted and incinerated quantities per facility (compression stations, underground stores and regasification plants) and natural gas losses on an aggregate basis for gas pipelines.⁴⁹

Estimates made by companies of the natural gas emitted at plants are based on records of the number of ventings and the volume of gas emitted at each venting according to the capacity of the installations and/or collectors that are affected in the venting process, or if this information is not available, based on flow and frequency data for the venting cycle. With regard to gas pipelines, information on leaks comes directly from the companies. The completeness of the available series of natural gas emissions by type of identified installation and/or plant has been ensured for the first years of the inventory period by estimating data not available through regression procedures or integration ratios.

Information requested by questionnaire is complemented with a mean annual molar composition of the natural gas transmitted, allowing a mean annual CO₂ content and a total carbon content of natural gas to be estimated for each company. Table 3.11.5 below shows the contents obtained.

Table 3.11.5.- Estimation of mean CO₂ and carbon contents in natural gas (% by mass)

Year	CO ₂	C (total)
1990	0.90%	74.05%
1991	0.90%	74.05%
1992	0.75%	74.28%
1993	0.38%	74.84%
1994	0.08%	75.23%
1995	0.03%	75.13%
1996	0.11%	74.51%
1997	0.24%	73.66%
1998	0.27%	72.45%
1999	0.32%	72.40%

⁴⁹ In 2006, those installations covered are: 5 regasification plants, 8 compression stations and 2 underground stores.

2000	1.03%	74.23%
2001	1.10%	74.37%
2002	1.10%	74.50%
2003	1.00%	74.48%
2004	1.11%	74.42%
2005	0.78%	75.01%
2006	1.02%	74.66%
2007	0.62%	74.73%

Note: Preparation based on the mean annual chemical characteristics provided by the main transport company.

CO₂ emissions generated at natural gas ventings or leaks have been calculated by applying the CO₂ content corresponding to the volume of gas declared by each company. This estimation procedure differs from the previous procedure with regard to emissions at flares since, as natural gas combustion occurs in this case, it is considered that 99.5%, IPCC's oxidation fraction by default, of the total carbon contained in the natural gas is oxidized (i.e. emission factor $CO_2 = (44/12) \cdot (\%C \text{ total}/100) \cdot 0.995$).⁵⁰

It is noted that, in the CRF Reporter, the total amount of natural gas supplied⁵¹ has been taken as a socio-economic variable for category 1B2B3 (Natural gas transmission) due to consistency with the variable requested for natural gas distribution (1B2B4), namely the amount of gas consumed. However, in order to estimate emissions, natural gas losses have been used instead. By calculating the ratio between both variables, losses and gas supplied, a series with a global, non-uniform, downward trend is obtained, presenting moments of sustained increase followed by intervals of decline. This uneven evolution over the series of losses, in absolute or percentage values, is clearly marked by the recorded variability in regasification plant ventings, the main emission source in the natural gas transmission network⁵².

f) Gas distribution network (including pipes, connections and regulating and metering stations, RMS): To estimate emissions for these activities, a country-specific methodology is applied. In effecting the calculation procedure, regard has been taken for the studies undertaken by the main natural gas distribution company in order to verify the

⁵⁰ The companies managing regasification plants have provided specific information at the company level for the mean annual compositions of natural gas acquired, and this has been applied to the respective volumes of natural gas declared. The characteristics given by the main transport company have been included as a default.

⁵¹ The amount of natural gas supplied is calculated by adding together the amounts consumed for energy purposes (consumption estimated in IPCC category 1A), non-energy purposes (as used in the petrochemical industry) and losses during natural gas transmission and distribution.

⁵² Regasification plant ventings have contributed between 71.4% and 97.4% of the natural gas emitted in the national transmission system during the 1990-2006 period. For 2007, the venting volume in these plants shows a significant decrease that consequently affect in its relative participation that drops down to 32.1%.

emission factors proposed in their internal emissions control procedure⁵³ for mains connections, regulation and metering stations and pipelines, in this latter case differentiated by pipe material and pressure. The reports provided by the said company provide both a comparative analysis with bibliographical factors as well as the empirical results obtained in a field study⁵⁴ specifically designed in the research area of the distribution company in view of the repercussion of the emission source. The procedure for the empirical determination focused on the emission factor for natural gas in the distribution network between 0.4 and 4 bars (medium pressure B) using polyethylene pipes, in view of their high contribution to the total emissions of natural gas and the differences detected between the factor originally proposed in their control procedure and those suggested in the literature for this pressure and material.

The procedure contemplated in this edition considers all natural gas emitted throughout the entire transmission system (pipes, connections and RMS) by type of pipe material and operating pressure. To calculate CO₂ emissions, the mean annual natural gas composition provided by the main national transmission company (please refer to the previous paragraph) has been applied.

Table 3.11.6 shows the emission factors, differentiated by combination of pipe material and operating pressure of the main distribution line, used to estimate all natural gas emissions on the main distribution line, connections and RMS. The connections and RMS have been included in the emission factor by assuming appropriate percentages of gas emissions for distribution lines: 55% for connections⁵⁵ and 2% for RMS⁵⁶.

⁵³ "Assessment of leaks from natural gas distribution networks. Proposed amendments to procedure PGM-087-E Rev.2") (AMF-LITEC 05/T/5), 2005 and "Assessment of leaks from natural gas distribution networks. Determination of the emission factor for Medium Pressure B Polyethylene lines") (AMF-LITEC 05/T/8), 2005.

⁵⁴ Sample of measurements from 21 regulation and metering stations applying the pressure variation method for the determination of leaks (AMF-LITEC 05/T/8).

⁵⁵ Range considered in Eurogas-Marcogaz for connections: 20-90% of distribution line leaks ("Joint Group Environment, Health and Safety. Working Group on Methane. Emissions Methodology for estimation of methane emissions in the gas industry. Final working group report. 2003").

⁵⁶ The lack of accurate information to estimate RMS leaks in this edition has been made up for by assuming the ratio observed between volumes of gas leaks from pipes and RMS estimated using the methodology applied in the 2005 edition.

Table 3.11.6.- Natural gas emission factors by type of pipe ($m^3 N/km$ of network)⁽¹⁾

Materials	Operating pressure (*)			
	HPA	MPB	MPA	LP
Steel	1.20	3.90	1.00	0.80
PVC		15.50	7.80	4.70
Fibrocement		37.20	9.30	7.80
Ductile cast iron		10.10	2.60	2.30
Grey cast iron		10.10	9.30	7.80
Bituminized plate		37.20	14.00	12.40
Lead				7.80
Polyethylene	1.00	0.50	0.30	0.30

(1) Length of network mid year.

(*) HPA (High Pressure A): between 4 and 16 bar; MPB (Medium Pressure B): between 0.4 and 4 bar (in practice, generally 4 bar); MPA: between 0.05 and 0.4 bar (in practice between 100 and 150 mbar); LP (Low Pressure): below 50 mbar.

The length of the distribution networks by type of pipe (material * working pressure) corresponding to the end of each year is provided by the Spanish Gas Association, SEDIGAS. By estimating a uniform evolution of the variable, the length mid year is calculated by taking the average lengths by type of pipe at the end of the corresponding year and the previous year.

Three periods can be seen in the series of natural gas emissions associated with the distribution system: from 1990 to 1992 and from 2001 to 2007 with an increase in emissions due to the development in gas infrastructures; and from 1992 to 2001 with a drop in emissions due to the replacement of pipes with higher emission potential (fibrocement, grey cast iron or bituminized plate), which counteracts network growth. Measures implemented to improve the distribution system and reduce natural gas leaks have included the progressive elimination of pipes made from materials with high levels of leakage from 1992 and installation of polyethylene pipes with a lesser emission potential. As a result of these actions, ratios of natural gas leaks per unit of network length or unit of distributed gas volume show an increase until 1992 followed by a downward trend as of that date.

Other gaseous fuels distributed by pipe are liquefied petroleum gases, propane-air and, until 1999, manufactured naphtha and coal gas. Given the chemical composition of these fuels, it has been considered that leaks of these fuels are only sources of NMVOC emissions.

It is noted that the socio-economic variable requested in the CRF Reporter is the consumed energy of gaseous fuels⁵⁷, while natural gas losses have been considered to estimate the emissions, based on data from the national pipeline grid. On observing both the absolute values and ratios of natural gas emitted to the total supplied, an increase can be seen until 1992 due to the significant increase in kilometres of low-pressure, fibre cement and grey cast iron pipelines. In later years, pipes are progressively replaced with networks

⁵⁷ The socio-economic datum indicated in the CRF corresponds to energy distributed for final consumption, whether as energy or otherwise, through pipes for LPG, propane-air and gas works gas, together with total natural gas energy distributed (calculated from the consumption in the transformation sector, final consumption and estimated losses).

producing fewer emissions, counteracting the general increase in length of the national grid, implying a fall in its own emissions in the first years of this period and during these years a continuous dropdown in the ratios of natural gas emitted.

3.11.2.2.- CH₄ EMISSIONS

CH₄ emissions from IPCC category 1B2 have been calculated by grouping the estimations done for each potential emission source highlighted in the previous section. Their estimation methodologies are described below:

a) Extraction, first treatment and loading of liquid and gaseous fuels: The determining criterion in the choice of estimation method, for both liquid and gaseous fuels, has been the availability of information on the socio-economic variables, which has led to the adoption, in both cases, of the simple methodology given in the EMEP/CORINAIR Guidebook⁵⁸.

The reference for methane emission factors is the CORINAIR Manual⁵⁹, which was the source of VOC⁶⁰ emission factors and their speciation coefficients between CH₄ and NMVOC⁶¹.

The activity variable for both types of fuel is the amount extracted domestically, a figure taken from national statistics prepared by the MICYT, "Statistics on Hydrocarbon Exploration and Production".

b) Sea terminals: Identical comment with regards to methodology and emission factor.

The total amount of crude oil acquired (imported) by refineries has been taken as the activity variable. The main reference sources used are the international oil-derived product questionnaires sent to international bodies, IEA and EUROSTAT.

c) Vacuum distillation: The EMEP/CORINAIR Guidebook develops a specific methodology for this emission activity, a detailed method⁶² whose information requirements are adapted to the data made available by the refineries themselves.

The emission factors used, with a distinction being made as to whether monitoring techniques are in place or not, come from the EMEP/CORINAIR Guidebook⁶³, which gives

⁵⁸ Please refer to chapter B521, chapter 4, of the aforementioned document (ed. 2005)

⁵⁹ CORINAIR Manual (1992). "Default Emission Factors Handbook". Second edition. CITEPA, part 6, sections 5.2 and 5.3, referring to VOC.

⁶⁰ The VOC factor for natural gas includes emissions due to desulphurization.

⁶¹ Part 1, Table 4.7 of the CORINAIR Manual.

⁶² Please refer to chapter B411, section 5, of the said document (ed. 2005).

⁶³ THC factor with no abatement techniques = 0.144 kg/m³ vacuum feed; THC emissions at controlled installations are insignificant (Guidebook EMEP/CORINAIR, ed, 2005, chapter B411, Table 8.1).

THC (total hydrocarbon) factors in terms of volume of vacuum feed (m^3 feed). To determine the methane emission factor, a speciation of 1% of CH_4 in THC emissions has been assumed. Likewise, since the socio-economic base datum is the mass of feed, the emission factor has been expressed in the same magnitude, applying a mean density of 0.885 kg/l. Thus, the factor obtained for uncontrolled installations is $1.6 \text{ g/tonne of vacuum feed}$ ($1.6 = 0.144 \cdot 1000 \cdot 0.001 \cdot 0.885$) and for controlled units is considered insignificant.

Data regarding the mass of feed in vacuum distillation units come directly from the plant as this was requested in the questionnaires sent to the refineries.

d) Flaring at refineries: The limited information on flared volumes and characterization of the gases consumed has been a determining factor in the choice of estimation procedure. Therefore, the Tier 1 methodological approach indicated in the IPCC Good Practice Guidance, section 2.7.1.1, has been adopted, taking the amount of processed crude oil as the activity variable.

The emission factor used, of 2 g/m^3 refinery feed, comes from that proposed for THC in the EMEP/CORINAIR Guidebook⁶⁴, originally expressed as volume of crude oil, based on assumptions of equivalence between THC and VOC, a speciation of 20% of methane in organic compounds emitted, and the percentage given in the EMEP/CORINAIR methodological guide⁶⁵. To convert this to mass of crude oil, the density given in the publication "Refining"⁶⁶ of 0.883 kg/litre of crude oil has been used.

Data regarding the mass of crude oil processed come directly from the plant as this was requested in the questionnaires sent to the refineries.

e) Flaring at regasification plants and underground store of natural gas: The calculation procedure used has been based on the simplified methodology described in the EMEP/CORINAIR Guidebook⁶⁷, consisting in applying a default factor to the volume of gas flared.

The emission factor chosen, $211 \text{ g/thousand m}^3\text{N}$, has been calculated from the factor recommended in the EMEP/CORINAIR Guidebook⁶⁸ ($0.2 \text{ g/m}^3\text{S}$) and a conversion factor from standard to normal m^3 of 288/273 (15°C for the standard temperature).

The volume, or mass, of gas burnt in flares is a direct datum from the companies included in the natural gas transport sector, information provided at the plant level via a questionnaire.⁶⁹

⁶⁴ Please refer to chapter B923, section 8, table 2, of the said document (1996 edition).

⁶⁵ U.S. EPA Chief.

⁶⁶ Value indicated on page 670 of the said document.

⁶⁷ Please refer to chapter B926, section 4, of the said document (1996 edition)

⁶⁸ Please refer to chapter B926, section 8, of the said document (ed. 2005). The emission factor has been selected from the report published by the Norwegian oil industry association (research programme, OLF, 1993), by recommendation of the methodological guidelines.

f) Natural gas transmission and distribution network (excluding flaring): Please refer to the respective sections corresponding to CO₂ emissions.

3.11.3.- Uncertainty and consistency over time

The variety of emission activities covered by this category and the consistency in the magnitude of their associated uncertainties is worthy of mention. On a global level, the uncertainty assigned to the activity variables is estimated to be 10% for activities related to petroleum products and 30% for those related to natural gas. Activity data for oil-derived products incorporate an uncertainty due fundamentally to the identification of the successive phases followed in production, transportation and distribution. With regard to natural gas, gas emissions estimated from monitoring the installations or from applying factors show a presumably higher uncertainty due to the methodology or emission factors applied in the estimation.

On the other hand, the global uncertainty of the methane factor is estimated to be 5%, influenced primarily by the margins of error of the natural gas composition⁷⁰ for carbon dioxide, the uncertainty in its emission factor can be globally considered to be around 25%.

With regard to the consistency of the series over time, it is noted that emission factors for methane and carbon dioxide through leaks and natural gas ventings, or burning of carbon dioxide at gas flares, are estimated from the mean annual composition of the natural gas provided by the gas transmission companies. The implicit factors for other emission sources reflect the specific characteristics of each plant, in the case of emissions declared by the refineries, or else they have remained constant over the entire inventory period. On the other hand, in order to determine the activity variables, base information has been taken from the same reference sources and has been treated in a consistent manner for the entire series. In the specific case of flaring in the oil refinery plants, it must be pointed out the improvement in the estimate originated by the availability of specific information about volumes and composition of gases burned in flares.

With regard to the completeness of the inventory, it is commented that carbon dioxide and methane estimates in this category contemplate the main emission sources. It is assumed that other sources not covered here are not relevant to total emissions in this category for the aforementioned pollutants. The reasons for this exclusion could be: a) they are not mentioned in methodological guidelines as potential sources, such as, for example, fugitive emissions at refineries not associated with processes, storage and distribution of oil-derived products; b) no factor has been found in literature, as is true of certain crude oil processes (atmospheric distillation or distillate sweetening); c) there is a lack of socio-economic variables, such as

⁶⁹ For the conversion of the volume quantities of incinerated gas expressed originally in terms of mass, the annual mean densities specific to each plant has been applied, with a default to the value allocated by the main transport company.

⁷⁰ The methane factor associated with the distribution of natural gas, principal source emitter of this IPCC category 1B2 pollutant, is based on the content of the natural gas component, according to the composition provided by the main natural gas distribution company.

fugitive emissions due to exploration⁷¹ or venting in the RMS associated to the transport network.

3.11.4.- Quality assurance and verification

Contacts have been made with the main natural gas distribution company in order to verify the emission factor for natural gas in distribution lines. The analysis will also take into account the comparative examination with the situation in other countries. From these verifications and analyses, estimates are derived for the degree of uncertainty associated with the activity variable.

3.11.5.- New calculations update

This section describes the main variations presented in the new edition of the inventory for 1990-2006 in comparison to the previous edition.

- Revision of the activity data in calcinations units, refining process belonging to 1B2aiv sub category. After comparing the available series of feed in the coke calcining unit of an oil refinery with the updated information regarding the period 1990-2001, the data related to years 1990, 1994, 1995 and 1999 has been rectified. The modification of the activity variable goes to the CO₂ estimates for those years, showing an absolute value difference (and variation related to the total CO₂-eq of the 1B2 category) of: 16.6 Gg (0.7%) during 1990; -8.0 Gg (-0.3%) during 1994; -1.4 Gg (-0.1%) during 1995; -6.6 Gg (-0.2%) during 1996 and, during 1999, 106.1 Gg (-4.0%) compared with the estimates of the previous edition.
- Revision of gas natural losses in the distribution network (subcategory 1B2ii Distribution) estimated for 2006. In the actual edition the information related to the gas network structure has been combined with the information about the effective distribution of natural gas, excluding from the calculation those autonomous communities that, although they have a laid distribution network, there is no evidence that they have in place an effective systematic distribution of natural gas in that network. This modification involves a 1.1% reduction in the data applied for 2006 related to the previous edition and, in terms of CO₂-eq, an emission reduction of 5.3 Gg (-0.2 of total CO₂-eq in 1B2 category).
- It has been rectified the data used for 2006 about the oil flares (1B2ci subcategory, Flares). It has been corrected the figure of processed crude in a refinery allocated in 2006 that by mistake, has been duplicated from the previous year. This modification regards the methane emissions, that experience, in CO₂-eq terms, a 0.002 Gg reduction

⁷¹ In this edition, following the recommendations of the UNFCCC Secretariat review team with reference to the inventory prepared in the previous edition, an analysis of the emitting processes of exploration and production activities associated emissions in oil and gas fields has been tackled by means of consultations with the fields operators. Up-to-date information about one operator has been received that is pending to be incorporated into the inventory until the completeness of the requested information for the estimate of the whole sector will be reached.

(lower than -0.001% of total $\text{CO}_2\text{-eq}$ of the 1B2 category) with respect to what has been estimated in the previous edition.

- Modification of the incinerated gas volume (subcategory 1B2cii Flares) referred to the years 1999, 2001 and 2006. It must be pointed out the revision tackled for 2006 as a result of a substantial rectification from the management company itself about the figure of incinerated gas by a regasification plant. This correction, that has lead to an increment of 53.7% in the activity data on flares for 2006, represents, in terms of $\text{CO}_2\text{-eq}$, an increase of 12.1 Gg (0.4% of the estimated emissions for the whole 1B2 category).

For the years 1999 and 2001 minor changes have been carried out (lower to $\pm 0.01\%$) in the quantities of incinerated gas following the detection of transcription errors occurred in previous editions. The update of these figures does not contribute to a significant variation in the estimated emissions, absolute or relative terms (0.002% for 1999 and -0.01% for 2001) with regard to the previous edition.

Figures 3.11.2 and 3.11.3 show the impact of all the aforementioned modifications on $\text{CO}_2\text{-eq}$ equivalent in absolute and percentage terms.

Figure 3.11.2.- $\text{CO}_2\text{-eq}$ emissions. Comparison of 2009 and 2008 editions

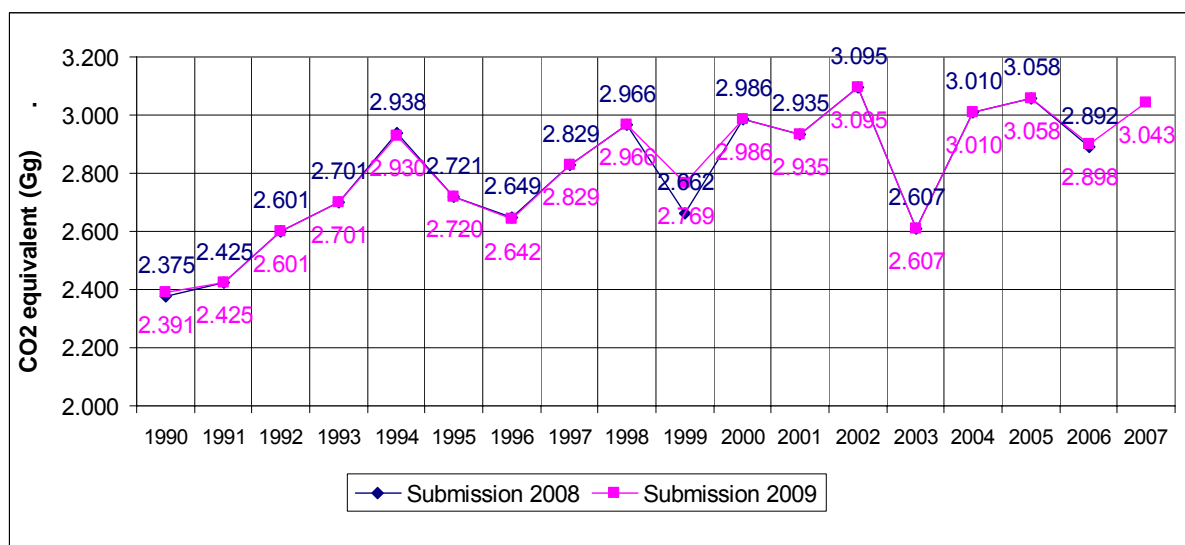
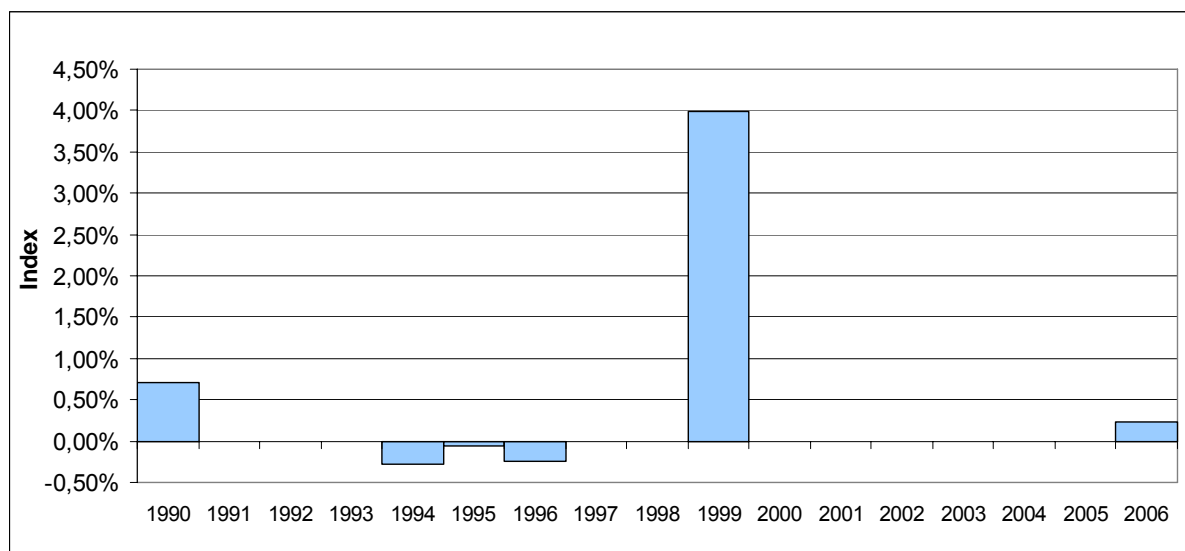


Figure 3.11.3.- CO₂-eq emissions. Percentage difference of 2009 vs. 2008 editions

3.11.6.- Improvement plans

The gas supply sector is a market that is experiencing an incipient de-regulation process. In forthcoming editions of the inventory it will be continued the search of the relationship of new supply companies as they join the gas market by requesting relevant information.

It is expected to complete the operators information of the oil and gas fields system, by incorporating the estimate of the said stated activities into the inventory, although it can be anticipated that the emissions amounts will be minor.

3.12.- Energy production and manufacturing industries (1A1)

3.12.1.- Description of the activity

Category 1A1 is a key source of N₂O by its contribution trend in 1994 and 1995. Table 3.12.1 presents the N₂O emissions expressed in CO₂-eq mass, supplementing this information with the time evolution index (100 in base year 1990) of said emissions and the contributions of CO₂-eq to the inventory total and energy sector.

Table 3.12.1.- N₂O emissions absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
N ₂ O (Gg of CO ₂ -eq)	283	558	679	703	751	725	739
CO ₂ -eq Index	100.0	197.4	240.4	248.7	265.7	256.5	261.5
% of CO ₂ -eq over total inventory	0.10	0.17	0.17	0.17	0.17	0.17	0.17
% CO ₂ -eq on energy	0.13	0.23	0.22	0.21	0.22	0.21	0.21

3.12.2.- Methodology

The activity variable used in this set of activities is fuel consumption. Given that sections 3.2, 3.3 and 3.4 have already shown the consumptions corresponding to each of the categories or sub-categories contemplated here and information regarding the methodological aspects of emission estimation has already been dealt with, these elements are not presented here.

3.12.3.- Uncertainty and consistency over time

As far as the uncertainty of the activity variables (fuel consumption) is concerned, reference is made to the corresponding paragraphs of sections 3.2, 3.3 and 3.4. The uncertainty of the N₂O emission factors is estimated according to the order of magnitude and in accordance with Table 2.12 of 2006 IPCC Guidance.

3.12.4.- Quality assurance and verification

Please refer to the paragraphs referring to quality assurance and verification in sections 3.2, 3.3 and 3.4.

3.12.5.- New calculations update

The main changes carried out in relation to the emissions estimation of N₂O for activity in this category versus the estimates in the previous edition are described below.

- It has been revised the lower heating values of the residual oil used in a power plant in 2005, which affects the consumption of the stated fuel expressed in energy units (TJ).
- For 2005 and 2006 the information regarding the fuel consumption of low-power electricity generation plants operating under the ordinary regime has been revised in accordance with the data appearing in Annex V of the Statistics on Electrical Power (prepared by the Ministry of Industry, Tourism and Trade, MITYC), which were not available at the time of the previous edition of the inventory for 2006, while it has been provided a revised edition for 2005.
- It has been eliminated the biogas consumptions in years 2002 to 2005 from a power plant shown on the stated Annex V of the Statistic on Electrical Power after having detected a double accounting of the stated consumption.
- In category 1A1b an error in the database has been corrected following the detection of the omission of the N₂O emissions for the year 2006 in a refinery.
- Within the activities compiled under category 1A1c, the consumption of natural gas (non specific combustion) has been revised for 2004 and 2006.

The combination of these changes implies an emissions variation of N₂O of little relevance over the inventory period (increments in terms of CO₂-eq of less than 3 Gg in the most significant year).

The comparison of N₂O emission results expressed in CO₂-eq terms between the inventory's current edition and the previous one is shown in absolute terms in figure 3.12.1, and in relative terms (percentage difference) in figure 3.12.2. The percentage difference in emissions is shown for both inventory editions. As illustrated in the last figure, the relative variation of CO₂-eq emissions as a consequence of new calculations effected is almost negligible, with the exception of 2006 when the relative variation is 2.08%.

Figure 3.12.1.- N₂O emissions. Comparison of 2009 and 2008 editions

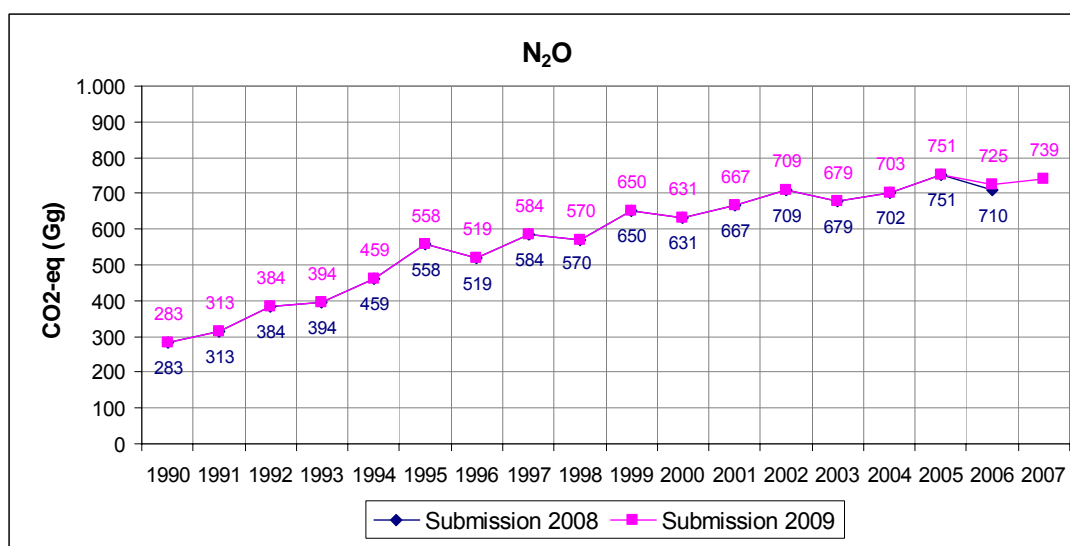
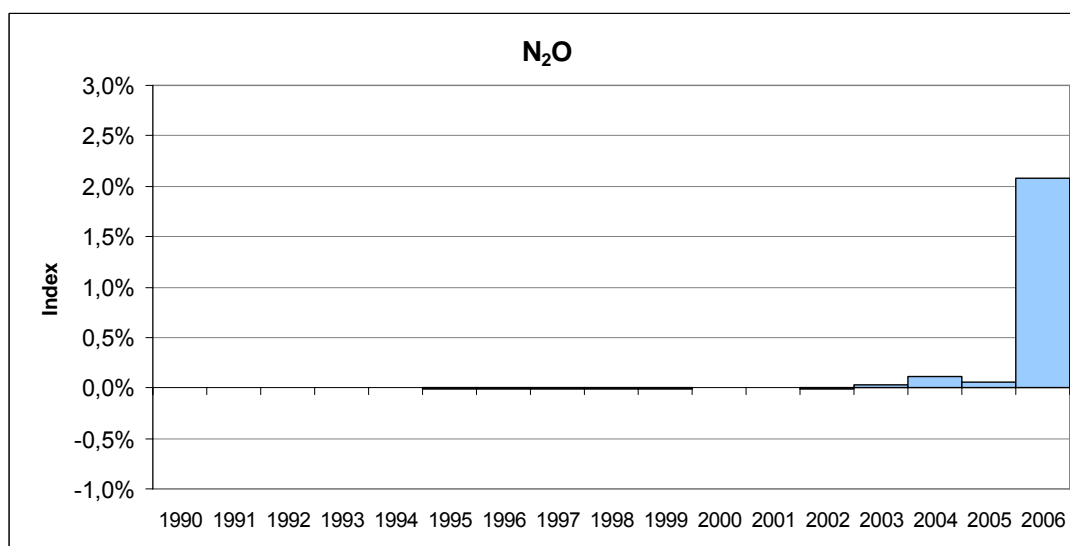


Figure 3.12.2.- N₂O emissions. Percentage difference of 2009 vs. 2008 editions



3.12.6.- Improvement plans

Please refer to the improvement plans highlighted in the corresponding paragraphs of sections 3.2, 3.3 and 3.4.

3.13.- Other sources

Following the IPCC nomenclature for source categories, other activities would also be considered if they fit under the title of energy in the inventory without being key sources. Some of the main "Other Sources" in this group are mentioned below:

In stationary combustion, both of an industrial origin (category 1A2) and as performed in other sectors included in category 1A4, CO₂ emissions from the use of "other fuels" do not represent a key source in the inventory either by level or trend due to the very slight participation of this type of fuel in these sectors.

Other crosstabs of activities with pollutants that, although included in the energy sector, are not identified as key sources either by level or trend in the inventory period are as follows:

- 1A1 – Stationary combustion in the energy sector: CH₄ emissions.
- 1A2 – Stationary combustion in industry: CH₄ and N₂O emissions.
- 1A3a – Civil aviation: CH₄ and N₂O emissions.
- 1A3b – Road transport: CH₄ emissions.
- 1A3d – Domestic sea traffic: CH₄ and N₂O emissions.
- 1A3c and 1A3e – Railways and other transportation: CO₂, CH₄ y N₂O emissions.
- 1A4 – Stationary combustion in other sectors N₂O emissions
- 1B1 – Fugitive emissions in coal mining and treatment: CO₂⁷².

⁷² In this activity, fugitive CO₂ emissions from mining activities have not been estimated as commented in section 3.10.2.2. The characterization diagnosis of this activity as a key source is therefore dependent on the availability of the corresponding estimate of these emissions.

4.- INDUSTRIAL PROCESSES

4.1.- Sector panorama

Industrial process emissions represented 7.88% in 2007 of total inventory emissions - in terms of CO₂ equivalent (CO₂-eq) - a reduction when compared to 1990's industrial processes that represented 9.13% of the total. On the other hand, the level of CO₂-eq emissions in this sector has registered an increase of 32.4% in 2007 with respect to 1990, going from 26,314 gigagrams (Gg) of CO₂-eq in 1990 to 34,852 Gg in 2007. In Table 4.1.1, are presented, in terms of CO₂-eq, the emissions from industrial processes broken down by component categories according to CRF guidelines. Figure 4.1.1 represents the evolution of said emissions in the period of 1990-2007.

Table 4.1.1.- CO₂ Equivalent Emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
2.A Mineral products	15,659	16,114	21,123	21,606	22,224	22,617	22,345
2.B Chemical industry	3,768	3,239	2,780	2,551	2,642	2,307	2,152
2.C Metal production	4,417	3,304	3,501	3,680	4,076	4,097	4,054
2.D Other industries	0	0	0	0	0	0	0
2.E Production of halocarbons and SF ₆	2,403	4,638	1,749	787	681	863	707
2.F Consumption of halocarbons and SF ₆	67	116	3,568	4,237	4,698	5,123	5,595
Industrial processes	26,314	27,411	32,722	32,860	34,322	35,008	34,852

Figure 4.1.1.- Evolution of CO₂-equivalent Emissions

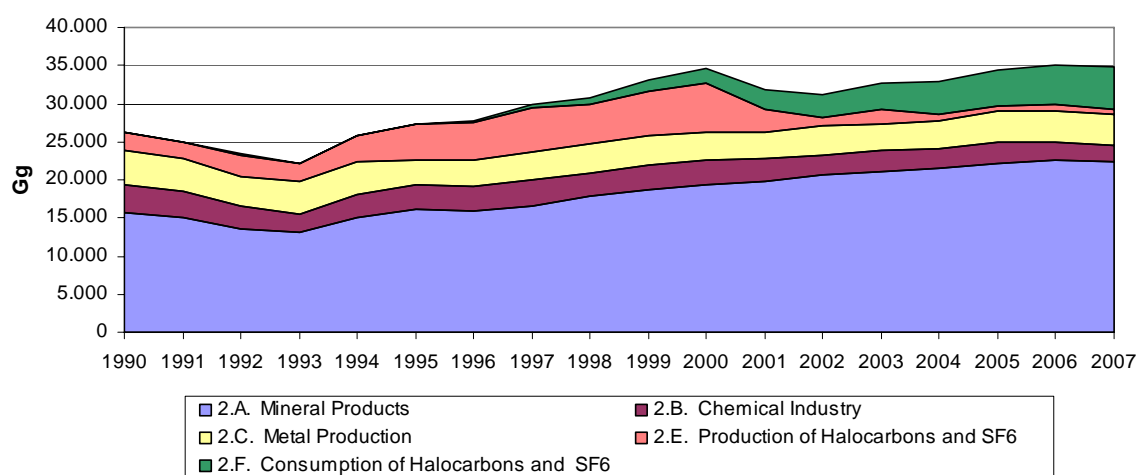


Figure 4.1.2 shows the contribution of the various source categories in this sector regarding the total emissions of CO₂-eq during the period 1990-2007. As can be seen, the combined contribution of the sector in every year is less than 10% of the total emissions, with

a decline from 2000 on caused by the increase in CO₂-eq emissions from the remaining sectors, although moderate upward variations are seen in the contribution in 2003 and 2006.

Figure 4.1.2.- Percentage of CO₂-eq emissions by category in relation to the total of the inventory

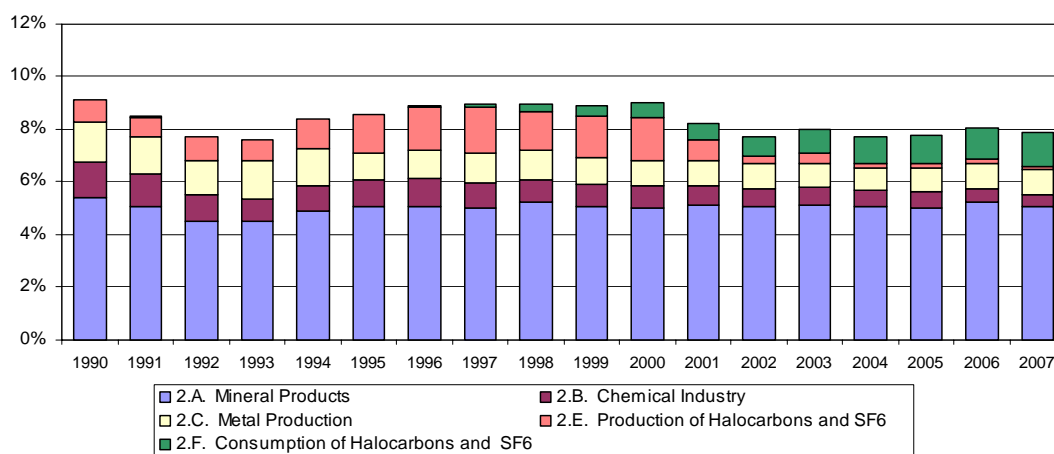
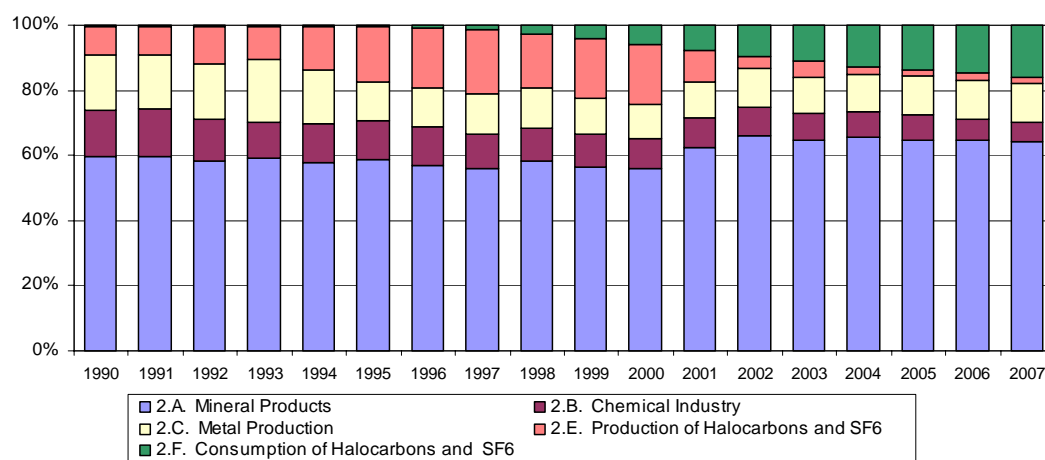


Figure 4.1.3 illustrates the distribution by source category of CO₂-eq emissions in the Industrial Processes sector. As can be seen in the figure, mineral products constitute this sector's main source of emissions (64.11% in 2007), followed by halocarbons and SF₆ consumption and metal production (16.05% and 11.63% respectively in 2007). The development of different categories can also be seen, with the greater variation rates occurring in fluorinated gas consumption, whose presence in 1990 is practically testimonial, and in halocarbons production, where an increase in CO₂-eq emissions is registered until the year 2000 followed by a subsequent decline in later years as a result of the implantation of recovery systems for gas emission.

Figure 4.1.3.- Percentage of CO₂-eq emissions by category in relation to the sector's total



The following chapter will examine the key sources of industrial processes. For the period 1990-2007, the following key sources have been identified:

- Cement production (2A1) due to its level of CO₂ emissions and trend during the 1990-2007 period.
- Limestone and dolomite use (2A3) due to its level of CO₂ emissions in the years 1996-2007 and for its trend in the 1991-1993 period.
- Nitric acid production (2B2) due to its N₂O emission level in the 1990-2003 period and trend during the 1990-2007 period.
- Iron and steel production (2C1) due to its level of CO₂ emissions during the 1990-2007 period and its trend in the years 1991-1992 and 1994-2007.
- Aluminium Production (2C3) due to its trend in PFC emissions in the years 1990 and 1999-2003 and 2005-2006.
- The manufacture of HCFC-22 (2E1) due to its HFC emission level in the 1990-2001 period and for its trend in the years 1990-1995, 1997-1998 and 2001-2007.
- Consumption of halocarbons and SF₆ (2F) due to its level of joint HFC and PFC emissions in the years 2000-2006 and its trend in the 1997-2007 period.
- Use of SF₆ in electrical equipment (2F8) due to its trend in 1990.

As a summary of the foregoing information Table 4.1.2 below presents, for the key categories in this sector, the contribution of the emissions to the level and trend, and the category's ranking in relation to the key sources¹, as well as the absolute values in terms of CO₂-eq, all referred to 2007.

Table 4.1.2.- Key sources: Level and Evolution

IPCC Activity		Gas	CO ₂ -eq (Gg) (2007)	Level Assessment (2007)			Contribution Trend (2007)		
Code	Description			%	Key source	Rank	%	Key source	Rank
2A1	Cement production	CO ₂	17,305	3.91	YES	8	0.79	YES	22
2A3	Limestone and dolomite use	CO ₂	2,129	0.48	YES	27	0.12	NO	41
2-2A1-2A2- 2A3-2C1	Other industrial processes	CO ₂	3,461	0.78	YES	20	0.24	NO	32
2B2	Nitric acid production	N ₂ O	1,359	0.31	NO	31	1.33	YES	16
2C1	Iron and steel production	CO ₂	2,363	0.53	YES	25	0.63	YES	23
2C3	Aluminium production	PFC	124	0.03	NO	57	0.50	NO	26
2E1	Manufacture of HCFC-22	HFC	423	0.10	NO	46	2.92	YES	10
2F	Consumption of halocarbons and SF ₆	HFC & PFC	5,255	1.19	YES	19	2.31	YES	12
2F8	SF ₆ in electrical equipment	SF ₆	340	0.08	NO	48	0.08	NO	46

¹ Ranking determined by the contribution of the emissions in the category to the level or the trend.

Explanation of the trend

The CO₂-eq emissions in this sector are clearly dominated by the contribution stemming from the decarbonation processes in mineral product industries, more specifically in the activity of cement production, with a share of close to 50% of the CO₂-eq emissions in the sector, or even more in some years. Thus, the trend that can be seen in Figure 4.1.1 is to a large extent in line with the social and economic evolution seen in cement (clinker) production, with a declines in the period 1990-1993 and a steady increase after 1994. It should be noted that the decrease in emissions in the interval 1990-1993 due to the downturn in cement production also reflects the trough of the cycle in the country's general economic activity.

As for the chemical industry, the evolution shows a certain stability with a decrease in the emissions over the period inventoried as a result of the closure of several production plants, especially for the manufacture of nitric acid and ammonia.

In the iron and steel industry, it is also possible to observe a relatively stable trend, although there has been significant technological change within the sector in steel manufacture as its production in electric arc furnaces is now more dominant rather than in basic oxygen furnaces.

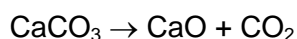
Finally, the contribution of fluorinated gas production and usage activities to the trend is clearly outstanding from 1995 on, with a slight increase in emissions due to the use of these gases and a decline in the HFC manufacturing activities, in the latter case essentially marked by the implementation of installations to diminish HFC-23 emissions in the manufacture of HCFC-22 after 2002, as is clearly shown in Figure 4.1.1.

The remaining sections of this chapter examine the activities (per IPCC category) or joint activities (combination of more than one IPCC category) of the Industrial Processes sector, having taken into account the previous key sources identification described (while in some cases two or more key sources were grouped together for convenience of exposition). In any case, the final section 4.11 provides a presentation (though condensed) of the sector's non-key sources.

4.2.- Cement production (2A1)

4.2.1.- Description of the activity

In this activity, the emission factor during the process of clinker manufacture as a result of the thermal disassociation of calcium carbonate and magnesium carbonate molecules present in the raw material with respect to the following chemical reactions:



These reactions are present in the processing of the raw material prior to the formation of hydraulic clinker compounds.

CO₂ emission is inherent in the process of clinker manufacture, as a nearly fixed value per tonne of clinker produced. The emissions corresponding to the activities of combustion in these processes are set within the CRF 1A2f category.

Table 4.2.1 details the CO₂ emissions for this activity, and it is this gas that makes this a key source. Table 4.2.2 shows these emissions in terms of CO₂-eq. The same Table presents the time development index (base 100, year 1990) of CO₂-eq emissions, and the contributing factors of the same to this category within the inventory total and the Industrial Processes sector.

Table 4.2.1.- CO₂ Emissions (Amounts in Gg)

1990	1995	2003	2004	2005	2006	2007
12,534	12,622	16,371	16,631	17,141	17,322	17,305

Table 4.2.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	12,534	12,622	16,371	16,631	17,141	17,322	17,305
CO ₂ -eq Index	100.0	100.7	130.6	132.7	136.8	138.2	138.1
% of CO ₂ -eq over total	4.35	3.95	3.99	3.90	3.89	4.00	3.91
% CO ₂ -eq on industrial processes	47.63	46.05	50.03	50.61	49.94	49.48	49.65

4.2.2.- Methodology

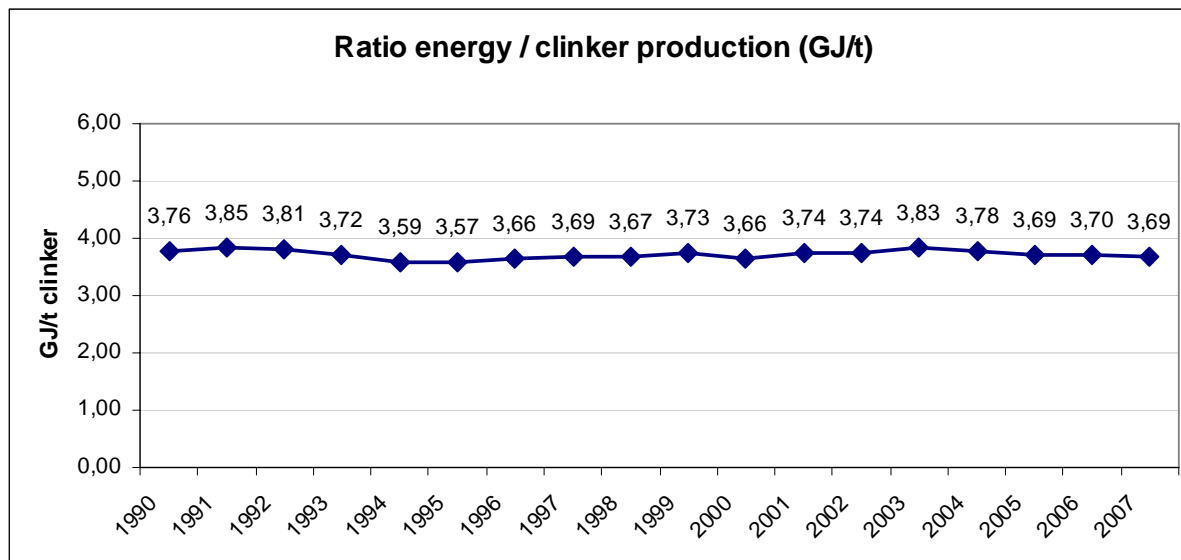
The CO₂ emissions estimates corresponding to this activity have been made using the IPCC Tier 2 method by means of the application of an emission factor to the quantity of clinker produced.

The information on clinker production has been obtained through the "Cement Industries" publication for the period 1990-1998 and by means of information provided for the period from 1999 to 2007 by the association of the cement manufacturing sector (OFICEMEN). The availability of this information has in turn determined the selection of a method of emissions estimates. Table 4.2.3 presents clinker production expressed in tonnes.

Table 4.2.3. – Clinker Production (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
23,211,731	23,373,454	30,316,646	30,798,002	31,742,484	32,078,063	32,045,543

When relating the clinker production with the energy consumption from cement factories, whose evolution is shown in figure 4.2.1, it is observed an energy requirement (GJ/t of the produced clinker) throughout the analyzed period. This keeps a very stable trend, varying the requirement between 3.57 GJ/t (1995) and 3.85 GJ/t (1992).

Figure 4.2.1.- Evolution of the energy requirement

There are a number of references (EMEP/CORINAIR, IPCC) proposing different emission factors for the estimation of CO₂ emissions. However, here it has been decided to use the information provided by the association of the cement production sector, which indicates CO₂ emissions arising from the decarbonation of 540 kg CO₂/t of clinker produced. This factor has been obtained by means of the application of the following formula to the analysis of clinker taken in 2005 from 12 cement factories (clinker from grey cement):

$$\begin{aligned} \text{Emission Factor [t CO}_2\text{/t clinker]} = & \\ & 0.785 \cdot (\text{Outgoing CaO [t CaO/t clinker]} - \text{Incoming CaO [t CaO/t Incoming material]}) + \\ & 1.092 \cdot (\text{Outgoing MgO [t MgO/t clinker]} - \text{Incoming MgO [t MgO/t Incoming material]}) \end{aligned}$$

the stoichiometric fractions of CO₂/CaO and CO₂/MgO are 0.785 and 1.092 respectively. The mean, minimum and maximum values thus obtained are as follows:

	CaO	MgO	Emission Factor (t CO ₂ /t clinker)
Mean value (12 plants)	65.66	1.93	0.540
Highest value	66.97	3.23	0.561
Lowest value	64.18	0.96	0.514

Source: Spanish Institute of Cement and its Applications

As an additional comment, it bears mentioning that the limestone used by Spanish cement companies is of high quality and low clay content (which decarbonizes less).

4.2.3.- Uncertainty and consistency over time

As for quantification of the uncertainty, It has been taken into account that the emission estimation has been done using a Tier 2 focus, and with activity data (clinker produced) provided by all the factories in the sector. It is thus considered that the uncertainty of the activity variable can be considered to be 1.5%, as the mean value in the range of 1-2% indicated in Table 3.2 of the IPCC 2000 Good Practice Guidance. With regard to the emission factor applied, mean values have been taken into account for the uncertainty ranges in steps (2), (3), (4) and (5) of the above table and these, when appropriately combined, give a combined uncertainty for the emission factor of 8.2%.

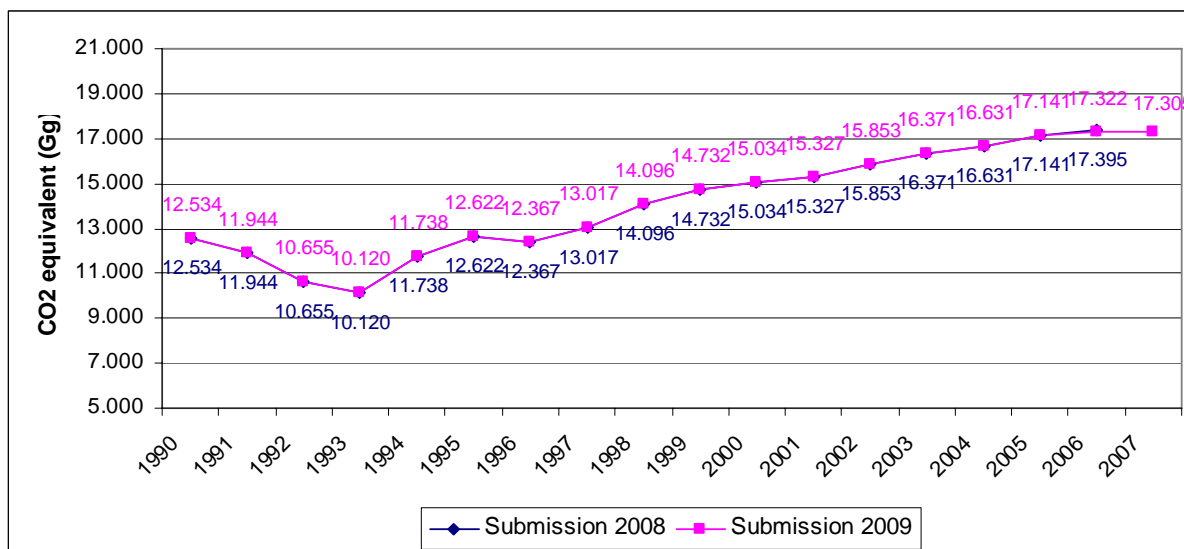
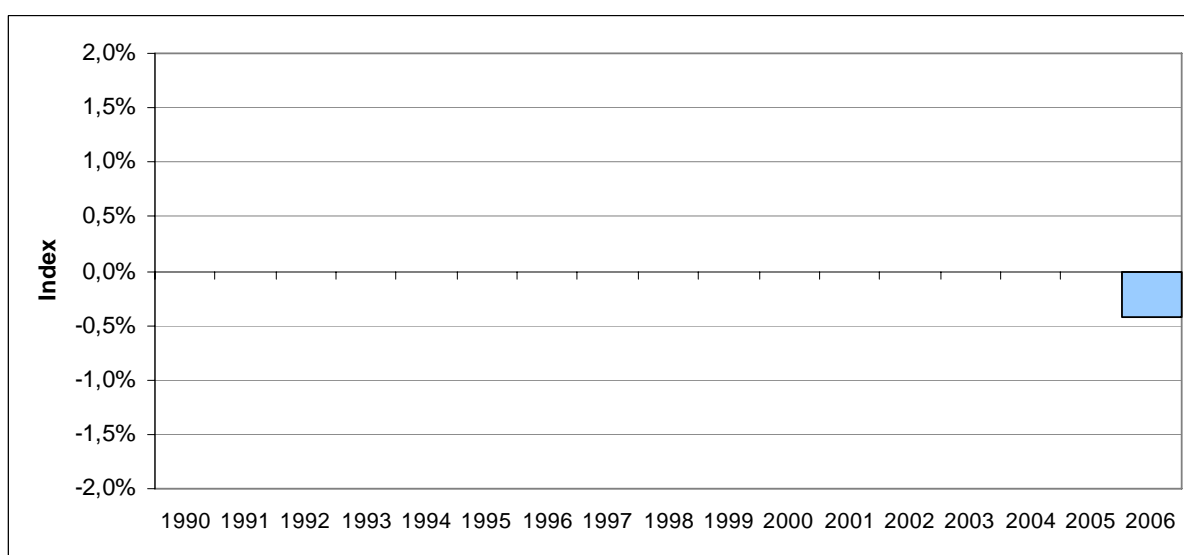
In relation to the time pattern, the series is considered consistent since it covers the set of sector plants during the inventoried period and because the information derives directly from the plants, having been furnished by the business association of the sector.

4.2.4.- Quality assurance and verification

The quality assurance activities performed include the revision of homogeneity of the clinker production series, taking into account that the provisional information facilitated for the last year of the previous edition of the inventory is at times revised in the current edition.

4.2.5.- New calculations

The variations caused by the new calculations stem from the review of the clinker production data corresponding to 2006 and imply a drop of 72.4 Gg in the CO₂ emissions. The comparison of the results in terms of CO₂-eq emissions between the current and the previous editions of inventory is given in absolute values in Figure 4.2.2 and in relative terms (percentage difference) in Figure 4.2.3. As can be seen, the relative variation in CO₂-eq emissions from this category in 2006 is -0.42%.

Figure 4.2.2.- CO₂-eq emissions. Comparison of 2009 and 2008 editions**Figure 4.2.3.- CO₂-eq emissions. Comparison of 2009 and 2008 editions: Percentage difference**

4.2.6.- Improvement plans

Looking to the future, through contacts with the OFICEMEN business association, it is expected to obtain specific factors for each plant which should improve the precision of the generic CO₂ factor for decarbonation currently used for the sector as a whole.

4.3.- Limestone and dolomite use (2A3)

4.3.1.- Description of the activity

This activity includes emissions originating from decarbonation of limestone and dolomite consumed in a variety of production processes (glass manufacture, glass frits, bricks and tiles, and magnesites), as well as that used for the desulphuration of gases discharged by chimney.

Table 4.3.1 details the CO₂ emissions for this activity, and it is this gas that makes this a key source. Table 4.3.2 shows these emissions in terms of CO₂-eq. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category to the totals for the inventory and the "Industrial Processes" sector.

Table 4.3.1.- CO₂ emissions (Amounts in Gg)

1990	1995	2003	2004	2005	2006	2007
1,220	1,234	2,081	2,204	2,293	2,473	2,129

Table 4.3.2.- CO₂-eq emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	1,220	1,234	2,081	2,204	2,293	2,473	2,129
CO ₂ -eq Index	100.0	101.1	170.5	180.6	187.9	202.6	174.4
% of CO ₂ -eq over total	0.42	0.39	0.51	0.52	0.52	0.57	0.48
% CO ₂ -eq on industrial processes	4.64	4.50	6.36	6.71	6.68	7.06	6.11

4.3.2.- Methodology

Limestone and dolomite consumption is taken as the activity variable for emissions estimates. This consumption has been obtained in the following manner:

- Magnesite production: by means of an individual questionnaire sent to the two production plants.
- Glass manufacture: by means of the information provided by the Spain business association for the glass industry (Vidrio España), with estimations via interpolation procedures in those years and sub-sectors of glass manufacture for those which did not have relevant information available; and, for the manufacture of glass frits, from the information provided by the National Association of Manufacturers of Glass Frits, Enamels and Ceramic Colours (ANFFECC) on CO₂ emissions as a result of decarbonation, under the assumption that these emissions originate 50% from the use of calcium carbonate and another 50% from sodium carbonate.
- Manufacture of bricks and tiles: calcium carbonate consumption has been estimated assuming that 12% of the clay is calcium carbonate (for the period 1990-2005, 12.64%

for 2006 and 11.62% for 2007) (information provided by the Spanish Association of Manufacturers of Bricks and Baked Clay Tiles, HISPALYT).

- Desulphuration: by means of a specific survey sent to thermal plants in which this type of emission abatement technique was used.

It should be mentioned that the following have not been included in this category: the CO₂ emissions due to the use of limestone and dolomite flux in the process of steel manufacture (sintering, blast furnace, steel furnaces), as these have been counted within category 2C1.

Table 4.3.3 details the estimated consumption of these materials expressed in tonnes.

Table 4.3.3.- Limestone and Dolomite Use (Amounts in tonnes)

	1990	1995	2003	2004	2005	2006	2007
Limestone	2,576,034	2,601,865	4,451,133	4,700,899	4,900,099	5,325,312	4,538,656
Dolomite	182,388	237,195	283,395	310,313	314,408	292,401	302,911

The estimation of CO₂ emissions has been done taking into consideration the emission factors derived from the stoichiometric ratio of calcium carbonate (limestone) and of calcium-magnesite carbonate (dolomite). It is understood that the information provided by the different sectors already discounts the mineral impurity factor, and complete efficiency is generally assumed in calcination (these last suppositions may in due course be verified and subsequently introduced explicitly as correction factors in the formula for the emission factor). Table 4.3.4 shows the emissions factors used.

Table 4.3.4.- Limestone and Dolomite Use. (g/GJ)

	CO ₂ Emission Factor (kg/t)
Limestone (CaCO ₃)	440
Dolomite (CaMg(CO ₃) ₂)	478

A specific example of the use of these emission factors is in the estimates of emissions originating from the desulphuration of gases from thermal power plants. In this case, individualized information was provided by the power plants using the desulphuration technique, with reference to the following parameters:

- Amount of raw material used (limestone)
- Concentration of calcium carbonate in the limestone used (%)
- Decarbonation factor (%): the percentage of carbonate dissociated while generating CO₂. This factor is specific to each power plant as it is essentially determined by the combustion method used at the installation.

The previous information on variables and parameters is used to estimate CO₂ emissions as the product of the amount of raw material used and the fraction representing

the yield in calcium carbonate, multiplied in turn by the decarbonated fraction and the stoichiometric factor of CO₂ generation in calcium carbonate decarbonation (0.44).

4.3.3.- Uncertainty and consistency over time

The quantification of uncertainties for the activity variable can be estimated at around 10%, taking into consideration that in most cases the information is specific to the plant, which should give a lower uncertainty value than that indicated but would be counterbalanced by the information at the sectorial level for some of the applications contemplated here. As far as the uncertainty of the emission factors, it is considered that it could be assimilated to the manufacture of lime which, according to Table 3.4 of the IPCC 2000 Good Practices Guidance, would be around 2%.

As commented previously, various aggregation sets are distinguished here with regard to the information on the activity variable. It is considered that the requirement for consistency over time is sufficiently verified for processes where information is directly provided at the plant level, and for the processes containing aggregate information at the sector level, such as in the manufacture of bricks and tiles, prior tasks have been performed to extrapolate samples from the reporting plants to the sector as a whole based on the production data in the sample and total for the sector. In this case too a good consistency profile over time has been obtained for the series.

4.3.4.- Quality assurance and verification

The main quality assurance tasks have referred to the examination of the carbonates contained in the raw materials utilized, a task that has been undertaken in conjunction with the technical teams of the main business associations for the activities and processes under consideration here.

4.3.5.- New calculations

No new calculations have been performed on this activity.

4.3.6.- Improvement plans

For further improvement, it is proposed to investigate further the coefficients of carbonate-rich raw materials to be able to assess the corresponding global emission factors with greater precision, in the understanding that this yield factor is the one that can show the most significant variability.

In the particular case of the manufacture of bricks and tiles it is proposed as an improvement the use (if available) of province factors containing carbonates in clays used for manufacturing these products.

4.4.- Iron and steel production (2C1)

4.4.1.- Description of the activity

The emissions produced in the iron and steel industry are compiled in this category, except for those associated with the combustion processes with energy recovery (included in category 1A2a), relative to the production of sinter, pig-iron and steel. The emissions stemming from coke-production have not been included here, but rather are compiled in categories 1A1c (combustion) and 1B1b (fugitive emissions). It can be included however - following the indications from the UNFCCC review team – the emissions deriving from the gas burning of flares of integrated steel plants and involve no energy recovery.

In 1990, there were three integrated iron and steel plants. Each of these plants has sinter furnaces, blast furnaces and basic oxygen steelworks, with steel production in these plants providing 44% of the national total (the 56% remaining corresponds to electric steelworks, given that there were no open hearth steel furnaces in Spain during the inventory period). However, in 2007 only two of the aforesaid integral plants remain, one of which lacks sintering and blast furnace facilities (the pig-iron necessary for steel production is supplied by the other plant, owned by the same company and geographically nearby), with oxygen steel production in 2007 at 22% of the total production and the electric arc-furnace steel representing the remaining 78%.

Table 4.4.1 details the greenhouse gases for this activity, with CO₂ making this a key source. Table 4.4.2 further supplements the previous information by expressing the overall emissions in CO₂-equivalent terms. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category to the totals for the inventory and the “Industrial Processes” sector.

Table 4.4.1.- Emissions (Amounts in Gg)

Pollutant	1990	1995	2003	2004	2005	2006	2007
CO ₂	2,491	1,326	1,826	1,951	2,298	2,353	2,363
CH ₄	1.0	0.7	0.7	0.7	0.8	0.6	0.7
N ₂ O	0.005	0.001	0.002	0.001	0.002	0.002	0.002

Table 4.4.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	2,513	1,342	1,841	1,967	2,314	2,367	2,379
CO ₂ -eq Index	100.0	53.4	73.3	78.2	92.1	94.2	94.7
% of CO ₂ -eq over total	0.87	0.42	0.45	0.46	0.52	0.55	0.54
% CO ₂ -eq on industrial processes	9.55	4.90	5.63	5.98	6.74	6.76	6.83

4.4.2.- Methodology

The CO₂ emissions estimates in the production of sinter, pig-iron and steel were made using the IPCC Tier 2 method by tracking the carbon through the production process, thus avoiding double accounting of the emissions. The election of this method has been possible

because it has been possible to have carbon mass balances available for the incoming and outgoing materials corresponding to each of the processes established within this category, as described below, with a distinction between the technologies used in steel production (electric steelworks versus basic oxygen steelworks) given the substantial differences in terms of technology and raw materials used. As for flaring, the estimate of CO₂ emissions is based on the same carbon content of each incinerated gas and on oxidation factors, as detailed below in this section.

As far as CH₄ emissions are concerned, only those corresponding to the loading of blast furnaces and flaring have been estimated. For the first of these activities it was used a factor proposed in the CORINAIR² Manual (part 1, heading 6.2.3) of 0.2 kg/t pig-iron used for the total volatile organic compounds, with a percentage of 90% CH₄ and 10% NMVOC; while for flaring it was applied emission factors selected from the different methodological guides of the energy activity variable (GJ) in terms of LHV (lower heating value) of each incinerated gas.

Lastly, the N₂O emissions presented in this category correspond exclusively to those produced by flaring, which were estimated, the same way as CH₄, by applying emission factors in the activity variable.

The production of steel, sinter and pig-iron, as presented in Table 4.4.3, is taken as an activity variable for emissions estimates. As for flaring, it is taken the quantities of incinerated gases expressed in terms of energy (TJ of lower heating value, TJ_{LHV}). The production figures for steel, sinter and pig-iron in basic-oxygen furnaces, as well as incinerated fuels in flaring, have been furnished directly by each of the integrated iron and steelworks plants. As for the production of arc-furnace steel, the information on production has been obtained for the years 1990-1994 through the Ministry of Industry, Tourism and Trade (MITYC); and the information for the years 1994-2007 has been provided by the Union of Iron and Steel Companies (UNESID).

Table 4.4.3.- Steel, sinter and pig-iron production (Amounts in tonnes)

	1990	1995	2003	2004	2005	2006	2007
Steel	13,162,544	12,817,855	16,580,455	17,978,623	17,842,351	18,331,755	18,979,255
Sinter	6,946,968	4,747,019	4,999,365	5,466,542	5,507,000	5,272,000	5,559,000
Pig Iron	5,588,228	4,158,830	3,837,132	4,095,004	4,187,000	3,578,000	4,142,000

The methodology followed to estimate CO₂ emissions for each of these processes is detailed below:

a) Steel production in basic-oxygen furnaces

The CO₂ emissions in basic oxygen furnaces have been estimated using a carbon mass balance between the incoming and outgoing materials, quantifying the carbon differential that would remain once the carbon mass inventoried in the outgoing carbon mass was subtracted from the incoming carbon mass (this carbon mass differential multiplied by a

² "Default Emission Factors Handbook" (1992). Second Edition. Edited by CITEPA for DG-XI CEC.

44/12 ratio results in the figure for CO₂ emissions estimated in this activity for each plant). The information needed to determine the carbon balance, whose structure is listed in Table 4.4.4, has been provided by means of a questionnaire sent to the two existing integrated iron and steelworks plants from 2000³ on, while for the period 1990-1999, since this information was not available, the total CO₂ emissions have been obtained in each plant's processing by applying the mean emission factor resulting from the period 2000-2002 to the tonnes of steel produced.

Lastly, for the third integral iron and steelworks plants existing in the 1990-1994 period, total CO₂ emissions have been estimated by applying the implicit emission factor resulting from the carbon balance in the 2000-2002 period from one of the two factories currently functioning with installations similar to the closed plant.

Table 4.4.4. – Steel Production in Basic-Oxygen Furnace. Carbon Balance

		Materials flow		Carbon content		Carbon Balance	
		UNIT	YEAR	UNIT	YEAR	UNIT	YEAR
INCOMING	Metal load						
	Steel scrap	t		% C		t C	
	Solid pig-iron	t		% C		t C	
	Slagging media						
	Rough chalk	t		% C		t C	
	Raw dolomite	t		% C		t C	
	Pig Iron	t		% C		t C	
	TOTAL INCOMING					t C	
OUTGOING	Scrap and scale	t		% C		t C	
	Steel	t		% C		t C	
	Recovered steelworks gas	kNm ³		% C/Nm ³		t C	
	Steelworks gas flare	kNm ³		% C/Nm ³		t C	
	Particulate diffuse emissions into water	t		% C		t C	
	Particulate diffuse emissions into air	t		% C		t C	
	TOTAL OUTGOING					t C	
Difference in carbon mass						t C	
CO₂ Emission						kt CO₂	
CO₂ implicit emission factor						(kg/t Steel)	

³ It should be mentioned that for years 2005 to 2007 the information of both plants was presented, regarding to the carbon balance of the different processes performed, in aggregate fashion (as a sole plant and summarising the carbon contents of the different input and output materials, without distinguishing the type of process performed)

b) Electric-furnace steel production

For electric steelworks, the calculation of process CO₂ emissions is made on the basis of the contribution, in terms of carbon balance, of: I) auxiliary consumption of fuels (coking coal, anthracite, blended coals, petroleum coke, foundry coke, natural gas); and of II) other auxiliary materials (graphite electrodes, dolomite, ...). For other material flows it was assumed they were in equilibrium in terms of carbon balance, that is, a null balance between incoming (scrap, pig-iron, iron alloys, refined coal) and outgoing materials (steel produced, slag and dust), according to technical information furnished by UNESID⁴.

c) Pig-iron

Pig-iron CO₂ emissions have been estimated using a carbon mass balance between incoming and outgoing blast furnace material, quantifying the carbon differential that would remain once the carbon mass in the inventoried outgoing carbon mass was subtracted from the incoming carbon mass (this carbon mass differential after application of the 44/12 ratio results in the figure of CO₂ emissions estimates in this activity).

The information related to carbon balance presented in Table 4.4.5, has been possible thanks to the information furnished by the sole plant where these processes have been executed in the years since 2000. (see note 3). As the information for the 1990-1999 period is not available, total CO₂ emissions have been obtained in the process for each existing plant in said years by applying the mean emission factor resulting in the 2000-2002 period to the tonnes of pig-iron produced.

⁴ This balance assumption of other materials should be reviewed in light of the new CO₂ guidelines certified by the emission trading rights (Decision 2007/589/EC).

Table 4.4.5.- Blast furnaces charging. Carbon Balance

		Materials flow		Carbon content		Carbon Balance	
		UNIT	YEAR	UNIT	YEAR	UNIT	YEAR
INCOMING	Mineral load	t		% C		t C	
	Slagging media						
	Calcium carbonate	t		% C		t C	
	Magnesium silicate	t		% C		t C	
	Reduction agents						
	Injected coal	t		% C		t C	
	Coke	t		% C		t C	
	TOTAL INCOMING					t C	
OUTGOING	Bottle glass powder	t		% C		t C	
	Sludges	t		% C		t C	
	Hopper dust	t		% C		t C	
	Run-off dust	t		% C		t C	
	Pig Iron	t		% C		t C	
	Blast furnace gas	kNm ³		g C/Nm ³		t C	
	Particulate diffuse emissions into water	t		% C		t C	
	Particulate diffuse emissions into air	t		% C		t C	
	TOTAL OUTGOING					t C	
Difference in carbon mass						t C	
CO₂ Emission						kt CO₂	
CO₂ implicit emission factor						(kg/t Pig-iron)	

d) Sinter

Total CO₂ emissions in the manufacture of sinter have been estimated using a carbon mass balance between the incoming and outgoing material of the sintering process, quantifying the carbon differential that would remain once the carbon mass of the inventoried outgoing material was subtracted from the incoming carbon mass, obtaining a CO₂ emission from this carbon mass differential elevated by a ratio of 44/12. Of these total emissions, those attributable to the consumption of fuels (combustion) in the sintering furnaces are discounted, with the remaining emissions being attributed to category 2C1, thus avoiding any double accounting of emissions.

This carbon balance has been possible from 2000 on thanks to the information furnished by the sole operating plant producing sinter during these years (see note 3). As the information for the 1990-1999 period is not available, total CO₂ emissions have been obtained in the process for each existing plant by applying the mean emission factor resulting from the period 2000-2002 to the tonnes of sinter produced, and discounting at each plant the emissions corresponding to fuel consumption (combustion).

Table 4.4.6 presents the template with the particulars requested to be able to determine the carbon balance in sinter production.

Table 4.4.6.- Sintering Plants. Carbon Balance

		Materials flow		Carbon content		Carbon Balance	
		UNIT	YEAR	UNIT	YEAR	UNIT	YEAR
INCOMING	Iron ore	t		% C		t C	
	Slagging media	t		% C		t C	
	Limestone	t		% C		t C	
	Recoveries	t		% C		t C	
	Bottle glass powder	t		% C		t C	
	Anthracite	t		% C		t C	
	Coke fines	t		% C		t C	
	Coke oven gas	kNm ³		g C/Nm ³		t C	
	TOTAL INCOMING					t C	
OUTGOING	Sinter	t		% C		t C	
	Particulate diffuse emissions into air	t		% C		t C	
	TOTAL OUTGOING					t C	
OTHER OUTGOINGS							
	Stack CO (not subtracted)			% C		t C	
Difference in carbon mass						t C	
CO₂ Emission						kt CO₂	
CO₂ implicit emission factor						(kg/t sinter)	

e) Flaring

To estimate CO₂ emissions of flaring from integrated iron and steelworks plants, preference is given to the calculation procedure based on the carbon content of each incinerated gas and the stoichiometric calculation raised to the mass of CO₂ is complemented by including the oxidation factors (please refer to equation [3.2.1] and the detailed explanation for the algorithm in heading 3.2.2). In those cases where the necessary data was not available in order to apply this algorithm, default emission factors were used with the fuels' standard characteristics. When it comes to CH₄ and N₂O emissions, emission factors selected from different methodological guidelines and institutional sources (CITEPA⁵) are applied to the activity variable energy (GJ) in terms of LHV for each incinerated gas. Table 4.4.7 shows the emission factors used for the estimation of emissions.

⁵ CITEPA. "Facteurs d'émission du protoxyde d'azote pour les installations de combustion et les procédés industriels". Etude bibliographique. Sébastien Cibick et Jean-Pierre Fontelle. Février 2002.

Table 4.4.7.- Flaring in iron and steel industry. (g/GJ)

	CO ₂ (t/TJ)	CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
L.P.G.	64.08	0.9	2.5
Coke oven gas	41.3-45 (1)	2.5	1.75
Blast furnace gas	242.9-293.5 (1)	0.3	1.75
Steel furnace gas	181.3-191.5 (1)	0.3	2.5
Natural gas	56	1.4	2.5

Source: For CH₄ EMEP/CORINAIR Guidebook. Part B. Chapter 332, Table 8.2 and Chapter 111, Table 27, assimilating the emission factors to those from activities contemplated in the mentioned chapters
CITEPA, for N₂O.

(1) The indicated range of CO₂ factors has been obtained by mass balance from the characteristics provided for the fuels in question in the period inventoried.

4.4.3.- Uncertainty and consistency over time

The process with a bigger uncertainty in this key-source is the one concerning incineration in flares, where the uncertainties are estimated in 30% of the activity variable (taking into account that some volumes of gas burnt in flares are estimated), and also in 10% in the emission factor (considering the partial knowledge about the composition of incinerated gases).

For the remaining group of processes under consideration, it has been jointly assumed that the uncertainty of the activity variables is 3%, and for the emission factor, the presumably greater uncertainty could be around 5%.

Notwithstanding, and relating uncertainty to the consistency over time, it is worth mentioning that the degree of uncertainty of the information is considered greater in the 1990-1999 period, due to the difficulty in compiling retrospectively the data relative to those years. Additionally, and in the case of the electric steelworks in particular, the variability existing during the period inventoried should be taken into consideration for the types and quality of the steel produced, the characteristics of which have an influence on the materials used in the production process. Thus, the ratios of CO₂ emissions per tonne of steel produced vary considerably between plants and years.

4.4.4.- Quality assurance and verification

Among the quality assurance activities within this category, the monitoring performed on the inter-annual oscillation in the carbon content emitted as CO₂ with respect to the incoming and outgoing carbon should be emphasized. In the presence of atypical values in any year, the causes and possible reasons for their appearance are investigated in conjunction with the plants in the sector or with the business association, effecting any corrections that may occasionally be necessary.

4.4.5.- New calculations

No new calculations have been performed on this activity.

4.4.6.- Improvement plans

One promising action aimed at improving this sector is the proposed collection of individualized information for all of the electric steelworks. This would allow the verification of specific information with a much greater level of breakdown than currently available. This proposal has already been made to the UNESID. Therefore, it is planned to perform a review, along with UNESID, about the carbon balance of other incoming and outgoing materials in the production of steel in electrical furnaces. This balance until now was supposed to be in carbon balance, but in the light of the new available information it is necessary to review this assumption. (See note 4).

4.5.- Industrial processes (2 except 2A1, 2A2, 2A3 and 2C1)

4.5.1.- Description of the activity

With respect to CO₂ emissions, this is a heterogeneous set of activities that groups together those corresponding to industrial processes with the exception of the production of cement and lime, the use of limestone and dolomite, and the processes for iron and steel production. Among the activities considered, the following should be pointed out for their importance to CO₂ emissions: the production and use of sodium carbonate, ammonia manufacture, carbide production, the production of ferroalloys and silicon-metal, aluminium production, the processes of decarbonation in the manufacture of wall tiles and ceramic flooring, as well as the use, in the glass industry and in the production of magnesite, of other types of carbonates not contemplated elsewhere.

Table 4.5.1 shows CO₂ emissions (exclusively), which make this a key source for the activities mentioned. Table 4.5.2 presents, in the same way, the time development index (base 100 year 1990) for these emissions, and the contributions of this category's CO₂ emissions to the total CO₂-eq emissions for the inventory and the "Industrial processes" sector, respectively.

Table 4.5.1.- CO₂ emissions (Amounts in Gg)

1990	1995	2003	2004	2005	2006	2007
2,635	2,922	3,332	3,374	3,543	3,488	3,461

Table 4.5.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	8,923	10,953	10,858	10,425	10,980	11,219	11,303
CO ₂ -eq Index	100.0	122.7	121.7	116.8	123.0	125.7	126.7
% of CO ₂ -eq over total	3.10	3.43	2.65	2.45	2.49	2.59	2.56
% CO ₂ -eq on industrial processes	33.91	39.96	33.18	31.73	31.99	32.05	32.43

4.5.2.- Methodology

a) Production and use of sodium carbonate

In Spain, there is only one sodium carbonate production plant, and it uses the Solvay Process. The production figures have been furnished directly by the plant itself.

In accordance with the IPCC Reference Manual (section 2.6.1) the CO₂ emissions associated with the Solvay manufacturing process are nil if it is executed under stoichiometric conditions, as can be inferred from the observation of the general net balance of the reactions belonging to this process, and which can be expressed according to the following reaction:



However, the real process is not effected in these conditions, but rather in conditions of CO₂ production excess which, according to the reference cited, stems from the (non-energetic) consumption of coke. This coke consumption should be discounted from potential emissions of energy-related coke so as to not incur in double accounting. The value of the emission factor for the production of sodium carbonate has been provided by the production plant itself. However, for confidentiality reasons the presentation of this factor is omitted as it may be possible to infer the production figures from reported emissions, and the company prefers to maintain strict confidentiality in this regard.

The apparent consumption of sodium carbonate has been taken as the activity variable for the use of this product. As for use, the figure of 415 kg CO₂/tonne of sodium carbonate given in Heading 2.6.2 of the IPCC 1996 Reference Manual has been taken as a reference for the emission factor.

b) Mineral products: Other

The estimation of emissions for this activity has been carried out using the default IPCC methodology of applying an emission factor per unit of material produced or consumed. In general, the activity variable used in the processes under consideration is the quantity of carbonates and reduction agents (except those included in other categories, such as sodium carbonate, calcium carbonate or dolomite) used in the manufacturing processes for different types of glass (information provided via a questionnaire completed by the plants themselves, through the Vidrio España (Spain Glass) business association, and magnesite production (information provided via a questionnaire completed by the production plants).

The exception to this activity variable is the process for manufacturing ceramic wall and floor tiles, as the CO₂ emissions are produced as a result of the decarbonation of the carbonates in the clay used as the basic raw material for the process. In this case, the activity variable considered has been the production of tiles, with a distinction being drawn between porous and non-porous tiles. This distinction is motivated by the fact that porous tiles need to use clay with a higher proportion of carbonates in order to achieve the porosity of the end product. The production data for each type of tile has been furnished by the Spanish Association of Manufacturers of Tiles, Pavements and Ceramic Tiles (ASCER).

Table 4.5.3 illustrates the quantities consumed of the distinct carbonates and reduction agents in the manufacture of glass and magnesite, as well as tile production according to the types under consideration⁶.

Table 4.5.3. – Other Mineral Products. Production and Consumption (Amounts in Gg; thousands of m² for floor tiles)

	1990	1995	2003	2004	2005	2006	2007
Production							
Porous tiles	100,900	176,314	232,446	234,049	237,181	241,898	241,315
Non-porous tiles	100,900	182,486	350,954	361,451	372,019	366,502	343,385
Consumption							
Barium carbonate	1.55	1.73	1.25	0.87	0.79	16.31	0.64
Lithium carbonate	-	-	-	-	0.001	0.02	0.01
Potassium carbonate	0.65	0.75	0.69	0.75	0.72	0.71	0.69
Magnesium carbonate	317.19	436.23	423.49	455.07	463.48	469.86	478.07
Ferrum carbonate	4.00	4.62	5.70	5.62	4.61	4.91	4.44
Coal	0.03	0.07	0.05	0.23	0.59	0.48	0.93

Note. For floor tiles, the figures presented are expressed in thousands of m² as this is how they were given in the original source.

For each of the types of carbonate used, the CO₂ emission factor is obtained from its corresponding molecular composition. In the case of coal used as a reduction agent, the CO₂ emission factor depends on the carbon content in the coal, therefore a range of factors is presented for the period inventoried. Finally, and in reference to the production of floor tiles, the emission factors used have been proposed by ASCER.

Table 4.5.4.- Other Mineral Products. CO₂ Emission Factors

	Factor	Unit
By production		
Porous tiles	735	kg/thousands m ²
Non-porous tiles	87.5	kg/thousands m ²
By consumption		
Barium carbonate	223.016	kg/t
Lithium carbonate	595.603	kg/t
Potassium carbonate	318.437	kg/t
Magnesium carbonate	522.238	kg/t
Ferrum carbonate	452.817	kg/t
Coal	3,229 – 3,600	kg/t

c) Ammonia production

For this activity, the ammonia production of each of the operating plants in Spain has been available, as presented in Table 4.5.5. There were four ammonia production plants operating in 1990, while only two plants remained active by 2007.

⁶ Floor tile production is expressed in thousands of m².

Table 4.5.5.- Ammonia production (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
572,985	550,597	524,619	490,763	541,812	488,131	525,835

In one of the plants that operated from 1990 to 1996, the production process was by direct synthesis of ammonia, performed in a closed circuit without reforming, using pure hydrogen and pure nitrogen by fractioned distillation of air. For this reason, no CO₂ emissions were produced in this plant.

For the remaining plants, however, the consumption of natural gas, naphtha or refinery gas used as raw materials in the production process has not been available, thus determining the selection of estimation method. As a result, the emission factors furnished by the plants themselves every year have been applied to the tonnes of ammonia produced. These factors range from 1,108-1,294 kg CO₂/tonne of ammonia when natural gas is used and range from 1,420-1,430 kg CO₂/tonne of ammonia when naphtha or refinery gas is used.

d) Carbide production

For carbide production, only the production statistics have been made available, which has therefore determined the methodology used in the emission estimates, in this case that proposed by default by the IPCC, namely the application of an emission factor per tonne of carbide produced.

Only two plants produce silicon carbide in Spain (both belonging to the same company), and the production figure has been furnished by the plants themselves. With regard to calcium carbide, the production data have been taken from the publication "The Chemical Industry in Spain" although the 2002 production has been maintained for the years 2003-2007 due to the absence of an information source. Table 4.5.6 details the production statistics (the information corresponding to silicon carbide is confidential).

Table 4.5.6.- Carbide Production (Amounts in tonnes)

	1990	1995	2003	2004	2005	2006	2007
Silicon carbide	C	C	C	C	C	C	C
Calcium carbide	43,604	43,600	40,900	40,900	40,900	40,900	40,900

C = Confidential

For calcium carbide, the emission factors applied have been those proposed in Section 2.11.2 of the IPCC 1996 Reference Manual, namely 1.8 t CO₂/tonne of calcium carbide and 11.6 kg CH₄/tonne of calcium carbide. However, for confidentiality reasons the presentation of these emission factors for silicon carbide is omitted as it may be possible to infer the production figures from reported emissions, and the company prefers to maintain strict confidentiality in this regard.

e) Ferroalloys

The methodology used for the estimation of ferroalloy emissions is that proposed by default by the IPCC, namely the application of an emission factor to the production volume of

each type of iron alloy. These production figures, shown in Table 4.5.7, have been provided by the production plants themselves.

Table 4.5.7.- Ferroalloy Production (Amounts in tonnes)

	1990	1995	2003	2004	2005	2006	2007
Ferrosilicon	37,589	38,131	66,485	67,340	64,166	62,348	66,561
Ferromanganese	49,512	57,368	125,638	158,749	154,771	142,625	152,201
Silicon-manganese	55,091	88,607	125,651	114,826	142,903	151,347	162,194

However, the default emission factors proposed by the IPCC for the estimation of CO₂ emissions have been replaced in this case by specific factors furnished by each plant and product (from 2001 on), as they vary depending on the raw materials used. The mean of both factors for 2001-2004 has been applied to all of the years in the series 1990-2004, as this average was considered more representative in the previous edition of the inventory. In 2005–2007 the specific factors provided for these years have been applied.

f) Aluminium production

The CO₂ emissions estimation methodology for aluminium manufacture is detailed in heading 4.7 (this activity is a key source because of its PFC emissions).

g) Silicon production

Given that only silicon metal production has been available for this activity, the estimation of CO₂ emissions has been carried out using the IPCC default methodology (applying an emission factor to the activity variable, namely silicon metal production). The production data, shown in Table 4.5.8, have been furnished directly by the sole manufacturing plant for this product.

Table 4.5.8.- Silicon metal production (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
12,060	18,820	29,203	33,315	37,043	33,620	35,843

As for the emission factor applied, the production plant has furnished a factor of 6,666 kg CO₂/tonne of silicon metal, factor taken as representative for the period 1990-2004; whereas for 2005-2007, the factors provided by the plant are also 6,602, 6,476 and 6,479 kg CO₂/tonne⁷.

4.5.3.- Uncertainty and consistency over time

It is obvious that the activities described in this heading have their uncertainties associated to activity variables and emission factors. Nonetheless, globally the uncertainty

⁷ The default emission factor proposed by the IPCC is 4.300 kg CO₂/tonne of silicon metal (Section 2.13.4.2, Table 2.15, of the IPCC 1996 Reference Manual).

associated with the combination of activity variables could be estimated at around 50%, whereas it would be around 20% for the combination of emission factors.

As regards consistency over time, a detailed monitoring of the processes mentioned here has been conducted in order to ensure homogeneity of the series of activity variables used. The emission factors are considered representative, either because they come from the analysis of detailed information from each plant, or are based on stoichiometric calculations.

4.5.4.- Quality assurance and verification

As for the quality control activities, the most outstanding are the procedures adopted to check the information individually at the plant level so as to take into consideration any peculiarities that may arise at each facility.

4.5.5.- New calculations

The changes made in the estimation of the emissions for this set of activities are described below. These include the new calculations effected even though they may not have directly affected the CO₂ emissions, the gas giving this source its status as a key source.

- In activity 2A7. the production figures for floor tiles (both porous and non-porous) have been reviewed for the entire period 1990-2006, in accordance with new information furnished by the Spanish Association of Ceramic Wall and Flooring Tile Manufacturers (ASCER). This review has implied a drop ranging between 5.5 Gg and 28.9 Gg in the CO₂ emissions for the whole period mentioned.
- In the production of calcium carbide (activity 2B4) the estimation of CH₄ emissions has been included for the whole period inventoried in accordance with the indications of the UNFCC Secretariat. Although this modification affects the emissions of CH₄ (a gas that does not classify this set of activities as a key source), it does affect the emissions in terms of CO₂-eq with increases ranging between 6.8 and 11 Gg of CO₂-eq.
- In the production of carbon black (activity 2B5), the activity variable (production figures) corresponding to 2004, 2005 and 2006 has been amended in accordance with the new information furnished by the only company manufacturing this product in the said years. Although this modification affects the emissions of CH₄ (a gas that does not classify this set of activities as a key source), it does affect the emissions in terms of CO₂-eq with increases of 6.5 Gg (2004), 8.2 Gg (2005) and 7.7 Gg (2006) in these emissions.
- The production corresponding to 2006 has been updated for one of the ethylene manufacturing plants (activity 2B5) in accordance with the new information provided by the plant itself. As with the previous activity, this amendment affects the emissions of CH₄ and represents, in CO₂-eq terms, a decline of 0.01 Gg.

Figure 4.5.1 shows the comparative evolution in absolute values for CO₂ emissions (the gas classifying this set of activities as a key source) between the results of the current edition and those of the previous edition, while Figure 4.5.2 presents the percentage difference in these emissions between inventory editions. As can be observed in the last Figure, the new calculations effected in the CO₂ emissions for this set of activities imply a fall ranging between 0.3 Gg of CO₂ and 28.9 Gg of CO₂.

Figure 4.5.1.- CO₂-eq emissions. Comparison of 2009 and 2008 editions

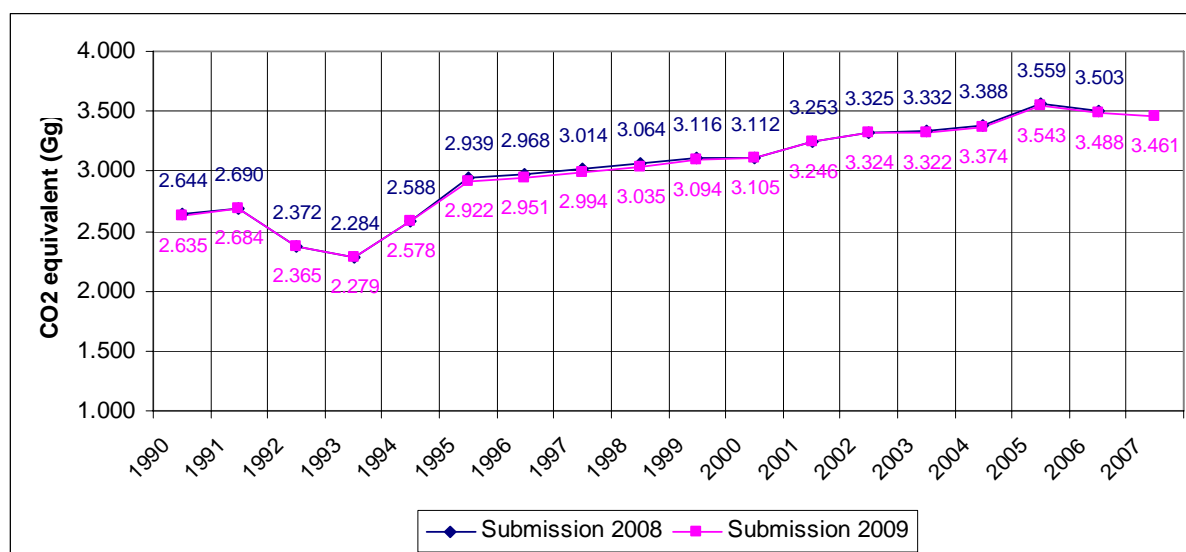
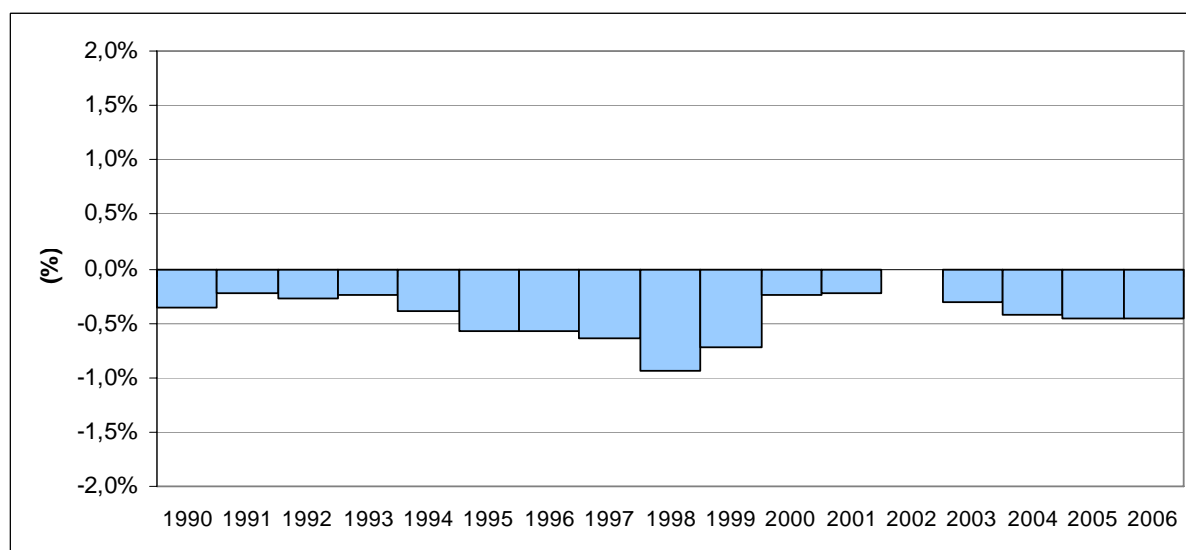


Figure 4.5.2.- CO₂-eq emissions. Comparison of 2009 and 2008 editions: Percentage difference



4.5.6.- Improvement plans

Given that information on activity variables is considered to be covered with a high degree of detail (at the plant level for most activities), the improvements planned involve incorporating specific plant-related information regarding the monitoring technologies, which might have as a consequence greater accuracy and precision in the level of emission factors applied, which nevertheless already incorporate certain process-specific aspects of the plants. In this line, priority will be given to the manufacturing activities for iron alloys and the production of calcium and silicon carbides.

4.6.- Nitric acid production (2B2)

4.6.1.- Description of the activity

The most common method used for obtaining nitric acid is the catalytic oxidation of ammonia with oxygen or air. Nitric oxide is formed (NO), which is oxidised into nitrogen dioxide (NO₂), and the latter is combined with water and oxygen to produce nitric acid with a concentration that ranges between 50% and 70% in weight ("weak acid"). For the production of highly concentrated nitric acid (98% in weight), the NO₂ is produced in the same way as described above, by being absorbed in highly concentrated acid, distilled, condensed and finally converted into highly concentrated nitric acid at a high pressure by means of adding a mixture of water and pure oxygen.

There are three types of processes depending on the operating pressure: low (< 1.7 bars), medium (1.7-6.5 bars) and high pressure (> 8 bars). In Spain, there were four nitric acid manufacturing plants in 2007: one operating at low pressure, two at medium pressure and one plant using both low and medium pressure processes.

Table 4.6.1 shows the N₂O emissions for this activity, and this gas is what makes it a key source. Table 4.6.2 shows these emissions in terms of CO₂-eq. The same table gives the time evolution index (100 in base year 1990) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category to the totals for the inventory and the "Industrial Processes" sector.

Table 4.6.1.- N₂O Emissions (Amounts in Gg)

1990	1995	2003	2004	2005	2006	2007
9.3	7.7	6.3	5.8	6.0	5.0	4.4

Table 4.6.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	2,884	2,384	1,965	1,788	1,860	1,555	1,359
CO ₂ -eq Index	100.0	82.7	68.1	62.0	64.5	53.9	47.1
% of CO ₂ -eq over total	1.00	0.75	0.48	0.42	0.42	0.36	0.31
% CO ₂ -eq on industrial processes	10.96	8.70	6.01	5.44	5.42	4.44	3.90

4.6.2.- Methodology

The nitric acid production figures used as the activity variable for emissions estimates have been obtained from data furnished by the manufacturing plants themselves for 1990, and from information contributed by the FEIQUE (the Business Federation of the Chemical Industry in Spain) and by the MITYC for the rest of the years in the period inventoried, broken down by plant and type of manufacturing process. Table 4.6.3 shows nitric acid production data. As can be seen, there has been a significant decrease in production over the period inventoried.

Table 4.6.3. – Nitric acid production (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
1,329,107	1,098,533	905,730	823,792	857,363	716,768	626,333

In the case of NO_x, the associated emission factors depend on the type of manufacturing process used, distinguishing between low, medium and high pressure. This is why it is necessary to have available activity variable information that differentiates each of the processes mentioned.

To make an estimate of N₂O emissions, an emission factor of 7 kg N₂O / t nitric acid has been taken, as originally mentioned by the FEIQUE in its communication to the MITYC (April 1998), and corroborated by this product's main manufacturer.

4.6.3.- Uncertainty and consistency over time

Considering that the information on nitric acid production has been provided by the manufacturing plants themselves, and assuming that the information comprises the whole of nitric acid production (intermediate and final), the uncertainty about the activity variable may be estimated at 2% according to heading 3.2.1 of the IPCC 2000 Good Practice Guidance.

As regards the emission factor applied, it is assumed that uncertainty is around 10% according to information furnished by the main firm in the sector, and its magnitude is similar to those shown in Table 3.8 of the IPCC 2000 Good Practice Guidance.

Regarding the time pattern, the series is considered to be consistent since it involves all of the plants in the sector over the period inventoried and because the information comes directly from the plants. The consistency analysis evidences the decrease in the number of plants over the period inventoried, falling from ten plants in 1990 down to four in 2007; this decrease is reflected in the production curve.

4.6.4.- Quality assurance and verification

For quality assurance purposes, a comparison has been made between the data furnished by plants and the sectorial statistics reported by the publication "Chemical Industry

in Spain” published by the MITYC⁸ with the purpose of detecting possible discrepancies in the data provided.

As regards the emission factor, the value used has been verified as a representative value within the variation range reported, by years and plants, from some production centres for the most recent period.

4.6.5.- New calculations

No new calculations have been performed on this activity.

4.6.6.- Improvement plans

The possibility of performing future estimations with data broken down by plant has been considered, analyzing in each case the use of possible abatement techniques (catalytic reductions, absorption).

4.7.- Aluminium production (2C3)

4.7.1.- Description of the activity

The production of primary aluminum is a key source of the inventory due to its associated PFC emissions. The information on activity variables and the parameters for the emissions estimation algorithm has been gathered by means of an individualized questionnaire sent to each of the three production plants. Of the manufacturing technologies mentioned in section 2.13.6 of the IPCC 1996 Reference Manual, two of the plants use the vertical stud Söderberg anode system, while the third one uses the pre-baked anode system (both side-worked and centre-worked).

Table 4.7.1 shows the CO₂ and PFC emissions for this activity, the latter being the gases making this a key source, in view of their contribution to the trend. Table 4.7.2 further supplements the previous information by expressing the overall emissions in CO₂-equivalent terms. The same Table presents the time development index (base 100, year 1990 for CO₂ and 1995 for PFC) of CO₂-eq emissions, and the contributing factors of the same to this category within the inventory total and the Industrial Processes sector. It is worth mentioning that this activity's CO₂ emissions are a key source when considered together with those related to other activities in the industrial processes sector (see Heading 4.5) and even though they are presented here to ensure homogeneity in the presentation, there is no double accounting for these emissions in the inventory.

⁸ This publication is available until 2002.

Table 4.7.1.- Pollutant emissions

	1990	1995	2003	2004	2005	2006	2007
CO ₂ (Gg)	610	610	641	649	662	682	676
CF ₄ (t)	122.2	114.0	26.4	25.4	20.2	18.9	17.6
C ₂ F ₆ (t)	9.6	9.9	2.0	1.9	1.3	1.3	1.0

Table 4.7.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	1,493	1,442	831	831	805	816	800
CO ₂ -eq Index	100.0	96.6	55.6	55.7	53.9	54.6	53.5
% CO ₂ -eq of total	0.52	0.45	0.20	0.20	0.18	0.19	0.18
% CO ₂ -eq on industrial processes	5.67	5.26	2.54	2.53	2.35	2.33	2.29

4.7.2.- Methodology

For the estimation of PFC emissions, we have opted to use the Tier 2 method referred to in the IPCC 2000 Good Practice Guidance, Heading 3.3 (equation 3.10 and Chart 3.3 “Tabereaux approach”), shown below:

$$\text{kg CF}_4 \text{ o C}_2\text{F}_6/\text{tonne Al} = 1,698 \cdot (p/\text{CE}) \cdot \text{AEF} \cdot \text{AED} \quad [4.7.1]$$

where

- p** = Average fraction amount of CF₄ or C₂F₆ generation (respectively) in the pot gas during anode effects.
CE = Current efficiency expressed as a fraction, rather than a percentage
AEF = Number of anode effects per pot day
AED = Anode effect duration in minutes

For the application of the above formula, the default values for the “*slope*” variable ($\text{slope} = 1.698 (p/\text{CE})$) from the IPCC 2000 Good Practice Guidance (Heading 3.3.1, Table 3.9) have been used together with the information on the “*AEF*” and “*AED*” variables furnished by the manufacturing plants through a specific questionnaire designed to that effect, distinguishing between the manufacturing method applied by plant and by series (side-worked and centre-worked pre-baked anodes and the vertical stud Söderberg process). Within each series, information is received on the anode effect frequency by cell and day and also of the anode effect duration in minutes. The *slope* variable coefficients by default, expressed in (kg_{PFC}/t aluminium) / (anode effect minutes/cell-day) are as follows:

Technology	CF ₄	C ₂ F ₆
Pre-baked Anodes. Centre-worked	0.14	0.018
Pre-baked Anodes. Side-worked	0.29	0.029
Söderberg. Vertical stud	0.068	0.003
Söderberg. Horizontal stud	0.18	0.018

Regarding the estimation of CO₂ emissions, the methodology used has been that proposed by the International Aluminium Institute (IAI) in its document entitled "Greenhouse Gas Emissions Monitoring and Reporting by the Aluminium Industry" (please refer to the bibliography) in accordance with the methodology suggested by "The Greenhouse Gas Protocol: a corporate accounting and reporting standard" (October 2001), prepared by the *World Business Council for Sustainable Development* (WBCDS) and the *World Resource Institute* (WRI). This methodology uses estimation procedures based on the balance of materials in CO₂-emitting sources during the aluminium manufacturing process. Specifically, and with regard to the situation at factories in Spain, the following procedures have been applied:

a) Pre-baked Anodes

a.1.- CO₂ emissions from the anode during electrolysis

$$\text{Emission CO}_2 \text{ (t)} = \text{NCC} \cdot \text{MP} \cdot (100 - S_a - \text{Ash}_a - \text{Imp}_a)/100 \cdot 44/12 \quad [4.7.2]$$

where

NCC	=	Net anode consumption (t anode / t aluminium)
MP	=	Aluminium production (tonnes)
S _a	=	Sulphur content in baked anode (%)
Ash _a	=	Ash content in baked anode (%)
Imp _a	=	Fluorine and other impurities in the baked anode (%)

a.2.- CO₂ emission from anode in furnace (volatile materials)

$$\text{Emission CO}_2 \text{ (t)} = (\text{GAW} - \text{BAP} - \text{HW} - \text{RT}) \cdot 44/12 \quad [4.7.3]$$

with

$$\text{HW (t)} = \text{H}_2/100 \cdot \text{PC}/100 \cdot \text{GAW}$$

where

GAW	=	Green anode weight (tonnes)
BAP	=	Baked anode production (tonnes)
HW	=	Weight of hydrogen from pitch (tonnes)
H ₂	=	Hydrogen content in pitch (% by weight)
PC	=	Average pitch content in green anodes (% by weight)
RT	=	Recovered tar (tonnes)

a.3.- CO₂ emission from anode in kiln (from packaging coke)

$$\text{CO}_2 \text{ Emission (t)} = \text{PCC} \cdot \text{BAP} \cdot (100 - \text{Ash}_{\text{PC}} - S_{\text{PC}})/100 \cdot 44/12 \quad [4.7.4]$$

where

PCC	=	Packing coke consumption per tonne of baked anode (coke t/ anode t)
BAP	=	Baked anode production (tonnes)
S _{PC}	=	Sulphur content in packing coke (% by weight)
Ash _{PC}	=	Ash content in packing coke (% by weight)

b) Söderberg Paste

Methodology: IAI for Söderberg paste

$$\text{CO}_2 \text{ emission (t)} = [(\text{PC} \cdot \text{MP}) - (\text{BSM} \cdot \text{MP}/1000) - [\text{BC}/100 \cdot \text{PC} \cdot \text{MP} \cdot (\text{S}_p + \text{Ash}_p + \text{H}_2)/100] - [(\text{100} - \text{BC})/100 \cdot \text{PC} \cdot \text{MP} \cdot (\text{S}_c + \text{Ash}_c)/100]] \cdot 44/12 \quad [4.7.5]$$

where

PC	=	Net paste consumption (t paste / t aluminium)
MP	=	Aluminium production (tonnes)
BSM	=	Emissions of benzene soluble matter (kg / t aluminium)
BC	=	Average binder content in paste (% by weight)
S _p	=	Sulphur content in pitch (%)
Ash _p	=	Ash content in pitch (%)
H ₂	=	Hydrogen content in pitch (%)
S _c	=	Sulphur content in calcinated coke (%)
Ash _c	=	Ash content in calcinated coke (%)

Parameter values included in the above formulas have been provided through questionnaires completed by the manufacturing plants themselves. However, it is worth pointing out that for the pre-baked anodes process, it has only been possible to obtain values for parameters corresponding since 2003 (with some exceptions) and values in 2003 have been assumed for the period 1990-2002.

On the other hand, in 2001, the series of side-worked pre-baked anodes disappeared from the plants and they were replaced by a new series of centre-worked pre-baked anodes with a considerably smaller number of anode effects by pot and day (AEF parameter in formula [4.7.1]), bringing about a decrease in emissions from 2001 on with respect to previous years.

Table 4.7.3 presents aluminium production, directly provided by the manufacturing plants themselves. Information on process parameters is not given here as this is confidential since all the plants belong to a single company.

Table 4.7.3.- Aluminium production (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
355,301	361,492	389,447	394,863	397,203	400,349	405,061

4.7.3.- Uncertainty and consistency over time

Given that primary aluminum production information is available not only at the plant level but also with broken down by the type of technology used, it is estimated that the overall uncertainty applicable to PFC emissions estimations may be around 20%. This figure is obtained as a result of combining the activity-variable uncertainty of approximately 1% with an average emission-factor uncertainty of around 20%, the latter being inferred from the technology and gas uncertainties indicated in Table 3.9 in the IPCC 2000 Good Practice Guidance.

As regards CO₂ emissions, it is estimated that emissions uncertainty may be around 5.8%, assuming uncertainties of 3% for the activity variable and 5% for the emission factor.

With regard to time patterns, the series is considered consistent since it covers all the plants in the sector over the period inventoried and because the information comes directly from the plants, both in relation to the activity variable as well as the parameters used in the emission estimation algorithms.

4.7.4.- Quality assurance and verification

Among the quality assurance activities within this category, the monitoring performed on the inter-annual oscillation in the carbon content emitted as CO₂ with respect to the incoming and outgoing carbon should be emphasized. In the presence of atypical values in any year, the causes and possible reasons for their appearance are investigated in conjunction with the plants in the sector or with the business association, effecting any corrections that may occasionally be necessary.

It is noted that the estimation method currently applied is that corresponding to Tier 2. Formerly, up to the inventory edition covering the period 1990 to 2002, the estimation method reported was Tier 3b. As this issue has been examined in detail with the experts of the only primary aluminium manufacturing company in Spain, it has been considered that the most feasible option consisted in using, for the *slope* parameter, the default values suggested by the IPCC Good Practice Guidance, since the estimation of the *slope* produced previously using technology-specific values from each plant showed a range of erratic results that implied a higher degree of imprecision in PFC emission factor estimation. It was therefore decided that the methodology classification should move from tier 3b to tier 2.

4.7.5.- New calculations

No new calculations have been performed on this activity.

4.7.6.- Improvement plans

No specific actions are anticipated with respect to emission estimations from this category.

4.8.- HCFC-22 manufacture (2E1)

4.8.1.- Description of the activity

Within the scope of this activity, HFC-23 emissions resulting as a sub-product of the production of HCFC-22 are considered. Throughout the period inventoried, three HCFC-22 manufacturing plants have been operating either partly or for the entire period.

Table 4.8.1 details the HFC-23 emissions for this activity, and it is this gas that makes this a key source. Table 4.8.2 shows these emissions in terms of CO₂-eq. The same table gives the time evolution index (100 in base year 1995) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category to the totals for the inventory and the "Industrial Processes" sector.

Table 4.8.1.- HFC-23 Emissions (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
205.4	396.4	134.4	38.8	28.5	44.1	36.1

Table 4.8.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	2,403	4,638	1,572	454	334	517	423
CO ₂ -eq Index	100.0	193.0	65.4	18.9	13.9	21.5	17.6
% of CO ₂ -eq over total	0.83	1.45	0.38	0.11	0.08	0.12	0.10
% CO ₂ -eq on industrial processes	9.13	16.92	4.81	1.38	0.97	1.48	1.21

4.8.2.- Methodology

The information on HFC-23 emissions is based on the estimations made by the centres themselves, supplemented by a default emission factor for the years 1990-1998 when the corresponding estimation by the plants has not been available. Therefore, the estimation methodology applied in this case is a combination of Tier 1 and Tier 2 methods using IPCC terminology.

No information on activity variables and process parameters is given here since this is confidential as the plants are currently owned by only two companies.

It is also worth mentioning that one of the plants has experienced an emission decrease since 2001 due to the building and commissioning of an installation to reduce HFC-23 emissions by means of compression, condensation, liquefaction and storage. Liquefied HFC-23 is loaded on cisterns and sent to an external handler for processing.

4.8.3.- Uncertainty and consistency over time

In accordance with the IPCC 2000 Good Practice Guidance, the uncertainty for HFC-23 emission estimations with the Tier 1 method is around 50% while the uncertainty for the Tier 2 method ranges from 1 to 2% with a 95% confidence interval. As a whole, and considering the supplemental information provided by experts in the sector, the uncertainty of the estimated emissions can be considered to be between 25 and 30%.

With regard to the time patterns, the activity variable is consistent since the information always comes from the manufacturing plants themselves. For the emission factors, as was already mentioned, it should be remembered that for the first years in the series, the estimation had been made by applying default emission factors, while for the subsequent years, all the information has been based on measures taken and provided by the plants themselves, and considering the emission abatement technologies introduced.

4.8.4.- Quality assurance and verification

Among the quality control activities within this category, the monitoring of the emission estimations provided by the plants themselves is worth mentioning, together with analysis of the HFC-23 collected for subsequent treatment in relation to the HCFC-22 production, with the purpose of detecting possible anomalies in the information presented.

4.8.5.- New calculations

No new calculations have been performed on this activity.

4.8.6.- Improvement plans

It has been planned to study, together with the two manufacturing firms, an assessment of how uncertainty has changed over time.

4.9.- Consumption of halocarbons and SF₆ (2F)

4.9.1.- Description of the activity

This group includes CRF category 2F activities producing HFC or PFC emissions, which correspond to refrigeration and air conditioning (2F1), plastic foam (2F2), fire fighting (2F3) and aerosols (2F4). SF₆ emissions in electrical equipment are not included here.

Table 4.9.1 shows the emissions for each type of gas in each of these activities. Considering that the use of these gases was marginal prior to 1995 and, therefore, the associated emissions were much reduced, the series is shown for the period 1995-2007. Table 4.9.2 gives these emissions expressed in CO₂-equivalent. The same table gives the time evolution index (100 in base year 1995) of the CO₂-eq emissions, and the contributions

of the CO₂-eq emissions in this category to the totals for the inventory and the “Industrial Processes” sector.

Table 4.9.1.- HFC and PFC emissions (Amounts in tonnes)

Category	Gas	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
2F1	HFC-125		3.7	10.4	19.1	29.6	41.6	53.9	66.3	78.7	91.2	103.8	116.3	129.0
	HFC-134a		58.8	139.5	259.8	412.4	576.1	737.6	903.1	1,078.4	1,245.5	1,416.3	1,587.9	1,748.3
	HFC-143a		4.3	12.2	22.3	34.4	48.3	62.7	77.0	91.5	106.0	120.5	135.1	149.8
	C ₃ F ₈		0.5	1.4	2.6	4.0	5.6	7.2	8.9	10.6	12.3	13.9	15.6	17.3
2F2	HFC-134a									9.3	65.7	77.9	76.7	72.0
	HFC-152a									177.5	186.7	170.2	113.4	89.2
2F3	HFC-23					0.1	0.2	0.3	0.7	4.0	9.3	10.9	14.8	16.7
	HFC-125	0.8	1.4	2.8	5.2	8.4	12.3	16.9	21.9	28.1	39.6	49.9	58.4	73.0
	HFC-227ea	0.3	0.6	2.7	6.2	15.7	33.2	51.6	67.5	86.7	100.4	108.2	112.5	121.9
	HFC-236fa					0.2	0.4	0.7	0.9	1.2	1.4	1.7	1.9	2.1
	C ₄ F ₁₀	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6
2F4	HFC-134a	1.6	3.4	3.6	93.7	204.2	230.1	220.2	159.9	124.7	138.7	121.9	98.7	94.8

Table 4.9.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	-	8	3,361	3,983	4,426	4,799	5,255
CO ₂ -eq Index	-	100.0	42,511.0	50,375.3	55,989.6	60,708.8	66,472.8
% of CO ₂ -eq over total	-	0.002	0.82	0.93	1.00	1.11	1.19
% CO ₂ -eq on industrial processes	-	0.03	10.27	12.12	12.90	13.71	15.08

4.9.2.- Methodology

The methodological specifications used for the emission estimates of each of the activities contemplated are presented below.

a) Refrigeration and air conditioning

For this sector, the information was obtained in some years from cooling and air conditioning business associations and, in connection with their use in the automobile industry, from information obtained by means of a questionnaire filled in by the vehicle manufacturing plants. In the first case, i.e. for stationary cooling and air conditioning devices, the inventory work team has extended the year-on-year variation rates to supplement the last years of the series, since no other information was available for this edition of the inventory. The emission factors, with respect to the national production of vehicles, are derived from the information obtained through questionnaires sent to the manufacturing plants, and for the rest of the sub-sectors, they have been taken from the IPCC guidelines.

The emission estimation methodology has been based on that described in Section 2.17.4.2 of the IPCC 1996 Reference Handbook and in Sections 3.7.4 and 3.7.5 of the IPCC 2000 Good Practice Guidance. According to these references, emissions may originate in the assembly, operation and disposal of the equipment. Each of these stages corresponds to

a separate emission calculation algorithm. The total emission will result from the addition of the emissions produced in each of the three stages.

b) Plastic foam

HFCs began to be used for plastic foam in 2003 as a replacement for other fluorinated gases that deplete the ozone layer. Information has been provided by the Technical Association for Applied Polyurethane (Asociación Técnica del Poliuretano Aplicado, ATEPA) in the case of rigid polyurethane foams, and by the Iberian Extruded Polystyrene Association (Asociación Ibérica de Poliestireno Extruido, AIPEX). Based on this information, the stock of each type of gas existing in each year has been calculated for each of these sub-sectors.

In order to estimate this sub-category's emissions, the IPCC Tier 2 method has been applied with the default emission factors appearing in Table 7.6 of the 2006 IPCC Guidance for the Greenhouse Gases Inventories. In the case of polyurethane (applied in closed cells), reference has been made to this table also provided the 12.5% emission factor for the first year and 2.5% for annual losses of the remaining gas stock, following the indications of experts in the sector. For extruded polystyrene, the emission factor taken in the case of HFC-134a is 25% for the first year and 0.75% for the annual loss from the stock of gas remaining; whereas the emission factor for HFC-152a is 50% in the first year and 25% for the stock of gas remaining.

c) Fire fighting equipment

With regard to fire-fighting, the information on the quantity of fluorinated gases consumed during maintenance and ex novo installation of fire extinguishing equipment has been obtained through a questionnaire sent to the main firms in the sector, making a distinction between fixed and portable devices. In relation to these data on activity variable, the inventory work team has extrapolated the information to give a total for the sector based on estimations of coverage from the reporting companies.

Taking the above information (quantity reported or estimated of HFC and PFC incorporated) into account, the stock present by year and type of gas stored in the equipment used for this activity has been estimated. The stock existing each year is the indicator taken as the socio-economic activity variable and is shown in Table 4.9.3.

Table 4.9.3.- HFC and PFC stored in fire-fighting equipment (Amounts in tonnes)

GAS	1990	1995	2003	2004	2005	2006	2007
HFC-23	-	5.200	1,733.906	2,007.283	2,164.673	2,250.037	2,437.464
HFC-125	-	-	79.740	185.967	217.897	295.019	333.503
HFC-227ea	-	16.605	562.147	791.959	997.038	1,167.954	1,460.645
HFC-236fa	-	-	23.845	28.653	33.221	37.561	41.685
C ₄ F ₁₀	-	1.000	9.085	9.830	10.539	11.213	11.855

For emissions estimation purposes, it has been assumed that, as per Section 2.17.4.4 of the IPCC 1996 Reference Manual and Section 3.7.6 of the IPCC 2000 Good Practice Guidance, the annual emission factor is 5% of the amount of gas stored in fire-fighting equipment each year.

d) Aerosols

Regarding the use of HFC and PFC as aerosol propellants, the information on activity variable (gases incorporated in aerosol devices) has been provided by the Spanish Aerosol Association (AEDA). This information includes:

- Amounts packed by type of package (national production + imports):
 - With inhaler and dosage meter
 - Others (Use in personal hygiene, domestic and industrial applications, and general use products)
- Amounts exported

From these information blocks, the “Apparent Consumption” series has been created as an algebraic sum of the national production + imports - exports. This apparent consumption series, as presented in Table 4.9.4, is taken as the activity variable for the emission estimation. The observation of this table provides evidence that the only type of gas used in aerosols sold in Spain is HFC-134a.

It is interesting to observe that according to the AEDA’s own source, the increase observed in HFC-134a consumption since 1998 with respect to previous years was due to the application of Directive 94/48, which came into effect in 1997 and prohibits decorative and festive products from containing flammable propellants, forcing manufacturers to replace them with HFC-134a.

Table 4.9.4.- Consumption of HFC for aerosol propellants (Amounts in tonnes)

HFC	1990	1995	2003	2004	2005	2006	2007
HFC-134a	-	3.240	134.624	142.871	100.886	96.477	93.215

Aerosol gases are released a short time after production: an average of 6 months after sale. The level of emission of injected gas in an aerosol is 100%. In line with the above information and Section 2.17.4.5 of the IPCC 1996 Reference Manual and Section 3.7.1 of the IPCC 2000 Good Practice Guidance, it is assumed that 50% of the emissions occur during the year the product is sold and the remaining 50% during the following year, thus considering an average 6-month span from sale to use. The emissions may be estimated by multiplying the number of aerosols sold in a year by the average unit charge of each specific gas (HFC or PFC) contained in a typical package. The presence of abatement technologies for these emissions is not considered.

There is no “Tier” classification for the estimation methodologies in this sector in the IPCC 2000 Good Practice Guide, and the one applied here is that proposed as the default methodology in the IPCC 1996 Reference Manual.

4.9.3.- Uncertainty and consistency over time

As regards the activity variable, we should differentiate between the significantly higher uncertainty of the cooling and air conditioning sub-sector and that present in the rest of the

activity sub-sectors mentioned above. Altogether, they indicate an uncertainty estimation of around 100%. A similar value can be assigned to the uncertainty for the emission factor of the combined sub-sectors under consideration.

As regards the time patterns, the limitations present during the last few years deserve a mention when considering HFC and PFC consumption data, mainly in the chilling and cooling sector, where the activity variable has had to be estimated through extrapolation procedures.

4.9.4.- Quality assurance and verification

In those sub-sectors where the base information is not comprehensive, quality has been monitored through the corresponding extrapolation of samples to the entire population, meaning that, based on the production coverage of firms furnishing data with respect to their coverage in relation to the total of the sub-sector, an emission estimation is eventually derived to represent the total coverage of the sector (particularly in the case of fire-fighting equipment and the charging phase for fluorinated gases in air conditioning equipment at vehicle manufacturing plants).

4.9.5.- New calculations

No new calculations have been performed on this activity.

4.9.6.- Improvement plans

Among improvement objectives, the review of activity variables and parameters involved in the emission estimation algorithm in the chilling and air-conditioning sub-sector are considered priorities for both stationary and portable equipment.

4.10.- SF₆ in electrical equipment (2F8)

4.10.1.- Description of the activity

SF₆ is used as an insulator in electrical equipment, since it presents efficiency advantages as an insulator practically irreplaceable in equipment working with very high voltages (over 52 kV); although it is also used in equipment for lower voltages, in which case it competes with other insulating procedures such as: oil-filling, vacuum or air cut. The mean SF₆ charge in electrical equipment depends on the size and functionality of the equipment to be insulated, which may vary between hundreds and thousands of kilograms in equipment working at voltages of 52 kV or higher, while in low-voltage equipment, the charge may range between 1 and 2 kilograms. The amount of accumulated SF₆ in electrical equipment may be calculated, depending on the different types of equipment, by adding together the number of devices included in each category by the typical charge of the equipment representing the category. In the case of Spain, this is the only source that has been identified as an SF₆ emitter.

This category's contribution to the total of CO₂-eq emissions in the inventory is not significant (see Table 4.10.2) and it does not constitute a key source for its emission level during the period inventoried, though it is a key source in 1990 due to its contribution to the trend.

Table 4.10.1 details the F₆ emissions for this activity, and it is this gas that makes this a key source. Table 4.10.2 shows these emissions in terms of CO₂-eq. The same table gives the time evolution index (100 in base year 1995) of the CO₂-eq emissions, and the contributions of the CO₂-eq emissions in this category to the totals for the inventory and the "Industrial Processes" sector.

Table 4.10.1.- SF₆ Emissions (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
2.80	4.53	8.69	10.63	11.37	13.54	14.22

Table 4.10.2.- CO₂-eq Emissions: absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CO ₂ -eq (Gg)	67	108	208	254	272	324	340
CO ₂ -eq Index	61.8	100.0	191.7	234.4	250.7	298.7	313.8
% of CO ₂ -eq over total	0.02	0.03	0.05	0.06	0.06	0.07	0.08
% CO ₂ -eq on industrial processes	0.25	0.40	0.63	0.77	0.79	0.92	0.98

4.10.2.- Methodology

Generally speaking, emissions may be generated in each of the following stages during the lifetime of electrical equipment containing ₆ insulation.

- 1) At the equipment manufacturing stage (including testing and charging operations).
- 2) During installation in the place where the equipment will operate.
- 3) During the equipment operating stage.
- 4) During the de-commissioning of the equipment.

These four points or stages in the lifetime of emissions-generating equipment correspond with the respective four terms that appear in the second element of the following equation [4.10.1], the transcription of Equation 3.16 in the IPCC Good Practice Guidance corresponding to the Tier 2a method, the one adopted for this activity emission estimation.

$$ET = EF + EI + EO + ER \quad [4.10.1]$$

where:

ET = Total Emissions

EF = Manufacturing Emissions

EI = Installation Emissions

EO = Equipment Operation Emissions

ER = Equipment Removal Emissions

For the specific application of the estimation method, the above terms have been quantified as follows:

- a) For the first two terms, the estimations considered were those provided by the SERCOBE (Equipment Manufacturers National Association) and shown in Table 4.10.3 below.

Table 4.10.3. – Estimation of SF₆ losses at manufacturing and installation stages
(Amounts in tonnes)

	1990	1995	2003	2004	2005	2006	2007
Manufacturing losses	-	1.006	2.840	3.333	3.160	3.363	3.010
Installation losses	-	0.055	0.107	0.270	0.090	0.080	0.120

- b) For the third term, a loss factor is applied to the accumulated stock of SF₆ in electrical equipment. The accumulated stock has also been provided by SERCOBE, drawing a distinction between medium and high voltage equipment (please refer to Table 4.10.4). For medium-voltage equipment, which are sealed, emissions in the operating stage are minimal or non-existent, while in high-voltage equipment, which are closed, emissions are comparatively higher. In line with the above, the emission factor selected for high voltage equipment has been 2% on an annual basis, the factor appearing in Equation 3.17 (corresponding to a Tier 2b approach) in Section 3.5 of the IPCC Good Practice Guidance, while for medium voltage equipment, after consultations made with experts in the sector, an emission factor of 0.2% per annum has been taken.
- c) As for the fourth element, the amount emitted during the decommissioning proper of the equipment is unknown. Notwithstanding, the number of items decommissioned is known, which in turn represent a stock of SF₆ in equipment taken out of service (awaiting final disposal and possible recovery of part of the gas). For this reason, the contribution of this term has been calculated by applying the same annual loss coefficient as for operational equipment (2%) to the estimated stock of SF₆ in decommissioned equipment withdrawn from service (please refer to Table 4.10.4).

Table 4.10.4.- Estimation of SF₆ stored in electrical equipment (Amounts in tonnes)

	1990	1995	2003	2004	2005	2006	2007
Operating equipment							
High voltage	139.900	169.600	241.400	297.504	342.104	436.110	475.350
Medium voltage	1.000	40.000	389.100	469.120	568.530	619.554	725.654
Decommissioned equipment	-	-	6.772	6.816	6.816	6.816	6.816

4.10.3.- Uncertainty and consistency over time

In the aggregate, and with regard to the emission factor, it is estimated that uncertainty might be around 30% (a higher value than those suggested for manufacturing and installation losses in Europe in Table 3.13 of the IPCC 2000 Good Practice Guidance. As regards the existing SF₆ stock, uncertainty could be around 20%, and a similar uncertainty could be estimated for the emission factor for leakages during operation.

In terms of consistency over time, it is interesting to differentiate the various components contributing to emissions. Thus, on the one hand, the manufacturing and installation losses reported by SERCOBE are derived from direct data and are considered homogeneous over time (however for 2006 there was a need to estimate the manufacturing and installation losses of a company that stopped reporting information to SERCOBE). With respect to the estimation of SF₆ stock in operating equipment, it should be noted that the series with direct information from 1995 to 2007 had to be extended by extrapolation to cover the initial years of the series (1990-1994), although the procedure is considered to produce a homogeneous series.

4.10.4.- Quality assurance and verification

The coverage is considered exhaustive when concerning the estimation of SF₆ manufacturing and installation losses and the emissions of operating equipment. However, regarding the decommissioning of equipment, by not having the necessary information, a estimation of emissions was kept as if the decommissioned equipment was stored and remained emitting the same rates as the operating equipment.

4.10.5.- New calculations

No new calculations have been performed on this activity.

4.10.6.- Improvement plans

As improvement actions, it is planned to include the potential emissions deriving from the equipment maintenance stage and, on the other hand, to gather specific information on equipment decommissioning management systems, including information on efficiency in SF₆ collection and its subsequent treatment, if any. In this sense, work is under way with SERCOBE, the electricity production, transmission and distribution companies, and with the main industrial sectors consuming high-voltage power.

4.11.- Other sources

Following CRF sources nomenclature, some other activities are considered which, though not inventory key sources, are included under the Industrial Processes heading. Some of the main "Other Sources" in this group are mentioned below:

- Category 2A2 includes emissions produced in decarbonation processes during the manufacture of lime and calcined dolomite. The information has been provided by the National Association of Lime and Derivatives Manufacturers of Spain (ANCADE)⁹. Additionally, direct information on lime production at integrated iron and steel plants has been available during the period 1990-1992.

The CO₂ emission factors suggested in the 1996 IPCC Reference Handbook (Table 2.2) are 790 and 910 kg CO₂/t of calcined material depending on whether it is calcite or dolomite. In order to make the emission estimation, however, we have used the methodology applied by the lime manufacturing sector association (ANCADE), starting from the amounts of finished product (quicklime or calcined dolomite) and their final degree of purity, since a correction has to be added to the CO₂ stoichiometric emission factor per tonne of quicklime or dolomite produced depending on the final product's degree of purity, i.e. the stoichiometric factor is applied to the tonnes of product once impurities are discarded.

CO₂ Emission = Production (t) · % Purity · CO₂ stoichiometric emission factor

The degree of purity is a characteristic of each installation and operating year, while the stoichiometric ratio is a fixed value for all installations and years (785 kg CO₂/t product for quicklime and 913 kg CO₂/t product for calcined dolomite). When the degree of purity of an installation is unavailable, the same degree of purity in the available information for the nearest year has been applied for the installation in question or, if necessary, the standard values recommended in "The Greenhouse Gas Protocol: a corporate accounting and reporting standard" (October 2001), developed by the *World Business Council for Sustainable Development* (WBCDS) and the *World Resource Institute* (WRI) (93% for quicklime and 95% for calcined dolomite).

For the production of lime in other industries and, considering that the manufacturing process differs from that used in the building industry, we have opted to use the emission factor (790 kg CO₂/t lime) suggested in the 1996 IPCC Reference Handbook mentioned above.

Although the coverage of production figures is presumably complete for the country as a whole (intermediate + final production), it is planned to carry out further investigation in case there may be activity centres unaccounted for with intermediate production previously.

- Halocarbon and SF₆ production, but for the manufacture of HCFC-22 (categories 2E2 and 2E3).

⁹ For companies that are not members of ANCADE, production is approximate as per estimations made by this association.

Within this category it is also included the fugitive emissions from the manufacturing of HFC-134a, HFC-227ea and HFC-32, which are the only kind of HFC that is produced in Spain. The emissions' estimation is made for the productions of HFC-143a and HFC-227ea by applying the default emission factor (0.5%) suggested by Section 2.16.2 of the IPCC 1996 Reference Manual regarding production of the considered HFC component. Only quantitative estimations were made available, provided by one of the plants in 2003, and for that reason, the use of this estimation would not be homogenous over time for the whole period. Regarding the production of HFC-32, the estimations of emissions from associated gases (HFC-23 and HFC-32) were made available. These were provided by the only HFC-32 production plant that began production in 2002, having incorporated said estimations in the inventory. The applied estimation methodology is therefore Tier 1 for the productions of HFC-143a and HFC-227-ea and Tier 2 for the production of HFC-32.

Finally, it is necessary to add two clarifications with respect to the list of activities appearing in CRF Reporter under category 2A7. First of all, the "*Glass production*" activity was estimated in editions prior to that sent in 2007 by applying a default emission factor to the tonnes of glass produced. Since the dispatch of the 2007 edition, the emissions have been estimated on the basis of the carbonates and reduction agents used in this industry, with these emissions being included in other activities of category 2A (specifically 2A3, 2A4 and 2A7). Secondly, it should be mentioned that the activity called "*Magnesia production*" should be interpreted as "*Magnesium carbonate*" since it is related to CO₂ emissions produced by decarbonation of this compound in glass and magnesite production (the activity variable is the amount of magnesium carbonate used and not the magnesium production).

5.- USE OF SOLVENTS AND OTHER PRODUCTS

5.1.- Sector panorama

Emissions in the use of solvents and other products make up a relatively minor source of emissions of greenhouse gases in the inventory. This is largely due to the contribution towards final CO₂ from immediate NMVOC emissions. This type of emissions represents 0.38% of total emissions in the inventory for 2007, as expressed in CO₂ equivalent. This shows a reduction when compared to 1990, when these emissions accounted for 0.48% of total emissions. On the other hand, CO₂-equivalent emissions in this sector registered a 20.6% increase in 2007 with respect to 1990, from 1,388 gigagrammes (Gg) of CO₂-equivalent in 1990 to 1,674 Gg in 2007. Table 5.1.1 shows emissions stemming from the use of solvents and other products in CO₂-equivalent terms, whilst Figure 5.1.1 shows the evolution of these emissions during the period 1990-2007.

Table 5.1.1.– CO₂-equivalent emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
3. Use of solvents and other products	1,388	1,344	1,596	1,518	1,482	1,517	1,674

Figure 5.1.1.– Evolution of CO₂-equivalent emissions

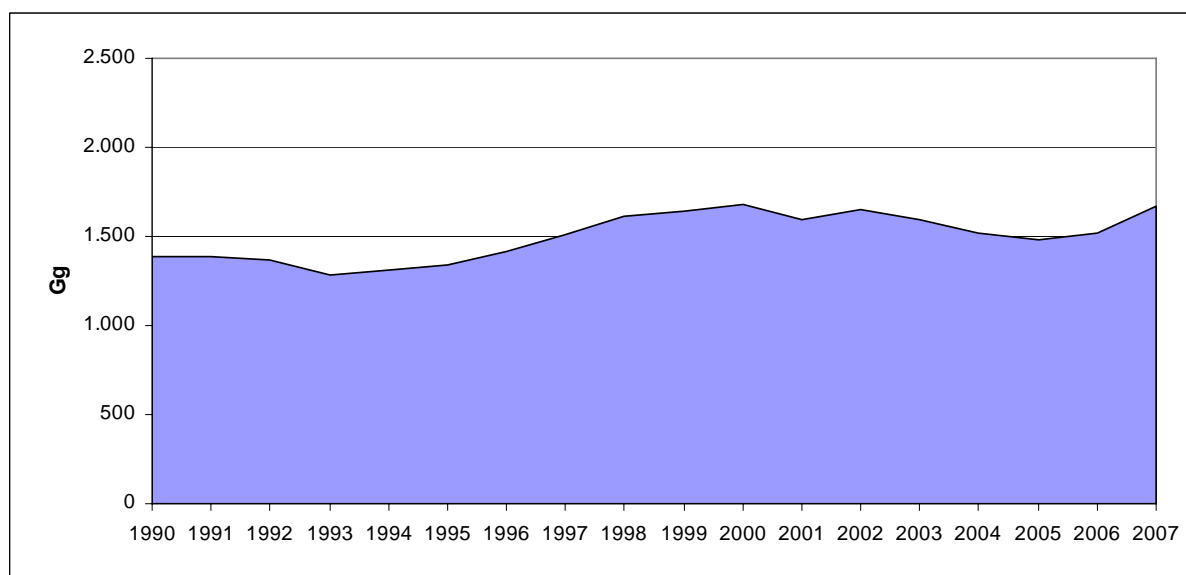
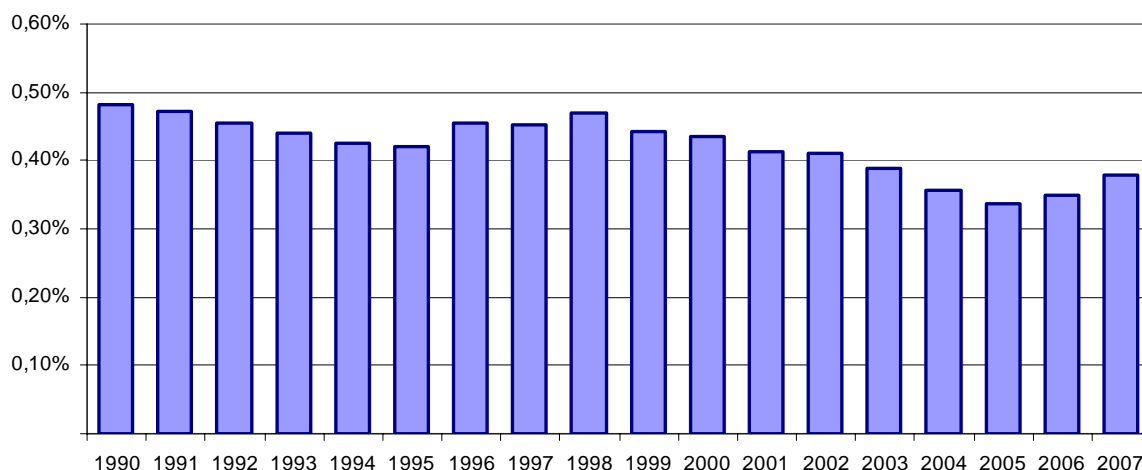


Figure 5.1.2 below shows that the relative importance of this category in the inventory is minimal (less than 0.5% during the period inventories): This is however a key source for the period 1994-1995 due to the trend in its CO₂ emissions, although its contribution to the trend in those years is less than 0.7%.

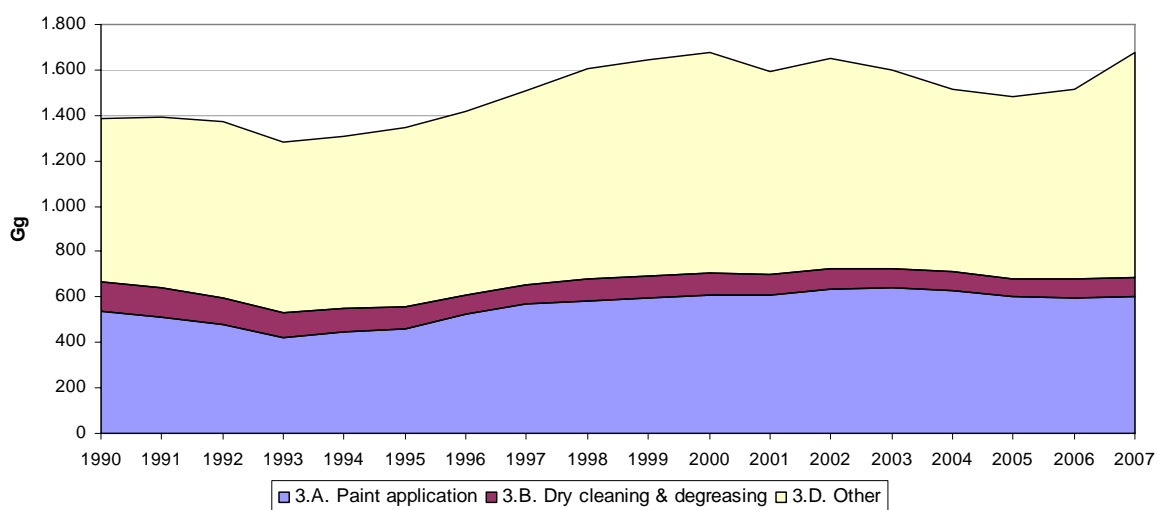
Figure 5.1.2. – Percentage of CO₂-equivalent emissions by category in relation to the inventory total



Explanation of the trend

The trend in CO₂-equivalent emissions for this sector is determined in order of importance by subcategories 3D (Other Uses of Solvents and N₂O, and Related Activities), 3A (Paint Application), and 3B (Dry Cleaning and Degreasing). Figure 5.1.3 below shows the evolution of CO₂-equivalent emissions for these subcategories.

Figure 5.1.3.- Evolution of CO₂-eq emissions



For subcategory 3D the main contribution originates from the use of N₂O for anaesthesia. This variable shows a sharp decrease from 2002, with an increase in 2006 that is more marked in 2007). This has a remarkable influence on the overall trend for this

category, as the contribution of this activity towards CO₂-equivalent emissions ranges from 16.4% to 32.0% throughout the inventoried period. As regards paint application activities (subcategory 3A) there is a decline in the consumption of paint for the period 1990-1993, followed by a later increase sustained until 2004, a slight decline in 2005, continuing with an upward trend in consumption from 2006 on. The increase in consumption is however offset by the reduction in the amounts of volatile organic compounds in paint (greater use of water-based paint instead of solvent-based paint), with a clear incidence on NMVOC emissions, leading to a fall in emissions despite the higher paint consumption.

5.2. Use of solvents and other products (3)

5.2.1.- Description of the activity

This sector comprises a heterogeneous group of categories with processes prioritizing the use of non-methane volatile organic compounds (NMVOC), which translate into final CO₂ emissions, as well as other products that have a direct warming potential (N₂O and eventually CO₂ immediate emissions, although the latter has not previously been reflected in this inventory category).

With respect to NMVOC, the emissions generated in the following categories are relevant:

- 3A Paint application
- 3B Dry cleaning and degreasing
- 3C Manufacturing and processing of other chemicals
- 3D Others – Use of solvents and N₂O and related activities

It is important to note that, in accordance with the unified methodology of the IPCC and EMEP/CORINAIR, the calculation of greenhouse gas emissions in this sector includes, as well as the immediate calculation of the CO₂ and N₂O emissions, the final CO₂ emissions stemming from the oxidation of emissions (immediate) of NMVOC corresponding to categories 3A, 3B and 3D.

As for the use of N₂O, it is worth mentioning that only the use of this gas in anaesthesia has been identified as a key emission source in the Spanish inventory, and said activity is included in Category 3D.

5.2.2.- Methodology

For NMVOC, the methodology applied for the estimation of emissions is essentially that of EMEP/CORINAIR, supplemented by contributions and inquiries made to the IIASA and EGTEI¹.

¹ IIASA: International Institute for Applied Systems Analysis.
EGTEI: Expert Group on Technical-Economic Issues.

With respect to specific issues, it should be noted that for some particularly relevant emission sources, the information has been obtained and processed at individual plant level (as in the case of vehicle manufacturing plants). For the remaining emission sources, a vast proportion of the data on activity variables comes from the corresponding business associations, among which the following should be identified: the Spanish Association of Manufacturers of Paint and Printing Dyes (ASEFAPI); the Spanish Chemical Industry Federation (FEIQUE); the Spanish Confederation of Plastics Businesses (ANAIP); Technical Association of Applied Polyurethane (ATEPA); National Association for Expanded Polystyrene (ANAPE); Industry Association of Rigid Polyurethane (IPUR); National Consortium of Rubber Manufacturers (COFACO); National Association of Companies for the Fostering and Extraction of Oleaginous Substances (AFOEX). National Association of Wood Protection Companies (ANEPROMA). Likewise, in the case of some activities, general statistical information such as population was obtained from the Spanish National Statistics Institute (INE), the Industrial Survey (from the INE) or the publication entitled "The Chemical Industry in Spain" from the Ministry of Industry, Tourism and Trade (MITYC).

As for emission factors, the methodology used attempts to quantify the NMVOC content in solvents and other products containing these substances. Where appropriate, the corresponding reduction factors are incorporated for the different applications and emissions abatement techniques used. More specifically, in the case of paint application, the differentiation between the different types of paint (water-based, solvent-based, etc.) is particularly relevant. As and when information on the development of these techniques over time is available, the factors are shown on an annualized basis.

The case of vehicle manufacturing plants deserves special mention, as each manufacturing plant received individualized treatment through the gathering of information on the amounts of concentrate and solvent used, their VOC content during the different phases of the paint lines and production process, as well as during the recovery and disposal processes installed at each centre, so that the emissions are estimated by mass balance.

Once the immediate NMVOC emissions are determined, their final conversion to CO₂ is performed using the following algorithm:

$$\text{CO}_2 \text{ Emission} = \text{NMVOC Emission} \cdot 0.85 \cdot 44/12$$

where 0.85 is the coefficient to transform the NMVOC to carbon mass, and 44/12 to express the carbon mass as CO₂ mass.

As far as N₂O is concerned, the emissions considered in the inventory are limited to the use of this gas for anaesthetic purposes, as mentioned above. Nitrous oxide, with its characteristically greater solubility in fats than in water, is transported in gaseous form by the blood to the central nervous system through the fluids contained in the latter, where it produces a state of complete unconsciousness or narcosis. Like many other volatile anaesthetic products, N₂O leaves the organism unchanged, that is to say, it is resistant to catabolism through biological processes. As a result of this peculiar quality, N₂O emissions are considered to be equal to its consumption for such uses. This consumption has been estimated on the basis of the information furnished by one of the major companies in this sector.

5.2.3.- Uncertainty and consistency over time

As for activity variables, they have been obtained either directly by means of a questionnaire sent to the plants, from business associations with wide national coverage, or else from statistics derived from national censuses. A mean uncertainty of ca. 50% has been assumed for these activity variables, as some of them are regarded as proxy for an objective variable. With regard to emission factors, it can be assumed that the mean uncertainty is around 25%.

In general, it is understood that the series of activity variables present a high degree of consistency over time as the information is acquired from stable reference sources with a thoroughly verified level of coverage at the national level. Nevertheless, it remains to assign many of the NMVOC emission factors to time periods, as it has not yet been possible to determine accurately the degree to which the new process and abatement technologies have been implemented in all the activities during the period inventoried.

5.2.4.- Quality assurance and verification

Among the quality assurance tasks, the monitoring of the processes used to apply paint in the vehicle manufacturing plants is worthy of note. Information concerning concentrate and solvents consumed, and their corresponding VOC content, is requested for each of the phases of the paint lines to obtain the amount of solvent used from these, the VOC content and the emissions produced. Any amounts that have been recovered or disposed of (recycled, incinerated or shipped to an external handler) are then discounted from this emission to give the total emissions of NMVOC. In the case of shortcomings or atypical values in the data, the causes of these anomalies are investigated in conjunction with the plants themselves in order to obtain the necessary corrections or justification of the corresponding values. In addition, this information allows the data to be compared from one plant to another, obtaining ratios for consumption and emissions (per painted vehicle and per treated surface) that can be used to perform verification procedures on the information provided. Table 5.2.1 shows the form for requesting the information needed to perform this mass balance.

Table 5.2.1.– VOC application questionnaire for vehicle plants

PROCESS	CONCENTRATE		SOLVENT		DISSOLUTION		TOTAL VOC
	kg	% VOC	kg	% VOC	kg	% VOC	kg
1.- Paint application							
Cataphoresis							
PVC Products (mastics)							
Priming							
Lacquer							
Refinishing							
Protective waxes							
± Adjustments							
2.- Degreasing and industrial cleaning							
Metal degreasing							
Other industrial cleaning							
Total manufacturing (1 + 2)							
3. Maintenance							
TOTAL CONSUMPTION (1 + 2 + 3):							
Recovery (recycling)							
Disposal (incineration)							
Dispatch to external treatment							
EMISSION							

Another quality assurance procedure carried out has involved the activity of paint application for decoration and construction. In this case, the reduction of the VOC content in paint over the period inventoried as a result of the application of different environmental regulations has been taken into account. This verification task, undertaken together with the corresponding business associations in the sector, has allowed adjustment for the increase in the use of waterborne paint as compared to solvent borne paint, as well as the ensuing decrease, in both absolute values as well as relative terms (emissions per tonne of paint applied), of NMVOC emissions over time.

5.2.5.- New calculations

In this edition of the inventory, due to the availability of new information, a revision has been carried out about the activity variable related to metal degreasing in 2006. Similarly, in 2006, the NMVOC emission factor for the domestic use of paint has been modified after detection of an incorrect value in the emission factor applied in the stated year. On the other hand, the activity variable (population) used in the estimate of NMVOC emissions in domestic use of solvents and pharmaceutical products has been revised for the period 1998-2006, updating the population figures of those years with those of the official figures of the municipal register (population as of January 1st). Finally, the activity variable (organic solvent consumption) related to wood protection processes in the period 1990-2006 has been revised, after detecting an error in the estimate of the stated consumption in the conversion of the sample data to population data. Overall, these new calculations represent a decrease of less than 0.1 Gg of CO₂-eq for each year in the period from 1990 to 1997 and an increase of between 0.7 and 5.7 Gg of CO₂-eq for the period from 1998 to 2006.

The comparison of the results for the CO₂-equivalent emissions between the present and the previous editions of the inventory are shown in Figure 5.2.1 in terms of absolute values, and in Figure 5.2.2 in relative terms (percentage difference). As can be seen in this last figure, the relative variation in CO₂-equivalent emissions as a consequence of the new calculations made for this activity ranges between 0.003% and 0.39% for the period 1990-2006.

Figure 5.2.1.– CO₂-equivalent emissions. Comparison of 2009 and 2008 editions

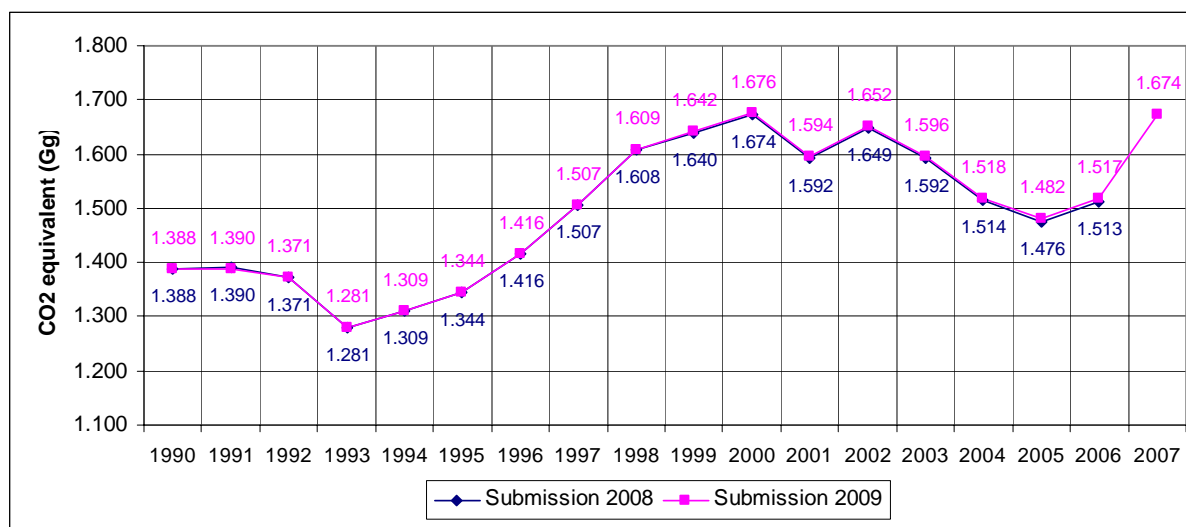
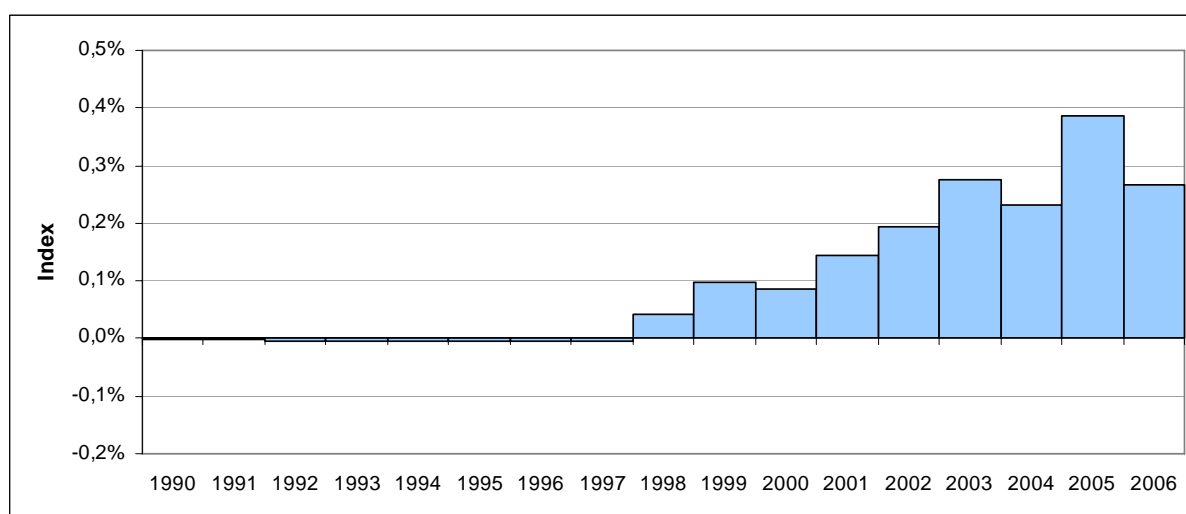


Figure 5.2.2.– CO₂-equivalent emissions. Percentage difference between 2009 and 2008 editions



5.2.6.- Improvement plans

In the “Use of solvents and other products” sector, a number of tasks are planned with the main business associations to undertake the revision of the basic activity variables as well as the characterization of the processes and techniques applied for the use of solvents and their VOC contents.

6.- AGRICULTURE

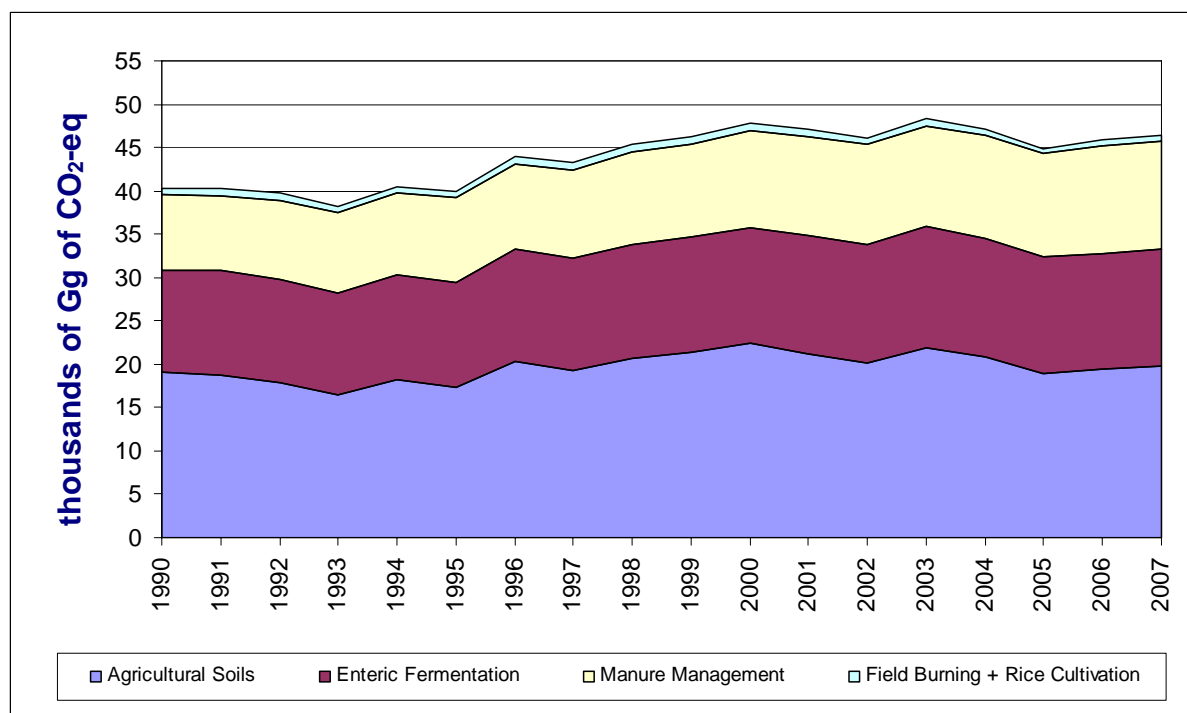
6.1.- Sector panorama

Agricultural emissions, whose pattern is shown in Table 6.1.1 and in Figure 6.1.1 experienced a 15.11% increase between 1990 and 2007, rising from 40.330 Gg to 46.426 Gg of CO₂-eq. (CO₂ equivalent).

Table 6.1.1.- CO₂-equivalent emissions (Amounts in Gg)

Category	1990	1995	2003	2004	2005	2006	2007
Agricultural Soils	19,090	17,404	21,885	20,758	18,891	19,437	19,735
Enteric Fermentation	11,780	12,044	14,005	13,696	13,486	13,332	13,560
Manure Management	8,695	9,781	11,589	11,984	11,871	12,356	12,439
Residue Burning + Rice Crops	765	648	845	754	630	693	693
Total Agriculture	40,330	39,877	48,323	47,192	44,878	45,818	46,426

Figure 6.1.1.- Pattern of CO₂ equivalent emissions



As shown in Figure 6.1.2., in 2007 agricultural emission make up 10.5% of the total emissions in Spain of CO₂-eq, which signifies that regardless of the increase in absolute emissions for this activity, an overall decrease in its contribution compared to 1990 when represented 14% of the total.

Figure 6.1.2.- Percentage of CO₂-eq emissions by category in relation to the total inventory

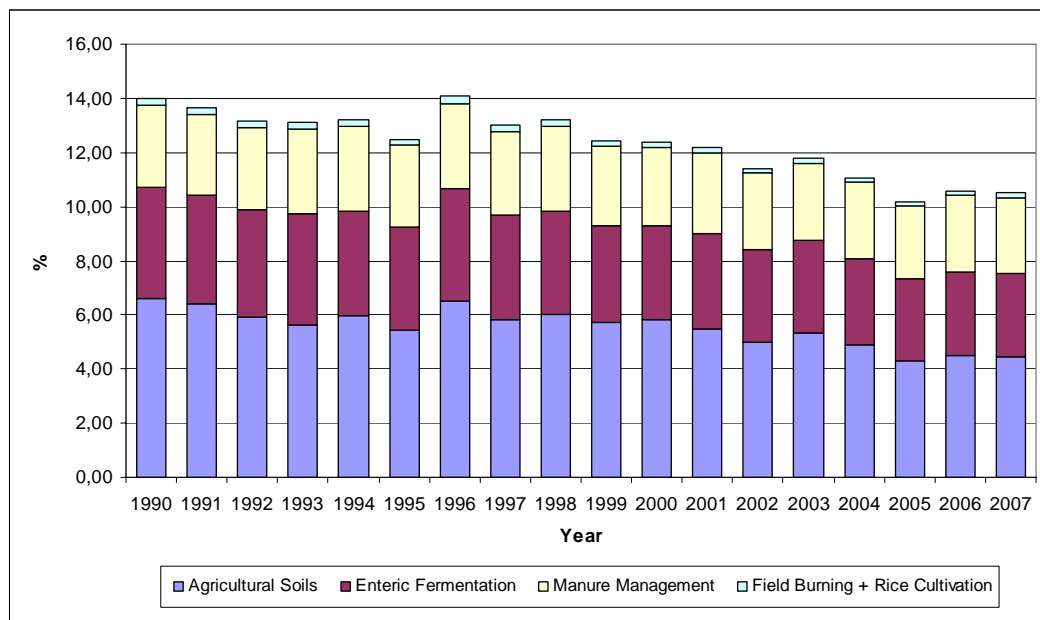
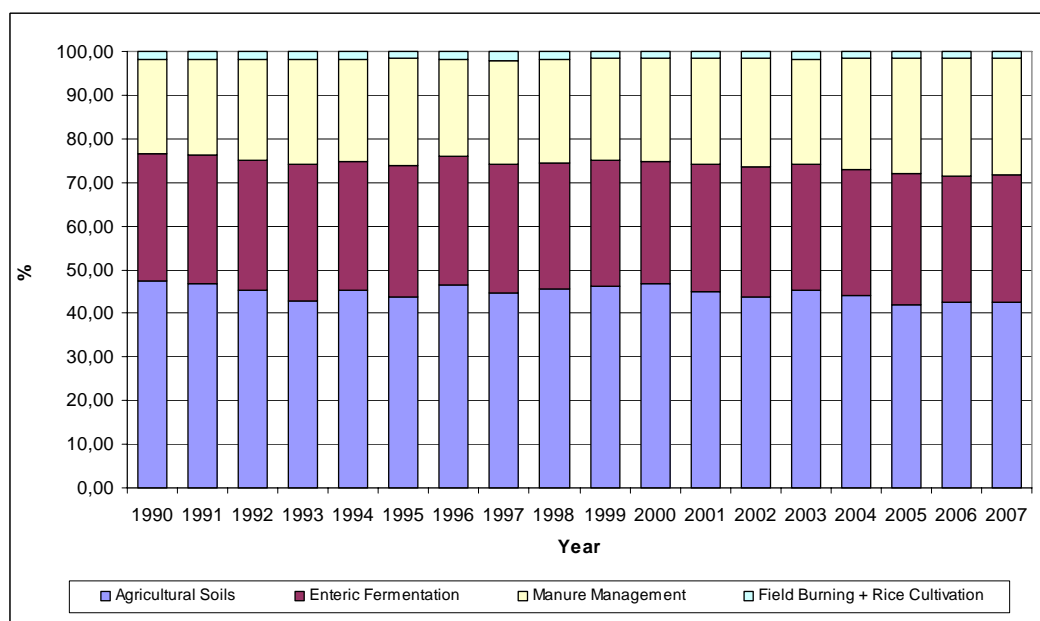


Figure 6.1.3 shows that the distribution of the emissions in this sector between categories has not suffered any major variation in the period inventoried. From largest to smallest, in 2007, Agricultural Soils contribute more than 42% of the sector's emissions, followed by Enteric Fermentation (29%) and Manure Management (26%).

Figure 6.1.3.- Percentage of CO₂-eq emissions by category in relation to the total sector



Key categories

In Agriculture Sector every key category is a net source of emissions, not a sink, therefore it could be also called “key sources”. The key sources identified for the period 1990-2007, considering the combination of gas and activity shown in Table 6.1.2, classified by contribution to the inventory emissions for 2007 (greatest first), are as follows:

- a) Enteric Fermentation in Domestic Livestock (CH₄): Source level 1990-2007 and by trend 1990, 1992, 1994-2007.
- b) Agricultural Soils - Direct Emissions (N₂O): Source level 1990-2007 and by trend 1990-1995 and 1997-2007.
- c) Manure management (CH₄): Source level 1990-2007 and by trend 1990-1998.
- d) Agricultural Soils - Indirect Emissions (N₂O): Source level 1990-2007 and by trend 1990-1995 and 1997-2007.
- e) Manure management (N₂O): Source level 1990-2007.
- f) Agricultural Soils - Animal Production (N₂O): Source level 1990-1992, 1995-1999 and 2007, and by trend 1992.

Table 6.1.2.- Key Sources: Contribution to Level and Trend

Code	Description	GHG	CO ₂ -e 2007	Contribution Level			Contribution Trend		
				%	K.Source	Rank	%	K. Source	Rank
4A	Enteric Fermentation in Domestic Livestock	CH ₄	13.560	3,07	YES	9	1,93	YES	14
4D1	Agricultural Soils - Direct Emissions	N ₂ O	9.975	2,26	YES	12	2,38	YES	11
4B	Manure Management	CH ₄	9.458	2,14	YES	15	0,01	NO	58
4D3	Agricultural Soils - Indirect Emissions	N ₂ O	7.911	1,79	YES	16	1,56	YES	15
4B	Manure Management	N ₂ O	2.981	0,67	YES	22	0,34	NO	28
4D2	Agricultural Soils - Animal Production	N ₂ O	1.620	0,37	NO	29	0,20	NO	34

Order: Category order number in relation to key sources (organized per level or trend contribution).

Explanation of the trend

According to Table 6.1.1, agricultural emissions show an increasing trend, punctuated with peaks and troughs, with a long-term increase of 15.11% over the inventoried period.

This trend is the result of the increase in the emissions from Enteric Fermentation (4A) and Manure Management (4B) activities, which are to a large extent linked to the number of animals. During the period 1990-2007, some animal species experienced a large increase in their number, especially non-dairy cattle and swine which have risen around 62% in number, therefore creating an increase in the emissions over the series.

Although a gradual increase in emissions is noticeable through the inventoried period, see Figure 6.1.1, a number of peaks and troughs are shown, mainly due to the variations in emissions from the Agricultural Soils (4D). The source of these inter-annual variations is the application of N to soils in the form of synthetic fertilizers (sub-section 4D1 of the activity, Direct Emissions). Table 6.4.2, in page 6.23, shows the contributions of N to soils by source

fertilizer and the importance of synthetic fertilizers, in terms of applied N, among these sources. In addition, these variations are intensified by the dependency of the activity variable, and subsequently the emissions, from activity 4D3, Indirect Emissions, with respect to the contributions of nitrogen in activities 4D1 and 4D2, which include synthetic fertilizers.

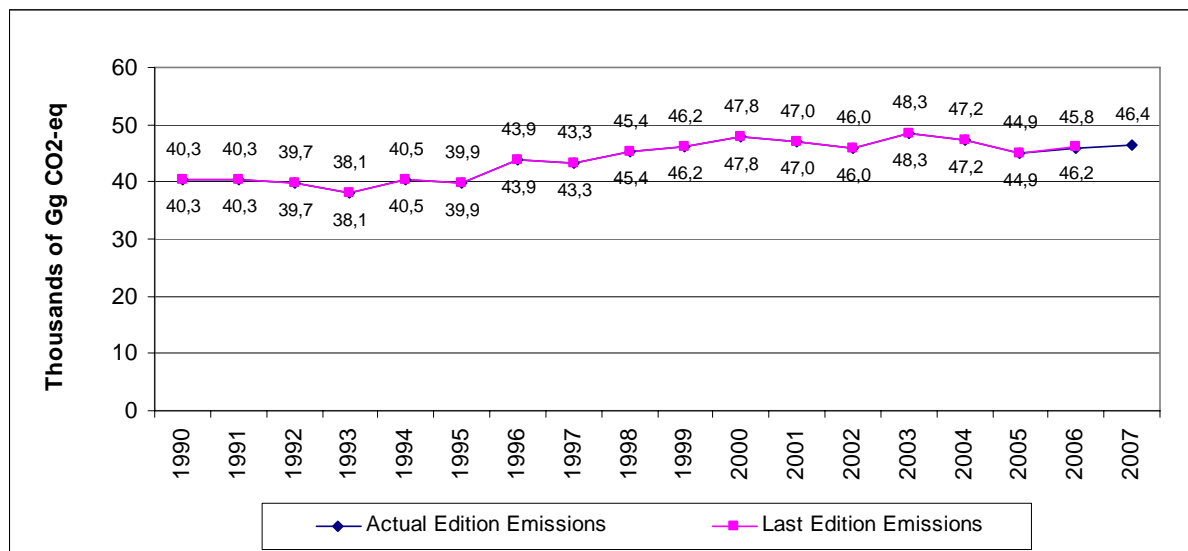
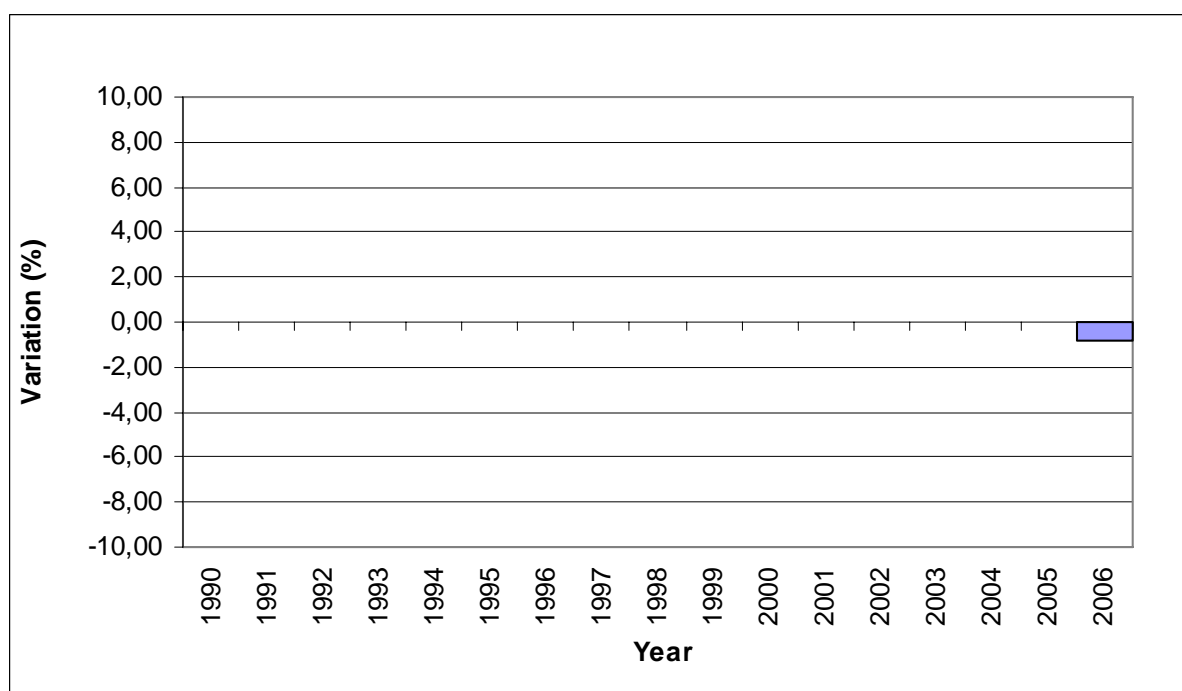
Despite the introduction of new regulations concerning Field Burning of Agricultural Residues (4F) which almost completely prohibit the practice of burning crops, this activity did not experience a major change in emissions due to the large influence of emissions in the field burning of cuttings from the pruning of olive trees and grapevines - of which there has been no reduction.

Finally, in response to successive questions posed by the review teams and despite their very small influence on the trend, an explanation will be given for the inter-annual variation in the emission factors for Enteric Fermentation (4A), in the cases of sheep, dairy and non-dairy cattle; and for Manure Management (4B), in the cases of dairy and non-dairy cattle and swine. These slight inter-annual variations are not due to methodological variations but to changes in the structure of the total number of animals in each of these categories accounted for by IPCC. These IPCC categories are comprised of sets of several animal groups in the Spanish Inventory; each of which has its own estimated emission factor. In particular, non-dairy cattle is made up of 14 groups, dairy cattle of 2, sheep 8, and swine 10. Since the composition of each animal group varies from year to year for the IPCC, in other words, the percentage each category of the Inventory represents in the total for a particular IPCC animal, is not constant for all years in the series, the weighted emission factor varies annually, resulting in the corresponding emission factor variations.

New calculations

As it is shown in Figures 6.1.4 and 6.1.5 a slight variation has been produced between the estimated emissions of the Inventory's present edition in relation to the estimations of the Inventory's previous edition.

The reasons for this variation are: the updating for year 2006, due to the availability of new statistical data, of: the number of heads of poultry and swine, crop surface and total production, and agricultural use of fertilizer and compost; as well as, the updating of residue burning parameters for years 2000 y 2004-2006. The recalculation per activity is addressed later under their respective headings.

Figure 6.1.4.- CO₂-eq. emissions comparison of 2009 vs 2008 editions**Figure 6.1.5.- Percentage difference of CO₂-eq. emissions for editions 2009 vs 2008**

6.2.- Enteric fermentation in domestic cattle - CH₄ (4A)

6.2.1.- Description of the emission-producing activity

This activity considers methane emissions stemming from the enteric fermentation among livestock populations. The amount of methane produced and emitted by these animals depends essentially on the make-up of their digestive system and their diet.

The type of digestive system is a determining factor for the levels of methane emissions. Ruminant species have higher emission rates due to the type of fermentation that generates methane in the rumen part of their digestion. In Spain, the main species of ruminants include: cattle, sheep and goats. The methane emission rates are far lower among the pseudo-ruminants (horses, mules, asses) and the monogastric species (swine).

As for diet, it can be said that, in general, the more eaten and the less digestible it is, the greater the methane emissions are. An animal's intake is directly related to its size, growth rate and productivity (milk, wool, offspring, etc.).

As shown in Table 6.2.1 and in Figure 6.2.1, in the period the emissions of this activity are inventoried there is a 15.11% increase from 11.780 Gg of CO₂-eq in 1990 to 13.560 Gg of CO₂-eq in 2007. The principal cause for this increase is the non-dairy cattle with an increase of 112.21 Gg of CH₄ (2,356 Gg of CO₂-eq) which represents a 58.50% increase. Swine also experienced a major increase of 62.03% but, given its reduced weight in emissions, it only represents an increase of 320.33 Gg of CO₂-eq. These variations are essentially due to the increase in the livestock population, not a major variation in its emission factor. Both goats and dairy cattle livestock underwent a reduction of 21.07 and 22.74%, respectively, in their emissions as a result of the decline in their headcount. The 67.9% fall in the number of mules and donkeys entails an identical reduction in their emissions, although given their lesser importance in absolute terms, this reduction only represents 36.61 Gg of CO₂-eq.

Table 6.2.1.- CO₂-equivalent emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
Dairy Cattle	2,446	2,201	2,121	2,068	2,028	1,936	1,889
Non Dairy Cattle	4,028	5,062	6,380	6,310	6,162	6,102	6,384
Sheep	4,258	3,782	4,321	4,119	4,089	4,060	4,038
Other	1,049	999	1,184	1,200	1,207	1,234	1,248
Total	11,780	12,044	14,005	13,696	13,486	13,332	13,560

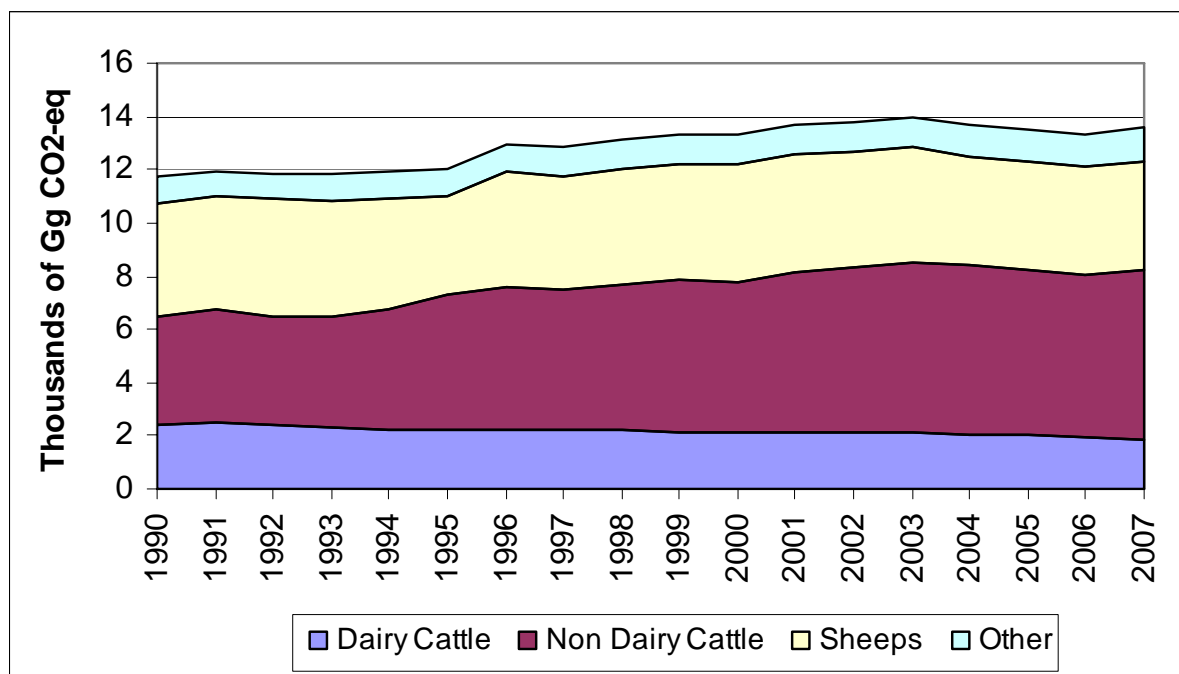
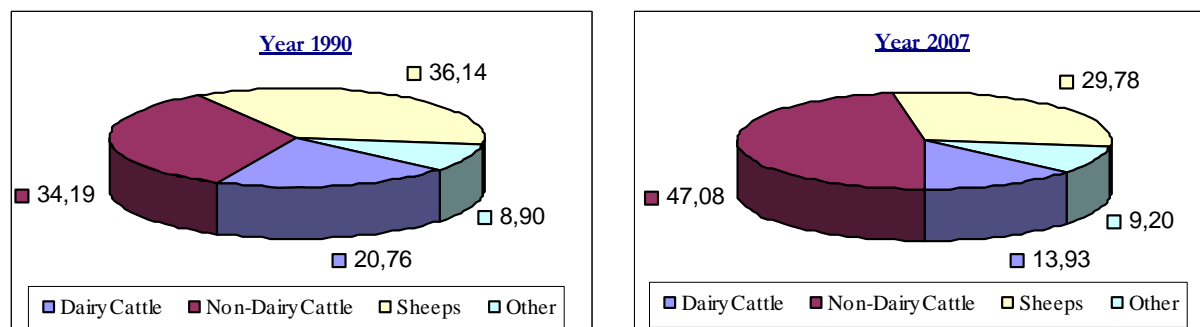
Figure 6.2.1.- CO₂-equivalent Emissions

Figure 6.2.2 shows the contribution, relative to emissions, for each of the activities that make up category 4.A. In 1990, sheep (4A3) appear as the major source of emissions with 36.14%, followed closely by non-dairy cattle (4A1b) with 34.19% of the emissions and then, of lesser importance, dairy cattle (4A1A) with 20.76%. In 2007, the main sources of CH₄ in this activity are non-dairy cattle with 47.08% of emissions, followed by sheep with 29.78% and dairy cattle with 13.93% of total emissions in this activity. The remainder of the animals in their totality, do not reach 10% of emissions in any of the years.

A major increase in the importance of the emissions from non-dairy cattle (it grows from 34% to 47%) can be seen and is caused by an increase in animal numbers. The other major sources (dairy cattle and sheep) experienced declines in their importance as emission sources.

Figure 6.2.2. – Distribution of emissions in Group 4A

6.2.2.- Methodological aspects¹

Choice of method

Two methodological approaches have been used in this activity: Tier 2 for animals with greater importance in emissions (cattle and sheep) and Tier 1 for the rest of the animals.

For the selection of the method, the criteria set out in Figure 4.2 (2000 IPCC Good Practice Guidance) have been adopted. Owing to the unavailability of statistics for many of the parameters required for the Tier 2 approach, it was decided to obtain this data from national methodologies based on existing statistics.

Activity variables

The activity variable data comes from the “Food and Agriculture Statistics Yearbook” and from the “Monthly Bulletins of Agrarian Statistics” (both published by the Ministry of Agriculture, Food and Fisheries, MAPA).

The MAPA documents previously cited, present information on the number of animals in a much more detailed and itemized manner than IPCC data requirements. Given the relevance for these emissions calculations of using the most specifically detailed information by category of animal, the category structure of the MAPA sources has been adopted. These animal categories can be found in Appendix 3.2.I.

In the case of cattle and swine livestock, in which more than one statistic per year is available (June and December for cattle, and April, August and December for swine) all the figures are used for the calculation of the annual mean number of heads in each animal category. In the case of swine, the statistics differ further between the swine living in an open-grazing system and the total for all swine. The number of heads of swine under an intensive regime (farm) is obtained by subtracting the number of grazing animals from the total (farm = total - grazing), effected at the level of province and each animal category.

Table 6.2.2 shows the pattern in the number of animals in the different species. In the 1990-2007 period, there was a significant increase in non-dairy cattle (61.67%), as well as in swine (62.03%), whereas dairy cattle and goats experienced a decline in the number of animals (42.95% and 21.07%, respectively). With only the headcount data available from the 1986 and 1999 censuses for equine species (horses, mules, asses), figures have been taken from the first census for the years 1990-1998 and for the second from the period 1999-2007. It is necessary to recall that the jump from 1998 to 1999 and, in general, the year-on-year variation rates are not representative.

¹ From now on, “Animals” will be understood as distinct species (cattle, sheep, pig, ...), “category” will refer to the breakdown of those animals according to classes considered in the MAPA Yearbook (please refer to Appendix I) and “breed” will refer to the distinct subspecies of animals in Spain (frisona, pirenaica, morucha, etc.)

Table 6.2.2.- Animal Numbers

Animal	1990	1995	2003	2004	2005	2006	2007
Non Dairy Cattle	3,468,803	4,356,381	5,537,064	5,531,611	5,398,028	5,350,773	5,607,848
Horses	247,778	247,778	238,096	238,096	238,096	238,096	238,096
Goats	3,663,314	2,522,528	3,162,054	2,833,223	2,904,691	2,956,730	2,891,574
Swine	16,393,253	18,617,153	23,640,109	25,231,662	25,243,572	25,902,349	26,562,566
Poultry	127,223,665	150,697,478	161,342,380	172,608,261	172,997,729	166,635,320	165,747,838
Other Poultry	14,024,101	17,205,721	19,770,207	21,243,425	20,620,392	19,158,403	24,281,503
Mules and Asses	256,743	256,743	82,416	82,416	82,416	82,416	82,416
Sheep	23,821,736	21,039,236	23,497,712	22,757,435	22,749,471	22,474,031	22,194,257
Dairy Cattle	1,610,541	1,278,120	1,114,787	1,069,173	1,028,249	963,041	918,840

Emissions estimate algorithm

For the animal categories in which a Tier 1 approach is used, the IPCC default emission factor (EF) for developed countries has been used (Table 4-3, 1996 IPCC Reference Manual).

For cattle and sheep, a Tier 2 approach has been adopted. Given the lack of default information in the IPCC references for several of the parameters required in this approach and for the level of disaggregation in the animal categories used in the national inventory, individual national procedures have been adopted to obtain these parameter values. These procedures are based mainly on the parameter estimates for the animal categories mentioned, based on data available in the bibliographic references for the various cattle or sheep breeds currently seen in Spain.

This section will explain these methodologies by animal species following the order in which the parameters appear in the 2000 IPCC Good Practice Guidance methodology.

Cattle

Weight is the first parameter for which direct statistics are lacking for each of the categories of cattle. An explanation of the methodology for calculating weight is found in the heading 3.3.2.1 of the UPV document (June 2006)².

The available production data for milk are not broken down between Frisian and other dairy breeds, and it has therefore been necessary to make an estimate based on the theoretical data for milk production by breed. A detailed explanation of this procedure can be found in heading 3.3.2.2 of the UPV document (June 2006).

To obtain the parameter on milk fat percentage, a similar process to the one used for weight and milk production is calculated based on bibliographic references for existing

² UPV (June 2006). "Methodology for the estimation of atmospheric emissions in the agricultural sector for the national inventory of emissions", prepared by a specific contract between the CV DGCEA and the Superior Technical School of Agricultural Engineers at the University of Valencia for technical consulting services in the area of animal husbandry and the environment (ref. CV122004).

breeds in Spain. A table with the values used can be found in the heading 3.3.3.5 of the UPV document (June 2006).

The digestibility of the diet for each animal class is calculated following the methodology set out in heading 3.3.3.7 of the UPV document (June 2006). It proposes certain percentages for a range of components in the diets of different animal categories, as well as the digestibility of each of these components, so that, finally, an average value is obtained for the digestibility for the diet.

The values taken for the conversion factor to methane (Y_m) for each category are those proposed in Table 4.8 "Developed Countries" of the IPCC Good Practice Guidance, with the exception of dairy cattle. This variation is justified because taken into account the inverse relationship existing between the digestibility of the diet and the Y_m factor, when Spanish dairy cattle are submitted to intensive production systems, with permanent stabling, and fed with concentrates and high-quality fodder (Calcedo, 2004³; Sinerio, 2003⁴), in other words with high-digestibility diets (> 70%), it is considered more appropriate to use a value of 0.055 for Y_m , an intermediate value between intensive feeding and the rest of the cattle, but closer to the latter as this is the class it would belong to if this adjustment were not made.

This emission factor for non-dairy cattle shows only a slight decline, 1.96%, between the values corresponding to 1990 and 2007, with respective figures of 55.29 to 54.21 kg CH₄/head and year. On the other hand, dairy cattle experienced an increase in their emission factor during the same years, from 72.31 to 97.92 kg CH₄/head and year, implying an increase of 35.42%. This increase is mainly due to the increase in milk-producing energy per head, simultaneously affected by the growth in milk production and the decline in the number of such animals in Spain.

Sheep

Most of the necessary parameters for the Tier 2 approach in sheep have been obtained through bibliographical data on the different breeds currently existing in Spain. For each of these breeds, the base data are available (please refer to Table 13 in the MAPA document (2000)) along with the percentage figures for each one by province (please refer to Table 14 in the MAPA document (2000)⁵). By combining these data, the mean sheep parameters required for each province are obtained.

The weight of the different categories is not available in the bibliography and as a result, as in the case of cattle, a methodology is needed for this calculation. This methodology is described in heading 3.4.2 of the UPV document (June 2006).

³ CALCEDO, V. (2004). "Milk quotas and structural change in Spain". Mundo Ganadero (World of Cattle Farming), June 2004, vol. XV (167), pp. 18-20.

⁴ SINEIRO, F. (2003) "Raising Dairy Cattle before the Intermediate Reform of the CAP", in White paper on agriculture and rural development. Specific Seminar on Spanish Agriculture within the Framework of the CAP. Madrid, February 6th-7th 2003.

⁵ MAPA (2000). Estimation of greenhouse gas emissions, Agriculture 2000. Ministry of Agriculture, Food and Fisheries, 2002.

The coefficients (C_{fi}), used in the calculations of maintenance energy, depending on the type of animal (Table 4.4; of the IPCC Good Practice Guidance) have been adapted to the defined sheep categories. Similarly, parameter C_a has been adapted using the values from Table 4.5 of the IPCC Good Practice Guidance. The default values appearing in Table 4.6 of the IPCC Good Practice Guidance for growth energy parameters “a” and “b” are also used.

Milk production, wool production and the number of births are obtained from the statistics per breed, as mentioned above.

The digestibility of the diet for each animal class is calculated following the methodology set out in heading 3.4.3.8 of the UPV document (June 2006). Certain percentages for the various components are proposed in the diets of the different animal categories, as well as digestibility values for each of these components, so that a mean digestibility value can finally be obtained for the diet.

For Y_m , values are taken from Table 4.9 of the 2000 IPCC Good Practice Guidance. Adult animals and lambs are understood to have a diet with a digestibility score of less than 65% but, since the diet of suckling lambs and young lambs (sacrificed at 30 and 90 days respectively) is based almost entirely on milk, the value is taken from the “digestibility greater than 65%” column in Table 4.9 mentioned above.

6.2.3.- Uncertainty and consistency of the data series over time

The uncertainty for the activity variable is around 3%. In the document entitled “Livestock Surveys 2004” from the MAPA⁶, a sampling error was noted in the execution of surveys for each animal. These uncertainties, with a 95% confidence interval, are 2% for cattle (as sampled at 6,000 farms), 4% for sheep and goats (both as sampled at 4,000 farms) and 4% for swine (as sampled at 6,000 farms).

For those animals to which the Tier 1 approach is applied, the IPCC’s default emission factors are used, whose uncertainty is 20% according to the 1996 IPCC Reference Manual (Table 4-3). For the uncertainty quantification of cattle and sheep, we have taken under consideration that the emissions estimation is performed by using the Tier 2 approach with national parameters. Given that the uncertainty of the default emission factor is 20% and that a Tier 2 methodology with national parameters is used for these animals, it is assumed that uncertainty may be around 10%.

For poultry, the IPCC Guides do not provide a default emission factor and as a national value is lacking for this factor, it has not been possible to estimate the emissions from these animals.

Regarding the time pattern, the series is considered consistent since it covers the set of animals with a wide representation in national territory and the information comes directly

⁶ This document is available electronically at:
<http://www.mapa.es/estadistica/pags/encuestaganadera/2004-encuesta.pdf>

from a long-established annual publication from the regulatory agency for cattle farms (please refer to heading 6.2.2, Activity variables).

6.2.4.- Monitoring, quality assurance and verification activities

One quality assurance procedure of relevance for its repercussions on emissions and because it affects all the key sources in agriculture is the computing of the livestock numbers using the various annual statistics for the same animals. The adoption of the mean between the values given by different year-on-year statistics ensures a closer approximation to the mean annual number of heads, avoiding in part possible seasonal variations.

In light of the lack of direct statistics, a bibliographical search was used to obtain the weight of cattle. As a result of this process, multiple sources (and values) were identified for the weight of each breed. Taking into consideration that no source could have exclusive priority on the grounds of greater relative reliability, the arithmetic mean of the values shown in sufficiently verified publications was used in order to minimize the deviation between the weight taken for the breed and the real value (for further explanation see Appendix 3, "Bovine weight" in the UPV document (June 2006)).

For dairy cattle milk production, the same procedure has been implemented; however, as more recent and better verified sources were available in this case, mean values were not taken but rather those presented in the most up-to-date and verified publications.

In the calculation of milk production, other quality assurance controls have also been implemented. The initial plan was to use the activity variable (milk production) broken down by province. However, after analyzing the data obtained with these statistics, a major disparity was observed in milk production by head in the same breed between different provinces. As a result, it was decided to take only the data on national milk production and break these down on the basis of a theoretical mean obtained from the bibliographic references detailing productions for each breed. After performing the pertinent calculations, the results obtained reflected an increase in per-capita milk production throughout the years of the period inventoried. Given that practically all dairy cattle in Spain belong to the Frisian breed, the Spanish confederation of associations of Frisian farmers (CONAFE, for its Spanish name) was contacted to investigate this improvement in the dairy yield. The results of the study verified the existence of a genetic improvement as being the determining factor in the increased milk production.

To obtain the percentage of fat content in milk the procedure performed was again like the one used for determining animal weight but it was not necessary to calculate means or provide a precedence criterion according to the publication's standards (see Table 14 of Section 3.3.3.2 of the UPV document (June 2006)).

6.2.5.- New calculations

Figures 6.2.3 and 6.2.4, respectively, show the comparisons expressed in absolute values and in relative percentage difference, for the emissions estimates between the current and previous editions of the inventory. The differences that exist between the two editions

are due to the updates in the production data for milk for cattle for 2005 and 2006; and to the revisions in the number of heads of swine in 2006 due to the availability of new information.

Figure 6.2.3 – Comparison of CO₂-eq. emissions for editions 2009 vs 2008

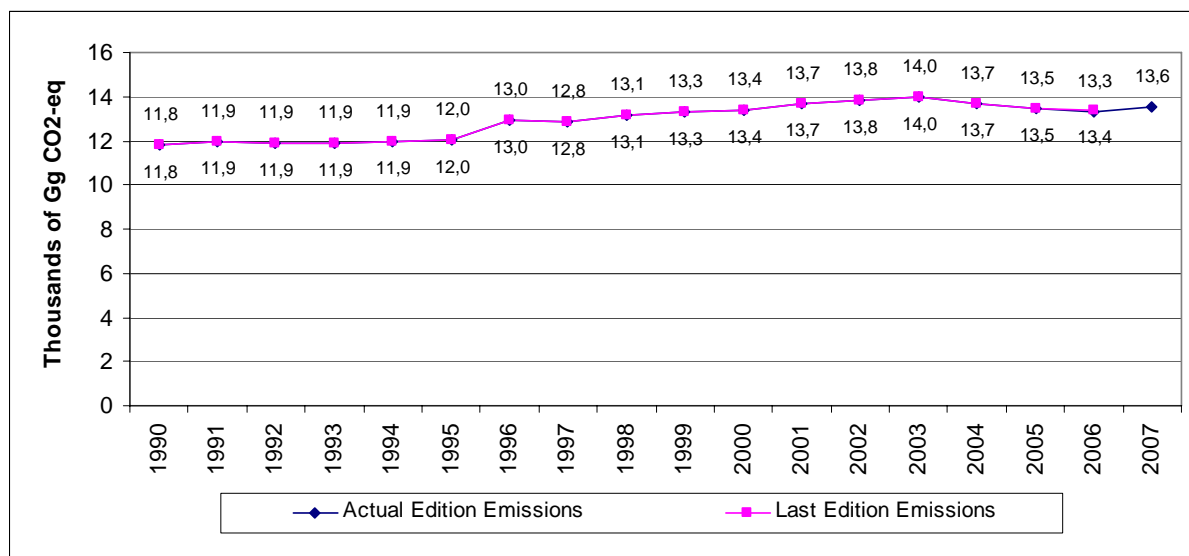
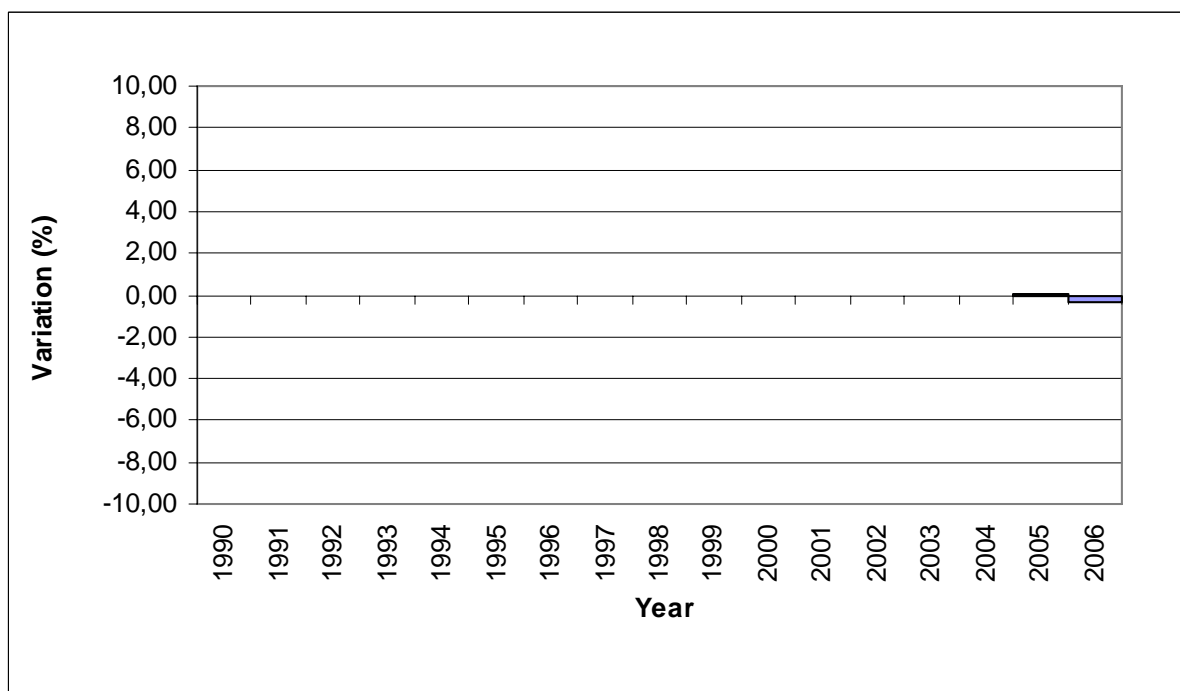


Figure 6.2.4 - Percentage difference of CO₂-eq. emissions for editions 2009 vs 2008



6.2.6.- Improvement plans

A large-scale global review of the methodology and the collection of the basic parameters is being carried out through the Inter-governmental Working Group for Livestock (GT INV-GAN) comprising representatives from the Ministry of the Environment and Rural and Marine Affairs with the collaboration of experts in the field. The results of these studies, once they have been verified, may be incorporated into the base information for this inventory sector.

6.3.- Manure management - CH₄ (4B)

6.3.1.- Description of the emission-producing activity

Methane emissions derived from the management systems for animal manure are included under this activity. Animal manure is mainly comprised of organic matter. When this matter is broken down in an anaerobic medium, the methanogenic bacteria present in that medium give rise to the generation of methane. The determining factor affecting the process of methane generation from animal manure is the proportion of the manure that decomposes anaerobically and this proportion in turn depends on the system adopted for manure management. When the manure is treated in liquid form (lagoons, tanks, pits, etc.) it tends to decompose anaerobically and produce elevated amounts of methane. On the other hand, when the manure is managed in solid form (windrows) or when it is spread on pasture land, it tends to decompose aerobically; methane production, in this case, is small or practically nil.

The evolution of methane emissions arising from manure management is shown in Table 6.3.1 and in Figure 6.3.1. Between 1990 and 2007, there is an increase of 51.79% from 6.231 to 9.458 Gg of CO₂-equivalent. Swine are the main source of emissions in this activity, representing a 59.90% increase in the emissions from manure management over this period, and are therefore the main factor in the increase of overall global emissions for this category. Other animals that also experienced an increase in emissions include non-dairy cattle (57.49% increase), poultry (27.25% increase), and other birds (68.25%) but owing to their reduced significance in this activity, their respective absolute increases are 50, 71 and 20 Gg of CO₂-equivalent, respectively. In general, those increases are motivated mainly by the increase in the respective numbers of such animals.

Table 6.3.1.- CO₂-equivalent emissions (Amounts in Gigagrams)

	1990	1995	2003	2004	2005	2006	2007
Swine	5,329	6,166	7,679	7,937	7,899	8,478	8,521
Cattle (Dairy and Non Dairy)	473	460	475	461	445	435	433
Poultry and Other Poultry	288	348	375	393	376	372	379
Other	140	126	136	129	126	128	125
Total	6,231	7,100	8,666	8,921	8,846	9,413	9,458

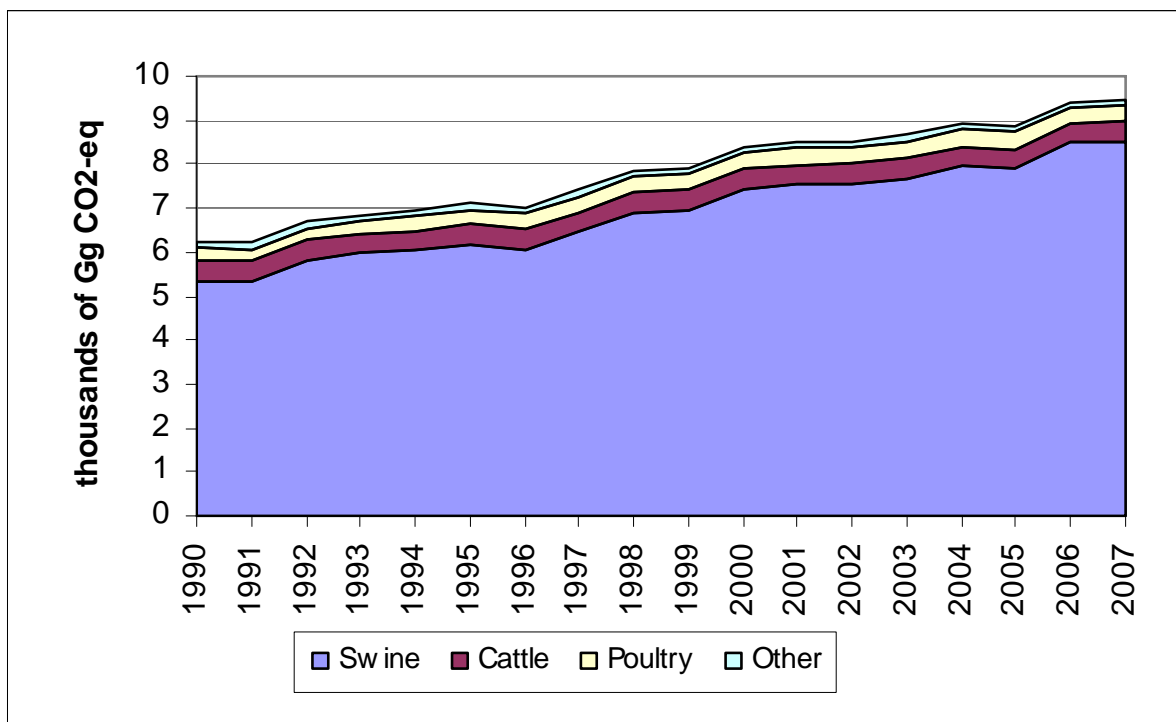
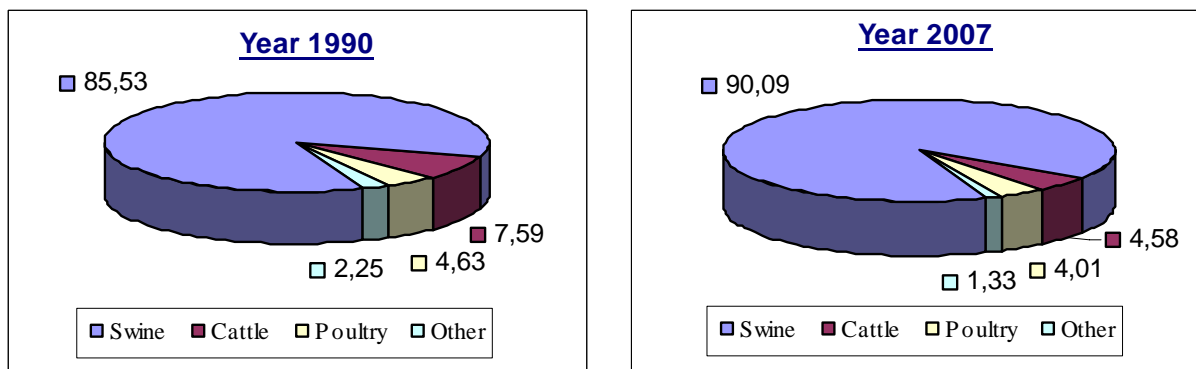
Figure 6.3.1.- CO₂-equivalent emissions

Figure 6.3.2 illustrates that swine (4B8) is the dominant source of emissions in this category, reaching to 85.53% and 90.09% of emissions in 1990 and 2007, respectively. Of the remaining animals, cattle (both dairy and non dairy) are worth noting, with 7.59% in 1990 and 4.58% in 2007, as well as birds (hens and chickens) with 4.63% in 1990 and 4.01% in 2007, leaving a very small “other” component.

Figure 6.3.2.- Distribution of emissions in Group 4B (CH₄)

6.3.2.- Methodological aspects

Choice of method

Two methodological approaches have been used in this activity: that of Tier 2 for animals with greater importance in emissions (cattle and swine) and Tier 1 for the rest of the animals.

In choosing a method, the criterion contained in Figure 4.3 “Decision Tree for Estimating CH₄ Emissions from Manure Management” in the 2000 IPCC Good Practice Guidance, was used. Given the possibility of being able to assign national values to methane conversion factor (MCF), B₀ (maximum capacity of methane production from manure) and VS (volatile solids) parameters, the criterion in Chart 3 in the previously mentioned figure was chosen (in the case of cattle and swine). As for the rest of the animals, given their lesser importance in emissions, it has been decided to apply the simple Tier 1 methodology.

In order to apply Tier 1 and Tier 2 approaches in the Spanish case, certain modifications have been undertaken and specific national values have been applied for certain parameters as detailed later in “Algorithm for Emissions Estimates”.

Activity variables

The basic activity variable for this category is the number of animals in the different herds. As a result, it shares its activity variable with category 4A (Enteric Fermentation). Therefore, to reiterate the information mentioned above for that category, please refer to the “Activity Variables” heading in Section 6.2.2.

Emissions estimate algorithm

As in the case of enteric fermentation, the specifications in the 2000 IPCC Good Practice Guidance have been followed in this category. For cattle and swine, a Tier 2 approach has been adopted, while the remaining animal categories have been treated with a Tier 1 approach. In any case, it is suitable to point out two main methodological peculiarities introduced in this group: the softening of the MCF and EF functions proposed by the IPCC, and the use of a system of classification for N excreted by the animals in accordance with the manure management system that differs from the default values proposed by the IPCC, as mentioned later.

For the estimation of the VS parameter for cattle, the function based on gross energy (GE) proposed by the IPCC was used. For manure management of swine, the VS is calculated: for each animal using the IPCC reference data (a pig of 82 kg live weight produces 0.50 kg MS/day of VS), adjusting the live weight in each class of animal following a linear relationship. This approximation is based on the Soil Conservation Service publication of the United States Department of Agriculture, (USDA, 1997), which presents a trend in this direction. The VS data for each swine category are given in Table 6.3.2.

Table 6.3.2.- Volatile Solids by swine category (kg of DM/head and day)

Category	Mean weight (kg)	VS (kg DM/head and day)
Suckling Pigs	13	0.0793
Swine (20 to 49 kg)	34.5	0.2104
Swine (50 to 79 kg)	64.5	0.3933
Swine (80 to 109 kg)	94.5	0.5762
Swine (> 109 kg)	130	0.7927
Breeding Sows not calved not covered	80	0.4878
Breeding Sows not calved covered	140	0.8537
Breeding Sows calved not covered	170	1.0366
Breeding Sows calved covered	200	1.2195
Breeding Boars	177	1.0797

In Spain there are neither statistics nor bibliographic references with accurate data on the percentages for application of each treatment system for management systems. Nonetheless, the fact that systems used in Spain do not correspond by default with those given by the IPCC for Western Europe does appear in the bibliography on the subject and is cited by experts. Therefore, we have opted to base usage values for the various treatments on expert opinion. For further elaboration of this issue, please refer to heading 5.2.3 of the UPV document (June 2006).

The MCF and EF functions for Tier 1 animals presented by the IPCC are step functions and, in view of the problems this caused for provincial administrative divisions with temperatures close to 15°C, it was decided to soften these functions (a revision deemed sound according to IGES-IPCC communication). This issue is further elaborated in Appendix 3.2.II. The temperatures used in these functions are derived from data obtained from the meteorological stations and synoptic reports from the Spanish State Meteorology Agency (AEMET).

6.3.3.- Uncertainty and consistency of the data series over time

The uncertainty for the activity variable (head count) is around 3%. A more detailed explanation of this value is found in Item 6.2.3.

For those animals to which the Tier 1 approach is applied, the IPCC's default emission factors are used, whose uncertainty is 20% according to the 1996 IPCC Reference Manual (Table 4-3). For the uncertainty quantification of cattle and sheep, we have taken under consideration that the emissions estimation is performed by using the Tier 2 approach with national parameters. Considering that the uncertainty for the default emission factor is 20% and that for these animals an advanced methodology is used with specific parameters, it is assumed that uncertainty may be estimated at around 10%. A higher reduction of uncertainty is not considered since data on manure management systems are based on expert's opinions due to the lack of statistics on the distribution of such systems.

Regarding the time pattern, the activity variable is considered consistent since it covers the set of animals with a wide representation in the entire national territory and derives the

information directly from a long-standing annual publication from the competent sector ministry, MAPA (see heading 6.2.2, Activity Variables).

6.3.4.- Monitoring, quality assurance and verification activities

It should be understood that the monitoring activities performed on the number of heads per animal category already discussed in heading 6.2.4 have the same inference in the calculation of emissions for this key category.

The remaining quality assurance activities mentioned in heading 6.2.4 (weight, milk production and fat), which are used for the determination of gross energy (GE) required by cattle, are to be interpreted as having the same inference in the calculation of emissions from this key category.

6.3.5.- New calculations

Figures 6.3.3 and 6.3.4, respectively, show the comparisons expressed in absolute values and in relative percentage difference, for the emissions estimates between the current and previous editions of the inventory. The differences that exist between the two editions are due to: the updates in the milk production data for dairy cattle for 2005 and 2006 includes a change in the FE for methane for those years; to the revisions in the number of heads of swine and poultry in 2006 due to the availability of new available information.

Figure 6.3.3 – Comparison of CO₂-eq. emissions for editions 2009 vs 2008

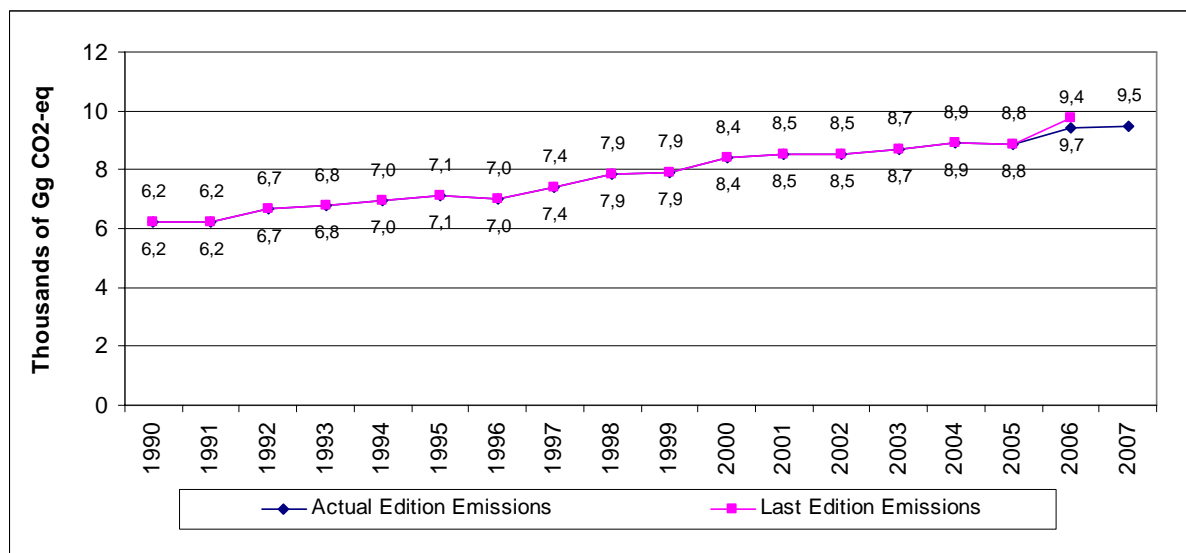
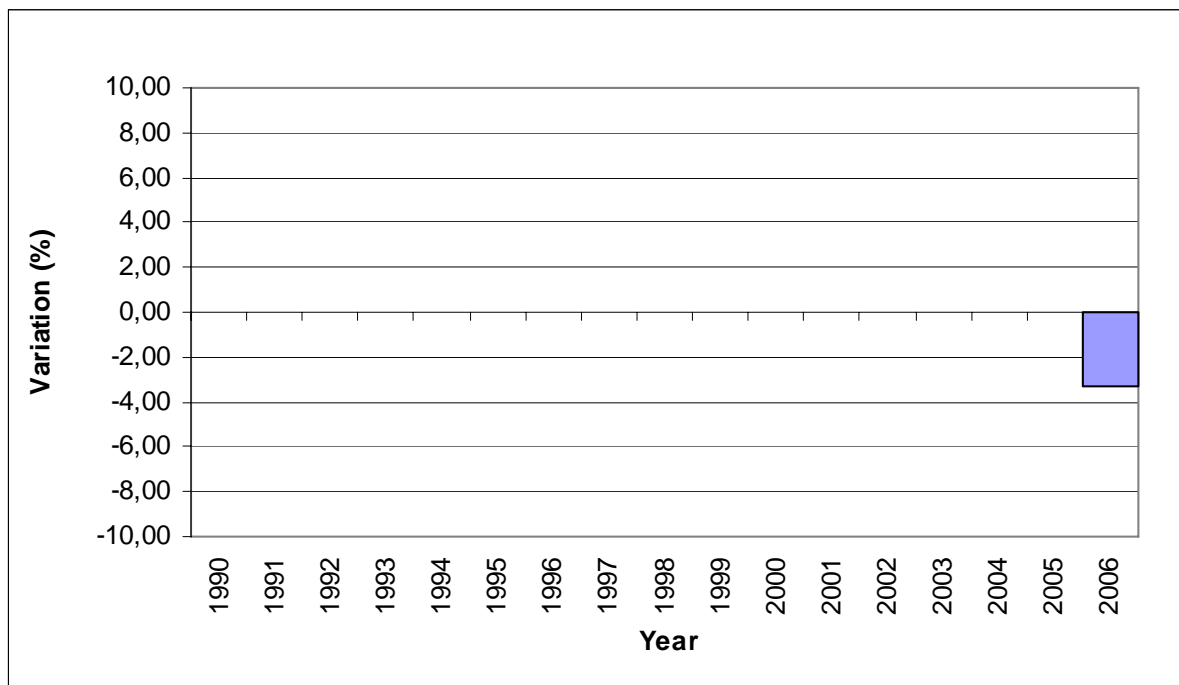


Figure 6.3.4 - Percentage difference of CO₂-eq. emissions for editions 2009 vs 2008

6.3.6.- Improvement plans

Some field studies are currently being carried out to determine the distribution of manure management systems in the Spanish case on a more solid statistical basis.

6.4.- Agricultural soils - N₂O (4D)

6.4.1.- Description of the emission-producing activity

The present edition considers activities 4D1 (Direct Emissions), 4D2 (Animal Production) and 4D3 (Indirect Emissions) as key sources of emissions from agricultural soils. In spite of being separate key categories, given the strong interrelation between the sub-groups involved in activity 4D and the homogeneity of the criterion in connection with the rest of the agricultural key sources, which are treated with two levels of depth in the IPCC classification (i.e. 4.A, 4.B, ...), they will be considered together with the 4D4 activity under a single section named 4D.

The N₂O emissions from agricultural lands are essentially of a biogenetic origin and basically come from the processes of nitrification and de-nitrification that take place in these soils. Nitrification consists of the microbe-aerobic oxidation of the ammonia ion (NH₄⁺) into a nitrate ion (NO₃⁻); de-nitrification is the microbe-anaerobic reduction of the nitrate ion (NO₃⁻) into molecular nitrogen (N₂), thus producing in both processes emissions of nitrous oxide (N₂O) as the intermediate gas.

In most cases, the emissions of N_2O increase in relation to the addition of nitrogen to the land. This nitrogen contribution can take place in any of the following ways:

- Incorporation of nitrogen synthetic-chemical fertilizers.
- Incorporation of organic fertilizers derived from animal manure (fertilizer and grazing).
- Nitrogen fixation by certain plant species.
- Incorporation of plant residues into soil.
- Use of compost and sludge in agriculture.

In addition, the N_2O emissions from the soil may be activated by the cultivation of organic soils (histosols) with high nitrogen content; however, this form of N insertion into the soil does not occur in Spain as, according to information provided by the MAPA Group, no agricultural crops exist in soils of this type.

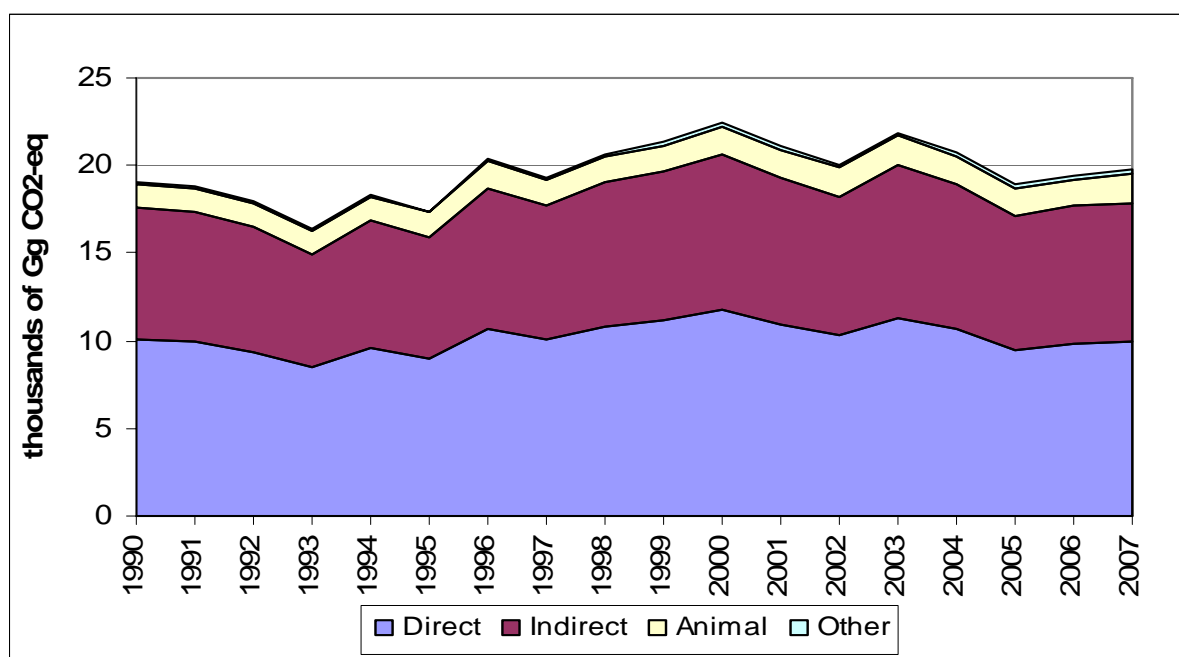
The indirect emissions of N_2O attributable to the nitrogen used in agriculture are estimated according to the methodology in the 1996 IPCC Reference Manual, Chapter 4, Section 5.4, in the following ways:

- Volatilization to the atmosphere and subsequent deposit of NO_x and NH_3 onto land and surface waters
- Nitrogen Leaching and Run-off.

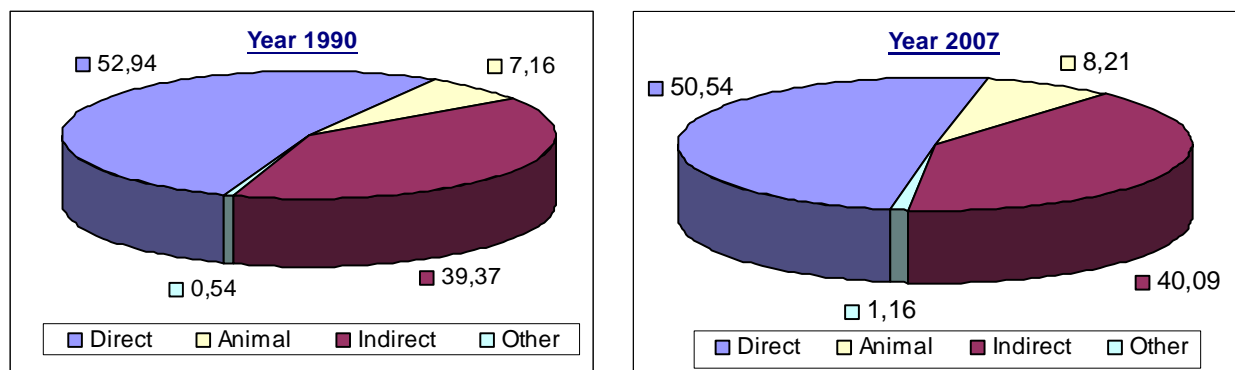
Global nitrous oxide emissions from agricultural soils, whose history is shown in Table 6.4.1 and in Figure 6.4.1, have experienced a 3.38% increase between 1990 and 2007, going from 19,090 to 19,735 Gg of CO_2 -eq. Direct emissions (4D1) decrease by 1.30% (131 Gg of CO_2 -eq) and indirect emissions increase some 5.26% (395 Gg of CO_2 -eq) due to the rise of N in organic fertilizer and grazing. Within the direct emissions only those contained in organic fertilizers register an increase value of 25.73% due to the increase in number of animals. This increase is similar, in percentage, to the one produced in crop residues, 20.75% (118 Gg of CO_2 -eq), due to the decrease in open field burning and an increase in olive and vineyard production. The rest of the direct emissions: show decreases in mineral fertilizers (of 11.50%) and biological fixation (of 7.83%). Indirect emissions (4D3) are based on the nitrogen added to soils as fertilizer (whether in mineral, organic, sludge or compost form) and, despite the reduction in mineral nitrogen and the increase in organic provision and grazing, the combined emissions in these three activities caused increases of 17.28% in atmospheric deposition and 3.60% in leaching and run-off. Emissions due to animal production (grazing) increased by 18.56% (254 Gg of CO_2 -eq) following an increase in total numbers of cattle. Emissions due to sludge and compost experience an increase of 244.77% and 6.49%, respectively. These major increases are a result of the corresponding increases in their respective activity variables: in the case of sludge, due to the huge expansion in the volume of waste-water treated (and in consequence of the sludge generated, mainly disposed of in agriculture), and in the case of compost, due to the growth of the activity itself.

Table 6.4.1.- CO₂ equivalent emissions (Amounts in Gigagrams)

	1990	1995	2003	2004	2005	2006	2007
Direct	10,106	8,979	11,300	10,707	9,522	9,885	9,975
Synthetic fertilizers	6,146	5,203	6,771	6,016	5,156	5,364	5,439
Organic fertilizers	2,155	2,313	2,584	2,695	2,680	2,695	2,709
N-fixing crops	1,237	1,077	1,187	1,144	1,125	1,140	1,140
Crop residue	569	387	759	852	561	687	687
Animal Production	1,366	1,373	1,676	1,604	1,583	1,560	1,620
Indirect	7,515	6,956	8,709	8,236	7,580	7,774	7,911
Atmospheric deposition	912	861	1,102	1,075	1,008	1,047	1,069
Leaching and run-off	6,604	6,095	7,607	7,162	6,572	6,727	6,842
Other	102	96	200	211	206	218	229
Compost	52	24	37	50	53	50	55
Sludge	51	71	163	161	152	168	174
Total	19,090	17,404	21,885	20,758	18,891	19,437	19,735

Figure 6.4.1.- CO₂ equivalent emissions

There are three key sources within this activity: a) Direct Emissions (4D1), b) Animal Production (4D2) and b) Indirect Emissions (4D3). Apart from these activities, there are some others containing sludge and compost emissions. Both in 1990 and in 2007, the main source of emissions within 4D was 4D1 (Direct), representing 52.94% and 50.54% respectively. The leading influence was 4D3 (Indirect) with 39.37% in 1990 and with 40.09% in 2008. The 4D2 (Grazing) went from 7.16% in 1990 to 8.21% in 2007. Meanwhile 4D4 (Others) saw an increase from 0.54% in 1990 to 1.16% in 2007.

Figure 6.4.2.- Distribution of emissions in group 4D

6.4.2.- Methodological aspects

Choice of method

In choosing a method, the criterion contained in Figure 4.7 “Decision Tree for estimating N₂O direct emission of agricultural soils” in the 2000 IPCC Good Practice Guidance, was used. The result of this decision process has been the selection of Tier 1a and 1b methodologies using country-specific parameters (Chart 3 and Chart 5). Once the different nitrogen contributions to soil are estimated (F_{SN} , F_{AM} , F_{BN} , F_{CR}) as per the equation 4.20 in the 2000 IPCC Good Practice Guidance, the corresponding default emission factors of the guidelines are applied since there are no country-specific alternative values for the factors themselves.

Activity variables

The comments below on the various activity variables charts included in category 4D follow the order in which these are described in the 2000 IPCC Good Practice Guidance.

For the total variable of nitrogen consumed in mineral fertilizers (N_{FERT}), the information is derived from statistics at the national level published by the National Statistics Institute (INE).

For animal manure used as fertilizers, the nitrogen input to soil is obtained by estimating the excreted nitrogen and subtracting the parts volatilized prior to application in the field. For a detailed explanation of this issue, please refer to the section on “Emissions estimation algorithm” in Section 6.5.2.

The information on cultivated areas is obtained from statistics on a provincial level compiled in MAPA’s publication “Food and Agriculture Statistics Yearbook”.

Agricultural Production: This is obtained by multiplying cultivated areas by the yields. Both production and yield data are found in statistics compiled on provinces in MAPA’s publication, “Food and Agriculture Statistics Yearbook”.

Compost and Sludge: The tonnes of waste-water treatment sludge used in agriculture for the years 1990, 1991, 1992, have been obtained by means of interpolation of the data corresponding to 1989 and 1993. The figures for these two years have been taken respectively from the information prepared by the former MOPT on sewage sludge in the publication "The Environment in Spain, 1991" (referring to the year 1991) and in the "Study on treatment and final disposal of urban wastewater sewage sludge", drawn up by the consulting firm "CADIC, S.A." for the Department of Water Quality at the MOPTMA [Ministry for Public Works, Transport and the Environment] (referring to the year 1993). For the period 1997-2007, the figures are provided from the "National Sewage Register" prepared by MAPA; for the 1994-1996 series they are obtained by means of interpolation based on the data corresponding to 1993 and 1997. Data on compost produced, assuming that it is used in its entirety for agriculture, are taken from the Ministry of the Environment (MMA) publication, "The Environment in Spain".

Data on crop surfaces and yields (and therefore, total production) are inserted into the database as crop per year and province. For the execution of the Inventory, 104 different types of crops are considered, some of them formed by groups of several crops of the same type. This crop disaggregation is used because the values of certain parameters in the calculation algorithm used are specific to each crop.

Table 6.4.2.- N contributions to soil (kt N)

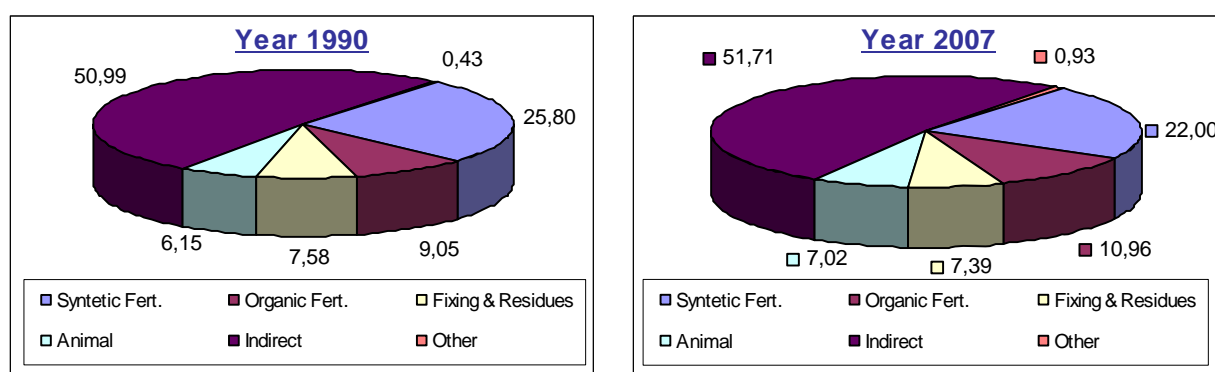
	1990	1995	2003	2004	2005	2006	2007
Direct	1,660	1,475	1,856	1,758	1,564	1,623	1,638
Fert. Synthetic	1,009	854	1,112	988	847	881	893
Fert. Organic	354	380	424	443	440	443	445
N-fixing crops	203	177	195	188	185	187	187
Crop residue	93	64	125	140	92	113	113
Animal Production	240	242	295	282	279	275	285
Indirect	1,995	1,845	2,316	2,189	2,013	2,063	2,100
Atmospheric deposition	187	177	226	221	207	215	219
Leaching and run-off	1,807	1,668	2,090	1,968	1,806	1,849	1,880
Other	17	16	33	35	34	36	38
Compost	8	4	6	8	9	8	9
Sludge	8	12	27	26	25	28	29
Total	3,911	3,577	4,500	4,264	3,889	3,997	4,060

Table 6.4.2 shows different nitrogen contributions to agricultural soils (t N) quantified in absolute values; Figure 6.4.3 details as percentages the relative weighting of the different origins shown. As illustrated, the main contribution corresponds to synthetic fertilizers, this contribution shows variations in both directions throughout the series, but, in fact, 2007 value is close to 1990 one. The second most important source involves animal manure, both as applied manure (organic fertilizers) as well as that deposited during grazing (animal production). These components experienced increases of 25.73% and 18.56% between 1990 and 2007, respectively, due to an increase in the number of head of livestock and, consequently, the excreta. Another important contribution is the biological fixation which recorded a 7.83% decrease between 1990 and 2007, while crop residues suffer an important increase (20.75%). Sludge experienced a strong increase (244.77%), while compost has

only a slight rise of 6.49%. Nonetheless, both of them only represent less than 1% of total nitrogen contributions to the agricultural sector.

Indirect emissions depend on nitrogen contributions and NH_3 and NO_x volatilization included in group 4D, and therefore, their increase is explained by the generalized increase in nitrogen contributions in the rest of the activities in this group.

Figure 6.4.3.- Distribution of N contributions (%)



Emissions estimate algorithm

As previously mentioned, the methodology of the 2000 IPCC Good Practice Guidance has essentially been followed for this group's emissions estimates. Notwithstanding, although default values proposed by the guidelines were used for the emission factors themselves, country-specific values were applied for a series of parameters used in the emissions estimate algorithm, in the manner described below.

The parameter $\text{Frac}_{\text{GASF}}$, ratio of volatilized N as NH_3 and NO_x , is obtained by calculating the emissions they released in the country-specific inventory employing the methodology EMEP/CORINAIR and as such IPCC's default value is not used for $\text{Frac}_{\text{GASF}}$. The same occurs for $\text{Frac}_{\text{GASM}}$, the ratio of volatilized N as NH_3 and NO_x is obtained from the Inventory calculation of the emission of these gases. It is worth noting the increase in the term F_{AM} , the amount of animal manure intentionally applied to soils, after adjustment - taking into consideration the amount of N volatilized in the form of NH_3 and NO_x . In the Spanish Inventory, F_{AM} , N applied to soil available for N_2O emissions is obtained by subtracting from the total N excreted, the amounts volatilized as N_2O and NH_3 during the manure management and the NH_3 and NO_x volatilized after applying the fertilizer.

The procedure followed for the calculation of excreted N and its allocation to different types of manure management is explained in detail in point 6.5.2 "Emissions Estimate Algorithm".

For the calculation of the N provided through biological fixation, two different methodologies are used, one which is country-specific for the calculation corresponding to agricultural land not actively cultivated (fallow land, natural pastures) and another using the IPCC methodology and national parameters corresponding to lands under active cultivation.

For a detailed explanation of the national methodology, please refer to heading 4.1.1.3.b in the MAPA document (2000)⁷. For nitrogen-fixing crops, equation 4.26 in the Tier 1b approach in the 2000 IPCC Good Practice Guidance is used. For the parameters, ($\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$, Frac_{DM} , and $\text{Frac}_{\text{NCRBF}}$)⁸ used in that equation, the values were obtained from the country-specific bibliographic references or the IPCC default values. Appendix 3.2.III gives a list with these parameter values for the different crops considered in the Inventory.

The N content in agricultural residues returned to soil is calculated using equation 4.29 from the 2000 IPCC Good Practice Guidance, assuming a zero value for the $\text{Frac}_{\text{FUEL-CR}}$, $\text{Frac}_{\text{CNST-CR}}$ and Frac_{FOD} parameters (the fraction of the residue used as fuel, in construction and for fodder) given that Spain has no such uses for the residues. Appendix 3.2.III shows a list of the values used for $\text{Res}_0/\text{Crop}_0$, Frac_{DM} and $\text{Frac}_{\text{NCRO}}$. The values for $\text{Frac}_{\text{BURN}}$, the burned residue ratio, are obtained from the different provisions on stubble-burning. Appendix 3.2.IV shows the corresponding list of values.

Animal production emissions (grazing) are calculated according to equation 4.18 in the 2000 IPCC Good Practice Guidance. For further details of the methodology, please refer to section 6.5.2 ("Emissions Estimate Algorithm").

Equation 4.32 (Tier 1b approach) in the IPCC Good Practice Guidance is used for the calculation of the N contained in atmospheric deposition. Within N contributions, both sludge and compost as applied to agriculture are included. As explained previously, the IPCC default values are not used for $\text{Frac}_{\text{GASF}}$ and $\text{Frac}_{\text{GASM}}$, since the NH_3 and NO_x emissions are calculated for the Inventory, therefore, these parameter values are obtained directly.

For leaching and run-off, equation 4.36 from the 2000 IPCC Good Practice Guidance is used, including sludge and compost contributions as in the previous case. The $\text{Frac}_{\text{LEACH}}$ parameter is a default value taken from the IPCC.

For the calculation of N content in sludge and compost, a national methodology has been used in the absence of IPCC references. The specifications in MAPA's "Agrarian Good Practices Handbook" (BOE, 1999) are used for sludge. A figure of 1.3% has been used for the amount of N in compost, based on the "Agrarian Good Practices Code Manual" published by the regional government of Catalonia (2000).

The emission factors used for the calculation of emissions are the default values contained in Tables 4.17 and 4.18 of the 2000 IPCC Good Practice Guidance.

6.4.3.- Uncertainty and consistency of the data series over time

The uncertainty of the activity variable depends on the source of the N contribution. Mineral fertilization uncertainty is around 5%, since direct consumption data derived from

⁷ In this document agricultural land without active crop use are referred to as "passive yields". The methodology used is only that referring to these "passive yields", not that proposed for grass crops.

⁸ $\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$, agricultural waste ratio; Frac_{DM} , dry matter fraction; and $\text{Frac}_{\text{NCRBF}}$, N fraction in the plant.

nationwide sectorial statistics are available. Organic fertilization and animal production are assigned an uncertainty below 20% based on the reliability of data on N excretion (obtained from food balances) and the adoption of professional management systems, which are more in agreement with the Spanish case than those provided by the IPCC. Biological fixation is based on national production statistics and on the parameters obtained from a bibliographic review, giving an estimated uncertainty of 30%. The estimation of agricultural residues is based on production statistics, physiological characteristics of the plant and on the stubble-burning ratio, giving an overall estimation of 40%. The activity variable for atmospheric deposition is the N volatilized as NH_3 and NO_x , and its uncertainty is determined by the EMEP/CORINAIR methodology used in the calculation of NH_3 and NO_x emissions. According to the uncertainty values provided with this methodology, its uncertainty is estimated to be 40%. Leaching and run-off have an estimated uncertainty of 200%, caused by the $\text{Frac}_{\text{LEACH}}$ parameter with a factor 3 uncertainty. Finally, in the case of sludge and compost, it is assumed that there is higher uncertainty, around 35%, mainly caused by inferior accuracy of data on production and the consequent N content.

The emission factors used are those provided by the IPCC. For the direct emission of soils, sludge and compost, the uncertainty figure is 400%, using as a reference the heading 4.7.1.6 in the 2000 IPCC Good Practices Guidance, where the coefficient 5 is used for the uncertainty range. In the case of indirect emissions, it has been set at 50% (heading 4.8.1.6 of the same reference). For animal production (grazing) a factor of 2 (-50% to +100%) is assumed as shown in Table 4.12 of said Guidance.

In reference to the time pattern, in general, the series are considered consistent since they cover the same set of crops, animals and mineral fertilizers, and the sources for the data have been the same for the entire series inventoried. This point should be qualified by adding that, in the case of sludge, data interpolation has had to be performed between 1989 and 1993 and between 1993 and 1997 in order to cover the full period inventoried, 1990-2007.

6.4.4.- Monitoring, quality assurance and verification activities

As previously explained in point 6.4.2, a bibliographical review has been performed for parameters such as dry matter, residue/crop ratio, carbon fraction and nitrogen fraction. During the process, quality labels were assigned to each of the parameters in order to discriminate the quality of the data sources. Finally, the highest ranked sources in relation to their quality labels were selected for the purpose of introducing their data into the emissions estimation algorithm.

Considering the great importance of the mineral fertilizer consumption data, the values obtained from different sources such as the INE, MAPA Yearbooks and the National Association of Fertilizer Manufacturers (ANFFE) have been cross-checked, and it was finally opted to take that of the INE.

6.4.5.- New calculations

There is no variation in the emission factors used; these continue to be those given by default in the 2000 IPCC Good Practice Guidelines, therefore all variations are due to the N added to the soils.

Only four cases of recalculation have been recorded in the contributions of N to soils. These recalculations are minor and do not create a great variation in this activity emissions (highest one is less than 0.1%).

The first recalculation is due to the variation in the number of heads of swine and poultry in 2006. This variation entails a modification of the nitrogen excreted and accordingly the nitrogen values applied in the activities "Organic Fertilizers" and "Animal Production".

The second variation source is caused by the parameter modification of the stubble field burning. This variation entails the cereals field burning disappearance since 2004, as well as some percentage changes of various crops burning in the year 2000. This provokes a slight variation in the emissions of agricultural residues in the years 2000 and 2004-2006.

The third variation arises from the correction of a mistake about the year 2004 rice surface area grown. This variation implies a change in the NH_3 volatilization and, thus, of the N mineral availability on the soils.

Finally, due to the availability of new data on the activity variable, the emissions from compost have been revised for 2006.

Figure 6.4.4.- Comparison of CO₂-eq. emissions for editions 2009 vs 2008

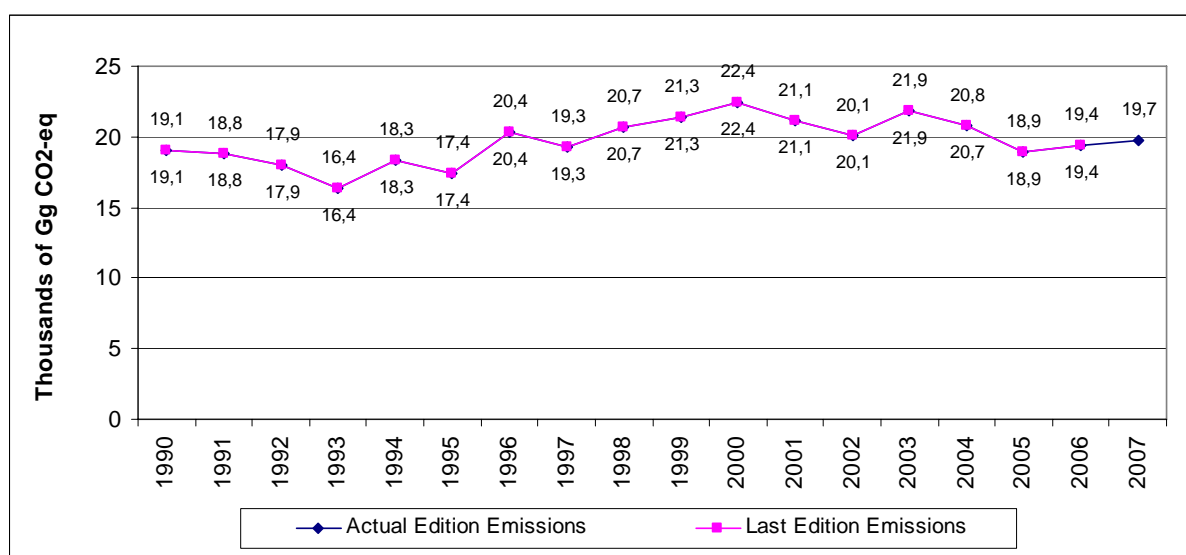
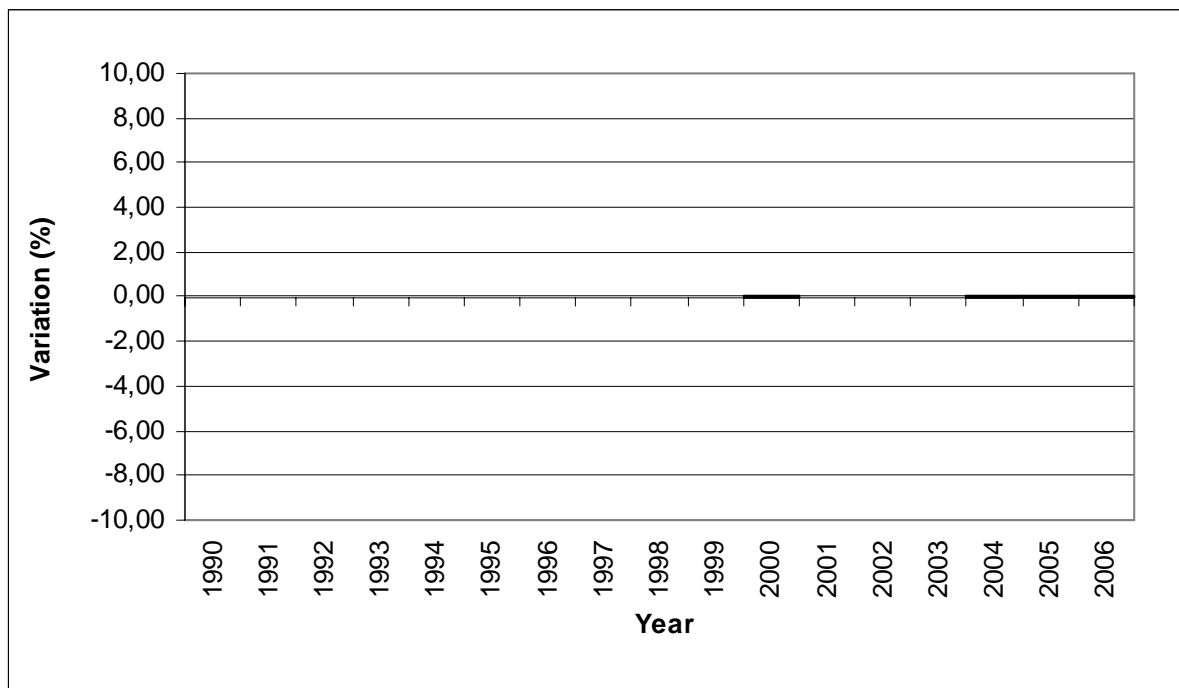


Figure 6.4.5.- Percentage difference of CO₂-eq. emissions for editions 2009 vs 2008

6.4.6.- Improvement plans

A large-scale global review of the methodology and the collection of the basic parameters is being carried out through the Inter-governmental Working Group for Agriculture (GT INV-AG) comprising representatives from the Ministry of the Environment and Rural and Marine Affairs with the collaboration of experts in the field. The results of these studies, once they have been verified, may be incorporated into the base information for this inventory sector.

6.5.- Manure management - N₂O (4B)

6.5.1.- Description of the emission-producing activity

The proportion of nitrogen excreted by the animals, either in manure or in urine, depends on the kind of animal, the dry matter eaten, and the concentration of nitrogen in their diet. The nitrogen retained during growth and in the products coming from the animal (milk, wool, eggs, etc.) generally varies between 10% and 30% of the total nitrogen consumed, with the remaining fraction being eliminated in manure or in urine. In animal production systems with a high content of nitrogen in their diet, more than half of the nitrogen eliminated is discharged in urine. Most of the nitrogen excreted in the manure is organic nitrogen although there are small fractions of mineral nitrogen. Organic nitrogen present in the manure must be mineralized to NH₃/NH₄⁺ before it can be broken down by nitrifiers and de-nitrifiers and generate nitrous oxide (N₂O). The intermediate process of mineralization to

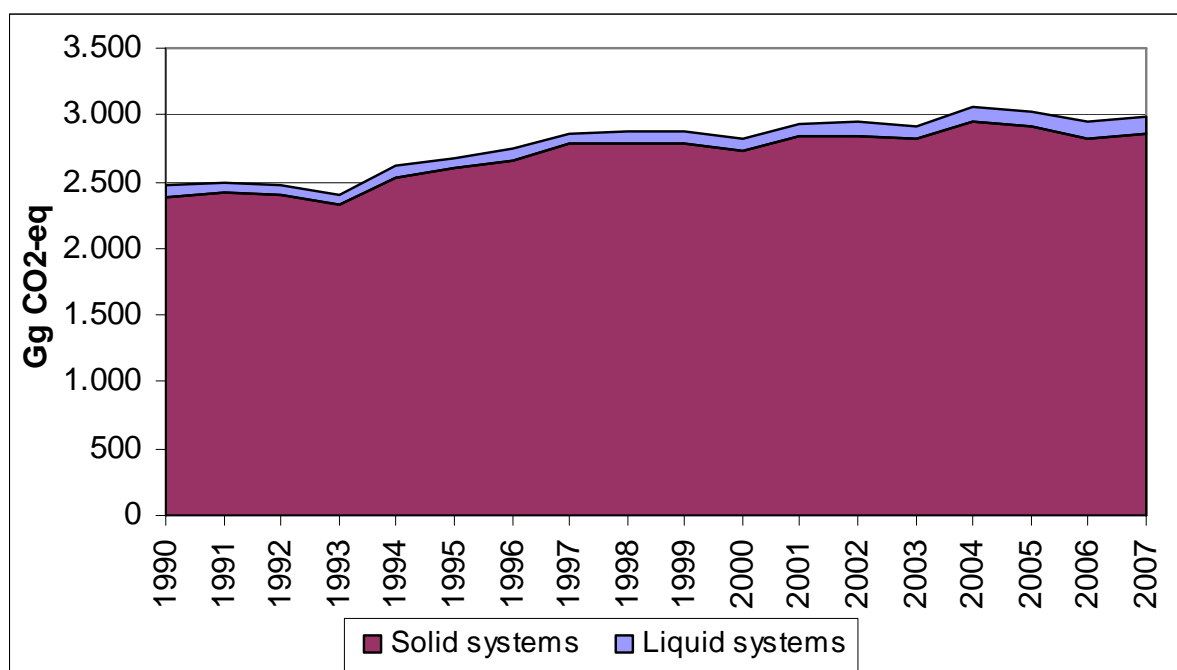
NH₃/NH₄⁺ is usually fast, leading to an increase in these two compounds in the manure storage phase. The concentration of nitrogen in urine varies widely depending on the nitrogen contained in the diet and water consumption. More than 70% of the nitrogen in urine is present in the form of urea, with the remaining percentage comprising amino acids and peptides. The excretions of the poultry species, however, contain uric acid as the main component. The hydrolysis of urea and uric acid into NH₃/NH₄⁺, from discharged urine, takes place quite quickly in both open-grazing and stabling systems. The production of N₂O during animal manure treatment and management may be caused by a combination of nitrification and de-nitrification of the nitrogen in the ammonia contained in the manure and in the urine. The amount emitted depends on the manure management system and the collection interval.

The nitrous oxide emissions stemming from manure management, the history of which is seen in Table 6.5.1 and in Figure 6.5.1, have experienced an increase of 20.95%, going from 2,465 Gg to 2,981 Gg of CO₂-eq. between 1990 and 2007. The increase in the emissions of both systems (solids and liquids) is due to the increase in livestock numbers over the period inventoried.

Table 6.5.1.- CO₂-equivalent emissions (Amounts in Gigagrams)

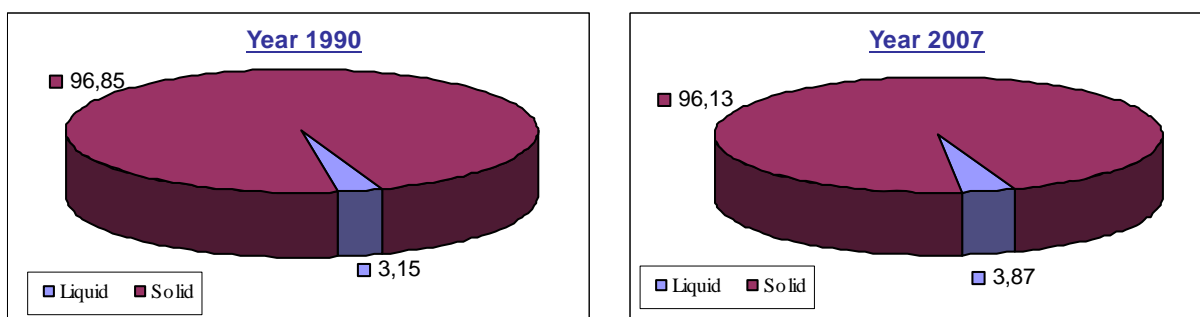
	1990	1995	2003	2004	2005	2006	2007
Liquid Systems	78	85	104	108	108	115	115
Solid Systems	2,387	2,595	2,819	2,956	2,917	2,828	2,866
Total	2,465	2,681	2,922	3,063	3,025	2,943	2,981

Figure 6.5.1.- CO₂-equivalent emissions



Of the two treatment systems, liquid and solid, it is the latter includes solid storage and dry stacking and completely dominates emissions with over 96%, while liquid systems are responsible for barely 4%, as seen in Figure 6.5.2. The contribution of treatments based on anaerobic lagoons and other alternative types is not considered significant in Spain for this activity. Nonetheless, this should not be taken to mean that there are no other types of treatment in Spain, but rather that, in cases such as open grazing or daily spreading of manure, contributions are compiled in group 4D.

Figure 6.5.2.- Distribution of emissions in Group 4B (N₂O)



6.5.2.- Methodological aspects

Choice of method

For the calculation of N₂O emissions stemming from the processing of manure, the default methodology of equation 4.18 in the 2000 IPCC Good Practice Guidance has been followed.

Country-specific values have been used for the parameters contained in this equation 4.18. This has been due to the peculiarities in manure management that exist in the case of Spain, revealing the use of IPCC default values to be a poor representation of the distribution of manure management systems, as well as the availability of studies on the N excreted by different categories of animals.

Activity variables

The basic activity variable for this activity is the N content treated by the manure management system. For the estimation of this N content, three variables are necessary: the number of animals, the N excreted per head and the percentage of N treated in each management system.

The number of animals in each of the different herds is shared as an activity variable with activity 4A (Enteric Fermentation). Therefore for a detailed explanation of this point, please refer to “Activity Variables” in section 6.2.2.

An explanation on the other two variables is given in the following section, “Emissions estimate algorithm”.

Emissions estimate algorithm

As noted above, in order to estimate the emissions for this group, the methodology of equation 4.18 in the 2000 IPCC Good Practice Guidance has essentially been followed. Nonetheless, although the default values proposed in that reference have been taken for the emission factors themselves, for a series of other parameters used in the equation, country-specific values have been applied as described below.

Section 5.2.2 of the UPV document (June 2006) contains a table with the nitrogen excreted per year or each animal category. In the case of cattle, sheep, swine and poultry, the data have been obtained through their respective nitrogen balances (see Appendix 9 of the UPV document (June 2006)). National data for goats and equine livestock (horses, mules and donkeys) are not available. It has therefore been decided to use the default values given in Table 4.20 of the 1996 IPCC Reference Manual selected from the "Middle East and Mediterranean" column and applying age-related correction factors for young animals as per table 4.14 of the 2000 IPCC Good Practice Guidance, assimilating goats to the situation of sheep.

As commented in item 6.3.2 with respect to manure treatment systems, there are no statistics or bibliographic references with precise data on the percentage of use of each treatment system in Spain. Nonetheless, the fact that systems used in Spain do not correspond with those given by the IPCC for Western Europe does appear in the bibliography on the subject and is cited by experts. As a result, it has been decided to base the usage values for the different treatment systems on expert opinion. Please refer to heading 5.2.3 of the UPV document (June 2006) for further development on this point.

The emission factors used are the default values included in Table 4.12 of the 2000 IPCC Good Practice Guidance.

6.5.3.- Uncertainty and consistency of the data series over time

There are various elements that contribute to the determination of the uncertainty of the final activity variable, the amount of nitrogen treated per waste management system. First, the uncertainty associated with the determination of the numbers in each animal category is estimated at around 3%, as documented in item 6.2.3. Secondly, the uncertainty for the amount of nitrogen contained in the excretion of each animal category, derived from calculations based on its nitrogen balance, is allocated a figure not greater than 5%. Finally, the error attributable to the distribution of treated nitrogen per management system, the element with the greatest uncertainty according to expert opinion, can be estimated at around 15%. In this way then, the combined uncertainty for the final activity variable may be less than 20%.

For the uncertainty of the emission factor, a factor of 2 (-50% to +100%) is assumed as given in Table 4.12 of the 2000 IPCC Good Practice Guidance.

Regarding the time pattern, the activity variable is considered consistent since it covers the set of animals with a wide representation in the entire national territory and derives the information directly from a long-standing annual publication from the competent sectorial ministry, MAPA (see heading 6.2.2, Activity Variables). The values for N excretion and the

usage percentages for different management systems are considered in this way to be representative for the whole of the period inventoried.

6.5.4.- Monitoring, quality assurance and verification activities

It should be understood that the monitoring activities performed on the number of heads per animal category already discussed in heading 6.2.4 have the same inference in the calculation of emissions for this key category.

6.5.5.- New calculations

During the present edition of the inventory the variation in emissions is restricted to 2006. This minor variation is due to data availability on the number of heads of poultry and swine for 2006.

Figure 6.5.3.- Comparison of CO₂-eq. emissions for editions 2009 vs 2008

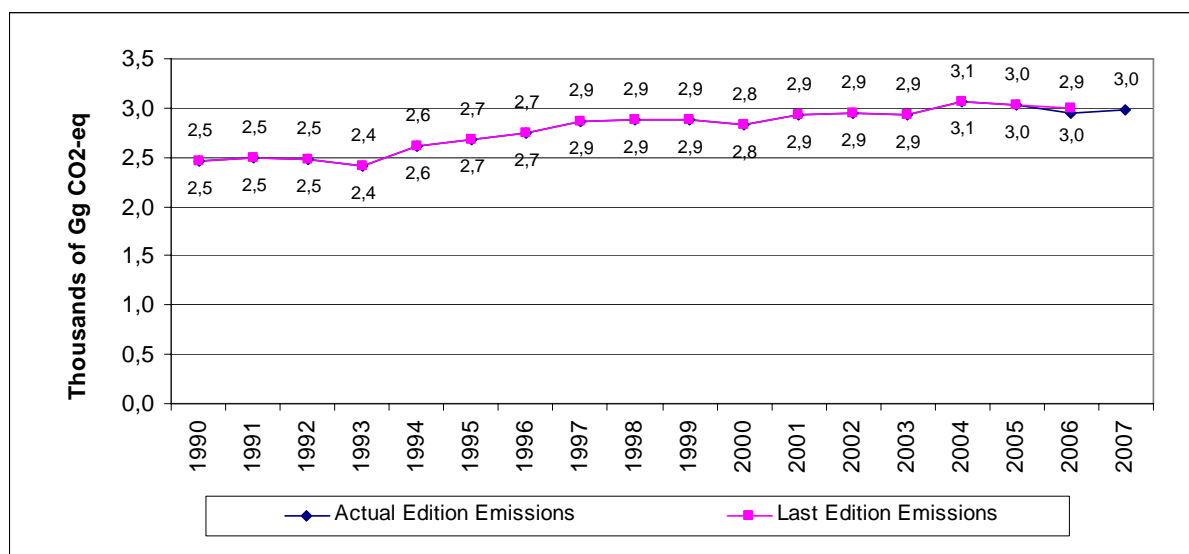
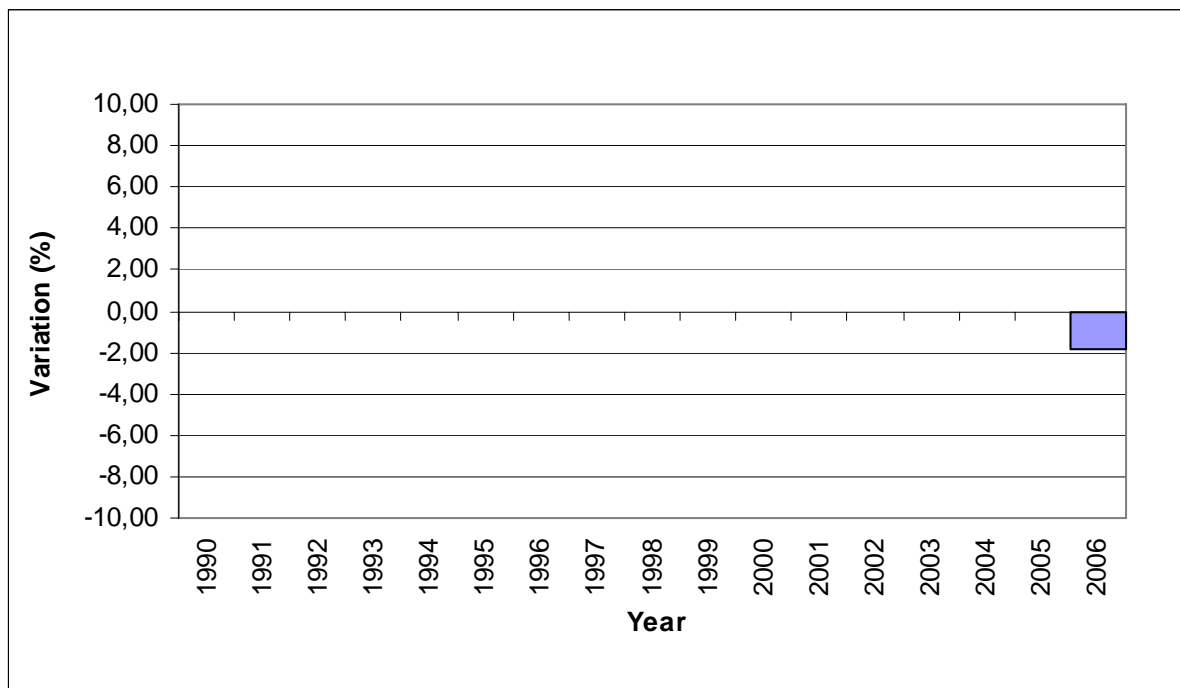


Figure 6.5.4.- Percentage difference of CO₂-eq. emissions for editions 2009 vs 2008

6.5.6.- Improvement plans

At the present time, field studies are being performed to determine empirically the percentages of use of the treatment systems in the Spanish case.

6.6.- Non-key sources

6.6.1.- Description of the emission-producing activity

The non-key sources in agriculture are: Rice growing (4C), Burning in fields of agricultural waste (4F) and Agricultural soils – Other (4D4). Activity 4D4 is explained in item 6.3, as a result, only the other two activities will be covered here.

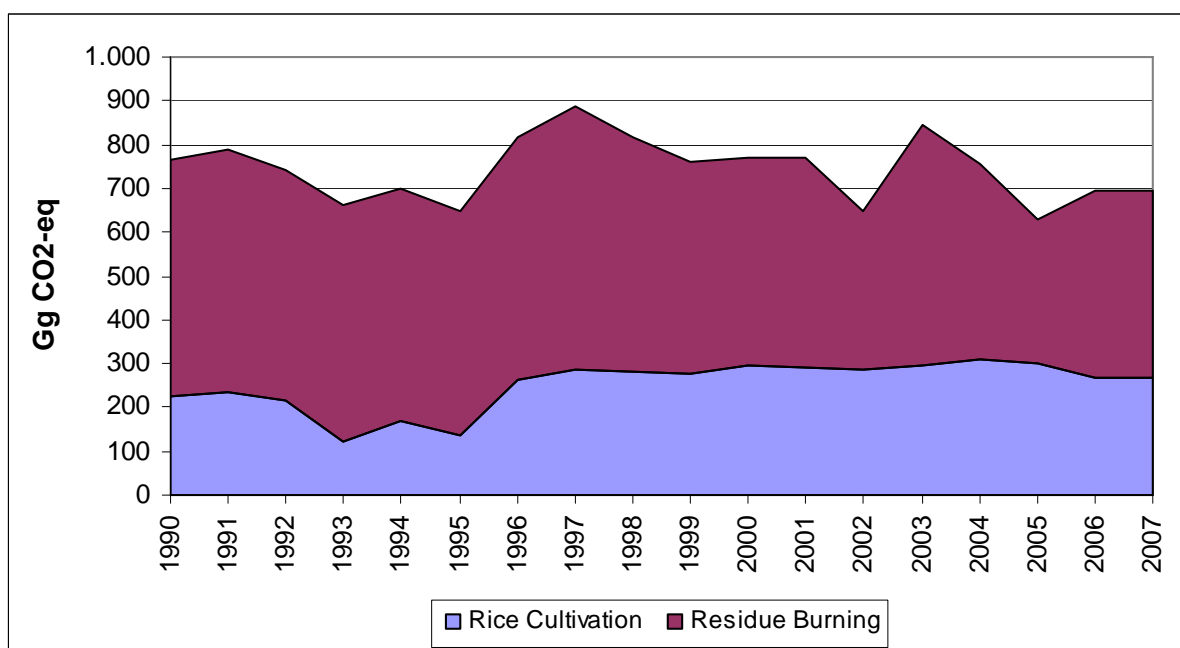
Activity 4F includes in situ burning of undergrowth and other straw-like residue from agricultural crops. Furthermore, it must be taken into account that the burning of stubble and straw is not considered a net source of carbon dioxide (CO₂) emissions, as it is assumed that carbon emission in the form of CO₂, produced by combustion, is compensated with deposition through the growth of plants in the following productive cycle. However, the emissions of CH₄ and N₂O and of other gases with an indirect effect on warming such as NO_x, COVNM, CO, and SO_x are taken into consideration in the inventory

Activity 4C includes methane emissions (CH₄) owing to rice crops. The anaerobic decomposition of organic material in flooded paddy fields is the process generating these

methane emissions. In the case of Spain, only the existence of continually flooded crops is considered, and as a result these are included within activity 4.C.1.a.

Figure 6.6.1 shows the evolution of the emissions in these two activities between 1990 and 2007. Rice cultivation does not undergo major changes, except in drought years. While the burning of residue presents a broken line due to the emission's variation in the burning of cuttings from the pruning of olive trees and grapevines caused by the inter-annual changes in their respective productions.

Figure 6.6.1.- CO₂-equivalent emissions from non-key sources



6.6.2.- Methodological aspects

For rice growing, the methodology in heading 4.3 of the 1996 IPCC Reference Manual has been followed, taking as the emission factor the one corresponding to Spain in Table 4-9 of the said manual.

For the burning of agricultural residues, the methodology in heading 4.4.3 of the Reference Manual has been followed, taking the values in Table 4.16 of the manual as the emission factors. The parameters selected for the calculation of the activity variable can be found in Appendix 3.2.III.

6.6.3.- Uncertainty and consistency of the data series over time

The information on the activity variable in Group 4C comes from the "Food and Agriculture Statistics Yearbook" and, using its methodological specifications, uncertainty is

around 3%, while an uncertainty of around 20% is estimated for the emission factor, for which information has been obtained from national studies,.

For activity 4F, the uncertainty of the emission factors, as can be inferred from the variation ranges shown in Table 4-16 (1996 IPCC Reference Manual), is 40% for CH₄ and 30% for N₂O. The activity variable is based on reliable statistics and bibliographic parameters, with a 40% uncertainty estimate.

6.6.4.- Monitoring, quality assurance and verification activities

The emission series in Group 4C registers a major relative decline in the years 1993-1995. The variation is due to a change in those years of the basic activity variable, cultivated hectares. After proving that the data for the activity variables used in the Inventory coincide with those in the "Food and Agriculture Statistics Yearbook", members of the old Ministry of Agriculture, Fisheries and Food who were consulted, confirmed the data and attributed the fall to the drought in those years.

6.6.5.- New calculations

Emissions from rice have undergone a recalculation, in year 2006, due to new available information of crop surface.

The third variation arises from the correction of a mistake about the year 2004 rice surface area grown. This variation implies a change in the NH₃ volatilization and, thus, of the N mineral availability on the soils. This variation entails the cereals field burning disappearance since 2004, as well as some percentage changes of various crops burning in the year 2000. In addition, for 2006, the total produce has been updated in accordance with the new data available.

6.6.6.- Improvement plans

A large-scale global review of the methodology and the collection of the basic parameters is being carried out through the Inter-governmental Working Group for Agriculture (GT INV-AG) comprising representatives from the Ministry of the Environment and Rural and Marine Affairs with the collaboration of experts in the field. The results of these studies, once they have been verified, may be incorporated into the base information for this inventory sector.

7.- LAND USE, LAND-USE CHANGE AND FORESTRY

7.1.- Sector panorama

Emissions and removals of greenhouse gases as a result of **Land Use, Land Use Change and Forestry (LULUCF)** are presented in this chapter. This sector is divided into several land uses: Forests, category 5A; Cropland, category 5B; Grassland, category 5C; Wetlands, category 5D; Settlements, category 5E; and Other lands, category 5F.

As a main methodological reference for this chapter, the Good Practice Guidance for Land Use, Land Use Change and Forestry of IPCC published in 2003 (henceforth designated as "GPG-2003"), has been utilized.

The Land Uses and Climate Changes Working Group (GT-USCC) is in charge of collecting and processing the information as mentioned in the National Inventory System description. The GT-USCC group comprises representatives of the Directorate-General for Sustainable Development of the Rural Environment, the Directorate-General for the Natural Environment and Forest Policy, the Spanish Office for Climate Change, and the Directorate-General of Environmental Quality and Assessment at the Ministry of the Environment and Rural and Marine Affairs, the National Geographic Institute at the Ministry of Public Works, and technical assistance provided by Análisis Estadístico de Datos, S.A. (AED), the Mediterranean Environmental Research Centre (Centro de Estudios Ambientales del Mediterráneo, CEAM), and Técnicas del Medio Ambiente Natural (TECMENA).

The estimations presented in this 2009 edition of the inventory (series 1990-2007), besides including those corresponding to the year 2007, modify those in the period 1990-2006, published in the previous edition of the inventory. This is due to updating and changes in the base information available and the revision of the methodology applied, aspects which are mentioned further on.

7.1.1.- Methodological aspects in land use estimation

Definitions of interest

The definitions adopted regarding categories of land use are the following:

- Forest or forest lands (FL), which comprises all the land with wooded vegetation consistent with the thresholds used to define forest lands. It also comprises vegetation systems currently inferior to the threshold of the forest lands category, but which are expected to surpass it, and pasture land systems that are not found in cropland or grassland areas. In the Spanish inventory case, and under the United Nations Framework Climate Change Convention, forests are deemed to be those areas where the **Fraction of Tree Crown Cover** (abbreviated, FCC) is 10% or more.

- Cropland or agricultural lands (CL), which comprises croplands, including those where the crops are grown on land converted from woodland into pasture.
- Grasslands (GL), including grasslands proper as well grazing lands not deemed cropland. It also comprises grasslands, meadows or pastures in land zones of the “dehesa” type.
- Wetlands (WL), which comprises flooded or water saturated land throughout the whole year or part thereof.
- Settlements or non-natural land (SL), which comprises all developed land, with the inclusion of transportation infrastructure and human settlements of all sizes, unless they are included in other categories.
- Other lands (OL), comprises barren land, rock, ice and other land areas that do not fall under any of the other categories.
- Pasture land: Generally, pasture land is an anthropized forest system composed mainly by a light woodland layer, which may or may not include scrub and in general includes a herbaceous layer that may or may not include agricultural crops; there is extensive agricultural, forestry and grazing activity that helps maintain its structure over time.

Allocations and reclassifications

In order to carry out the allocation of different land uses in categories 5A to 5F of CRF-REPORTER, the cartography of CORINE LANDCOVER from 1990 (CLC90) and 2000 (CLC00) have been used as a base, harmonizing the nomenclature changes between both years of the CORINE LANDCOVER. CORINE LANDCOVER has been chosen as the basis for data retrieval on the different land usage surface areas as it is the only available cartography for the year 1990 that covers the whole of Spain.

In the case of the forest surface areas, these have been superimposed by the coverage of the Forest Map of Spain (Mapa Forestal de España, MFE50)^{1,2}. This superposition was needed to identify the pasture land extension.

In the case of forests, a meticulous task was performed in order to allocate correctly the pasture land surface areas.

The integration of the Spanish Forestry Map into the CORINE LANDCOVER has permitted the reallocation of all the tesseras which on the forestry map are deemed to be pasture lands, this reallocation has meant a modification in the codification of the CLC90 and CLC00 (categories CORINE LANDCOVER which intersect with pasture lands of the forestry map are reallocated as pasture lands). Likewise the superposition of the forestry map with CORINE LANDCOVER has allowed for the adjustment of criterion used to allocate as forest,

¹ Spanish Forestry Map, scale 1:50,000 (MFE50) of the Directorate-General for Biodiversity (DGB), drafted between the years 1998 and 2007.

² The work of coverage superposition of CORINE LANDCOVER with those of MFE, has been performed by the Nature Databank of the Directorate-General for Biodiversity.

according to the fraction of tree crown cover (data obtained by MFE50)³. The summary of how the reclassification was performed is indicated in Chart 7.1.1.

Chart 7.1.1.- Changes performed in the CLC90 and CLC00 coverage

1. All the tesseras with structural type 3 (pasture lands according to MFE50) have been reclassified, according to FCC, from woodlands into pasture lands considered as "OL" (if FCC < 10%) or forest (FCC >=10%) considered as "FL".
2. The category "Agricultural-Forestry Systems¹" has been created, containing pasture lands with an FCC between 10 and 20%, due to the agrarian use carried out on these surface areas and the need to differentiate them from other categories of "FL" which do not have any agrarian use. This surface area of the "Agricultural-Forestry System¹" will be included in the UNFCCC category as "FL" for the purposes of reporting to the Convention.
3. The categories considered to be pasture lands, 24410 (grasslands, meadows or pastures with woodland converted into pastures) and 24420 (Agricultural crops with woodland converted into pastures), but which according to MFE50 present a structural type other than 3 (corresponding to pasture lands), have been allocated to natural grasslands¹ (24410) and to croplands¹ (24420), independently from the fraction of tree crown cover.
4. The surface area of pasture land in the MFE50 that is not in CORINE LANDCOVER has been reclassified in CORINE LANDCOVER so as to incorporate it as pasture land, as the GT-USCC decision was to consider the MFE50 pasture land area. The CORINE LANDCOVER categories 24210, 24211, 24221, 24330, 24410, 32100, 32110, 32111, 32120, 32121 and 32122 are considered "GL" as the result of the cartography superposition process.
5. In allocating as forest the corresponding categories of CORINE LANDCOVER have been taken into account, discounting those surface areas which have a woodland FCC inferior to 10%. These surface areas (whose FCC is inferior to 10%) have been reallocated to a new category (Forestry surface area – forest – with FCC < 10%¹).
6. The surface area occupied by underbrush with dispersed woodland and whose FCC is greater than 10% is also deemed as forest land.
7. For the remaining categories, the original allocations of CORINE LANDCOVER have been preserved.

¹ These correspond to intermediate categories in the process of homogenization and allocation.

Procedure for surface area adjustment

The superposition process has produced more than 5,700,000 tesseras for each coverage performed, with slight modifications in the total surface area. In Table 7.1.1 the original data of the CORINE LANDCOVER coverage is shown, along with those obtained with the superposition of CORINE LANDCOVER and MFE50, and the resulting differences are shown in the totals.

³ This work of obtaining the surface areas by categories of land use according to the time-series, and the estimate of surface area changes between the aforementioned categories, has been performed by CEAM.

Table 7.1.1.- Total surface area of CLC90 and CLC00 in the original cartography, along with that obtained from the superposition with the forestry map (CLC and MFE)

	CLC90	CLC00
CORINE LANDCOVER ORIGINAL (1), Ha	65,729,423	65,729,423
CORINE LANDCOVER and MFE50 (2), Ha	64,205,777	65,763,120
Difference (1)-(2), Ha	-1,523,646	33,697
Difference (% in relation to the original)	-2.3	0.05

Part of the discrepancies may be justified due to slight displacements between the two cartographies of CORINE LANDCOVER and MFE50, although a cartographic correction of this type has not been proposed

Analyzing the content of the CORINE LANDCOVER and MFE50 cartographies in detail, it can be seen that the surface area without defined content (areas outside geographic limits and seas or oceans) is likewise variable between the two reference years, 1990 and 2000.

Discounting the superimposed CORINE LANDCOVER and MFE50 surface area from the previous table, the tesseras not allocated to a territorial unit of the Spanish map or for which a land use code is missing result in a total national surface area of 50,649,190 Ha which will be deemed as the national territory area for the purpose of surface area analysis in this chapter. The previous figure really corresponds to CLC00, having added an adjustment surface area of 890 Ha to the CLC90 in order to match up the total national surface area over time.

Seeing that at the moment, the only available verified information on a national level is from CORINE LANDCOVER, the year-on-year change, throughout the whole inventory period, has been estimated according to linear projections upon the changes detected between the aforesaid reference years, interpolating between 1990 and 2000 and extrapolating subsequent to 2000; in the case of reforestation of croplands, the direct data provided by the Directorate-General for the Sustainable Development of the Rural Environment have been taken into account with regard to the conversion of these lands from agricultural use to forestry use.

7.1.2.- Results from the surface area estimation of land use

As a result of the aforementioned procedures, the figures of estimated surface areas in the different categories of land use and of the changes taking place in the surface areas throughout the years of the inventory period are shown in this section.

To obtain the surface areas that may be allocated (total surface and surface area that remains in the same category) to each of the categories for a specific year, the following equation is performed:

$$U_i^t = R_i^t + \sum_{j \neq i} C_{ji}^t = \left(U_i^{t-1} - \sum_{j \neq i} C_{ij}^t \right) + \sum_{j \neq i} C_{ji}^t$$

where,

U_i^t = estimated surface area of the category i in the year t (Ha)

R_i^t = surface area that continues being of the same category i in the year t (Ha).
It corresponds to that existing in the year $t-1$ minus the lands converted in the year t to another category of land use.

C_{ji}^t = surface area which passes from category j to that of i in the year t (Ha).

C_{ij}^t = surface area which passes from category i to that of j in the year t (Ha).

According to the preceding formula, the conversions refer to a specific year, and the calculation of the surface areas that continue in the same category of land use change, depending on the detractions from that use and the conversions to that use. The formula calculates the surface area stocks by usage at the end of each reference year, after having collected the conversions between uses. Notwithstanding the preceding, in the case of forest systems, the conversions are considered according to the GPG-2003, having a maturity period of 20 years, until they are fully integrated into forest use to which they have been reconverted from other uses. For this reason, the tables of IPCC-CRF-REPORTER report each year the aggregate conversion figures which have not yet matured (until 20 years have elapsed) from the initial period of conversion. In subsection 7.2 of Forest Systems it is reported coherently, breaking down the conversions of forest use by means of a section that compiles the converted surface areas which are in transition, until their maturing as final forest use.

Table 7.1.2 presents, for each of the categories of land use and for the aggregate of the same, the estimated surface areas between 1990 and 2007. Table 7.1.3 shows the surface areas by land use as reported in the CRF-REPORTER, putting special emphasis upon the differentiation in the category of forest lands, that is, between the surface areas that remain as forest and surface areas that have been converted to forest, but which are in a maturing process until 20 years have elapsed from their conversion to such a use. Table 7.1.4 provides information regarding the changes of use between categories taking place in each of the years in the period 1990-2007.

Table 7.1.2.-Evolution of the total surface areas by categories (Amounts in hectares)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
FL	13,522,734	13,522,734	13,522,734	13,522,734	13,579,780	13,659,174	13,755,758	13,844,880	13,928,549
CL	21,359,011	21,345,544	21,332,078	21,318,611	21,248,046	21,155,114	21,044,974	20,942,302	20,845,089
GL	4,668,729	4,674,504	4,680,279	4,686,053	4,691,829	4,697,603	4,703,377	4,709,153	4,714,927
WL	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965
SL	768,014	787,856	807,698	827,542	847,384	867,226	887,070	906,913	926,756
OL	10,246,737	10,234,587	10,222,436	10,210,285	10,198,186	10,186,108	10,174,046	10,161,977	10,149,904
Total	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190

	1999	2000	2001	2002	2003	2004	2005	2006	2007
FL	13,982,938	14,045,063	14,082,293	14,104,032	14,127,285	14,148,179	14,168,862	14,190,939	14,207,904
CL	20,777,181	20,701,530	20,650,795	20,615,567	20,578,823	20,544,439	20,510,267	20,474,698	20,444,246
GL	4,720,702	4,726,477	4,732,252	4,738,027	4,743,802	4,749,578	4,755,353	4,761,129	4,766,904
WL	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965
SL	946,599	966,442	986,287	1,006,130	1,025,974	1,045,818	1,065,662	1,085,507	1,105,351
OL	10,137,805	10,125,713	10,113,598	10,101,469	10,089,341	10,077,211	10,065,081	10,052,952	10,040,819
Total	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190

FL: Forestry or woodland areas; CL: Croplands; GL: Grasslands; WL: Wetlands; SL: Settlements; OL: Other land

Table 7.1.3.- Evolution of the surface areas just as reported in the CRF-REPORTER (Amounts in hectares)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
FL remaining	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734
FL transition	-	-	-	-	57,046	136,440	233,024	322,146	405,815
CL	21,359,011	21,345,544	21,332,078	21,318,611	21,248,046	21,155,114	21,044,974	20,942,302	20,845,089
GL remaining	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954
GL transition	5,775	11,550	17,325	23,099	28,875	34,649	40,423	46,199	51,973
WL	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965
SL remaining	748,172	768,014	787,856	807,699	827,541	847,384	867,227	887,070	906,913
SL transition	19,842	19,842	19,842	19,843	19,843	19,842	19,843	19,843	19,843
OL	10,246,737	10,234,587	10,222,436	10,210,285	10,198,186	10,186,108	10,174,046	10,161,977	10,149,904
Total	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190

	1999	2000	2001	2002	2003	2004	2005	2006	2007
FL remaining	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734
FL transition	460,204	522,329	559,559	581,298	604,551	625,445	646,127	668,204	685,170
CL	20,777,181	20,701,530	20,650,795	20,615,567	20,578,823	20,544,439	20,510,267	20,474,698	20,444,246
GL remaining	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954	4,662,954
GL transition	57,748	63,523	69,298	75,073	80,848	86,624	92,400	98,176	103,950
WL	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965	83,965
SL remaining	926,756	946,599	966,443	986,286	1,006,130	1,025,974	1,045,818	1,065,662	1,085,507
SL transition	19,843	19,843	19,844	19,844	19,844	19,844	19,844	19,845	19,845
OL	10,137,805	10,125,713	10,113,598	10,101,469	10,089,341	10,077,211	10,065,081	10,052,952	10,040,819
Total	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190	50,649,190

FL: Forestry or woodland areas; CL: Croplands; GL: Grasslands; WL: Wetlands; SL: Settlements; OL: Other land

Table 7.1.4.- Matrix of changes in land use for each year throughout the inventory period (Amounts in hectares)

From	to	1990	1991	1992	1993	1994	1995	1996	1997	1998
CL	FL	-	-	-	-	57,046	79,394	96,584	89,122	83,669
CL	GL	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
CL	SL	7,692	7,692	7,692	7,692	7,744	7,764	7,781	7,775	7,770
OL	SL	12,150	12,150	12,150	12,151	12,099	12,078	12,062	12,068	12,073

From	to	1999	2000	2001	2002	2003	2004	2005	2006	2007
CL	FL	54,389	62,125	37,230	21,739	23,253	20,894	20,682	22,077	16,966
CL	GL	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
CL	SL	7,744	7,751	7,729	7,715	7,716	7,714	7,714	7,716	7,711
OL	SL	12,099	12,092	12,115	12,129	12,128	12,130	12,130	12,129	12,133

FL: Forestry or woodland areas; CL: Croplands; GL: Grasslands; WL: Wetlands; SL: Settlements; OL: Other land

7.2.- Forest systems. Forests (5A)

The estimation of removals and emissions of CO₂ of forests within the LULUCF sector and the estimation of non-CO₂⁴ gas emissions from forest fires is calculated by the General Directorate for Biodiversity (which belongs to the Ministry of Environment). These estimations are made by the Directorate General for Environmental Quality and Assessment at the Ministry of the Environment and Rural and Marine Affairs, which is the National Authority of the National Polluting Emissions Inventory System. These are the points dealt with in this category of forests.

In the examination of key categories a separate analysis has been made for the LULUCF sector. Within this sector, the forests, regarding the process of net uptakes of CO₂, comprise a key category, due to the level, throughout all the years of the inventory period and, due to this trend, in the sub-periods 1990-1992; 1994-2007. In their own right, forest fires are identified as key sources of CH₄ and N₂O in the trend seen in the years 1991 and 1994. For a methodological report regarding this point see Appendix 1 "Key categories".

Estimation of carbon forest sinks

In the process of carbon fixation by the forest land in the period 1990-2007 the following subcategories of land use can be observed within the forestry systems: a) forest that continues to be a forest, b) forest in maturing period, which is derived from land converted in preceding years but which has not yet reached 20 years maturity and c) croplands that become forest in the aforesaid year. Table 7.2.1 shows the surface evolution of the stated subcategories of land use. The increase in forest land areas is due to reforestation of croplands under the Common Agrarian Policy. The calculation methodology for estimating the carbon sinks due to this land conversion is presented further on in this chapter under the heading 7.2.2.2 *Lands that become forest* (see also Appendix A3.3). The conversion to forest in the remaining land use has not been identified in the period 1990-

⁴ The emissions of CO₂ produced by forest fires and lumber extraction from forests is already discounted in the biomass variation balances (net increase) in the National Forest Inventory.

2007. Table 7.2.2 shows the carbon fixation quantification by the stated land use subcategories of the forestry systems.

Table 7.2.1.-Evolution of the total surface areas by categories (Amounts in hectares)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
FL remaining	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734
FL transition	0	0	0	0	0	57,046	136,440	233,024	322,146
CF	0	0	0	0	57,046	79,394	96,584	89,122	83,669
TOTAL	13,522,734	13,522,734	13,522,734	13,522,734	13,579,780	13,659,174	13,755,758	13,844,880	13,928,549

	1999	2000	2001	2002	2003	2004	2005	2006	2007
FL remaining	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734	13,522,734
FL transition	405,815	460,204	522,329	559,559	581,298	604,551	625,445	646,127	668,204
CF	54,389	62,125	37,230	21,739	23,253	20,894	20,682	22,077	16,966
TOTAL	13,982,938	14,045,063	14,082,293	14,104,032	14,127,285	14,148,179	14,168,861	14,190,938	14,207,904

Table 7.2.2.- Carbon fixation in forest land (Gg C)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
FL remaining	5,857	5,857	5,857	5,857	5,857	5,857	5,857	5,857	5,857
FL transition	0	0	0	0	0	126	303	545	770
CF	0	0	0	0	126	177	243	224	230
TOTAL	5,857	5,857	5,857	5,857	5,982	6,159	6,402	6,626	6,856

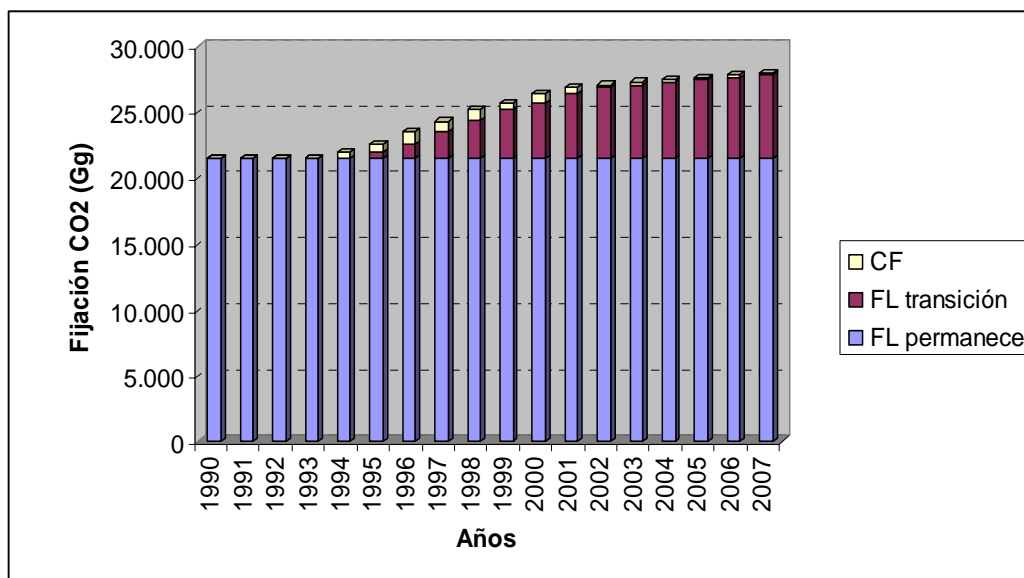
	1999	2000	2001	2002	2003	2004	2005	2006	2007
FL remaining	5,857	5,857	5,857	5,857	5,857	5,857	5,857	5,857	5,857
FL transition	999	1,141	1,335	1,461	1,518	1,581	1,627	1,668	1,730
CF	142	194	126	56	64	45	41	62	33
TOTAL	6,998	7,192	7,318	7,374	7,438	7,483	7,524	7,586	7,620

FL remaining: Forests that remain forests (for its abbreviation in English)

FL transition: Lands reforested in previous years, but which are still in their maturing period of 20 years (for its abbreviation in English)

CF: Croplands that each year convert to forests (for its abbreviation in English)

In Figure 7.2.1.- Evolution of the trend in CO₂ removal in forest land (Gg of CO₂), the trend in C removal is represented, already expressed in CO₂ (Gg of CO₂), from the year 1990 to 2007, by the categories FL remains, FL transition and CF previously described.

Figure 7.2.1.- Evolution of the trend in CO₂ removal in forest land (Gg of CO₂)

FL remaining: Forests that remain forests (for its abbreviation in English)

FL transition: Lands reforested in previous years, but which are still in their maturing period of 20 years (for its abbreviation in English)

CF: Croplands that each year convert to forests (for its abbreviation in English)

Estimation of non-CO₂ gas emissions from forest fires

Regarding forest fires, Table 7.2.3 presents the data about burned surfaces and table 7.2.4 an estimation of non-CO₂ gas emissions. The methodology for this estimation is presented further on in this chapter under the heading 7.2.2.3 (see also Appendix 3.3).

Table 7.2.3.- Total burned surface (in hectares)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Burned surface	72,117	105,964	39,834	33,266	250,407	42,137	10,280	21,259	42,404

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Burned surface	23,930	45,079	19,170	25,197	53,674	51,711	69,350	71,084	29,403

Table 7.2.4.- Non-CO₂ gas emissions in forest fires which have a greenhouse effect (Amounts in tonnes)

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998
CH ₄	8,140	11,642	4,327	3,704	25,019	6,850	1,999	5,990	5,841
CO	71,228	101,867	37,860	32,414	218,919	59,935	17,490	52,410	51,112
N ₂ O	56	80	30	25	172	47	14	41	40
NOx	2,023	2,893	1,075	920	6,217	1,702	497	1,488	1,451

Gas	1999	2000	2001	2002	2003	2004	2005	2006	2007
CH ₄	3,672	7,576	3,097	4,881	6,732	5,414	11,249	24,336	1,650
CO	32,133	66,292	27,098	42,706	58,908	47,373	98,432	212,938	14,437
N ₂ O	25	52	21	34	46	37	77	167	11
NOx	913	1,883	770	1,213	1,673	1,345	2,795	6,047	410

7.2.1.- Description of the sources

This category includes the net removals of carbon resulting from living biomass, dead organic matter and soils in forest land remaining forest land and land converted to forest land. Forest that remains forest and land that becomes forest are considered here. Also included are non-CO₂ gas emissions of a greenhouse effect caused by forest fires.

7.2.2.- Methodology

Calculations of carbon emissions and removals due to the LULUCF Sector (*Land Use, Land Use Change and Forestry*) in Spain have been carried out on the basis of the IPCC (*Intergovernmental Panel on Climate Change*) Good Practice Guidelines for LULUCF, using:

- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, from now on Reference Manual 1996 IPCC ⁵.
- Good Practice Guidance for Land Use, Land-Use Change and Forestry, 2003, GPG2003, from now on GPG-2003⁶.

The main data sources used are the following:

- National Forestry Inventory (NFI)
 - NFI2. ICONA Second National Forest Inventory (1986-1995). ICONA – National Institute for Nature Conservation. Ministry of Agriculture, Food and Fisheries
 - NFI3. DGMNPF Third National Forest Inventory (1997-2007). Directorate-General for the Natural Environment and Forest Policy. Ministry of the Environment and Rural and Marine Affairs.
- CORINE LANDCOVER 1990 and 2000 (CLC90 and CLC00, respectively)
- Spanish Forest Map (MFE50) from the DGB (map made between 1998 and 2007).
- Reforestation of croplands under the Common Agrarian Policy, information provided by the Ministry of the Environment and Rural and Marine Affairs.
- Productivity map of potential forestry in Spain. Ministry of Environment, 2000.
- Biomass Expansion Factors (BEF-D), internationally validated in the COST-E21 action. Centre for Ecological Investigation and Forestry Applications (CREAF).

After the numbering of tables, figures and equations used in this chapter, between brackets, we give the numbering system established for the equations, tables and figures in the reference document for the calculations, GPG2003.

⁵ <http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm>

⁶ <http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm>

The methodology and emission factors used are summarized in the following table 7.2.5. The precision level (*Tier* in GPG-2003) applied in the methodology for obtaining and managing data is also reported. It is possible to choose any of three tiers: from 1 to 3, from a lesser to a greater tier of completeness, having basically applied tier T1, even though complemented with data on country-specific values (CS). In the successive sections a more complete description of the methodology is developed.

Table 7.2.5.- Methodology and emission factor used

		CO ₂	
		Method	Emission factor
Forest	Forest land remaining forest land	T1, CS, D	D, CS
	Living biomass	T1, D, CS	D, CS
	Dead organic matter	T1	-
	Soils	T1	-
	Lands converted to forest land	T1	D, CS

T1: GPG2003 Methodology, Tier 1.

CS: Country-specific methodology and emissions factor.

D: GPG2003 default methodology and emissions factor.

7.2.2.1.- Forest land remaining forest land

The land-use category “Forest land Remaining Forest land” in GPG2003 describes the estimation of changes in carbon stock from five different carbon sinks: aboveground biomass, underground biomass, deadwood, residues and organic matter in the soil.

Equation 7.2.1 presents the estimation algorithm for the annual carbon emissions or fixings in forests that remain forests.

Equation 7.2.1.-Annual change in carbon stocks in living biomass in forest land remaining forest land

(Equation 3.2.1. in GPG2003)

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

where,

ΔC_{FF} = is the annual change in carbon stocks in forest land remaining forest land (tonnes C x year¹)

$\Delta C_{FF_{LB}}$ = is the annual change in carbon stocks in living biomass (including aboveground and underground biomass) in forest land remaining forest land (tonnes C x year)

$\Delta C_{FF_{DOM}}$ = is the annual change in carbon stocks in dead organic matter (including deadwood and waste material) in forest land remaining forest land (tonnes C x year¹)

$\Delta C_{FF_{Soils}}$ = is the annual change in carbon stocks in soils in forest land remaining forest land (tonnes C x year¹)

7.2.2.1.1. Change in carbon stocks in living biomass

To calculate the carbon stocks in living biomass, the **Stock Change Method** described in the IPCC Good Practice Guidance GPG-2003 is used, in accordance with equation 7.2.2 Annual change in carbon stocks in living biomass in forest land remaining forest land:

Equation 7.2.2.- Annual change in carbon stocks in living biomass in forest land remaining forest land

(Equation 3.2.3. in GPG2003)

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

and

$$C = [V \bullet D \bullet BEF] \bullet (1 + R) \bullet CF$$

where,

$\Delta C_{FF_{LB}}$ = annual change in carbon stocks in living biomass (includes biomass above and below ground) in forest land remaining forest land (tonnes C year¹)⁷

C_{t_2} = total carbon in biomass calculated at the time t_2 , (tonnes C)

C_{t_1} = total carbon in biomass calculated at the time t_1 , (tonnes C)

V = specific merchantable wood volume (m³)

D = basic wood density (tonnes dry matter (d.m.) m⁻³ merchantable volume)

BEF = biomass expansion factor for conversion of merchantable volume to aboveground tree biomass, dimensionless.

⁷ Therefore, the label associated with losses will be label "IE" because the quantification of the same has already been discounted from the gross growth.

R = root-to-shoot ratio, dimensionless

CF = carbon fraction of dry matter (default = 0.5), (tonnes C (tonnes **d.m.**)⁻¹)⁸

The data of merchantable volume used (V) is taken from Table 301 of the National Forestry Inventories for each province. This table contains, among other data, the merchantable volume with bark (VCC) in m³ by hectare, stratum and species.

In this report, the Biomass Expansion Factor ($BEF \cdot D$)⁹ parameters used were calculated in CREAM (Centre for Ecological Investigation and Forestry Applications). They are equal to the product of D (density corresponding to each species) and BEF (biomass expansion factor calculated for each species) as can be seen in the BEFD table (Table BEFD, at the end of Appendix 3.3.), and convert m³ of timber-yielding volume (including bark) into tonnes of dry matter of above-ground biomass. These factors have been used because they are internationally validated in Action Cost E21, by referring specifically to forest species in Spanish territory, therefore being closer to the current national situation than the default factors of IPCC, and also because they are deemed conservative.

By applying the root expansion factor (R), the total annual value of biomass, both above and below ground, is obtained (B_T). Table 3.A.1.8 of the GPG2003 puts forward a series of values for R and those corresponding to the type of vegetation are taken, namely coniferous trees and broad-leaved trees, and the mean values have been calculated for these, with the following results:

- Forest of coniferous trees. $R = 0.337$
- Forest of broad-leaved trees. $R = 0.326$

Using the result of biomass total (B_T) for each NFI and province, its value in each year can be calculated: to obtain these values, the difference between NFI2 and NFI3 is calculated and divided by the number of years elapsed between them, obtaining a constant (the annual increment of B_T) which has to be added in each year to obtain the B_T value of the following year.

In the case of the provinces which do not yet have NFI3 available (6 provinces in Andalusia as of December, 2008), the average value has been obtained from all the annual increments of B_{TOTAL} in the provinces of Andalusia that have completed the NFI3 (Córdoba and Jaén), and this value is added, based on the data from the NFI2, to obtain the B_{TOTAL} value in each year.

The starting data used to perform the calculations are expressed by surface area unit (per hectare). Therefore, in order to obtain the B_{TOTAL} value, the average national value per

⁸ By shoot it is understood as the total aboveground biomass.

⁹ Biomass Expansion Factors ($BEF \cdot D$) obtained by CREAM. These values are validated internationally (COST E21). $BEF \cdot D$ values not calculated by the CREAM are obtained by comparison with similar species or are assigned the default value of 0.8 (= 1.6*0.5), in accordance with the IPCC-1996 publication (please see the $BEF \cdot D$ table at the end of Appendix 3.3).

hectare is calculated (see Appendix A.3.3.2) multiplying the same by the surface area of *forest land remaining forest land*.

The surface area data has been obtained from the information provided by CORINE LANDCOVER (CLC90 and CLC00) and the Spanish Forestry Map (MFE50).

Finally, the default value proposed in GPG-2003 has been applied for the fraction coefficient of carbon stock in dry matter (**CF**), the value being 0.5 tonnes of carbon per tonne of dry matter.

By calculating the difference between the carbon stock in living biomass for one year with that of the previous year, the annual increment in carbon stock in living biomass is obtained.

In Appendix A.3.3.1 of this document, the case of one province (Madrid) is used as a detailed example, in order to verify the methodology used in each calculation of the carbon stocks stemming from biomass growth.

Losses of biomass resulting from harvesting, fuel wood gathering or disturbances in *forest land remaining forest land* are not established, because this information is already included in the National Forest Inventories, according to the Stock Change Method, developed in GPG2003.

7.2.2.1.2. Change in the carbon stocks in dead organic matter

Changes in carbon stocks in two types of dead organic matter pools are considered in GPG2003:

- dead wood
- residues/litter

Under the Tier 1 assumption and, taking into account that there is no significant change in the forest type or forest management, the estimation of these values is not necessary. In the IPCC Guidelines, it is considered that the time average value of these pools remains constant, with inputs to dead matter pools balanced by outputs. Therefore, in the CRF the zero value has been allocated, and not the "NO" label.

7.2.2.1.3. Change in carbon stocks in soils

This category comprises two different sub-groups:

- the organic fraction of mineral forest soils,
- organic soils.

The emissions or removals of CO₂ on the part of the soil are associated with the changes in the organic carbon pools in the soil. These changes are the result of the balance between the uptake of photosynthetically fixed carbon and the losses from decomposition. In

general, this dynamic of forest soil carbon is the result of changes in the type of forest or the intensity of its management.

Under the hypothesis of Tier 1, the approach adopted in Spain, it is assumed that when forest remains forest, the carbon stocks in soil organic matter of mineral soils remain constant if there are no major changes in forest management, type of forest, or disturbances due to other causes. Therefore, a value of 0 has been allocated in the CRF, and not the “NO” label.

In the same way, the changes in the carbon stocks in organic soils (peat bogs and similar) are associated with drainage and disturbances resulting from forest management, and have not been considered in this inventory, seeing that these type of soils are not nationally relevant (surface area of less than 0.1% of the national total surface area).

7.2.2.2.- Land converted to forest land

According to GPG-2003, managed lands become forests both through natural regeneration and from non-natural regeneration (including plantations). The estimation of emissions and absorptions of carbon coming from the conversion of land for forestry uses has been calculated by means of the annual change in carbon stocks in the following three types of deposits in land converted to forest: i) living biomass, ii) dead organic matter and iii) the soil.

The calculation of CO₂ changes in land that becomes forest is performed using the Equation 7.2.3. Annual change in carbon stocks in land converted to forest land.

Equation 7.2.3.- Annual change in carbon stocks in land converted to forest land

(Equation 03.02.21. in GPG-2003)

$$\Delta C_{LF} = \Delta C_{LF_{LB}} + \Delta C_{LF_{DOM}} + \Delta C_{LF_{Soils}}$$

where,

ΔC_{LF} = is the annual change in carbon stocks in land converted to forest land (tonnes C x year⁻¹)

$\Delta C_{LF_{LB}}$ = is the annual change in carbon stocks in living biomass in land converted to forest land (tonnes C x year⁻¹)

$\Delta C_{LF_{DOM}}$ = is the annual change in carbon stocks in dead organic matter in land converted to forest land (tonnes C x year⁻¹)

$\Delta C_{LF_{Soils}}$ = is the annual change in carbon stocks in soils of land converted to forest land (tonnes C x year⁻¹)

7.2.2.2.1. Change in carbon stocks in living biomass

The annual changes in carbon stocks in living biomass are estimated by distinguishing between natural and non-natural regeneration using the following equation 7.2.4. Annual change in carbon stocks in living biomass in land converted to forest land

Equation 7.2.4.- Annual change in carbon stocks in living biomass in land converted to forest land

(Equation 03.02.22. in GPG-2003)

$$\Delta C_{LF_{LB}} = \Delta C_{LF_{Growth}} - \Delta C_{LF_{Loss}}$$

where,

$\Delta C_{LF_{LB}}$ = is the annual change in carbon stocks in living biomass in land converted to forest land (tonnes C x year⁻¹)

$\Delta C_{LF_{Growth}}$ = annual increment in carbon stocks in living biomass due to growth in land converted to forest land (tonnes C x year⁻¹)

$\Delta C_{LF_{Loss}}$ = annual decrease in carbon stocks in living biomass due to losses from harvesting, fuel wood gathering and disturbances in land converted to forest land, (tonnes C x year⁻¹)

A) Increment in carbon stocks in living biomass ($\Delta C_{LF_{Growth}}$)

The amount of carbon increasing in living biomass has been calculated using the equation 7.2.5, proposed in the GPG-2003.

Equation 7.2.5.- Annual increment in carbon stocks in living biomass in land converted to forest land

(Equation 03.02.23. in GPG-2003)

$$\Delta C_{LF_{Growth}} = \left[\Delta_k A_{INT_k} \bullet G_{TotalINT_k} + \Delta_m A_{EXT_m} \bullet G_{TotalEXT_m} \right] \bullet CF$$

where,

$\Delta C_{LF_{Growth}}$ = annual increment in carbon stocks in living biomass due to growth in land converted to forest land (tonnes C x year⁻¹)

$\Delta_k A_{INT_k}$ = land area converted to intensively managed forests under condition k (plantations included) (Ha)

$G_{TotalINT_k}$ = annual growth rate of biomass in intensively managed forest under condition k (including plantations) (tonnes d.m. x Ha⁻¹ x year⁻¹)

$\Delta_m A_{EXT_m}$ = land area converted to extensively managed forests under condition m (natural regenerations included) (Ha)

$G_{TotalEXT_m}$ = annual growth rate of biomass in extensively managed forest under condition m (including natural regenerations) (tonnes d.m. x Ha⁻¹ x year⁻¹)

k, m = represents the different conditions in which intensively and extensively managed forest are growing, respectively.

CF = carbon fraction of dry matter (default=0.5), (tonnes C x tonnes d.m.⁻¹).

Obtaining starting data and calculations is dependent on the forest's management:

- in the case of intensive management, the selected areas are those corresponding to reforested agrarian lands (croplands), as these areas are regenerated in a non-natural way.
- in the case of extensive management, assuming that these are forest areas that do not comply with the forest conditions but, due to the increase in mass and the Fraction of Tree Crown Cover (>10%), have become a forest. That is to say, natural forest regeneration with a minimum of human intervention.¹⁰

A.1) Intensive Management:

The part of equation 7.2.5 corresponding to intensive management is referenced in equation 7.2.5.a as follows:

Equation 7.2.5.a.- Annual increment in carbon stocks in living biomass due to growth in land converted to forest land by intensive management

$$\Delta C_{LF_{Growth}^{INT}} = \left[\Delta_k A_{INT_k} \bullet G_{TotalINT_k} \right] \bullet CF$$

where,

$\Delta C_{LF_{Growth}^{INT}}$ = annual increment in carbon stocks in living biomass due to growth in land converted to forest land by intensive management (tonnes C x year⁻¹)

$\Delta_k A_{INT_k}$ = land area converted to intensively managed forests under condition k (plantations included) (Ha)

¹⁰ This situation however, has not been recorded in the inventory, as will be seen further on, because extensively managed lands that from other uses convert to forest land, have not been identified.

$G_{TotalINT_k}$ = annual growth rate of biomass in intensively managed forest under condition k (including plantations) (tonnes d.m. x Ha⁻¹ x year⁻¹)

k = represents the different conditions in which intensively managed forests are growing.

CF = carbon fraction of dry matter (default=0.5), (tonnes C x tonnes d.m.⁻¹).

The area (A_{Int}) is obtained starting from the forestry data of croplands provided by the Ministry of Environment, and the Rural and Marine Environment.

For calculating the annual growth rate of biomass in forests ($G_{Total INT}$), the equation 7.2.6 has been used.

Equation 7.2.6.- Biomass in croplands converted to forest land.

(Equation 3.2.5. in GPG2003)

$$G_{TotalINT} = G_W \cdot (1 + R)$$

$$G_W = I_v \cdot D \cdot BEF$$

where,

$G_{TotalINT_k}$ = annual growth rate of biomass in intensively managed forests under condition k (including plantations) (tonnes d.m. x Ha⁻¹ x year⁻¹)

G_W = average annual aboveground biomass increment (tonnes d.m. x Ha⁻¹ x year⁻¹)

R = root-to-shoot ratio (dimensionless)

I_v = average annual net increment in volume suitable for industrial processing (m³ x Ha⁻¹ x year⁻¹)

D = basic wood density (tonnes d.m. x Ha⁻¹ x year⁻¹)

BEF = biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment (dimensionless)

The annual average increment of aboveground biomass in plantations is taken from the Potential Productivity Map of Spain (published by the former Ministry of Environment). This map divides the national surface area into 14 categories of annual increment of aboveground merchantable volume (in m³/Ha) (see Table 7.2.6)¹¹, and allocates to each Region of Spain a percentage of surface area corresponding to each category.

¹¹ The 14 categories considered have been established by combining various lithological and potential productivity factors, as shown in Table A.3.3.4 in Appendix A.3.3.1.

Table 7.2.6.- Forest systems productivity ($m^3 ha^{-1} year^{-1}$)

Categories	Productivity range ($m^3 ha^{-1} year^{-1}$)	Average productivity ($m^3 ha^{-1} year^{-1}$)
Ia	>9.00	12.33
Ib	8.25-9.00	8.63
Ic	7.50-8.25	7.88
IIa	6.75-7.50	7.13
IIb	6.00-6.75	6.38
IIIa	5.25-6.00	5.63
IIIb	4.50-5.25	4.88
IVa	3.75-4.50	4.13
IVb	3.00-3.75	3.38
Va	2.25-3.00	2.63
Vb	1.50-2.25	1.88
VIa	1.00-1.50	1.25
VIb	0.50-1.00	0.75
VII	<0.50	0.25

Source: Productivity map of potential forestry in Spain, 2000.

In category Ia, with only a value “greater than”, the average minimum values have been taken by default from Table 3A.1.7. of GPG-2003 corresponding to the species *Pinus radiata*, *Eucalyptus globulus* and *E. camadulensis*, as those in the table’s list of species most accurately representing the Spanish situation.

The annual increments of aboveground merchantable volume for each region are presented in Table 7.2.7

Table 7.2.7.- Potential productivity by region ($m^3 ha^{-1} year^{-1}$)

Region	Iv ($m^3 Ha^{-1} year^{-1}$)
Andalusia	4.70
Aragon	3.49
Asturias	10.89
Balearic Islands	4.54
C. Valencian	3.92
Canary Islands	3.64
Cantabria	9.49
Castile and León	4.11
Castile La Mancha	3.43
Catalonia	5.12
Basque Country	9.55
Extremadura	5.34
Galicia	9.93
La Rioja	4.09
Madrid	3.94
Murcia	2.78
Navarre	6.64

Source: Own elaboration from the data of the Potential Productivity Map of Spain, year 2000.

As in *forest land remaining forest land*, the aboveground Biomass Expansion Factor (BEFD) used was calculated in CREAM (Centre for Ecological Investigation and Forestry Applications), designated as (*BEF-D*), which are equal to the product between D and BEF and the root expansion factor has been obtained from Table 3A. 1.8 in GPG-2003.

With only limited information available regarding breakdown by species used for reforestation, some average values of aboveground and root biomass expansion factors have been considered $((BEF \cdot D)_{med}$ and R_{med}):¹²

$$- (BEF \cdot D)_{med} = 0.72$$

$$- R_{med} = 0.331$$

A.2) Extensive Management

The part of equation 7.2.5 corresponding to extensive management is referenced in the equation 7.2.5.b. as follows:

Equation 7.2.5.b.– Annual increment in carbon stocks in living biomass due to growth in land converted to forest land by extensive management

$$\Delta C_{LF_{Growth}EXT} = [\Delta_m A_{EXT_m} \cdot G_{TotalEXT_m}] \cdot CF$$

$\Delta C_{LF_{Growth}EXT}$ = annual increment in carbon stocks in living biomass due to growth in land converted to forest land by extensive management (tonnes C x year⁻¹)

$\Delta_m A_{EXT_m}$ = land area converted to extensively managed forests under condition m (natural regenerations included) (Ha)

$G_{TotalEXT_m}$ = annual growth rate of biomass in extensively managed forest under condition m (including natural regenerations) (tonnes d.m. x Ha⁻¹ x year⁻¹)

k, m = it represents the different conditions in which intensively and extensively managed forest are growing, respectively.

CF = carbon fraction of dry matter (default=0.5), (tonnes C x tonnes d.m.⁻¹).

Forest biomass under conditions of extensive management are estimated to be using the same methodology as in section 7.2.2.1, *Forests remaining as forest land*, but since the surface area of lands that become extensively managed forest is null, this activity is deemed not to occur.

B) Decrease in carbon stocks in living biomass ($\Delta C_{LF_{Loss}}$)

Losses of biomass resulting from harvesting, fuel wood gathering or disturbances in *land that becomes forest land* are not established, because this information is already

¹² Average calculated based on the average values of broadleaved and coniferous trees.

included in the initial data, therefore the calculation is focused exclusively on the part corresponding to carbon stock increments in living biomass ($\Delta C_{LF_{Growth}}$).

7.2.2.2.2. Carbon stock changes in dead organic matter and soils

As in *forest land remaining forest land*, in the GPG-2003, it is assumed, under Tier 1, that annual transfers into the dead wood pool are the same as the transfer out, so the net change is zero (it is deemed to remain constant over time). Soil contributions are being investigated, but at the moment it is assumed, under Tier 1, that the net transfers in soils “from” and “to” are null. Therefore the calculation of carbon stock change is focused exclusively on the part corresponding to living biomass.

7.2.2.3.- Non CO₂ greenhouse gas emissions, forest fires

In this section, non CO₂ greenhouse gas emissions due to biomass burning are taken into account. Biomass burning occurs in many types of land uses causing emissions of CO₂, CH₄, N₂O, CO and NO_x. There are two main types of biomass burning covered in this section:

- Burning in managed forests.¹³
- Burnings which have forest land use change as a result of the same. In this case and according to national circumstances, it is assumed that fires which cause forest land conversion to another type of land does not occur, so this part is not regarded.

Methodology

Generally fires can be grouped into prescribed (or controlled) fires and wildfires. Fires associated with land clearing and ecosystem management activities are usually controlled fires. The purpose of these fires is usually to get rid of unwanted biomass. As no data were available concerning prescribed or controlled fires, an estimate of emissions could not be made.

According to the Good Practice Guidelines (GPG2003), as the methods applied do not capture removals by regrowth after natural disturbances, it is not necessary to report the CO₂ emissions associated with natural disturbances events.

The methodology described below can be used to estimate CH₄, N₂O, CO and NO_x emissions from biomass burning on managed forest land. The results of the aforementioned emissions estimate are likewise presented in this section.

The accuracy of the estimates depends on the available data. The data of activity variables used, including the estimate of the quantity of carbon emitted as CO₂, are specific to Spain, complying with the requirements demanded in the methodological focus of Tier 2;

¹³ The whole national area is or has been managed, so the “non-managed forest lands” cases are not taken into account.

while for N/C coefficient and for non CO₂ gas emission factors, the default values of GBP-2003 are taken into account.

The emissions of non-CO₂ gases can be estimated based on the total carbon released using Equation 7.2.7 (Equation 3.2.19 in the GPG2003 publication).

Equation 7.2.7. Calculation of non-CO₂ gases using estimated carbon released

(Equation 03.2.19. in GPG-2003)

EQUATION 3.2.19				
CALCULATION OF NON-CO ₂ GASES USING ESTIMATED CARBON RELEASED				
Emissions of CH ₄	= (carbon released)	(emission ratio)	16/12	
Emissions of CO	= (carbon released)	(emission ratio)	28/12	
Emissions of N ₂ O	= (carbon released)	(N/C ratio)	(emission ratio)	44/28
Emissions of NO _x	= (carbon released)	(N/C ratio)	(emission ratio)	46/14

Calculations are made separately for each greenhouse gas, using the appropriate emission factors, the main values thereof are shown in the second column in the following Table 7.2.8, which is taken from chart 3A.1.15 of the GPG-2003. These factors are referred to open burning of cleared forests. An **emission factor** and an N/C ratio are needed to use Equation 3.2.19 of publication GPG-2003. The **N/C** ratio used in the case of burned fuel is 0.01, as indicated in GPG-2003 in section 3.2.1.4.2.2 of emission factor selection in its Tier 1 focus.

Table 7.2.8.- Emission ratios for open burning of cleared forests

Compound	Emission ratios		
	Central value	Lower Limit	Upper Limit
CH ₄	0.012	0.009	0.015
CO	0.06	0.04	0.08
N ₂ O	0.007	0.005	0.009
NO _x	0.121	0.094	0.148

Source: GPG-2003

Regarding the **carbon released**, the described methodology allows an estimate of the carbon immediately released during a fire. This is in the order of 20% of the aboveground carbon biomass and 60% of the residual carbon biomass (according to section 11.3 of the report on “National Inventory of Air Emissions 1990-2006”, published by the Ministry of the Environment and Rural and Marine Affairs, based on the article by Rodríguez Murillo, 1994).

The statistic information necessary for calculating emissions arising from fires is taken from “Forest fires in Spain”, published by the Area of Defence against Forest Fires of the Directorate-General for the Natural Environment and Forest Policy.

The estimations are calculated only for forest lands affected by forest fires, considering as forest lands those covered with woody species which produce merchantable wood or other products.

In order to calculate the carbon released in a forest fire, the previous existing biomass is used as the starting point. The commercial and non-commercial surface areas are studied separately.

In forest lands (with or without commercial use), the biomass that can be affected by fires can be divided into different parts:

1. Aboveground Biomass:
 - a. Commercial fraction (M): formed by commercial-size logs.
 - b. Rest of aboveground tree biomass (B): branches, leaves and stems which are not big enough to be commercial.
2. Underground biomass (U): formed by roots.
3. Residual biomass or litter in soils (PL): aboveground biomass litter which has fallen on the ground.

Total biomass (T) is: $T = M + B + U + PL$

T is calculated dividing the available data and the commercial and non-commercial areas.

Commercial (commercially used) forest lands.

In these areas, the merchantable volume data is available, which multiplied by the Carbon density per species (0.227 t/m³ for coniferous trees and 0.316 t/m³ for broadleaved trees, see Table 7.2.9), the carbon mass in merchantable volume is obtained.

Non-commercial (non-commercially used) forest lands.

The initial datum is the surface affected by forest fires. Multiplying this value and the biomass factors per hectare for the corresponding species groups (43 m³/Ha for coniferous trees and 73 m³/Ha for broadleaved trees, see Table 7.2.9), the total biomass volume affected by fires is obtained. The product of this volume and the carbon density give the carbon mass contained in the non-commercial areas affected by fires.

Table 7.2.9.- Factors for forest fires emissions model

	CONIFEROUS	BROADLEAVED
Biomass volume per hectare	43 m ³ /Ha	73 m ³ /Ha
Carbon estimated in the species	0.227 g/cm ³	0.316 g/cm ³

Source: Rodriguez Murillo (1994)

The carbon estimation related to commercial fraction (M) before the fire is:

$$M = (Mc*dc + Mf*df) + (Sc*ic*dc + Sf*if*df)$$

where,

M Commercial fraction

Mc Coniferous commercial fraction in commercial areas

<i>Mf</i>	Broad-leaved commercial fraction in commercial areas
<i>Sc</i>	Coniferous wooded surface area in non-commercial areas
<i>Sf</i>	Broadleaved wooded surface in non-commercial areas
<i>ic</i>	Coniferous biomass factor
<i>if</i>	Broadleaved biomass factor
<i>dc</i>	Carbon density for coniferous trees
<i>df</i>	Carbon density for broadleaved trees

The relations between the different parts of the total biomass (T), according to Rodriguez Murillo (1994), using as a basis the variable commercial fraction (M) provided by forest fire statistics are as follows:

1. Expansion factor from commercial fraction (M) to total biomass (T): $T=2.7M$
2. Belowground biomass estimated at 25% of the aboveground biomass: $U= 0.25(M+B)$
3. Residual biomass on the ground estimated at 10% of the plant biomass: $PL=0.1(M+B+U)$

Therefore, the total carbon mass (T) is calculated as:

$$T = M + B + U + PL$$

where,

T	Total Biomass
M	Commercial fraction
B	Aboveground biomass remaining
U	Roots
PL	Residual or litter in soils

These factors of effectively burned biomass (20% of carbon forming part of the aboveground biomass and 60% of residual biomass carbon, as mentioned above) are applied in both types of forest land (commercially used and non-commercially used).

Presentation of results

According to the proposed methodology, the estimation of greenhouse gas emissions appears in Table 7.2.4.

7.2.3.- Uncertainty and time-series consistency

The base information collecting phase continues regarding characterization of activity variables and parameters that intervene in estimation algorithms, both in carbon removal from forest lands, as well as forest fire emissions.

Time-series with base information and results, for both category 5A as well as estimated surfaces of categories 5B to 5F, are deemed consistent over time: on the one hand, the base information characteristics used in CORINE LANDCOVER and the forestry map, and on the other hand, the maintenance between years of the estimation algorithms used.

7.2.4.- Inventory quality assurance and quality control

In reference to quality assurance, procedures have been applied for the identification of sources deemed to be more reliable regarding activity variables and parameters for the emissions estimation algorithm. In this inventory edition, the most updated information available has been used regarding the national forestry inventory, the reforestation statistics of croplands and the forest fire statistics.

Referenced procedures have been used for the calculation of carbon removals and forest fire emissions. The estimation algorithms and the calculation results have been reviewed by the GT-USCC group.

The base documentation and the results have been integrated into the file for the national inventory system.

7.2.5.- Recalculations

The results of this report modify those reported previously for the period 1990-2006 due to new base information available and changes in methodology explained throughout the document.

The INF has included new provinces in the knowledge base of the merchantable volume with bark (VCC) and the results obtained have been applied to the forest land remaining forest land calculations.

In the process of continuous updating of the methodology, the potential productivity table, previously referred as "annual increment of aboveground merchantable volume by Region" (Table 7.2.5) has been restructured.

7.2.6.- Planned Improvements in calculating absorptions and emissions related to forest lands

The possibility of including in future inventories the estimations related to other factors, such as carbon balance in soil deposits and dead organic matter is being investigated.

Moreover, additional information required by the Kyoto Protocol is being elicited and analyzed with regard to the activities specified in articles 3.3. (forestation, reforestation and deforestation) and 3.4 (forest management and cropland management) in the case of Spain.

7.3.- Agricultural crops (5B)

Agricultural crops include the entire annual and permanent crops as well as fallow land (lands left uncultivated for one or more years in order to rest). Annual crops are made up of herbaceous plants with an annual cycle, such as cereals, pulse, tubers, industrial crops, and forage crops; while permanent crops consist of woody plants with a multi-year cycle, among which olive trees, grapevines and fruit trees stand out due to the surface area occupied in Spain. Likewise, there are surface areas with combinations of herbaceous and woody crops that are comprised within cropland surface areas (agriculture-forestry), except when such lands may be classified as forest land, according to the criterion mentioned in section 7.1.1.

7.3.1.- Description of the category

In this category croplands that remain croplands are considered as well as lands that convert from other uses to croplands. In the inventory period (1990-2007), conversions of land from other uses to croplands has not been observed.

7.3.2.- Methodology

7.3.2.1.- Croplands that remain croplands

Change in carbon stocks in living biomass

In accordance with indications in the GPG-2003, it is estimated that the biomass carbon content in annual herbaceous crops is recycled annually, because the fraction of residual biomass that can decompose in situ and incorporate itself into the soil is deemed insignificant.

For woody crops, in line with the GPG-2003, and depending on their maturity cycle phase, source or sink effects may take place at limited temporary intervals, while for mature stationary systems, the net balance may be considered null. Spain has a very important surface area dedicated to woody crops as shown in the time series 1990-2007, seen in table 7.3.1, the surface area for which covers nearly 10% of the total national surface area. The stated tables shows the woody crops surfaces, divided by crop type.

Table 7.3.1.- Surface areas of permanent crops (Ha)

Year	Permanent crops							Total 10.01.01
	Fruit				Non fruit		Remaining Permanent Crops	
	Orange Tree	Mandarin Tree	Almond Tree	Other Fruit	Olive tree for oil	Wine vineyard		
1990	127,021	67,477	584,109	344,521	1,877,466	1,393,047	244,437	4,638,078
1991	134,485	97,072	637,548	365,889	2,122,255	1,123,308	246,524	4,727,081
1992	134,485	97,072	637,548	365,889	2,122,255	1,123,308	246,524	4,727,081
1993	134,485	97,072	637,548	365,889	2,122,255	1,123,308	246,524	4,727,081
1994	134,485	97,072	637,548	365,889	2,122,255	1,123,308	246,524	4,727,081
1995	134,485	97,072	637,548	365,889	2,122,255	1,123,308	246,524	4,727,081
1996	121,673	97,072	637,548	365,319	1,995,228	1,085,011	245,389	4,547,240
1997	124,467	86,425	629,087	337,221	2,034,844	1,082,411	233,894	4,528,349
1998	129,579	89,383	630,132	337,094	2,074,552	1,078,043	225,153	4,563,936
1999	125,865	91,966	624,321	336,704	2,039,601	1,073,997	262,165	4,554,619
2000	120,870	94,746	650,750	344,675	2,087,974	1,090,773	268,904	4,658,692
2001	125,089	96,288	627,947	340,508	2,135,402	1,109,356	250,398	4,684,988
2002	121,445	98,148	602,079	328,306	2,143,972	1,091,473	249,112	4,634,535
2003	123,704	99,992	596,873	341,066	2,170,508	1,081,008	253,024	4,666,175
2004	121,861	104,171	593,250	333,894	2,198,743	1,095,969	336,852	4,784,740
2005	118,130	105,300	585,273	324,167	2,221,136	1,072,128	325,504	4,751,638
2006	122,924	105,462	549,541	317,212	2,230,191	1,031,081	307,075	4,663,487
2007	122,924	105,462	549,541	317,212	2,230,191	1,031,081	307,075	4,663,487

Source: Food and Agriculture Statistical Yearbook

The aboveground biomass increment in woody crops has been estimated by applying the default value of the biomass accumulation rate per Ha and year, as represented in section 3.3.1.1.1 of the GPG-2003; according to table 3.3.2 of this publication, it is 2.1 t C/Ha/year for temperate climates. Even though the available activity data allow for distinguishing two humidity regimes, a differentiated biomass accumulation factor has not been found for each one of them in the GPG-2003. Therefore the said default factor has been applied to the complete surface area, without differentiating the humidity regimes. Moreover, based on the decrease in the Leaf Area Index (LAI) and the transparency of the tree crown covers observed in times of tree pruning (which oscillates between 30% to 60% reduction), it is estimated that pruning reduces growth by 50%.

In Table 7.3.2, the estimation of carbon fixation is shown as a result of multiplying the surface areas in Table 7.3.1 by the net fixation factor of carbon fixation ($1.05 = 2.1 \cdot (1-0.5)$ t C/Ha*year).

Table 7.3.2.- Carbon fixation in permanent croplands (Gg C)

Year	Permanent crops							Total permanent crops
	Fruit				Non fruit		Remaining Permanent Crops	
	Orange Tree	Mandarin Tree	Almond Tree	Other Fruit	Olive tree for oil	Wine vineyard		
1990	133	71	613	362	1,971	1,463	257	4,870
1991	141	102	669	384	2,228	1,179	259	4,963
1992	141	102	669	384	2,228	1,179	259	4,963
1993	141	102	669	384	2,228	1,179	259	4,963
1994	141	102	669	384	2,228	1,179	259	4,963
1995	141	102	669	384	2,228	1,179	259	4,963
1996	128	102	669	384	2,095	1,139	258	4,775
1997	131	91	661	354	2,137	1,137	246	4,755
1998	136	94	662	354	2,178	1,132	236	4,792
1999	132	97	656	354	2,142	1,128	275	4,782
2000	127	99	683	362	2,192	1,145	282	4,892
2001	131	101	659	358	2,242	1,165	263	4,919
2002	128	103	632	345	2,251	1,146	262	4,866
2003	130	105	627	358	2,279	1,135	266	4,899
2004	128	109	623	351	2,309	1,151	354	5,024
2005	124	111	615	340	2,332	1,126	342	4,989
2006	129	111	577	333	2,342	1,083	322	4,897
2007	129	111	577	333	2,342	1,083	322	4,897

Source: Food and Agriculture Statistical Yearbook

However, since data are not available on these crops in their maturing cycle phase, the net absorptions have been deemed as zero until a complete analysis is performed on the data pertaining to woody crop surface areas to show the difference between the stationary mature crops and others.

Change in carbon stocks in soils

The organic carbon variation in the soil has not been estimated, taking into account that the methodology described in GPG-2003 does not allow an adequate calculation in the case of Spain. This is due to the fact that, current information available regarding activities that could produce a change in stocks is preliminary, the majority of which is still in the process of being compiled. Using a conservative approach, it is assumed at the moment that there are no changes.

7.3.2.2.- Land converted to cropland

Conversion of land for other uses to cropland has not been taken into account. The conversion has been made in the opposite direction, as the comparison between CLC90 and CLC00 shows that the surfaces areas devoted to agricultural crops have dropped nearly 1,000,000 hectares.

7.3.3.- Uncertainty and time-series consistency

The compiling and estimation phase of uncertainties associated to activity variables continues.

7.3.4.- Inventory quality assurance and quality control

Quality control regarding surface area estimation is being implemented, verifying the data of CORINE LANDCOVER with statistic sources and national cartographic sources of land types and use. In the category reassignment of UNFCCC categories, the data from the Directorate-General for Sustainable Development of the Rural Environment at the Ministry of the Environment and Rural and Marine Affairs are taken into account as a reliable source of reforestation under the Common Agrarian Policy. In this regard, a close relationship is maintained with the Statistics Department of the Ministry of the Environment and Rural and Marine Affairs. The control is carried out mainly by comparing the CLC with the maps of use and exploitations.

7.3.5.- Recalculations

No new calculations have been performed since the previous delivery.

7.3.6.- Planned Improvements in calculating absorptions and emissions related to croplands

The influence of management procedures applied to croplands is being collected and to this end, information concerning ecological and integrated agricultural practices is being compiled. These practices began to be implemented after 1990 and are becoming increasingly more frequent in Spain.

7.4. Grassland (5C)

Land considered as grassland is that land used specifically for grazing and which is cleared of wooded vegetation. Woodlands converted into pastures, which in general are used specifically for grazing and small wood production and therefore do not meet the definition of forest, have been included at the moment in the category of other lands.

In this section, carbon (C) absorptions are reported, likewise CO₂ sinks in the “grasslands”, and specifically, in the subcategory of cropland converted to grassland. The absorption of C is established by the net removal of C in “lands converted to grasslands”.

In the examination of key categories a separate analysis has been made for the LULUCF sector. Within this sector, grasslands do not comprise a key source, neither due to the level nor to the trend, in any of the inventory period years. Notwithstanding the aforementioned, and due to the exhaustive information presented here, this section 7.4 will continue to specify grasslands.

Estimation of carbon sinks

The quantification of carbon fixation in grasslands, arising from cropland conversions throughout the period 1990-2007, is shown in table 7.4.1. As will be explained further on, the

source is the net incremental carbon fixation in soils converted from agricultural use to grassland.

Table 7.4.1.- Carbon fixation in grassland derived from croplands (Gg C)

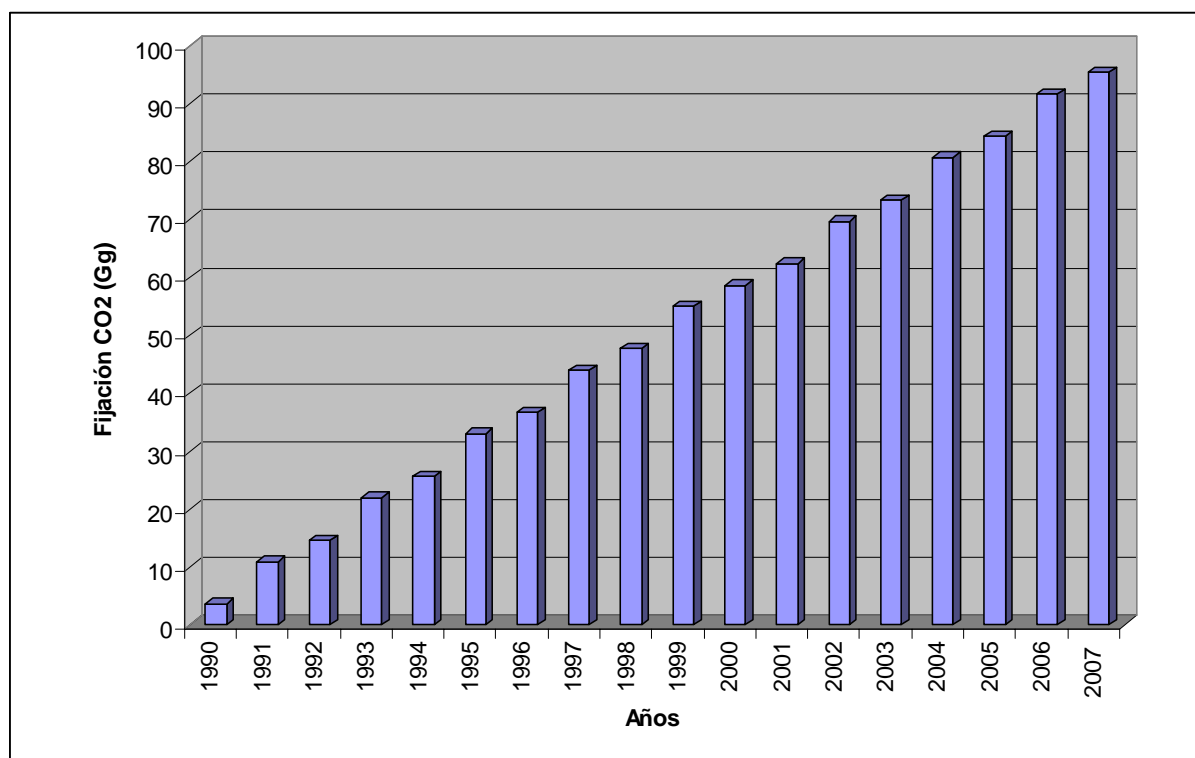
ktC	1990	1991	1992	1993	1994	1995	1996	1997	1998
CG	1	3	4	6	7	9	10	12	13
TOTAL	1	3	4	6	7	9	10	12	13

	1999	2000	2001	2002	2003	2004	2005	2006	2007
CG	15	16	17	19	20	22	23	25	26
TOTAL	15	16	17	19	20	22	23	25	26

CG: Croplands that become grasslands

Figure 7.4.1 Evolution of the trend in CO₂ fixation in grassland (Gg of CO₂) represents the evolution over time of this carbon fixation, expressed as mass (Gg) of CO₂, from 1990 to 2007.

Figure 7.4.1.- Evolution of the trend in CO₂ fixation in grassland (Gg of CO₂)



7.4.1.- Description of sources and sinks

In this category, grasslands that remain grasslands are considered as well as lands converted from other uses (croplands) to grasslands.

In grasslands remaining as such, net carbon changes are not considered to take place in either living biomass or in the soils. Regarding changes in land use, the only conversion to grasslands detected has been derived from croplands, generally due to their abandonment. Thereafter an evergreen herbaceous cover is established, which slowly increases the organic matter in the soil, producing C removal while farming activities are not carried out. This conversion is not very large and is estimated to be around 5,775 Ha/year, for each of the inventory period years (1990-2007).

Moreover, it is worth pointing out that in the grasslands: i) the practice of adding lime to the soil is not performed (to correct its acidity); ii) burnings are not performed either, and iii) if fertilizers are applied they are comprised within the aggregate calculation of agricultural fertilizer use, therefore the GHG emissions derived from grasslands are deemed null.

7.4.2.- Methodology

Currently, the GT-USCC is in the phase of adapting the emission factors and the estimation methodologies to national circumstances. At the moment, the methodologies of Level 1 are applied in this document; therefore the default values are used.

7.4.2.1.- Grassland remaining as grassland

In accordance with the methodology in Level 1 of the GPG-2003, only the carbon increments in soils must be considered, therefore changes in aboveground biomass are not reported. The carbon stock changes in soils are due to changes in the management system of the aforesaid soils, however, as we have not been able to identify up to now what management changes have occurred and where, it has not been possible to estimate the carbon stock changes in the soils of grasslands that remain as grasslands.

7.4.2.2.- Land converted to grassland

It is considered that this conversion takes place on dry land where annual crops, usually cereals, were planted. Therefore the conversion is from croplands to grasslands (CL to GL). It is estimated that this conversion, between the years 1990 and 2000, was 57,570 Ha in the aggregate, therefore the annual conversion rate is 5,775 Ha/year between those years, an average that is maintained up to 2007. When information becomes available from CORINE LANDCOVER 2006 for the entire country, the estimates for 2001 to 2007 will be revised.

As a result of the conversion of croplands to grasslands, it is assumed that the previous dominant vegetation is substituted by natural grassland, generally not introduced by planting. The methodology of Level 1 of GPG-2003 is applied and the previous land use is considered an annual crop (generally cereal), therefore it is deemed that there are no losses in aboveground biomass, taking into account that grassland biomass on average is in the same order of magnitude or greater.

The carbon stock changes in the soil are given by the land use change. In order to calculate the organic carbon stock changes in soils (SOC), when converting land from other uses (in this case from croplands) to grassland, equation 3.4.8 of the GPG-2003 is used.

According to this equation, as presented below, the carbon stock changes are determined by the reference values of the carbon stocks in the soils, upon initial use (crops) and final use (grassland), and by the changes between the initial and final uses of the following: i) the land use factor; ii) the land management factor, and iii) the land contribution factor. The annual rates for emission (sources) or absorption (sinks) are calculated as the stock difference (over time) between the final use and the initial use, divided by the number of years of the time period elapsed until the change becomes stationary (default value: 20 years).

Equation 7.4.1.- Annual carbon stock change in mineral soils for a single pasture system (equation 3.4.8 of GPG-2003)

$$\Delta C_{PP_{Minerales}} = [(COS_0 - COS_{0-T}) \cdot S] / T$$

$$COS = COS_{REF} \cdot F_{UT} \cdot F_{RG} \cdot F_E$$

Where:

$\Delta C_{PP_{Minerales}}$ = annual change in carbon stocks in mineral soils, in tonnes of C per year⁻¹

COS_0 = organic carbon stocks in grassland soil in the inventory year, in tonnes of C per Ha⁻¹

COS_{0-T} = organic carbon stocks in cropland soil T years before the inventory, in tonnes of C per Ha⁻¹

T = period of net incremental changes of carbon in soils converted from cropland to grassland, in years (default value: 20 years).

S = surface area of land converted from cropland to grassland, in Ha

COS_{REF} = carbon stocks used as reference, in tonnes of C Ha⁻¹, see table 7.4.2

F_{UT} = change factor in stocks for one type of land use or in change of land use, dimensionless; see Tables 7.4.3 and 7.4.4

F_{RG} = change factor in stocks for management regimen, dimensionless; see tables Table 7.4.3 and 7.4.4

F_E = change factor in stocks for organic matter contribution, dimensionless; see Tables 7.4.3 and 7.4.4

The COS_{REF} values are taken from table 3.3.3 (identical to 3.4.4) of the GPG-2003, for the value of initial use and for the value of final use. The factors related to land use, land management, and land contribution, are taken from table 3.3.4, for the initial use, and from table 3.4.5, for the final use, both from the GPG-2003. For ease of reference by readers, the said tables are presented below, complete or extracted, with the selected values of the

parameters highlighted in grey. The values selection of parameters is based on the opinion of national experts of the GT-USCC.

Table 7.4.2.- Default reference value (with native vegetation) of organic C stocks in the soil (COS_{REF}) (in tonnes of C per Ha, to a depth of 0-30 cm) (Table 3.3.3 of GPG-2003)

Region	Soils AAA ¹	Soils ABA ²	Sandy soils ³	Spodic soils ⁴	Volcanic soils ⁵	Wetland soils ⁶
Boreal	68	NA	10 [#]	117	20 [#]	146
Temperate cold, dry	50	33	34	NA	20 [#]	87
Temperate cold, humid	95	85	71	115	130	
Temperate warm, dry	38	24	19	NA	70 [#]	88
Temperate warm, humid	88	63	34	NA	80	
Tropical, dry	38	35	31	NA	50 [#]	86
Tropical, humid	65	47	39	NA	70 [#]	
Tropical, very humid	44	60	66	NA	130 [#]	

Note: The data derived from soil databases described by Jobbagy and Jackson (2000) and Bernoux *et al.* (2002). Mean stocks are shown. A default error estimate of 95% (expressed as 2X standard deviations as percent of the mean) are assumed for soil-climate types. NA denotes "not applicable" because these soils do not normally occur in some climate zones.

Indicates where no data were available and default values from *IPCC Guidelines* were retained.

- 1 Soils with high activity clay (AAA) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these included Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols).
- 2 Soils with low activity clay (ABA) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols).
- 3 Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psamments).
- 4 Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols).
- 5 Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols).
- 6 Soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; USDA classification Aquic suborders).

Table 7.4.3.- Relative factors of stock change (F_{UT} , F_{RG} and F_E) (more than 20 years) for different cropland management activities (Table 3.3.4 of GPG-2003, extract)

Factor value type	Level	Temperature regime	IPCC 96 Default value	Humidity ¹ regime	OBP Revised default value	Error ^{2,3}	Description
Land use (F_{UT})	Fallow land (<20 years)	Temperate and tropical	0.8	Dry	0.93	± 10%	It represents annual cropland temporarily not in use (i.e. conservation stocks) or other cropland not used and repopulated with evergreen grass
Farming (F_{RG})	Complete	Temperate	1.0	Dry and very humid	1.0	NA	Substantial disturbances in the soil due to farming operations with total and/or frequent investment (throughout the year) At the moment of planting, the surface area covered with residues is scarce (e.g., less than 30%)
Entrance (F_E)	Average	Temperate	1.0	Dry and very humid	1.0	NA	Representative of an annual cereal crop, in which all the crop residues are returned to the soil. If residues are eliminated additional organic matter is added (e.g., manure).

1 Where data were sufficient, separate values were determined for temperate and tropical temperature regimes and dry and wet moisture regimes. Temperate and tropical zones correspond to those defined in the Chapter 3 introduction (3.1); wet moisture regime corresponds to the combined moist and wet zones in the tropics and wet zone temperate region (see Figure 3.1.3); dry zone is the same as defined Figure 3.1.3.

2 ± two standard deviations, expressed as a percent of the mean; where sufficient studies were not available for a statistical analysis a default, based on expert judgement, of ± 50% is used. NA denotes "Not Applicable", where factor values constitute defined reference values.

3 This error range does not include potential systematic error due to small sample sizes that may not be representative of the true impact for all regions of the world.

4 The second value applies to the Aquic soil class as defined in the *IPCC Guidelines*. No significant differences were found for different soil types in the updated estimates produced here for the *Good Practice Guidance*.

Table 7.4.4.- Relative stock change factors for pasture management [see section 3.4.7 the methods used for estimating the stock change factors] (Table 3.4.5 of GPG-2003)

Factor	Level	Climate regime	Default values of IPCC Guidelines	OBP Revised default value	Error ^{1,2}	Definition
Land use (F_{UT})	All	All	1.0	1.0	NA	All permanent pastures are allocated a land use factor equal to 1.
Management (F_{RG})	Improved pasture	Temperate/boreal	1.1	1.14	± 10%	It represents pastures managed in a sustainable way with moderate grazing pressure and are the object of at least one improvement (e.g., fertilization, species improvement, irrigation)
Contribution (applied only to pastures)	Nominal	All	NA	1.0	NA	Applicable to improved pastures when additional managed contributions have not been used

1 ± two standard deviations, expressed as a percent of the mean; where sufficient studies were not available for a statistical analysis a default, based on expert judgement, of ± 50% is used. NA denotes "Not Applicable", where factor values constitute defined reference values.

2 This error range does not include potential systematic error due to small sample sizes that may not be representative of the true impact for all regions of the world.

The summary of the variable values (surface areas converted to grasslands) and parameters (Tables 7.4.2, 7.4.3 and 7.4.4) selected for calculation according to the formula in Equation 7.4.1 is shown in Table 7.4.5.

Table 7.4.5.- Selected values for the application of Level 1 in the estimation of carbon stock changes in cropland soils after conversion to grassland.

Parameter	Initial value	Final value	Unit
Surface area converted annually	5,775		Ha
COS_{REF}	24	24	Tonnes C Ha ⁻¹
Land Use Factor (F_{UT})	0.93	1	Dimensionless
Management Factor (F_{RG})	1	1,14	Dimensionless
Contribution Factor (F_{E})	1	1	Dimensionless

In a more visual and clearer sample of this methodology, Table 7.4.6 is included below with the surface areas converted to grasslands, as well as the surface areas that generate fixations that year. Due to the non-availability of data for the years prior to 1990, it is deemed that there are no land use changes to grassland for the previous years, therefore resulting in a triangular form of the said table.

These land use changes entail carbon fixation in soils as shown in Table 7.4.7.

Table 7.4.6.- Surface area of cropland converted to grassland and surface area with C removal (Ha)

		Year reported																	
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Year the change occurred	1990	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1991		5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1992			5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1993				5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1994					5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1995						5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1996							5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1997								5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1998									5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	1999										5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	2000											5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
	2001												5,775	5,775	5,775	5,775	5,775	5,775	5,775
	2002													5,775	5,775	5,775	5,775	5,775	5,775
	2003														5,775	5,775	5,775	5,775	5,775
	2004															5,775	5,775	5,775	5,775
	2005																5,775	5,775	5,775
	2006																	5,775	5,775
	2007																		5,775
Changes occurred in the year		5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775	5,775
Total C fixing surface area		5,775	11,550	17,325	23,100	28,875	34,650	40,425	46,200	51,975	57,750	63,525	69,300	75,075	80,850	86,625	92,400	98,175	103,950

Table 7.4.7.- C fixation in soils converted to Grassland (t C).

		Year reported																	
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Year the change occurred	1990	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1991		1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1992			1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1993				1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1994					1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1995						1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1996							1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1997								1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1998									1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	1999										1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	2000											1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
	2001												1,455	1,455	1,455	1,455	1,455	1,455	1,455
	2002													1,455	1,455	1,455	1,455	1,455	1,455
	2003														1,455	1,455	1,455	1,455	1,455
	2004															1,455	1,455	1,455	1,455
	2005																1,455	1,455	1,455
	2006																	1,455	1,455
	2007																		1,455
Changes occurred in the year		1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455	1,455
Total C fixing surface area		1,455	2,911	4,366	5,821	7,277	8,732	10,187	11,642	13,098	14,553	16,008	17,464	18,919	20,374	21,830	23,285	24,740	26,190

7.4.3.- Uncertainty and time-series consistency

The compiling and estimation phase of uncertainties associated to activity variables continues. For the absorption/emission factors involved in the methodology employed, the information of GPG-2003 will be used in the case of default factors, and supplemented with uncertainty assessments of national factors and parameters.

7.4.4.- Inventory quality assurance and quality control

Quality control regarding surface area estimation is being implemented, verifying the data of CORINE LANDCOVER with statistical sources and national cartographic sources of land types and use. In this regard, a close relationship is maintained with the Statistics Department at the Ministry of the Environment and Rural and Marine Affairs.

7.4.5.- Recalculations

No new calculations have been performed since the previous delivery.

7.4.6.- Planned Improvements in calculating absorptions and emissions related to grasslands

The GT-USCC is developing a more detailed methodology based on national factors drawn from a database which is in the process of being compiled. It foresees the extrapolation to national territory using the different region soil maps and information derived from projects under way (e.g., Project BALANGEIS, CARBOEUROPE IP, NITROEUROPE IP).

7.5. Wetlands (5.D)

7.5.1.- Description of sources and sinks

Changes are not observed in wetland surface areas in the country. Therefore, the 83,965 Ha of land classified as wetlands remain as such during the entire time-series 1990-2007.

7.5.2.- Methodology

Seeing that changes in the surface areas of wetlands do not take place in the time period considered, no carbon source or sink is reported for these lands.

7.5.3.- Uncertainty and time-series consistency

These have not been estimated, except for the consideration of activity data as a whole regarding the surface area estimation.

7.5.4.- Inventory quality assurance and quality control

These have not been estimated, except for the consideration of activity data as a whole regarding the surface area estimation.

7.5.5.- Recalculations

No new calculations have been performed since the previous delivery.

7.5.6.- Planned Improvements in calculating absorptions and emissions related to wetlands

Results will be reported on uncertainty and time-series consistency regarding activity data, as well as quality assurance and control regarding the quality of subsequent inventories.

Activity data are being monitored regarding some companies registered in the sector of extraction and handling of peat, in order to determine if extractions are taking place in our territory. At the moment and due to absence of information, they are deemed to be non-existent, having regard for the small extension of peat bogs and the type of protection under which they are monitored.

7.6.- Settlements (5.E)

This has to do with all those territories specifically used as human settlements, which in general comprise the population centres and their conurbations.

7.6.1.- Description of sources and sinks

The settlements surface area undergoes a growth of 357,178 Ha in the time series (1990-2007), the same takes place as a result of the conversion of cropland (139,112 Ha) or other lands (218,066 Ha). The annual increment throughout the time-series considered is around 19,800 Ha. The extrapolation performed between 2000 and 2007 will be reviewed when the data from CORINE LANDCOVER 2006 for the entire country become available.

7.6.2.- Methodology

7.6.2.1.- Settlements remaining as settlements

As the methodologies for estimating the sources and sinks in settlements remaining as settlements are still under development by the IPCC (included as an Appendix in IPCC, 2003), no emission or uptake estimations have been attempted for this category.

7.6.2.2.- Land converted to settlements

Aboveground biomass eliminated in the conversion depends on the initial type of use. In the case of cropland conversions, it is assumed that they come from annual crops in their entirety, therefore level 1 is used. As seen in preceding sections, aboveground biomass immediately prior to the conversion is 5 t C/Ha (default value from Table 3.4.9 for temperate warm and dry climates).

In this case it is difficult to estimate the organic carbon changes in the soil, taking into account the sealing process of the same, therefore it has not been possible to estimate the changes taking place with the available information.

7.6.3.- Uncertainty and time-series consistency

These have not been estimated, except for the consideration of activity data as a whole regarding the surface area estimation.

7.6.4.- Inventory quality assurance and quality control

Not performed, except for the consideration of activity data as a whole regarding the surface area estimation.

7.6.5.- Recalculations

No new calculations have been performed since the previous delivery.

7.6.6.- Planned Improvements in calculating absorptions and emissions related to settlements

Work is in progress regarding the uncertainty assessments and the verification and improvement of the time series consistency with regard to activity data as well as the quality assurance and quality control procedures.

7.7.- Other lands (5.F)

This includes lands not classified in any of the preceding categories.

7.7.1.- Description of sources and sinks

The large surface area for this category, about 10 million hectares, is because it includes all the underbrush, woodland below 10% tree crown cover (forest definition used by Spain for submitting information to the FAO).

Pasture lands are likewise included here, even though they have a forestry-pasture land use on some occasions. This is due to the fact that they are not considered forest ecosystems per se, nor croplands or grasslands, therefore they are deemed as a sub-category within other lands. Fertilization by applying minerals is not carried out there, due to the fact that at the most, extensive grazing is practised. Likewise, no wood is extracted, except for pruning specifically done to maximize acorn production, which may be deemed balanced out by subsequent growth.

7.7.2.- Methodology

7.7.2.1.- Other land remaining as other land

In this case it has been decided that changes are not carried out in the different stocks within the large categories included. The more specific analysis of the categories continues, especially in the cases of pasture land and underbrush.

7.7.2.2.- Land converted to other lands

Conversions from other uses to other lands do not take place.

7.7.3.- Uncertainty and time-series consistency

These have not been estimated, except for the consideration of activity data as a whole regarding the surface area estimation.

7.7.4.- Inventory quality assurance and quality control

Not performed, except for the consideration of activity data as a whole regarding the surface area estimation.

7.7.5.- Recalculations

No new calculations have been performed since last year.

7.7.6.- Planned Improvements in calculating absorptions and emissions related to croplands

The extraction of pasture lands from the category of other lands is under way, as well as the underbrush, deemed to be sinks, but at the moment these have not been located in any of the other categories of land use.

Work is in progress regarding the uncertainty assessments and the verification and improvement of the time series consistency with regard to activity data as well as the quality assurance and quality control procedures.

7.8.- Other

At the moment, timber-yielding products are not reported in this inventory publication. The possibility of doing so in future editions is being investigated.

7.9.- Direct emissions of N₂O by N fertilization in forests and other lands

In Spain forest soils are not fertilized. In any case, all the nitrogen fertilizer emissions are included in Agriculture (section 4).

7.10.- Non-CO₂ gas emissions due to drainage of forest and wetland soils.

In Spain forest soils are not drained. Regarding non-CO₂ gas emissions in wetlands, it has been decided not to prepare estimations for this category. Therefore the corresponding cells in table CRF 5 (II) are filled in by writing NO.

7.11.- N₂O emissions due to disturbances associated with conversion of other uses of land to croplands

No surface area has been identified as converting from other use of soil to cropland, therefore this category is not reported and the table CRF 5(III) is filled in by writing NO.

7.12.- CO₂ emissions through applying lime-based improvements in agriculture

There is no record of applying lime-based improvements to soil in Spain.

7.13.- Biomass burning

Information regarding biomass burning in forest lands is compiled in section 7.2. (forests). For the remaining land uses, it either does not occur or is not estimated.

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8.- WASTE

8.1.- Sector panorama

The emissions corresponding to the waste treatment and disposal have been estimated in 2007 at 13.978 gigagrammes (Gg) of CO₂-equivalent (CO₂-eq), a figure that represents 3.16% of the CO₂-eq emissions in the entire inventory that year; a relative contribution that has increased with respect to its counterpart in 1990, when that percentage was 2.65%. The main pollutant emitted in this sector is methane representing in 2007, 32.6% of the total emissions of this gas in the inventory, and in second place, at a great distance, nitrous oxide, such that the contribution of the waste sector to the inventory total was 4% in 2007. Table 8.1.1 shows CO₂-equivalent emissions in sub-categories according to IPCC nomenclature with a breakdown in Figures 8.1.1, 8.1.2, and 8.1.3 of the four waste treatment categories respective to the pattern of absolute values, the contribution of total inventory emissions, and the relative contribution of the waste sector emissions for the period from 1990 to 2007.

Table 8.1.1.- CO₂ equivalent emissions (Amounts in Gg)

	1990	1995	2003	2004	2005	2006	2007
6.A Disposal in landfills	4.976	6.896	9.371	9.060	9.226	9.506	9.761
6.B Waste-water handling	2.313	2.492	3.169	3.269	3.331	3.397	3.542
6.C Waste incineration	95	36	18	9	9	10	10
6.D Other	254	405	616	611	594	644	665
Waste	7.637	9.829	13.174	12.948	13.160	13.557	13.978

Figure 8.1.1.- Pattern of CO₂ equivalent emissions

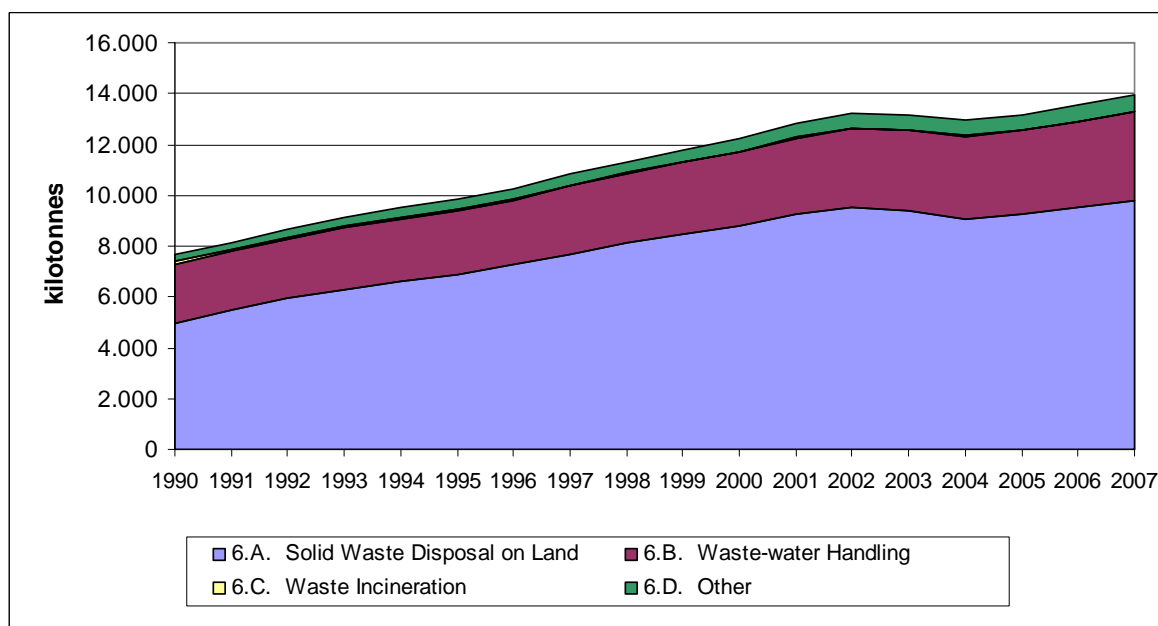


Figure 8.1.2.- Percentage of CO₂-eq emissions by category in relation to the total inventory

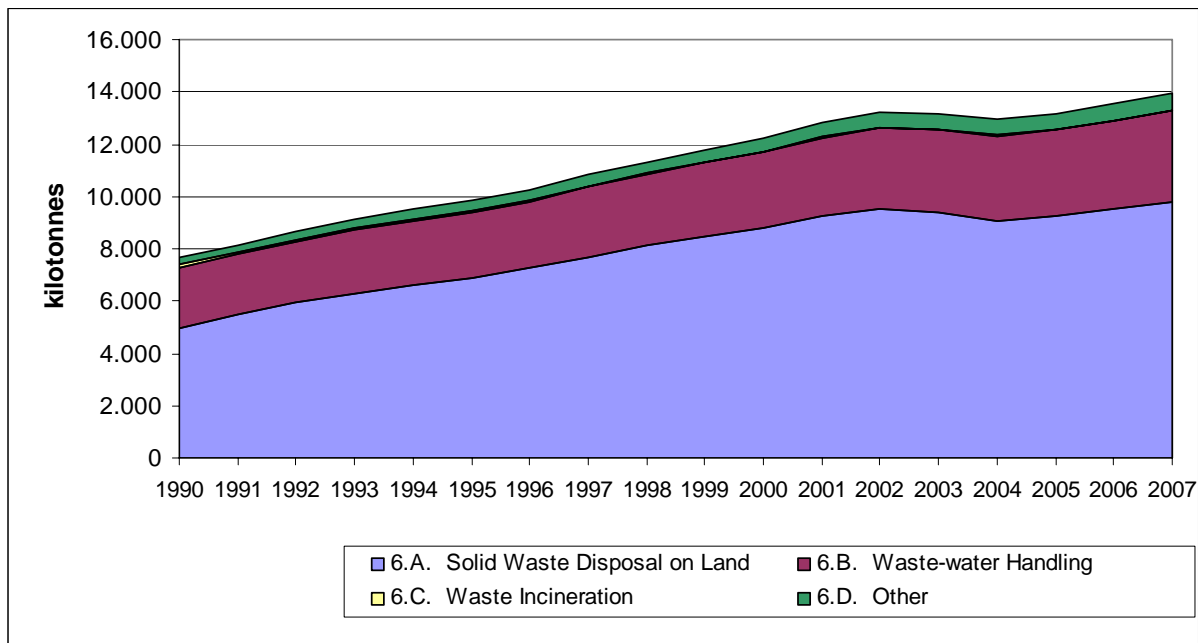
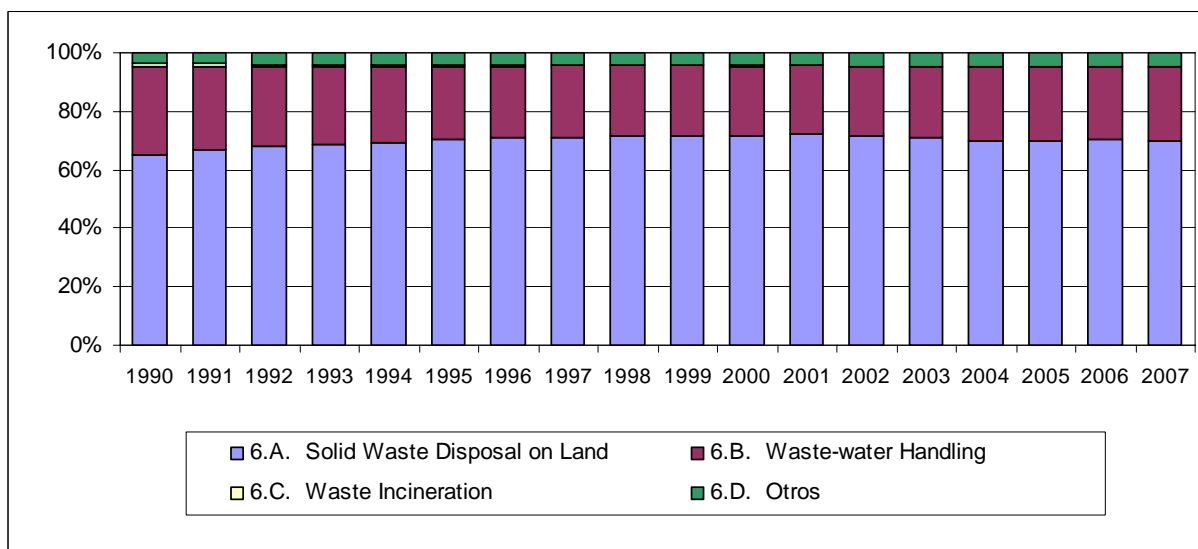


Figure 8.1.3.- Percentage of CO₂-eq emissions by category in relation to the total sector



The emissions analysis for the 1990-2007 period has permitted the identification of the following key sources:

- Waste Disposal in Landfills due to its CH₄ emissions level and due to its trend for the whole 1990-2007 period.

- Waste-water handling by CH₄ emissions in the sub-periods 1993-1999 and 2002-2007.

To summarize the above, Table 8.1.2 illustrates the following key categories in this sector, the emissions contribution level and the trend, as well as the absolute values expressed in CO₂-eq, all with reference to 2007.

Table 8.1.2.- Key Sources: Level and Evolution

IPCC Activity		Gas	CO ₂ -eq (Gg) (2007)	Level Assessment(2007)			Contribution Trend (2007)		
Code	Description			%	Key S.	Order	%	Key S.	Order
6A	Waste Disposal in Landfills	CH ₄	9.747	2,20	YES	13	1,11	YES	18
6B	Waste-water treatment	CH ₄	2.321	0,52	YES	26	0,19	NO	35

Order: Category order number in relation to key sources (organized per level or trend contribution).

Compared to the 2008 edition of the Inventory, N₂O emissions have lost their consideration as a key source in the current 2009 edition with regard to activity 6B Waste Water Treatment.

Explanation of the trend

Pending confirmation in coming years, the almost stabilization and decrease in the CH₄ emission trends caused by deposits in controlled landfills, which began in 2002, seem motivated by two main factors: The first is the increase in the volume of biogas captured and burned (a good part with energy recovery) which practically eliminates the direct emission of CH₄, substituting it with CO₂ of biogenic origin and therefore not accounted for in the country inventory. The second factor, with a longer term effect, is due to a discontinuation in the long line of waste previously deposited into landfills that now are routed to other destinations, e.g. composting or biomethanization, for more adequate treatment of organic matter.

The increase in waste generation and the temporary offset in its decomposition provoke the upward trend of the emissions of waste disposal in landfills even with the adopted measures to use alternative means for the waste elimination or treatment and the reduction techniques by means of capturing the generated biogas.

Notably, combustion emissions with energy recovery of biogas are found in the Energy sector; accounting in the Waste sector only the Waste incineration that is not used in energy recovery.

There is also an upward trend in the emissions of CH₄ and N₂O deriving from wastewater treatment, due to the increase in the magnitude of the variables for this activity, related with those of production (in the case of industrial wastewaters) and the increase in population and treatment coverage (in the case of domestic wastewater).

In terms of waste incineration, the emissions have a sharply declining trend, since many facilities now carry out combustion with energy recovery and so are not included in the Waste group but rather in the Energy group.

As for the section “Other”, which includes sludge treatments, there is a strong upward trend in terms of emissions as a consequence of the increase in the corresponding variables for this activity, but in any case with a level of contribution to emissions in the sector that is always less than 10%.

To offer a general overview of the evolution of these trends and their effect upon the changes to waste management systems, and the growing importance among these of selective waste collection, separation for recycling, selective composting of organic waste, the incorporation of biomethanization plants, and the alternative disposal of non-recoverable materials in landfills, the following tables 8.1.3.a (absolute values) and 8.1.3.b (percentages) show the evolution of the amounts of waste according to the treatment/elimination systems used over the inventory period. Both tables illustrate the increasing importance of selective collection, composting, incineration (with energy recovery) and biomethanization, while the levels for controlled landfills are stabilized (the ones where the level of recovered biogas increases) and the decrease in uncontrolled tipping continues, all within the context of a pattern of increasing total generated waste.

Table 8.1.3.a.- MSW treatment systems (Amounts in tonnes)

Year	Selective Collection	Compost	Incineration	Controlled Landfills	Uncontrolled Landfills	Biomethanization	Generated Waste
1990	0	769.116	606.395	7.439.907	3.287.347	0	12.102.765
1991	0	569.258	634.905	8.326.355	4.012.050	0	13.542.568
1992	0	440.258	649.398	9.290.079	4.612.589	0	14.992.323
1993	0	467.987	635.082	9.900.302	4.457.104	0	15.460.474
1994	0	542.218	625.022	10.685.855	3.610.796	0	15.463.891
1995	0	665.294	693.491	11.670.683	2.630.321	0	15.659.789
1996	450.227	760.634	705.348	12.184.045	1.769.067	0	15.869.321
1997	559.978	946.237	1.008.912	12.668.683	2.859.765	0	18.043.574
1998	734.746	955.216	1.093.166	13.372.340	2.562.151	0	18.717.619
1999	872.711	1.060.933	1.038.501	13.934.692	2.356.100	0	19.262.937
2000	1.067.442	1.322.456	1.061.361	15.073.475	1.398.472	0	19.923.206
2001	1.189.382	1.479.447	1.078.967	14.803.886	1.395.323	0	19.947.005
2002	1.554.167	1.844.313	1.226.972	14.953.931	718.213	0	20.297.597
2003	1.806.873	1.999.223	1.338.835	14.417.068	836.473	70450	20.468.922
2004	2.036.049	2.361.992	1.514.971	14.974.093	731.425	328.995	21.947.525
2005	2.133.435	2.404.264	1.915.279	15.083.378	715.713	434.173	22.686.242
2006	2.519.340	2.567.917	2.024.586	15.642.129	700.000	425.667	23.879.639
2007	2.814.534	2.791.393	2.323.839	16.088.206	659.650	425.667	25.103.288

Table 8.1.3.b.- MSW treatment systems (Amounts in %)

Year	Selective Collection	Compost	Incineration	Controlled Landfills	Uncontrolled Landfills	Biomethanization	Total
1990	0,00	6,35	5,01	61,47	27,16	0,00	100
1991	0,00	4,20	4,69	61,48	29,63	0,00	100
1992	0,00	2,94	4,33	61,97	30,77	0,00	100
1993	0,00	3,03	4,11	64,04	28,83	0,00	100
1994	0,00	3,51	4,04	69,10	23,35	0,00	100
1995	0,00	4,25	4,43	74,53	16,80	0,00	100
1996	2,84	4,79	4,44	76,78	11,15	0,00	100
1997	3,10	5,24	5,59	70,21	15,85	0,00	100
1998	3,93	5,10	5,84	71,44	13,69	0,00	100
1999	4,53	5,51	5,39	72,34	12,23	0,00	100
2000	5,36	6,64	5,33	75,66	7,02	0,00	100
2001	5,96	7,42	5,41	74,22	7,00	0,00	100
2002	7,66	9,09	6,04	73,67	3,54	0,00	100
2003	8,83	9,77	6,54	70,43	4,09	0,34	100
2004	9,28	10,76	6,90	68,23	3,33	1,50	100
2005	9,40	10,60	8,44	66,49	3,15	1,91	100
2006	10,55	10,75	8,48	65,50	2,93	1,78	100
2007	11,21	11,12	9,26	64,09	2,63	1,70	100

In sections 8.2 and 8.3 of this chapter the Waste sector activities (according to IPCC category) are examined, having taken into account for this grouping, the identification of key sources given above, and in either case, with an illustration (albeit summarized) of the sector's non-key sources shown in the final section, 8.4.

8.2.- Landfill waste disposal - CH₄ (6A)

8.2.1.- Description of the emission-generating activity

The disposal of municipal solid waste (MSW) in landfills (controlled and uncontrolled) constitutes the main system for waste treatments in Spain with a percentage, in 2006, of 68.4% of the total MSW generated. The quantity of MSW tons deposited in landfills in 2007 (16.747.856) is slightly inferior to that of 2006 (16.342.129) in spite of the increase within those years of the country's generation of urban waste. This asymmetric pattern is reflective of the intense growth of alternative waste systems, even though waste disposal in landfills continues being the predominant disposal system (see previous Tables, 8.1.3.a and 8.1.3.b.)

The main gas emitted and what makes this category a key source is methane. In landfill disposal a distinction is made between managed and unmanaged processes.

a) Controlled Landfills

In the case of controlled landfills, there may be additional treatment for the capture and energy recovery of the biogas produced. In this sense, 37 landfills have been identified as having applied some system of combustion to capture biogas some or all the years during

the period 1990-2007, whether for elimination (combustion with flares) or for energy recovery (combustion in boilers, turbines or engines). These landfills are, in general, of a large scale and each of them was provided with an individualized questionnaire for the collection of information for the inventory.

The types of waste about which information was requested in the questionnaire are divided into four classes: household waste, refuse from composted waste, residues (sludge) from urban wastewater treatment plants and other waste not classified in the previous categories (demolition waste, voluminous, ash from combustion processes, etc.). The degree of response for some contents of the questionnaire (deposit, capture and molar composition) is very high; nevertheless, the specific individual information per landfill related to some algorithm parameters for the emissions calculations (K, MCF and Ox) continue to be scarce. To some activity variables it has been necessary to apply inference techniques to complete the data series necessary for emission estimation. More specifically, it has been necessary to extrapolate, backwards in some cases, the series of tonnes of MSW deposited when the information received does not cover those initial years of landfill activity. There have also been cases of landfills that have never remitted the completed questionnaire and so the amount of captured biogas is unknown since no other alternative source to provide this information.

In general, the process of MSW degradation in landfills requires a variable period of maturity, depending as much on the composition of the waste as on the conditions of the landfill. The time is theoretically indefinite, although the significant period of emissions can stretch to some 35 years. This fact means that, for emissions calculations, the quantities to consider are the MSW deposited since 1970.

In the period from 1970 to 1990, the calculation of the waste deposited at managed SWDS without biogas capture and unmanaged SWDS has been arrived at by multiplying the coefficient of MSW generation per inhabitant and day, by the population, the number of days in the year and the fraction of MSW generated that is deposited in each type of landfill. From 1990 on, the information is provided directly by the Ministry of the Environment, and Rural and Marine Affairs (MARM) in the publication, "The Environment in Spain". In managed SWDS with biogas recovery, the monitoring of the waste deposited there dates back to the start of activities and the information is provided via a questionnaire completed by the landfills themselves.

It is worth mentioning that, for the selected landfills performing biogas recovery, comparing the information provided by the publication "The Environment in Spain" and used in the previous edition of the inventory with that obtained by means of the questionnaire to these landfills and used in the current edition, an increase can be seen in the tonnes of MSW deposited in these landfills. It can be inferred here, assuming that the information obtained for the current edition via the questionnaire is more credible, that the estimation of the amount deposited in those landfills was under-valued in the previous edition of the inventory.

b) Uncontrolled landfill sites

With respect to uncontrolled landfills, there is no statistical information available for the characterization of the parameters of depth, so in the absence of said information it has been assumed that 50% are deep (depth ≥ 5 metres) and the remaining 50% are shallow (depth

< 5 metres). At the same time, within uncontrolled landfills, whether deep or shallow, certain burn coefficients have been assumed by the team carrying out the inventory for the reduction in volume. These coefficients have evolved over the course of the inventory period.

Table 8.2.1 shows the quantities of MSW deposited in landfills from 1970 to 2007 classified by type of site, distinguishing between controlled landfills with or without collection of biogas and for the uncontrolled landfills, distinguishing between burnt and unburnt waste.

Table 8.2.1.- MSW disposal in landfills (Amounts in tonnes)

Year	Managed SWDS (MSWDS)			Unmanaged SWDS (USWDS)		
	Without recovery	With recovery	Total MSWDS	USWDS Not burnt	USWDS Burnt	Total USWDS
1970	1.635.179		1.635.179	1.085.762	3.257.287	4.343.049
1971	1.691.903		1.691.903	1.110.801	3.332.402	4.443.203
1972	1.744.445		1.744.445	1.135.996	3.407.987	4.543.983
1973	1.795.367		1.795.367	1.137.074	3.411.221	4.548.295
1974	1.854.438	338.000	2.192.438	1.163.817	3.491.453	4.655.270
1975	2.647.425	701.420	3.348.845	1.196.777	2.792.481	3.989.258
1976	2.754.435	616.227	3.370.662	1.239.538	2.892.256	4.131.794
1977	2.728.187	769.299	3.497.486	1.237.740	2.888.061	4.125.801
1978	2.238.967	1.435.423	3.674.390	1.280.834	2.988.614	4.269.448
1979	2.112.945	1.713.571	3.826.516	1.320.544	3.081.268	4.401.812
1980	2.833.799	1.646.857	4.480.656	1.333.221	2.475.983	3.809.204
1981	2.668.001	1.586.749	4.254.750	1.297.653	2.409.926	3.707.579
1982	2.708.399	1.649.262	4.357.661	1.334.867	2.479.038	3.813.905
1983	2.656.841	2.048.115	4.704.956	1.364.379	2.533.846	3.898.225
1984	2.694.567	2.580.895	5.275.462	1.401.592	2.602.958	4.004.550
1985	2.624.206	2.813.624	5.437.830	2.054.236	2.054.236	4.108.472
1986	2.549.007	3.127.240	5.676.247	2.096.246	2.096.246	4.192.492
1987	2.550.819	3.696.336	6.247.155	2.188.465	2.188.466	4.376.931
1988	3.236.325	4.006.939	7.243.264	1.940.530	1.940.531	3.881.061
1989	2.447.426	4.538.886	6.986.312	1.893.907	1.893.908	3.787.815
1990	2.441.529	4.998.379	7.439.907	2.136.776	1.150.571	3.287.347
1991	2.346.423	5.979.932	8.326.355	2.607.832	1.404.218	4.012.050
1992	2.472.955	6.817.124	9.290.079	2.998.183	1.614.406	4.612.589
1993	3.032.921	6.867.381	9.900.302	2.897.118	1.559.986	4.457.104
1994	3.358.559	7.327.296	10.685.855	2.347.017	1.263.779	3.610.796
1995	4.026.020	7.644.663	11.670.683	2.104.257	526.064	2.630.321
1996	4.367.144	7.816.901	12.184.045	1.415.254	353.813	1.769.067
1997	4.546.541	8.122.142	12.668.683	2.573.788	285.977	2.859.765
1998	4.619.047	8.753.293	13.372.340	2.305.936	256.215	2.562.151
1999	4.739.060	9.195.632	13.934.692	2.120.490	235.610	2.356.100
2000	5.422.025	9.651.450	15.073.475	1.258.625	139.847	1.398.472
2001	4.865.110	9.938.776	14.803.886	1.255.791	139.532	1.395.323
2002	4.982.165	9.971.766	14.953.931	646.392	71.821	718.213
2003	4.717.255	9.699.813	14.417.068	752.826	83.647	836.473
2004	4.625.555	10.348.538	14.974.093	731.425	73.143	731.425
2005	4.580.342	10.503.036	15.083.378	644.142	71.571	715.713
2006	4.656.736	10.985.393	15.642.129	630.000	70.000	700.000
2007	4.636.737	11.451.469	16.088.206	659.650	65.965	593.685

Table 8.2.2 shows the absolute emissions for this category, in CH₄ mass (first row) and expressed in terms of CO₂-eq absolute value and time index (in the second and third row); in

the fourth and fifth rows, respectively, the weighting (as a percentage) of these emissions in terms of CO₂-eq emissions of the inventory totals and the waste sector.

Table 8.2.2.- Emissions: Absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CH ₄ (Gg)	246	323	445	431	439	452	464
CO ₂ -eq (Gg)	4.976	6.896	9.371	9.060	9.226	9.506	9.761
CO ₂ -eq index	100,00	138,58	188,32	182,06	185,41	191,03	196,16
% CO ₂ -eq over total inventory	1,73	2,16	2,12	2,28	2,13	2,09	2,20
% CO ₂ -eq over waste sector	65,16	70,16	71,13	69,97	70,11	70,12	69,83

8.2.2.- Methodological aspects

In the calculation of methane emissions from the decomposition of waste deposited in managed SWDS and of the unburned waste deposited in unmanaged SWDS, the first-order kinetic model proposed in the “2000 IPCC Good Practice Guidelines”, has been used, in accordance with its Tier 2 approach. According to this model, each unit of degradable organic carbon mass present in waste at the moment of its deposit is reduced, with the passing of time t , according to the equation:

$$Q_t = Q_0 e^{-kt}$$

where k is the pace at which the carbon present in the waste diminishes, Q_0 is the amount of degradable organic carbon present at the moment of disposal, and Q_t the amount remaining in the waste after the time t has elapsed. Thus, the carbon emitted during the period $(t, t + 1)$ will be:

$$C_t = Q_t - Q_{t+1} = Q_0 e^{-kt} (1 - e^{-k})$$

At times the calculation of annual methane emissions has been made under the implicit assumption that all the waste generated each year is deposited at the beginning of the same and that the chemical reaction generating the emission is triggered immediately after deposit. It is clear that both assumptions represent an approximation to maximum annual emissions, not the mean value, which would be desirable. As from the previous edition of the inventory, this has led the inventory work team to propose a more realistic approach at least with regard to the moment of the waste deposit (with respect to the delay in the start of the chemical reactions, there is currently no sufficient and verified information available to carry out a modification of the calculation procedures). This approach is taken as a result of the unfamiliarity with times of the year in which the waste is deposited in landfills; only the total annual amount is known, so it has been thought appropriate to adopt a statistical approach as a solution to the problem. In the end, it has been assumed that the probability of deposit of each unit of mass at the different times of year follows a uniform distribution, that is, the probability that a deposit was made at a particular time of the year is the same as that of any other and is equal to one. As a result, by applying a first-order kinetic model, a mass of waste deposited at point x in the year with an amount of degradable organic carbon Q_0 will be converted after time t into:

$$Q_t = Q_0 e^{-k(t-x)}$$

where x is a random variable uniformly distributed over the closed interval $[0,1]$. The mathematical expectation of the carbon content at the end of period t will therefore be:

$$E(Q_t) = \int_0^1 Q_0 e^{-k(t-x)} dx = \frac{1 - e^{-k}}{k} e^{-kt} Q_0$$

and, in turn, the mathematical expectation of the carbon emitted during the period $(t, t + 1)$ will be:

$$E(C_t) = E(Q_t) - E(Q_{t+1}) = \frac{1 - e^{-k}}{k} (e^{-kt} - e^{-k(t+1)}) Q_0 = \frac{(1 - e^{-k})^2}{k} e^{-kt} Q_0$$

In accordance with the foregoing, total emissions of a year from the deposits in the previous years of waste with the same parameter value k , are calculated by means of the following formula:

$$E_t = \frac{(1 - e^{-k})^2}{k} \sum_{i=0}^t R_{t-i} L_0 (t-i) e^{-k(t-i)} \quad [8.2.1]$$

The parameter values used in Equation [8.2.1] are:

- * Degradable organic carbon (DOC)
- * Methane Correction Factor (MCF)
- * The fraction (by volume) of methane in landfill (F)
- * The fraction of DOC decomposes into biogas (DOC_F)
- * The methane generation rate constant (k)

The values of these parameters stem from two sources: The 2000 IPCC Good Practice Guidance or from the questionnaire returned by the landfills themselves (in the latter case, provided they are in the ranges established in the Guidelines). The values of the parameters have been weighted by the MSW quantities to obtain the real mean values for the same.

DOC: The degradable organic carbon content in MSW has been obtained by applying Equation [8.2.2] mentioned above (Equation 5.4 of the IPCC Good Practice Guidance) to the data on the standard composition information derived from the data evaluated in the corresponding questionnaires provided by landfills that perform biogas capture, as well as, the information on the national mean standard composition from the remaining landfills that is provided by the publication, "The Environment in Spain" (see Table 8.2.3). For waste from origins other than direct household collection, specific values of the DOC parameter have been selected by the Inventory working team: i) compost plant refuse (0.09), ii) wastewater sludge (0.18) and iii) others (0.05).

Table 8.2.3.- National mean composition of MSW (Amounts in %)

Year	Organic material	Paper and wood	Plastics	Glass	Ferrous metals	Non-ferrous metals	Wood	Textiles	Glues and rubber	Batteries	Other	DOC (%)
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Year	Organic material	Paper and wood	Plastics	Glass	Ferrous metals	Non-ferrous metals	Wood	Textiles	Glues and rubber	Batteries	Other	DOC (%)
1970	52,00	17,00	3,00	2,50	4,50	1,30	4,00	4,80	4,00	0,10	6,80	17,72
1971	51,86	17,29	3,43	2,57	4,43	1,26	3,86	4,80	3,86	0,11	6,53	17,77
1972	51,71	17,57	3,86	2,64	4,36	1,21	3,71	4,80	3,71	0,11	6,32	17,82
1973	51,57	17,86	4,29	2,71	4,29	1,17	3,57	4,80	3,57	0,12	6,05	17,87
1974	51,43	18,14	4,71	2,79	4,21	1,13	3,43	4,80	3,43	0,13	5,80	17,92
1975	51,29	18,43	5,14	2,86	4,14	1,09	3,29	4,80	3,29	0,14	5,53	17,97
1976	51,14	18,71	5,57	2,93	4,07	1,04	3,14	4,80	3,14	0,14	5,32	18,02
1977	51,00	19,00	6,00	3,00	4,00	1,00	3,00	4,80	3,00	0,15	5,05	18,07
1978	50,88	19,06	6,00	3,13	4,00	1,00	2,98	4,80	3,00	0,15	5,00	18,07
1979	50,75	19,13	6,00	3,25	4,00	1,00	2,95	4,80	3,00	0,15	4,97	18,07
1980	50,63	19,19	6,00	3,38	4,00	1,00	2,93	4,80	3,00	0,15	4,92	18,07
1981	50,50	19,25	6,00	3,50	4,00	1,00	2,90	4,80	3,00	0,15	4,90	18,06
1982	50,38	19,31	6,00	3,63	4,00	1,00	2,88	4,80	3,00	0,15	4,85	18,06
1983	50,25	19,38	6,00	3,75	4,00	1,00	2,85	4,80	3,00	0,15	4,82	18,06
1984	50,13	19,44	6,00	3,88	4,00	1,00	2,83	4,80	3,00	0,15	4,77	18,06
1985	50,00	19,50	6,00	4,00	4,00	1,00	2,80	4,80	3,00	0,15	4,75	18,06
1986	48,13	19,88	6,75	6,10	4,00	1,00	2,73	4,80	1,88	0,15	4,58	17,91
1987	48,75	19,75	6,50	5,40	4,00	1,00	2,76	4,80	2,25	0,15	4,64	17,96
1988	49,38	19,63	6,25	4,70	4,00	1,00	2,78	4,80	2,63	0,15	4,68	18,01
1989	47,50	20,00	7,00	6,80	4,00	1,00	2,71	4,80	1,50	0,15	4,54	17,86
1990	46,75	20,00	7,00	6,80	4,00	1,00	2,71	4,80	1,50	0,15	5,29	17,75
1991	46,00	20,00	7,00	6,80	4,00	1,00	2,71	4,80	1,50	0,15	6,04	17,63
1992	45,00	20,25	8,79	6,85	4,06	1,00	1,84	4,81	1,26	0,18	5,96	17,33
1993	44,00	20,50	10,57	6,90	4,12	1,00	0,96	4,82	1,02	0,20	5,91	17,02
1994	44,00	20,70	10,57	6,90	4,12	1,00	0,96	4,82	1,02	0,20	5,71	17,10
1995	44,00	20,85	10,58	6,95	3,81	1,00	0,98	4,91	1,01	0,20	5,71	17,20
1996	44,00	21,00	10,58	7,00	3,50	1,00	1,00	5,00	1,00	0,20	5,72	17,30
1997 - 2007	44,00	21,20	10,59	6,90	3,43	0,68	0,96	4,81	1,01	0,20	6,22	17,29

Note: In the 1997-2005 period, the information on the composition of the MSW has remained constant.

$$\text{Percentage of DOC (all in one)} = 0.4(A) + 0.17(B) + 0.15(C) + 0.30(D) \quad [8.2.2]$$

For the application of equation [8.2.2], the following categories of MSW components cited in Table 8.2.3 are associated with the variables, (A), (B), (C) and (D) that appear here:

- (A) is associated with the "Paper and Carton" and "Textiles" components
- (B) is not associated with any compound from the table.
- (C) is associated with the "Organic Matter" component.
- (D) is associated with the "Wood" component.

The mean weighted percentage of DOC in landfills with biogas capture is the following:

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
17,60	17,15	16,70	16,36	16,40	16,18	16,00	15,95	15,78	15,90	15,89	15,99	16,01	15,91	15,52	15,01	15,00	14,65

It should be noted that in landfills where activity is known via the individual questionnaire, the information under the category "Cuttings" has been gathered for more precise determination of the DOC parameter.

MCF: The information about the methane correction factor of controlled landfills that capture biogas is provided via a questionnaire completed by the landfills themselves, whenever they are within the admissible variation range considered in table 5.2 of the 2000 IPCC Good Practice Guidance, and in the absence of such information and for all other landfills the default value $MCF = 1$ as recommended in table 5.1 by the 2000 IPCC Good Practice Guidance. The weighted mean percentage of the methane correction factor in landfills with capture during the period 1990-2007 is 1.

For uncontrolled landfills, a value of $MCF=0.8$ has been assumed for those measuring more than 5 meters deep and $MCF=0.4$ for those measuring less than 5 meters deep, as recommended in Table 5.1 of the 2000 IPCC Good Practice Guidance.

F: In relation to the fraction by volume of CH_4 in biogas the same procedure applies as for other parameters. Starting with the value indicated for the landfill, provided that it falls within the admissible variation range given in Table 5.2 of the 2000 IPCC Good Practice Guidelines and in the absence of such value recommended by the same guidelines (0.5), the weighted average percentage of methane in landfills with capture is as follows:

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
51,05	51,07	51,13	51,19	51,88	51,68	51,73	51,73	51,75	51,83	51,85	51,84	51,86	51,80	51,87	51,89	51,62	51,62

DOC_F: The fraction of the degradable organic carbon is the value recommended by the 2000 IPCC Good Practice Guidelines (0.55). Four of the landfills with recovery surveyed responded to this parameter, with values ranging between 0.6 and 0.5.

K. The constant rate of methane generation takes the value recommended by the IPCC Good Practice Guidance (0.05) with the exception of three controlled landfills surveyed whose fraction is 0.07, 0,043 and 0,049 respectively.

Once the methane generated has been estimated (see Table 8.2.4), the calculation of the gas emission proceeds as follows. First of all, the amount captured, C_t , is subtracted from the amount generated, G_t , as it will be destined to other uses, mainly for use as fuel due to its energy potential, and so will not be emitted as methane but usually as biogas combustion gases. After calculation of this difference, $G_t - C_t$, which corresponds to the methane potentially emitted as such, the oxidation reduction factor is applied (1- OX) with the product of both giving the estimated amount, E_t , of methane emitted (see table 8.2.5), as shown in the following equation [8.2.3]:

$$E_t = [G_t - C_t] * (1 - OX) \quad [8.2.3]$$

where:

E_t = amount of CH_4 emitted in the inventory reference year "t" (tonnes of CH_4 /year)

G_t = amount of CH_4 emitted in the inventory reference year "t" (tonnes of CH_4 /year)

C_t = amount of CH_4 recovered in the inventory reference year "t" (tonnes of CH_4 /year)

OX = oxidation factor for the methane generated and not recovered (fraction)

OX: The oxidation factor of methane generated and not recovered takes the value recommended by the 2000 IPCC Good Practice Guidance (0.1). Information has been obtained from three landfills, two of them answered 0,1 and the other 0,07.

C_t: As mentioned previously, the recovery has been performed in 36 landfills during at least one year of the period 1990-2007, from which it was possible to obtain information on captures from 33 of the same. The quantity captured C_t has been estimated as the minimum between the 70 % of the methane generated and the quantity reported in the questionnaire as captured or burned (R_t); thus $C_t = \min(0.7 \cdot G; R_t)$.

Table 8.2.4.- Generation of biogas and methane in controlled landfills (Amounts in tonnes)

Year	Landfills with no capture		Landfills with capture	
	Biogas generated	Methane generated	Biogas generated	Methane generated
1990	381.339	104.227	347.274	110.079
1991	389.191	106.373	399.299	128.508
1992	397.602	108.672	453.158	145.774
1993	411.204	112.390	503.459	161.922
1994	427.856	116.941	556.294	178.958
1995	451.254	123.336	609.212	195.869
1996	477.546	130.523	660.577	212.409
1997	504.517	137.894	712.465	229.079
1998	530.974	145.125	767.440	246.728
1999	557.467	152.366	820.726	259.855
2000	590.218	161.318	880.853	278.838
2001	615.216	168.150	942.414	297.730
2002	640.288	175.003	1.000.186	315.573
2003	661.209	180.721	1.058.305	330.589
2004	680.096	185.883	1.109.060	346.961
2005	697.562	190.657	1.159.068	361.719
2006	715.020	195.429	1.212.446	376.614
2007	731.406	199.907	1.259.975	390.607

Table 8.2.5.- Emission and recovery of CH₄ in controlled landfills (Amounts in tonnes)

Year	Landfills with no capture		Landfills with capture					
	Methane generated	Methane emitted	Methane generated	Methane burned in flares	Methane with energy recovery	Total captured	Methane emitted (escaped)	Number of landfills with capture
1990	104.227	93.804	104.227	2.822	89	2.911	96.451	1
1991	106.373	95.736	106.373	3.554	121	3.675	112.350	1
1992	108.672	97.805	108.672	4.332	395	4.728	126.942	2
1993	112.390	101.151	112.390	5.665	977	6.642	139.752	3
1994	116.941	105.247	116.941	9.687	1.288	10.975	151.185	5
1995	123.336	111.003	123.336	6.894	4.832	11.727	165.728	6
1996	130.523	117.470	130.523	7.907	6.962	14.869	177.785	7
1997	137.894	124.105	137.894	8.949	7.499	16.448	191.368	8
1998	145.125	130.613	145.125	9.541	11.861	21.402	202.794	11
1999	152.366	137.130	152.366	10.280	13.674	23.954	212.311	13
2000	161.318	145.186	161.318	10.654	22.157	32.811	221.424	14
2001	168.150	151.335	168.150	9.666	22.743	32.409	238.789	16
2002	175.003	157.503	175.003	14.742	27.624	42.367	245.886	16
2003	180.721	162.649	180.721	16.953	52.250	69.203	235.248	19
2004	185.883	167.295	185.883	18.971	86.776	105.746	217.093	25
2005	190.657	171.591	190.657	26.849	85.743	115.194	221.873	29
2006	195.429	175.886	195.429	19.275	96.100	118.665	232.155	31
2007	199.907	179.917	199.907	16.941	102.524	122.281	241.493	33

Of the pollutants emitted from the methane burned in biogas recovery in controlled landfills only those corresponding to flares are included here. That is, when there is no energy recovery from burnt biogas but there is energy recovery, the corresponding emissions, including in such cases the combustion of supporting fuels, are accounted for in category 1A1a in the Energy sector. The emissions have been calculated multiplying the tones of methane burned by the emission factors that correspond to flares (see Table 8.2.6). For CH₄ the emission factors have been derived from the information on efficiency percentages in the burning of hydrocarbons taken from Table 2.4-3 of the section 2.4 "Municipal Solid Waste Landfill" in the EPA AP-42 5th Ed.; assuming that the complementary efficiency units in the burn constitute the fractions of the methane escaped. The N₂O factor has been derived by the inventory's working team on the basis of the value 1.75g N₂O/GJ_{PCI} for the biogas, referred to in the CITEPA publication, "Facteurs d'émission du protoxide d'azote pour les installations de combustion et les procédés industriels" Finally, for NO_x and CO factors, the source of information has been Table 2.4-4 of section 2.4 "Municipal Solid Waste Landfill" from the EPA AP-42 5th Ed.

Table 8.2.6 shows the emission factors and Table 8.2.7 shows the emissions estimated according to the information in the previous paragraph.

Table 8.2.6.- Controlled landfills with biogas capture. Emission factors

	Flares	Unit
CH ₄	8.000	g CH ₄ /t CH ₄
CO	17.545	g CO/t CH ₄
N ₂ O	90	g N ₂ O/t CH ₄
NO _x	950	g NO _x /t CH ₄

Table 8.2.7.- Emissions (flares) of methane burnt in controlled landfills with biogas capture (Amounts in tonnes)

YEAR	CH ₄	CO	NO _x	N ₂ O
1990	22,57	49,51	2,68	0,25
1991	28,43	62,36	3,38	0,32
1992	34,66	76,01	4,12	0,39
1993	45,32	99,39	5,38	0,51
1994	77,50	169,96	9,21	0,87
1995	55,15	120,96	6,55	0,62
1996	63,26	138,73	7,51	0,71
1997	71,59	157,01	8,50	0,81
1998	76,33	167,39	9,07	0,86
1999	82,24	180,36	9,77	0,93
2000	85,23	186,92	10,12	0,96
2001	77,33	169,59	9,19	0,87
2002	117,94	258,66	14,01	1,33
2003	135,63	297,44	16,11	1,53
2004	151,76	332,84	18,03	1,71
2005	214,79	471,06	25,52	2,42
2006	154,20	338,18	18,32	1,73
2007	135,53	297,23	16,10	1,52

In the case of unmanaged SWDS, a fraction of its mass is burned, for the purpose of reducing its volume and, in such cases, generates, in addition to the biogas emissions from the unburned fraction of MSW, those corresponding to the combustion of the burned fraction.

The estimate of the emissions from the burned fraction is obtained by multiplying the activity variable (previously converted from the gross to combustible dry mass)¹ by the corresponding emission factors. Of the dry combusted fraction of the total burned waste in unmanaged SWDS, 85% is considered to be renewable organic in origin and 15% is fossil in

¹ For the conversion to dry mass, a scaling factor of 0.52 is used (i.e. 48% humidity is assumed) and for the conversion from dry mass to dry mass to combustible a factor of 0.875 is applied (from the standard waste composition, it is inferred that 13% is not combustible).

origin². The value of the CO₂ emission factor for the fossil fraction of waste burned is estimated as 2.933 g CO₂/tonnes of the fossil fraction of waste burned. This value is reached assuming a combustion performance percentage of 80% (i.e. $2,933 = 0.8 * 1000 * 44/12$). For SO₂, NO_x, N₂O, heavy metals and persistent organic pollutants, the same factors have been taken as for MSW incineration and for NMVOCs, CH₄, and CO, the information is derived from Part I, sections 12.2.2 and 12.3 for the CORINAIR Manual (1992)

8.2.3.- Uncertainty and consistency over time

The uncertainty associated with the activity variables is 30% in both managed SWDS without biogas capture and unmanaged SWDS, based on the reliability of the information in the reference source, "The Environment in Spain", and questionnaires for landfills which capture biogas and the uncertainty of the incinerated fraction in uncontrolled landfills.

For the parameters determining the emission factor, the uncertainties proposed in Table 5.2 of the 2000 IPCC Good Practice Guidance are generally assumed, giving as a result an uncertainty in the emission factor estimated at 70.4%.

8.2.4.- Quality monitoring and verification

A significant effort has been undertaken to improve the quality of the data provided by the questionnaires to landfills that capture biogas, requesting the list of waste disposed according to the European Waste Catalogue from those that would have classified the requested components in order to assign the DOC corresponding to the constituents present in the MSW as per Table 6.3 of the 1996 IPCC Reference Manual. Construction and demolition waste (CDW) has also been excluded from the total amount of waste disposed.

Additionally, a detailed examination has been performed of those managed SWDS which completed the survey. The series of all landfills that appear in the book, "The Environment in Spain" have been analyzed and technicians from the Ministry of the Environment, and the Rural and Marine Environment have been contacted to make up for missing information. However, it was not possible to review data prior to 2005.

² These percentages are reached by considering the combustible components of both origins as shown in the last row of Table 8.2.3. Specifically, the following streams are considered to be fuels of non-fossil origin: the organic matter (44%), paper and cardboard (21.20%), wood (0.96%); on the other hand, the consideration of fossil fuels is applied to plastics (10.59%); textiles (4.81%) are divided between fossil and non-fossil in a proportion of 0.25 and 0.75; for rubber and gum (1.01%) the proportion for the division between fossil and non-fossil is 2/3 and 1/3; finally, for the "other waste" stream (6.22%) the fraction of fossil fuel is 0.1, non-fossil fuel is 0.7 and 0.2 is the remainder of non-combustible matter. Apart from this non-combustible matter, there are also other amounts corresponding to glass (6.9%), ferrous metals (3.43%) and non-ferrous metals (0.68%). Pooling all the combustible matter together gives a total of 87.5% combustible matter (74.5% non-fossil and 13.1% fossil). These latter coefficients applied to the total combustible matter finally give the figures indicated in the main text, namely 85% carbon from non-fossil combustible matter and 15% fossil combustible matter.

In the exploratory analysis of data on MSW deposited in unmanaged SWDS, potential anomalies were identified in the time between the period 1993-1996 and the period 1997-1999. During the investigation, the original data sources were corroborated so that the information appears as declared in the original source, without being able to identify any anomaly so, following the comparison, the information in the series from the original source (The Environment in Spain) was maintained.

8.2.5.- New calculations

It has been updated the data of 36 landfills that provided information through the individualized questionnaire for the estimation of emissions of methane generated and methane captured by the landfills, this has resulted in new calculations for this category of the inventory. The Garraf (Barcelona) landfill is among the 36 landfills and due to an error was omitted in the previous edition.

The comparison of the results for CO₂-equivalent emissions between the current and prior inventory publications is expressed in absolute values in Figure 8.2.1 and in relative terms (percentage difference) in Figure 8.2.2.

Figure 8.2.1.- CO₂-eq. emissions Comparison of 2009 and 2008 editions

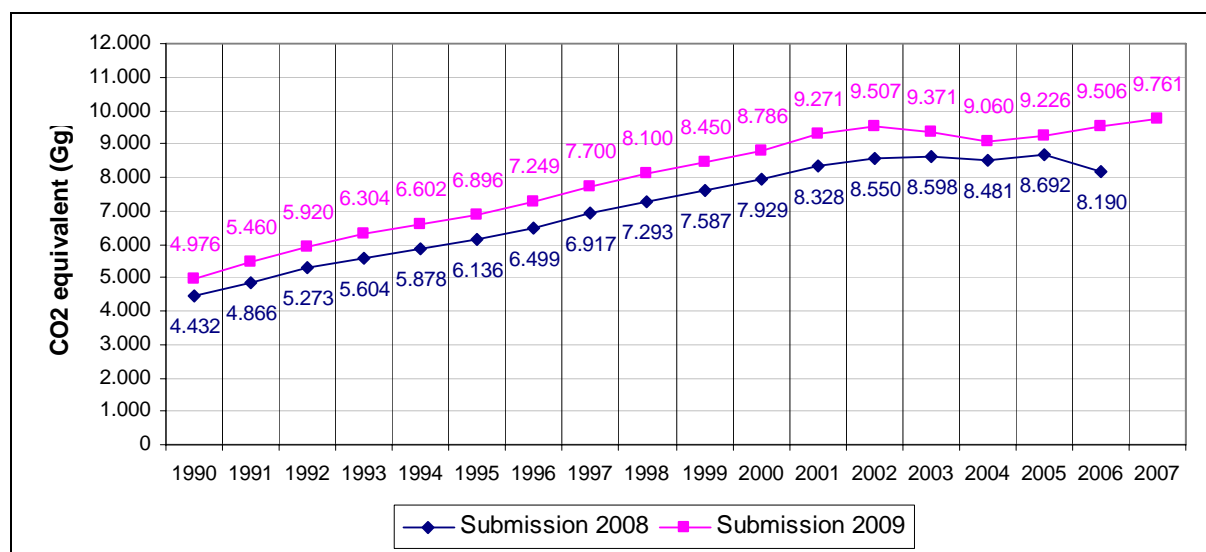
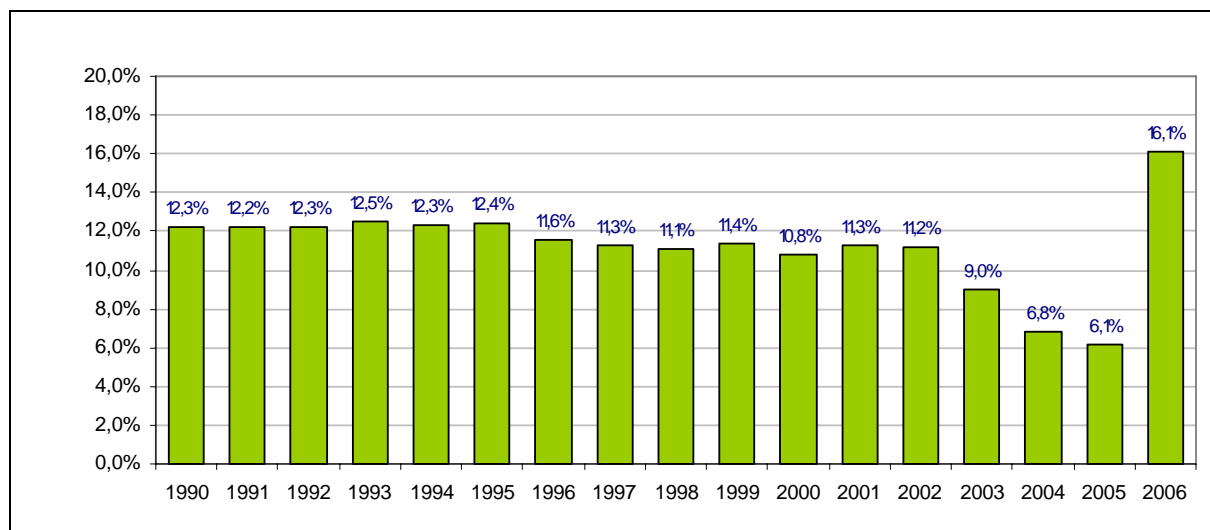


Figure 8.2.2.- CO₂-eq. emissions Percentage difference of 2009 vs 2008 edition

8.2.6.- Improvement plans

The intention is to continue developing the work already carried out in previous editions of the inventory with respect to direct and individual data collection for landfills with biogas recovery through questionnaires. This new base information will improve the contrasts in the individual parameters of landfill management, and the revision of the estimations for waste deposited in controlled landfills. As a result of this work it is considered that there will be a significant improvement in the quality of the information and reliability of the corresponding emission estimations.

Accordingly, the collaboration process continues with the General Sub-Directorate of Production and Sustainable Production of the Ministry of the Environment, and the Rural and Marine Environment to improve the information about: the balance use and destination of the different types of waste, landfill procedures and management, and the emerging treatments for waste (composting, biomethanization, etc.)

Biomethanization in Spain is a recent waste treatment practice and its use is very limited, it is carried out as a deposit alternative in big controlled landfills as the La Galiana (Madrid) or Garraf (Barcelona). It's planned to elaborate individualized questionnaires to these plants to add their emissions to the inventory.

8.3.- Industrial and domestic-commercial waste water treatment – (CH₄) (6B)

8.3.1.- Description of the emission-generating activity

This category includes wastewater treatment from both the industrial sector and the domestic-commercial sector.

a) Industrial wastewater

Firstly, the data source is separated between specific sources, by those that provide individualized information at the plant level, and area sources, in which the information appears aggregated by industrial sector or sub-sector.

The activity variable taken for the point sources, comprising oil-derived product refineries and paper pulp manufacturing plants, has been the volume of treated industrial wastewater about which information has been obtained by means of individualized questionnaires and whose total is shown in Table 8.3.1.a below.

Table 8.3.1.a.- Industrial wastewater. Activity variables: Point sources

VOLUME OF TREATED WASTEWATER						
1990	1995	2003	2004	2005	2006	2007
30.247.954	30.857.672	106.697.123	98.006.780	94.115.936	100.585.477	105.838.282

On the other hand, for area sources, covering the sectors of food and beverage and the chemical industry, the activity variable considered has been the organic load in both the water lines and the sludge lines, expressed in terms of chemical oxygen demand (COD), whose data, as well as for the relevant parameters for the emissions estimation algorithm, are derived from the discharge regulation studies conducted by the Directorate-General for Hydraulic Works and Water Quality, with the reference year of 1994 for the food and agriculture sector and 1996 for the chemical sector.

From these studies, information was compiled on: a) production or consumption of main raw material, b) discharge ratio, expressed in m³ of discharge per product or unit of main raw material, c) volume discharged, expressed in m³; d) ratio of organic load per unit discharged, expressed in kg of COD/m³ of wastewater discharged; and e) parameter value DS_{ind} indicating the fraction of the organic waste load removed as sludge from the treated discharge.

The base information mentioned in these area sources are shown in Table 8.3.1.b below, with a breakdown by activity sub-sector.

- Food and agriculture industry: vegetable oils, coffee, meat, beer, canned fish, canned vegetables, dairy products, wines and liquors.
- Chemical Industry: Pharmacy and Organic Chemistry.
 - CNAE 24.41: Pharmaceutical products manufacturing
 - CNAE 24.42: Pharmaceutical products manufacturing and other pharmaceutical products for medicinal use
 - CNAE 24.14: Organic chemistry basic products manufacturing
 - CNAE 24.15: Fertilizers and nitrogen fertilizers compound manufacturing

Table 8.3.1.b.- Industrial wastewater. Activity variables: Area sources

Sector: Industrial	Sub sector	(Production/Consumption)		Disposal Ratio		D _{ind} (kg COD/m ³)	DS _{ind}
		Amount	Ut	Amount	Ut		
Food Reference Year: 1994	Vegetable Oils	10.482.798	Mg	6,00	m ³ /Mg	0,93	0,8
	Sugar	1.339.999	Mg	3,25	m ³ /Mg	5,92	0,8
	Coffee	116.700	Mg	1,09	m ³ /Mg	2,20	0,8
	Meat	934.000	Mg	8,70	m ³ /Mg	0,92	0,8
	Beer	24.280.003	HI	2,00	m ³ /HI	0,55	0,8
	Canned Fish	670.000	Mg	15,00	m ³ /Mg	2,67	0,8
	Canned Vegetables	14.749.998	Mg	15,00	m ³ /Mg	2,00	0,8
	Dairy prod.	4.765.900	Mg	2,00	m ³ /Mg	1,75	0,8
	Wine and Liquor	38.235.555	HI	6,00	m ³ /HI	0,93	0,8
Chemistry (Reference year: 1996)	Pharmacy	59.800.653	m ³	0,93	m ³ /m ³	5,53	0,8
	CNAE: 24.41	54.804.020	m ³	0,955	m ³ /m ³	6	0,8
	CNAE: 24.42	4.996.634	m ³	0,6	m ³ /m ³	0,4	0,8
	Organic Chemistry	84.777.439	m ³	0,68	m ³ /m ³	1,46	0,8
	CNAE: 24.14	31.430.199	m ³	0,75	m ³ /m ³	3,68	0,8
	CNAE: 24.15	53.347.237	m ³	0,64	m ³ /m ³	0,16	0,8

To obtain homogeneous time series for the activity variables over the whole of the 1990-2007 period, the production figures for the reference years in each of the two sectors considered, 1994 for the agriculture and food sector and 1996 for the chemical sector, are projected using the corresponding industrial production indices as compiled by the National Statistics Institute (INE).

b) Domestic/commercial wastewater

For domestic/commercial waste water, the activity variable selected is organic load, expressed in mass of Biochemical Oxygen Demand (BOD₅). For the calculation of this variable, the population data currently served by waste-water treatment stations has been used, as detailed in the publication "The Environment in Spain" from the MARM for the years 1994 and 1997; through interpolation and extrapolation, a homogeneous series has been obtained for the period from 1990 to 2007 .

For the degradable organic load, a value of 300 mg has been assumed under BOD₅/litre of wastewater and a flow of 200 litres/inhabitant equivalent per day, and 365 operating days per year. The product of this load concentration (300 mg). BOD₅/litre of said daily flow (200/litres/inhabitant-equivalent and day) times 365 days of the year gives the load, D_{dom} for 21.9 kg BOD₅/litre inhabitant-equivalent and day, or of 60 g of BOD₅/litre inhabitant-equivalent and day, coinciding with which appear in the definition of load per inhabitant – equivalent to Section 6 of Article 2 of the 91.271/EEC directive on *municipal wastewater treatment*. For the parameter value DS_{dom} representing the fraction of the organic load (BOD₅) withdrawn as sludge from the treated disposal flow, a value of 0.75 has been assumed. Table 8.3.2 below shows the values for the final activity variable, load in tonnes of BOD₅ per year for the water lines (TOW_{dom}) and sludge lines (TOS_{dom}) for this domestic-commercial wastewater.

Table 8.3.2.- Domestic-Commercial Wastewater. Activity variables

Year	Population (Inhab. Eq.)	D _{dom} (*)	DS _{dom}	TOW _{dom} t BOD ₅ year	TOS _{dom} t BOD ₅ year
1990	82.467.586	21,9	0,75	451.510	1.354.530
1991	83.126.385	21,9	0,75	455.117	1.365.351
1992	83.785.184	21,9	0,75	458.724	1.376.172
1993	84.443.984	21,9	0,75	462.331	1.386.992
1994	85.102.783	21,9	0,75	465.938	1.397.813
1995	85.761.582	21,9	0,75	469.545	1.408.634
1996	86.420.382	21,9	0,75	473.152	1.419.455
1997	87.079.181	21,9	0,75	476.759	1.430.276
1998	87.737.980	21,9	0,75	480.365	1.441.096
1999	88.396.780	21,9	0,75	483.972	1.451.917
2000	89.055.579	21,9	0,75	487.579	1.462.738
2001	89.714.378	21,9	0,75	491.186	1.473.559
2002	90.373.178	21,9	0,75	494.793	1.484.379
2003	91.051.977	21,9	0,75	498.400	1.495.200
2004	91.690.776	21,9	0,75	502.007	1.506.021
2005	92.349.576	21,9	0,75	505.613	1.516.842
2006	93.008.374	21,9	0,75	509.221	1.527.663
2007	94.325.971	21,9	0,75	516.435	1.549.305

Table 8.3.3 shows the absolute emissions for this category, in CH₄ mass (first row) and expressed in terms of CO₂-eq absolute value and time index (in the second and third row); in the fourth and fifth rows, respectively, the weighting (as a percentage) of these emissions in terms of CO₂-eq emissions of the inventory totals and the waste sector.

Table 8.3.3.- Emissions: Absolute values, indices and ratios

	1990	1995	2003	2004	2005	2006	2007
CH ₄ (Gg)	59	70	96	99	102	105	111
CO ₂ -eq (Gg)	2.313	2.492	3.169	3.269	3.330	3.397	3.542
CO ₂ -eq index	100,00	107,76	137,03	141,34	143,98	146,87	153,13
% CO ₂ -eq over total inventory	0,80	0,78	0,77	0,77	0,75	0,78	0,80
% CO ₂ -eq over waste sector	30,28	25,35	24,05	25,24	25,31	25,06	25,34

8.3.2.- Methodological aspects

For specific industrial sources, with individualized questionnaires sent to each plant, the methane emission factor selected, with regard to the volume of wastewater treated, is derived from Table 2 in Chapter B9101 of the EMEP/CORINAIR Guidebook.

For the area sources, using information based on studies or sectoral statistics without individualized data for plants, the methodology in Section 5.2 of the 2000 IPCC Good Practice Guidance has been applied.

Calculating the contributions of the water and sludge lines, the emissions are obtained as a product of the degradable organic load (water and sludge) through the methane

emission factors, discounting from this product the amount of methane recovered. In this way, the methane emission factors are expressed as the product of the respective parameter B_0 of maximum capacity for methane production times the weighted methane conversion factor, WMCF.

The values adopted for the parameters required by the algorithms expressing the emission factors in the water and sludge lines are highlighted in the sections below, differentiating in each case between industrial waste water and domestic-commercial waste water.

B_0 , Maximum capacity for methane production

For the maximum capacity of methane production (B_0), whether in the water line or sludge line, the default values recommended in the 2000 IPCC Good Practice Guidance have been taken, namely:

- 0.25 kg CH₄/kg of COD or industrial water
- 0.60 kg CH₄/kg of BOD₅ for domestic-commercial water

WMCF, Weighted methane conversion factor

The Weighted Methane Conversion Factor, WMCF, has been calculated in accordance with Equation 5.8 in the 2000 IPCC Good Practice Guidance, as a summation, extended to the treatment systems (aerobic and anaerobic) of the methane conversion factor (MCF) corresponding to each treatment system multiplied by the fraction currently treated (WS-waters or SS-sludge) carried out in the corresponding system, differentiating between the water treatment line, sub index "i", and the sludge treatment line, sub index "j", as specified below for industrial wastewater and domestic-commercial wastewater.

a) Industrial wastewater

- On the water line $\sum_x (WS_{ix} \times MCF_x) = (0.33 \times 0) + (0.67 \times 0.15)$,
where the first product corresponds to aerobic treatment and the second to anaerobic treatment.
- On the water line $\sum_y (SS_{jy} \times MCF_y) = (0.5 \times 0) + (0.5 \times 0.3)$,
where, similarly to the water line, the first product corresponds to aerobic treatment and the second to anaerobic treatment.

b) Domestic/commercial wastewater

- On the water line $\sum_x (WS_{ix} \times MCF_x) = (1 \times 0.005)$,
where the first product corresponds to a single aerobic treatment.

- On the water line $\sum_y (SS_{jy} \times MCF_y) = (0.15 \times 0) + (0.85 \times 0.3),$

where, similarly to the water line, the first product corresponds to aerobic treatment and the second to anaerobic treatment.

EF, methane emission factor

The Methane Emission factor, EF, has been calculated in accordance with Equation 5.7 of the 2000 IPCC Good Practice Guidance, as the product of the respective B_0 and MFC values mentioned above for industrial and domestic-commercial wastewater, and in each of them where the contributions of water and sludge lines were calculated. Thus, factors may be expressed as indicated below in following Tables 8.3.1.a, 8.3.1.b and 8.3.5:

a) Industrial wastewater

Table 8.3.4.a.- Industrial wastewater. Emission factors: Area sources (Amounts in g CH_4 /Production unit)

Industrial sector	Sub sector	Emission factor
Chemistry	Pharmacy	105,56
	Organic chemistry	21,78
Food industry	Vegetable oils	112,14
	Sugar	385,48
	Coffee	48,06
	Meat related	161,00
	Beer	22,03
	Canned fish	801,00
	Canned vegetables	600,75
	Dairy products	70,09
	Wine and liquors	112,14

Table 8.3.4.b.- Industrial wastewater. Emission factors: Point sources

Sectors: Oil Refining and Wood Pulp	
3,7	g CH_4 /m ³ treated water

b) Domestic/commercial wastewater

Table 8.3.5.- Domestic-commercial wastewater. Emission factors

Water treatment line (EFw)	
3	g CH_4 /kg BOD ₅
Sludge line (EFs)	
153	g CH_4 /kg BOD ₅

EE, Gross emissions, methane recovery and net emissions

The algorithm is completed by first estimating gross emissions, GE, as a summation of the products of: a) the activity variable, expressed as volume of industrial waste water discharged from point sources of industrial origin, COD mass for industrial water from area sources and BOD₅ mass for domestic-commercial wastewater and b) the corresponding emission factor.

Secondly, where appropriate, recovered methane amount R is deducted from GE, thus obtaining the estimated amount of net emissions NE.

For industrial wastewater from area sources, it is estimated that the amount of recovered CH₄ is 50% on the sludge line and there is no recovery on the water line; and in specific sources, it is assumed that there is no recovery, as there is no information to that respect. For domestic-commercial wastewater, it is estimated that, of the total amount of CH₄ produced on the water and sludge lines, 50% is recovered for energy-related purposes.

The human consumption of proteins (as an N₂O emitter)

The 1996 IPCC Reference Manual methodology was used in the calculation of nitrous oxide emissions. Protein consumption (Table 8.3.6) has been obtained from the publication "Nutrition in Spain" by the old Ministry of Agriculture, Food and Fisheries (MAPA), with an updated version of the years 2005 to 2007 of the series 1990-2007 provided by MAPA's Directorate General for the Industry and Food Markets of the Ministry of the Environment, and the Rural and Marine Environment.

The parameter values required to calculate the emission estimate algorithm are those suggested in the Manual. The nitrogen fraction present in protein is 0.16 kg N/kg protein and the emission factor is 0.01 kg N₂O-N/kg N in wastewater. For the population, the National Institute of Statistics series estimated to July 1st is used.

Table 8.3.6.- National average human protein consumption (Amounts in g/inhab/day)

1990	1995	2003	2004	2005	2006	2007
97,01	90,34	96,51	98,14	96,73	95,43	97,27

8.3.3.- Uncertainty and consistency over time

The uncertainty associated with the activity variables is presumably high in both industrial and domestic-commercial waste water. In the first case, the base information refers to years in the middle of the 90s, the date from which the 1990-2007 temporal series were estimated by extrapolation through application of the corresponding industrial processes rates. For domestic-commercial waste water, the direct base information comes from the years 1994 and 1997, following interpolation and extrapolation procedures for the calculation of the equivalent population served. Overall, we may assume a factor of three (from -30% to -300%) for each of these two variables.

For the parameters determining the emission factor, in general the uncertainties suggested in Tables 5.3 and 5.5 of the 2000 IPCC Good Practice Guidance are assumed.

On the basis of the uncertainty ranges indicated, the series are generally considered consistent over time, except for the activity variable of industrial water from point sources in the wood-pulp manufacturing sub-sector where a discontinuity has been identified in the series for 1997. This discontinuity is being investigated further.

8.3.4.- Quality monitoring and verification

Quality monitoring has been limited to the verification of the intrinsic consistency of the emission estimates algorithm applied to water treatments depending on their origin and the data source. However, so far there has not been any additional monitoring of the evolution of activity variables and other significant parameters in the determination of emission factors.

8.3.5.- New calculations

The protein consumption has been updated for years 2005 and 2006. Therefore, as can be seen in figures 8.3.1 (absolute values) and 8.3.2 (percentage difference) no discrepancies have been observed in the estimations of CO₂-eq emissions between the current and previous editions of the inventory for the period 1990-2004.

The comparison of the results for CO₂-equivalent emissions between the current and prior inventory publications is expressed in absolute values in Figure 8.3.1 and in relative terms (percentage difference) in Figure 8.3.2

Figure 8.3.1.- CO₂-eq. emissions Comparison of 2009 and 2008 editions

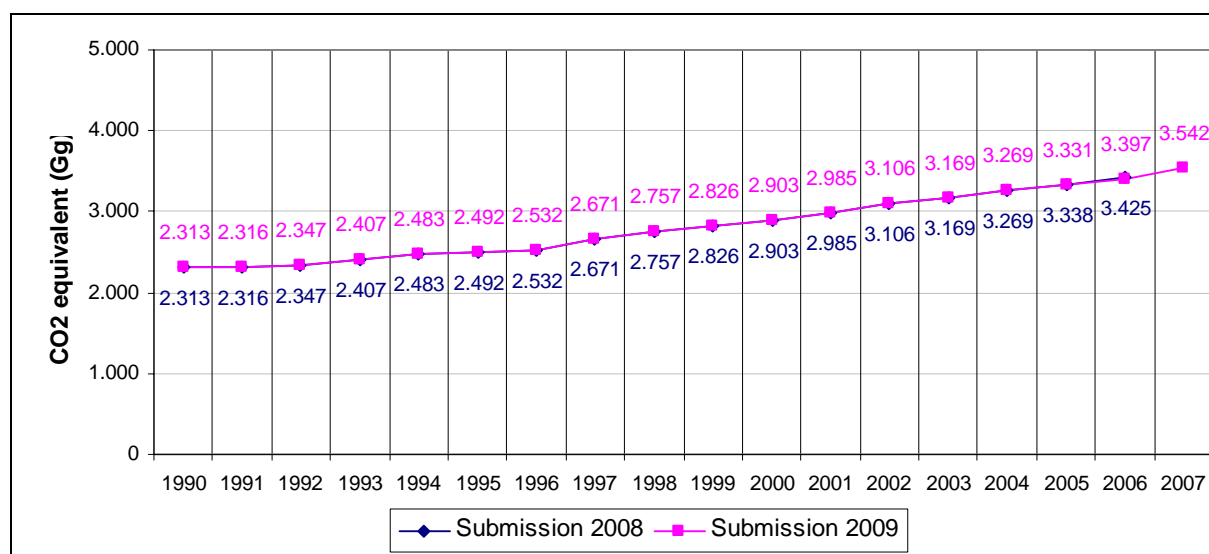
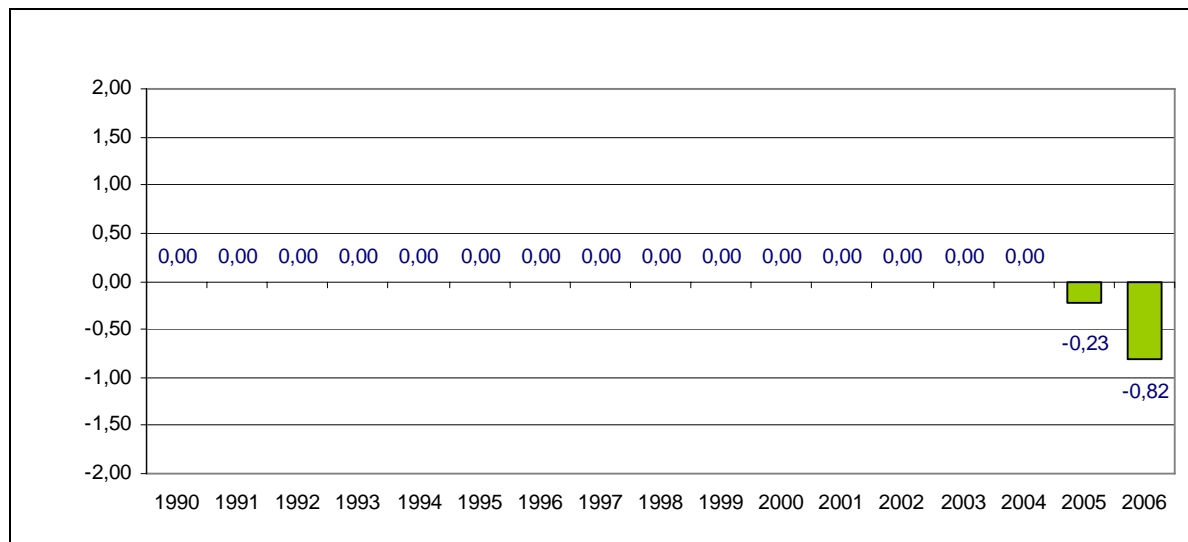


Figure 8.3.2.- CO₂-eq. emissions Percentage difference between 2009 vs 2008 editions

8.3.6.- Improvement plans

Since the uncertainty presently associated with the activity variable, the volume discharged and the organic load have been acknowledged, the collaboration of the Directorate-General for Water at the Ministry of the Environment, and Rural and Marine Affairs becomes a priority to have access to and be able to process the pertinent information from the database of waste water treatment plants. To achieve this collaboration, a proposal has already been defined by the Unit in charge of preparing the emissions inventory (Subdirectorato-General for Air Quality and Industrial Environment).

8.4.- Other non-key sources

Information on other waste sector activities not included in any key source by level or by trend is presented in this section. In 8.4.1 the ratios of Waste incineration (category 6C) are given; in 8.4.2 the remaining non-key sources "Other" (category 6D) are given - including in these the N₂O emissions derived from human consumption of protein and the CH₄ emissions from sludge spreading.

The emissions in terms of CO₂-eq of these categories 6C and 6D were already shown in table 8.1.1 and in figure 8.1.1.

8.4.1.- Waste incineration (6C)

8.4.1.1.- Description of the emission-generating activity

Within this category, the emissions produced by the incineration of corpses, hospital wastes, urban solid waste without energy recovery, and all sludge from wastewater

treatment. Emissions deriving from industrial waste incineration have not been estimated yet, for which, although some activity centres have already been identified, the information could not be processed exhaustively in this edition of the inventory.

Table 8.4.1 shows the absolute emissions for this category, in CO₂ mass (first row) and expressed in CO₂-eq in absolute value and time index (in the second and third row); and next in the fourth and fifth rows, respectively, the weighting (as a percentage) of these emissions with regard to the CO₂-eq emissions of the inventory totals and the waste sector.

The significant decrease in the emissions levels recorded up to 2004 is essentially determined, as shown below, by i) the transfer from the Waste sector to the Energy sector in the accounting of emissions of incinerated municipal solid waste insofar as these incinerators engage in energy recovery, and ii) the decrease of incinerated hospital waste in Spain.

Table 8.4.1.- CO₂-equivalent emissions absolute values, indices and relative contributions

	1990	1995	2003	2004	2005	2006	2007
CO ₂ (Gg)	85	28	8	4	3	3	4
CO ₂ -eq (Gg)	95	36	18	9	9	10	10
CO ₂ -eq index	100,00	37,77	19,19	9,95	9,83	10,10	10,60
% CO ₂ -eq over total inventory	0,03%	0,01%	0,004	0,002	0,002	0,002	0,002
% CO ₂ -eq over waste sector	1,24	0,36	0,14	0,07	0,07	0,07	0,07

8.4.1.2.- Methodological aspects

Details of the methodology applied to each of the activities considered to estimate CO₂ emissions are given below.

a) Incineration of corpses

The incineration of corpses in crematoriums is currently the principal activity contributing to CO₂ emissions. The support fuels and other material elements incinerated in the process also contribute to the emissions.

Cremation is a practice of relatively recent introduction in Spain and its use is still limited, though growing, as may be seen in Table 8.4.2 showing the evolution of the number of corpses incinerated, and the information it contains has been provided by the European Federation of Funeral Services³. The series of crematoriums between 1990 and 2006 have been revised, modifying some values in 2005 and 2006. The data for 2007 is obtained by data extrapolation of 2006.

Table 8.4.2.- Incineration of corpses. Activity variables

1990	1995	2003	2004	2005	2006	2007
------	------	------	------	------	------	------

³ Through a member of the Working Committee on Cemeteries Statistics and Incineration

5.686	15.413	65.361	67.446	75.613	78.378	88.789
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It is worth noting that taking into consideration that the information base unit required by the CRF-Reporter is expressed in terms of mass instead of by number of corpses incinerated, we have converted the units by using an average weight of 65 kg per corpse.⁴

The information on emission factors has been taken from the source providing data. The emission factors applied have been as follows: SO₂ (13 g/c.i.), NO_x (156 g/c.i.), NMVOC (14,6 g/c.i.), CH₄ (0,08 g/c.i.), CO (725 g/c.i.), CO₂ (39 kg/c.i.) and NH₃ (3,2 g/c.i.).

b) Clinical waste incineration

The clinical waste suitable for treatment by incineration are those with a low infection potential (Group III) and those named “*cytotoxic waste*” which present a high infection potential (Group IV).

The waste included in Group III may be treated by sterilization procedures with no need to resort to incineration as a practice for their control. During the 90s, in Spain, it was common to incinerate this type of waste, but in time, this practice has been replaced by sterilization. Group IV wastes must always be incinerated for proper treatment.

The estimates of the amount of this type of waste generated is carried out based on the number of hospital beds, multiplying it by a waste generation factor per bed and day, which, when applied to the number of existing beds and the number of days in the year, provides the amount of waste generated. When the quantities of both types of waste have been calculated, there is a part corresponding to Group III which is treated by sterilization, while the remaining part of this Group III and the whole of those included in Group IV are incinerated. Furthermore, the incineration may be carried out entirely in Spain or the waste may be sent abroad for incineration. The final activity variable is the amount of waste incinerated in Spain. The information on basic data, parameters and final activity variable for this heading is shown in Table 8.4.3 below.

⁴ This is the value indicated in Note 1 in the footnotes to Table 8.1 of chapter B991-7 in the EMEP/CORINAIR Manual.

Table 8.4.3.- Clinical waste incineration. Activity variables

Year	No. beds	gr/bed/day		Production of biosanitary waste (t/y)			Steriliz. (t/y)	Incinerat. Spain (t/y)	Incinerat. Abroad (t/y)
		Group III	Group IV	Total	Group III	Group IV			
1990	115.695	426	174	25.337	17.989	7.348	10.866	14.397	74
1991	120.323	414	169	25.604	18.182	7.422	10.993	13.536	1.075
1992	125.136	402	164	25.852	18.361	7.491	11.121	12.674	2.057
1993	130.141	389	159	26.031	18.478	7.553	11.248	11.813	2.970
1994	135.347	377	154	26.232	18.624	7.608	11.376	10.951	3.905
1995	137.469	365	149	25.791	18.314	7.476	11.503	10.090	4.198
1996	139.591	353	144	25.323	17.986	7.337	11.631	9.228	4.464
1997	141.713	340	139	24.776	17.587	7.190	11.758	8.367	4.651
1998	143.835	328	134	24.255	17.220	7.035	11.886	7.505	4.864
1999	145.957	316	129	23.707	16.835	6.872	12.013	6.644	5.050
2000	148.081	303	124	23.079	16.377	6.702	12.141	5.782	5.156
2001	146.369	290	119	21.851	15.493	6.358	12.268	4.921	4.662
2002	146.104	277	114	20.851	14.772	6.079	12.396	4.059	4.396
2003	144.916	264	109	19.730	13.964	5.765	12.523	3.198	4.009
2004	145.877	252	104	18.955	13.418	5.537	12.651	2.336	3.968
2005	145.892	240	100	18.105	12.780	5.325	12.780	1.471	3.854
2006	145.892	240	100	18.105	12.780	5.325	12.780	1.471	3.854
2007	145.892	240	100	18.105	12.780	5.325	12.780	1.471	3.854

The information regarding number of hospital beds is provided by the Statistics Yearbook of Spain, edited by the National Institute of Statistics, and by the Public Health Facilities Statistics of the Ministry of Health Management's Institute of Health Information. The parameter for the generation of hospital waste per bed and day has been obtained from the "Study of Spain's generation and management of clinical wastes" created by the Institute on Sustainable Resources for the Ministry of the Environment, and the Rural and Marine Environment; in its downward pattern, a marked trend can be noted for waste in Groups III and IV after having been re-classified as a waste stream that does not present any risk of toxicity or infections. Similarly, the information on sterilized waste and on waste incinerated in Spain has been provided by the previously cited study.

The main source of the emission factors are Tables 8.3 and 8.4 from Chapter B927 in the EMEP/CORINAIR Guide Book; from which it is assumed that the factor for CH₄ is 0, since none is stated, and for N₂O, the factor of 100 g. per tonne is taken, similar to that quoted in the same source for the incineration of household waste. For the calculation of CO₂ of non-biogenic origin, 36% has been assumed for fossil origin and 64% of biogenic origin; regarding an emission of CO₂ of 1500 kg per tonne of waste incinerated, hence the factor of CO₂ of fossil origin changes to 1500 x 0.36 = 540 kg per tonne of waste. Emissions are calculated by multiplying the waste incinerated in Spain times the corresponding emission factor.

c) The incineration of municipal waste without energy recovery

This activity considers the emissions produced in MSW incineration within the operating incinerators not performing energy recovery. Given that the MSW incinerators have progressively shifted from incineration without recovery to with energy recovery, or have also applied the recovery option since the beginning of their activity, the accounting for the MSW incineration emissions has been shifting from the Waste sector to the Energy sector, in

accordance to IPCC instructions and FCCCC guidelines for emission inventories. According to the information available, from 2004, no emissions have been attributed from the "Waste" sector as all incineration facilities have undertaken incineration with energy recovery since then. The base information about the activity variable (amount of waste incinerated) is taken from the publication "The Environment in Spain".

The references for the emission factors are: for SO₂, NO_x, VOC, CO, N₂O, NH₃, Tables A1.1 to A1.6 in Appendix 1 of Chapter B-921 of the EMEP/CORINAIR Guidebook, third edition, having assumed that between the years 1990 and 1995, emission's control technique was simply "particle abatement", and from 1996 and in subsequent years has been "particle abatement + acid gas abatement." In the case of the VOC, 95% of NMVOC and 5% of CH₄ have been assumed. For the CO₂ a factor of 324 kg/tonne has been assumed, calculated assuming 36% of fossil origin and 64% of biogenic origin in the waste and considering that the overall factor for CO₂ per tonne of waste is 900 kg (fossil + biogenic)/tonne. The values indicated for CO₂ have been estimated by the inventory work team from the data on MSW composition.

d) Incineration of sludge from wastewater treatment

The emissions produced by incineration of sludge in the wastewater treatment have been estimated for this category. A distinction is drawn between the values for this variable depending on the type of emission source, which in turn constrains the data source used. Thus we obtain: 1) the values assumed for area sources (Table 8.4.4.a) and 2) those obtained from the questionnaire for point sources (Table 8.4.4.b).

With respect to the first, the area sources, the data for the years 1990, 1991, 1992, have been obtained by means of interpolation of the data corresponding to 1989 and 1993. The figures for these two years have been taken respectively from the information prepared by the former Ministry of Public Works on sewage sludge in the publication "The Environment in Spain" (referring to the year 1991) and in the "Study on treatment and final disposal of urban waste water sewage sludge", drawn up by the consulting firm "CADIC, S.A." for the Department of Water Quality at the MOPTMA [Ministry for Public Works, Transport and the Environment] (referring to the year 1993). For the period 1997-2007, the figures are provided by MAPA's "National Sewage Register; for the 1994-1996 series they are obtained by means of interpolation based on the data corresponding to 1993 and 1997. From 2003 to 2004 a decline in the amount of sludge incinerated is determined as a consequence of the review update conducted by MAPA for 2004 to 2006 period. Regarding the second source, the information is provided from the information obtained from the questionnaires sent to oil refinery and paper pulp manufacturing plants when sewage sludge is incinerated there. For the oil refinery sector, the data in the questionnaires covering the years 2007-2007, has been extended backwards using the series for the volume of wastewater treated; for the paper pulp manufacturing plants, the series only covers the years 1997-2005 where direct response of the questionnaire was obtained. As a result of this increase in the data coverage, a considerable increase can be observed after 1997.

Table 8.4.4.a.- Incineration of sludge obtained from urban wastewater treatment
(Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
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17.092	39.816	76.813	39.171	39.724	41.067	41.041
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Table 8.4.4.b.- Incineration of sludge obtained from industrial wastewater treatment
(Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
497	463	810	2.143	2.076	1.873	2.431

The emission factors have been provided from the information at the foot of Table 2, Chapter B-925 in the EMEP/CORINAIR Guide Book, assuming for each one the abatement techniques the supposedly most appropriate ones from the options appearing at the foot of the Table. Thus, for NMVOC, CH₄ and CO, has been taken directly from the value proposed in that reference; whereas for SO_x, NO_x and N₂O, the Inventory work team has selected the values considered most reasonable - in light of the abatement technique, from those proposed in said reference. In the case of the CO₂, in accordance with the IPCC and EMEP/CORINAIR methodologies, a factor equal to zero has been taken assuming that it comes from the incineration of renewable organic waste.

8.4.1.3.- New calculations

The new calculations are performed in the period 2005-2006 due to the update of the corpse incinerations series in 2005 and 2006.

Figures 8.4.1 and 8.4.2 illustrate the difference in emissions of Category 6C between the estimates in the 2008 and 2009 emissions. Figure 8.4.1 shows the absolute levels of emissions for each of the two editions; Figure 8.4.2. shows the percentage differences for the 2008 edition level.

Figure 8.4.1.- CO₂-eq. emissions Comparison of 2008 and 2007 editions

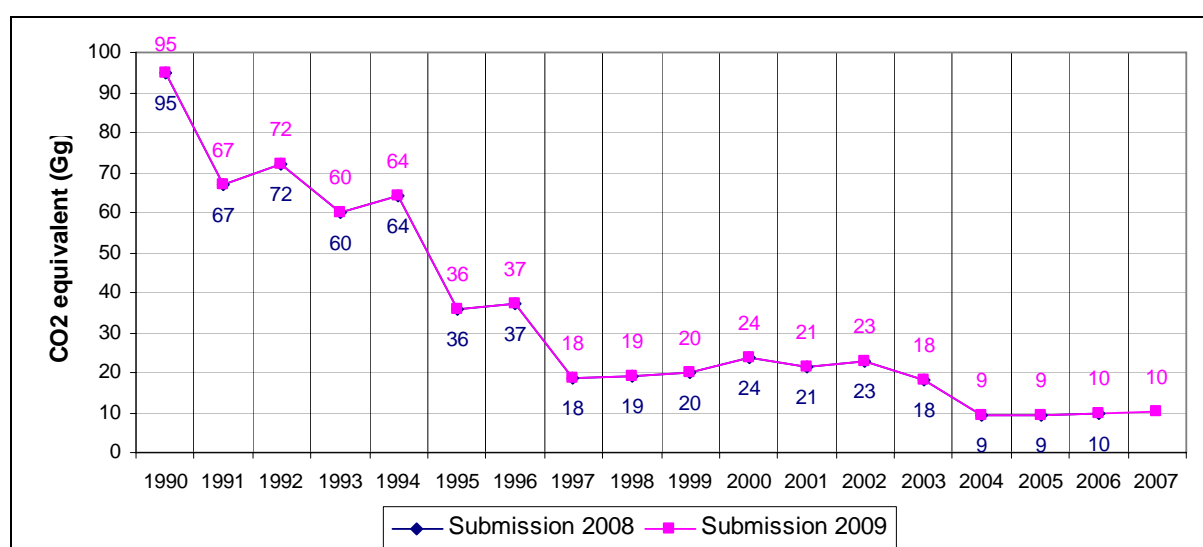
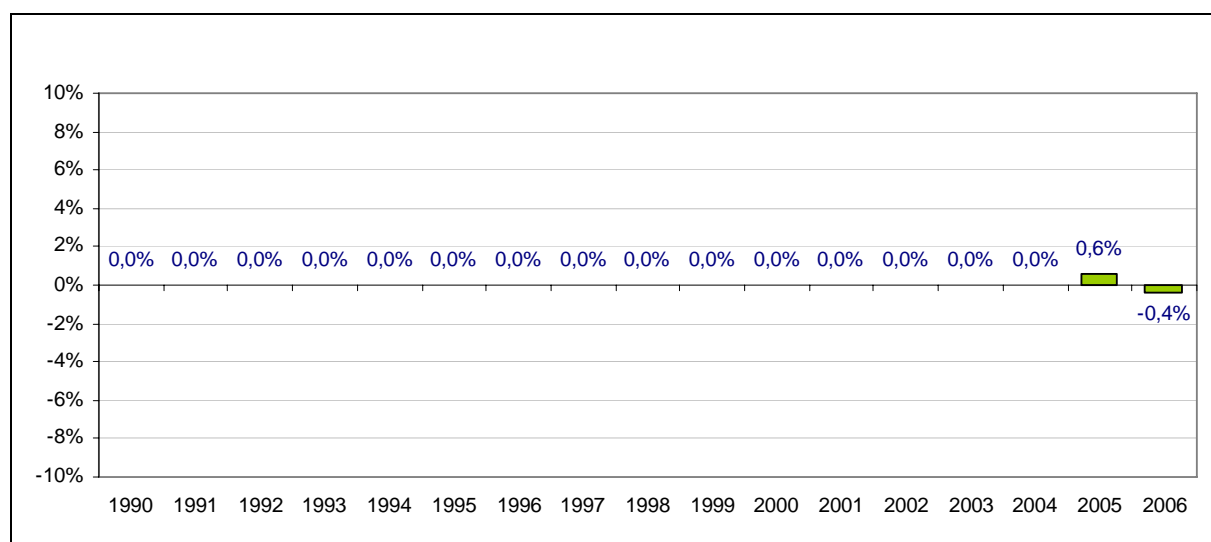


Figure 8.4.2.- CO₂-eq. emissions Percentage difference 2009 vs 2008 edition

8.4.2.- Other sources (6D)

Category 6D includes the CH₄ emissions from the sludge spreading at treatment plant.

The sludge spreading (as CH₄ emitter)

In this activity, the emissions are collected for sludge spreading that arises from wastewater treatment plants for drying and which may be considered as a process that is an integral part of wastewater treatments.

An attempt has been made to update the fraction series of the sludge drying, but the data for this activity has not been available. Due to the lack of better information the fraction of the sludge treated in wastewater treatment plants by drying in the open air for spreading, is equal to one. Table 8.4.5 illustrates the figures of the activity variable for sludge spreading.

The estimated gases have been the fractions of the NMVOC and CH₄ of the VOC, the respective values of 20 kg (NMVOC) and 29 kg CH₄ per tonne of all dried sludge (see page 14 of the "Report on Complementary Information in the Frame of the Assistance Provided for CORINAIR 90 Inventory", CITEPA). The previously mentioned figure of 20 kg is the mean in the dispersion range that is spread of 7.1 kg to 29 kg (see page 14, "Report on Complementary Information in the Frame of the Assistance Provided for CORINAIR 90 Inventory").

Table 8.4.5.- Sludge spreading (Amounts in tonnes)

1990	1995	2003	2004	2005	2006	2007
416.884	665.155	1.012.158	1.002.857	975.396	1.057.572	1.092.252

10.- RECALCULATIONS AND IMPROVEMENTS

10.1.- Explanation and justification of recalculations

The edition of the greenhouse gas inventory corresponding to 2009, covering the period between 1990 and 2007, has led to recalculations for the period 1990-2006 in a series of activities (and gases). These recalculations have been caused by several factors, including: a) methodological revisions; b) updated base information; c) correction of errors. Consideration of these changes has been promoted by the verification procedures and complemented by recommendations made in the Spanish inventory revision reports commissioned by the Framework Convention on Climate Change Secretariat (FCCCS).

Sections 10.2 and 10.3 below mention the implications that emission levels and trends have had in the new calculations, referring to the analysis of the inventory's emissions excluding the emissions and sinks from the LULUCF sector. The comments regarding the recalculations of the emissions and sinks of the LULUCF sector are specifically presented in Chapter 7 of Appendix 3.3. Section 10.4 dedicated to the planned improvements of the inventory includes, however, the description of the foreseen improvements for the LULUCF sector.

10.2.- Implications on emission levels

In CO₂-equivalent terms and on an aggregate inventory level, see Figure 10.2.1, annual changes have remained within a range that varies from year to year between -0.06% (2006) and 0.26% (1999), therefore being considered as minor changes (less than 1% in absolute value)¹

If we examine these changes by activity sector, the causes of the variations due to recalculations can be identified as specified below.

In the "Energy" sector, see Figure 10.2.2, changes occur throughout the whole series, and that can be grouped as follows: i) Updating the base information provided directly by the large plants in the chemical sector caused an emissions discount due to fuels reassignment from the energy sector to the process sector, where the CO₂ emissions had already been counted; ii) availability of new and more precise information about other point sources that improves the estimate quality of the emissions with reference to the activity variables (fuels consumption) and to the emission factors in accordance with specific fuels; iii) revision, in the years from 2004 to 2006, of natural gas consumption from updated information provided by the national balance of this fuel. Due to these revisions relative variations occur in a range from -0.33% in 2006 to 0.03% in 1998 and 1999.

¹ Last year's revision of the previous edition of each inventory usually suffers greater changes as a large part of the information on activity variables is provisional, partial or completely missing (this is frequently the case with information on the energy balance).

In the “Industrial Processes” sector, see Figure 10.2.3, the most relevant changes arise from the revision of the activity variables in the decarbonation processes in fine ceramic materials (for the whole 1990-2006 period) and in the clinker production (2006) due to the updating of activity variable information. In addition, with regard to calcium carbide production, and following the FCCCS review team, an estimate of the methane emissions has been included that was not present in previous editions of the inventory.

In the “Use of solvents and other products”, see Figure 10.2.4, the recalculations (with an absolute value of not greater than 0.4%), are due to various revisions of variables for some activities in this sector, mainly the domestic use of solvents and pharmaceutical products.

In the “Agriculture” sector, see Figure 10.2.5, the revision has focused essentially on 2006, with a variation of -0.79% that was motivated by: i) the revision of the figures for swine (correction of an error detected in the previous edition of the inventory) and poultry (new information available); ii) the availability of updated information related to milk production statistics; and iii) a revision of the parameters for the burnt fraction of the various agricultural residues. For the other years in the series, the variations are practically undetectable (about 0.02%).

In the “Waste” sector, see Figure 10.2.6, is where the most significant revision in relative terms has been introduced, with increments that range from 4% to 8% between the years 1990 and 2005. The cause has been the volume increment of waste deposited in landfill as shown in the information collected by the questionnaires individually submitted to the main landfills. In 2006, together with the above mentioned cause, the variation is due to a correction of a lack of information on the deposit of waste in one of the main landfills. It must be pointed out that, without this second effect, the variations in the trend observed in the period 1990-2005 would have extended to 2006 (i.e. its trend variation would no longer be anomalous).

Turning now to examine the gases, it is possible to identify variations that to a large extent reflect the changes described in the sectors dominating the contribution of the respective gases.

As for CO₂ it can be seen that Figure 10.2.7 reproduces quite faithfully the profile of Figure 10.2.2 of the Energy sector, since this is a consequence that on the review made in this sector prevail the variations occurred with that gas.

Concerning CH₄, the variations shown in Figure 10.2.8 that range between 1.46% (2005) and 2.65% (2006), are essentially the reflection of the modifications made in the landfill category of Waste sector, that for year 2006 combined with the manure management emission revision as a consequence of the stated update about the amount of swine animals.

The downward variations experienced in N₂O, see Figure 10.2.9), with values ranging between -0,18%% (2006) and -0.05% (2000) are mainly due to the mixed effect of the changes in Agriculture and in Waste, although they represent a minor amount in the inventory as a whole.

To conclude, fluorinated gases, please refer to Figures 10.2.10, 10.2.11 and 10.2.12 have not experienced any revisions in this edition with respect to the previous one.

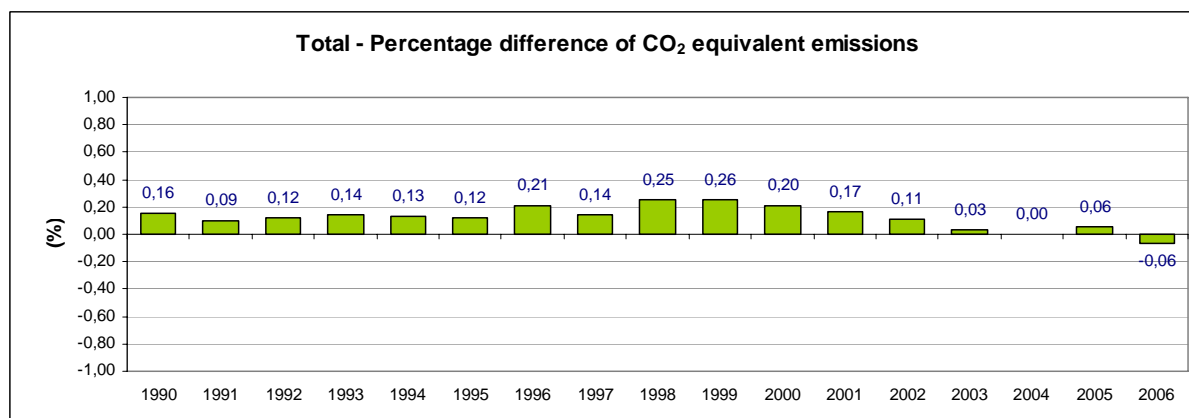
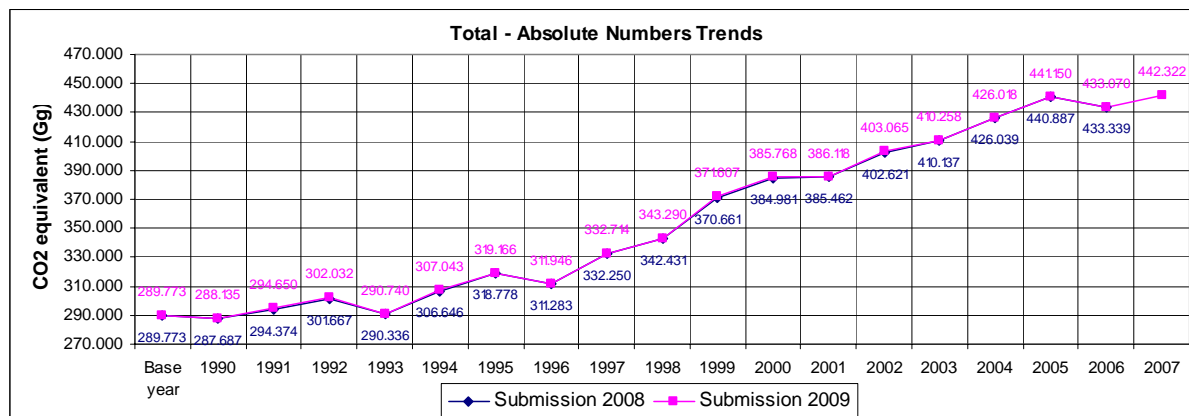
Figure 10.2.1.- Comparison of overall levels

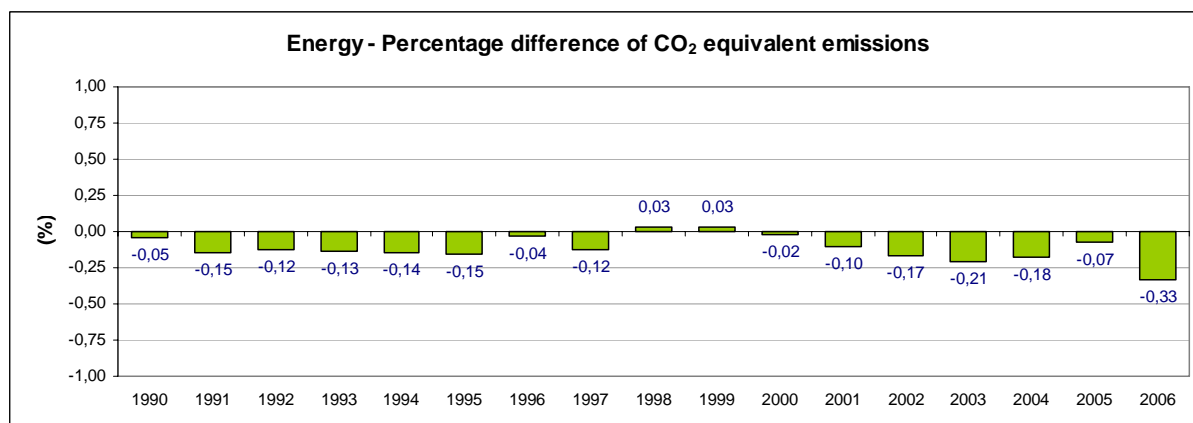
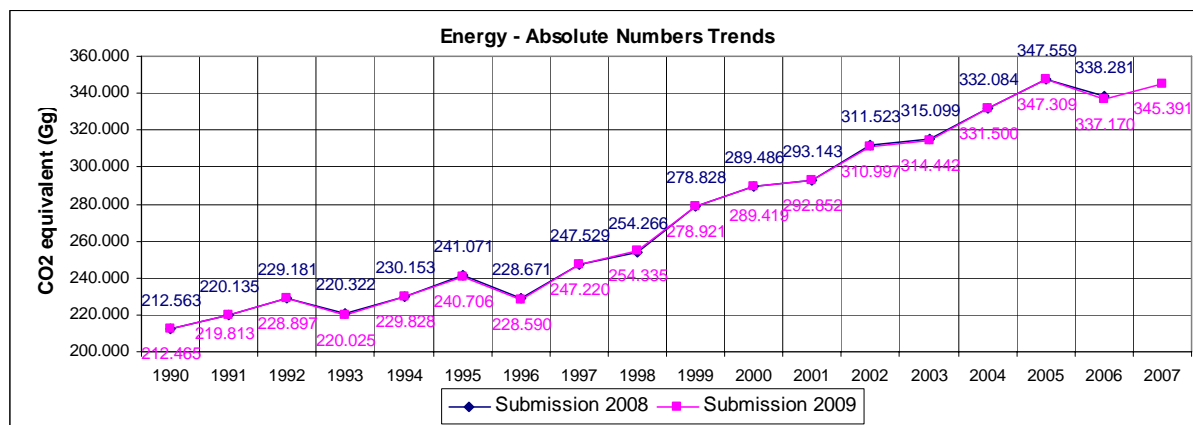
Figure 10.2.2.- Comparison of levels in the energy sector

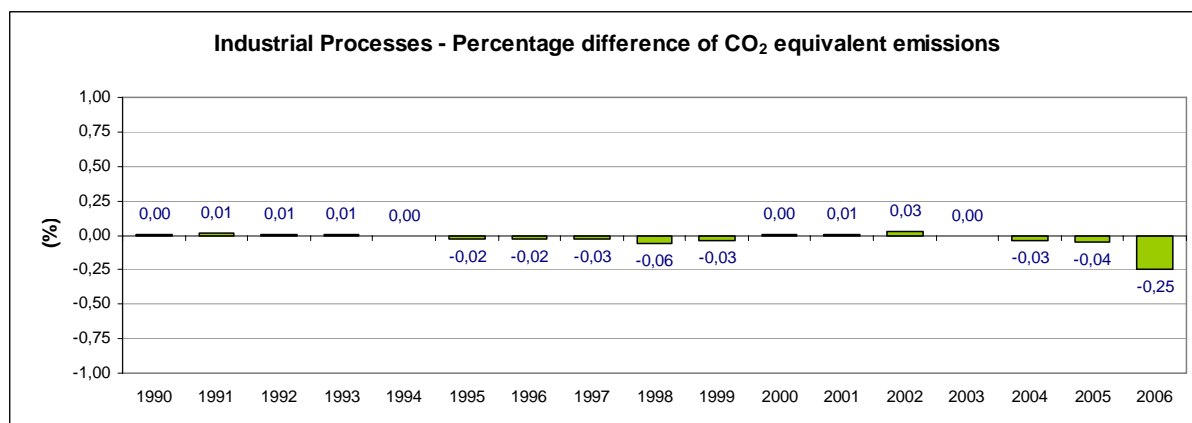
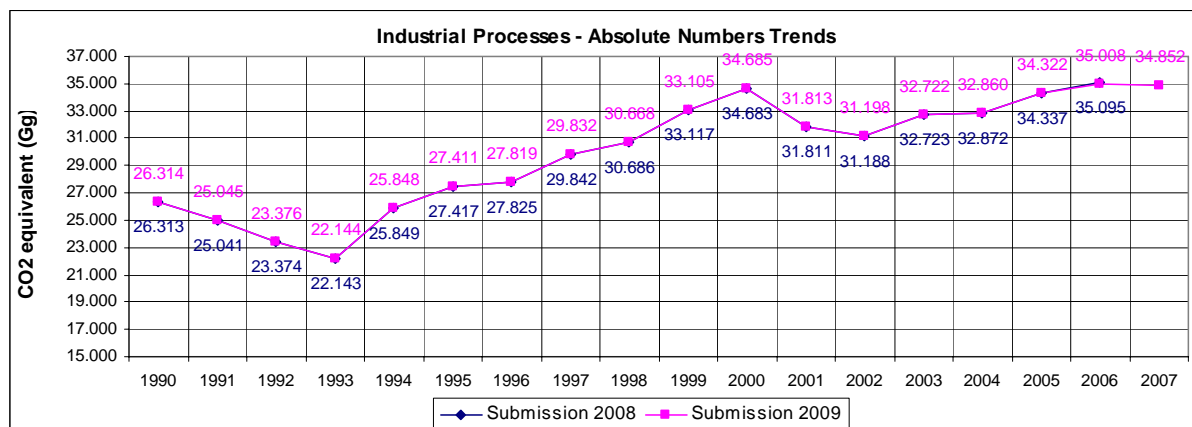
Figure 10.2.3.- Comparison of levels in industrial processes

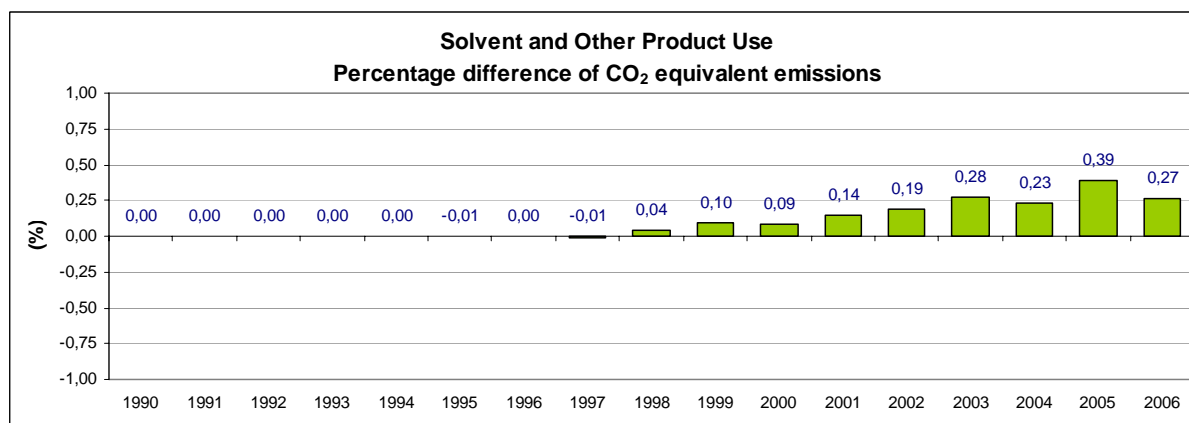
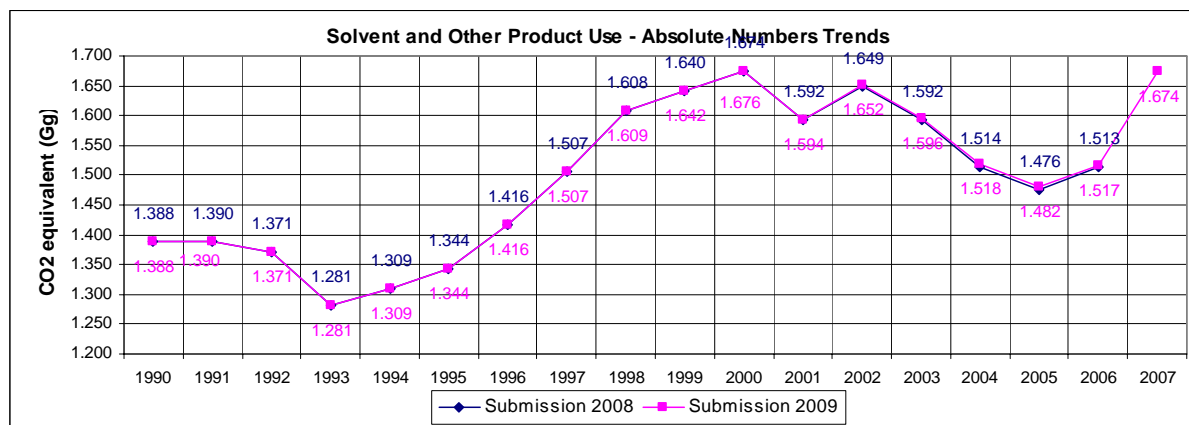
Figure 10.2.4.- Comparison of levels in use of solvents and other products

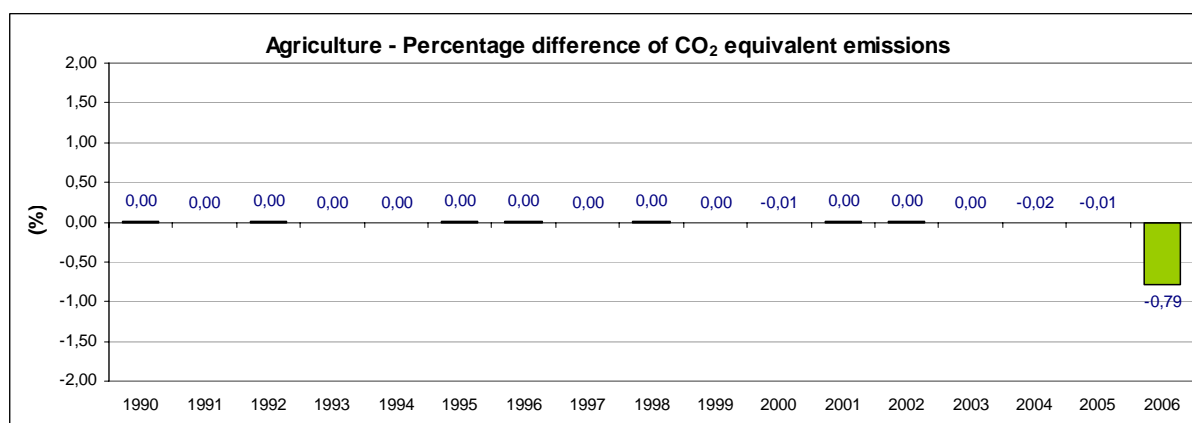
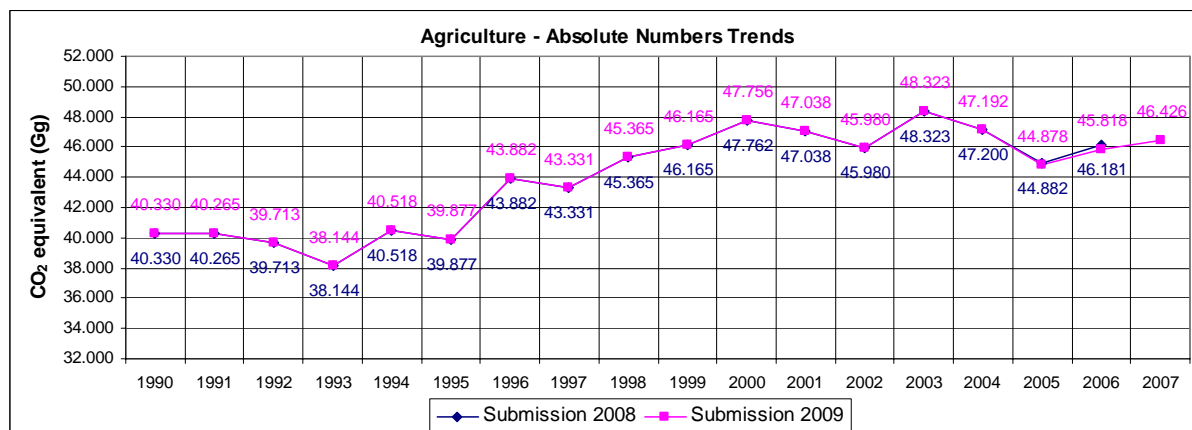
Figure 10.2.5.- Comparison of levels in agriculture

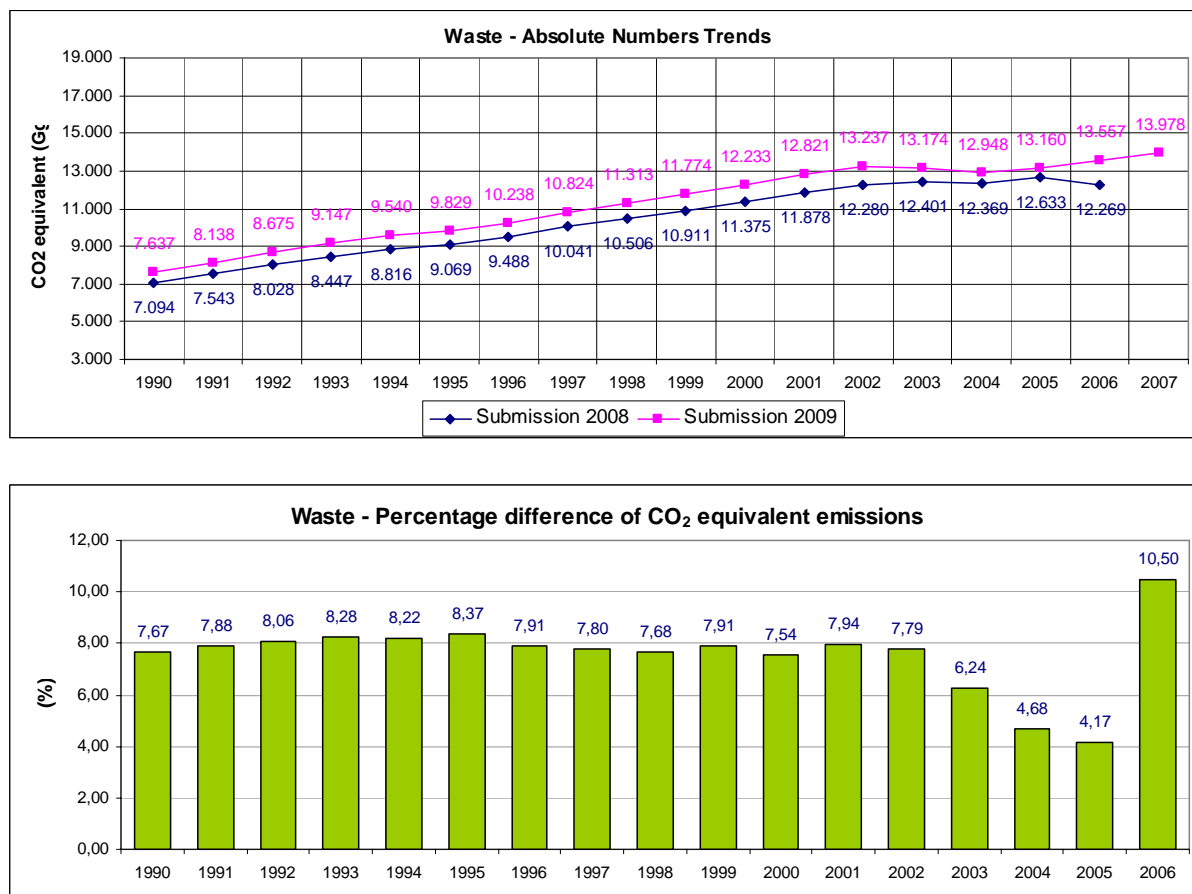
Figure 10.2.6.- Comparison of levels in waste

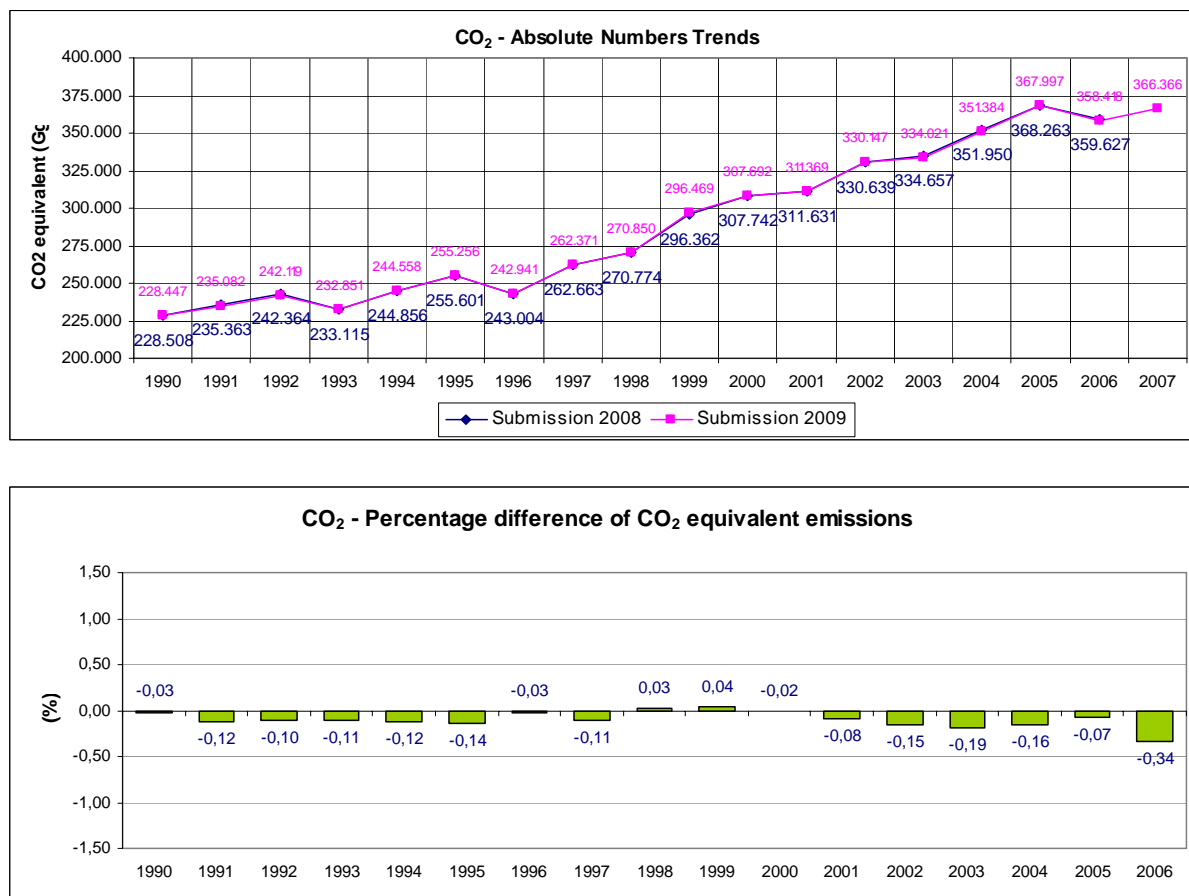
Figure 10.2.7.- Comparison of levels of CO₂ emissions

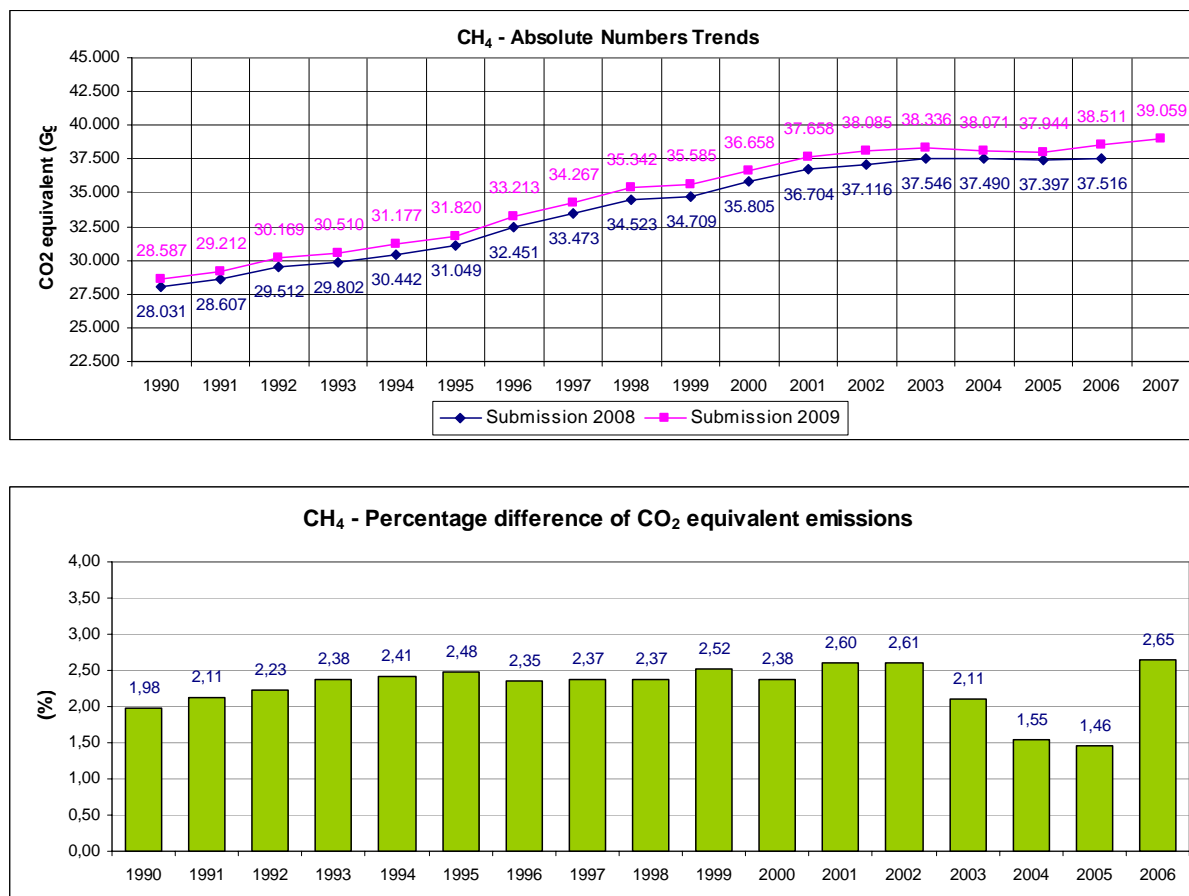
Figure 10.2.8.- Comparison of levels of CH₄ emissions

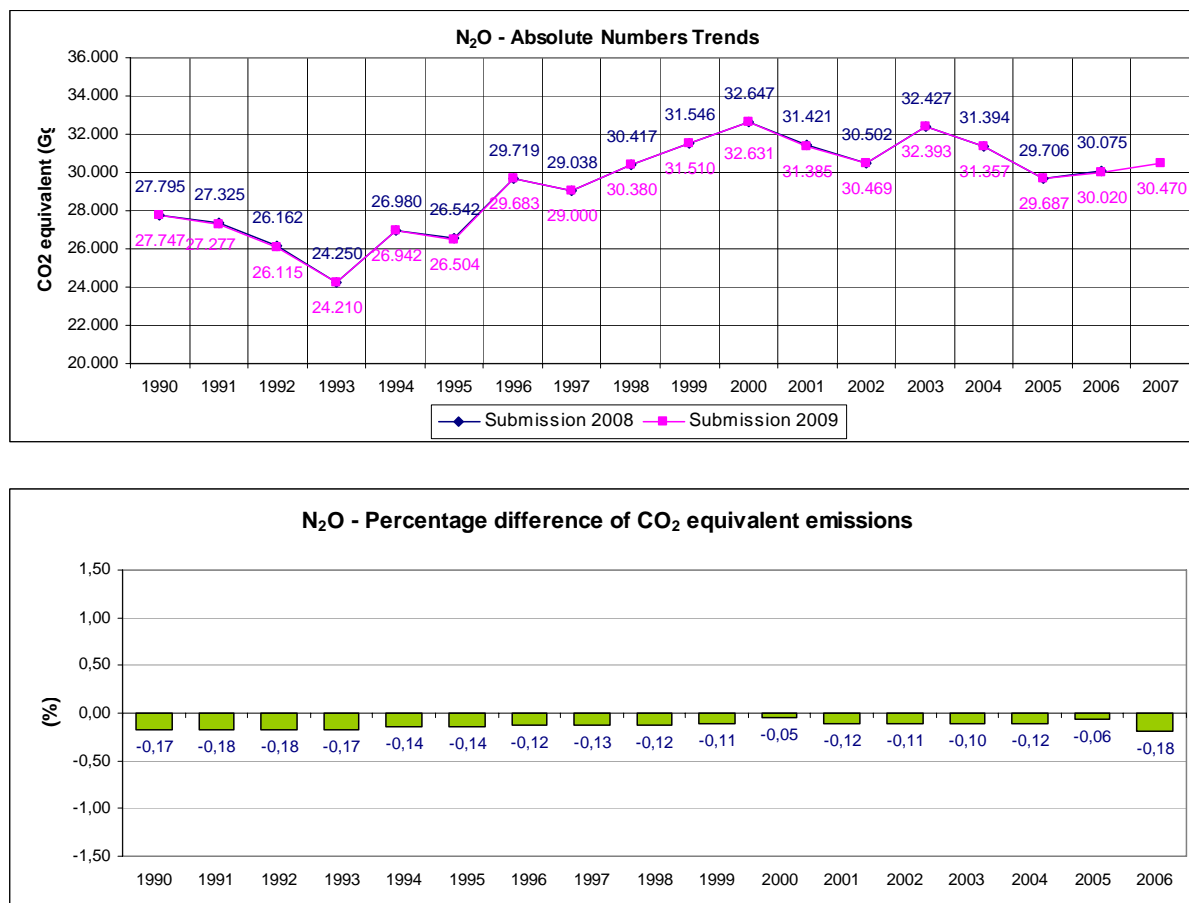
Figure 10.2.9.- Comparison of levels of N₂O emissions

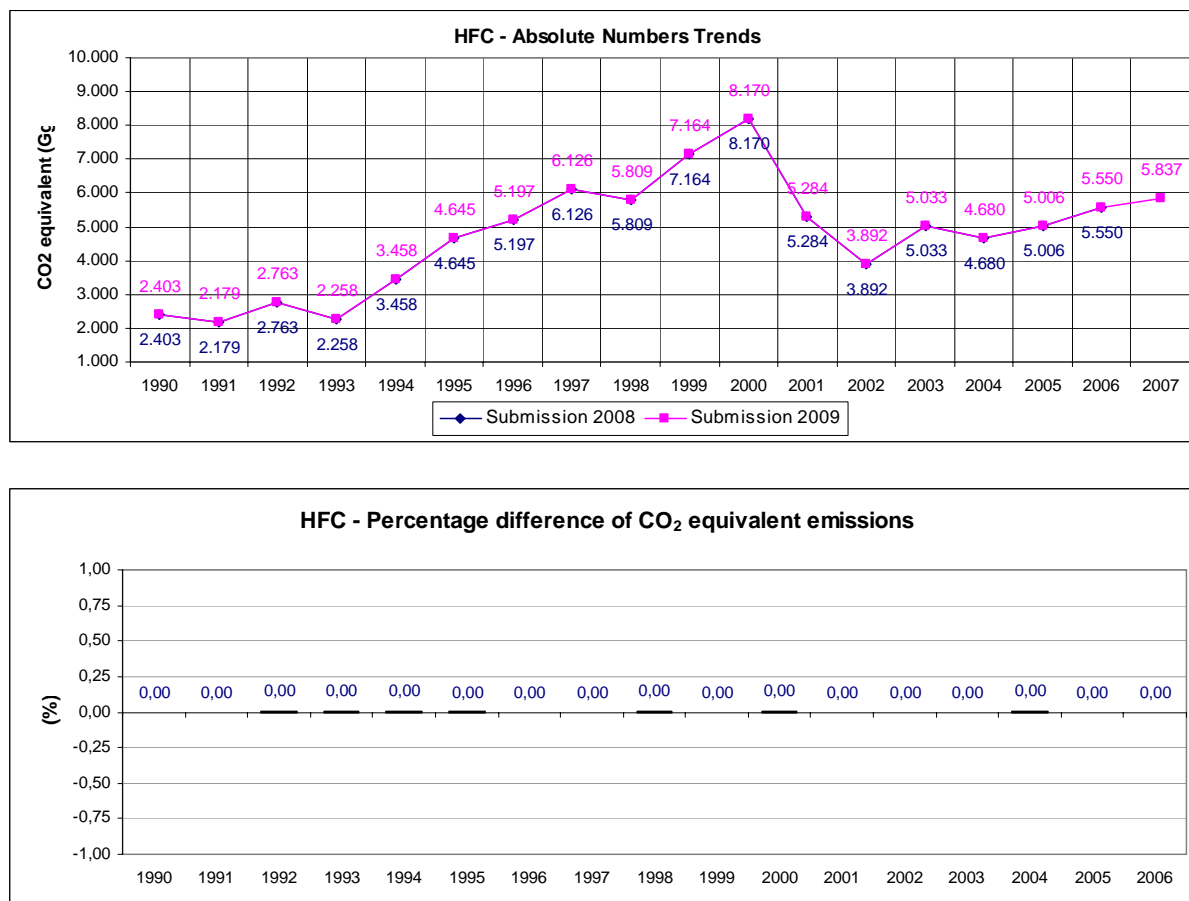
Figure 10.2.10.- Comparison of levels of HFC emissions

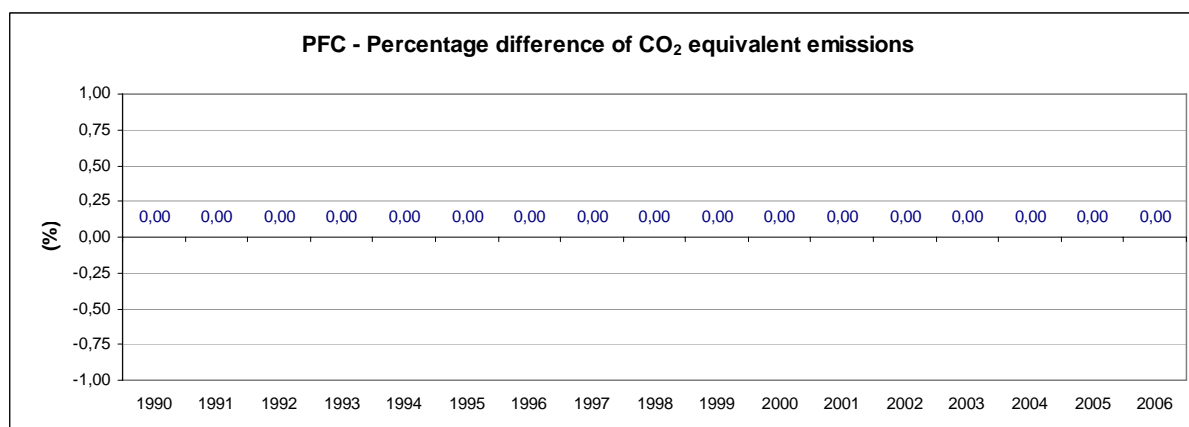
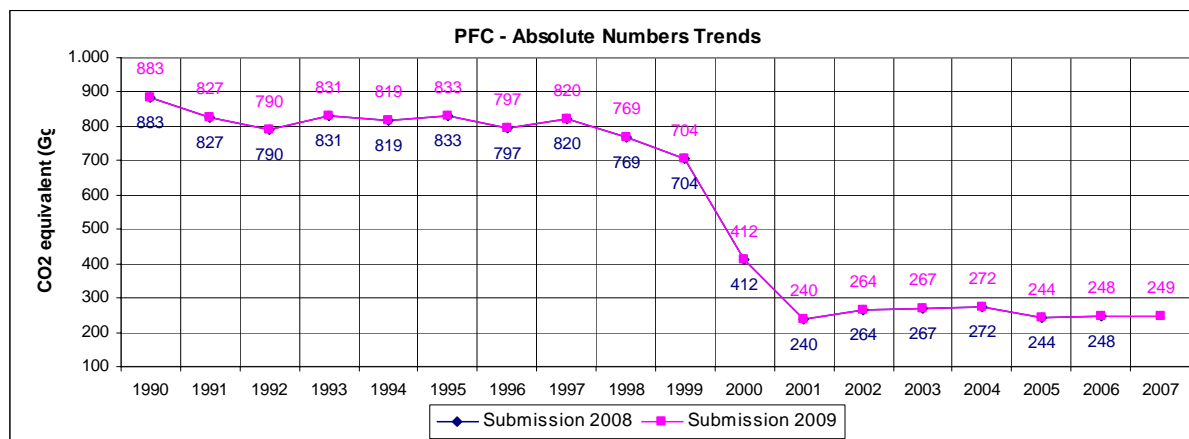
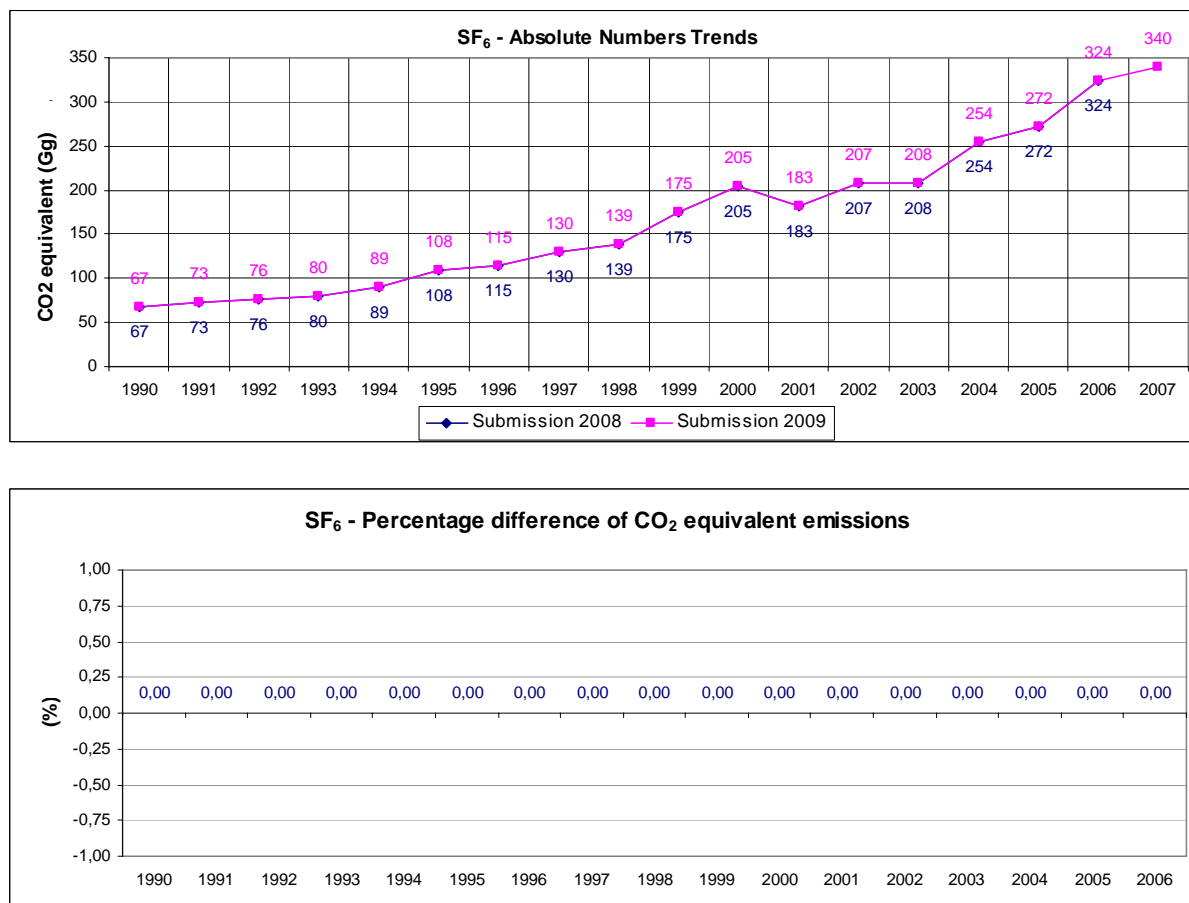
Figure 10.2.11.- Comparison of levels of PFC emissions

Figure 10.2.12.- Comparison of levels of SF₆ emissions

10.3.- Implications on emission trends

To illustrate the implications of the recalculations on emission trends, Figures 10.3.1 10.3.9 show the evolution in the form of indices of the compared results (CO₂-equivalent emissions) between the edition corresponding to 2009 of the inventory and the previous edition from 2008.

In order to compare indices, the difference (in each year) is calculated between the values of the indices corresponding to the 2009 edition and those of the 2008 edition (Ed 2009 – Ed 2008).

In Figure 10.3.1 it is possible to see the practical overlapping between the diagrams of the evolution indices over time for the series of aggregate CO₂-equivalent emissions between both editions of the inventory. The differences are mainly positive, with a maximum of 0,3 in 1999, except in 2004 and 2006, where the difference is practically negligible. Thus, in the years shared by both series as a whole, 1990-2006, it can be said that the profile of the trend is maintained.

Comments on the evolution of the trends by activity sectors are given below based on the evidence shown, namely in Figure 10.3.2 to Figure 10.3.6.

By examining Figure 10.3.2, the conclusion can be drawn that the trend profiles in the Energy sector are also very similar. In this case, the differences between the indices are negative with the exception of the minimum positive values of 1998 and 1999, with a maximum of -0.4 relative to 2006. Therefore, the common profile of this sector's trend is maintained between both inventory editions.

Figure 10.3.3 shows the comparison of the time evolution profiles for the Industrial Processes sector with slight differences, always with a mainly negative sign, with a maximum absolute value of 0.4 in 2006. These minor changes have generally been motivated by the revision of the activity variable in the following industrial sub-sectors: cement production, fine ceramics and some chemical sector activity. The reason for this difference is due to the fact that the emissions from flares at integrated iron and steel plants that in previous editions of the emission inventory were allocated to the Waste sector were reassigned in the 2008 inventory edition to the Industrial Processes sector, and given their inter-annual variation of said emissions these variations are also reflected in the indices' evolution. Overall, the repercussion of the recalculations is basically translated in a very small variation of the index of the current edition in comparison to the previous one, but both essentially keep a similar trend profile.

The time evolution profiles for the Use of Solvents and Other Products sector (as shown in figure 10.3.4, coincide exactly until 1998 and with slight positive variations starting from 1999, with 0,4 as maximum absolute value in 2005, therefore resulting in a very similar trend pattern when comparing both editions of the inventory in this sector.

Figure 10.3.5 shows the indices of the time evolution for the Agricultural sector, the difference in the indices appears only in 2006 where the index difference reach -0,9 points. This change is mainly the result of an update of the activity variables of swine and poultry

number, as well as the milk production data. Overall, a similar profile is kept in both indices' trend.

In the Waste sector there have been significant changes, see Figure 10.3.6, in the time evolution indices between the two editions of the inventory. The main cause has been the upward revision of the series of the waste volume deposited in controlled landfills, specially in the 2003-2006 period, where the correction of an error detected in the data for the previous edition must be added for 2006. The result is a remarkable change in the level and profile in the years 2003-2006 between the series in both directions, while in the rest of the years the differences are not significant (no greater than 0.2 points).

Comments on trend evolution through gases are given below based on the evidence shown, namely in Figures 10.3.7 to 10.3.12.

As for CO₂, the differences in the time indices are small, with the most remarkable difference in the last years of the period analyzed and a maximum difference of 0.05 points in 2006. In general, the CO₂ index differences between series in both directions are similar to those of the Energy sector, reflecting the high contribution this sector has on emissions of this gas. Thus, it can be said that for this gas there are no notable changes in the trend profile between the estimations of both editions of the inventory.

Concerning CH₄, the differences in the time evolution indices, shown in Figure 10.3.8, are mainly determined by the recalculations, already mentioned above, carried out in the Waste sector, this is reflected in an increase in the new index until 2003, when the series of both editions cross. The comments regarding the evolution of both indices that can be made are similar to the ones concerning the Waste sector.

Figure 10.3.9 shows the time evolution indices for the N₂O emissions in the group of activities emitting this gas. As can be seen, the differences are in absolute value always less than 0.1 points. Therefore, both indices basically maintain the same trend patterns.

Figures 10.3.10, 10.3.11 and 10.3.12 respectively show the comparison of the time evolution indices for HFC, PFC and SF₆, between the current and previous editions of the inventory. As can be observed no variations exist in any year of the series.

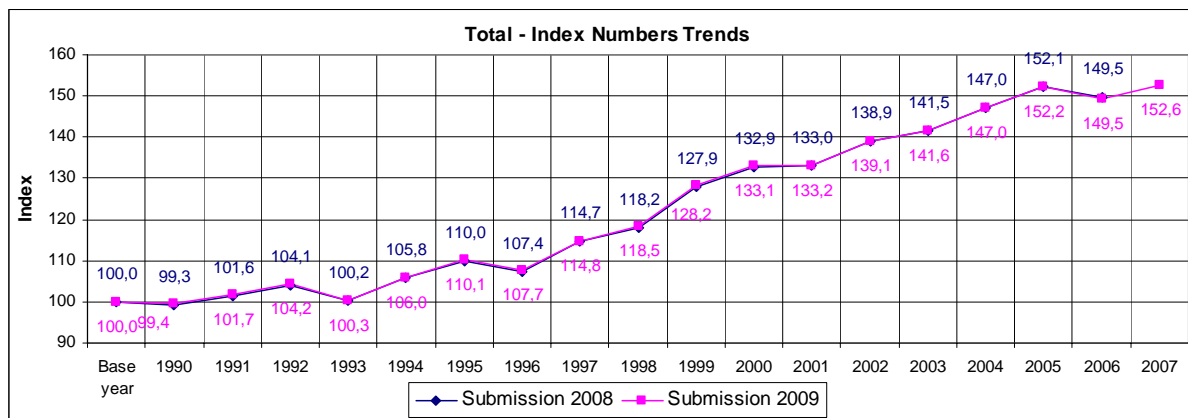
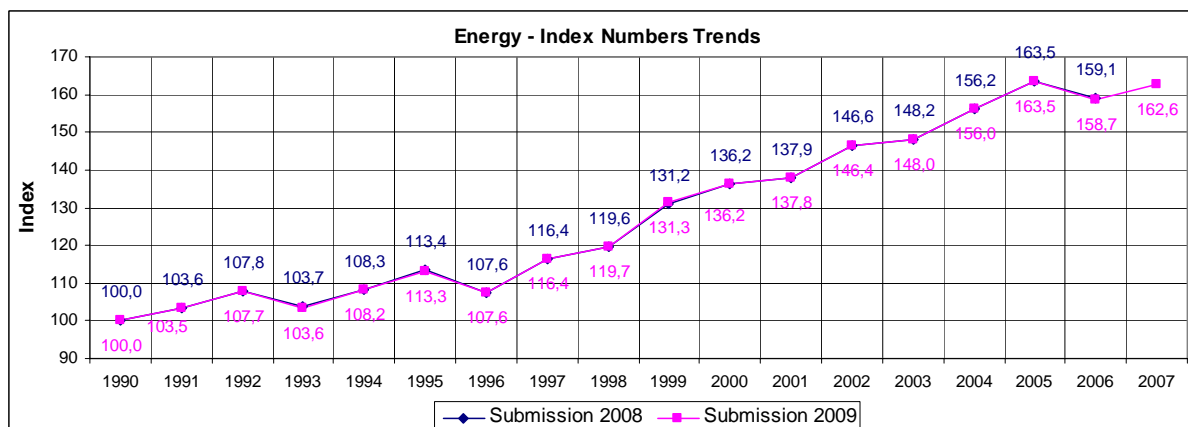
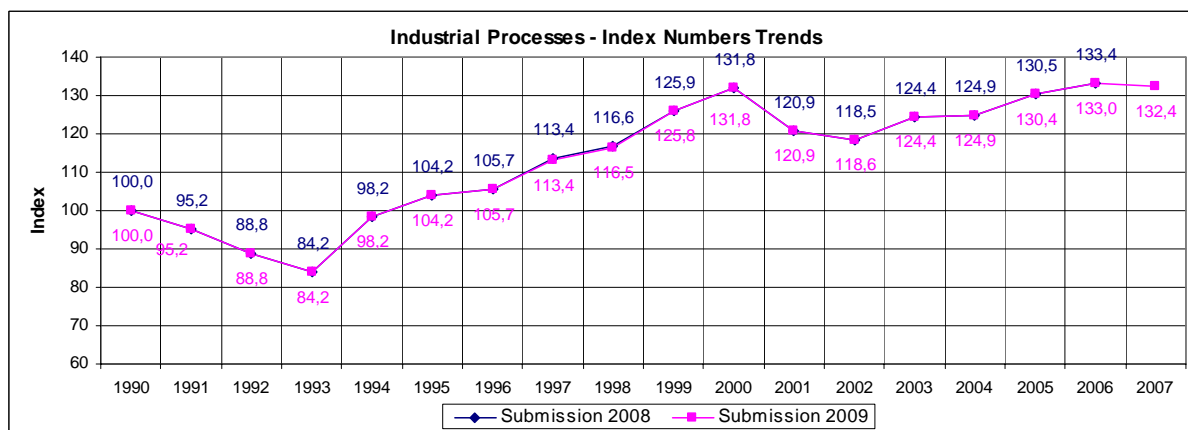
Figure 10.3.1.- Comparison of overall trends**Figure 10.3.2.- Comparison of trends in energy****Figure 10.3.3.- Comparison of trends in industrial processes**

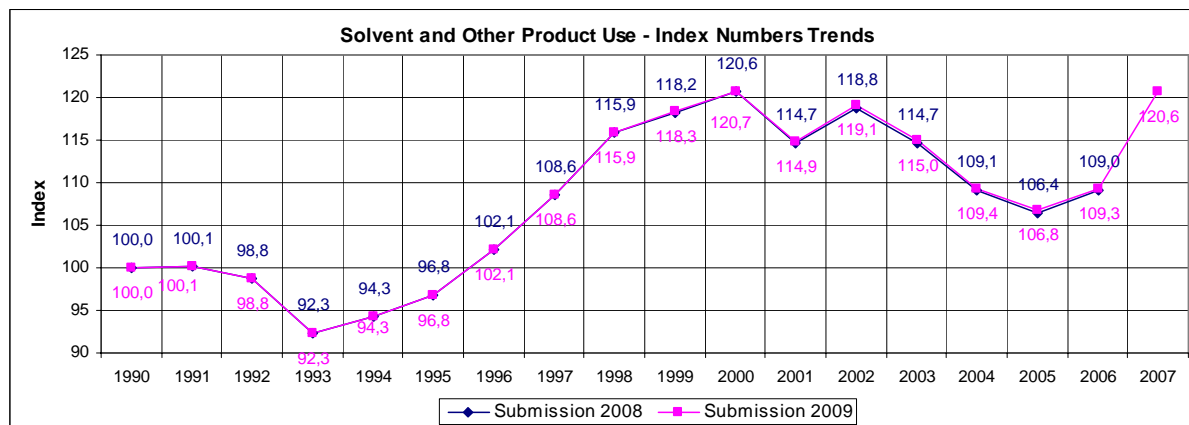
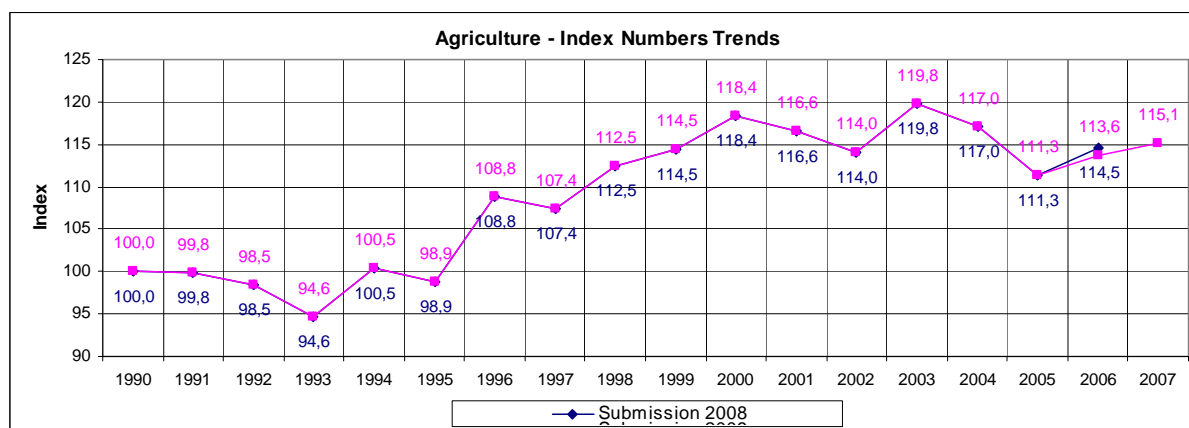
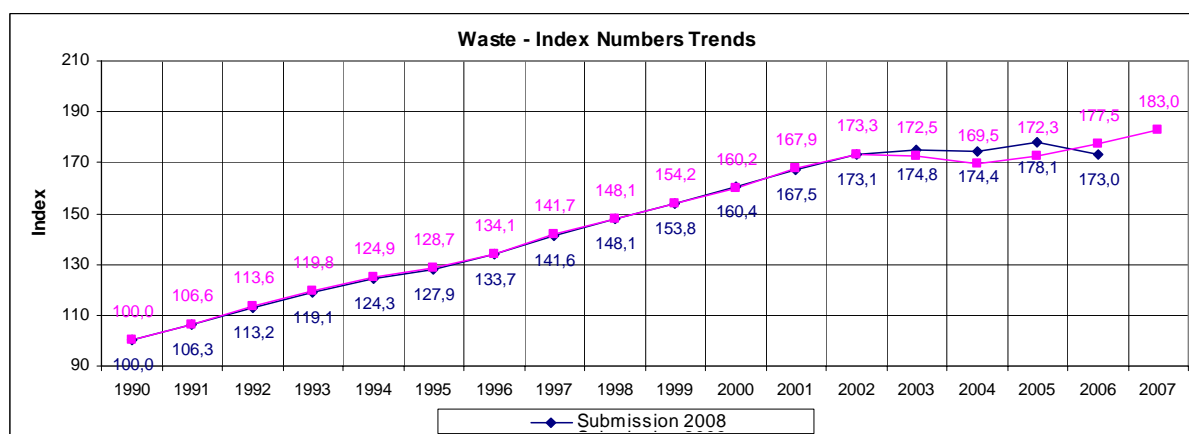
Figure 10.3.4.- Comparison of trends in use of solvents and other products**Figure 10.3.5.- Comparison of trends in agriculture****Figure 10.3.6.- Comparison of trends in waste**

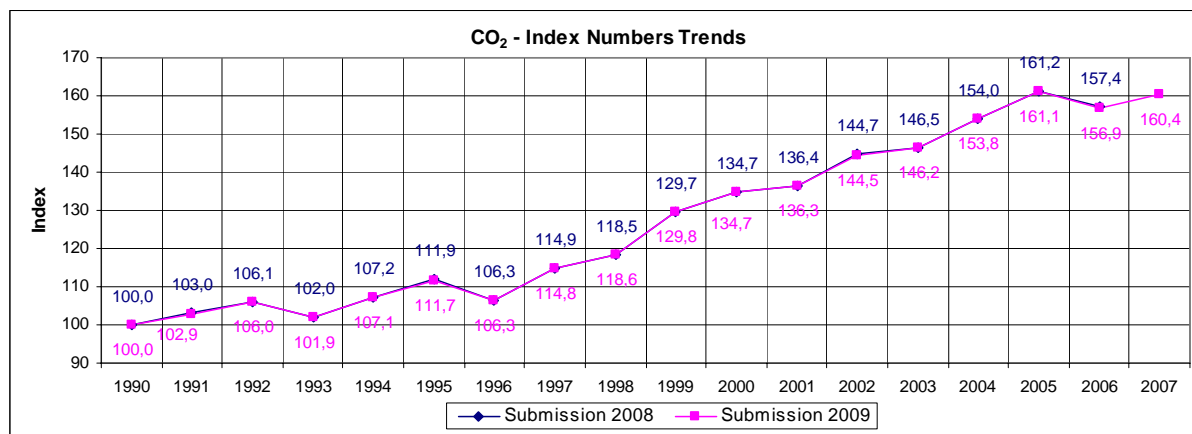
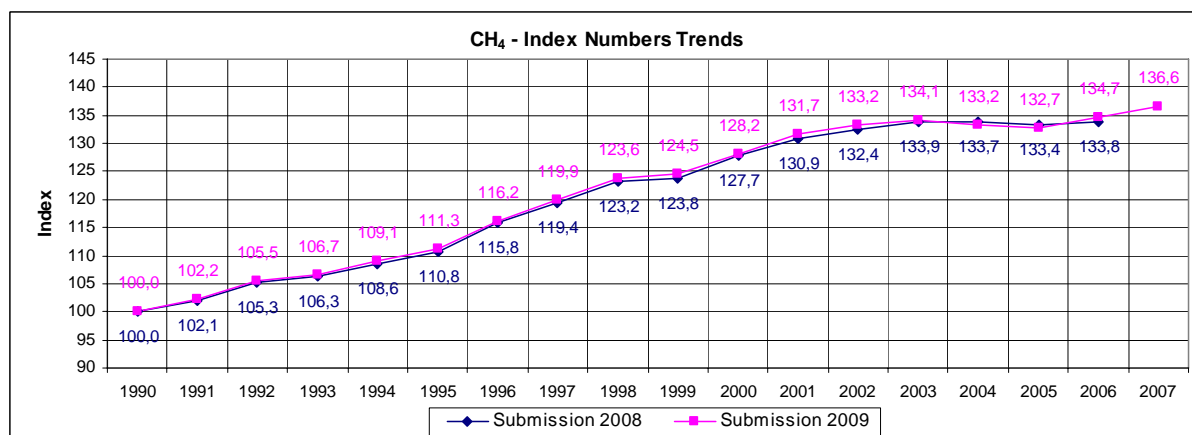
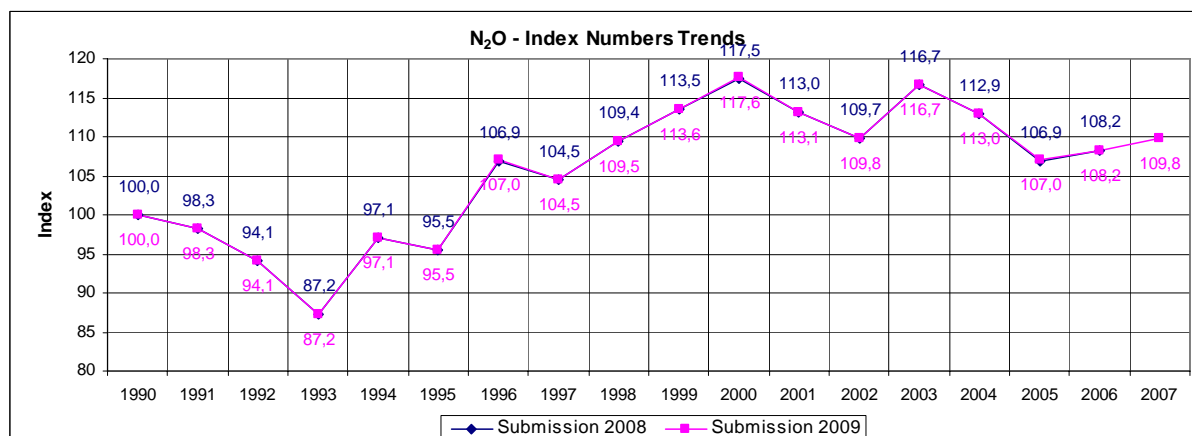
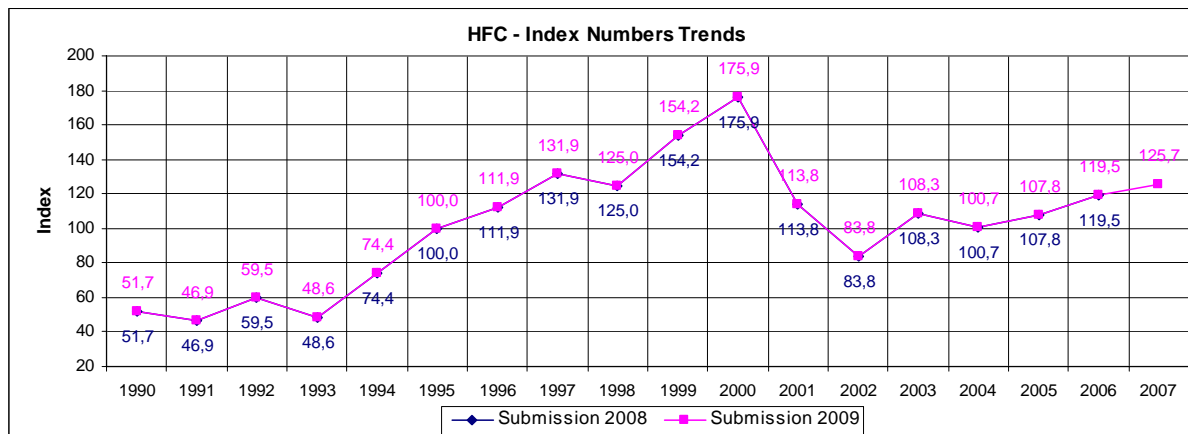
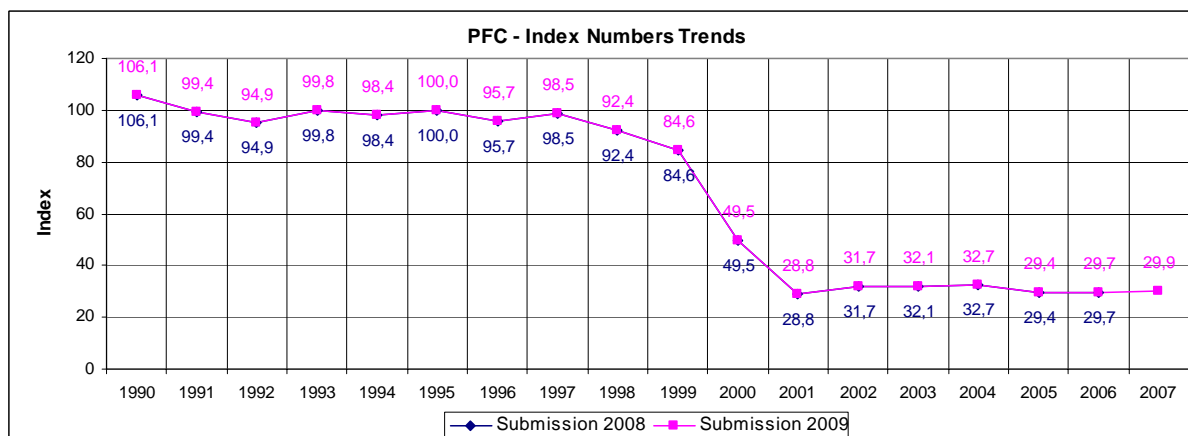
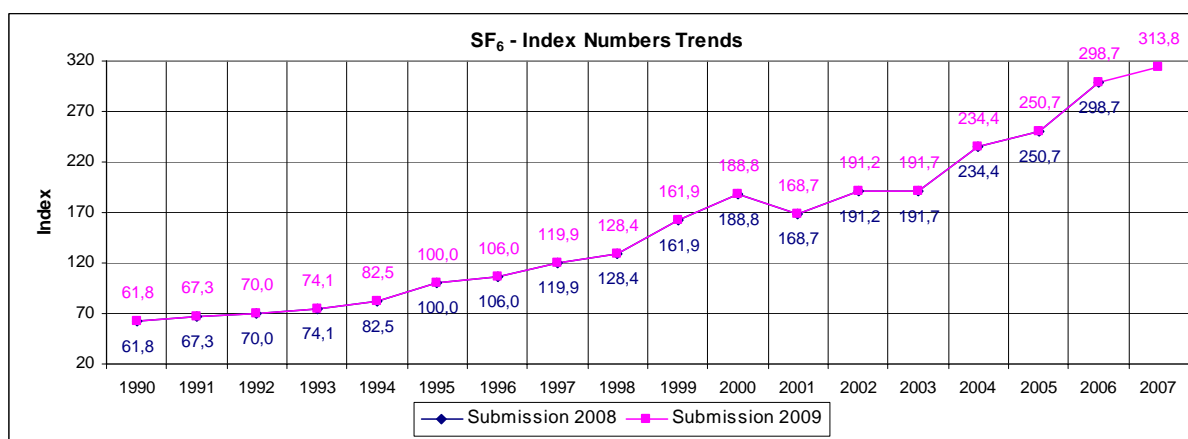
Figure 10.3.7.- Comparison of trends of CO₂ emissions**Figure 10.3.8.- Comparison of trends of CH₄ emissions****Figure 10.3.9.- Comparison of trends of N₂O emissions**

Figure 10.3.10.- Comparison of trends of HFC emissions**Figure 10.3.11.- Comparison of trends of PFC emissions****Figure 10.3.12.- Comparison of trends of SF₆ emissions**

10.4.- Recalculations and improvements anticipated in the inventory

10.4.1.- New calculations

The new calculations made in this 2007 edition of the inventory have had a relatively limited scope, as previously stated in section 10.2. The most outstanding changes are: i) the revision carried out in the Waste sector for the volume deposited in controlled landfills; ii) the Energy sector revision, as the fuel information was updated for various sectors, as well as the revision of a significant amount of fuel in the chemistry industry that has passed from being considered as energy consumption to being considered non-energy consumption; iii) the deduction in computable CO₂ from the emissions of the petrol and diesel fuel renewable fraction consumed in road traffic. Other changes are more specific and readers are, advised to refer to the section on “new calculations” in the related sector chapters.

10.4.2.- Improvements planned for the inventory

Among the inventory improvements foreseen, consideration is given on the one hand to horizontal improvements influencing the whole system of the national inventory and, on the other hand, improvements aimed at specific activity sectors.

10.4.2.1.- Horizontal

The main transversal actions foreseen for the improvement of the inventory are as follows:

- Giving continuity to the quantifying approach of the improvement objectives for the national inventory system and quantifying the objectives-resources balance.
- Improve the development of the institutional arrangements, particularly regarding the cooperation between the government ministries through their focal groups and work groups established with the participation of distinct ministries and collaborating entities. Among these groups it is also included one composed by autonomous communities for the harmonization of national and autonomous inventories.
- Continuing the effort already initiated in the upgrade of the inventory in order to include among the inventory's base information, the one provided by the development of the trading instruments for emissions (basic data on certified CO₂ emissions). In this streamlining sense, a collaboration agreement has been reached with the departments of the Ministry of the Environment, and the Rural and Marine Environment and the Ministry of Industry, Tourism and Trade on the one hand, and the regions on the other, with the scope that the Regional Governments will complete a questionnaire for each facility subject to the Directive on Emissions Trading Regime²; through this questionnaire the autonomous communities will provide to the Central Administration

² Individual questionnaire administered to installations regulated by Decision 2007/589/CE on guidelines for monitoring and reporting of greenhouse gases emissions.

base information and estimated CO₂ emissions certified by each facility submitted to the stated monitoring regime of CO₂ emissions.

- Identifying the key-categories by using a Tier 2 approach and including the activities from the LULUCF sector.
- Selective application in determined activity sectors (among them Agriculture) of Tier 2 approach in order to estimate uncertainty.
- Continuing the development and documentation of identification methods of atypical values and methods of replacement of anomalous/absent values by integrating them in existing procedures towards quality control and inventory verification.

10.4.2.2.- Sectorial

Although a detailed list of sectorial improvements has already been given for each activity in the corresponding sectorial chapters, the ones considered to be the most relevant are mentioned here again for the reader's convenience.

a) Energy

a.1) Energy in general

One priority approach is the methodological review for preparing a balance of liquid fuels (fossil and biogenic) that it supposed to be carried out along with the relevant units of the MITYC's General Secretariat. This point includes both the quantification of sectorial breakdown in the consumption of these types of fuels in energy activities (as well as non-energy use) and the precise evaluation of the characteristics (sulphur and carbon contents, heating value) of said fuels.

An analogous treatment is also proposed for the improvement of the information concerning the consumption of biomass and other waste-derived fuels. In this regard a collaboration is planned with the Energy Saving and Diversification Institute of the Ministry of Industry, Tourism and Trade IDAE-MITYC and with the General Sub-Directorate for Sustainable Production and Consumption at the Ministry of the Environment and Rural and Marine Affairs. The collaboration with the IDAE-MITYC will be extended towards the improvement of the information regarding the balance of specific fuels from co-generation units (the ones for which information is already obtained for the emissions inventory through an explicit exploitation made by the IDAE). Particularly how the fractions of fuels attributable to the production of electricity and heat are harmonized with the information concerning the national energy balance.

In addition, it is planned to include the recommendations regarding energy aspects of the Quality Assurance Program of the National Inventories of Air Emissions carried out by CIEMAT in 2007-2008.

a.2) Combustion in the sector of energy industries (1A1)

It is planned to intensify the monitoring of the fuel characteristics to identify with greater precision the atypical values occasionally reported by large combustion installations (mainly power stations and oil refineries). This information is received via an individual

questionnaire from each plant. It is also expected to continue and extend the individual analysis of large landfills, especially the ones performing biogas recovery.

Concerning solid fuel transformation plants (coke ovens), it is planned to incorporate those not located at iron and steel plants into the information gathering system via individualized questionnaires sent to plants. This approach is expected to be applied according to the plant-level information supplied in reports certifying CO₂ emissions within the framework of the Directive on Emissions Trading. In this way, individual plant information is expected to be available on both emissions produced in coke ovens and national coke and coke oven gas productions with specifications of the characteristics of these fuels.

a.3) Combustion in industry (1A2)

A first line of action in the improvement plans is to continue to improve access by individualized information per plant in certain non-ferrous metallurgical sectors where the number of plants in existence is low and therefore there is a positive cost/benefit relationship for having information on a per plant basis (this includes secondary lead and secondary copper manufacturing activities, where individualized information is available for some of the production plants). The same approach is intended to be applied to iron foundries.

Another line of improvement is to explore potential industrial sub-sectors performing captive lime production operations that have not yet been investigated (sugar refineries, copper works, calcium carbide) as these could imply, by not being considered in commercial circuits, that fuel consumptions and emissions associated with this activity are being undervalued.

Finally, although these plans will require more time, it is hoped that the basic information on biomass consumption as well as standardization of its classes can be improved as this is relevant to determine the characteristics of calorific values and emission factors.

a.4) Combustion in transport (1A3)

With regard to air transport, a collaboration project between different national bodies (DGCEA, National Agency for Air Safety – AESA- and SENASA – Services and Research Air Navigation and Aeronautic Safety Enterprise) and international organizations (EUROCONTROL) is currently in progress to apply a methodology already developed for the traffic model and aeronautical traffic emissions (model MECETA). In future editions, the plan is to introduce methodological aspects and information from this programme into the national inventory.

Concerning road transport, the estimation procedure will continue to evolve in parallel with new developments arising in the COPERT methodology (forthcoming incorporation of the COPERT IV version) and with the revised composition of the country's fleet of vehicles. Regarding vehicles, and in collaboration with the Directorate-General for Roads at the Ministry of Public Works and the Directorate-General for Road Traffic at the Ministry of the Interior, it is proposed to advance the estimation of the effective fleet of vehicles travelling on main roads (interurban and rural traffic). In the longer term, it is also planned to collect information directly from traffic indicators in urban centres.

Lastly, for sea traffic, the implementation of a new collaboration mechanism, currently in an early phase, with the Directorate-General for the Merchant Navy, the State Ports body and with the Association of Spanish Shipping Lines ANAVE, is being promoted in order to access and process information corresponding to activity variables in national sea traffic, and even corresponding to sea routes followed by this traffic.

a.5) Combustion in other sectors (1A4)

For future editions of the inventory a review of the methodology will be carried out with particular regard for mobile agricultural and forestry machinery to integrate information about energy requirements standards and other relevant parameters for the emissions estimation algorithms and to take into account the progressive renewal and consequent introduction of technologies intended for the abatement of emissions in this kind of machinery, according to applied legislation. This work line, started in the current inventory edition in collaboration with the Directorate General for Agricultural and Breeding Resources at the Ministry of the Environment and Rural and Marine Affairs, is currently under development.

a.6) Other combustion (1A5)

This category explores the types of information collected about combustion activities not yet identified in the inventory, such as military activities other than general institutional services, and particularly inquire about their coverage regarding the national fuel balance.

a.7) Fugitive emissions (1B)

It is intended to still investigate the relationship of new gas supply companies as they join the gas market by requesting the relevant information regarding the objective of obtaining a more specific breakdown regarding certain market segments.

It is expected to complete the operators' information in the oil and gas field by incorporating the estimate of the stated activities into the inventory, it can be anticipated that the amount will be smaller.

b) Industrial processes

b.1) Mineral products (2A)

As for cement production, through contacts with the Spanish Group of Cement Manufacturers, OFICEMEN, it is expected in future to obtain specific factors per plant that could lead to greater precision in the generic CO₂ factor for decarbonation currently used for the whole sector.

Regarding the use of limestone and dolomite, it is proposed to further investigate the coefficients of carbonate-rich raw materials to be able to assess the corresponding global emission factors with greater precision, in the understanding that this yield factor is the parameter that can show a greater variability. In the particular case of the manufacture of bricks and tiles it is proposed the use (if available) of provincial factors containing carbonates in clays used for manufacturing these products.

b.2) Chemical industry (2B)

This sector's priority is focused on completing the investigation concerning the nitric acid manufacturing industry, using an individualized questionnaire sent to plants with the objective of distinguishing operating methods according to technologies, in order to obtain a more tuned balance (higher tier methodological approach) for this activity's N₂O emissions. The same approach is planned to be included in the production processes of calcium and silicon carbides.

b.3) Metal production (2C)

In the case of iron and steel, it is planned to perform a review, along with UNESID (Union of Iron and Steel Companies), about the carbon balance of other incoming and outgoing materials in the production of steel in electrical furnaces. This balance until now was supposed to be in carbon balance, but in light of newly available information it is necessary to review this assumption. In addition, priority will be given to the improvement of the information related to the ferroalloys production processes.

b.4) Consumption of halocarbons and SF₆ (2F)

Regarding the consumption of HFC, the review of activity variables and parameters involved in the emission estimation algorithm for the chilling and air-conditioning sub-sector are considered priorities for both stationary and portable equipment. Concerning the consumption of SF₆ in electrical equipment, it is planned to obtain specific information about the management systems for decommissioning equipment, including information about the efficiency of gathering SF₆ and its eventual subsequent treatments. In this sense, work is being done with SERCOBE (Spanish Association of Equipment Manufacturers), the electricity production, transport and distribution companies, and with the main industrial sectors of high voltage electricity consumption.

c) Use of solvents and other products

In the "Use of solvents and other products" sector, a number of tasks are planned with the main business associations to undertake the revision of the basic activity variables as well as the characterization of the processes and techniques applied for the use of solvents and their VOC content.

d) Agriculture

A deep review is being concluded regarding the methodology and the procedures for obtaining information about the basic parameters of farming and breeding activities for the emissions inventory through Breeding (GT INV-GAN) and Agricultural (GT INV-AG) Work Groups at the Ministry of the Environment and Rural and Marine Affairs and with the collaboration of academic experts, consultants and business associations.

Furthermore, some researches are currently being carried out in the field to determine the distribution of manure management systems in the Spanish case on a sounder statistical basis.

e) Land use, Land use change and Forestry

The next LULUCF projects (see chapter 7), regarding the improvement of the inventory's information in this sector, will have as a main priority the implementation of the methodology for estimating emissions and sinks of 5B and 5F categories, and continuing the estimation of the surfaces (surface changes) by categories of land use, on the basis of CORINE-LANCOVER 2006 new information and from SIOSE system, as already mentioned in chapter 7.

f) Waste

A general priority for the improvement of the Waste sector is to continue with the procedures already in place for data verification (time series) from waste production and its distribution according to treatment systems and technologies. All this will be carried out in collaboration with the General Sub-Directorate of Production and Sustainable Production at the Ministry of the Environment and Rural and Marine Affairs. Concrete actions in specific sub-sectors allow redesigning of those related with landfill waste and waste water treatment.

f.1) Waste Disposal in Landfills

The intention is to continue developing the work already carried out in previous editions of the inventory with respect to direct and individual data collection for landfills with biogas recovery through questionnaires. This new base information will improve the contrasts in the individual parameters of landfill management, and the revision of the estimations for waste deposited in controlled landfills.

Biomethanization in Spain is a recent waste treatment practice and its use is very limited, it is carried out as a deposit alternative in big controlled landfills. It is planned to draw up individualized questionnaires for these plants to add their emissions to the inventory.

f.2) Waste water treatment

Since the uncertainty presently associated with the activity variable, the volume discharged and the organic load have been acknowledged, the collaboration of the Directorate-General for Water at the Ministry of the Environment and Rural and Marine Affairs becomes a priority to have access to and be able to process the pertinent information from the database of waste water treatment plants. To achieve this collaboration, a proposal has already been defined by the Unit in charge of preparing the emissions inventory (Sub Directorate-General for Air Quality and Industrial Environment).

APPENDIX 1: KEY CATEGORIES

In order to optimize resource allocation to improve the accuracy and precision of emission inventory estimates, it is necessary to prioritize quality monitoring and assurance procedures for activities that, from the point of view of their contribution to the uncertainty of inventory estimates, are revealed as key or priority categories.

Key sources have been identified, first of all, for the whole set of categories in the inventory, excluding those categories within the sector “Land Use, Land Use Change, and Forestry” (LULUCF). These key categories have then been additionally considered, but separately from LULUCF activities¹.

In this sense, the IPCC Good Practice Guidance 2000 defines an emission source as a key source if its estimate has a significant influence on the total inventory estimate either in terms of the absolute value of its emissions or the trend.

From an operative point of view, the aforementioned Guidance establishes two approaches or tiers for identifying key sources. The Tier 1 approach is aimed at determining the influence, whether in terms of the absolute value or trend of the series, that an emission source can have on the uncertainty of the total inventory estimate but without needing to resort to formal uncertainty analysis procedures. The Tier 2 approach is similar but takes into account prior information obtained from formal uncertainty analysis. In the current edition of the inventory, key categories have been identified with the Tier 1 approach.

When this first approach is used, a distinction must be made between the identification of a source as a key source in terms of the absolute value or the trend or both. To identify the source in terms of the absolute value, a threshold is first set (usually 95%) for the accumulated distribution function of emissions according to inventory activities, with these having been placed in order of decreasing contribution (in terms of CO₂-eq emissions). It can be considered that all activities included in the accumulated distribution function within that threshold guarantee a percentage of around 90% of the overall uncertainty of the inventory².

¹ The LULUCF 2003 IPCC Good Practice Guidance provided a distinction between “key categories” and “key sources”. The first definition is more comprehensive, as it includes both “sources” and “sinks”, whereas the second definition relates to emission sources only. This distinction has been preserved for the IPCC 2006 Guide, but was not included in previous IPCC Guides.

² Studies developed and published in “Methodological Choice in Inventory Preparation. Suggestions for Good Practice Guidance” (Flugsrud,1999), comparing the accumulated fractions of level/trend assessments with the fractions of uncertainty in inventories from different countries, showed that a reasonable approximation to 90% of the overall uncertainty of the inventory was covered by selecting a threshold of 95% in assessments.

To identify the source in terms of the trend, the tier 1 approach also sets a 95% threshold but in this case established according to the contribution of activities to the trend's metrics³. The specifics provided by the LULUCF 2003 IPCC Good Practice Guidance have been applied for identifying the categories in sector LULUCF, related to the metrics on absolute trend values (equations 5.4.1 through 5.4.3).

Besides the consideration, where applicable, of a category as key in terms of absolute value and/or trend, in quantitative terms, qualitative judgments with regard to those categories are also of interest in some cases and, in addition to level and/or trend criteria, deserve attention for other possible reasons as candidates likely to have a significant influence on overall inventory estimates. In this case we find the following categories, among others:

- the use of HFC in air conditioning and refrigeration activities where little information is available on the activity variable, and where it may be presumed that an expansion may take place in the future, as HFCs replace other types of gases, such as CFCs and HCFCs, and as these latter types of gases reach the end of the periods for which their use is allowed;
- N₂O emissions from traffic, where a great variability has been distinctly observed for emission factors which are implicit in comparisons between different countries, as the volume of these emissions is dependent, and very sensitive, on estimates of the breakdown of vehicles into different categories and technologies (ages);
- the allocation of fuel consumption to military activities and the classification of such consumptions within the fuel balance of the national inventory;
- the determination of the contribution of the national segment to air and sea traffic as compared to total traffic (domestic and international). In the Spanish inventory the proportion of fuel attributed to domestic air traffic is remarkably higher to the proportion estimated through traffic models, such as the PAGODA Model, developed by EUROCONTROL.

³ The respective metrics for the absolute value and the trend correspond to formulas (1) and (2) below:

$$(1) \quad L_{x,t} = \frac{E_{x,t}}{E_t}$$

$$(2) \quad T_{x,t} = L_{x,t} * \left| \frac{(E_{x,t} - E_{x,0})}{E_{x,t}} - \frac{(E_t - E_0)}{E_t} \right|$$

where:

$L_{x,t}$ is the level assessment for category x in year t

$T_{x,t}$ is the trend assessment for category x in year t

$E_{x,t}$ and $E_{x,0}$ are emissions estimations for category x in year t and year 0, respectively

0 is the "reference year 90/95" (i.e. 1995 for fluorinated compounds and 1990 for all other pollutants in the current inventory edition). The term "base year" is reserved for the reference year 90/95 of the 2006 edition, series 1990-2004, from the inventory edition verified in 2007 by the appointed team by the SCMCC. In this last edition an Assigned Amount was established, and it will be taken as reference to assess the compliance of Spain of its commitment with the Kyoto Protocol during the 2008-2012 period.

These two activities will be the subject of special research in future editions of the inventory.

Going back to the quantitative identification of key sources, it can be said that the criteria adopted in this edition respond to the principles set out in the IPCC 2000 Good Practice Guidance, leaving in any case a wide margin for incorporating national considerations. Among the specifically national elements, the following are considered relevant for the identification of key sources with the objective of allowing a more detailed analysis of significant inventory activities:

- CO₂ emissions due to stationary combustion within the Energy Sector (excluding those from transport) have been broken down by cross-relating the type of fuel with the following major categories: solids, liquids, gaseous, and others, with the following sub-categories: thermal power plants (1A1a), oil refineries (1A1b), transformation of solid fuels (1A1c), and other sources (1A4). In a similar manner, emissions of CH₄ and N₂O have been broken out for each fuel type and source of emission activity. The following sub-categories have been defined: energy generation and fuel transformation (1A1), industrial sector (1A2), and other sources (1A4).
- In the road traffic category, CO₂ emissions have been disaggregated according to the type of fuel, with emissions associated with diesel vehicles being analyzed separately from emissions corresponding to petrol vehicles
- With regard to fugitive emissions in the Energy Sector, emissions have been differentiated for each energy sub-category, solid fuels (1B1), oil-derived products and gas (1B2), by type of pollutant, CO₂ and CH₄
- In order to ensure an exhaustive analysis of the inventory, the index of categories given in Table 7.1 of the aforementioned IPCC 2000 Good Practice Guidance has been expanded by adapting it to the list of national emission sources of pollutants with an atmospheric warming potential. It is important to highlight the presence of activities identified as key sources due to their absolute value and/or trend in the set of new categories identified for this purpose, including:
 - Limestone and dolomite production (2A3) due to CO₂
 - Other industrial processes due to CO₂, excluding the production of cement (2A1), lime (2A2), limestone and dolomite (2A3), and iron and steel (2C1)
 - Halocarbon and SF₆ consumption (2F) due to HFC and PFC gases
 - Use of solvents and other products (3) due to CO₂
 - Agricultural soil emissions associated with animal production (4D2) due to N₂O

Once the analysis approach has been presented and the level of disaggregation has been discussed, the results obtained from the identification of key emission sources are then shown for the absolute value of the initial year (1990) and the final year (2007), Tables A1.1 and A1.2, and of the trend in 2006, Table A1.3, for the categories in the inventory excluding those from the LULUCF sector.

Activities identified as key categories (sources or sinks) in the LULUCF sector, due to their contribution to levels or trends have included the following:

- Carbon fixation (CO₂ uptake) in forest systems (category 5A)
- Aggregated emissions for CH₄ y N₂O due to fires in forest systems (category 5A)

A summary of the results of identifying key categories for the whole of the inventoried period is shown in Table A1.4.a for all categories excluding those from the LULUCF sector, and on Table A1.4.b for activities in the LULUCF sector.

Finally, it is of interest to point out that the contents of the sectorial chapters (chapter 3 "Energy"; chapter 4 "Industrial Processes"; chapter 5 "Use of solvents and other products"; chapter 6 "Agriculture"; chapter 7 "Land use, land use change, and forestry"; and chapter 8 "Waste") of the inventory include analyses of all the key sources identified here.

Table A1.1. – Contribution by activities to the “Level” – Year 1990

IPCC SOURCE CATEGORIES		Fuel	Gas	Gg CO ₂ -eq	Contribution (1)	Cumulative (2)
1A1a	Public Electricity and Heat Production	Solid	CO ₂	57.787,48	20,06	20,06
1A3b	Road transportation	Gasoline	CO ₂	25.928,33	9,00	29,05
1A2	Stationary combustion - Industry sector	Liquid	CO ₂	24.519,80	8,51	37,56
1A3b	Road transportation	Diesel	CO ₂	24.435,56	8,48	46,04
1A4	Stationary combustion - Other sectors	Liquid	CO ₂	21.680,13	7,52	53,57
1A2	Stationary combustion - Industry sector	Solid	CO ₂	13.237,79	4,59	58,16
2A1	Cement production		CO ₂	12.534,33	4,35	62,51
4A	Enteric Fermentation in Domestic Livestock		CH ₄	11.779,63	4,09	66,60
1A1b	Petroleum refining	Liquid	CO ₂	10.860,82	3,77	70,37
4D1	Agricultural Soils - Direct Emissions		N ₂ O	10.105,85	3,51	73,88
1A2	Stationary combustion - Industry sector	Gaseous	CO ₂	8.438,89	2,93	76,81
4D3	Agricultural Soils - Indirect Emissions		N ₂ O	7.515,36	2,61	79,42
4B	Manure Management		CH ₄	6.230,60	2,16	81,58
1A1a	Public Electricity and Heat Production	Liquid	CO ₂	6.006,63	2,08	83,66
6A	Waste Disposal on Land		CH ₄	4.742,18	1,65	85,31
1A3a	Civil Aviation		CO ₂	4.129,65	1,43	86,74
2B2	Nitric acid production		N ₂ O	2.884,16	1,00	87,74
2-2A1-2A2-2A3-2C1	Other industrial processes		CO ₂	2.634,71	0,91	88,66
2C1	Iron and steel production		CO ₂	2.490,64	0,86	89,52
4B	Manure Management		N ₂ O	2.464,77	0,86	90,38
2E1	HFC-23 emissions in HCFC-22 manufacturing		HFC	2.403,18	0,83	91,21
1A4	Stationary combustion - Other sectors	Solid	CO ₂	2.282,29	0,79	92,00
1A1c	Stationary combustion - Manufacture of Solid fuels and others	Solid	CO ₂	1.847,39	0,64	92,64
1B1	Fugitive emissions - Solid fuels		CH ₄	1.817,54	0,63	93,28
1B2	Fugitive emissions - Oil and natural gas		CO ₂	1.760,36	0,61	93,89
1A3d	National navigation		CO ₂	1.499,79	0,52	94,41
4D2	Agricultural Soils - Animal Production		N ₂ O	1.366,32	0,47	94,88
1A4	Stationary combustion - Other sectors	Gaseous	CO ₂	1.318,59	0,46	95,34
SUB TOTAL				274,702.80		
TOTAL EMISSIONS (without LULUCF)				288,134.66		
PERCENTAGE OF THE TOTAL				95.34		

(1). Simple percentage of the activity category the overall level of the inventory

(2). Accumulated percentage of the activity categories divided by the overall level of the inventory.

Table A1.2. – Contribution by activities to the “Level” – Year 2007

IPCC SOURCE CATEGORIES		Fuel	Gas	Gg CO ₂ -eq	Contribution (1)	Cumulative (2)
1A3b	Road transportation	Diesel	CO ₂	76.542,10	17,30	17,30
1A1a	Public Electricity and Heat Production	Solid	CO ₂	71.081,95	16,07	33,37
1A2	Stationary combustion - Industry sector	Gaseous	CO ₂	35.621,07	8,05	41,43
1A1a	Public Electricity and Heat Production	Gaseous	CO ₂	25.879,82	5,85	47,28
1A2	Stationary combustion - Industry sector	Liquid	CO ₂	25.749,54	5,82	53,10
1A4	Stationary combustion - Other sectors	Liquid	CO ₂	24.910,44	5,63	58,73
1A3b	Road transportation	Gasoline	CO ₂	21.185,15	4,79	63,52
2A1	Cement production		CO ₂	17.304,59	3,91	67,43
4A	Enteric Fermentation in Domestic Livestock		CH ₄	13.559,54	3,07	70,50
1A1b	Petroleum refining	Liquid	CO ₂	11.371,67	2,57	73,07
1A4	Stationary combustion - Other sectors	Gaseous	CO ₂	11.282,71	2,55	75,62
4D1	Agricultural Soils - Direct Emissions		N ₂ O	9.974,70	2,26	77,88
6A	Waste Disposal on Land		CH ₄	9.747,19	2,20	80,08
1A1a	Public Electricity and Heat Production	Liquid	CO ₂	9.706,12	2,19	82,27
4B	Manure management		CH ₄	9.457,63	2,14	84,41
4D3	Agricultural Soils - Indirect Emissions		N ₂ O	7.910,80	1,79	86,20
1A3a	Civil Aviation		CO ₂	7.582,05	1,71	87,92
1A2	Stationary combustion - Industry sector	Solid	CO ₂	5.694,09	1,29	89,20
2F	Consumption of halocarbons and sulphur hexafluoride		HFC&PFC	5.255,16	1,19	90,39
2-2A1-2A2-2A3-2C1	Other industrial processes		CO ₂	3.460,74	0,78	91,17
1A3d	National navigation		CO ₂	3.260,45	0,74	91,91
4B	Manure management		N ₂ O	2.981,17	0,67	92,58
1A3b	Road transportation		N ₂ O	2.851,37	0,64	93,23
1B2	Fugitive emissions - Oil and natural gas		CO ₂	2.482,49	0,56	93,79
2C1	Iron and steel production		CO ₂	2.362,93	0,53	94,32
6B	Waste-water Handling		CH ₄	2.320,58	0,52	94,85
2A3	Limestone and dolomite use		CO ₂	2.128,67	0,48	95,33

SUB TOTAL 421.664,72

TOTAL EMISSIONS (without LULUCF) 442.321,56

PERCENTAGE OF THE TOTAL 95,33

(1). Simple percentage of the activity category divided by the overall level of the inventory

(2). Accumulated percentage of the activity categories divided by the overall level of the inventory.

Table A1.3. – Contribution by activities to the “Trend” – Year 2007

IPCC SOURCE CATEGORIES		Fuel	Gas	Gg CO ₂ -eq Reference Year 90/95	Gg CO ₂ - eq2007	Trend (1)	Contribution (2)	Cumulative (3)
1A3b	Road transportation	Diesel	CO ₂	24.435,56	76.542,10	0,06	17,30	17,30
1A1a	Public Electricity and Heat Production	Gaseous	CO ₂	427,14	25.879,82	0,04	11,10	28,40
1A2	Stationary combustion - Industry sector	Gaseous	CO ₂	8.438,89	35.621,07	0,03	10,02	38,41
1A3b	Road transportation	Gasoline	CO ₂	25.928,33	21.185,15	0,03	8,06	46,47
1A1a	Public Electricity and Heat Production	Solid	CO ₂	57.787,48	71.081,95	0,03	7,46	53,93
1A2	Stationary combustion - Industry sector	Solid	CO ₂	13.237,79	5.694,09	0,02	6,37	60,29
1A2	Stationary combustion - Industry sector	Liquid	CO ₂	24.519,80	25.749,54	0,02	5,10	65,40
1A4	Stationary combustion - Other sectors	Gaseous	CO ₂	1.318,59	11.282,71	0,01	4,08	69,48
1A4	Stationary combustion - Other sectors	Liquid	CO ₂	21.680,13	24.910,44	0,01	3,57	73,05
2E1	HFC-23 emissions in HCFC-22 manufacturing		HFC	4.637,88	422,84	0,01	2,92	75,97
4D1	Agricultural Soils - Direct Emissions		N ₂ O	10.105,85	9.974,70	0,01	2,38	78,35
2F	Consumption of halocarbons and sulphur hexafluoride		HFC&PFC	7,91	5.255,16	0,01	2,31	80,66
1A1b	Petroleum refining	Liquid	CO ₂	10.860,82	11.371,67	0,01	2,28	82,94
4A	Enteric Fermentation in Domestic Livestock		CH ₄	11.779,63	13.559,54	0,01	1,93	84,86
4D3	Agricultural Soils - Indirect Emissions		N ₂ O	7.515,36	7.910,80	0,01	1,56	86,42
2B2	Nitric acid production		N ₂ O	2.884,16	1.359,14	0,00	1,33	87,76
1A4	Stationary combustion - Other sectors	Solid	CO ₂	2.282,29	553,49	0,00	1,29	89,04
6A	Waste Disposal on Land		CH ₄	4.742,18	9.747,19	0,00	1,11	90,15
1B1	Fugitive emissions - Solid fuels		CH ₄	1.817,54	884,27	0,00	0,83	90,98
1A1c	Stationary combustion - Manufacture of Solid fuels and others	Solid	CO ₂	1.847,39	945,11	0,00	0,82	91,80
1A3b	Road transportation		N ₂ O	679,46	2.851,37	0,00	0,80	92,60
2A1	Cement production		CO ₂	12.534,33	17.304,59	0,00	0,79	93,39
2C1	Iron and steel production		CO ₂	2.490,64	2.362,93	0,00	0,63	94,02
1A1b	Petroleum refining	Gaseous	CO ₂	45,08	1.478,07	0,00	0,62	94,64
1A3a	Civil Aviation		CO ₂	4.129,65	7.582,05	0,00	0,57	95,21
SUB TOTAL				258.367,43	391.509,80	0,327		
TOTAL EMISSIONS (without LULUCF)				289.920,73	442.321,56	0,343		
PERCENTAGE OF THE TOTAL				89,12	88,51	95,33		

(1). Please refer to formula 2 in the footnote on page 2 above.

(2). Simple percentage of the activity category divided by the overall level of the inventory

(3). Accumulated percentage of the activity categories divided by the overall level of the inventory.

Table A1.4.a – Summary of the contribution of activities to the inventory

IPCC SOURCE CATEGORIES		Fuel	Gas	Key Source Category	Criterion (1)		Comments	
ENERGY								
1A1a	Public electricity and heat production	Gaseous	CO ₂	YES	YES	YES	Level in 1997-2007	Trend in 1993-1995,1997-2007
1A1a	Public electricity and heat production	Solid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1994,1996-2007
1A1a	Public electricity and heat production	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1992,1994-2007
1A1a	Public electricity and heat production	Other	CO ₂					
1A1b	Petroleum refining	Gaseous	CO ₂	YES		YES		Trend in 1997-2000,2002-2007
1A1b	Petroleum refining	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1992,1994-1996,1998-2007
1A1c	Manufacture of solid fuels and other energy industries	Gaseous	CO ₂	YES		YES		Trend in 1991,1996
1A1c	Manufacture of solid fuels and other energy industries	Solid	CO ₂	YES	YES	YES	Level in 1990-1994	Trend in 1992-2007
1A1c	Manufacture of solid fuels and other energy industries	Liquid	CO ₂	YES		YES		Trend in 1994-2000
1A1	Stationary combustion - Energy sector		CH ₄					
1A1	Stationary combustion - Energy sector		N ₂ O					
1A2	Stationary combustion - Energy sector	Gaseous	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990,1992-2007
1A2	Stationary combustion - Energy sector	Solid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A2	Stationary combustion - Energy sector	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A2	Stationary combustion - Energy sector	Other	CO ₂					
1A2	Stationary combustion - Energy sector		CH ₄					
1A2	Stationary combustion - Energy sector		N ₂ O					
1A3a	Civil aviation		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1997,2007
1A3a	Civil aviation		CH ₄					
1A3a	Civil aviation		N ₂ O					
1A3b	Road transportation	Gasoline	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A3b	Road transportation	Gas/Diesel Oil	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
1A3b	Road transportation		CH ₄					
1A3b	Road transportation		N ₂ O	YES	YES	YES	Level in 1997-2007	Trend in 1993-2007
1A3d	National navigation		CO ₂	YES	YES	YES	Level in 1990-1996,1999-2007	Trend in 1993-1994,1997-1998
1A3d	National navigation		CH ₄					
1A3d	National navigation		N ₂ O					
1A3c+1A3e	Other transport		CO ₂					
1A3c+1A3e	Other transport		CH ₄					
1A3c+1A3e	Other transport		N ₂ O					
1A4	Stationary combustion - Other sectors	Gaseous	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1991-2007
1A4	Stationary combustion - Other sectors	Solid	CO ₂	YES	YES	YES	Level in 1990-1996	Trend in 1991-1992,1994-2007
1A4	Stationary combustion - Other sectors	Liquid	CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1994,1996-2007
1A4	Stationary combustion - Other sectors		CH ₄	YES		YES		Trend in 1995,1999
1A4	Stationary combustion - Other sectors		N ₂ O					
1B1	Fugitive emissions - Solid fuels		CO ₂					
1B1	Fugitive emissions - Solid fuels		CH ₄	YES	YES	YES	Level in 1990-1998	Trend in 1991-2007
1B2	Fugitive emissions - Oil and natural gas		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1991, 1993-1994
1B2	Fugitive emissions - Oil and natural gas		CH ₄	YES		YES		Trend in 1991-1992

(1). Identification of the Criteria (level, trend) for which the emission source is considered a key source.

Table 1.4.a (Continued) – Summary of the contribution of activities to the inventory (exc. UTCUTS)

IPCC SOURCE CATEGORIES		Fuel	Gas	Key Source Category	Criterion (1) Level Trend		Comments	
INDUSTRIAL PROCESSES								
2A1	Cement production		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
2A2	Lime production		CO ₂					
2A3	Limestone and dolomite use		CO ₂	YES	YES	YES	Level in 1996-2007	Trend in 1991-1993
2C1	Iron and steel production		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1991-1992, 1994-2007
2-2A1-2A2-2A3-2C1	Other industrial processes		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990, 1992-1994
2	Industrial processes		CH ₄					
2B2	Nitric acid production		N ₂ O	YES	YES	YES	Level in 1990-2003	Trend in 1990-2007
2C3	Aluminium production		PFC	YES		YES		Trend in 1990, 1999-2003, 2005-2006
2E1	Production of HCFC-22 (HFC-23 emission)		HFC	YES	YES	YES	Level in 1990-2001	Trend in 1990-1995, 1997-1998, 2001-2007
2E2+2E3	Production of halocarbons and SF ₆ (except HCFC-22)		HFC&PFC					
2F	Consumption of halocarbons and sf ₆		HFC&PFC	YES	YES	YES	Level in 2000-2007	Trend in 1997-2007
2F7	Electrical equipment		SF ₆	YES		YES		Trend in 1990
USE OF SOLVENTS AND OTHER PRODUCTS								
3	Solvent and other product use		CO ₂	YES		YES		Trend in 1994-1995
3	Solvent and other product use		N ₂ O					
AGRICULTURE								
4A	Enteric Fermentation in Domestic Livestock		CH ₄	YES	YES	YES	Level in 1990-2007	Trend in 1990, 1992, 1994-2007
4B	Manure management		CH ₄	YES	YES	YES	Level in 1990-2007	Trend in 1990-1998
4B	Manure management		N ₂ O	YES	YES		Level in 1990-2007	
4C	Rice cultivation		CH ₄					
4D1	Agricultural soils - direct emissions		N ₂ O	YES	YES	YES	Level in 1990-2007	Trend in 1990-1995, 1997-2007
4D2	Agricultural soils - animal production		N ₂ O	YES	YES	YES	Level in 1990-1992, 1995-1999	Trend in 1992
4D3	Agricultural soils - indirect emissions		N ₂ O	YES	YES	YES	Level in 1990-2007	Trend in 1990-1995, 1997-2007
4D4	Agricultural soils – Others		N ₂ O					
4F	Field burning of agricultural wastes		CH ₄					
4F	Field burning of agricultural wastes		N ₂ O					
WASTE								
6A	Waste Disposal on Land		CO ₂					
6A	Waste Disposal on Land		CH ₄	YES	YES	YES	Level in 1990-2007	Trend in 1990-2007
6B	Waste-water Handling		CH ₄	YES	YES		Level in 1993-1999, 2002-2007	
6B	Waste-water Handling		N ₂ O					
6C	Waste incineration		CO ₂					
6C	Waste incineration		CH ₄					
6C	Waste incineration		N ₂ O					

(1). Identification of the Criteria (level, trend) for which the emission source is considered a key source.

Table A1.4.b – Summary of the contribution of LULUCF activities

IPCC CATEGORIES		Fuel	Gas	Key Category	Criterion (1)		Comments	
					Level	Trend		
LULUCF								
5A	Fixation of carbon in forestry systems		CO ₂	YES	YES	YES	Level in 1990-2007	Trend in 1990-1992, 1994-2007
5A	Fires in forestry systems		CH ₄ & N ₂ O	YES		YES		Trend in 1991, 1994

(1). Identification of the criterion (level, trend) by which the category is considered a key source.

APPENDIX 2: DETAILED EXAMINATION OF THE METHODOLOGY AND DATA TO ESTIMATE CO₂ EMISSIONS FROM THE BURNING OF FOSSIL FUELS

To facilitate the presentation given in chapter 3 “Energy” of this report, detailed information on activity variables, algorithms and factors for estimating CO₂ emissions from the burning of fossil fuels were included in this chapter and that is why the presentation of this material is not repeated in this appendix. Please refer then to chapter 3 for the corresponding information.

APPENDIX 3.- OTHER DETAILED METHODOLOGICAL DESCRIPTIONS OF CERTAIN SECTORS

The sections in this appendix give some detailed methodological descriptions of emission estimations for certain sectors or activity categories, providing additional information on the corresponding sectorial chapters.

A3.1.- Fugitive emissions. Solid fuel transformation (CO₂)

In past editions, contacts made with the integrated iron and steel sector during the inventory validation and verification phases proved that application of the emission factors usually cited in the literature does not guarantee the balance of carbon mass between the inputs and outputs of coke ovens. Taking this principle into consideration, the methodology for this category has been arrived at by calculating the differential carbon that would remain after subtracting the mass of carbon in the inventoried output products from the mass of carbon in inputs and then increasing the resulting amount by the ratio 44/12.

This approach has been developed from information provided by the two integrated iron and steel plants in existence between 2000-2007. For the period between 1990 and 2002, a single factor has been applied, per tonne of coke produced, obtained by averaging out the overall information available for the years 2000-2002. For 2003 and 2004, the high variability in implicit factors that, in some cases, fell outside conventional ranges caused the coke plants not located at steel and iron works, on the one hand, to use the average value for the period 2000-2002 in subsequent years; and on the other hand, in the coke ovens located at iron and steel plants have used the specific factors per plant derived in 2003, whereas in 2005-2007, and starting from the said implicit factors at each of the centres, an assignment has been made maintaining the restriction in the total carbon balance at the centres.

Table A3.1.1 shows the general template prepared to collect information from integrated iron and steel plants.

Table A3.1.1.- Opening and extinction of coke ovens. Carbon Balance

		Products Flow		Carbon Content		Carbon Balance	
		Value	Unit	Value	Unit	Value	Unit
INPUT	Coking Coal		kt		% C		t C
	Anthracite and Sub-bituminous Coal		kt		% C		t C
	Coal Paste		kt		% C		t C
	Total Input						t C
OUTPUT	Coke		kt		% C		t C
	Coke Oven Gas		TJ (PCI)		t C/TJ(PCI)		t C
	Coke Powder		kt		% C		t C
	Benzol		kt		% C		t C
	Tar		kt		% C		t C
	Brea		kt		% C		t C
	Particulate Diffuse Emissions into		kt		% C		t C
	Particulate Diffuse Emissions into Air		kt		% C		t C
	Total Outputs						t C
Difference in carbon mass							t C
CO₂ emission							kt CO₂
Implicit CO₂ emission factor							kg/t coke

A3.2.- Agriculture

a) Categories of animals

To prepare the Spanish inventory, animals were divided into categories (sub-divisions of animals). These categories are based on those given in "Food and Agriculture Statistics Yearbook" published by the MAPA (please refer to Table A3.2.1).

Even so, some categories were not suitable for emission calculations and it was decided that these should be divided into sub-categories. This is the case of the lamb category, which has been subdivided into suckling lambs, spring lambs, replacement rams and replacement ewes.

A list of the categories used in the Inventory can be seen in Table A3.2.2.

Table A3.2.1.– Categories from the Food and Agriculture Statistics Yearbook

CATTLE

Provinces and Autonomous Communities	Total Bovine Livestock	Animals less than 12 months			Animals from 12 to 24 months			Animals more than 24 months									
		For slaughter	Others		Males	Females		Males	Females								
			Males	Females		For slaughter	For breeding		Not calved				Calved				
									For slaughter	Dairy		Non dairv	Dairy		Non Dairv		
										Friskians	Others		Friskians	Others			

SHEEP

Provinces and Autonomous Communities	Total Ovine Livestock	Lambs	Studs	Female for breeding				
				Never lambed		Lambled		
				Not covered	Covered once		Milked	Not milked
					Milking	Non milking		

GOATS

Provinces and Autonomous Communities	Total Goats	Kid	Studs	Female for breeding			
				Never lambed		Lambled	
				Not covered	Covered once	Milked	Not milked

SWINE

Provinces and Regional Communities	Total	Piglet	Swine from 20 to 49 kg l.w.	Swine for slaughter			Boar	Breeder more than 50 kg l.w.			
				From 50 to 79 kg l.w.	From 80 to 109 kg l.w.	From 110 kg l.w.		Sows			
								Never farrowed		Farrowed	
								Not covered	Covered	Covered	Not covered

HORSES AND ASSES

Provinces and Autonomous Communities	Total	Animals less than 12 months	Animals from 12 to 36 months	Animals more than 36 months		
				Studs	Breeding females	Non breeding females

MULES

Provinces and Autonomous Communities	Total	Animals less than 12 months	Animals from 12 to 36 months	Animals more than 36 months
--------------------------------------	-------	-----------------------------	------------------------------	-----------------------------

Table A3.2.2.– Categories of animals used in the inventory

Dairy Cattle	Frisians						
	Other						
Other Cattle	Old < 12 months	Slaughter					
		Other	Males	Slaughter			
			Replacement				
		Females	Slaughter				
	Replacement						
	12 months <Old< 24 months	Males			Slaughter		
					Replacement		
		Females			Slaughter		
					Replacement		
	Old > 24 months	Studs					
		Females	Not calved	Slaughter			
				Dairy	Frisians		
Other							
Breeding cow							
Calved			Breeding cow				
Sheep	Replacement lambs	Males					
		Females					
	Suckling lamb						
	Spring lamb						
	Breeding	Males					
		Females	Not lambed				
			Lambled	Not dairy			
Dairy							
Swine	Sucking Pigs						
	Swine (20 to 49 kg).						
	Young swine	From 50 to 79 kg					
		From 80 to 109 kg					
		More than 109 kg					
	Breeding sows	Not farrowed	Not covered				
			Covered				
		Farrowed	Not covered				
Covered							
Breeding Boars							
Goats	Animals less than 1 year						
	Animals more than 1 year						
Horses	Animals less than 1 year						
	Animals more than 1 year						
Mules and Asses	Animals less than 1 year						
	Animals more than 1 year						
Poultry	Broilers						
	Hens						
	Other Poultry	More than 1 year					
		Less than 1 year					

b) Softened functions for MCF and EF in manure management

The IPCC methodology provides some step-functions for MCFs and EFs of CH₄ emissions in manure management. For the Spanish inventory, emissions are broken down according to provinces, which is more disaggregated than is required by the IPCC (country). The use of these functions creates large inter-annual variations between provinces with mean temperatures of around 15°C. It was decided, therefore, to soften the functions and make them continuous to preserve the consistency of the series over time. This modification was sent to the UNFCCC and was approved by this organization.

MCF factors, which initially only depended on climatic regions, have been adjusted by a function that depends on temperature. The values of this function, given in degrees of temperature, are as follows:

Table A3.2.3.– MCFJK according to management system and temperature

Mean Annual Temperature (°C)	Methane conversion factor for manure management systems of cattle and swine (MCFs)				
	Liquid/Slurry	Solid storage	Pasture	Daily spread	Other
	MCF	MCF	MCF	MCF	MCF
10	39.00	1.00	1.00	0.10	1.00
11	39.01	1.03	1.03	0.12	1.00
12	39.06	1.07	1.07	0.14	1.00
13	39.18	1.12	1.12	0.18	1.00
14	39.42	1.17	1.17	0.21	1.00
15	39.80	1.22	1.22	0.25	1.00
16	40.36	1.27	1.27	0.30	1.00
17	41.13	1.33	1.33	0.34	1.00
18	42.14	1.38	1.38	0.39	1.00
19	43.42	1.44	1.44	0.45	1.00
20	45.00	1.50	1.50	0.50	1.00
21	46.91	1.56	1.56	0.56	1.00
22	49.18	1.62	1.62	0.61	1.00
23	51.84	1.68	1.68	0.67	1.00
24	54.92	1.74	1.74	0.74	1.00
25	58.45	1.81	1.81	0.80	1.00
26	62.45	1.87	1.87	0.87	1.00
27	66.96	1.93	1.93	0.93	1.00
28	72.00	2.00	2.00	1.00	1.00

Source: own preparation from the revised methodology.

These values are obtained by taking the temperatures 10, 20 and 28 °C as mark of class for each climatic region. For each class mark, the default MCF value provided by the IPCC is taken (shown in table 3.1.II.1) and the above values are reached by softening the linear function thus obtained. The softened function proposed by the Inventory Work Team¹ is as follows:

$$Factor(t) = Factor(10) + b(10 - t)^m$$

¹ This variation in methodology was reported to the IPCC Technical Support Unit.

where:

Factor(t) = Emission factor at temperature t.

Factor(10) = Emission factor at temperature of 10°C (known).

b, m = Parameters that depend on the manure management system.

The following table shows the values of parameters “b” and “m” according to the type of treatment.

Table A3.2.4.- MCF values according to manure management system

	Cold	Temperate	Warm	m	b
Pasture	1	1.5	2	1.179	0.033
Daily spread	0.1	0.5	1	1.380	0.017
Solid storage	1	1.5	2	1.179	0.033
Dry lot	1	1.5	5	3.538	0.0001
Liquid/slurry	39	45	72	2.900	0.008
Anaerobic lagoon	0-100	0-100	0-100		
Pit storage below animal confinements (<1 month)	0	0	30	1.636	1
Pit storage below animal confinements (>1 month)	39	45	72	2.900	0.008
Anaerobic digester	0-100	0-100	0-100		
Burned for fuel	10	10	10	0	0

Source: own preparation from the revised methodology.

Similarly, default EF values are softened for Tier 1 animals, thereby obtaining the following result:

Table A3.2.5.- MCF values per Tier 1 animal

	Cold	Temperate	Warm	m	b
Sheep	0.19	0.28	0.37	1.179	0.006
Goats	0.12	0.18	0.23	1.031	0.006
Camels	1.6	2.4	3.2	1.179	0.053
Horses	1.4	2.1	2.8	1.179	0.046
Mules and Asses	0.76	1.14	1.51	1.157	0.026
Poultry	0.078	0.117	0.157	1.201	0.002

c) Base parameters for crops

A series of IPCC parameters are used in common by the methodologies to calculate the N content in biological fixation, the content in crop residue and emissions from burning. These parameters are:

- Residue/crop product ratio.
- Dry matter content.
- Carbon fraction.
- Nitrogen fraction.

Tables 4.17 (p. 4.85, 1996 IPCC Guidelines) and 4.16 (p. 4.58, IPCC Good Practice Guidance) show values for these parameters for some crops. Given the limited selection of crops included in these tables, a bibliographical search has been conducted of values for these parameters in order to complete the set of crops considered in the Spanish inventory.

Table A3.2.6 gives the values of these parameters together with their source. These sources (with their corresponding ID code) are:

- 1: IPCC Guidelines & IPCC Good Practice Guidance.
- 2: Martínez X. (2006). "Gestión y tratamiento de residuos agrícolas". RETEMA: Revista Técnica de Medio Ambiente, year 19, nº 111 (Mar-Apr, 2006), p. 62-75
- 3: Domínguez A., Roselló J. Personal communication
- 4: Crop parameters: Harvest. Harvest index. 2006.
<<http://c100.bsyse.wsu.edu/cropsyst/manual/parametres/crop/harvest.htm#Hlconsts> >
- 5: Krider, J.N. et al. Agricultural waste management field handbook. Washington D.C.: Natural Resources Conservation Service (NRCS), 1999.
- 6: Villalobos F.J., Mateos L., Orgaz F. y Fereres E. (2002). Fitotecnia. Bases y tecnologías de la producción agrícola.
- 7: Wheeler R.M. (2003). Carbon balance in bioregenerative life support systems: some effects of system closure, waste management, and crop harvest index. Advances in Space Research: the Official Journal of the Committee on Space Research (COSPAR), 2003, 31(1):169-75, included in reference 6 (Villalobos, F.J., et al.).
- 8: Agencia Andaluza de la Energía (1999). Potencial y aprovechamiento energético de la biomasa del olivar en Andalucía. Consejería de Innovación, Ciencia y Empresa Ed. 24 pág. En:
<http://www.agenciaandaluzadelaenergia.es/cocoon/aae/portal/com/bin/contenidos/publicaciones/aprovechamiento_energetico/1130059713839_potencial_y_aprovechamiento.pdf>
- 9: Senovilla, L. y Antolín, G. (2005). Revalorización energética de los residuos de la industria vitivinícola. Proyecto Final de Carrera. Cátedra de Energías Renovables. Universidad de Valladolid. Escuela Técnica Superior de Ingenieros Industriales. En:
<http://www.eis.uva.es/energias-renovables/trabajos_05/SenovillaArranz.pdf>

When choosing a value, the criterion adopted has been one of authoritativeness, with the IPCC values given in the IPCC Good Practice Guidance being considered to be of better quality than those from the IPCC Reference Manual, in the event of any discrepancy. Table A3.2.6 includes quality labels ranging from A to E, with A being the best quality and E the worst.

Of all the values in Table A3.2.6, it was finally decided to incorporate into the Inventory as crop parameter information those data associated with quality codes A, B or C in their respective labels, with those labelled D or E being discarded as of an insufficient standard.

Table A3.2.6.- Crop parameters

Crop		Residue/ Crop ratio	Source	Q	Dry matter	Source	Q	Carbon fraction	Source	Q	Nitrogen fraction	Source	Q
VEGETABLES	Saltwort	0.25	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Chicory and Other	0.25	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Garlic	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Artichoke	0.80	1	A	0.17	6	B	0.4100	3	C	0.0274	3	C
	Celery	1.00	4	D	0.05	6	B	0.4100	3	C	0.0274	3	C
	Kale Cabbage	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Aubergine	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Pumpkin and Marrow	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Cardoon	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Onion	1.00	4	D	0.08	6	B	0.4100	3	C	0.0274	3	C
	Spring Onion	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Cabbages	4.00	7	C	0.14	6	B	0.4100	3	C	0.0274	3	C
	Cauliflower	4.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Endive	0.25	4	D	0.06	6	B	0.4100	3	C	0.0274	3	C
	Asparagus	1.00	4	D	0.08	6	B	0.4100	3	C	0.0274	3	C
	Spinach	0.25	7	C	0.09	6	B	0.4100	3	C	0.0274	3	C
	Flowers	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Strawberry	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Hot Pepper	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Lettuce	0.18	7	C	0.05	6	B	0.4400	3	B	0.0314	3	B
	Melon	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Turnip and Others	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Potato	0.43	1	A	0.45	1	A	0.4226	1	A	0.0110	1	A
	Gherkin	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Cucumber	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Pepper	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Leek	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Radish	1.00	7	C	0.10	1	E	0.4100	3	C	0.0274	3	C
	Watermelon	1.00	4	D	0.10	1	E	0.4100	3	C	0.0274	3	C
	Tomato	1.00	7	C	0.10	1	E	0.4100	3	C	0.0274	3	C
	Carrot	1.00	4	D	0.16	6	B	0.4100	3	C	0.0274	3	C

Table A3.2.6 (Continued).- Crop parameters

Crop		Residue/ Crop ratio	Source	Q	Dry matter	Source	Q	Carbon fraction	Source	Q	Nitrogen fraction	Source	Q
FRUIT TREES	Avocado Pear Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Apricot Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Almond Tree	3.17	2	C	0.85	6	B	0.5700	3	C	0.0036	3	C
	Hazel Tree	3.17	4	D	0.95	6	B	0.5700	3	C	0.0036	3	C
	Cherry and Morello Ch.	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Custard Apple Tree	0.00	4	E	0.80	4	E	0.5700	3	C	0.0036	3	C
	Plum Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Fig Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Lemon Tree	0.07	2	C	0.80	4	E	0.5500	3	B	0.0203	3	B
	Mandarin Tree	0.07	2	C	0.80	4	E	0.5500	3	B	0.0203	3	B
	Apple Tree	0.16	2	C	0.80	4	E	0.5700	3	C	0.0036	3	C
	Peach Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Quince Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Orange Tree	0.07	2	C	0.80	4	E	0.5500	3	B	0.2030	3	B
	Medlar Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Walnut Tree	3.17	2	C	0.80	4	E	0.5700	3	C	0.0036	3	C
	Pickling Olives	1.13	2	C	0.7815	8	B	0.4952	8	B	0.0039	8	B
	Olive Tree For Oil	1.13	2	C	0.7815	8	B	0.4952	8	B	0.0039	8	B
	Pear Tree	0.16	4	D	0.80	4	E	0.5700	3	C	0.0036	3	C
	Plane Tree	0.00	4	E	0.80	4	E	0.5700	3	C	0.0036	3	C
	Dessert Grapes	0.43	2	C	0.736	9	C	0.5700	3	C	0.0036	3	C
	Wine Grapes	0.43	2	C	0.736	9	C	0.5700	3	C	0.0036	3	C
GRAIN LEGUMES	Lupin	1.00	4	E	0.85	4	E	0.4252	4	C	0.0250	5	C
	Chickpea	1.00	4	E	0.85	4	E	0.4252	4	C	0.0250	5	C
	Dry Pea	1.38	7	D	0.90	6	B	0.2211	4	C	0.0130	6	B
	Green Pea	1.50	1	A	0.87	1	A	0.2415	4	C	0.0142	1	A
	Dry Broad Bean	1.00	4	E	0.85	6	B	0.2721	4	C	0.0160	6	B
	Broad Bean	1.00	4	E	0.85	6	B	0.4252	4	C	0.0250	5	C
	Dry Bean	1.65	7	D	0.89	6	B	0.2041	4	C	0.0120	6	B
	Green Bean	2.10	1	A	0.86	1	A	0.2041	4	C	0.0120	6	B
	Lentil	1.43	7	D	0.85	4	E	0.4252	4	C	0.0250	5	C
	Vetch	1.00	4	E	0.85	6	B	0.4932	4	C	0.0290	6	B
LEGUMES FOR FODDER	Lucerne	0.00	1	A	0.25	6	B	0.4422	4	C	0.0260	6	B
	Sainfoin	0.00	1	A	0.25	4	E	0.4252	4	C	0.0250	5	C
	Clover	0.00	1	A	0.25	4	E	0.4252	4	C	0.0250	5	C
	Common Vetch	0.00	1	A	0.25	6	B	0.5102	4	C	0.0300	6	B
	Yero	0.00	1	A	0.25	4	E	0.4252	4	C	0.0250	5	C
	Zulla	0.00	1	A	0.25	4	E	0.4252	4	C	0.0250	5	C

Table A3.2.6 (Continued).- Crop parameters

Crop		Residue/ Crop ratio	Source	Q	Dry matter	Source	Q	Carbon fraction	Source	Q	Nitrogen fraction	Source	Q
INDUSTRIAL CROPS	Cotton	2,00	4	E	0,93	6	B	0,2450	4	E	0,0098	6	B
	Rapeseed	4,00	7	C	0,83	6	B	0,2000	4	E	0,0080	6	B
	Sugar Cane	2,00	4	E	0,83	1	A	0,4235		A	0,0040	1	A
	Flax	2,00	4	E	0,93	6	B	0,2650	4	E	0,0106	6	B
	Hops	2,00	4	E	0,85		E						
	Sugar Beet	0,30	1	A	0,15	1	A	0,4072		A	0,0228	1	A
	Table Beetroot	0,30	1	A	0,15	1	A	0,4072		A	0,0228	1	A
	Tobacco	2,00	4	E	0,78	6	B				0,0400	6	B
	Soy	2,10	1	A	0,87	1	A	0,3912	4	C	0,0230	1	A
	Sunflower	2,08	7	D	0,87	6	B	0,2000	4	E	0,0080	6	B
CEREALS	Oat	1,30	1	A	0,92	1	A	0,4118	4	C	0,0070	1	A
	Rice	1,40	1	A	0,85	1	A	0,4144		A	0,0067	1	A
	Barley	1,20	1	A	0,85	1	A	0,4567		A	0,0043	1	A
	Rye	1,60	1	A	0,90	1	A	0,3840	4	C	0,0048	1	A
	Maize	1,00	1	A	0,78	1	A	0,4709		A	0,0081	1	A
	Sorghum	1,40	1	A	0,91	1	A	0,5400	4	B	0,0108	1	A
	Wheat	1,30	1	A	0,85	1	A	0,4853		A	0,0028	1	A
	Triticale	1,30	4	E	0,90	6	B	0,5600	4	C	0,0070	6	B
	Sorghum For Fodder	0,00	1	A	0,26	6	B	0,5400	4	E	0,0108	4	D
	Maize For Fodder	0,00	1	A	0,85	5	B	0,5200	4	C	0,0065	5	B
OTHERS	Pumpkin For Fodder	0,00	1	A									
	Cabage For Fodder	0,00	1	A	0,12	6	B				0,0300	6	B
	Polyphytic Pastures	0,00	1	A	0,25		E	0,5250	4	C	0,0210	5	B
	Other Forage Grasses	1,00	4		0,18	4					0,0150	4	
	Other Arable Land Crops	1,00	4		0,10	4					0,0150	4	
	Other Pulses	1,81	4		0,85	4					0,0150	4	
	Other Pulses For Fodder	1,00	4		0,20	4					0,0300	4	
	Other Cereals	1,50	4		0,85	4					0,0150	4	
	Other Citrics	0,07	4		0,80	4					0,0150	4	
	Other Fodder	1,00	4		0,10	4					0,0150	4	
	Other Industrial Crops	2,00	4		0,80	4					0,0150	4	
	Other Woody Crops	1,00	4		0,80	4					0,0150	4	
	Other Non-Citric Crops	1,00	4		0,80	4					0,0150	4	
	Other Tubers	0,50	4		0,40	4					0,0150	4	

This table is, therefore, the expansion and adjustment to the situation in Spain of table 4-17 of the IPCC Reference Manual. Both tables are incomplete, in other words they do not show all of the crops considered in the Inventory and so the emissions estimations can only be effected on the crops for which complete data are available on the parameters appearing in table A3.2.6, without taking into account those associated with D or E quality labels, as explained above.

d) Percentages of agricultural stubble-burning

Agricultural stubble burnt in the fields has suffered a severe contretemps during the inventory period due to successive regulations that are becoming more and more restrictive. Table A3.2.7 shows the burnt fractions per type of crop and period. Crops that do not appear here are not considered to involve stubble-burning.

Spanish regulations for cereals differentiate between two geographical areas, one in the south (zone A) and the other in the north (zone B), each with different burning percentages as shown in the table.

Table A3.2.7.- Burning percentages

Period	Crop	Burned fraction (%)
1990-1999	Cereals	7.1
	Tubers	100
	Sugar cane	100
	Cotton	50
	Flax, rapeseed, sunflower and other industrial crops	50
	Soy	50
	Tobacco	100
	Flowers	100
	Vegetables (plant, bulb or root)	50
	Vegetables (fruit)	50
2000	Cereals (Zone A)	2.4
	Cereals (Zone B)	1.2
	Tubers	50
	Sugar cane	50
	Cotton	33.3
	Flax, rapeseed, sunflower and other industrial crops	33.3
	Vegetables (fruit)	20
	Other crops	like 1990
2001-2003	Cereals (Zone A)	1.2
	Cotton	33.3
	Tobacco	100
	Flowers	100
2004-2007	Tobacco	100
	Flowers	100
	Cotton	33.3

A3.3.- Land use, land use change and forestry

Additional comments and tables are provided in this section about the contents of chapter 7 (Land use, land use change, and forestry) of the report on the inventory for the period 1990-2007. This section comprises two subsections on the following:

- a) Illustration of the methodology used for category 5A (forests) for calculations of biomass
- b) Calculation of the intermediate basic variable carbon emitted as CO₂ in forest fires

A3.3.1.- Illustration of the methodology used for category 5A (forests) for calculations of biomass

The calculation of existing carbon due to live biomass in a forest which is preserved as a forest has been carried out using a procedure based on GPG-2003.

As a practical illustration, a real case is shown for the Spanish province of Madrid. A similar calculation was carried out for all Spanish provinces.

Data on timber-yielding volume in m³ per hectare and species are taken for each province, as provided by the two National Forestry Inventories. The product of these volumes times the biomass expansion parameters² (BEF·D), gives as a result the **annual value for above-ground biomass (Ba)**, expressed in tons of dry mass per hectare.

$$Ba = V \bullet BEF \cdot D$$

where,

Ba = air biomass (ton m.s. ha⁻¹)

V = timber volume (m³ ha⁻¹)

$BEF \cdot D$ = biomass expansion factor to convert the timber volume into above-ground tree biomass (ton m.s. m⁻³)

The total annual biomass value (B_{TOTAL}) for above-ground and underground biomass is then obtained as a result of applying the root expansion factor (R) to the annual factor above, as shown by table A3.3.1.

$$B_{TOTAL} = Ba \bullet (1 + R)$$

where,

B_{TOTAL} = total biomass (ton m.s. ha⁻¹)

Ba = above-ground biomass (ton m.s. ha⁻¹)

² These biomass expansion parameters (BEF) are shown below, on table A3.3.5

R = root/shoot ratio³ (dimensionless)

A number of values are proposed for R in Table 3A.1.8 of GPG-2003. A mean value has been calculated by taking the values for different types of coniferous and broadleaved vegetation:

- Coniferous forest. $R = 0.337$
- Broadleaved forest. $R = 0.326$

Table A3.3.1.- Conversion of the bark-inclusive volume as measured in IFN2 into an annual value for biomass (above-ground and underground)

VCC	Species	Vcc (m3/ha)	BEFD (t/m3)	R	Btotal=Vcc•BEFD•(1+R)
NFI2	Cupressus	0.0365383	0.55	0.337	0.027
	Juniperus communis				
	J.oxycedrus	0.3659812	0.80	0.337	0.391
	Pinus halepensis	0.5916723	0.74	0.337	0.585
	Pinus nigra	0.6212050	0.64	0.337	0.532
	Pinus pinaster	5.6768778	0.55	0.337	4.174
	Pinus pinea	3.2296098	0.73	0.337	3.152
	Pinus sylvestris	15.6057050	0.62	0.337	12.936
	Pinus uncinata	0.0516865	0.80	0.337	0.055
	CONIFEROUS				
	Riparian species	1.1965877	0.62	0.326	0.984
	Castanea sativa	0.1368613	0.75	0.326	0.136
	Fraxinus spp	1.2656449	0.83	0.326	1.393
	Other BROADLEAVED	0.2356150	0.80	0.326	0.250
	Quercus faginea	0.1209293	1.11	0.326	0.178
	Quercus ilex	3.3036242	1.28	0.326	5.607
	Quercus pyrenaica, Q. pubescens	2.3156311	1.11	0.326	3.408
	Quercus suber	0.0290874	1.28	0.326	0.049
	BROADLEAVED				
Madrid	TOTAL	34.78			33.86

The value for each year can be obtained with the result of the B_{TOTAL} for each inventory and per province. The constant value obtained from the difference amongst the inventories divided by the number of years between them, is the **increase in annual B_{TOTAL}** . This value must be added each year to calculate the B_{TOTAL} value for the next year (see Table A3.3.2).

³ Where the shoot is considered to be equal to full above-ground biomass

Table A3.3.2.- B_{TOTAL} values ($G \dot{t}$) each year from data in the Second and Third National Forestry Inventory

Madrid	$B_{total}=V_{cc} \cdot BEFD \cdot (1+R)$ (tn m.s. • ha ⁻¹)	Years of inventories	Years between inventories (A) (year)	Dif. $G \dot{t}$ amongst inventories (B) (tn m.s. • ha ⁻¹)	B/A (tn m.s. • ha ⁻¹ • year ⁻¹)
IFN3	40.90 ⁽¹⁾	2000			
IFN2	33.86 ⁽¹⁾	1990	10	7.05	0.70

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Madrid	33.86 ⁽¹⁾	34.56	35.27	35.97	36.68	37.38	38.09	38.79	39.50	40.20	40.91 ⁽¹⁾

(1): Data corresponding to the years of each of the two National Forestry Inventories (IFN3 and IFN2)

This calculation method for stocks has been carried out for all provinces, each of which have in turn been grouped in their respective Autonomous Community, and so the results for each Autonomous Community have been obtained, as shown in the following Table A3.3.3.

Table A3.3.3.- Values B_{total} annual Autonomous Community

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007
Galicia	80,19	85,01	89,82	90,78	91,75	92,71	93,67	94,64	95,60	96,56
Baleares	47,76	47,18	46,60	46,49	46,37	46,25	46,14	46,02	45,91	45,79
Murcia	13,90	18,18	22,46	23,31	24,17	25,02	25,88	26,74	27,59	28,45
Asturias	90,46	100,50	110,55	112,55	114,56	116,57	118,58	120,59	122,60	124,61
Cantabria	128,21	127,41	126,61	126,45	126,29	126,13	125,97	125,81	125,65	125,49
Navarra	122,65	121,52	120,40	120,17	119,95	119,72	119,50	119,27	119,05	118,83
La Rioja	83,07	91,22	99,37	101,00	102,63	104,26	105,89	107,52	109,15	110,78
Madrid	33,86	37,38	40,91	41,61	42,32	43,02	43,73	44,43	45,14	45,84
Extremadura	17,81	20,48	23,16	23,69	24,23	24,76	25,30	25,83	26,37	26,90
Cataluña	58,67	65,54	72,41	73,78	75,15	76,53	77,90	79,28	80,65	82,02
Canarias	50,44	55,39	60,33	61,32	62,31	63,29	64,28	65,27	66,26	67,25
Castilla y León	36,35	42,07	47,78	48,92	50,07	51,21	52,35	53,49	54,64	55,78
Castilla la Mancha	20,73	23,67	26,61	27,20	27,78	28,37	28,96	29,55	30,14	30,72
Aragón	29,39	33,44	37,49	38,30	39,11	39,92	40,73	41,54	42,35	43,16
País Vasco	66,67	82,79	98,90	102,13	105,35	108,57	111,79	115,02	118,24	121,46
Valencia	14,11	17,98	21,86	22,64	23,41	24,19	24,97	25,74	26,52	27,29
Andalucía	19,60	22,30	24,99	25,53	26,07	26,61	27,15	27,69	28,23	28,77

Input data for the calculations are given per unit of surface (hectares). The total biomass is thus obtained by multiplying by the corresponding surface.

To calculate the annual average increase of aerial biomass in plantations from the Map of Potential Forest Productivity in Spain 14 land categories have been considered to take account of the various lithological elements and constraints factors that limit the growing rate of productive forests. These 14 land categories are shown in Table A3.3.4.

Table A3.3.4.- Table of land categories according to the combination of lithologic factors and constraints limiting the growth rate of productive forests

Categories	Constraints on growth of productive forests
Ia	Land without constraints on the growth of productive forests in optimal soils
Ib	Land without constraints on the growth of productive forests in soils with restrictions
Ic	Land without constraints on the growth of productive forests in only "acceptable" soils
IIa	Land with weak constraints in optimal soils
IIb	Land with weak constraints in soils with restrictions
IIIa	Land with moderate constraints in optimal soils
IIIb	Land with moderate constraints in soils with restrictions
IVa	Land with moderately severe constraints in optimal soils
IVb	Land with moderately severe constraints in soils with restrictions
Va	Land with severe constraints in optimal soils
Vb	Land with severe constraints in soils with restrictions
VIa	Land with very severe constraints in optimal soils
VIb	Land with very severe constraints in soils with restrictions
VII	Land with sufficiently severe constraints so as to prevent productivity

The area of forest which is kept as a forest includes two subsections: a) constant forest area which was already a forest in 1990 (*Ffct.*), and b) areas that become forests after reforestation of agricultural land; this is considered to be in a transition state for at least 20 years (*FF transition*). For case a) carbon estimates have been made in accordance with section 7.2.2.1. *Forest Areas kept as Forests, from Chapter 7*. The methodology for this is explained in the same section of the appendix. For case b) carbon estimates have been made in accordance with section 7.2.2.2 *Areas becoming Forest Land*. Estimates for fixed carbon are shown in Table A3.3.5. and in Figure 7.2.1 in Chapter 7:

Table A3.3.5.- Carbon fixation for forest systems (Gg CO₂)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
FL remaining	21.474	21.474	21.474	21.474	21.474	21.474	21.474	21.474	21.474
FL transition	-	-	-	-	-	461	1.109	2.000	2.822
CF	-	-	-	-	461	648	890	822	842
TOTAL	21.474	21.474	21.474	21.474	21.935	22.583	23.473	24.296	25.138

	1999	2000	2001	2002	2003	2004	2005	2006	2007
FL remaining	21.474	21.474	21.474	21.474	21.474	21.474	21.474	21.474	21.474
FL transition	3.664	4.185	4.896	5.358	5.565	5.798	5.964	6.116	6.343
CF	522	710	462	207	233	166	152	227	122
TOTAL	25.659	26.370	26.832	27.039	27.272	27.438	27.590	27.817	27.939

FL remaining: Forests that remain forests (for its abbreviation in English)

FL transition: Lands reforested in previous years, but which are still in their maturing period of 20 years (for its abbreviation in English)

CF: Croplands that each year convert to forests (for its abbreviation in English)

Table A3.3.6.- Biomass expansion factors

BIOMASS EXPANSION FACTORS ("BEFD, Biomass Expansion Factor")

BROADLEAVED SPECIES	BEFD	COMPARISON SPECIES
<i>Acacia</i> spp.	0.80	
<i>Acer</i> spp.	0.90	Ulmus
<i>Alnus glutinosa</i>	0.62	
Out-of-mountain Trees (Riverbank)	0.62	Alnus
Riparian trees	0.62	Alnus
<i>Arbutus unedo</i>	0.80	
<i>Betula</i> spp.	0.73	
<i>Castanea sativa</i>	0.75	
<i>Ceratonia siliqua</i>	1.28	Q ilex
<i>Corylus avellana</i>	0.80	
<i>Crataegus</i> spp.	0.80	
<i>Erica</i> spp.	0.80	
<i>Eucalyptus</i> spp.	0.81	
<i>Fagus sylvatica</i>	0.81	
<i>Fraxinus</i> spp.	0.83	
<i>Ilex</i> spp.	0.80	
<i>Laurus azorica</i>	0.80	
Mixed Riverbank Trees	0.62	Alnus
Mixed Small Broadleaved Species	0.80	
<i>Myrica faya</i>	0.80	
<i>Olea europaea</i>	1.28	Q ilex
Other Species	0.80	
Other Broadleaved Species	0.80	
Other Laurisilvas	0.80	
<i>Persea indica</i>	0.80	
<i>Phillyrea latifolia</i>	0.80	
<i>Phoenix canariensis</i>	0.80	
<i>Platanus</i> spp.	0.90	Ulmus
<i>Populus</i> sp.	0.62	Alnus
<i>Prunus</i> spp.	0.80	
<i>Quercus canariensis</i>	1.00	
<i>Quercus faginea</i>	1.11	
<i>Quercus ilex</i>	1.28	
<i>Quercus petraea</i>	0.84	
<i>Quercus pubescens</i> (<i>Q. humilis</i>)	0.89	
<i>Quercus pyrenaica</i>	1.11	Q faginea
<i>Quercus robur</i>	0.84	Q petraea
<i>Quercus rubra</i>	0.80	
<i>Quercus suber</i>	1.28	Q ilex
<i>Robinia pseudacacia</i> . <i>Sophora japonica</i>	0.80	
<i>Robinia pseudacacia</i> . <i>Sophora japonica</i> . <i>Gleditsia triacanthos</i> .	0.80	
<i>Salix</i> spp.	0.80	
<i>Sorbus</i> spp.	0.80	
<i>Tilia</i> spp.	0.90	Ulmus
<i>Ulmus</i> spp.	0.90	

CREAF values
Values obtained by comparison to other species
Best practice reference values (1.6*0.5=0.8)

CONIFEROUS SPECIES	BEFD	COMPARISON SPECIES
<i>Abies alba</i>	0.61	
<i>Abies pinsapo</i>	0.61	Abies alba
<i>Cedrus</i> sp.	0.55	P pinaster
<i>Chamaecyparis lawsoniana</i>	0.44	P radiata
Allochthonous Coniferous Sp.	0.44	P radiata
Coniferous Species, except pines and fir-trees	0.64	P nigra
<i>Cupressus</i> sp.	0.55	P pinaster
<i>Juniperus</i> spp.	0.80	
<i>Larix</i> spp.	0.64	P nigra
Other Coniferous Species	0.64	P nigra
Other Pines	0.64	P nigra
<i>Picea abies</i>	0.44	P radiata
<i>Pinus canariensis</i>	0.55	P pinaster
<i>Pinus halepensis</i>	0.74	
<i>Pinus nigra</i>	0.64	
<i>Pinus pinaster</i>	0.55	
<i>Pinus pinea</i>	0.73	
<i>Pinus radiata</i>	0.44	
<i>Pinus sylvestris</i>	0.62	
<i>Pinus uncinata</i>	0.61	
<i>Pseudotsuga menziesii</i>	0.44	P radiata
Sabins/Junipers	0.80	

SOURCES:

Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories
National Forest Inventory (DGB; Ministry of the Environment)
Centre for Ecologic Research and Forestly Applications (CREAF)
Drafted by the Protection Service against Harmful Agents (SPCAN) in accordance with IFN data

A3.3.2.- Calculation of the Intermediate Basic Variable Carbon Emitted as CO₂ in Forest Fires

The intermediate basic variable 'Mass of Carbon emitted as CO₂ from Forest Fires' must be calculated in accordance with IPCC methodology (GPG-2003) in order to obtain a calculation of the emissions of greenhouse effect gases from forest fires other than CO₂.

The mass of carbon before the fire must be determined as a prerequisite for this calculation. This mass of carbon will be affected by the fire, leading to emissions of CO₂.

The table below shows the algorithm and the results of the calculations for the mass of carbon before the fire. This mass of carbon will be affected by the fire, leading to emissions of CO₂.

Table A3.3.7.- Estimated carbon stocks before the forest fire (tonnes of C)

Carbon before the forest fire	1990	1991	1992	1993	1994	1995	1996	1997	1998
$M=Mc*dc + Mf*df + Sc*ic*dc + Sf*if*df$	942,129	1,347,391	500,781	428,739	2,895,644	792,759	231,338	693,230	676,058
$PL=0,2455 M$	231,293	330,785	122,942	105,255	710,881	194,622	56,793	170,188	165,972
$B=0,9636 M$	907,835	1,298,346	482,553	413,133	2,790,243	763,903	222,917	667,996	651,449

Carbon before the forest fire	1999	2000	2001	2002	2003	2004	2005	2006	2007
$M=Mc*dc + Mf*df + Sc*ic*dc + Sf*if*df$	425,029	876,844	358,426	564,873	779,178	626,609	1,301,964	2,816,535	190,955
$PL=0,2455 M$	104,345	215,265	87,994	138,676	191,288	153,833	319,632	691,459	46,879
$B=0,9636 M$	409,558	844,927	345,379	544,312	750,816	603,801	1,254,572	2,714,013	184,004

where

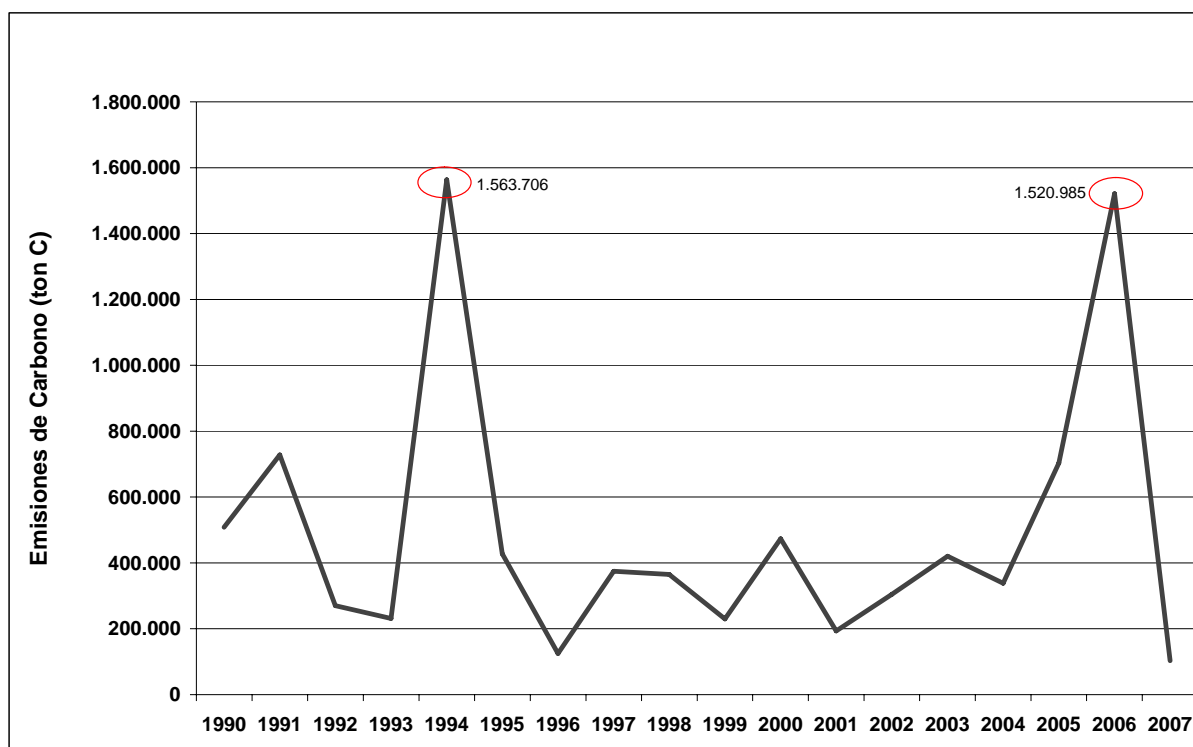
- M** Commercial Fraction
- PL** Leaf Litter/Waste
- B** Rest of Above-ground Biomass

Table A3.3.8.- Emissions originated from the forest fires in mass of C and of CO₂

Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998
$C=(0,2*(B+M) + 0,6*PL)$	508.768	727.618	270.432	231.528	1.563.706	428.106	124.927	374.358	365.085
$CO_2=(0,2*(B+M) + 0,6*PL)*44/12$	1.865.484	2.667.934	991.583	848.935	5.733.588	1.569.721	458.066	1.372.646	1.338.644

Emissions	1999	2000	2001	2002	2003	2004	2005	2006	2007
$C=(0,2*(B+M) + 0,6*PL)$	229.524	473.513	193.557	305.043	420.772	338.381	703.086	1.520.985	103.120
$CO_2=(0,2*(B+M) + 0,6*PL)*44/12$	841.589	1.736.215	709.710	1.118.491	1.542.830	1.240.732	2.577.984	5.576.946	378.105

Figure A3.3.1.- Time series for carbon emissions from forest fires and identification of years for which this category is key) (Tonnes of C)



APPENDIX 4: REFERENCE APPROACH AND COMPARISON WITH SECTORIAL APPROACH

Reference approach

The reference approach provides a means of dealing with CO₂ emissions from combustion (IPCC category 1A), based exclusively on national aggregate information from: a) domestic production of primary fuels; b) net balance of foreign trade (imports minus exports) of primary and secondary fuels; c) stock variation (initial stock minus final stock) of primary and secondary fuels; and d) non-energy use of primary and secondary fuels.

This procedure, which follows a top-down approach, can be used to compare CO₂ emission estimates in combustion processes with the sectorial approach, which follows a bottom-up approach and is in fact used to present the results of the Spanish national inventory.

Description of the approach

The principle of this procedure is to calculate all carbon emissions from fossil fuels consumed in the country, without distinguishing the process or socio-economic activity in which the fuel was used.

Socio-economic data relating to foreign trade, origin or destination of the fuels, determine the availability for national consumption (apparent consumption)¹. In this procedure, it is assumed that the estimated fuel element is fully consumed in combustion activities or for non-energy purposes.

The approach contemplates that the carbon in the fuel can either be emitted directly into the atmosphere or remains in the non-fuel product that uses it as a raw material or intermediate material², or as residue in combustion ashes. Taking this principle into consideration, carbon emissions are estimated from the total carbon contained in the available fuel, subtracting the part retained in the product or ashes. It is noted that the estimation of carbon emissions takes into account immediate carbon emissions but not the delayed oxidation that may occur in carbon stored in non-energy products.

¹ Total availability of primary fuels and the net amount (net balance of foreign trade adjusted by stock variation) for secondary fuels.

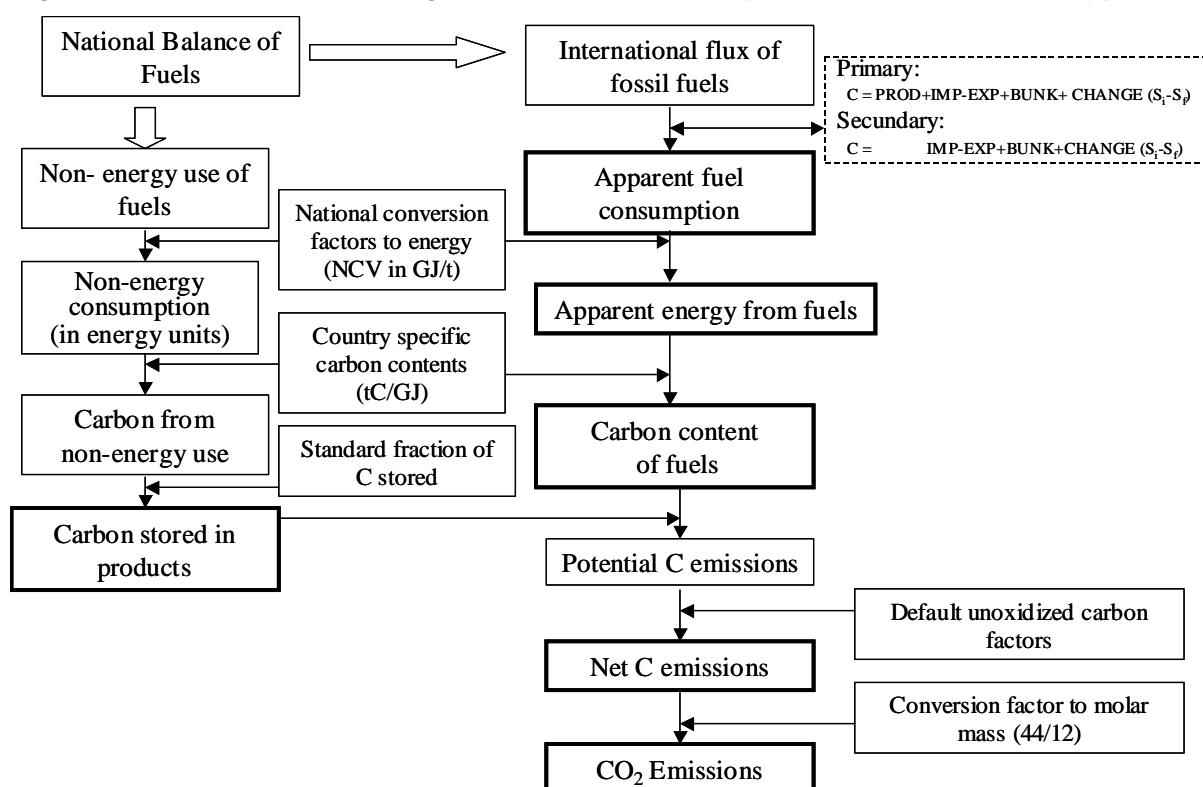
² Intermediate inputs such as lubricants or naphtha (obtained through oil refining) may be considered here, amongst products with no energy-related uses.

Methodological aspects

Choice of method

The reference approach has been developed by following the methodological criteria given in the 1996 IPCC Reference Manual (please refer to explanatory diagram in figure A4.1 below). It is only necessary to highlight a certain qualification of the methodology described by the IPCC with relation to fuels for non-energy use; in the case of “coal oils and tar”, the production of gross naphtha and tar at coke ovens has been adopted as variable while for “pitch and tars”, the data reported under the section “Non-energy use” of the national energy balance³ have been directly applied.

Figure A4.1.- IPCC methodological criteria for development of the reference approach



Abbreviations: C: Apparent consumption; PROD: Production of a primary fuel; IMP: Imports; EXP: Exports; BUNK: International bunkers; VAR(YES-S₀): Variation in stock (difference between stock at beginning of year, YES, and end of year, S₀).

Socio-economic variables

The variables that play a part in this estimation are associated with fossil fuels and are:

³ IPCC recommends applying proxy variables for both groups (IPCC 1996 Reference Manual).

- a) Origin-destination flows: This includes export, import, international bunkers (for sea and aviation) and variation in domestic stock. For primary fuels, production is also included along with the variables already mentioned.
- b) Non-energy uses.

All socio-economic data come from the fuel balance prepared as part of the emissions inventory. The main sources of national reference consulted to prepare the fuel balance in terms of variables are listed below:

- a) Energy balances produced by the International Energy Agency (IEA) and EUROSTAT up until the year before the last in the inventoried period, and international energy questionnaires from the MITYC (Ministry for Industry, Commerce, and Tourism) for the last year in the inventoried period (for which no energy balances are available). These sources are used in the reference approach in order to collect background information regarding origin-destination flows, international bunkers (for sea and aviation) and non-energy inputs.
- b) Statistics prepared by MITYC with input-output flow data at coke paste factories and coke ovens, "Statistics on Coke Paste Manufacture, Coke Ovens and Blast Furnace Gas", to gather information on the non-energy use of "Coal oils and tar", not available from the previous source.
- c) Plant direct information on its use of solid fuels as inputs to the production of non-energy products (sodium carbonate), which complements the above mentioned sources.⁴

The provisional nature of the balance of the national inventory must be highlighted for the last year of the inventory period (2007), as some of the base information used for the last inventoried year is itself provisional. The tally of the annual balances is the result of summarizing and comparing all the information available in the preparation phase of the current inventory.

Emissions estimation algorithm

Certain characteristics of fossil fuels and their forms of use play a part in the estimation algorithm (please refer to explanatory diagram in Figure A4.1 for more details): a) lower heating values (LHV); b) carbon contents; c) fraction of carbon stored in products that use fuels as raw materials or intermediate materials and d) non-oxidized carbon fraction.

The characteristics given in CRF Reporter correspond to average annual data for the standard fuel consumed; therefore, the representative values must not be interpreted as

⁴ The characterization of fuels consumed in this process differs from the procedure adopted as default in the reference approach (see next paragraph *Emissions estimation algorithm*). So, taking into account this better knowledge on the fuel characteristics and the process in which the fuel is consumed, the decision has been taken of applying this assumed more precise emission factors to calculate the energy consumption and emissions associated to this process.

representative values for every item making up the apparent consumption, (production, import, export, variation in stock, or international bunkers), but for total effective consumption. This recommendation is especially important in the case of coals, pit-coal and anthracite, whose energy capacity shows significant variations in terms of their domestic or international origin.

When determining mean annual LHV and carbon content values, the implicit characteristics used in the sectorial approach have been taken into account to estimate CO₂ emissions in IPCC category 1A. The national inventory provides specific information, on a sector or plant level, on fuels consumed in relevant socio-economic sectors such as refineries, thermal power plants, integrated iron and steel plants or natural gas transportation and distribution; fuels from the other combustion activities have been assigned standard characteristics in the sectorial approach.

The fraction of oxidized carbon and the fraction of stored carbon (for products that use fuels as raw materials or intermediate materials during manufacture) are characteristics for which there is currently no exhaustive national information. Therefore, the values suggested in the 1996 IPCC Reference Manual are applied by default.

A more detailed description is given below of the values and estimation procedures for the different parameters:

a) Lower heating values (LHV):

Origin-destination movements of solid and liquid fossil fuels in the reference approach are expressed in terms of mass, with original figures from the inventory fuel balance being reproduced. The apparent consumption of these fuels is then converted to energy units (TJ of lower heating value) by applying a representative national LHV.

In the case of fossil fuels considered on a sectorial level, the mean annual factor obtained by weighting the LHV applied in each activity A, LHV_A, with the corresponding fuel consumption in terms of mass, M_A, was chosen in the reference approach:

$$PCI_{E.R,t} = \frac{\sum_A PCI_{A,t} M_{A,t}}{\sum_A M_{A,t}} \quad t = t_0, \dots, t_n$$

When national fuel consumption is exclusively for non-energy purposes and therefore this has not been taken into account in any combustion activity, then the default LHV proposed in the 1996 IPCC Reference Manual has been adopted directly.

Original data on gaseous fuels (natural gas) are expressed in terms of upper heating value energy (TJ of UHV). To convert this to lower heating value energy units, the factor inferred with information provided by the main national natural gas transporting company has been applied.

b) Carbon content (C):

The criterion observed in the choice of carbon content has been to favour comparison with the sectorial approach⁵. Therefore, in the reference approach, fuels were assigned the annual carbon contents implied in the sectorial approach, C_{ES} , based on the associated carbon emission and the calculated fuel consumption:

$$C_{E.R,t} = C_{E.S,t} = \frac{Emission C_{E.S,t}}{Consumed Energy_{E.S,t}} = \frac{\left(\frac{12}{44}\right) \left(\frac{1}{CO_{Oxidated}}\right) Emission CO_{2,E.S,t}}{Consumed Energy_{E.S,t}} \quad t = t_0, \dots, t_n$$

By developing the previous formula with CO_2 emissions and consumptions per emission activity, A, the equation could be expressed as follows:

$$C_{E.R,t} = \left(\frac{12}{44}\right) \left(\frac{1}{CO_{Oxidated}}\right) \frac{\sum_A Emission CO_{2,A,t}}{PCI_{E.R,t} \sum_A M_{A,t}} \quad t = t_0, \dots, t_n$$

As occurred with the lower heating values, this algorithm is not applicable when annual consumptions of a fuel are used exclusively for non-energy purposes. In that case, IPCC default values are selected.

c) Fraction of carbon stored in products that use fuels as raw materials or intermediate materials during manufacture:

As has already been indicated in the introduction to the sub-section *Emissions estimation algorithm*, the main reference source was the 1996 IPCC Reference Manual. The default values suggested in this guide have been respected, with the exception of that proposed for coal oils and tar (coming from coking coal), adjusted in line with expert judgement⁶. For all other products not contemplated by the IPCC (petroleum coke and other petroleum products), estimations of this factor have been assigned (please refer to Table A4.1).

Table A4.1.- Fraction of carbon stored in products made from fuels

Product/Fuel	Fraction of Carbon Stored
Naphtha	0,8
Lubricants	0,5
Bitumen	1
Coal oil and tars	0,9
Natural gas	0,33
Petroleum coke	0,8
Anthracite (*)	1
Coking coal(*)	1
Other petroleum products	0,8

(*): Inputs to the production of sodium carbonate

⁵ Comparison aimed at detecting partial coverage in both fuel assignments and the identification of combustion source activities in the inventory.

⁶ The main item corresponds to gross tar, for which a fraction above that proposed by the IPCC is assumed.

Comparison between the reference approach and the sectorial approach

In the national inventory, discrepancies observed between both methods are relatively low, not exceeding 2% in terms of CO₂ emissions for any year in the period 1990-2007 (threshold above which the IPCC asks for justification of the discrepancy). Table A4.2 shows the percentage differences in terms of energy and CO₂ emissions⁷.

Table A4.2.- Difference between reference approach and sectorial approach

Year	Percentage difference Reference approach vs. sectorial approach	
	Energy ⁽¹⁾	CO ₂ Emissions ⁽²⁾
1990	1,81	1,67
1991	2,27	1,97
1992	1,39	1,61
1993	1,62	1,49
1994	1,94	1,71
1995	0,82	1,40
1996	1,32	2,23
1997	1,35	2,67
1998	1,21	2,27
1999	0,34	0,88
2000	-0,19	0,90
2001	-0,83	0,29
2002	-1,13	-0,12
2003	-1,30	0,15
2004	-0,34	0,83
2005	-1,05	-0,32
2006	-0,11	0,68
2007	0,45	1,25

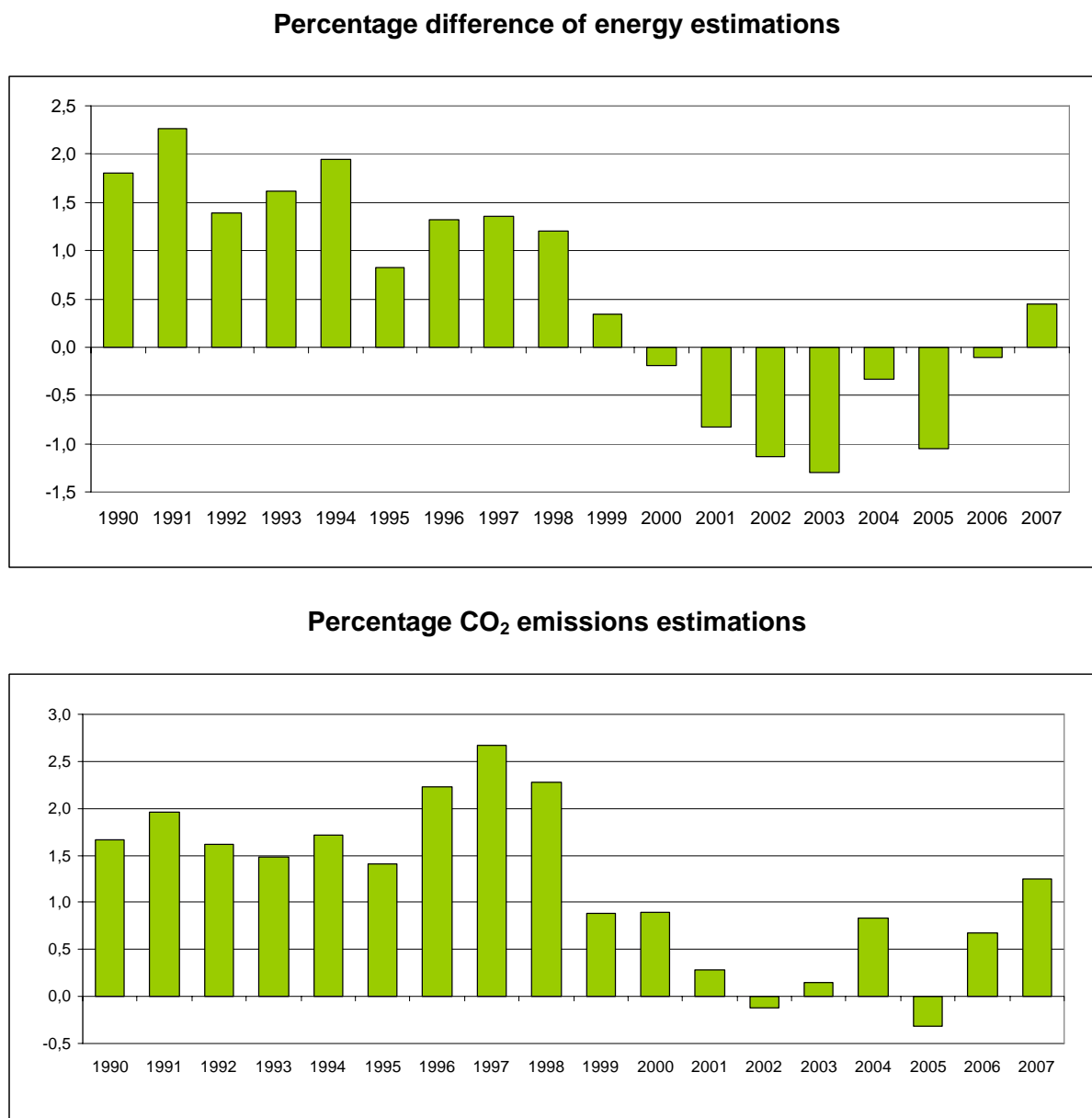
(1): Reference approach: apparent energy consumption after subtracting the part used for non-energy purposes.

(2): Reference approach: emissions associated with total effective carbon emissions (subtraction of carbon stored in non-energy product)

Figure A4.2 represents annual variation rates for energy and CO₂ emission estimations obtained with both approaches (reference and sectorial). For the reference approach, apparent energy consumption data have been taken, excluding non-energy use and CO₂ emissions derived from effective carbon emissions⁸.

⁷ Energy: amount of energy, expressed in terms of lower heating value (LHV), contained in the fuel, which represents the maximum amount released during the entire combustion process; CO₂ emissions: emissions derived from the carbon content contained in the fuel, considering a partial oxidation of the carbon during combustion.

⁸ Potential effective carbon except for the part stored in products for non-energy use.

Figure A4.2.– Estimation variation rate

The examination of the upper panel in Figure A4.2, on data related to energy consumption, shows alternation in the sign of the discrepancies between approaches, with percentages ranging between -1-1% and 2-3%. During a first period (1990-1995), the estimations obtained with the reference approach exceed the values resulting with the sectorial approach, but this sign is inverted in a second period (2000-2006), before recovering in 2007 to levels close to those of 1999. This reversal is also shown, with a steeper slope, for the gaseous fuels series, the most significant contribution of which to the global differences occurs in the last years of the period inventoried. Solid fuels show a general decreasing trend, though positive differences are present throughout the period. These positive differences compensate for the negative differences shown by liquid fuels for

the period 1990-1996, and for the negative differences of gaseous fuels in 2007, as well as for the joint contribution, with negative figures, provided by liquid and gaseous fuels for the period 1998-2006.

As regards CO₂ emissions, estimates provided by the reference approach are generally higher than those from the sectorial approach (range between -0.3% and 2.7%). The bottom panel at figure A4.2 shows a decreasing trend for the differences associated to emissions, moving from values near 2% for the first years in the period to lesser marked variations, below 1.3%, with a reversal in the overall trend of around -0.3% in 2002 and 2005. The evolution of the general series is determined by the combination of positive differences for solid and liquid fuels.

It should be noted that a different treatment is given, following criteria given in the CRF Reporter, to energy and CO₂ emissions. While in the first case the energy consumed for non-energy purposes is fully subtracted from the apparent energy consumption, for emissions, as only the stored carbon element is eliminated from the calculation, emissions resulting from non-combustion processes due to fossil fuel consumption for non-energy use or raw or intermediate materials are still included in the CRF.

Variations observed in the estimations due to both methods have been justified by two fundamental aspects: a) structural differences in the approaches themselves and b) considerations regarding variables and parameters.

Structural differences between the approaches

This group includes, among others, the points given below:

- a) List of fuels: The reference approach only contemplates fossil fuels (gaseous, liquid and solid) available in the year. This list is extended in the sectorial approach to incorporate, in some cases, within the 'Other fuels' category, waste from non-Fuel products calculated in other years but that due to a delay in time, appear as fuels in the form of industrial and/or domestic waste (used oil or used tyres as fuel and incinerated plastic containers).

By considering the lower consumption values given in the sectorial approach⁹, this aspect is deemed of little importance in the national inventory.

- b) List of source activities: When comparing, the sectorial approach covers the combustion activities of IPCC category 1A.

In turn, the reference approach, by assuming that available or apparent consumption matches domestic consumption, possible losses that might occur in the distribution phase of certain fuels (natural gas) are calculated as energy consumption. Therefore, the reference approach partially includes emissions generated by category 1B (for

⁹ Via questionnaires, the national inventory has collected information on consumption (mainly used tyres and oil) at cement factories.

example, due to losses during natural gas transportation and distribution, or when opening and extinguishing coke ovens).

Although the CRF Reporter gives the option to deduct such emissions by including these sources (particularly leakages in natural gas distribution) in the section Raw and intermediate materials and non-energy use of fuels, this alternative has been ruled out since, by definition, these do not come under this category. By observing the balance of the national inventory and estimations calculated with the sectorial approach, this question is assumed to be of little importance in total emissions and national apparent energy consumption.

As has already been mentioned in this section, CO₂ emissions estimated using the reference approach also include immediate emissions resulting from non-energy consumption of fuels that are covered by the Industrial Processes sector, as is the case of the use of natural gas in nitric acid production.

- c) CO₂ emissions estimation methodology: In the reference approach, a carbon mass balance is applied, with mean factors. For its part, there is no such uniformity in the technique applied in the sectorial approach (carbon balance, mean factors based on energy, measured emissions,...)

The choice of weighted heating values and carbon content values minimizes the effects of this point.

Some considerations associated with variables and parameters

- 1) Existence of statistical differences in the fuel balance of the inventory.

Negative differences (consumption higher than the amounts of fuel theoretically available) could mean values being counted twice, leading, if consumed as raw or intermediate material or with non-energy use, to undervaluing estimations in the reference approach due to deducting carbon content stored in these materials. Similarly, if fuel is consumed for energy purposes, emissions from the sectorial approach would be overvalued by increasing emissions associated with this fuel. This factor is assumed to have certain importance for particular fuels, such as natural gas.

- 2) Lack of information regarding the use and lifecycle of non-energy products, so as to allow a determination of national values on fractions of stored carbon. Additionally, a mention must be made about the limited availability of data on fuels that, in the process for manufacturing non-energy products, partially have energy purposes (combustion) besides acting as components of the products.
- 3) Limited information on national physical and chemical characteristics, such as heating values and carbon contents for raw materials.
- 4) Default values may be applied to those primary fuels which are consumed mainly or exclusively for processing and transformation into secondary fuels (as for coking coal and crude oil). This criterion may cause an apparent violation of the principle of energy or carbon conservation in the conversion process, which would in turn be projected

onto the comparison between the reference and the sectorial approaches. Given the high order of magnitude of the crude oil processed, the estimate drawn from the reference approach is extremely sensitive to any variations on the parameters applied for crude oil; thus, we may surmise that this approximation may be one of the major sources of discrepancies between the two approaches.

- 5) Considerations on the application of sectorial mean factors (heating values and carbon contents) for the reference approach. Approximations in the calculations for the reference approach with factors previously inferred from the sectorial approach produce discrepancies with the sectorial approach when dealing with transferred or declassified products. In this way, the mean properties of fuels finally consumed according to the classification per fuel type are applied within the reference approach for the conversion into energy or carbon mass terms to the amounts available for consumption.

APPENDIX 5.- COMPLETENESS ASSESSMENT

This Appendix shows, in the form of summary tables, the main activity categories that include activities that have not been estimated and that as such were highlighted in section 1.8 of the inventory report as representing exceptions to the completeness of coverage by the inventory.

This specifically includes the following groups or categories of activities:

- Activities related to Land Use, Land Use Changes and Forestry.
- Potential emissions from fluorinated gases.
- Emissions from fuel use in military activities.

Details of each of these activities are given below.

a) Activities related to Land Use, Land Use Changes and Forestry (LULUCF).

For the LULUCF sector, although the complete time series has been estimated for surface areas and changes of surface area between land use categories, it has not been possible to estimate the emission and absorption flows for all the sub-categories of categories 5B to 5F; however, estimates have been made for the uptake of CO₂ in forest systems (forests that remain as forests and croplands that become forests) and for croplands that become grasslands, as well as the emissions from forest fires. For categories 5B to 5F the methodology of emission and absorptions estimation is yet to be defined and, where appropriate, the necessary base information completed in order to apply the methodology, so in this edition the quantitative results of those flows have not been included.

Therefore, Table A5.1 includes the estimation status matrix for emissions/absorptions by categories and the exceptions to the completeness of the inventory in this LULUCF sector. The rows of the table include the types of potential emission/absorption deposits and the columns contain the land use categories.

Table A5.1.– Categories contributing to inventory estimations

	5A Forest land	5B Cropland	5C Grassland	5D Wetland	5E Settlements	5F Other land
Living Biomass	E	NE	NE		NE	NE
Dead Organic Matter	NE					
Soils	NE	NE	E ⁽¹⁾		NE	NE
Non-CO₂ GHG (from forest fires)	NE	NE	NE			
Flooded Land				NE		
Peat land				NE		

E = Estimated; NE = Not Estimated

(1): Partial Estimation

b) Potential emissions from fluorinated gases.

Potential emissions of fluorinated gases (HFC, PFC and SF₆) have not been estimated due to the lack of specific information on foreign trade flows (imports and exports) by type of gas as well as information on amounts destroyed. With regard to production data, although the amounts of HFC-32, HFC-143a and HFC-227ea produced are available, the corresponding information has not been included in the CRF Reporter for reasons of confidentiality as there are only two companies manufacturing these gases. Table A5.2 provides the breakdown of the information corresponding to 2007 regarding the fluorinated gases for which emissions have been estimated using the so-called actual approach of the IPCC methodology.

Table A5.2.– Potential fluorinated gas emissions

	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-236fa	CF ₄	C ₂ F ₆	C ₃ F ₈	C ₄ F ₁₀	SF ₆
Potential Emissions of Halocarbons (by type) and SF₆	NE	C,NE	NE	NE	C,NE	NE	C,NE	NE	NE	NE	NE	NE	NE
Production	NE	C	NE	NE	C	NE	C	NE	NE	NE	NE	NE	NE
Importation	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
In Bulk	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
In Products	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Exportation:	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
In Bulk	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
In Products	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Destroyed Amount	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

C: Confidential

NE: Not estimated

c) Emissions from fuel use in military activities.

With regard to the use of fuels in military activities, both in stationary and mobile sources, the inclusion of such consumptions has not been established within the fuel balance of the national inventory. In line with the IPCC methodology, this emissions source is included in category 1A5. Table A5.3 shows the information corresponding to this category as mentioned in CRF Reporter.

Table A5.3.– Other combustion sources

	Consumption (TJ)	Emissions		
		CO ₂ (Gg)	CH ₄ (Gg)	N ₂ O (Gg)
1.A.5 Other	NO	NA	NA	NA
a. Stationary	NO	NA	NA	NA
Liquids	NO	NA	NA	NA
Solids	NO	NA	NA	NA
Gaseous	NO	NA	NA	NA
Biomass	NO	NA	NA	NA
Other	NO	NA	NA	NA
b. Mobil	NO	NA	NA	NA
Liquids	NO	NA	NA	NA
Solids	NO	NA	NA	NA
Gaseous	NO	NA	NA	NA
Biomass	NO	NA	NA	NA
Other	NO	NA	NA	NA

NO: Does not occur

NA: Not applicable

APPENDIX 6.- ADDITIONAL INFORMATION CONSIDERED AS PART OF THE INVENTORY REPORT

This appendix includes tables showing emission trends for the aggregate total of the inventory and for gases with both direct and indirect global warming impacts. These tables complement the information presented in sections ES.2, ES.3 and ES.4 of the “Executive Summary” chapter and sections 2.1, 2.2, 2.3 and 2.4 in chapter 2 “Greenhouse gas emission trends”. Due to space limitations the tables presentation has been reduced to the following years: 1990, 1995, and 2003 to 2007.

The tables included here show inventory emissions for each substance broken down by source category (according to the summary tables of the CRF Reporter). Table references and contents are as follows:

- Table A6.1 shows the total CO₂-equivalent emissions for the inventory, corresponding to the aggregation of the emissions of direct greenhouse gases.
- Tables A6.2 to A6.7 show emissions of CO₂, CH₄, N₂O, HFC, PFC and SF₆, respectively, in terms of CO₂-equivalent. It must be noted that for HFC and PFC, the table adds emissions of the individual substances contained in each of these two groups in a weighted manner. It is also observed that fluorinated gas emissions fall into a limited number of activity categories, namely the steel industry and the production and consumption of halocarbons and SF₆.
- Finally, Tables A6.8, A6.9 and A6.10 show indirect greenhouse gas emissions (NO_x, CO and NMVOC) and Table A6.11 shows SO₂ emissions.

Table A6.1.– CO₂ equivalent emissions (Figures in Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	288.134,66	319.165,94	410.257,65	426.018,47	441.150,50	433.069,76	442.321,56
1. Energy	212.465,02	240.705,53	314.441,60	331.500,24	347.308,80	337.170,02	345.391,32
A. Fuel Combustion Activities	208.238,44	236.503,10	310.719,22	327.426,00	343.222,11	333.217,17	341.370,89
1. Energy Industries	77.694,33	86.812,83	106.527,96	115.937,68	126.075,05	117.080,64	123.035,49
2. Manufacturing Industries and Construction	46.660,84	53.314,58	68.625,76	70.744,03	71.518,09	69.737,08	68.329,69
3. Transport	57.483,20	66.983,36	97.471,78	101.290,31	105.547,66	108.611,49	112.268,53
4. Other Sectors	26.400,07	29.392,34	38.093,71	39.453,98	40.081,32	37.787,96	37.737,18
5. Other							
B. Fugitive Emissions from Fuels	4.226,58	4.202,42	3.722,38	4.074,25	4.086,69	3.952,85	4.020,43
1. Solid Fuels	1.835,17	1.482,64	1.115,18	1.064,42	1.028,78	1.054,63	977,80
2. Oil and Natural Gas	2.391,41	2.719,78	2.607,20	3.009,82	3.057,91	2.898,21	3.042,63
2. Industrial Processes	26.314,29	27.411,17	32.722,32	32.860,15	34.321,67	35.007,86	34.852,48
A. Mineral Products	15.659,31	16.114,21	21.123,32	21.606,05	22.224,41	22.616,89	22.344,97
B. Chemical Industry	3.767,76	3.238,91	2.779,90	2.551,33	2.642,00	2.307,02	2.151,65
C. Metal Production	4.417,13	3.303,93	3.501,46	3.679,71	4.076,32	4.097,44	4.053,52
D. Other Production							
E. Production of Halocarbons and SF ₆	2.403,18	4.637,88	1.749,17	786,53	680,93	863,42	707,20
F. Consumption of Halocarbons and SF ₆	66,92	116,24	3.568,47	4.236,53	4.698,01	5.123,09	5.595,13
G. Other							
3. Solvents and Other Product Use	1.387,85	1.343,58	1.596,23	1.517,91	1.481,74	1.517,27	1.674,20
4. Agriculture	40.330,18	39.877,02	48.323,12	47.191,80	44.878,13	45.817,68	46.425,65
A. Enteric Fermentation	11.779,63	12.043,91	14.005,24	13.696,07	13.485,88	13.331,53	13.559,54
B. Manure Management	8.695,38	9.781,38	11.588,63	11.983,76	11.871,24	12.356,46	12.438,81
C. Rice Cultivation	227,45	137,22	297,89	309,03	300,26	268,47	268,47
D. Agricultural Soils	19.089,69	17.403,76	21.884,72	20.757,85	18.890,99	19.437,03	19.734,65
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	538,03	510,76	546,64	445,08	329,76	424,20	424,20
G. Other							
5. Land Use Change and Forestry							
6. Waste	7.637,31	9.828,64	13.174,38	12.948,35	13.160,16	13.556,93	13.977,90
A. Solid Waste Disposal on Land	4.976,12	6.895,78	9.371,01	9.059,55	9.226,21	9.506,10	9.761,07
B. Wastewater Handling	2.312,54	2.491,99	3.168,78	3.268,64	3.330,63	3.397,20	3.541,60
C. Waste Incineration	94,77	35,80	18,19	9,43	9,31	9,57	10,05
D. Other	253,88	405,08	616,40	610,74	594,02	644,06	665,18
7. Other							

Table A6.2.– CO₂ emissions by sector (Figures in Gg of CO₂-equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	228.446,83	255.255,70	334.020,63	351.384,17	367.996,87	358.418,06	366.366,37
1. Energy	207.118,87	234.847,74	307.586,92	324.325,25	339.873,66	329.931,60	338.144,87
A. Fuel Combustion Activities	205.340,89	232.932,27	305.597,09	322.071,87	337.631,97	327.527,11	335.568,86
1. Energy Industries	77.356,89	86.200,91	105.754,15	115.107,31	125.178,24	116.199,14	122.137,31
2. Manufacturing Industries and Construction	46.196,49	52.782,49	67.874,29	69.964,17	70.721,35	68.943,79	67.542,86
3. Transport	56.506,50	65.588,65	94.864,20	98.544,47	102.653,41	105.586,25	109.142,05
4. Other Sectors	25.281,01	28.360,21	37.104,45	38.455,94	39.078,97	36.797,92	36.746,64
5. Other							
B. Fugitive Emissions from Fuels	1.777,99	1.915,47	1.989,82	2.253,38	2.241,70	2.404,50	2.576,02
1. Solid Fuels	17,63	13,38	72,03	72,80	89,91	124,94	93,53
2. Oil and Natural Gas	1.760,36	1.902,09	1.917,79	2.180,58	2.151,79	2.279,56	2.482,49
2. Industrial Processes	20.002,78	19.364,23	25.170,27	25.793,24	26.867,48	27.262,35	26.994,27
A. Mineral Products	15.659,31	16.114,21	21.123,32	21.606,05	22.224,41	22.616,89	22.344,97
B. Chemical Industry	832,10	794,32	750,89	706,21	726,56	696,59	735,91
C. Metal Production	3.511,37	2.455,70	3.296,06	3.480,98	3.916,51	3.948,87	3.913,39
D. Other Production							
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use	1.022,05	915,78	1.240,04	1.247,90	1.238,39	1.206,96	1.210,44
4. Agriculture	0,00	0,00	0,00	0,00	0,00	0,00	0,00
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes							
G. Other							
5. Land Use Change and Forestry							
6. Waste	303,13	127,94	23,40	17,78	17,33	17,14	16,78
A. Solid Waste Disposal on Land	218,47	99,89	15,88	13,89	13,59	13,29	12,53
B. Wastewater Handling							
C. Waste Incineration	84,66	28,05	7,52	3,89	3,74	3,85	4,26
D. Other							
7. Other							

Table A6.3.– CH₄ emissions by sector (Figures in Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	28.587,41	31.819,76	38.336,36	38.071,42	37.944,16	38.510,51	39.058,70
1. Energy	3.627,84	3.389,46	2.840,68	2.964,21	3.014,23	2.723,16	2.607,87
A. Fuel Combustion Activities	1.179,28	1.102,53	1.108,20	1.143,37	1.169,31	1.174,92	1.163,49
1. Energy Industries	54,84	53,95	94,57	127,41	145,84	156,66	159,24
2. Manufacturing Industries and Construction	64,30	77,98	155,43	167,18	177,82	176,66	177,11
3. Transport	240,77	238,75	202,26	191,16	186,64	183,78	169,44
4. Other Sectors	819,38	731,86	655,94	657,63	659,02	657,81	657,70
5. Other							
B. Fugitive Emissions from Fuels	2.448,56	2.286,93	1.732,49	1.820,83	1.844,91	1.548,25	1.444,38
1. Solid Fuels	1.817,54	1.469,26	1.043,15	991,62	938,87	929,69	884,27
2. Oil and Natural Gas	631,02	817,67	689,34	829,21	906,04	618,55	560,11
2. Industrial Processes	72,64	76,50	78,10	72,99	70,82	68,59	72,29
A. Mineral Products							
B. Chemical Industry	51,49	60,77	63,57	57,49	54,96	55,04	56,60
C. Metal Production	21,15	15,73	14,52	15,50	15,86	13,55	15,68
D. Other Production							
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4. Agriculture	18.650,42	19.680,06	23.431,50	23.304,06	22.912,14	23.373,05	23.645,24
A. Enteric Fermentation	11.779,63	12.043,91	14.005,24	13.696,07	13.485,88	13.331,53	13.559,54
B. Manure Management	6.230,60	7.100,44	8.666,18	8.920,57	8.845,90	9.413,45	9.457,63
C. Rice Cultivation	227,45	137,22	297,89	309,03	300,26	268,47	268,47
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	412,73	398,49	462,19	378,38	280,11	359,60	359,60
G. Other							
5. Land Use Change and Forestry	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6. Waste	6.236,51	8.673,75	11.986,08	11.730,16	11.946,97	12.345,70	12.733,30
A. Solid Waste Disposal on Land	4.742,18	6.788,65	9.353,53	9.044,15	9.210,91	9.491,33	9.747,19
B. Wastewater Handling	1.240,30	1.479,68	2.015,51	2.074,93	2.141,70	2.209,96	2.320,58
C. Waste Incineration	0,15	0,33	0,64	0,34	0,34	0,35	0,36
D. Other	253,88	405,08	616,40	610,74	594,02	644,06	665,18
7. Other							

Table A6.4.– N₂O emissions by sector (Figures in Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	27.747,40	26.504,20	32.392,92	31.356,97	29.687,34	30.020,30	30.470,38
1. Energy	1.718,31	2.468,32	4.014,00	4.210,78	4.420,90	4.515,25	4.638,58
A. Fuel Combustion Activities	1.718,28	2.468,30	4.013,93	4.210,75	4.420,83	4.515,15	4.638,55
1. Energy Industries	282,60	557,97	679,24	702,96	750,97	724,84	738,94
2. Manufacturing Industries and Construction	400,06	454,11	596,04	612,68	618,92	616,63	609,72
3. Transport	735,94	1.155,96	2.405,32	2.554,69	2.707,61	2.841,45	2.957,05
4. Other Sectors	299,67	300,27	333,32	340,41	343,33	332,23	332,85
5. Other							
B. Fugitive Emissions from Fuels	0,03	0,02	0,07	0,04	0,07	0,10	0,03
1. Solid Fuels							
2. Oil and Natural Gas	0,03	0,02	0,07	0,04	0,07	0,10	0,03
2. Industrial Processes	2.885,86	2.384,16	1.966,21	1.788,02	1.861,23	1.556,03	1.359,81
A. Mineral Products							
B. Chemical Industry	2.884,16	2.383,82	1.965,43	1.787,63	1.860,48	1.555,39	1.359,14
C. Metal Production	1,69	0,34	0,77	0,39	0,76	0,65	0,67
D. Other Production							
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use	365,80	427,80	356,19	270,01	243,35	310,31	463,76
4. Agriculture	21.679,77	20.196,96	24.891,62	23.887,74	21.965,99	22.444,62	22.780,41
A. Enteric Fermentation							
B. Manure Management	2.464,77	2.680,93	2.922,45	3.063,19	3.025,35	2.943,01	2.981,17
C. Rice Cultivation							
D. Agricultural Soils	19.089,69	17.403,76	21.884,72	20.757,85	18.890,99	19.437,03	19.734,65
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	125,30	112,27	84,46	66,70	49,65	64,59	64,59
G. Other							
5. Land Use Change and Forestry	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6. Waste	1.097,67	1.026,95	1.164,90	1.200,41	1.195,86	1.194,08	1.227,81
A. Solid Waste Disposal on Land	15,47	7,23	1,59	1,51	1,71	1,47	1,36
B. Wastewater Handling	1.072,24	1.012,31	1.153,27	1.193,71	1.188,93	1.187,24	1.221,02
C. Waste Incineration	9,96	7,41	10,03	5,20	5,23	5,37	5,44
D. Other							
7. Other							

Table A6.5.– HFC emissions by sector (Figures in Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	2.403,18	4.645,44	3.892,39	5.032,78	4.679,87	5.006,09	5.549,63
1. Energy	0,00	0,00	0,00	0,00	0,00	0,00	0,00
A. Fuel Combustion Activities	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Energy Industries							
2. Manufacturing Industries and Construction							
3. Transport							
4. Other Sectors							
5. Other							
B. Fugitive Emissions from Fuels	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Solid Fuels							
2. Oil and Natural Gas							
2. Industrial Processes	2.403,18	4.645,44	3.892,39	5.032,78	4.679,87	5.006,09	5.549,63
A. Mineral Products							
B. Chemical Industry							
C. Metal Production							
D. Other Production							
E. Production of Halocarbons and SF ₆	2.403,18	4.637,88	1.170,65	1.749,17	786,53	680,93	863,42
F. Consumption of Halocarbons and SF ₆		7,56	2.721,75	3.283,60	3.893,34	4.325,16	4.686,21
G. Other							
3. Solvents and Other Product Use							
4. Agriculture							
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes							
G. Other							
5. Land Use Change and Forestry							
6. Waste							
A. Solid Waste Disposal on Land							
B. Wastewater Handling							
C. Waste Incineration							
D. Other							
7. Other							

Table A6.6.– PFC emissions by sector (Figures in Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	882,92	832,51	267,31	272,04	244,41	247,63	249,12
1. Energy	0,00	0,00	0,00	0,00	0,00	0,00	0,00
A. Fuel Combustion Activities	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Energy Industries							
2. Manufacturing Industries and Construction							
3. Transport							
4. Other Sectors							
5. Other							
B. Fugitive Emissions from Fuels	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Solid Fuels							
2. Oil and Natural Gas							
2. Industrial Processes	882,92	832,51	267,31	272,04	244,41	247,63	249,12
A. Mineral Products							
B. Chemical Industry							
C. Metal Production	882,92	832,16	190,11	182,84	143,19	134,36	123,78
D. Other Production							
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆		0,35	77,20	89,20	101,22	113,27	125,34
G. Other							
3. Solvents and Other Product Use							
4. Agriculture							
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes							
G. Other							
5. Land Use Change and Forestry							
6. Waste							
A. Solid Waste Disposal on Land							
B. Wastewater Handling							
C. Waste Incineration							
D. Other							
7. Other							

Table A6.7.– SF₆ emissions by sector (Figures in Gg of CO₂ equivalent)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	66,92	108,34	207,66	254,00	271,63	323,62	339,97
1. Energy	0,00	0,00	0,00	0,00	0,00	0,00	0,00
A. Fuel Combustion Activities	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Energy Industries							
2. Manufacturing Industries and Construction							
3. Transport							
4. Other Sectors							
5. Other							
B. Fugitive Emissions from Fuels	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1. Solid Fuels							
2. Oil and Natural Gas							
2. Industrial Processes	66,92	108,34	207,66	254,00	271,63	323,62	339,97
A. Mineral Products							
B. Chemical Industry							
C. Metal Production							
D. Other Production							
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆	66,92	108,34	207,66	254,00	271,63	323,62	339,97
G. Other							
3. Solvents and Other Product Use							
4. Agriculture							
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes							
G. Other							
5. Land Use Change and Forestry							
6. Waste							
A. Solid Waste Disposal on Land							
B. Wastewater Handling							
C. Waste Incineration							
D. Other							
7. Other							

Table A6.8.– NO_x emissions by sector (Figures in Gg)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	1.246,38	1.347,15	1.501,35	1.531,65	1.530,25	1.481,35	1.498,46
1. Energy	1.201,98	1.308,95	1.462,84	1.497,27	1.498,86	1.448,12	1.465,38
A. Fuel Combustion Activities	1.195,26	1.303,80	1.457,62	1.491,66	1.493,82	1.442,95	1.460,27
1. Energy Industries	257,48	303,36	331,74	355,87	359,01	331,16	343,25
2. Manufacturing Industries and Construction	216,02	220,21	320,36	333,79	344,19	342,68	342,61
3. Transport	566,48	618,28	624,35	616,56	603,08	580,06	583,18
4. Other Sectors	155,28	161,95	181,18	185,44	187,54	189,05	191,24
5. Other							
B. Fugitive Emissions from Fuels	6,72	5,15	5,22	5,61	5,04	5,16	5,12
1. Solid Fuels	0,08	0,06	0,07	0,07	0,07	0,07	0,07
2. Oil and Natural Gas	6,64	5,09	5,15	5,54	4,97	5,09	5,05
2. Industrial Processes	13,35	10,84	11,22	10,33	10,88	10,52	10,18
A. Mineral Products							
B. Chemical Industry	8,49	6,09	5,15	4,00	4,51	3,91	3,42
C. Metal Production	3,03	3,00	3,89	4,12	4,15	4,30	4,39
D. Other Production	1,83	1,74	2,17	2,21	2,22	2,31	2,37
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use							
4. Agriculture	29,64	26,70	26,98	23,85	20,31	22,52	22,70
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils	15,03	13,61	17,13	16,07	14,52	14,99	15,17
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	14,61	13,09	9,85	7,78	5,79	7,53	7,53
G. Other							
5. Land Use Change and Forestry							
6. Waste	1,40	0,67	0,31	0,19	0,20	0,20	0,19
A. Solid Waste Disposal on Land	0,90	0,42	0,08	0,07	0,08	0,07	0,07
B. Wastewater Handling							
C. Waste Incineration	0,51	0,25	0,23	0,12	0,12	0,12	0,13
D. Other							
7. Other							

Table A6.9.– CO emissions by sector (Figures in Gg)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	3.884,78	3.477,20	2.831,58	2.693,71	2.556,76	2.538,32	2.555,24
1. Energy	3.156,72	2.777,34	1.987,68	1.906,70	1.862,27	1.767,85	1.762,88
A. Fuel Combustion Activities	3.153,19	2.774,51	1.984,60	1.903,41	1.859,06	1.764,61	1.759,73
1. Energy Industries	18,04	25,60	24,31	26,54	29,37	27,05	27,70
2. Manufacturing Industries and Construction	216,14	192,33	215,24	223,29	224,80	222,33	228,10
3. Transport	2.349,52	2.016,16	1.213,27	1.120,65	1.070,83	981,51	969,62
4. Other Sectors	569,49	540,42	531,77	532,93	534,06	533,73	534,31
5. Other							
B. Fugitive Emissions from Fuels	3,54	2,83	3,08	3,29	3,20	3,24	3,14
1. Solid Fuels	2,55	1,94	2,15	2,25	2,18	2,26	2,18
2. Oil and Natural Gas	0,99	0,89	0,93	1,04	1,03	0,98	0,97
2. Industrial Processes	298,15	292,93	378,94	406,54	412,17	408,79	430,76
A. Mineral Products	0,00	0,00	0,00	0,00	0,00	0,00	0,00
B. Chemical Industry	8,46	8,64	7,54	7,59	7,55	7,68	7,56
C. Metal Production	289,69	284,30	371,40	398,95	404,61	401,10	423,20
D. Other Production		0,00	0,01	0,00			
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use							
4. Agriculture	412,73	398,49	462,19	378,38	280,11	359,60	359,60
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	412,73	398,49	462,19	378,38	280,11	359,60	359,60
G. Other							
5. Land Use Change and Forestry							
6. Waste	17,18	8,43	2,77	2,08	2,21	2,08	1,99
A. Solid Waste Disposal on Land	16,73	7,75	1,51	1,39	1,51	1,35	1,25
B. Wastewater Handling							
C. Waste Incineration	0,44	0,68	1,26	0,69	0,70	0,72	0,74
D. Other							
7. Other							

Table A6.10.– NMVOC emissions by sector (Figures in Gg)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	1.095,24	1.031,11	1.039,94	1.020,02	990,45	973,63	958,22
1. Energy	570,95	548,29	402,57	377,85	367,53	343,22	326,81
A. Fuel Combustion Activities	507,41	476,43	335,24	310,47	300,44	282,51	268,08
1. Energy Industries	8,96	8,04	9,22	9,77	10,26	9,98	9,94
2. Manufacturing Industries and Construction	17,25	17,32	32,05	33,97	35,87	36,20	37,07
3. Transport	422,39	393,05	234,08	206,51	193,47	175,02	159,41
4. Other Sectors	58,80	58,02	59,89	60,23	60,83	61,32	61,67
5. Other							
B. Fugitive Emissions from Fuels	63,54	71,86	67,33	67,38	67,09	60,70	58,72
1. Solid Fuels	0,50	0,38	0,42	0,44	0,42	0,44	0,43
2. Oil and Natural Gas	63,05	71,48	66,91	66,94	66,66	60,26	58,30
2. Industrial Processes	56,94	46,70	59,97	65,71	61,77	66,50	66,07
A. Mineral Products	11,67	0,01	0,01	0,01	0,01	0,01	0,01
B. Chemical Industry	11,39	13,99	16,09	15,30	14,57	14,42	14,25
C. Metal Production	1,58	1,68	2,17	2,37	2,33	2,37	2,41
D. Other Production	32,30	31,03	41,70	48,03	44,86	49,70	49,40
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use	395,64	364,36	491,85	502,94	501,98	491,95	492,70
4. Agriculture	57,89	55,89	64,82	53,07	39,28	50,43	50,43
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	57,89	55,89	64,82	53,07	39,28	50,43	50,43
G. Other							
5. Land Use Change and Forestry							
6. Waste	13,83	15,87	20,72	20,45	19,89	21,53	22,20
A. Solid Waste Disposal on Land	5,36	2,45	0,39	0,34	0,33	0,33	0,31
B. Wastewater Handling							
C. Waste Incineration	0,13	0,11	0,09	0,05	0,05	0,05	0,05
D. Other	8,34	13,30	20,24	20,06	19,51	21,15	21,85
7. Other							

Table A6.11.– SO₂ emissions by sector (Figures in Gg)

	1990	1995	2003	2004	2005	2006	2007
Total (Gross Emission)	2.166,84	1.781,91	1.266,80	1.309,89	1.265,93	1.161,52	1.156,03
1. Energy	2.146,82	1.763,54	1.249,56	1.293,71	1.250,35	1.144,92	1.139,58
A. Fuel Combustion Activities	2.082,30	1.688,38	1.207,87	1.251,92	1.210,14	1.111,51	1.111,02
1. Energy Industries	1.604,01	1.199,86	986,41	1.040,53	1.013,21	914,67	905,33
2. Manufacturing Industries and Construction	334,05	343,31	126,07	115,62	110,58	109,14	113,43
3. Transport	84,90	80,88	53,24	54,84	45,72	49,98	58,27
4. Other Sectors	59,34	64,33	42,16	40,93	40,63	37,73	34,00
5. Other							
B. Fugitive Emissions from Fuels	64,52	75,16	41,69	41,79	40,22	33,41	28,56
1. Solid Fuels	0,04	0,03	0,03	0,04	0,03	0,04	0,03
2. Oil and Natural Gas	64,48	75,13	41,65	41,75	40,18	33,37	28,52
2. Industrial Processes	14,40	13,54	12,04	11,99	12,42	12,60	12,45
A. Mineral Products							
B. Chemical Industry	9,76	8,88	6,09	5,75	6,09	6,35	6,27
C. Metal Production	4,27	4,24	5,48	5,74	5,83	5,78	5,76
D. Other Production	0,37	0,43	0,47	0,49	0,50	0,47	0,42
E. Production of Halocarbons and SF ₆							
F. Consumption of Halocarbons and SF ₆							
G. Other							
3. Solvents and Other Product Use							
4. Agriculture	4,41	4,26	4,94	4,04	2,99	3,84	3,84
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Wastes	4,41	4,26	4,94	4,04	2,99	3,84	3,84
G. Other							
5. Land Use Change and Forestry							
6. Waste	1,22	0,57	0,27	0,15	0,16	0,16	0,16
A. Solid Waste Disposal on Land	0,79	0,36	0,06	0,05	0,05	0,05	0,05
B. Wastewater Handling							
C. Waste Incineration	0,42	0,21	0,21	0,10	0,11	0,11	0,11
D. Other							
7. Other							

APPENDIX 7.- UNCERTAINTY ASSESSMENT

The results given in the Executive Summary chapter, in chapter 2 “Emission Trends” and in the sectorial chapters 3 to 8 refer to the estimations of central emission values for combinations of activities and pollutants. The aggregation of the emissions, weighted according to the global warming potentials of each gas considered, is reflected in the estimation of the central value for the overall emission of the inventory. The central value is, however, only an indicator of the level of the random variable that is the estimated emission of each pollutant source and gas. To characterize the accuracy of the estimation, it is useful to establish methods to determine the uncertainty of that estimation. The 2000 IPCC Good Practice Guidance offers two approaches to quantify the uncertainty of each activity and gas and to determine the uncertainty of the weighted emission of the inventory. The tier 1 approach, which has been adopted to estimate the uncertainty in this edition of the inventory, determines the uncertainty by using error propagation equations in two stages.

In the first stage, the uncertainty of the emission from a source category and gas is approximately estimated taking into account the fact that such emissions can be given as the result of an activity variable multiplied by an emission factor and then taking into account the combination of the uncertainties in these two factors as expressed in the following equation:

$$U_E = \sqrt{U_A^2 + U_F^2} \quad [A7.1]$$

where:

U_E represents the uncertainty associated with the emission

U_A represents the uncertainty associated with the activity variable

U_F represents the uncertainty associated with the emission factor

and where U_E , U_A and U_F express, in percentage terms, the ratios (uncertainty coefficients) whose numerator is half the 95% confidence interval of the variable considered and the denominator is the expected value of the variable.

In the second stage, the uncertainty of an aggregate is approximately estimated from the uncertainties of its components, activity sources by pollutant, making up the inventory. The uncertainty is therefore estimated in terms of level and in terms of trend (the difference

between emissions in the current year and reference year 90/95¹, hereinafter referred to as year 90/95) as expressed in equation [A7.2].

$$U_{E_{total}} = \frac{\sqrt{(U_{E_1} E_1)^2 + (U_{E_2} E_2)^2 + \dots + (U_{E_n} E_n)^2}}{E_1 + E_2 + \dots + E_n} \quad [A7.2]$$

where:

$U_{E_{total}}$ represents the uncertainty associated with total emissions

U_{E_i} represents the uncertainty associated with each component emission

E_i represents the expected value of each component emission

and where $U_{E_{total}}$ and U_{E_i} express, in percentage terms, the ratios (uncertainty coefficients) whose numerator is half the 95% confidence interval of the variable considered and the denominator is the expected value of the variable.

To estimate the uncertainty in the trend (the difference between emissions in the current year and the year 90/95), two types of sensitivity have been defined to evaluate these differences:

- Type A sensitivity.

This is the change in the difference in inventory emissions between the year 90/95 and the current year, expressed as a percentage, resulting from a 1% increase in emissions of a given source and gas in both the year 90/95 and the current year.

- Type B sensitivity.

This is the change in the difference in inventory emissions between the year 90/95 and the current year, expressed as a percentage, resulting from a 1% increase in emissions of a given source and gas in the current year only.

Conceptually, type A sensitivities arise from uncertainties that equally affect the year 90/95 and current year while type B sensitivities arise from uncertainties that only affect the current year. Uncertainties that are correlated between years are normally associated with Type A sensitivities while uncertainties that are not correlated between years are associated with Type B sensitivities. These two types of sensitivities imply simplifications for the correlation analysis. To make the algorithm work, it is assumed, by default, that the emission factor uncertainties correspond to type A sensitivities and are normally correlated between

¹ The term "reference year 90/95" corresponds to a hybrid year in which year 1995 of the current inventory edition is selected for fluorinated compounds and year 1990 is selected for the rest of the pollutants. The term "base year" is reserved for the reference year 90/95 of the 2006 edition, series 1990-2004, from the inventory edition verified in 2007 by the appointed team by the SCMCC. In this last edition an Assigned Amount was established, and it will be taken as reference to assess the compliance of Spain of its commitment with the Kyoto Protocol during the 2008-2012 period.

years, whereas activity variables correspond to type B sensitivities and are not correlated between years, unless otherwise mentioned as will be seen below in the application of the algorithm to this inventory. Once the emission uncertainties have been calculated according to each of the two types of sensitivity indicated above, these can be aggregated using the error propagation equation to give the overall uncertainty in the trend.

The calculation procedure takes place using a spreadsheet reproducing the concepts and formulas in columns A to M of Table 6.1, Section 6.3.2, of the aforementioned 2000 IPCC Good Practice Guidance.

To make the estimation procedure operative, data corresponding to the following columns must be introduced as primary information in the spreadsheet:

- A-B These show the source categories considered in the analysis (A) and the gas emitted (B), respectively. Source categories and gas are sorted by order of importance in the inventory of the reference year for the table. With relation to the base year and the year 90/95, 2005 and 2006 have been taken as reference years for this analysis as they are the most recent among those available, with the exception of 2007, which was not chosen as a part of the base information, such as the national fuel balance, as of the date the inventory was prepared, is still provisional.
- C Emissions by source category and gas, in terms of CO₂-equivalent, in the year 90/95. The data inserted here are the central values of the estimated emissions in the inventory for the base year, i.e. 1990 for CO₂, CH₄ and N₂O and 1995 for fluorinated gases.
- D Emissions by source category and gas, in terms of CO₂-equivalent, in 2005 and 2006. The data included here are the central values of estimated emissions in the inventory for 2005 and 2006. The information is presented in separate tables on the aforementioned appendix for each reference year, one for 2005 and the other for 2006.
- E Uncertainty associated with the activity variable, expressed as a percentage calculated from the uncertainty coefficient, a ratio whose numerator is half the 95% confidence interval of the variable considered and the denominator is the expected value of the variable.
- F Uncertainty associated with the emission factor, expressed as a percentage calculated from the uncertainty coefficient, a ratio whose numerator is half the 95% confidence interval of the emission factor considered and the denominator is the expected value of the emission factor.
- Y/N In this column, Y indicates those source categories where the activity variable is considered to be correlated between years and N indicates when there is no correlation of the activity variable between years. Therefore, source categories marked with a Y are the exception to type B sensitivities in activity variables.

The other columns of the table are calculated with the above information according to the formulas specified in the aforementioned Section 6.3.2 and Table 6.1 of the 2000 IPCC Good Practice Guidance.

With regard to the information inserted in columns E and F, brief general details of the main sources selected are given below (for more details see the sectorial chapters of this document: chapter 3 “Energy”; chapter 4 “Industrial Processes”; chapter 5 “Use of solvents and other products”; chapter 6 “Agriculture”; and chapter 8 “Waste”):

- As main references, the 1996 IPCC Reference Manual, the 2000 IPCC Good Practice Guidance and the 2006 IPCC Guide.
- The most realistic estimations considered by the inventory work team integrating data from another series of sources are the following:
 - With regard to fuel activity variables, information from the fuel balance variability analysis (supply vs. demand and statistical errors) and the individualized questionnaires to plants.
 - For CO₂ emission factors in combustion, from the variability analysis of the fuel's heating value and carbon content per energy unit or per unit of mass or volume. Also criteria have been introduced regarding the predictable uncertainty in oxidation coefficients, parameters for which some information has been obtained from experts from the energy sector. For CH₄ and N₂O factors in combustion, broad bands have been taken to cover the variability observed in the IPCC and the EMEP/CORINAIR Guide Book references for both stationary and mobile combustion.
 - For fugitive emissions from energy, the variability explained in the EMEP/CORINAIR Guide Book has also been taken into account besides the variability detailed in the IPCC references.
 - For emissions generated in industrial processes, information from the IPCC Guidelines has been complemented with information received by the inventory work team from sectorial experts and, if applicable, from individualized questionnaires to plants.
 - To determine the uncertainty of the activity variables and CH₄ and N₂O emission factors from agriculture, information available in the IPCC Guidelines and MAPA documents has been complemented with suppositions assumed by the inventory work team regarding uncertainty in the allocation of cattle management systems and agricultural practices.
 - To determine the uncertainty of the activity variables and CH₄ and N₂O emission factors from waste treatment, information available in the IPCC Guidelines has been complemented with suppositions assumed by the inventory work team regarding the uncertainty of waste management systems and relevant parameters in treatment processes.
 - For activity variables and emission factors in the production of fluorinated hydrocarbons (HFC-23 emissions as a sub-product of HCFC-22 manufacture), higher levels have been considered for the presumed accuracy in estimation procedures used by manufacturing plants. For both the activity variables and

HFC and PFC emission factors in the consumption of HFCs and SF₆, joint factors of 2 have been assumed given the lack of accuracy and coverage of some of the data sources used.

- For a wide set of activities and gases, information has been compared to data declared in the inventories of other countries from the European Union.

Tables A7.1 and A7.2 of this appendix show the estimation of the overall inventory uncertainty for 2005 and 2006 after following the tier 1 approach proposed in the 2000 IPCC Good Practice Guidance. The tables below reproduce the structure and formulas of Table 6.1 in that document.

It must be mentioned that the resulting overall uncertainty refers to total national greenhouse gas emissions, without accounting the amount of CO₂-eq collected in sinks nor the forest fires emissions, both included in the LULUCF sector. In the calculation, categories identified as key sources due to their level and/or trend have been analyzed individually for each corresponding year. All other emission sources have been dealt with as an aggregate in an additional category.

Table A7.1.– Uncertainty calculation for GHG emissions with the IPCC Tier 1 method – Year 2005

A		B	C	D			E	F	G
Key Sources (Year 2005)		Gas	Reference Year 90/95 Emissions (Gg CO ₂ -eq)	Year 2005 Emissions (Gg CO ₂ -eq)	Contribution Level 2005 (%)	Cumulative Level 2005 (%)	AD Uncertainty (%)	EF Uncertainty (%)	Combined Uncertainty (%)
IPCC Code	Description of IPCC Category								
1A1a	Public Electricity and Heat Production – Solid	CO ₂	57,787	75,996	17.2	17	2	4	4.5
1A3b	Road transportation - Diesel	CO ₂	24,436	69,417	15.7	33	5	2.2	5.5
1A2	Stationary combustion - Industry sector - Gaseous	CO ₂	8,439	37,877	8.6	42	5	1.5	5.2
1A4	Stationary combustion - Other sectors - Liquid	CO ₂	21,680	27,688	6.3	48	15	2.2	15.2
1A2	Stationary combustion - Industry sector - Liquid	CO ₂	24,520	27,368	6.2	54	10	3.2	10.5
1A3b	Road transportation - Gasoline	CO ₂	25,928	23,113	5.2	59	3	2.1	3.7
1A1a	Public Electricity and Heat Production – Solid	CO ₂	427	20,375	4.6	64	1.75	1.5	2.3
2A1	Cement production	CO ₂	12,534	17,141	3.9	68	1.5	8.3	8.4
4A	Enteric Fermentation in Domestic Livestock	CH ₄	11,780	13,486	3.1	71	3	11	11.4
1A1b	Petroleum refining-liquid	CO ₂	6,007	12,964	2.9	74	1.5	2	2.5
1A1a	Public Electricity and Heat Production - Liquid	CO ₂	10,861	11,622	2.6	76	3.5	2.7	4.4
1A4	Stationary combustion - Other sectors - Gaseous	CO ₂	1,319	10,839	2.5	79	5	1.5	5.2
4D1	Agricultural Soils - Direct Emissions	N ₂ O	10,106	9,522	2.2	81	18	400	400.4
6A	Waste Disposal on Land	CH ₄	4,742	9,211	2.1	83	30	70.4	76.5
4B	Manure management	CH ₄	6,231	8,846	2.0	85	3	11	11.4
4D3	Agricultural Soils - Indirect Emissions	N ₂ O	7,515	7,580	1.7	87	188	50	194.5
1A3a	Civil Aviation	CO ₂	4,130	6,854	1.6	88	35	5	35.4
1A2	Stationary combustion - Industry sector - Solid	CO ₂	13,238	5,099	1.2	90	5	15.1	15.9
2F	Consumption of halocarbons and sulphur hexafluoride	HFC&PFC	8	4,426	1.0	91	100	141	172.9
2-2A1-2A2-2A3-2C1	Other industrial processes	CO ₂	2,635	3,543	0.8	91	50	20	53.9
4B	Manure management	N ₂ O	2,465	3,025	0.7	92	16	100	101.3
1A3b	Road transportation	N ₂ O	679	2,613	0.6	93	10	50	51.0
1A3d	National navigation	CO ₂	1,500	2,513	0.6	93	50	3.2	50.1
2C1	Iron and steel production	CO ₂	2,491	2,298	0.5	94	3	4.9	5.7
2A3	Limestone and dolomite use	CO ₂	1,220	2,293	0.5	94	10	2	10.2
1B2	Fugitive emissions related to oil and natural gas	CO ₂	1,760	2,152	0.5	95	10	25	26.9
6B	Waste-water Handling	CH ₄	1,240	2,142	0.5	95	200	100	223.6
2E1	HFC-23 emissions in HCFC-22 manufacturing	HFC	4,638	334	0.1	95	15	20	25.0
1A4	Stationary combustion - Other sectors - Solid	CO ₂	2,282	552	0.1	95	20	15.1	25.1
2B2	Nitric acid production	N ₂ O	2,884	1,860	0.4	96	2	10	10.2
1A1c	Stationary combustion - Manufacture of solid fuels and other - Solid	CO ₂	1,847	943	0.2	96	5	5	7.1
1B1	Fugitive emissions related to solid fuels	CH ₄	1,818	939	0.2	96	5	40	40.3
1A1b	Petroleum Refining - Gaseous	CO ₂	45	1,470	0.3	97	3.5	3	4.6
2C3	Aluminium production	PFC	832	143	0.0	97	1	20	20.0
***	Other Emission Sources	***	10,344	14,907	3.4	100	100	100	141.4
Total gross emissions			290,368	441,150					

(*): In category 2E1 for HFC, the uncertainties given for the activity variable and emission factor are percentages derived from the uncertainty assigned to HFC-23 emissions, the base information in this category.

Table A7.1.– Uncertainty calculation for GHG emissions with the IPCC Tier 1 method – Year 2005 (Continued)

A		B	H	YN	I	J	K	L	M
Key Sources (Year 2005)		Gas	Combined Uncertainty (% Total Emissions 2005)	AD Correlated Between Years(Y/N)	Type A Sensibility	Type B Sensibility	Uncertainty in Trend by EF Uncertainty (%)	Uncertainty in Trend by AD Uncertainty (%)	Uncertainty in Trend (%)
IPCC Code	Description of IPCC Category								
1A1a	Public Electricity and Heat Production - Solid	CO ₂	0.8	N	-0.041	0.262	-0.16	0.74	0.76
1A3b	Road transportation – Diesel	CO ₂	0.9	N	0.111	0.239	0.24	1.69	1.71
1A2	Stationary combustion - Industry sector - Gaseous	CO ₂	0.4	N	0.086	0.130	0.13	0.92	0.93
1A4	Stationary combustion - Other sectors - Liquid	CO ₂	1.0	N	-0.018	0.095	-0.04	2.02	2.02
1A2	Stationary combustion - Industry sector - Liquid	CO ₂	0.7	N	-0.034	0.094	-0.11	1.33	1.34
1A3b	Road transportation – Gasoline	CO ₂	0.2	N	-0.056	0.080	-0.12	0.34	0.36
1A1a	Public Electricity and Heat Production – Gaseous	CO ₂	0.1	N	0.068	0.070	0.10	0.17	0.20
2A1	Cement production	CO ₂	0.3	N	-0.007	0.059	-0.05	0.13	0.14
4A	Enteric Fermentation in Domestic Livestock	CH ₄	0.3	N	-0.015	0.046	-0.17	0.20	0.26
1A1a	Public Electricity and Heat Production - Liquid	CO ₂	0.1	N	0.013	0.045	0.03	0.09	0.10
1A1b	Petroleum refining-liquid	CO ₂	0.1	N	-0.017	0.040	-0.05	0.20	0.20
1A4	Stationary combustion - Other sectors - Gaseous	CO ₂	0.1	N	0.030	0.037	0.05	0.26	0.27
4D1	Agricultural Soils - Direct Emissions	N ₂ O	8.6	N	-0.020	0.033	-8.03	0.83	8.07
6A	Waste Disposal on Land	CH ₄	1.6	S	0.007	0.032	0.49	0.21	0.53
4B	Manure management	CH ₄	0.2	S	-0.002	0.030	-0.02	-0.01	0.02
4D3	Agricultural Soils - Indirect Emissions	N ₂ O	3.3	S	-0.013	0.026	-0.66	-2.48	2.57
1A3a	Civil Aviation	CO ₂	0.5	N	0.002	0.024	0.01	1.17	1.17
1A2	Stationary combustion - Industry sector - Solid	CO ₂	0.2	N	-0.052	0.018	-0.78	0.12	0.79
2F	Consumption of halocarbons and sulphur hexafluoride	HFC&PFC	1.7	S	0.015	0.015	2.14	1.52	2.63
2-2A1-2A2-2A3-2C1	Other industrial processes	CO ₂	0.4	N	-0.002	0.012	-0.03	0.86	0.86
4B	Manure management	N ₂ O	0.7	S	-0.002	0.010	-0.25	-0.04	0.25
1A3b	Road transportation	N ₂ O	0.3	N	0.005	0.009	0.27	0.13	0.30
1A3d	National navigation	CO ₂	0.3	N	0.001	0.009	0.00	0.61	0.61
2C1	Iron and steel production	CO ₂	0.0	N	-0.005	0.008	-0.03	0.03	0.04
2A3	Limestone and dolomite use	CO ₂	0.1	N	0.002	0.008	0.00	0.11	0.11
1B2	Fugitive emissions related to oil and natural gas	CO ₂	0.1	N	-0.002	0.007	-0.04	0.10	0.11
6B	Waste-water Handling	CH ₄	1.1	N	0.001	0.007	0.09	2.09	2.09
2E1	HFC-23 emissions in HCFC-22 manufacturing	HFC	0.0	N	-0.023	0.001	-0.46	0.02	0.46
1A4	Stationary combustion - Other sectors - Solid	CO ₂	0.0	N	-0.010	0.002	-0.15	0.05	0.16
2B2	Nitric acid production	N ₂ O	0.0	N	-0.009	0.006	-0.09	0.02	0.09
1A1c	Stationary combustion - Manufacture of solid fuels and other - Solid	CO ₂	0.0	N	-0.006	0.003	-0.03	0.02	0.04
1B1	Fugitive emissions related to solid fuels	CH ₄	0.1	N	-0.006	0.003	-0.25	0.02	0.25
1A1b	Petroleum Refining - Gaseous	CO ₂	0.0	N	0.005	0.005	0.01	0.03	0.03
2C3	Aluminium Production	PFC	0.0	N	-0.004	0.000	-0.08	0.00	0.08
***	Other Emission Sources	***	4.8	N	-0.003	0.051	-0.28	7.26	7.27
Uncertainty in total emissions			10.9	Trend uncertainty (differences year 2005 and “reference year 90/95”):					12.3
				Trend uncertainty (% regarding the central estimated value for “reference year 90/95”):					6.4

Table A7.2. – Uncertainty calculation for GHG emissions with the IPCC Tier 1 method – Year 2006

A		B	C	D			E	F	G
Key Sources (Year 2005)		Gas	Reference Year 90/95 Emissions (Gg CO ₂ -eq)	Year 2006 Emissions (Gg CO ₂ -eq)	Contribution Level 2006 (%)	Cumulative Level 2006 (%)	AD Uncertainty (%)	EF Uncertainty (%)	Combined Uncertainty (%)
IPCC Code	Description of IPCC Category								
1A3b	Road transportation - Diesel	CO ₂	24,436	72,962	16.8	17	5	2.2	5.5
1A1a	Public Electricity and Heat Production - Solid	CO ₂	57,787	65,583	15.1	32	2	4	4.5
1A2	Stationary combustion - Industry sector - Gaseous	CO ₂	8,439	37,139	8.6	41	5	1.5	5.2
1A2	Stationary combustion - Industry sector - Liquid	CO ₂	24,520	26,743	6.2	47	10	3.2	10.5
1A4	Stationary combustion - Other sectors - Liquid	CO ₂	21,680	25,875	6.0	53	15	2.2	15.2
1A1a	Public Electricity and Heat Production - Gaseous	CO ₂	427	23,857	5.5	58	1.75	1.5	2.3
1A3b	Road transportation - Gasoline	CO ₂	25,928	22,054	5.1	63	3	2.1	3.7
2A1	Cement production	CO ₂	12,534	17,322	4.0	67	1.5	8.3	8.4
4A	Enteric Fermentation in Domestic Livestock	CH ₄	11,780	13,332	3.1	70	3	11	11.4
1A1b	Petroleum refining-liquid	CO ₂	10,861	11,683	2.7	73	3.5	2.7	4.4
1A1a	Public Electricity and Heat Production - Liquid	CO ₂	6,007	11,293	2.6	76	1.5	2	2.5
1A4	Stationary combustion - Other sectors - Gaseous	CO ₂	1,319	10,378	2.4	78	5	1.5	5.2
4D1	Agricultural Soils - Direct Emissions	N ₂ O	10,106	9,885	2.3	80	18	400	400.4
6A	Waste Disposal on Land	CH ₄	4,742	9,491	2.2	83	30	70.4	76.5
4B	Manure management	CH ₄	6,231	9,413	2.2	85	3	11	11.4
4D3	Agricultural Soils - Indirect Emissions	N ₂ O	7,515	7,774	1.8	87	188	50	194.5
1A3a	Civil Aviation	CO ₂	4,130	7,204	1.7	88	35	5	35.4
2F	Consumption of halocarbons and sulphur hexafluoride	HFC&PFC	8	4,799	1.1	89	100	141	172.9
1A2	Stationary combustion - Industry sector - Solid	CO ₂	13,238	4,683	1.1	90	5	15.1	15.9
2-2A1-2A2-2A3-2C1	Other industrial processes	CO ₂	2,635	3,488	0.8	91	50	20	53.9
4B	Manure management	N ₂ O	2,465	2,943	0.7	92	16	100	101.3
1A3d	National navigation	CO ₂	1,500	2,763	0.6	93	50	3.2	50.1
1A3b	Road transportation	N ₂ O	679	2,743	0.6	93	10	50	51.0
2A3	Limestone and dolomite use	CO ₂	1,220	2,473	0.6	94	10	2	10.2
2C1	Iron and steel production	CO ₂	2,491	2,353	0.5	94	3	4.9	5.7
1B2	Fugitive emissions related to oil and natural gas	CO ₂	1,760	2,280	0.5	95	10	25	26.9
6B	Waste-water Handling	CH ₄	1,240	2,210	0.5	95	200	100	223.6
2E1	HFC-23 emissions in HCFC-22 manufacturing	HFC	4,638	517	0.1	95	15	20	25.0
1A4	Stationary combustion - Other sectors - Solid	CO ₂	2,282	545	0.1	96	20	15.1	25.1
2B2	Nitric acid production	N ₂ O	2,884	1,555	0.4	96	2	10	10.2
1A1c	Stationary combustion - Manufacture of solid fuels and other - Solid	CO ₂	1,847	888	0.2	96	5	5	7.1
1B1	Fugitive emissions related to solid fuels	CH ₄	1,818	930	0.2	96	5	40	40.3
1A1b	Petroleum Refining - Gaseous	CO ₂	45	1,232	0.3	97	3.5	3	4.6
2C3	Aluminium production	PFC	832	134	0.0	97	1	20	20.0
***	Other Emission Sources	***	10,344	14,544	3.4	100	100	100	141.4
Total gross emissions			290,368	433,070					

(*) In category 2E1 for HFC, the uncertainties given for the activity variable and emission factor are percentages derived from the uncertainty assigned to HFC-23 emissions, the base information in this category.

Table A7.2. - Uncertainty calculation for GHG emissions with the IPCC Tier 1 method – Year 2006 (Continued)

A		B	H	YN	I	J	K	L	M
Key Sources (Year 2006)		Gas	Combined Uncertainty (% Total Emissions 2006)	AD Correlated Between Years (Y/N)	Type A Sensibility	Type B Sensibility	Uncertainty in Trend by EF Uncertainty (%)	Uncertainty in Trend by AD Uncertainty (%)	Uncertainty in Trend (%)
IPCC Code	Description of IPCC Category								
1A3b	Road transportation - Diesel	CO ₂	0.9	N	0.126	0.251	0.28	1.78	1.80
1A1a	Public Electricity and Heat Production - Solid	CO ₂	0.7	N	-0.071	0.226	-0.28	0.64	0.70
1A2	Stationary combustion - Industry sector - Gaseous	CO ₂	0.4	N	0.085	0.128	0.13	0.90	0.91
1A2	Stationary combustion - Industry sector - Liquid	CO ₂	0.6	N	-0.034	0.092	-0.11	1.30	1.31
1A4	Stationary combustion - Other sectors - Liquid	CO ₂	0.9	N	-0.022	0.089	-0.05	1.89	1.89
1A1a	Public Electricity and Heat Production - Gaseous	CO ₂	0.1	N	0.080	0.082	0.12	0.20	0.24
1A3b	Road transportation - Gasoline	CO ₂	0.2	N	-0.057	0.076	-0.12	0.32	0.34
2A1	Cement production	CO ₂	0.3	N	-0.005	0.060	-0.04	0.13	0.13
4A	Enteric Fermentation in Domestic Livestock	CH ₄	0.4	N	-0.015	0.046	-0.16	0.19	0.25
1A1b	Petroleum refining-liquid	CO ₂	0.1	N	-0.016	0.040	-0.04	0.20	0.20
1A1a	Public Electricity and Heat Production - Liquid	CO ₂	0.1	N	0.008	0.039	0.02	0.08	0.08
1A4	Stationary combustion - Other sectors - Gaseous	CO ₂	0.1	N	0.029	0.036	0.04	0.25	0.26
4D1	Agricultural Soils - Direct Emissions	N ₂ O	9.1	N	-0.018	0.034	-7.14	0.87	7.20
6A	Waste Disposal on Land	CH ₄	1.7	S	0.008	0.033	0.59	0.25	0.64
4B	Manure management	CH ₄	0.2	S	0.000	0.032	0.00	0.00	0.00
4D3	Agricultural Soils - Indirect Emissions	N ₂ O	3.5	S	-0.012	0.027	-0.59	-2.22	2.30
1A3a	Civil Aviation	CO ₂	0.6	N	0.004	0.025	0.02	1.23	1.23
2F	Consumption of halocarbons and sulphur hexafluoride	HFC&PFC	1.9	S	0.016	0.017	2.32	1.65	2.85
1A2	Stationary combustion - Industry sector - Solid	CO ₂	0.2	N	-0.052	0.016	-0.78	0.11	0.79
2-2A1-2A2-2A3-2C1	Other industrial processes	CO ₂	0.4	N	-0.002	0.012	-0.03	0.85	0.85
4B	Manure management	N ₂ O	0.7	S	-0.003	0.010	-0.25	-0.04	0.26
1A3d	National navigation	CO ₂	0.3	N	0.002	0.010	0.01	0.67	0.67
1A3b	Road transportation	N ₂ O	0.3	N	0.006	0.009	0.30	0.13	0.33
2A3	Limestone and dolomite use	CO ₂	0.1	N	0.002	0.009	0.00	0.12	0.12
2C1	Iron and steel production	CO ₂	0.0	N	-0.005	0.008	-0.02	0.03	0.04
1B2	Fugitive emissions related to oil and natural gas	CO ₂	0.1	N	-0.001	0.008	-0.03	0.11	0.11
6B	Waste-water Handling	CH ₄	1.1	N	0.001	0.008	0.12	2.15	2.16
2E1	HFC-23 emissions in HCFC-22 manufacturing	HFC	0.0	N	-0.022	0.002	-0.44	0.04	0.44
1A4	Stationary combustion - Other sectors - Solid	CO ₂	0.0	N	-0.010	0.002	-0.15	0.05	0.16
2B2	Nitric acid production	N ₂ O	0.0	N	-0.009	0.005	-0.09	0.02	0.10
1A1c	Stationary combustion - Manufacture of solid fuels and other - Solid	CO ₂	0.0	N	-0.006	0.003	-0.03	0.02	0.04
1B1	Fugitive emissions related to solid fuels	CH ₄	0.1	N	-0.006	0.003	-0.25	0.02	0.25
1A1b	Petroleum Refining - Gaseous	CO ₂	0.0	N	0.004	0.004	0.01	0.02	0.02
2C3	Aluminium production	PFC	0.0	N	-0.004	0.000	-0.08	0.00	0.08
***	Other Emission Sources	***	4.7	N	-0.003	0.050	-0.30	7.08	7.09
Uncertainty in total emissions			11.4	Trend uncertainty (differences year 2006 and "reference year 90/05"):					11.6
				Trend uncertainty (% regarding the central estimated value for "reference year 90/95") :					5.7

APPENDIX 8.- INVENTORY REFERENCE FOR APPLICATION OF THE EMISSIONS TRADING DIRECTIVE

This appendix presents the documentation regarding CO₂ emission factors and lower heating values (LHV) of fuels that has been considered in the 1990-2007 edition of the national inventory when more accurate specific information has not been available.

Table A8.1.– Default CO₂ emission factors and heating values for the 2007 inventory

Fuel	CO ₂ Emission Factor (tCO ₂ /TJ) Oxidation Factor Not Included	Oxidation Factor	CO ₂ Emission Factor (tCO ₂ /TJ) Oxidation Factor Included	Lower Heat Value (LHV)	
				GJ _{LHV} /Unit	GJ _{LHV} /Unit
Natural Gas (2) (3)	56.3	0.995	56	38.35	thousands m ³ N
Residual Oil (4)	76.8	0.99	76	40.18	tonnes
Diesel	73.7	0.99	73	42.4	tonnes
Generic LPG	65.7	0.99	65	45.5	tonnes
Propane	64.2	0.99	63.6	46.2	tonnes
Butane	66.9	0.99	66.2	44.78	tonnes

(1) The LHV can also be expressed in relation to mass, with a value of 48.48 GJ / tonne

(2) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

(3) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

Table A8.2.– Commission Decision 2004/156/EC. Monitoring and reporting guidelines

Fuel	CO ₂ emission factor (tCO ₂ /TJ) Level 1	Emission factor source	Oxidation factor Decision 2004/156/CE Level 1	CO ₂ emission factor (tCO ₂ /TJ) including oxidation factor
A) Liquid Fossil Fuels				
<i>Primary Fuels</i>				
Crude Oil	73.3	IPCC 1996 (1)	0.995	72.9
Orimulsion	80.7	IPCC 1996	0.995	80.3
Natural Gas Liquids	63.1	IPCC 1996	0.995	62.8
<i>Secondary Fuel/Products</i>				
Gasoline	69.3	PCC 1996	0.995	69.0
Kerosene (2)	71.9	IPCC 1996	0.995	71.5
Shale Oil	77.4	National Communication Estonia, 2002	0.995	77.0
Gas/Diesel Oil	74.1	IPCC 1996	0.995	73.7
Residual Fuel Oil	77.4	IPCC 1996	0.995	77.0
LPG	63.1	IPCC 1996	0.995	62.8
Ethane	61.6	IPCC 1996	0.995	61.3
Naphtha	73.3	IPCC 1996	0.995	72.9
Bitumen	80.7	IPCC 1996	0.995	80.3
Lubricants	73.3	IPCC 1996	0.995	72.9
Petroleum Coke	100.8	IPCC 1996	0.995	100.3
Refinery Feedstock	73.3	IPCC 1996	0.995	72.9
Other Oil	73.3	IPCC 1996	0.995	72.9
B) Solid Fossil Fuels				
<i>Primary Fuels</i>				
Anthracite	98.3	IPCC 1996	0.99	97.3
Coking coal	94.6	IPCC 1996	0.99	93.7
Other bituminous coal	94.6	IPCC 1996	0.99	93.7
Sub-bituminous coal	96.1	IPCC 1996	0.99	95.1
Lignite	101.2	IPCC 1996	0.99	100.2
Oil Shale	106.7	IPCC 1996	0.99	105.6
Peat	106	IPCC 1996	0.99	104.9
<i>Secondary Fuels</i>				
BKB & Patent Fuels	94.6	IPCC 1996	0.99	93.7
Coke Oven / Gas Coke	108.2	IPCC 1996	0.99	107.1
C) Gaseous Fossil				
Carbon Monoxide	155.2	Based on a NCV of 10,12 TJ/t (3)	0.995	154.4
Natural Gas (Dry)	56.1	IPCC 1996	0.995	55.8
Methane	54.9	Based on a NCV of 50,01 TJ/t (3)	0.995	54.6
Hydrogen	0	Substance without Carbon	0.995	0.0

(1) Revised 1996 IPCC guidelines for National Greenhouse Gas Inventories: Reference Manual, 1.13.

(2) Kerosene, excluding aviation kerosene.

(3) J. Falbe and M.Regitz, Römpp CEIME Lexikon, Stuttgart, 1995.

Table A8.3.– Sector: Iron and steel industry

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Anthracite (2)	98.3	0.98	96.3	30.26
Coking Coal (2)	93.7	0.98	91.8	28.4
Coke (3)	107.1	0.98	105	30.3
Petroleum Coke	99.3	0.99	98.3	32.5
Residual Oil (4)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (5) (6)	56.3	0.995	56	48.48
Generic LPG	65.7	0.99	65	45.5
Propane	64.2	0.99	63.6	46.2
Butane	66.9	0.99	66.2	44.78
Coke Oven Gas (7)	-	0.995	-	-
Blast Furnace Gas (7)	-	0.995	-	-
Steel Plant Gas (LD) (7)	-	0.995	-	-
Refinery Gas (8)	54.4	0.995	54.1	48.3

(1) Emission factor without oxidation factor.

(2) Variable values depending on characteristics. The value used in 2002 has been maintained

(3) Mean values obtained from the analysis of LPS in the 2007 Inventory (integrated iron and steel)

(4) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(5) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(6) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

(7) Specific plant and year values

(8) Value calculated on the basis of data provided by supplying refineries.

Table A8.4.– Sector: Cement

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor (1)	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Domestic coal (2)	114.3	0.98	112	20.51
Imported coal (2)	101.0	0.98	99	25.53
Petroleum Coke	99.3	0.99	98.3	32.5
Residual Oil (3)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (4) (5)	56.3	0.995	56	48.48
Generic LPG	65.7	0.99	65	45.5
Propane	64.2	0.99	63.6	46.2
Butane	66.9	0.99	66.2	44.78
Tyres	83.7	0.98	82	31.39
Waste Oil	73.7	0.99	73	40.19
Solvents	83.8	0.99	83	33.27

(1) Emission factor without oxidation factor.

(2) These data have been taken from mean values obtained from the analysis of the LPS in the Inventory (thermal power plants), due to the lack of information on the specific characteristics of domestic coals consumed in the sector.

(3) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(4) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(5) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

Table A8.5.– Sector: Lime

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Anthracite	100.3	0.98	98.3	28.646
Coke Oven Coke	110.3	0.98	108.09	36.819
Petroleum Coke	101.8	0.99	100.76	35.564
Residual Oil (2)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (3) (4)	56.3	0.995	56	48.48

Values indicated in the above table are default values when no specific information is available for the fuel with regard to lower heating value (LHV) or carbon content of the fuel.

(1) Emission factor without oxidation factor.

(2) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(3) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(4) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

Table A8.6.– Sector: Glass

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Coke Oven Coke (2)	107.1	0.98	105	30.3
Residual Oil (3)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (4) (5)	56.3	0.995	56	48.48
Generic LPG	65.7	0.99	65	45.5
Propane	64.2	0.99	63.6	46.2
Butane	66.9	0.99	66.2	44.78

(1) Emission factor without oxidation factor.

(2) These data have been taken from mean values obtained from the analysis of the LPS in the Inventory (integrated iron and steel plants), due to the lack of information on the specific characteristics of coke consumed in the sector. Nevertheless, this should be revised when specific information is available from plants in the sector.

(3) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(4) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(5) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

Table A8.7.– Sector: Glass frits

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Residual Oil (2)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (3) (4)	56.3	0.995	56	48.48
Generic LPG	65.7	0.99	65	45.5
Propane	64.2	0.99	63.6	46.2
Butane	66.9	0.99	66.2	44.78

(1) Emission factor without oxidation factor.

(2) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(3) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(4) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

Table A8.8.– Sector: Bricks and roof tiles

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Petroleum Coke (2)	99.3	0.99	98.3	32.5
Residual Oil (3)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (4) (5)	56.3	0.995	56	48.48

(1) Emission factor without oxidation factor.

(2) These data have been taken from mean values obtained from information provided by OFICEMEN, the main sector consuming this fuel

(3) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(4) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(5) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

Table A8.9.– Sector: Floor and wall tiles

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Residual Oil (2)	76.8	0.99	76	40.18
Natural Gas (3) (4)	56.3	0.995	56	48.48
Generic LPG	65.7	0.99	65	45.5
Propane	64.2	0.99	63.6	46.2
Butane	66.9	0.99	66.2	44.78

(1) Emission factor without oxidation factor.

(2) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(3) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(4) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

Table A8.10.– Sector: Paper pulp, paper and card

Fuel	Gross Emission Factor (1) (kg CO ₂ /GJ _{PCI})	Oxidation Factor	Emission Factor (kg CO ₂ /GJ _{PCI})	NCV (GJ/t)
Steam Coal (2)	-	-	-	-
Sub-bituminous coal (2)	-	-	-	-
Petroleum Coke (2)	-	-	-	-
Residual Oil (3)	76.8	0.99	76	40.18
Gas/Diesel Oil	73.7	0.99	73	42.4
Natural Gas (4) (5)	56.3	0.995	56	48.48
Generic LPG	65.7	0.99	65	45.5
Propane	64.2	0.99	63.6	46.2
Butane	66.9	0.99	66.2	44.78

(1) Emission factor without oxidation factor.

(2) Specific values corresponding to the manufacturing centres using these fuels

(3) The limitation on the percentage of sulphur as per Royal Decree 287/2001 means that no distinction is made between low sulphur content fuel oils N° 1 and N° 2

(4) The LHV can also be expressed in relation to the volume, with a value of 38.35 GJ / thousands m³N

(5) To convert UHV to LHV in natural gas, the conversion factor of 0.901 is used

