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Ministério da Agricultura, do Mar,
do Ambiente e do Ordenamento do Território

**PORTUGUESE NATIONAL INVENTORY REPORT
ON GREENHOUSE GASES, 1990 - 2010**

**SUBMITTED UNDER THE UNITED NATIONS FRAMEWORK
CONVENTION ON CLIMATE CHANGE AND THE KYOTO
PROTOCOL**

Amadora

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Lead Authors

Hugo Maciel	Energy Agriculture
Teresa Costa Pereira	General Chapters Land Use, Land UseChange and Forestry Waste
Tiago Seabra	Energy Industrial Processes
Pedro Torres	Transports Solvents and Other Product Use

Contributing Authors

Paulo Canaveira	Land Use, Land UseChange and Forestry
Inês Mourão	Land Use, Land UseChange and Forestry

To obtain a copy of this report, the Common Reporting Format (CRF) tables or any other information concerning methodologies, activity data or emission factors, and also to send comments and suggestions, please contact:

Agência Portuguesa do Ambiente
Departamento de Alterações Climáticas, Ar e Ruído
Rua da Murgueira-Zambujal
2720-865 Amadora – PORTUGAL
tel:+351 21 472 14 60 fax:+351 21 471 83 82
e-mail: geral@apambiente.pt
<http://www.apambiente.pt>

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DGEG – Direcção Geral de Energia e Geologia: Luisa Basílio

Direcção Regional do Ambiente – Madeira: Henrique Santos Rodrigues

Direcção Regional do Ambiente – Açores: Sónia Santos

EDP Distribuição: Carlos Rochinha

EDP Produção: Nélia Soares

Gabinete de Planeamento, Estratégia e Relações Internacionais/ ex-MOPTC: Ana Rita Cabana, Margarida Roxo

GPP - Gabinete de Planeamento e Políticas/ ex-MADRP: Teresa Avelar, José Paulino, Ana Pina

IFAP - Instituto de Financiamento da Agricultura e Pescas: Rita Araújo

IGP - Instituto Geográfico Português: João Geirinhas, Alexandra Fonseca

INAG - Instituto da Água: Fernanda Gomes, Simone Martins

INE - Instituto Nacional de Estatística: Carlos Carvalho

INRB,I.P. – Instituto Nacional de Recursos Biológicos: Rui Fernandes

ISA – Instituto Superior de Agronomia: Margarida Tomé

IST - Instituto Superior Técnico: Tiago Domingos, Helena Martins

REN: Rui Vicente Martins

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Preface

The Portuguese Environmental Agency (*Agência Portuguesa do Ambiente*)/ Ministry for Agriculture, Sea, Environment and Land Use Planning (*Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território* - MAMAOT), in accordance to its attributions as national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions, has prepared the National Inventory of Greenhouse Gas (GHGs) Emissions and Sinks to comply with international commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the European Commission.

The Conference of Parties to the UNFCCC and the Council Decision 280/2004/EC, concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, define that each Party should provide each year an update of its inventory of emissions and removals of Greenhouse Gases (GHG) not controlled by the Montreal Protocol, taking into account the UNFCCC Reporting Guidelines on Annual Inventories. This includes a report on annual emissions estimates (CRF tables), accompanied by a National Inventory Report (NIR), describing the input data, methodologies, background information and explanation on the whole process of inventory preparation. The report describes all formulas used for calculation of emissions, and is an important piece in the process of consultation with sectoral experts in the National System, as well as people who want to learn and get a general view of the methods and data used in the Portuguese inventories.

The 2012 NIR objective is to present a general overview of the inventory, overall results for 2010 and trends since 1990. More detailed information about emissions, activity data and emission factors are presented in the CRF tables that are also part of the 2012 Portuguese Submission on GHG emissions.

As a Party to the Kyoto Protocol, Portugal is also obliged to submit information under Article 5, paragraphs 1 and 2, and Article 7, paragraphs 1 and 4 of the Kyoto Protocol. This report aims also to fulfil these commitments.

Accordingly the Portuguese submission under the UNFCCC and the European mechanism for monitoring Community GHG emissions includes three parts:

- 1 – National Inventory Report (the present report);
- 2 – CRF (Common Reporting Format) data tables for the period 1990-2010, and KP-LULUCF for the years 1990, 2008-2010, which were compiled with the CRF Reporter software (version 3.5.2);
- 3 – SEF (Standard Electronic Tables) for the reporting of Kyoto units in the national registry in 31.12.2011 and transfers of units during 2011.

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EXECUTIVE SUMMARY

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

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, Portugal is requested to provide each year an update of its inventory of emissions and removals of greenhouse gas not controlled by the Montreal Protocol. As a member of the European Union, the country is also required to report emission inventories data under the mechanism for monitoring European Community greenhouse gas emissions and for implementing the Kyoto Protocol (EU monitoring mechanism, Decision 280/2004/EC of the European Parliament and the Council).

This report aims to comply with the above-mentioned international commitments under the UNFCCC and the European Commission (EU), taking into account the adopted Reporting Guidelines on Annual Inventories (FCCC/SBSTA/2004/8) and the requirements of Decision 280/2004/EC.

The NIR presents a description of the methods, assumptions and background data used in the preparation of the 2012 national inventory submission of GHG. The Revised (1996) IPCC Guidelines for National Greenhouse Gas Inventories (IPCC,1997), the 2006 IPCC Guidelines (2006, IPCC), and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC,2000) have been applied as far as possible. The present report however is a shorter version of a document to be provided later in the year and aims to present the main general chapters of the report, as required by Decision 280/2004/EC.

The GHG emission inventory includes estimates for the six gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF₆), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x). The period covered is 1990-2010.

The inventory covers the whole Portuguese territory, i.e., mainland Portugal and the two Autonomous regions of Madeira and Azores Islands. Included are also the emission estimates from air traffic and navigation realized between all national areas.

Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for all years in the period from 1990 to 2010, i.e., the inventory is internally consistent.

The information is structured according to the following source sectors: energy production and transformation, combustion in industry, domestic, agriculture, fisheries, institutional and commerce sectors, transportation (road, rail, maritime and air), industrial production and use of solvents, waste production (urban, industrial and hospitals solid wastes, and domestic and industrial waste water treatment), agriculture and animal husbandry emissions, as well as emissions and sinks from forestry.

This report includes also supplementary information in accordance with Article 7, paragraph 1, of the Kyoto Protocol, following the requirements of the Annex of Decision 15/CMP.1 and

includes information on changes in the national system and nations registry, information related to Article 3, paragraphs 3 and 4, and Article 3, paragraph 14. It also presents information on the accounting of Kyoto units, including the Standard Electronic Tables (SEF).

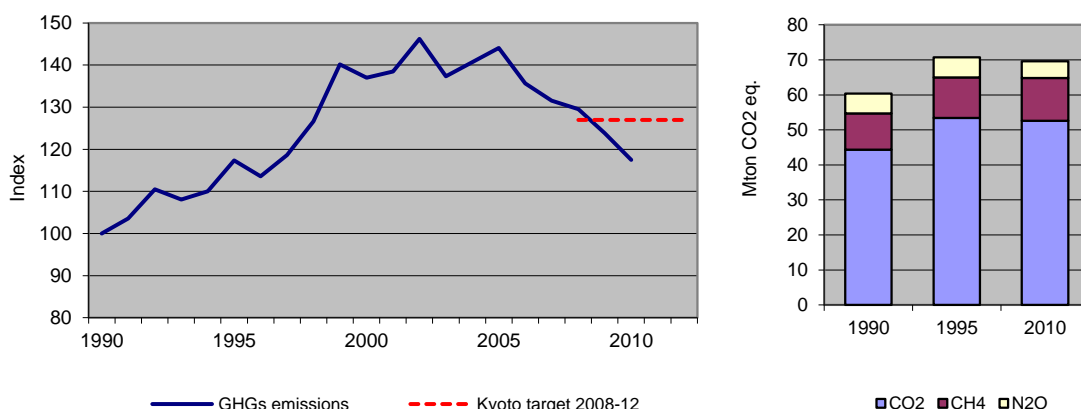
The Portuguese Environmental Agency (APA)/ Ministry for Agriculture, Sea, Environment and Land Use Planning (MAMAOT), is the national entity responsible for the overall coordination and updating of the National Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants (INERPA) and the coordination of the national system that was established through Council of Ministers Resolution 68/2005, of 17 March.

ES.2 Summary of national emissions and removal related trends

ES.2.1 Greenhouse Gas Inventory – UNFCCC

In 2010, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated at about 70.6 Mt CO₂e, representing an increase of 17.5 per cent compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27% compared to the 1990 level.

Figure ES. 1 – GHG emissions (without LULUCF)



After a steady increase of the Portuguese emissions during the 90s, the growth of emissions has been more moderate and started to stagnate in the early 2000s, registering thereafter, in particular after 2005, a decrease. These trends reflect largely the evolution of the Portuguese economy which was characterized by a strong growth associated to the increase of energy demand and mobility in the 90's, and to the more recent situation of stagnation or even recession in the Portuguese economy.

In most recent years, however, this relationship started to change and a decoupling of the emissions growth from the economic activity can be observed.

This situation is in part consequence of the implementation of some measures, such as the introduction of natural gas (1997), the installation of combined cycle thermoelectric plants using natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial processes, the improvement in car efficiency and the improvement of fuels quality. Furthermore, in most recent years there has been an

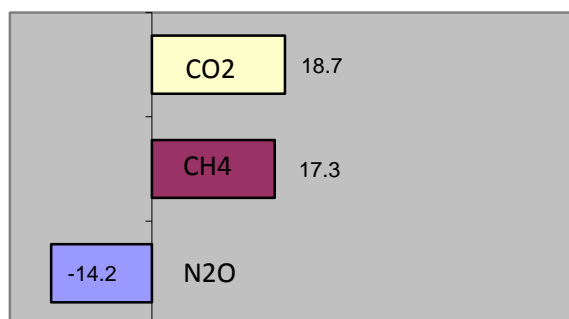
expressive development and installation of equipments for the use of renewable energy sources with a particular expansion of windmills.

The trends of the most recent years have however been strongly influenced by the slowdown in industrial activity and consequent reduction in fuel consumption, and the cessation of some activities in the country such as the production of ammonia in 2009 with the relocation of the production facilities to India. Another fact to note is the introduction of the use of high-performance catalysts and optimization of the ratio ammonia / air in the production of nitric acid which had an influence in the decrease of emissions.

The principal source of GHGs in Portugal in 2010 is the energy sector. The largest gas emitted is CO₂ representing approximately 75 per cent of total GHGs emissions expressed as global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for almost 92 per cent of total CO₂ emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2010, 83% of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas) whereas the renewable energy represents the remaining part, i.e. 17% in average. (Figure 2.2) The situation is however changing in the most recent years, with a progressive increase of the renewable energy sources such as wind.

Figure below illustrates the GHG trend in the period 1990-2010. CO₂ is the gas having registered the biggest increase, 18.7 per cent¹.

Figure ES. 2– Change of emissions by gas over the period 1990-2010 (per cent)



The overall trend for direct GHG emissions in the 1990-2010 period is presented in figure below.

¹ Portugal has chosen 1995 as the base year for fluorinated gases. However, F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2010: 1.8%)

Table ES. 1 – GHG emissions and removals in Portugal by gas

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂ equivalent (Gg)											
CO ₂ emissions including net CO ₂ from LULUCF	37,158	39,989	41,221	39,489	39,016	44,492	37,901	40,384	46,094	53,339	52,377
CO ₂ emissions excluding net CO ₂ from LULUCF	44,317	46,199	50,233	48,858	49,488	53,430	50,791	53,593	58,071	65,833	64,669
CH ₄ emissions including CH ₄ from LULUCF	10,430	10,805	10,714	10,671	11,106	11,561	11,453	11,597	12,161	12,290	11,493
CH ₄ emissions excluding CH ₄ from LULUCF	10,217	10,486	10,609	10,600	11,059	11,320	11,360	11,563	11,990	12,201	11,311
N ₂ O emissions including N ₂ O from LULUCF	5,602	5,602	5,566	5,510	5,569	5,748	6,032	6,017	5,912	5,989	6,071
N ₂ O emissions excluding N ₂ O from LULUCF	5,543	5,519	5,525	5,473	5,535	5,674	5,985	5,981	5,846	5,938	6,000
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	66	88	121	162	217	307
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	0	0	0	0
SF ₆	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	5	6	6	6	6	6
Total (including LULUCF)	53,190	56,397	57,501	55,670	55,691	61,873	55,478	58,125	64,335	71,842	70,254
Total (excluding LULUCF)	60,077	62,205	66,367	64,932	66,082	70,496	68,230	71,264	76,075	84,196	82,293

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% change
CO ₂ equivalent (Gg)											1990-10
CO ₂ emissions including net CO ₂ from LULUCF	52,758	57,090	58,258	56,996	64,566	54,421	50,811	48,541	44,788	42,471	14.3
CO ₂ emissions excluding net CO ₂ from LULUCF	65,098	69,097	64,230	66,497	68,573	63,941	61,346	60,122	56,766	52,619	18.7
CH ₄ emissions including CH ₄ from LULUCF	12,071	12,602	13,124	12,015	12,487	11,827	11,502	11,620	11,734	12,167	16.7
CH ₄ emissions excluding CH ₄ from LULUCF	11,955	12,443	12,466	11,863	11,975	11,724	11,468	11,602	11,660	11,984	17.3
N ₂ O emissions including N ₂ O from LULUCF	5,821	5,876	5,401	5,550	5,358	5,035	5,288	5,079	4,854	4,842	-13.6
N ₂ O emissions excluding N ₂ O from LULUCF	5,762	5,806	5,228	5,479	5,213	4,971	5,237	5,030	4,792	4,757	-14.2
HFCs	391	494	599.63	674.84	771.59	864.58	961.54	1,065.17	1,147.43	1,231.87	-
PFCs	0	0	0.05	0.05	0.05	0.03	0.03	0.04	0.00	0.00	-
SF ₆	6	6	6.81	7.51	7.12	8.10	6.86	5.93	6.45	7.12	-
Total (including LULUCF)	71,047	76,067	77,390	75,243	83,190	72,156	68,569	66,311	62,529	60,719	14.2
Total (excluding LULUCF)	83,212	87,846	82,530	84,522	86,540	81,509	79,020	77,825	74,372	70,599	17.5

NA- Not applicable; NE - Not estimated; NO - Not occurring

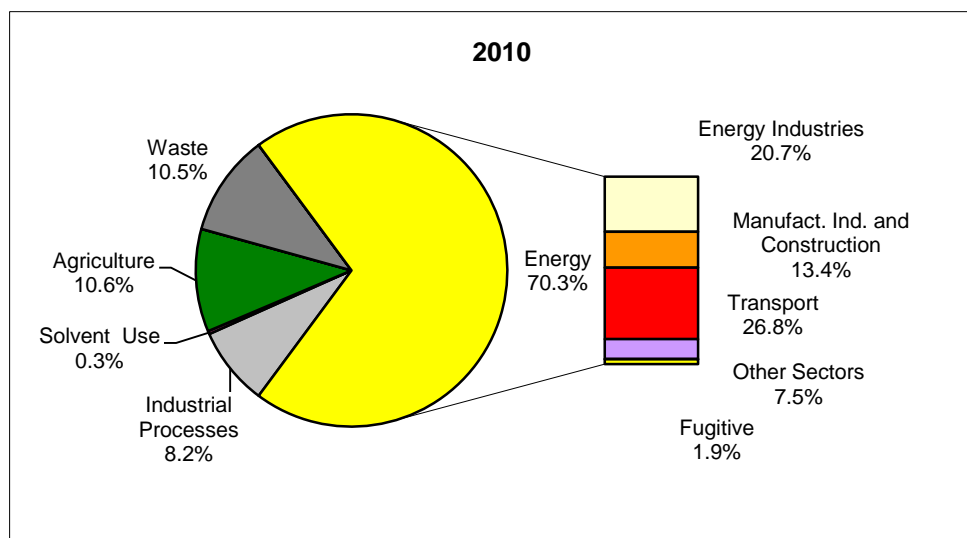
ES.3 Overview of source and sink category's emission estimates and trends

ES.3.1 Greenhouse Gas Inventory – UNFCCC

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into six large sectors: Energy, Industrial Processes, Solvent use, Agriculture, Land-Use Change and Forestry, and Waste. The figure below represents direct GHG emissions by sector for 2010.

Throughout this report, the reference to “total emissions” is meant to refer to “total emissions without LULUCF on a carbon equivalent basis”. Furthermore the references to 1990 represent the year 1990 as estimated for this submission which is different from the assign amount (except when specify otherwise). This difference is mainly due to revision on the time series or methodology improvements).

Figure ES. 3 – GHG emissions in Portugal by sector: 2010



Energy is by far the most important sector, accounting for 70 per cent of total emissions in 2010, and presenting an increase of 21 per cent over the 1990-2010 period. Energy industries and transport are the two most important sources representing respectively 21 per cent and 27 per cent of total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation and transportation, which have grown steadily until the mid 2000s due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the growth of mobility. The situation seems to have changed in the most recent years where we can observe stagnation or even decrease of these trends.

Transport sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2010 these emissions increased 84 per cent, due to the steady growth of vehicle fleets and road travel, in association with the increase in family income and the strong investment in road infrastructure in the 90s. Indirectly the increase in road traffic activity also augmented the emissions from fossil fuel storage, handling and distribution. However, this situation has changed in the last years, as the growth of transport emissions has started to decline in most recent years.

Agriculture, was in the period analyzed, one of the most significant sources of GHG emissions, and was responsible for 10.6 per cent of the Portuguese emissions in 2010, corresponding to a decrease of 7.4 per cent since 1990. The waste and industrial processes sectors represented, respectively, 10.5 per cent and 8.2 per cent of the country emissions in 2010, recording an increase of approximately 24.3 per cent and 23.4 per cent since 1990. Solvent use represents less than 1 per cent of total emissions, and is mainly related to NMVOC emissions².

The accounting of land use change and forestry category are still under revision. According to the last estimates the sector is estimated to be a net sink in the whole period, representing a sequester of -9.9 Mt CO₂e. in 2010.

Figure below presents the overall sectoral trend for direct GHG emissions in the 1990-2010 period.

² These are converted into ultimate carbon dioxide after being emitted to atmosphere.

Table ES. 2 – GHG emissions and removals in Portugal by sector

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂ equivalent (Gg)											
1. Energy	40,980	42,726	47,127	45,810	46,461	49,929	47,275	49,859	54,289	61,780	60,276
2. Industrial Processes	4,664	4,761	4,423	4,356	4,331	5,072	5,174	5,447	5,625	6,015	6,262
3. Solvent and Other Product Use	332	316	326	286	316	312	334	357	292	293	300
4. Agriculture	8,113	8,214	8,088	7,917	8,122	8,124	8,388	8,289	8,256	8,410	8,624
5. Land-Use Change and Forestry ⁽⁷⁾	-6,887	-5,808	-8,866	-9,261	-10,391	-8,623	-12,752	-13,139	-11,740	-12,354	-12,039
6. Waste	5,988	6,187	6,403	6,562	6,852	7,058	7,059	7,313	7,614	7,698	6,831
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GHGs SOURCE AND SINK	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% change 1990-10
CO ₂ equivalent (Gg)											
1. Energy	61,277	65,172	60,491	62,075	64,158	59,526	56,523	55,757	54,057	49,654	21.2
2. Industrial Processes	6,032	6,353	6,358	6,914	6,944	6,729	7,258	7,149	5,498	5,756	23.4
3. Solvent and Other Product Use	302	292	290	315	322	286	303	266	272	228	-31.3
4. Agriculture	8,347	8,282	7,604	7,891	7,678	7,533	7,688	7,540	7,508	7,515	-7.4
5. Land-Use Change and Forestry ⁽⁷⁾	-12,164	-11,779	-5,141	-9,279	-3,350	-9,353	-10,451	-11,514	-11,842	-9,880	43.5
6. Waste	7,254	7,748	7,788	7,326	7,439	7,433	7,248	7,113	7,036	7,446	24.3
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-

NA- Not applicable; NE - Not estimated; NO - Not occurring

ES.4 Information on indirect GHG and SO_x emissions

Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO_x and NMVOCs are precursor substances for ozone which is a GHG. SO_x produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Table ES.3– Indirect GHG and SO_x emissions

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
(Gg)											
CO	865	880	912	892	877	863	854	819	805	777	726
NO _x	248	260	278	269	270	281	269	270	277	285	279
NM VOC	313	317	323	311	312	306	305	305	303	296	280
SO ₂	322	314	375	319	294	329	271	286	334	344	304
Gas emissions	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% change 1990-10
(Gg)											
CO	657	631	593	568	525	492	462	456	414	405	-53.2
NO _x	283	290	268	275	272	248	241	221	209	197	-20.5
NM VOC	267	264	248	243	230	223	216	211	196	200	-36.2
SO ₂	285	283	191	193	195	170	163	117	79	72	-77.7

In 2010, all these gases emissions have decreased from 1990 levels: SO_x -77.7 per cent, CO -53.2 per cent, NMVOC -36.2 per cent and NO_x -20.5 per cent (previous table).

Energy is the major responsible sector for emissions of NO_x, SO_x and CO. Its contribution for NMVOC emissions is also significant, together with Solvent use and Industrial processes.

Within energy, transportation is responsible for the major share of NO_x emissions, 35.5 per cent of 2010 totals. Despite the fast growing trends of the transport sector (mainly road) since the 90s, the introduction of new petrol-engine passenger cars with catalysts converters and stricter regulations on diesel vehicles emissions, limited the growth of these emissions or even its decrease. In fact, the situation started to change in the last years, as transport emissions growth has first stabilised and started to decline in the most recent years. Since the early 2000s, NO_x emissions from transport has been presenting a decreasing tendency; and CO and NMVOC emissions recorded real reductions in the 1990-2010 period, respectively, -74 per cent and -84 per cent.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 31 per cent of the 2010 totals.

SO_x emissions are mainly generated in the energy industry sector (approximately 36 per cent of total emissions in 2010) and combustion in manufacturing industries (approximately 34 per cent of total emissions in 2010), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. The situation is however improving with a significant development of renewable sources (mainly wind) and energy efficiency measures, among other factors as reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 from November 10th). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO_x emissions. The emissions variation in the period 1990-2010 shows in fact a decrease in SO_x emissions in both sub-categories: energy industries and manufacturing industries -87 per cent and -66 per cent. Since 2007, SO_x emissions from the energy industries registered a significant reduction (approximately -75 per

cent) which is explained by the implementation of two new abatement systems (desulfurization in two Large Point Source Energy Plants in Mainland Portugal).

1 INTRODUCTION

1.1 Background information

1.1.1 Global warming and climate change

Although key greenhouse gases - CO₂, CH₄, N₂O, Ozone – occur naturally in the atmosphere, human activities have increased the atmospheric concentrations of greenhouse gases since the pre-industrial era. Other substances which are exclusively produced by industrial activities are also greenhouse gases: stratospheric ozone depleting substances (CFCs, HCFCs and halons which are covered by the Montreal Protocol), and some other fluorine-containing halogenated substances – HFCs, PFCs and SF₆. There are also several gases that do not have a direct effect in global warming but affect the formation or destruction of other GHG. CO, NO_x, and NMVOCs are precursor substances for ozone which is a GHG. SO_x produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Land-Use and Land-Use Change (LULUCF), particularly deforestation, is another factor that contributes to the phenomenon of global warming and climate change as it changes carbon stocks and carbon sequestration and consequently the CO₂ fluxes from and to the atmosphere.

According to the IPCC, the average surface temperature of the earth has risen by about 0.6-0.7°C in the past 100 years and will rise by another 1.4-5.8°C in the next 100 years, depending on the GHG's emissions scenario.

An increase in global temperatures can result in a cascade of environmental effects, including the rise of sea level and changes in the amount and pattern of precipitation. These changes may increase the frequency and intensity of extreme weather events, such as floods, droughts, heat waves, hurricanes, and tornados. Other consequences include higher or lower agricultural yields, glacial retreat, reduced summer stream flows, species extinctions and increases in the ranges of disease vectors.

1.1.2 Climate change in Portugal

The mean temperature has risen in all regions of Portugal since the 1970s, at a rate of approximately 0.45 °C per decade. The time-series analysis of the mean annual temperature since 1931, shows that 1997 was the warmest of the last 75 years and that 7 of the 10 warmest years occurred after 1990s (1997, 1995, 2006, 1996, 1990, 1998 and 2003).

Also an observation of temperature indices indicates that the increase of the mean temperature was accompanied by a change in the frequency of very hot days and a decrease in the frequency of very cold ones.

The heat wave duration index has also been rising. Heat waves are defined when, in a period of at least 6 consecutive days, the daily maximum temperature is 5 °C higher than the daily mean value of the reference period (1961-1990). Although they can occur at any time of the year, heat waves have a more significant impact in the summer months. Heat waves were more frequent in the 1990s. The heat waves of 1981, 1991, 2003 and 2006 were of particular significance due to their duration and spatial extension.

The last 2 decades of the 20th century were particularly dry in mainland Portugal as opposed to the average values registered between 1961 and 1990. In fact, only in 6 of the last 20 years of the past century the annual precipitation was higher than the average. In 2001 and 2002,

however, the annual precipitation values were higher than the average observed in the reference period. The driest of the past 75 years was 2005, and 2004 was the second driest on record.

The seasonal trend in the mean precipitation values recorded since 1931 shows a systematic and statistically significant reduction in precipitation in the spring over the last three decades of the 20th century, with slight increases during the other seasons. In 2000 and 2001, spring precipitation rose to values not observed since the late 1960s.

Annual variability of winter precipitation increased over the last 30 years, with the occurrence of both drier and rainier winters. The winter of 2000/2001 was particularly rainy (the third most rainy of the last 30 years), and winter of 2001/2002 was the fifth driest of the last 3 decades. The winter of 2004/2005 was the driest winter observed in the last 75 years. The autumn of 2006 was the third most rainy since 1931.

All models from the different scenarios forecast a significant increase in the mean temperature for all regions of Portugal until the end of the 21st century. In the mainland, summer maximum temperature increases are estimated to vary between 3 °C and 7 °C in coastal and interior areas, respectively, accompanied by a strong increment in the frequency and intensity of heat waves.

With regard to precipitation, future climatic uncertainty is considerably stronger. Nevertheless, most models project a reduction in total precipitation in all regions, with more intense periods of rain in shorter time frames in the winter.

1.1.3 The Convention, the Kyoto Protocol and national commitments

The United Nations Framework Convention on Climate Change (UNFCCC) appeared as an answer of the international community to the emerging evidences of climate change and was adopted and was opened for signature in Rio de Janeiro in 1992.

Portugal has ratified the UNFCCC on May 31st, 1994. The ultimate objective of the Convention is the “stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.”

The Kyoto Protocol (KP), adopted some years later in 1997, represents a deepening in the commitments inscribed in the Convention. The Protocol introduced legally binding commitments for developed countries to reduce their collective emissions of greenhouse gases by at least 5 per cent by the period 2008-12 (first commitment period of the Protocol), below their 1990 level.

Portugal signed and ratified the KP on the April 29th, 1998, and May 31st, 2002, respectively. The EU as a whole agreed to a -8% reduction. Under the EU burden-sharing agreement Portugal is committed to limiting its emissions during the first commitment period to no more than +27 per cent compared to the 1990 level.

The KP entered into force on the February 16th, 2005, after Russia's ratification in November 2004 which fulfilled the requirement that at least 55 Parties to the Convention, including developed countries accounting for at least 55% of that group's CO₂ emissions in 1990.

Detailed rules for the implementation of the Protocol were set out at the 7th Conference of the Parties (in Marrakech) and are described in the Marrakech Accords adopted in 2001. At the first Conference of the Parties serving as the Meeting of the Parties to the Protocol (COP/MOP) held in Canada (December 2005) the rules for the implementation of the Protocol agreed at COP7 were adopted.

At present, international negotiations are focused on future commitments for the period after 2012.

1.1.4 History of national inventories

Air emission inventories in Portugal were only initiated in the late 80s, early 90s when the first estimates of NO_x , SO_x and VOC emissions from combustion were made under the development of the National Energetic Plan (PEN - Plano Energético Nacional), and emissions from combustion and industrial processes were made under OECD inventory and under CORINAIR85 programme. A major breakthrough occurred during the CORINAIR90 inventory realized during 1992 and 1993 by General-Directorate of Environment (DGA, renamed now as APA). This inventory exercise, aiming also EMEP and OECD/IPCC, extended the range of the pollutants (SO_x , NO_x , NMVOC, CH_4 , CO, CO_2 , N_2O and NH_3) and emission sources covered, including not only combustion activities but also storage and distribution of fossil fuels, production processes, use of solvents, agriculture, urban and industrial wastes and nature (forest fires and NMVOC from forest). Information received under the Large Combustion Plant (LCP) directive was also much helpful to improve inventory quality and the individualization of Large Point Sources, as well as statistical information received from the National Statistical Institute (INE) allowing the full coverage of activity data for most emission sources. The CORINAIR90 Default Emission Factors Handbook (second edition), updating the first edition from CORINAIR85 was used extensively in the development of the current inventory and it was also a key point in the amelioration of the inventory.

The fulfilment of international compromises under conventions UNFCCC and CLRTAP, together with the publication of the IPCC Draft Guidelines for National Greenhouse Gas Inventories (IPCC, 1995) and latter of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), has result in substantial improvement of the methodologies that are used in the inventory, particularly for agriculture and wastes, and that were included at first time in the First National Communication in 1994. The inventory that resulted from CORINAIR90 (CEC,1992) and subsequent modifications from IPCC methodology still structures the present day methodology in what concerns activity data and methodology. Under the evaluation of the first communication the inventory was subjected to a review made by an international team. The second, third, fourth and fifth communications were also reviewed by international experts. These exercises had an important role in problem detection and contribute to overall improvement.

Since its first compilation, the Portuguese inventory has been continuously amended mainly from the use of more detailed methodologies, better access to underlying data allowing the development of the comprehensiveness of the inventory, and better database storage and calculation structure. Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for the different years considered (1990-2008), i.e., the inventory is internally consistent. Some major studies have contributed to the improvement of the inventory:

- Study of VOC emissions in Portugal, in 1995. This study made in collaboration with FCT (Faculdade de Ciências e Tecnologia) led to an important improvement in emission estimates from solvent sector, which is still used as basic information source for this sector;
- Study of Emission and Control of GHG in Portugal (Seixas et al, 2000). This project aimed the first development of projections toward 2010 and the identification of control measures to accomplish the Kyoto Protocol. This also

led to improvements in the inventory: extension of the inventory including for the first time also carbon dioxide sinks (forest); a first attempt to estimate solid waste methane emissions from urban solid wastes using a Tier2 approach and, in general terms, a better insight into additional parameters used in the inventory methodologies, and that has resulted from interaction with several institutional agents: General Directorate of Energy, Ministry of Agriculture; and the inter-ministerial transport group;

- Study for the quantification of carbon sinks in Portugal (Pereira *et al.*, 2002), made under the development of PNAC and PTEN national programmes;
- Revision of the Energy Balances with comparison of information collected at APA (LCP Directive) and Statistical Information received at DGEG: Energy Balances. The 1990s – DGE (2003);
- PNAC 2004 (National Plan for Climate Change) approved by Ministers Council and published recently in the National Official Journal (OJ nº 179, 31 July 2004, I Série B/ Resolução do Conselho de Ministros nº 119/2004);
- PNAC 2006 (National Plan for Climate Change) approved by Ministers Council and published in the National Official Journal (OJ nº 162, 23 August 2006, I Série B/ Resolução do Conselho de Ministros nº 104/2006)
- Sectorial Studies and Proposal for a PTEN (National Plan on Emission Ceilings);
- PNALE (National Plan for Allocation of Emissions) 2005-2007 or Portuguese PNALE I, adopted by Ministers Council (Resolução do Conselho de Ministros n.º 53/2005) and published in the National Official Journal (OJ nº 44, 3 March 2005, I Série B);
- Bilateral meetings (APA/UE) for the determination of the Baseline Scenario under the CAFE program (APA, 2004);
- Methodological Development Programme (PDM) under the implementation of the National Inventory System;
- UNFCCC reviews, in particular the in-depth review (September/October 2004), and the centralised reviews (October 2005 and September 2008).
- UNFCCC in-depth review of the Initial Report in May 2007 which fixed the Assigned Amount for the first commitment period.

1.1.5 Greenhouse gas emissions inventories

Parties to the Convention (Article 4(1)(a)) “shall develop, periodically update, publish and make available to the COP, ..., national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies”.

Portugal, as a Party to the Convention, is required to produce and regularly update National Greenhouse Gas Inventories. Furthermore Parties shall submit a National Inventory Report (NIR) containing detailed and complete information on their inventories, in order to ensure the transparency of the inventory.

The inventory covers the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x). Emissions are estimated for each civil year from 1990 to 2008.

As a general rule the inventory covers emissions occurring in the whole Portuguese territory, i.e., mainland Portugal and the two autonomous regions of Madeira and Azores Islands. The only exception to this rule, which results in an inconsistency, refers to data for the two Portuguese islands in what concerns Land Use Change and Forestry (IPCC category 5) which have not been compiled; therefore this category refers only to mainland Portugal, with the exception of fires emissions which includes the Islands. Emissions from air traffic and navigation realized between places in territorial Portugal, including movements between mainland and islands, are also include in national emission total.

The economic sectors covered are the following: energy production and transformation, combustion in industry, domestic, agriculture, fisheries, institutional and commerce sectors, transportation (road, rail, maritime and air), industrial production and use of solvents, waste production, disposition and treatment (urban, industrial and hospitals solid wastes, and domestic and industrial waste water), agriculture, animal husbandry emissions, as well as emissions and removals from forestry and land use change.

1.1.6 Global warming potentials

A Global Warming Potential (GWP) is defined as the cumulative radiative forcing over a specified time horizon resulting from the emission of a unit mass of gas relative to some reference gas (IPCC, 1997). The reference gas used is CO₂. The mass emission of each gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide equivalents (CO₂ e). The parties to the UNFCCC have agreed to use GWPs based on a 100-year time horizon.

Table 1.1 – Global Warming Potentials (100-year time horizon)

GHG	GWP
CO ₂	1
CH ₄	21
N ₂ O	310
HFC	
HFC-23	11 700
HFC-32	650
HFC-41	150
HFC-43-10mee	1 300
HFC-125	2 800
HFC-134	1 000
HFC-134 ^a	1 300
HFC-152 ^a	140
HFC-143	300
HFC-143 ^a	3 800
HFC-227ea	2 900
HFC-236fa	6 300
HFC-245ca	560
PFC	
CF ₄	6 500
C ₂ F ₆	9 200
SF ₆	23 900

1.2 Institutional arrangements for inventory preparation

1.2.1 Institutional arrangements in place

In order to comply with the commitments at the international and EC levels, respectively, the Article 5(1) of the Kyoto Protocol and Decision 280/2004/EC of the European Parliament and of the Council, a National Inventory System of Emissions by Sources and Removals by Sinks of Air Pollutants - (SNIERPA) was created. This system contains a set of legal, institutional and procedural arrangements that aim at ensuring the accurate estimation of emissions by sources and removals by sinks of air pollutants, as well as the communication and archiving of all relevant information.

The principal objective of the national system is to prepare and ensure the transparency, consistency, comparability, completeness, accuracy and timeliness of the inventory of air pollutants (INERPA), in accordance with the directives defined at international and EC levels, in order to make easier and more cost-effective the tasks of inventory planning, implementation and management,

The system was established through Council of Ministers Resolution 68/2005, of 17 March, which defines the entities relevant for its implementation, based on the principle of institutional cooperation. This clear allocation of responsibilities is essential to ensure the inventory takes place within the defined deadlines.

For the sake of efficiency, the Portuguese national system has been broadened to include a wider group of air pollutants than just GHG not covered by the Montreal Protocol, allowing for improvements in information quality, as well as an optimisation of human and material resources applied to the preparation of the inventory.

Three bodies are established with differentiated responsibilities. These are:

The Portuguese Environmental Agency (APA)/ Ministry for Agriculture, Sea, Environment and Land Use Planning, is the Responsible Body responsible for: the overall coordination and updating of the National Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants (INERPA); the inventory's approval, after consulting the Focal Points and the involved entities; and its submission to EC and international bodies to which Portugal is associated, in the several communication and information formats, thus ensuring compliance with the adopted requirements and directives.

CAOS Sustentabilidade, was a private company contracted by APA to support the inventory unit on the development of a methodological approach and the implementation of a procedure to quantify KP-LULUCF activities.

The sectoral Focal Points work with APA in the preparation of INERPA, and are responsible for fostering intra and inter-sectoral cooperation to ensure a more efficient use of resources. Their main task includes coordinating the work and participation of the relevant sectoral entities over which it has jurisdiction. It is also the Focal Points duty to provide expert advice on methodological choice, emission factor determination and accuracy of the activity data used. Focal Points play a vital role in sectoral quality assurance and methodological development.

The involved entities are public or private bodies which generate or hold information which is relevant to the INERPA, and which actions are subordinate to the Focal Points or directly to the Responsible Body.

All governmental entities have the responsibility to ensure, at a minimum, co-funding of the investment needed to ensure the accuracy, completeness and reliability of the emissions inventory.

The RCM also includes a procedure for the official consideration of the inventory. This consideration is done at the level of the designated representatives of Focal Points and Involved Entities.

The SNIERPA is composed of three technical elements:

- A Quality Control and Quality Assurance System (QA/QC System)
- A Methodological Development Programme (MDP), and
- An integrated IT system for the management (SIGA) of the SNIERPA (this last not yet implemented).

Figure 1.1 – SNIERPA 's main elements relations

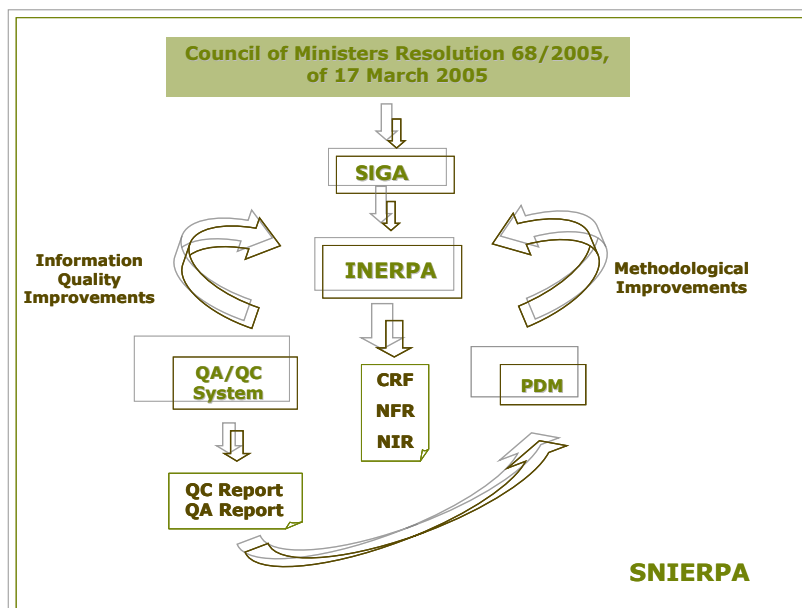


Table below lists the main focal points and involved entities, by sector of activity.

Table 1.2 – Bodies that contribute information relevant to the preparation of the INERPA

Sector of Activity	Focal Point	Involved Entities
National Statistics ³	National Statistics Institute	
Environment Statistics ⁴	Institute for the Environment	
Energy Statistics	Directorate-General for Geology and Energy	
Energy:		
Industry and civil construction.....	Directorate-General for the Enterprise	
Transport.....		
Road.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications and Directorate-General for Driver Licensing	Studies and Planning Office of the Institute of Portugal's Roads, Directorate-General of Land and Water Transport
Rail.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications	Studies and Planning Office, National Institute of Rail Transport, "Comboios de Portugal", National Railway Network
Aviation.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications	Studies and Planning Office, National Civil Aviation Institute
Sea.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications	Studies and Planning Office, Port and Sea Transport Institute, Port Administration
Fugitive Emissions from Fossil Fuels.....	Directorate General for Geology and Energy	
Industrial Processes	Directorate-General for Enterprise	
Solvent Use and Other Products.....	Directorate-General for Enterprise	
Agriculture	Environmental Auditor of the Ministry for Agriculture, Fisheries and Forestry	Zootechnical Station Rebello da Silva Agro-Chemical Laboratory
Forestry and Land Use Change		
Forestry	Directorate-General of Forestry	
Land Use Change.....	Portuguese Geographical Institute	
Waste		
Disposal/incineration of waste	Institute for Waste Management	
Wastewater.....	Water Institute	Directorate-General for Health

Changes in national system since the last submission are described in chapter **Erro! A origem da referência não foi encontrada..**

1.2.2 Overview of inventory planning

All the participating organisations are represented in a inventory working group (GT SNIERPA) set up to support the annual production of the national inventories and the fulfillment of the reporting requirements.

Each year, typically in June according to the agreed calendar of INERPA, the APA, the coordinator of this WG, organizes a kick off meeting to plan and launch the work for the following inventory submission. The issues raised by the annual review processes as well as issues identified via QA/QC procedures are discussed at this meeting with the aim of defining the annual MDP. Bilateral meetings occur as necessary as consequence of this meeting aiming at discussing the specific issues related to each sector and to agree on the actions to be implemented in the framework of SNIERPA for the next inventory compilation.

The following table presents the overall calendar of the inventory process, which includes four main phases: inventory planning, inventory compilation, QA/QC verification and inventory improvement.

Table 1.3 - Calendar for the inventory process

Date	Task	Process
June	Kick-off meeting of SNIERPA WG for the launch of the annual inventory work	Inventory Planning
30 September	Deadline for routine data collection/ delivery by FP and/or IE to the APA	Inventory Compilation
20 October	Conclusion of Methodological Development Plan (MDP) work	Inventory Compilation
15 December	NFR submission to FP and/or IE for review	Inventory Compilation
22 December	Deadline for NFR comments from FP and/or IE	Inventory Compilation
31 December	Official NFR submission to EC (DG ENV) [under National Emissions Ceilings]	Reporting
5 January	CRF submission to FP and/or IE for review	Inventory Verification/ Improvement
11 January	Deadline for CRF comments from FP and/or IE	Inventory Verification/ Improvement
5 – 15 January	Implementation of QC 1 to CRF, NFR and NIR	Inventory Verification/ Improvement
15 January	Preliminary CRF and Short NIR submission to EC (DG ENV) [Monitoring Mech. of GHG under EU]	Reporting
5 February	NFR submission to FP and/or IE for review	Inventory Verification/ Improvement
11 February	Deadline for NFR comments from FP and/or IE	Inventory Verification/ Improvement
15 February	Official NFR submission to UNECE [CLRTAP]	Reporting
15 February	- Deadline for implementation of QC 1 to the NIR and IIR - Implementation of QC 2 to CRF and NIR - NIR and IIR submission to FP and/or IE for review	Inventory Verification/ Improvement
9 March	- Deadline for implementing QC 2 to CRF and NIR - Deadline for NIR and IIR comments from FP and/or IE	Inventory Verification/ Improvement
15 March	Submission of CRF and NIR (final versions) to the EC (DG ENV) [Monitoring Mech. of GHG under EU]	Reporting
15 March	Submission of IIR to UNECE [CLRTAP]	Reporting
15 April	Submission of CRF and NIR (final version) to the UNFCCC [UNFCCC and Kyoto Protocol]	Reporting

1.2.3 Institutional arrangements for Kyoto Protocol

Additional provisions to deal with the supplementary information under Kyoto Protocol refer mainly to arrangements to account for further requirements concerning Art. 3.3 and 3.4.

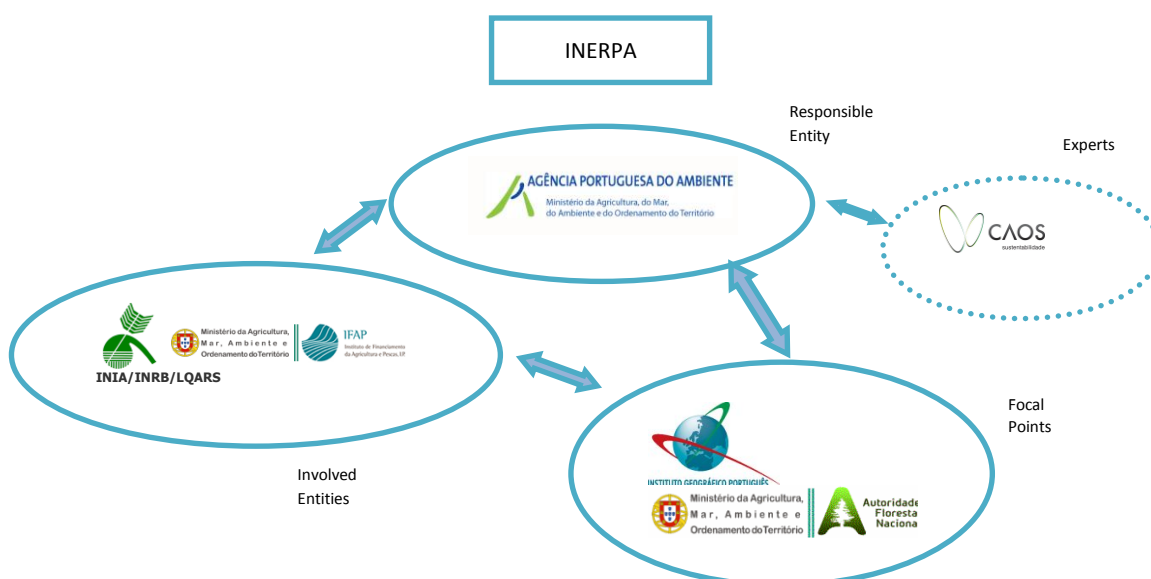
An inter-institutional work group was created (WG 3.3&3.4) in the scope of the National Inventory System (SNIERPA) in order to work on the definition of the methodology to identify the areas and account for the emissions/removals. This group includes the following entities:

- MAMAOT – Ministry for Agriculture, Sea, Environment and Land Use Planning / Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território
 - APA – Portuguese Agency for the Environment (www.apambiente.pt)
 - GPP – Gabinete de Planeamento e Políticas (<http://www.gpp.pt>)
 - AFN – Forestry National Authority/ Autoridade Florestal Nacional estais/MAMAOT (<http://www.afn.min-agricultura.pt>)
 - IFAP (ex-INGA) – Instituto Financiamento da Agricultura e Pescas (www.ifap.min-agricultura.pt)
 - LQARS – Laboratório Químico Agrícola Rebelo da Silva (<http://www.iniap.min-agricultura.pt>)
- ISA – Instituto Superior de Agronomia / Technical University of Lisbon (<http://www.isa.utl.pt>)

- IGP – Portuguese Geographic Institute/ Instituto Geográfico Português (<http://www.igeo.pt/gdr/projectos/prek/>)
- IST – Instituto Superior Técnico/ Technical University of Lisbon (<http://www.ist.utl.pt>)
- UE – Universidade de Évora
- Caos (<http://www.caos.com.pt>)

The representation of these multiple entities in WG 3.3&3.4 aims at gathering the necessary competences, data and knowledge required to comply with the reporting and accounting requirements of these activities.

Figure 1.2 – Main elements of Working Group 3.3&3.4



1.3 Inventory Preparation Process

1.3.1 Responsibility

The Portuguese Environmental Agency (*Agência Portuguesa do Ambiente* - APA) is the national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions. According to these attributions, APA makes an annual compilation of the Portuguese Inventory of air emissions which includes GHG's sources and sinks, acidifying substances as well as other pollutants. The reporting obligations to the EU and the international instances are also under the responsibility of the APA.

The designated representative is:

Agência Portuguesa do Ambiente

Departamento de Alterações Climáticas, Ar e Ruído (Department of Climate Change, Air and Noise)

Address: Rua da Murgueira, 9/9A, 2610-124 Amadora, Portugal

Telephone: +351 21 472 83 82

Fax: + 351 21 471 90 74

Filomena Boavida - filomena.boavida@apambiente.pt

1.3.2 Calculation, data archiving and documentation system

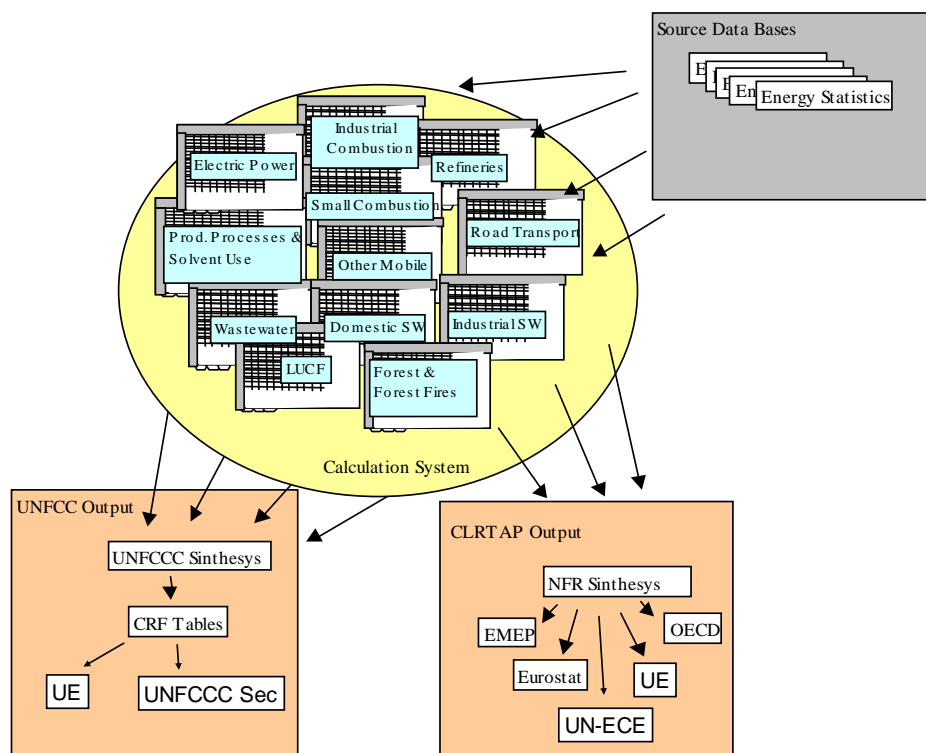
The emissions calculations have been performed by APA. However many other institutions and agencies contributed to the inventory process, providing activity data, sectoral expert judgment, technical support and comments. All calculation and reporting rely in a set of different Excel spreadsheet workbooks which had been developed in order that all information and calculations occur automatically. The structure of the information system is outlined in figure below.

The information received from the several data suppliers is stored in its original format (paper or magnetic). A copy of this information is converted into the working workbooks, where data is further processed, linkage made and calculations performed, maintaining hence the integrity of the original data sources.

The informatics system has been developed to answer to the various international obligations and national needs. At present, the different demands refer to: UNFCCC (CRF format); UNECE/CLRTAP (NFR format); LCP Directive (NFR format); as well national needs such as the State of Environment Reports. There is independency between emission calculations and the required structure necessary for each obligation which allows flexibility in the inventory.

In what refers to the maintenance of the annual inventory documentation, the information is archived in a way that enables each inventory estimate to be fully documented and reproduced if necessary. When major changes are done in methodology and emission factors, older spreadsheets are frozen and work restarts with copies of those spreadsheets, making a clear reference to the period when they were used. Minor corrections, which do not affect the estimations, are not stored due to storage area limitations.

Figure 1.3 – Electronic System Structure of the estimation and reporting system



Annually reported data, e.g. CRF tables, are stored both in paper and magnetic format. APA had planned to develop an integrated IT system for the management (SIGA) of the inventory. However, this project has not been implemented yet due to several resource constraints. Furthermore, the present system is considered to ensure the basic requirements/functions of an IT system: centralized data processing and storage.

1.4 General overview of methodologies and data sources used

The inventory has been compiled, to the extent as possible, in accordance with the recommendations from the UNFCCC Reporting Guidelines on Annual Inventories (SBSTA 1999 and SBSTA 2002). The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) have been applied as far as appropriate and feasible. Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003) has been implemented, as far as possible, for the compilation of this 2010 submission.

Table below gives an overview of the methodologies and emission factors used in the inventory. Default methods and emission factors used and the choice between Tier 1 and Tier 2 approaches, were case by case dictated by the availability of proper background information and from national circumstances.

Table 1.4 – Summary of methods and emission factors (CRF summary 3 table)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂		CH ₄		N ₂ O		HFCs		PFCs		SF ₆	
	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF
1. Energy	CR,D,T1,T2	CR,CS,D,OT	CR,OTH,T1	CR,D,OTH	CR,T1,T2,T3	CR,D						
A. Fuel Combustion	CR,T1,T2	CR,D,OTH,PS	CR,T1,T2,T3	CR,D,OTH	CR,T1,T2,T3	CR,D						
1. Energy Industries	T2	CR,D,PS	T2	CR,D	T2	CR,D						
2. Manufacturing Industries and Construction	T2	CR,D,PS	T2	CR,D,OTH	T2	CR,D						
3. Transport	CR,T1,T2	CR,D,OTH	CR,T1,T2,T3	CR,D,OTH	CR,T1,T2,T3	CR,D						
4. Other Sectors	T2	CR,D	T2	CR,D	T2	CR,D						
5. Other	T1	CR,D	T1	CR	T1	D						
B. Fugitive Emissions from Fuels	D	CS,D	CR,OTH	CR,OTH	NA	NA						
1. Solid Fuels	NA	NA	NA	NA	NA	NA						
2. Oil and Natural Gas	D	CS,D	CR,OTH	CR,OTH	NA	NA						
2. Industrial Processes	CR,D,OTH,T	CR,CS,D,OT	D,OTH	CR,OTH	D	CR,OTH			NA	NA		
A. Mineral Products	CR,D,OTH,T2	CR,CS,D,OTH	OTH	OTH	NA	NA						
B. Chemical Industry	D,T2	CS,PS	D	CR,OTH	D	CR,OTH	NA	NA	NA	NA	NA	NA
C. Metal Production	D,T2	D,PS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D. Other Production	CR	CR										
E. Production of Halocarbons and SF ₆							NA	NA	NA	NA	NA	NA
F. Consumption of Halocarbons and SF ₆							NA	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	CR,D	CR,CS,OTH			D	CR,CS,OTH						
4. Agriculture			D,T2	CS,D	D,T1a	D						
A. Enteric Fermentation			T2	CS								
B. Manure Management			T2	CS	D	D						
C. Rice Cultivation			D	CS								
D. Agricultural Soils			NA	NA	T1a	D						
E. Prescribed Burning of Savannas			NA	NA	NA	NA						
F. Field Burning of Agricultural Residues			D	D	D	D						
G. Other			NA	NA	NA	NA						
5. Land Use, Land-Use Change and Forestry	NE	NE	NE	NE	NE	NE						
A. Forest Land	NE	NE	NE	NE	NE	NE						
B. Cropland	NE	NE	NE	NE	NE	NE						
C. Grassland	NE	NE	NE	NE	NE	NE						
D. Wetlands	NE	NE	NE	NE	NE	NE						
E. Settlements	NE	NE	NE	NE	NE	NE						
F. Other Land	NE	NE	NE	NE	NE	NE						
G. Other	NE	NE	NE	NE	NE	NE						
6. Waste	D	CS,D	D,T2	CR,CS,D	D	CR,D						
A. Solid Waste Disposal on Land	NA	NA	T2	CS,D	NA	NA						
B. Waste-water Handling						CR,D						
C. Waste Incineration	D	CS,D	D	CR,D	D	CR						
D. Other	NA	NA	NA	NA	NA	NA						
7. Other (as specified in Summary 1.A)			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: (1) Methods applied: D (IPCC default), RA (Reference Approach), T1 (IPCC Tier 1), T1a, T1b, T1c (IPCC Tier 1a, Tier 1b and Tier 1c, respectively), T2 (IPCC Tier 2), T3 (IPCC Tier 3), C (CORINAIR), CS (Country Specific), M (Model).

(2) Emission Factors: D (IPCC default), C (CORINAIR), CS (Country Specific), PS (Plant Specific), M (Model), MB-Mass Balance.

Table below gives an overview of the institutions and data sources providing data for the compilation of the Portuguese emission inventories.

Table 1.5 – Inventory Data Sources

IPCC category	IPCC sub-category	Sources of data
CRF 1 A – Energy. Fuel Combustion	CRF 1A1 – Energy Industry	<ul style="list-style-type: none"> • Large Point Source Surveys (LPS) • Large Combustion Plants (LCP) • EDP Sustainability Annual Reports • General Directorate for Geology and Energy (DGEG): energy balances • Autonomous Gov. of Azores • National Statistical Institute (INE)
	CRF 1A2 - Manufacturing Industries and Construction	<ul style="list-style-type: none"> • LPS, LCP, EPER/PCIP • Regional Air Inventories • DGEG: energy balances
	CRF 1A3 – Transport	<ul style="list-style-type: none"> • DGEG: energy balances • ACAP • ANECRA • Road Institute (IEP) • INE • General Directorate of Terrestrial Transportation (DGT) • INAC
	CRF 1A4 – Other Sectors	<ul style="list-style-type: none"> • DGEG: energy balances
CRF 1 B – Fugitive Emissions from Fuels		<ul style="list-style-type: none"> • DGEG: energy balances and statistical yearbooks • GALP
CRF 2 – Industrial Processes	CRF 2A – Mineral Products	<ul style="list-style-type: none"> • LPS, LCP • CIMPOR, SECIL • DGEG: energy balances • Portuguese Association of Producers of Bitumen Materials (APORBET) • European Asphalt Pavement Association (EAPA) • Technology Centre for Ceramics and Glass (CTCV)
	CRF 2B – Chemical Industry	<ul style="list-style-type: none"> • DGEG: energy balances • LCP • INE • Regional Air Inventories
	CRF 2C – Metal Production	<ul style="list-style-type: none"> • DGEG: energy balances • LCP • SN • INE • Regional Air Inventories
	CRF 2D – Other Production	<ul style="list-style-type: none"> • LCP • DGEG: energy balances • CELPA
	CRF 2F – Consumption of Halocarbons and SF6	<ul style="list-style-type: none"> • INE • APIRAC • Data from Industry Importers- • EDP, REN
CRF 3 – Solvent and Other Product Use		<ul style="list-style-type: none"> • DGEG: energy balances • Gen-Dir for Economic Activities Enterprise (DGAE) • INE
CRF 4 – Agriculture		<ul style="list-style-type: none"> • Ministry of Agriculture • National Forest Authority (AFN) • INE: agriculture survey
CRF 5 – Land Use Change and Forestry		<ul style="list-style-type: none"> • AFN • IGP • ISA

IPCC category	IPCC sub-category	Sources of data
CRF 6 – Waste	CRF 6A – Solid Waste Disposal on Land	<ul style="list-style-type: none"> • APA • INE • Quercus Survey
	CRF 6B – Wastewater Handling	<ul style="list-style-type: none"> • National Institute for Water (INAG) • INE
	CRF 6C – Waste Incineration	<ul style="list-style-type: none"> • APA • General Direction for Health/Ministry of Health • Data from Incineration Units

1.5 Brief description of key source categories

Key category analysis to the 2010 Portuguese inventory estimates (1990-2010) was conducted using Tier 2 approach with the LULUCF sector. Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2010 period.

The Tier 2 analysis with LULUCF resulted in the identification of 55 key categories, listed in the following table.

This analysis is however preliminary as uncertainty analysis are under deep revision and related data used refer mainly to previous uncertainty analysis.

Table 1.6 – Summary overview of Portuguese key categories (1990-2010) based on Tier 2 approach

IPCC CATEGORIES	ACTIVITY	GHG	Key source Categor	Criteria for Identificat	Comments on level assessment	2010 emissions estimate (kton CO2 eq.)
1A 3 b Road Transportation	All Fuels	CO2	✓	Level Trend	All years	8,046.5
1A 1a Public Electricity and Heat Production	Solid Fuels	CO2	✓	Level Trend	All years	6,002.4
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO2	✓	Level Trend	2004, 2005, 2006, 2007, 2008, 2009, 2010	4,703.8
2 A 1 Cement Production	Production Quantities	CO2	✓	Level	All years	3,376.3
1A 2 f Other	Liquid Fuels	CO2	✓	Level	All years	3,361.2
6 A Municipal SWDL	SW Disposal on Land	CH4	✓	Level Trend	All years	3,070.0
4 A ENTERIC FERMENTATION	Population size	CH4	✓	Level	All years	2,766.5
5 E 2 Land converted to Settlements	Emissions/Removals	CO2	✓	Level Trend	All years	2,052.2
1A 2 f Other	Gaseous Fuels	CO2	✓	Level Trend	2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	1,907.5
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N2O	✓	Level Trend	All years	1,855.9
1A 4 b Residential	Liquid Fuels	CO2	✓	Level	1990, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	1,841.3
6 B Industrial Wastewater	Wastewater	CH4	✓	Level	All years	1,512.7
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH4	✓	Level Trend	All years	1,507.4
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	1,171.5
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N2O	✓	Level Trend	All years	1,102.4
4 B MANURE MANAGEMENT	Animal Excretion	CH4	✓	Level Trend	All years	1,064.8
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	✓	Level Trend	1990	1,057.7
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO2	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2005	1,037.7
1A 4 a Commercial / Institutional	Liquid Fuels	CO2	✓	Level	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007	767.3
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	✓	Level Trend	All years	756.3
1B 2 b Natural gas	Gaseous Fuels	CH4	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2009, 2010	544.0
5 B 2 Land converted to Cropland	Emissions/Removals	CO2	✓	Level Trend	All years	492.6
5 D 2 Land converted to Wetlands	Emissions/Removals	CO2	✓	Level	All years	487.5
1B 2 a Oil	Liquid Fuels	CO2	✓	Level Trend	1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2010	474.3
2 A 2 Lime Production	Production Quantities	CO2	✓	Level Trend	All years	431.5
1A 3 a ii Domestic	Liquid Fuels	CO2	✓	Level	1990, 1995, 1996, 1997, 1998	398.2
4 C RICE CULTIVATION	Culture Surface	CH4	✓	Level	2010	391.9
2 A 7 Other	Production Quantities	CO2	✓	Level Trend	2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	214.5
6 B 1 Industrial Wastewater	Wastewater	N2O	✓	Level Trend	All years	203.1
1A 4 b Residential	Biomass	CH4	✓	Level Trend	All years	187.6
1A 2 f Other	Solid Fuels	CO2	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	158.0
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH4	✓	Level	1991, 2003, 2005	157.1
1B 2 d Other (Geothermal)	Energy Production	CO2	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	128.7
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	✓	Level Trend	All years	90.1
1B 2 b Natural gas	Gaseous Fuels	CO2	✓	Trend		71.3
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	✓	Level	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	62.4
3 A PAINT APPLICATION	Paint application	CO2	✓	Level Trend	1991, 1992, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2006	56.9
5 B 2 Land converted to Cropland	Emissions/Removals	N2O	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	49.3
2 F 2 Foam Blowing	Consumption	HFC	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008, 2009	47.7
1A 4 b Residential	Biomass	N2O	✓	Level Trend	All years	39.7
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N2O	✓	Level Trend	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	36.3
1A 2 f Other	Biomass	N2O	✓	Level	1990, 1991, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	27.6
1A 1a Public Electricity and Heat Production	Solid Fuels	N2O	✓	Level Trend	All years	27.2
1A 1a Public Electricity and Heat Production	Biomass	N2O	✓	Level Trend	2000, 2003, 2005, 2006, 2007, 2008, 2009, 2010	26.7
2 C Iron and Steel Production	Production Quantities	CO2	✓	Trend		17.7
1A 2 f Other	Gaseous Fuels	N2O	✓	Trend		14.5
1A 1a Public Electricity and Heat Production	Other Fuels	N2O	✓	Trend		12.6
2 F 8 Electrical Equipment	Consumption	SF6	✓	Trend		7.1
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	✓	Level	All years	3.5
1A 1a Public Electricity and Heat Production	Liquid Fuels	N2O	✓	Level Trend	1990, 1992	2.5
2 B 1 Ammonia Production	Production Quantities	CO2	✓	Level Trend	1990, 1999, 2000, 2001, 2003, 2004, 2005, 2007, 2008	0.0
5 C 2 Land converted to Grassland	Emissions/Removals	CO2	✓	Level	2010	-546.3
5 F 2 Land converted to Other Land	Emissions/Removals	CO2	✓	Level Trend	All years	-729.8
5 A 2 Land converted to Forest Land	Emissions/Removals	CO2	✓	Level Trend	All years	-2,951.4
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO2	✓	Level Trend	All years	-8,199.5
Sub-total with LULUCF		All gases				51,396.4
% of total with LULUCF		All gases				84.6
TOTAL EMISSIONS WITH LULUCF		All gases				60,719.0

1.6 Information on QA/QC

The APA has the overall responsibility for the GHG inventory in Portugal, including the competence for the coordination of the Quality Assurance and Quality Control System. The conceptualization of the system has however been done under an external consultancy with Ecoprogresso. Each public organization contributing with data to the inventory is responsible for the quality of their own data. The inventory staff is responsible for the implementation of QA/QC procedures.

The QA/QC system is an integral part of the SNIERPA, which was created by the March, 17th Resolution of the Council of Ministers nr. 68/2005.

The QA/QC system is composed of two main elements: a Quality Control and Quality Assurance Programme and a Procedures Manual. The first schedules the application of the general (QC1) and specific (QC2) Quality Control as well as Quality Assurance (QA) procedures, described in detail in a Manual. The procedures were defined according to Good Practice and Uncertainty Management Guide (IPCC, 2000) and adapted to the specific National Inventory (INERPA) characteristics.

Quality Control tier 1 (QC1) procedures defined in the QA/QC Manual include a series of checklists, which consider basic checks on the accuracy of data acquisition processes (including, e.g., transcription errors) and checks on calculation procedures, data and parameters.

It includes also cross-checking among subcategories in terms of data consistency, verification of NIR and CRF tables. Documentation and archiving procedures include checks on information handling which should enable the recalculation of the inventory. QC tier 2 (QC2) procedures, on the other hand, include technical verifications of emission factors, activity data, comparison of results among different approaches.

Both QC1 and QC2 procedures have been applied by the inventory team during the inventory calculation and compilation following the QA/QC plan.

An important tool for data checking is the implied emissions factor (IEF) graph of the CRF Reporter. This utility enables the visual verification of time series. When inconsistent trends are detected the underlying data are analysed and corrected if necessary.

The results of quality control of national submissions under the EC GHG Monitoring Mechanism (e.g. completeness checks, consistency checks), and the issues raised during the annual review process of the UNFCCC, constitute additional processes of technical verification and represent valuable sources of error detection.

1.7 General uncertainty assessment

Emission estimates from the GHG inventory pretend to express the best estimate of emissions, which should not be over-estimated neither under-estimated. Nevertheless, natural variability of certain emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameters due to errors in original monitoring data, reference studies and expert judgment, all this factors lead to a certain error or level of uncertainty in emission estimates. However, the main purpose of the realization of the uncertainty assessment is not to contest the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of future inventories and guide future methodological developments. The uncertainty

analysis was performed only for the direct GHG: CO₂, CH₄, N₂O, HFC and SF₆, considering all emissions in CO₂ equivalent (CO₂e). The uncertainty of all source activities was determined including the LULUCF categories.

A tier 1 methodology was used to estimate total uncertainty for the inventory, for each individual year and also the uncertainty in trend. Basically this method of classical analysis, which is explained in more detail in IPCC(2000) and in Annex B, attributes uncertainty values to activity data and emission factors, for each of the pollutants, and uses error propagation rules to combine uncertainty estimates for each individual source into total uncertainty. In accordance with IPCC (2000) considerations the uncertainty in Global Warming Potentials (GWP) is not included in uncertainty quantification. The uncertainty values, both for activity data and emission factors, are discussed in the detailed analysis of emission estimates for each individual source sector.

The uncertainty assessment was performed using inventory data for all years from 1990 to 2010. The results are presented in the table below. The full range of emission possibilities, considering the confidence limit may be observable in Figure 1.4.

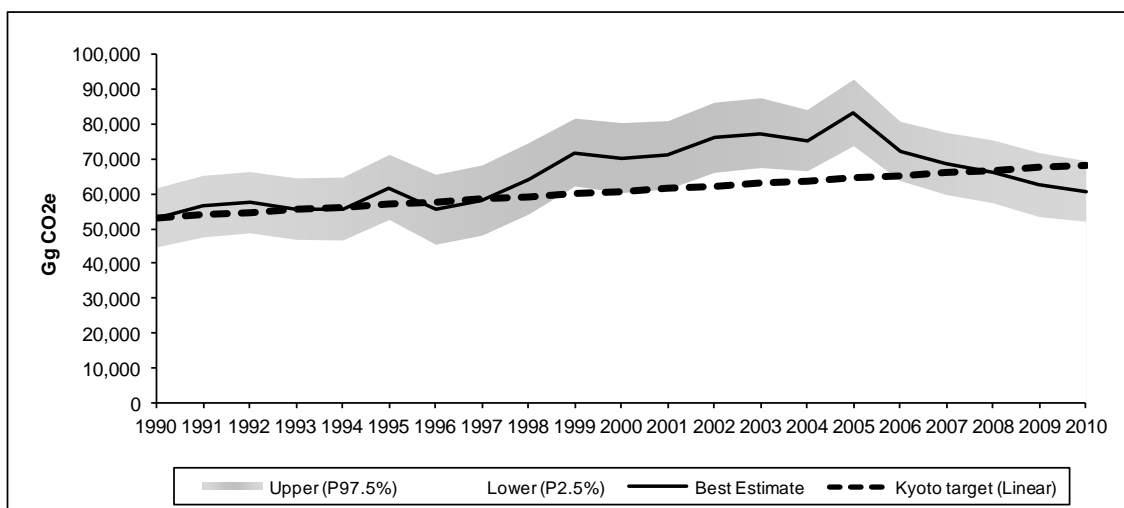
Total uncertainty varies along years from a minimum value of 11.5% up to 17.5%, in the period from 1990 to 2010. The uncertainty in trend from 1990 to 2010 is 14.4%. Uncertainty values are defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

Table 1.7 – Uncertainty of the annual emission estimates, by gas and total uncertainty

Year	CO2	CH4	N2O	LULUCF	F Gases	Total
	per cent					
1990	3.29	25.79	114.69	77.41	0.00	15.37
1991	3.32	25.49	115.78	104.76	0.00	15.12
1992	3.22	25.55	115.43	57.17	0.00	14.64
1993	3.35	25.85	116.89	54.19	0.00	15.26
1994	3.42	25.28	116.24	50.41	0.00	15.64
1995	3.31	24.96	110.32	67.51	66.35	14.57
1996	3.83	24.94	112.36	51.47	65.31	17.54
1997	3.64	24.96	112.30	49.19	65.05	16.79
1998	3.43	24.56	111.53	55.90	63.52	15.38
1999	3.03	24.46	110.79	52.64	58.12	13.59
2000	3.02	21.58	116.99	56.93	60.34	14.36
2001	3.21	23.38	115.72	54.58	65.05	13.86
2002	3.11	24.06	117.48	58.30	67.46	13.31
2003	3.24	23.32	111.69	152.94	65.46	13.02
2004	3.09	20.43	112.74	61.86	63.62	11.69
2005	2.79	20.53	112.51	211.99	65.47	11.52
2006	2.92	21.08	113.23	62.47	65.47	11.74
2007	3.52	21.77	115.49	54.00	67.00	12.89
2008	3.66	22.81	114.08	51.43	69.35	13.47
2009	3.65	24.00	118.84	52.53	71.09	14.62
2010	3.94	24.78	121.29	58.58	71.15	14.81

Uncertainty analysis will be revised in the near future to take better account of the latest methodological developments, in particular concerning the LULUCF sector. The estimates presented are provisional.

Figure 1.4 - Trend of total GHG emissions with LULUCF and lower and upper estimates considering the 95% confidence interval



1.8 Overview of the completeness

CRF Table 9 (Completeness) gives an overview of the level of completeness of the 2012 submitted inventories to the UNFCCC and EC. Additional information on this issue is given in the subchapters.

The inventory covers the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x).

As a general rule the inventory covers emissions realized in the whole Portuguese territory, i.e., mainland Portugal and the two autonomous regions of Madeira and Azores Islands.

1.9 Future developments

Future improvements are defined under the MDP which is settled each year in the context of the SNIERPA and is developed under the responsibility of the APA in cooperation with the sectoral Focal Points. The MDP pretends to reflect the results of the various review processes, in particular the UNFCCC reviews, the annual inventory compilation process (all experts and entities involved can make proposals for methodological development), and generally the results of the application procedures of Quality Control and Quality Assurance which have been defined under the Control and Quality Assurance System.

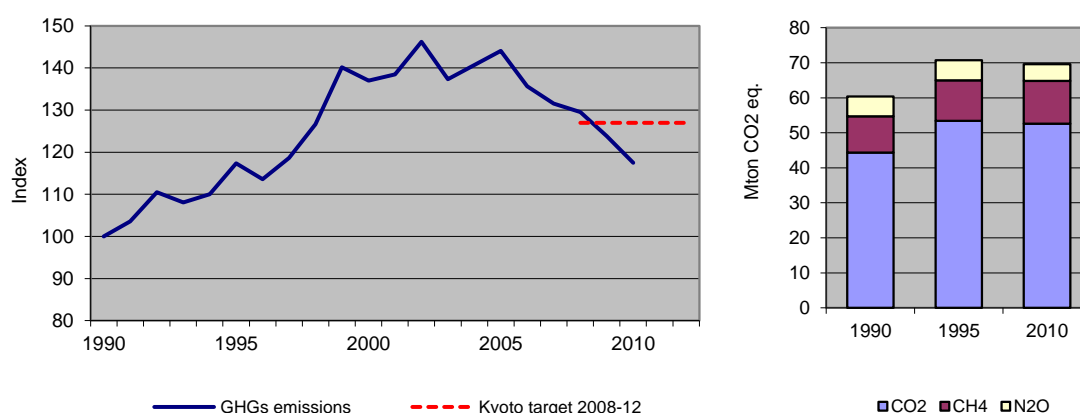
Uncertainty analysis will be revised in order to take account of the last methodological developments, in particular concerning the LULUCF sector.

2 TRENDS IN PORTUGUESE GHG EMISSIONS

2.1 Trends of Total Emissions

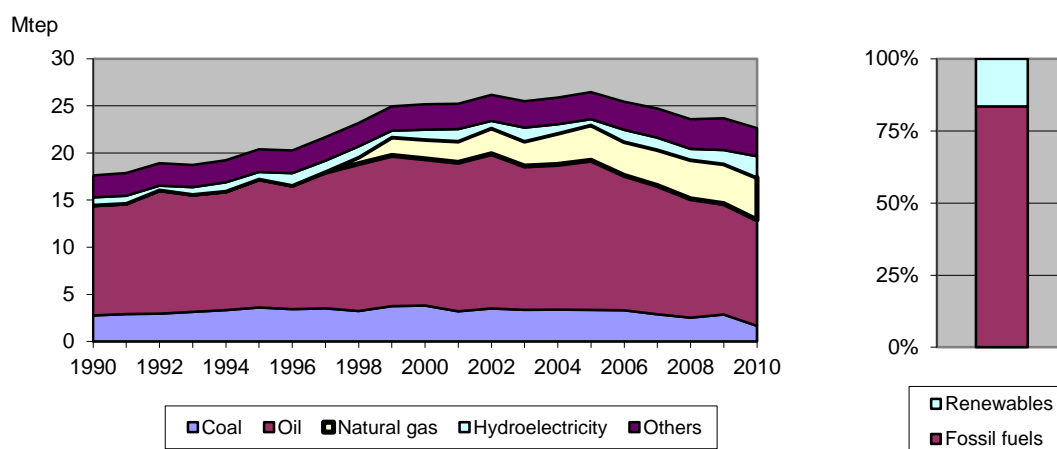
In 2010, total Portuguese GHG emissions without LULUCF were estimated at about 70.6 Mt CO₂e, representing an increase of 17.5 per cent compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27 per cent compared to the 1990 level.

Figure 2.1– GHG emissions (without LULUCF)



The principal source of GHGs in Portugal in 2010 is the energy sector. The largest gas emitted is CO₂ representing approximately 75 per cent of total GHGs emissions expressed as global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for about 92 per cent of total CO₂ emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2010, 83 per cent of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas) whereas the renewable energy represents the remaining part, i.e. 17 per cent in average (Figure 2.2). The situation is however changing in the most recent years, with a progressive increase of the renewable energy sources such as wind.

Figure 2.2 – Primary energy consumption trends and share of fossil/renewables in 2010



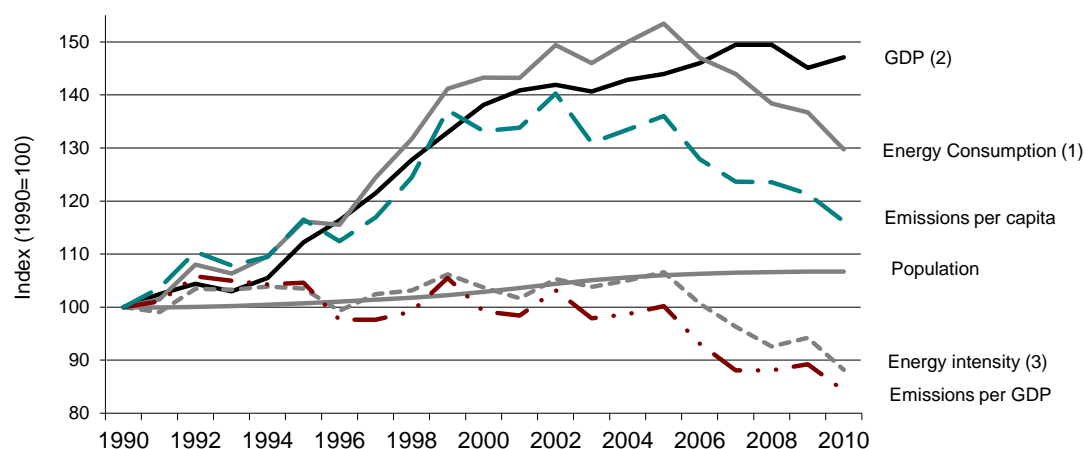
Notes: Hydroelectricity: domestic production. Others: includes fuelwood, wastes, and biogas. Fossil fuels: includes coal, oil and natural gas. Renewables: includes domestic hydroelectricity and others.
Source: DGGE.

The average annual emissions growth rate for the overall period 1990-2010 is less than 1 per cent. However, as illustrated in there are roughly three different periods that can be identified in terms of the annual average rate evolution: from 1990 to 1995 3.7 per cent; from 1995 to 1999 4.7 per cent, and since 2000 a more moderate increase and a decreasing tendency since 2005 can be recognised.

Driving factors for emissions growth are amongst others, economic growth and higher energy demand, increasing road transport volume and distance driven supported by strong development of road infrastructure and rapid growth in private car ownership. Climatic variables, such as precipitation, which vary to years have also a significant effect on hydropower generation and then produces substantial inter-annual variations in emissions.

During the 1990s Portugal experienced a significant economic growth with an increase in GDP of about 40 per cent in the period 1990-2010, corresponding to an average annual increase of 2.1 per cent. The most rapid growth occurred from the years 1993 to 2000, where the average annual growth rate reached the 4.1 per cent. Since 2001, economic growth slowed considerably, contributing, at least partially, to the more moderate emissions growth registered in the most recent years.

Figure 2.3– GHG emissions per capita, per unit of GDP and energy consumption



Notes:

Primary Energy Consumption; GDP at 2000 prices.; Energy Consumption per GDP.

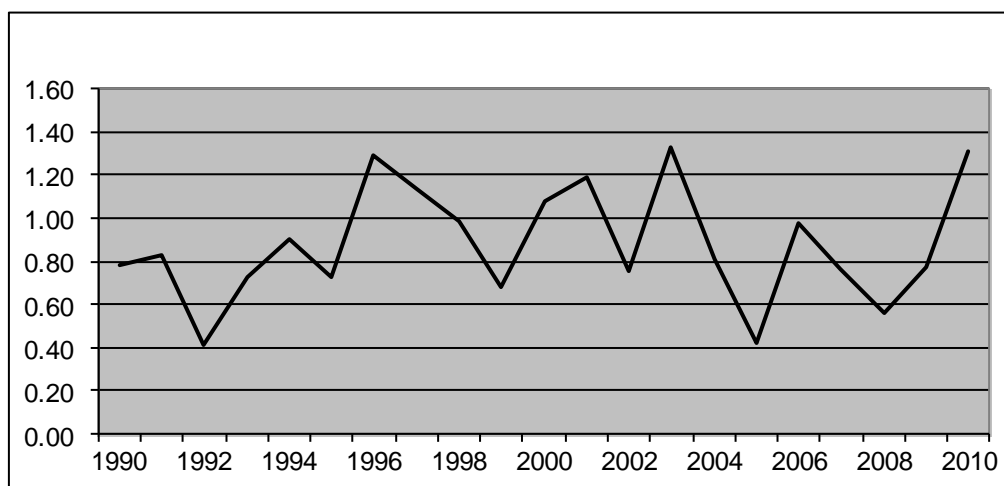
Sources: INE, DGEG.

During the period analyzed, the country has achieved a decoupling of emission trends from economic growth, in particular for the most recent years. The decrease of carbon intensity (GHG emissions per GDP unit) observed in the recent years (see previous figure), is surely related to the implementation of some important measures that had a positive effect in the emissions levels, such as the introduction of natural gas (1997), the installation of new combined cycle thermoelectric plants using natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial processes, the improvement of car efficiency and fuels quality.

The level of emissions in the period analyzed show significant inter-annual variations, which are related to the pronounced fluctuations of hydroelectric power generation, that is highly affected by annual variations in precipitation. Concerning recent years, year 2003 had a higher value of total annual water availability (hydraulic index (HI) of 1.33, meaning that it rained 33% more than an average hydrologic year) (see Figure 2.4) which has allowed a considerable increase of hydroelectric power production and the subsequent reduction in CO₂ emissions from electricity production in thermal plants (see Figure 2.5). As compared to 2003, hydroelectric power production decreased in 2004 (HI of 0.81) and 2005 leading to the increase in GHG emissions. The year 2005 recorded in fact one the lowest figures on record concerning water availability (HI of 0.42), which resulted in a significant increase in fossil fuel consumption and consequently on emissions. The latest years 2007 to 2009 present nevertheless a change in this relation, since the precipitation was lower (HI/2007=0.76, HI/2008=0.56, HI/2007=0.77) than the previous year (HI/2006= 0.98) and the emissions from the energy sector were lower these years. This is due to a conjunction of factors as the decrease in the primary energy consumption, the bigger importance of electricity importation, the proliferation of renewable and low-carbon fuels. In the most recent years this tendency has been accentuated by the slowdown of industrial activity and the consequent reduction of fuel consumption, and the cessation of some activities in the country such as the production of ammonia in 2009 with the relocation of production facilities to India. Another fact of note is the introduction of the use of high-performance catalysts and

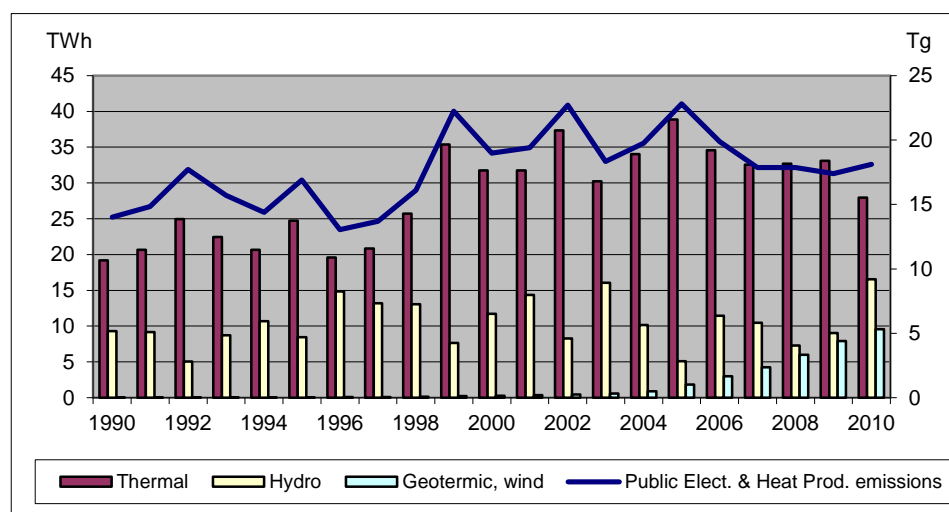
optimization of the ratio ammonia / air in the production of nitric acid which had an influence in the decrease of emissions.

Figure 2.4 – Hydraulic index



Note: HI = 1 corresponds to the average hydrologic availability.
Source: EDP, REN

Figure 2.5 – Gross electric power production and emissions from electricity and heat generation



Source: DGGE.

2.2 Trends by Gas

Over the 1990-2010 period, CO₂ is the gas having registered the biggest increase (18.7%) and N₂O decreased by about 14.2%. F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2010: 1.8%).

Figure 2.6 – Change of GHG emissions by gas over the period 1990-2010

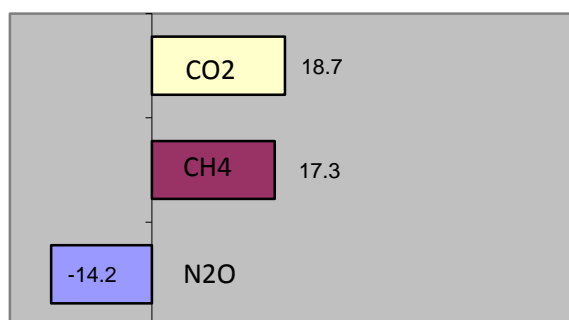


Figure below illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2010, being evident CO₂ as the primary GHG, accounting for about 74.5% of Portuguese emissions on a carbon equivalent basis in 2010 (LULUCF excluded). The second most important gas is CH₄, followed by N₂O, representing, respectively, 17.0% and 6.7% of total emissions in 2010. Portugal has chosen 1995 as the base year for fluorinated gases. In 2010 these gases represented about 1.8% of total GHG emissions.

Throughout the report, the reference to “total emissions” is meant to refer to “total emissions without CO₂ from LUCF on a carbon equivalent basis”. Furthermore the references to 1990 represent the year 1990 as estimated for this submission which is different from the assign amount (except when specify otherwise). This difference is mainly due to the revision of the time series or methodology improvements.

Figure 2.7 – GHG emissions by gas

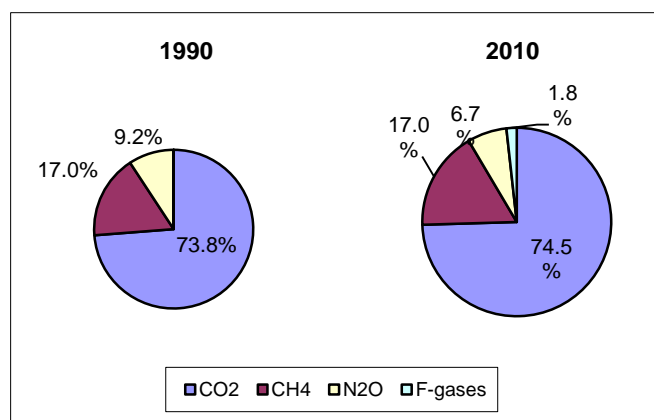


Table 2.1 – GHG emissions and removals in Portugal by gas

GHG EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂ equivalent (Gg)											
CO ₂ emissions including net CO ₂ from LULUCF	37,158	39,989	41,221	39,489	39,016	44,492	37,901	40,384	46,094	53,339	52,377
CO ₂ emissions excluding net CO ₂ from LULUCF	44,317	46,199	50,233	48,858	49,488	53,430	50,791	53,593	58,071	65,833	64,669
CH ₄ emissions including CH ₄ from LULUCF	10,430	10,805	10,714	10,671	11,106	11,561	11,453	11,597	12,151	12,290	11,493
CH ₄ emissions excluding CH ₄ from LULUCF	10,217	10,486	10,609	10,600	11,059	11,320	11,360	11,563	11,990	12,201	11,311
N ₂ O emissions including N ₂ O from LULUCF	5,602	5,602	5,566	5,510	5,569	5,748	6,032	6,017	5,912	5,989	6,071
N ₂ O emissions excluding N ₂ O from LULUCF	5,543	5,519	5,525	5,473	5,535	5,674	5,985	5,981	5,846	5,938	6,000
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	66	88	121	152	217	307
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	0	0	0	0
SF ₆	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	5	6	6	6	6	6
Total (including LULUCF)	53,190	56,397	57,501	55,670	55,691	61,873	55,478	58,125	64,335	71,842	70,254
Total (excluding LULUCF)	60,077	62,205	66,367	64,932	66,082	70,496	68,230	71,264	76,075	84,196	82,293

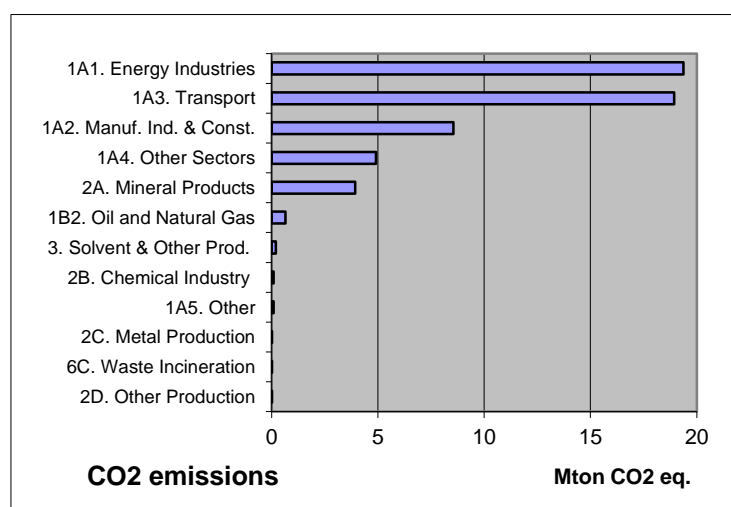
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% change 1990-10
CO ₂ equivalent (Gg)											
CO ₂ emissions including net CO ₂ from LULUCF	52,758	57,090	58,258	56,996	64,566	54,421	50,811	48,541	44,788	42,471	14.3
CO ₂ emissions excluding net CO ₂ from LULUCF	65,098	69,097	64,230	66,497	68,573	63,941	61,346	60,122	56,766	52,619	18.7
CH ₄ emissions including CH ₄ from LULUCF	12,071	12,602	13,124	12,015	12,487	11,827	11,502	11,620	11,734	12,157	15.7
CH ₄ emissions excluding CH ₄ from LULUCF	11,955	12,443	12,466	11,863	11,975	11,724	11,468	11,602	11,660	11,984	17.3
N ₂ O emissions including N ₂ O from LULUCF	5,821	5,876	5,401	5,590	5,358	5,035	5,288	5,079	4,854	4,842	-13.6
N ₂ O emissions excluding N ₂ O from LULUCF	5,762	5,806	5,228	5,479	5,213	4,971	5,237	5,030	4,792	4,757	-14.2
HFCs	391	494	599.63	674.84	771.59	864.58	961.54	1,065.17	1,147.43	1,231.87	-
PFCs	0	0	0.05	0.05	0.05	0.03	0.03	0.04	0.00	0.00	-
SF ₆	6	6	6.81	7.51	7.12	8.10	6.86	5.93	6.45	7.12	-
Total (including LULUCF)	71,047	76,067	77,390	75,243	83,190	72,156	68,569	66,311	62,529	60,719	14.2
Total (excluding LULUCF)	83,212	87,846	82,530	84,522	86,540	81,509	79,020	77,825	74,372	70,599	17.5

NE - Not Estimated; NO - Not Occurring; NA – Not Applicable

Next figures summarize the sources categories of emissions by gas (F-gases not presented).

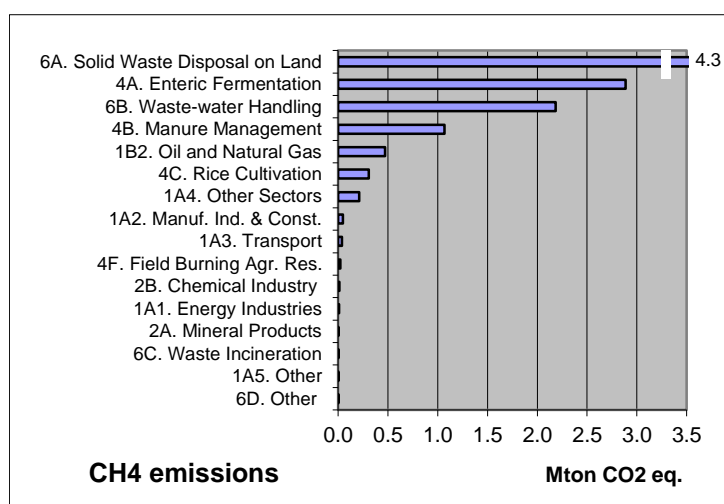
The largest GHG gas emitted is CO₂ which is mainly generated from fossil fuel combustion in energy-related activities (IPCC categories 1). Some other non-energy production processes such as cement production (included in category 2A), are also responsible for considerable quantities of CO₂ emissions.

Figure 2.8 – 2010 sources categories of CO₂



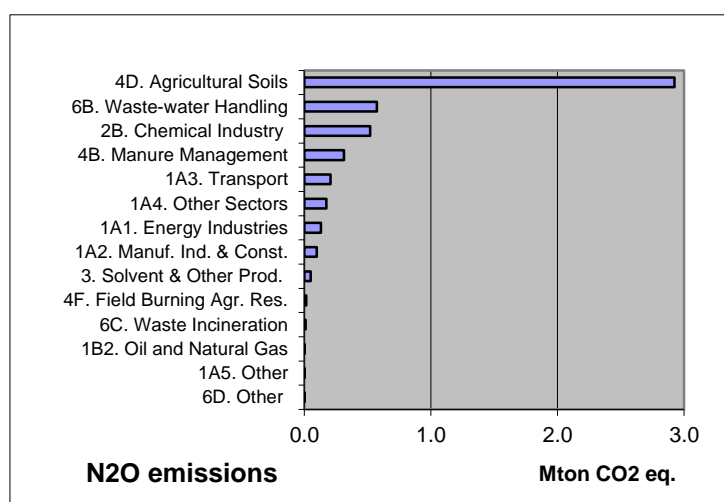
CH₄ is primarily generated through anaerobic decomposition of organic matter in biological systems, like decomposition of municipal and animal wastes, waste-water handling systems, or enteric fermentation in animals. Other sources are also responsible for these emissions, such as biomass burning, the distribution of natural gas and petroleum, and the incomplete fossil fuel combustion.

Figure 2.9 – 2010 sources categories of CH₄



N₂O emissions are associated with direct and indirect emissions from agricultural soils, mainly related to the use of synthetic and manure fertilizers, manure deposition by livestock, nitrogen fixation by N-fixing crops (leguminous plants), and incorporation of crop residues into soils. Other significant sources are fossil fuel combustion particularly in the transport sector, chemical industry (nitric acid production), wastewater treatment, and biomass burning (agricultural residues and residential combustion, and waste incineration).

Figure 2.10 – 2010 sources categories of N₂O



2.3 Trends by Sector

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into six large IPCC categories: Energy, Industrial Processes, Solvent use, Agriculture, LULUCF, and Waste.

Emissions (Figure 2.11, Table 2.2) have risen for all the sectors with the exception of Agriculture and Solvents Use. The LULUCF has not been considered in this provisional report.

Figure 2.11 – GHG emissions and removals by sector

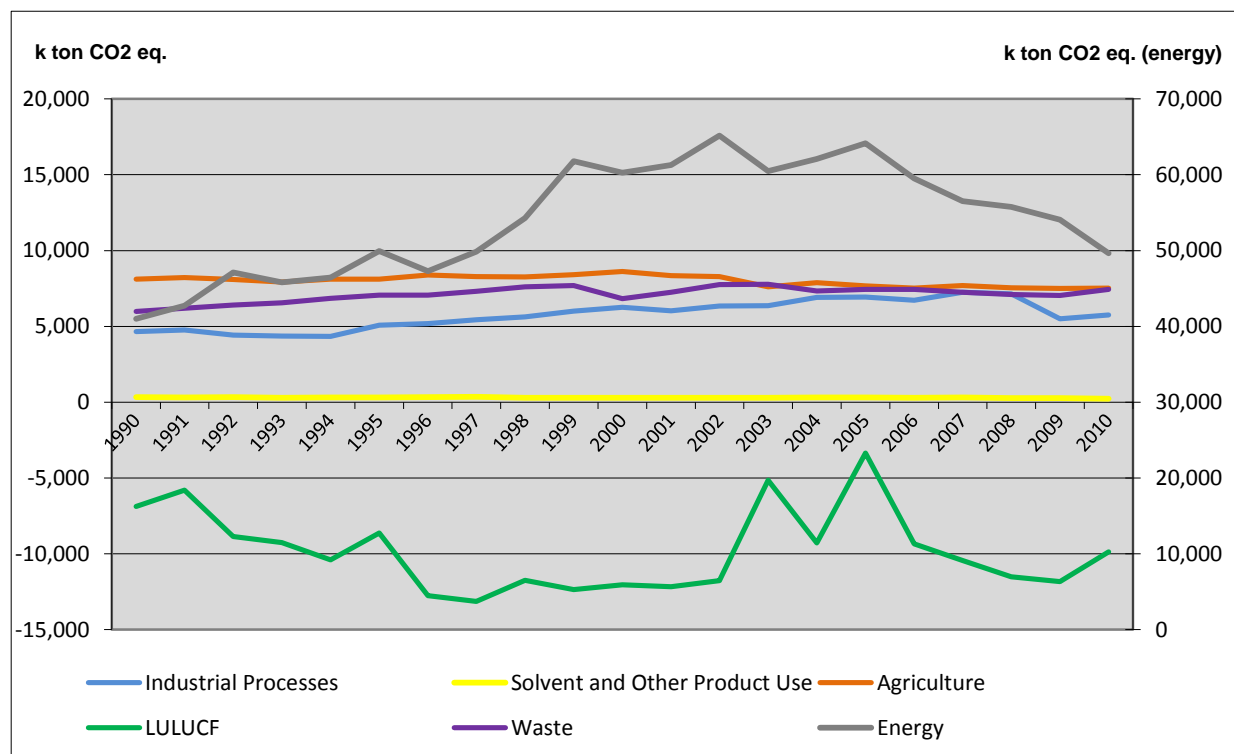


Figure 2.12 – GHGs emissions percentage change (1990-2010) by IPCC category (LULUCF excluded)

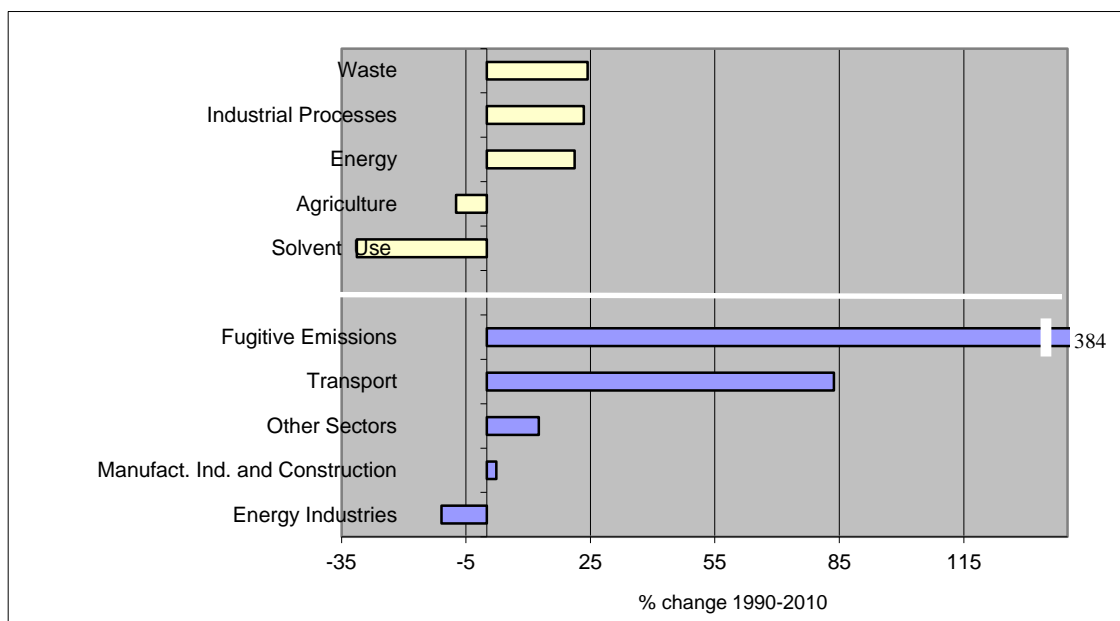


Table 2.2 – GHG emissions and removals by sector

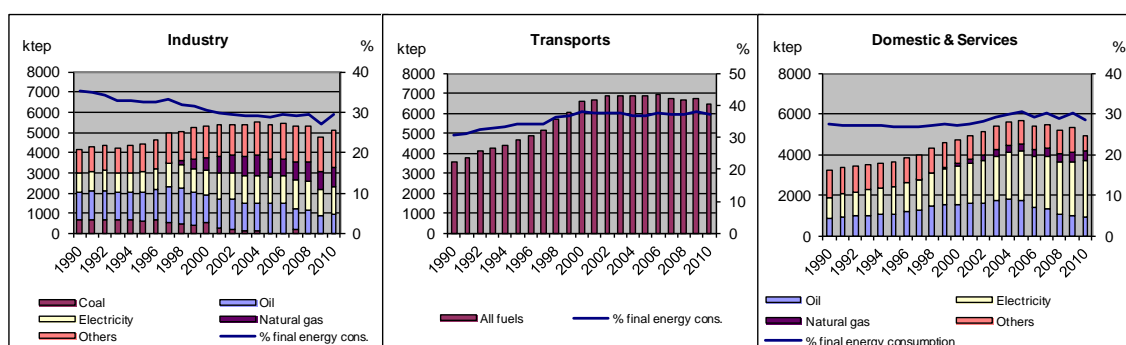
GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂ equivalent (Gg)											
1. Energy	40,980	42,726	47,127	45,810	46,461	49,929	47,275	49,859	54,289	61,780	60,276
2. Industrial Processes	4,664	4,761	4,423	4,356	4,331	5,072	5,174	5,447	5,625	6,015	6,262
3. Solvent and Other Product Use	332	316	326	286	316	312	334	357	292	293	300
4. Agriculture	8,113	8,214	8,088	7,917	8,122	8,124	8,388	8,289	8,256	8,410	8,624
5. Land-Use Change and Forestry ⁽⁷⁾	-6,887	-5,808	-8,866	-9,261	-10,391	-8,623	-12,752	-13,139	-11,740	-12,354	-12,039
6. Waste	5,988	6,187	6,403	6,562	6,852	7,058	7,059	7,313	7,614	7,698	6,831
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GHGs SOURCE AND SINK	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% change 1990-10
CO ₂ equivalent (Gg)											
1. Energy	61,277	65,172	60,491	62,075	64,158	59,526	56,523	55,757	54,057	49,654	21.2
2. Industrial Processes	6,032	6,353	6,358	6,914	6,944	6,729	7,258	7,149	5,498	5,756	23.4
3. Solvent and Other Product Use	302	292	290	315	322	286	303	266	272	228	-31.3
4. Agriculture	8,347	8,282	7,604	7,891	7,678	7,533	7,688	7,540	7,508	7,515	-7.4
5. Land-Use Change and Forestry ⁽⁷⁾	-12,164	-11,779	-5,141	-9,279	-3,350	-9,353	-10,451	-11,514	-11,842	-9,880	43.5
6. Waste	7,254	7,748	7,788	7,326	7,439	7,433	7,248	7,113	7,036	7,446	24.3
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-

Energy is by far the most important sector, accounting for 70 per cent of total emissions in 2010, and presenting an increase of 21 per cent over the 1990-2010 period. Transport and energy industries are the two most important sources representing respectively 27% and 21% of total emissions. Within the energy industries, public electricity and heat production represents alone 17.5% of the total emissions. This reflects the country important dependence on fossil fuels for electricity generation and transportation, which have grown steadily until the mid 2000s due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the growth of mobility. The situation seems to have changed in the most recent years, where we can observe stagnation and decrease of these trends.

The sectoral evolution of energy consumption presented in the next figure, shows that the sectoral structure of the energy demand has been changing. The share of the industrial sector,

which represented in 1990, 35 per cent of the final energy demand, decreased to 30 per cent in 2010. On the other hand, as previously mentioned, transports have been increasing importance, having raised from 31 per cent in 1990 to 38 per cent of the final energy consumption in the early 2000s. The increase of energy consumption of this sector was 91 per cent from 1990 to 2005, but the variation dropped to 81 in the 1990-2010 period. Also, the services is one of the sectors that have increased the most, having registered a 218 per cent rise of energy consumption from 1990 to 2005, and having slowing its increase to 156 per cent from 1990 to 2010. In 2010, this sector together with the domestic sector, represented 28 per cent of the share of the total energy consumed.

Figure 2.13 – Final energy consumption by main sectors and fuel



Mobile sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. The overall energy consumed for transportation is supplied by petroleum-based products, with nearly one third being gasoline (29 per cent in 2004). This fuel has been losing relatively importance since 1990, when the share was 40 per cent of the sectoral energy consumption. In the period 1990-2010 the emissions of transportation sources increased 84 per cent, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel from 1990 to the early 2000s, reflecting the increase in family income and the strong investment in the road infrastructure of the country in the 1990s decade. Indirectly the increase in road traffic activity also augments the emissions from fossil fuel storage, handling and distribution. As previously said, the situation seems to have stabilized in the early 2000s and then started to decline since 2005.

Still within the energy sector, the category “other sectors”, which include the residential and commercial activities, also registered a significant increase in the 1990-2005 period (with almost 53.5 per cent rise), but this tendency has decelerated (around 13 per cent increase in the 1990-2010 period), due to a certain extent to the stagnation of the economic growth, and also to other factors as energy conservation measures.

Agriculture, was in the period analyzed, one of the most significant sources of GHG emissions, and was responsible for 10.6 per cent of the Portuguese emissions in 2010, corresponding to a decrease of 7.4 per cent since 1990. This fact is related to the relatively decrease of importance of the sector in terms of the national economy, and is associated for instance with the reduction of the livestock production of certain categories of animals (e.g. swine), the extensification of cattle production and the decrease of fertilizer consumption.

Waste represented approximately 10.5 per cent of Portuguese emissions in 2010, recording an increase of approximately 24.0 per cent since 1990. The emissions for this sector have grown significantly in the period 1990-1999. This increase in emissions is primarily related to the rise of

waste generation (associated with development of the family income and the urbanization growth registered in the country during the last decade) and the deposition of waste in landfills.

Industrial processes represented 8.2 per cent of the Portuguese emissions in 2010, and have grown 23.4 per cent since 1990. These emissions which are generated as by-product of many non-energy-related activities, are mostly related to the increase of cement production, road paving, limestone and dolomite use, lime production, glass and ammonia production.

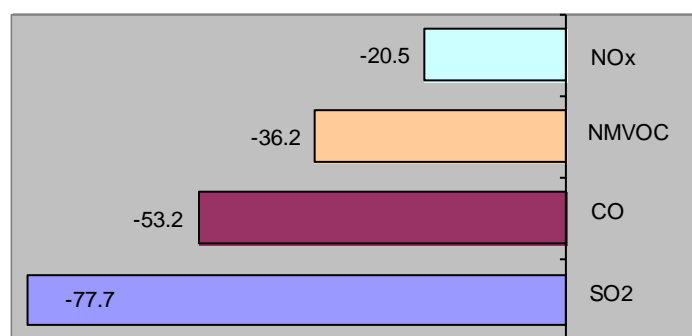
Solvent use represents less than 1 per cent of total emissions, and is mainly related to NMVOC emissions³.

Estimates of emissions and sinks from land use change and forestry category suffered a thorough revision and data trends for this chapter have deeply changed since last submission. According to the this revision the sector is estimated to be a net sink in the whole period, representing a sequester of -9.9 Mt CO₂e. in 2010.

2.4 Indirect GHG and SO_x emissions

Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO_x, and NMVOC are precursor substances for ozone which is a GHG. SO_x produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Figure 2.14 – Indirect GHG and SO_x emissions: 1990-2010 variation



³ These are converted into ultimate carbon dioxide after being emitted to atmosphere.

Table 2.3 – Indirect GHG and SO_x emissions: 1990-2010

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
(Gg)											
CO	865	880	912	892	877	863	854	819	805	777	726
NO _x	248	260	278	269	270	281	269	270	277	285	279
NM VOC	313	317	323	311	312	306	305	305	303	296	280
SO ₂	322	314	375	319	294	329	271	286	334	344	304
Gas emissions	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	% change 1990-10
(Gg)											
CO	657	631	593	568	525	492	462	456	414	405	-53.2
NO _x	283	290	268	275	272	248	241	221	209	197	-20.5
NM VOC	267	264	248	243	230	223	216	211	196	200	-36.2
SO ₂	285	283	191	193	195	170	163	117	79	72	-77.7

In 2010, all these gases emissions have decreased from 1990 levels: SO_x -77.7 per cent, CO -53.2 per cent, NMVOC -36.2 per cent and NO_x -20.5 per cent (previous table).

Energy is the major responsible sector for emissions of NO_x, SO_x and CO. Its contribution for NMVOC emissions is also significant, together with Solvent use and Industrial processes.

Within energy, transportation is responsible for the major share of NO_x emissions, 35.5 per cent of 2010 totals. Despite the fast growing trends of the transport sector (mainly road) since the 90s, the introduction of new petrol-engine passenger cars with catalysts converters and stricter regulations on diesel vehicles emissions, limited the growth of these emissions or even its decrease. In fact, the situation started to change in the last years, as transport emissions growth has first stabilised and started to decline in the most recent years. Since the early 2000s, NO_x emissions from transport has been presenting a decreasing tendency; and CO and NMVOC emissions recorded real reductions in the 1990-2010 period, respectively, -74 per cent and -84 per cent.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 31 per cent of the 2010 totals.

SO_x emissions are mainly generated in the energy industry sector (approximately 36 per cent of total emissions in 2010) and combustion in manufacturing industries (approximately 34 per cent of total emissions in 2010), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. The situation is however improving with a significant development of renewable sources (mainly wind) and energy efficiency measures, among other factors as reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 from November 10th). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO_x emissions. The emissions variation in the period 1990-2010 shows in fact a decrease in SO_x emissions in both sub-categories: energy industries and manufacturing industries -87 per cent and -66 per cent. Since 2007, SO_x emissions from the energy industries registered a significant reduction (approximately -75 per cent) which is explained by the implementation of two new abatement systems (desulfurization in two Large Point Source Energy Plants in Mainland Portugal).

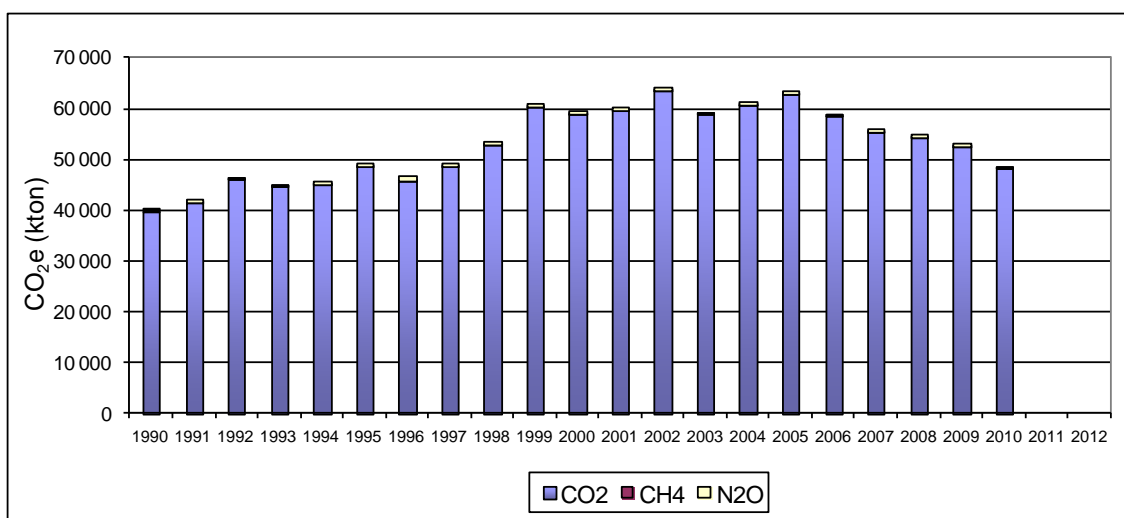
3 ENERGY (CRF 1.)

3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting in 2010 for 70.9 per cent of total emissions of CO₂e excluding LULUCF. Total emissions from this sector have increased 21.2 per cent from base year to last year, although the rise in emissions did not occur in a continuous manner. Thus, the year with maximum emissions occurred in 2002, as may be seen in Figure 3.1. The oscillations in CO₂e emission for the energy sector are mainly due to inter-annual variation in availability of hydropower. In recent years there has been a decreasing trend in emission resulting not only from a period of economic stagnation in Portugal but also with the implementation of measures that had a positive impact in the reduction of emissions, such as the introduction of lower carbon intensive fuels, the installation of combined cycle thermoelectric plants and co-generation units, and the use of renewable energy sources.

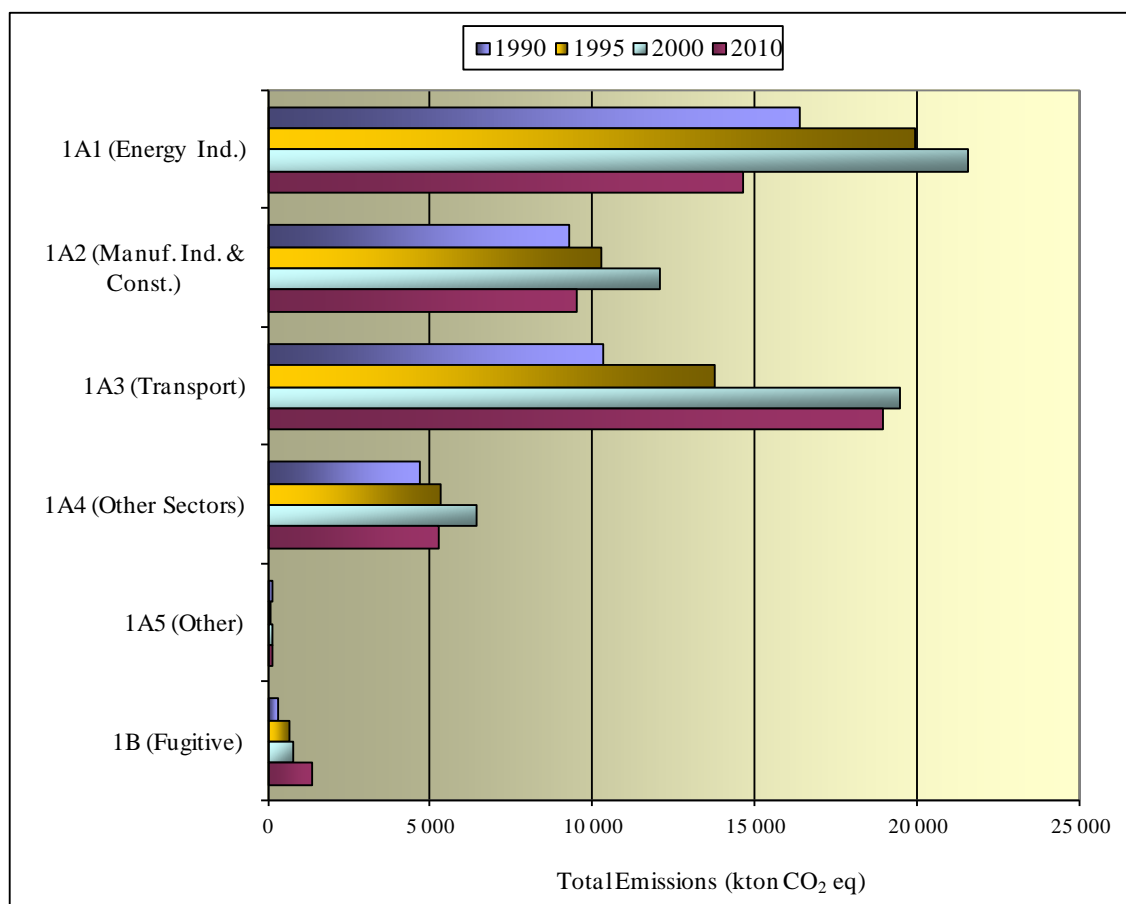
The relative importance of total CO₂e emissions from the Energy sector has increased, from 68.3 per cent in 1990 to 70.9 per cent in 2010. By far the most important gas emitted by this sector in 2010 is CO₂, with 97.1 per cent of sector emissions expressed in CO₂e.

Figure 3.1 – Total CO₂e emissions from the Energy Sector (CRF 1)



Considering the importance of each of the sub-sectors, which are presented in Figure 3.2, it is clearly visible the dominance of emissions from the Energy Industry (1A1) and from Transportation activities (1A3). It is also clear the accentuated increase that emissions from this last category have suffered during the period from 1990 till 2000, and the decrease in emission for all sector from 2000 to 2010 (except for 1B). The Energy Industry the Manufacturing Industries and Construction sectors represent, in terms of absolute values, the biggest decrease in emission from 2008 to 2010.

Figure 3.2 – Importance of CO₂e emissions from sub-sectors in Energy sector in selected years – 1990, 1995, 2000 e 2010.



3.1.1 Fuel Combustion Activities (CRF 1.A.)

Energy emissions are primarily related to fossil fuel combustion. In Portugal transport and public electricity and heat production industries were the primary sources of Portuguese GHG emissions, representing, respectively, 27.0 per cent and 17.5 per cent of total GHG emissions excluding LULUCF in year 2010. It is noticeable the significant increase in emissions from transportation in comparison to the other sub-source categories. Manufacturing industries and construction is the third larger source within Fuel Combustion Activities with 13.5 per cent of total emissions in 2010. GHG emissions from Refining of Petroleum Products is another relevant source with 3.3 per cent of total emissions for this sector. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 7.5 per cent of total sector emissions. Emissions for each sector in selected years are presented in Figure 3.3, and the full time trend in Figure 3.4.

The emissions from the incineration of municipal solid wastes (MSW) that occurs with energy recovery are accounted in this sector as recommended by the IPCC GPG.

Figure 3.3 – Total GHG emissions in source 1A, expressed as CO₂e, in 1990, 1995, 2000 and 2010

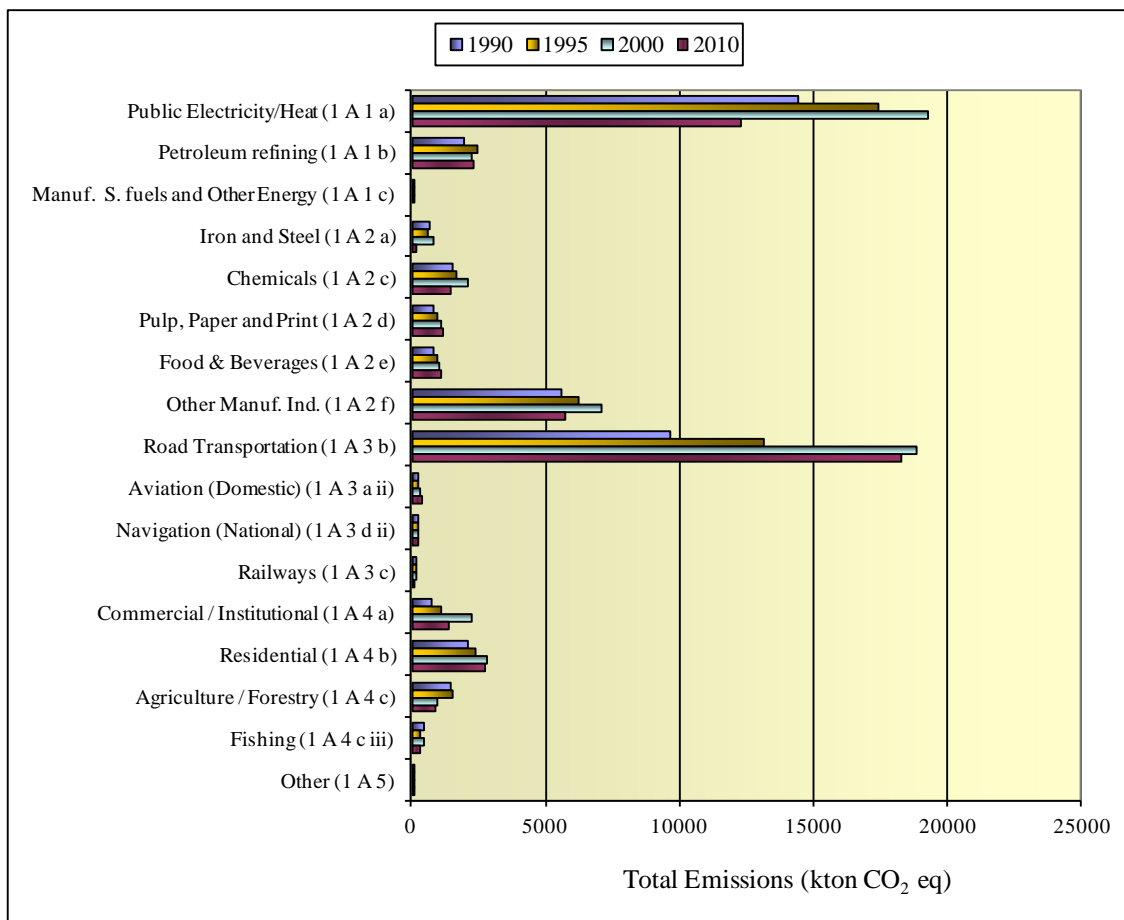
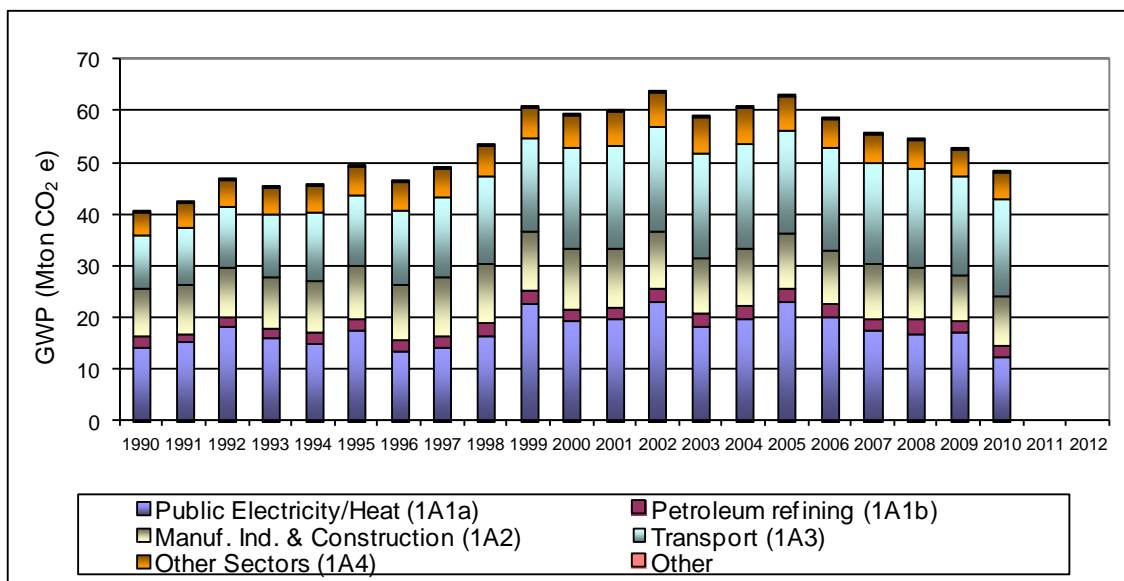


Figure 3.4 – Trend of total GHG emissions in source 1A, expressed as CO₂e, by sub-sector



GHG emissions from this activity sector are almost fully dominated by direct CO₂ emissions, which represent about 98.2 per cent of GHG emissions in 2010. CH₄ and N₂O are minor

sources, respectively 0.6 per cent and 1.2 per cent of total GHG emissions from the 1 A sector in 2010.

CO₂ emissions are dependent on the carbon content of the fuel used and, for this reason, estimates of CO₂ emissions are more accurate and methodology simpler to apply using fuel consumption data only. During the combustion process some carbon is released in smaller amounts in the form of other gases, including CH₄, CO, NMVOC and airborne particulate matter. It is presumed that all these other carbon containing non-CO₂ gases oxidise to CO₂ in the atmosphere and are included in carbon dioxide estimates (ultimate CO₂)⁴.

Emissions from fossil fuel combustion include also other atmospheric contaminants such as N₂O, NO_x, SO_x, NH₃, particulate matter, heavy metals and toxic organic compounds. Unlike CO₂, emissions estimates of these air contaminants require more detailed information, such as operating conditions, combustion and emission control technologies and fuel characteristics.

Fossil fuel combustion from international bunkers, i.e., international aviation and maritime transportation, also generates air emissions in a similar way to other fuel combustion activity. In accordance with international guidelines, these emissions are not included in national totals, but are reported separately as a memo item.

Biomass combustion also generates gas emissions. Carbon dioxide emissions from this source are estimated in the inventory but not included in national emissions totals being considered that there are no net emissions of CO₂, as carbon released during biomass combustion had been in fact fixed from atmosphere by the photosynthetic process and when is burnt and returns to atmosphere does not increase the atmospheric/biosphere CO₂ pool. This activity is reported separately for information purposes only. Nevertheless non-CO₂ emissions from combustion of biofuels and other biomass fuels are however considered in inventory totals.

3.1.2 Fugitive Emissions from Fuels (CRF 1.B.)

Apart from fuel combustion emissions, the Energy sector includes also other from production, transmission, storage and distribution of fossil fuels. Generated gases from these sources are CO₂, NMVOC, SO_x, CH₄, NO_x and CO, and emissions per sub-sector source are presented in Figure 3.5 where the major importance of emissions due to oil refining, transport and distribution for the beginning of the period may be seen, while the importance of emissions from storage and transportation of natural gas, became more relevant in recent years.

GHG emissions occurring as CO₂ are responsible for 54.2 per cent of 1B total emissions in 2010, being the remaining 45.8 per cent emissions almost exclusively CH₄. Emissions by gas are represented in Figure 3.6.

⁴ Three CO₂ quantities may be referred in the inventory with different definitions: (1) End of pipe CO₂ - Carbon dioxide effectively emitted from the source: exhaust, chimney, etc; (2) Ultimate CO₂ - carbon dioxide increase contribution to atmosphere. Includes end of pipe CO₂ but also the conversion of other gases and particles that are emitted to atmosphere containing carbon and that are supposedly later converted in CO₂; (3) Fossil ultimate CO₂ - CO₂ emissions resulting from carbon with fossil origin: fossil fuels, mineral rocks and all other non biomass carbon.

Figure 3.5 – Trend of total GHG emissions in source 1B, expressed as CO₂e, by sub-sector

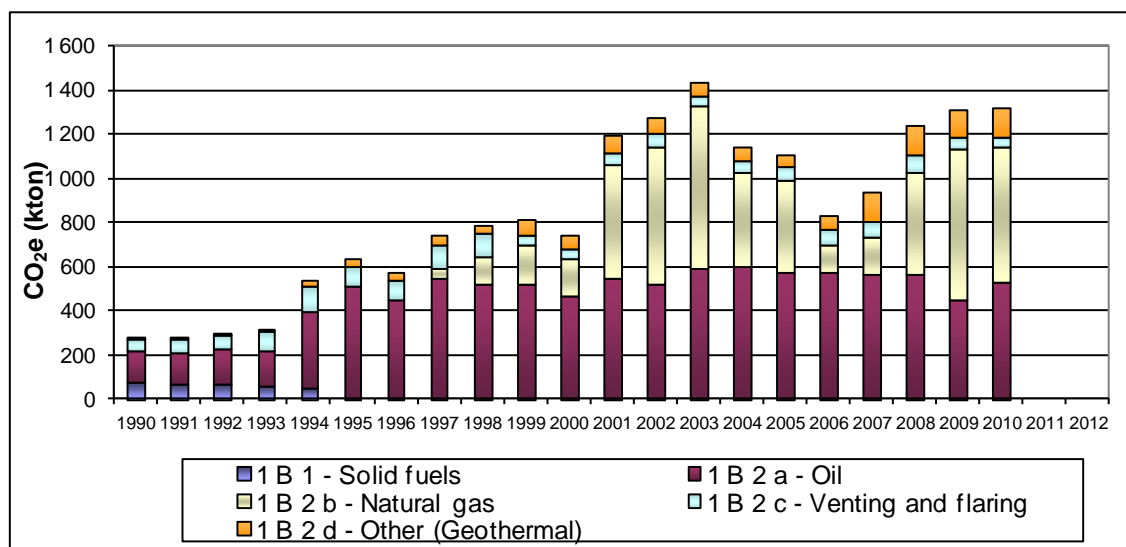
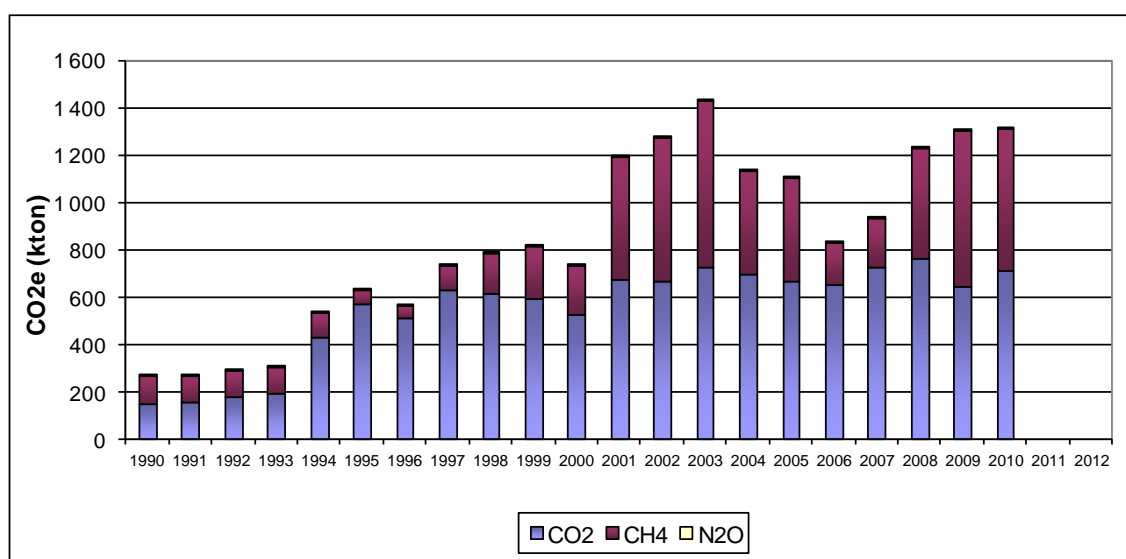


Figure 3.6 – Trend of total GHG emissions in source 1B, expressed as CO₂e, by GHG



3.2 International Bunker Fuels

International bunkers fuels used in international aviation and international navigation are presented in the figure below.

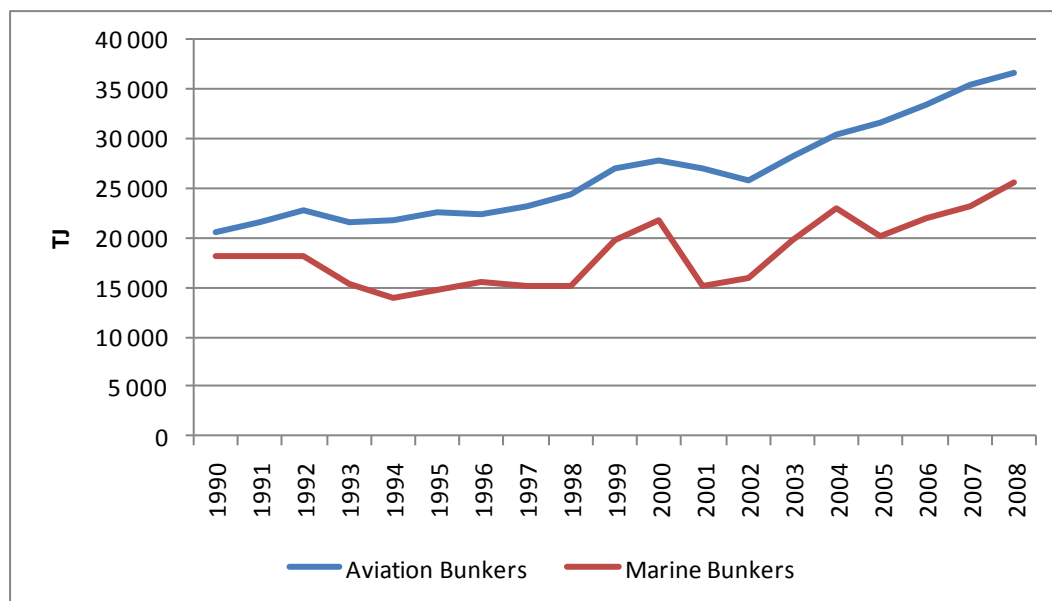


Figure 3.7 – International navigation and aviation bunkers

3.2.1 International aviation bunkers

The majority of jet fuel is used for international aviation. In 2008 the quantity of jet fuel for international aviation was about 88% of total jet fuel. This percentage was estimated according with the origin and destiny of the flight as recommended by 2006 IPCC guidelines.

Until 2006, the classification for international fuel used by the national fuel authority (DGEG) was different from the one used in national inventory. DGEG split was based in the flag of the aircraft rather than in the origin and destiny of the flight. Some efforts were made in the fuel balance to use the IPCC criteria and since 2007 the difference between the reference approach (RA) and the sectoral approach (SA) has decreased as presented in the figure below.

The international aviation energy consumption data from the IEA differ to some extent from the DGEG fuel balance. This discrepancy results from a reporting error to the IEA. The data from IEA includes consumption from domestic aviation and this occurs because domestic consumption is missed classified as international aviation when reported to the IEA. DGEG is developing efforts to correct this reporting error.

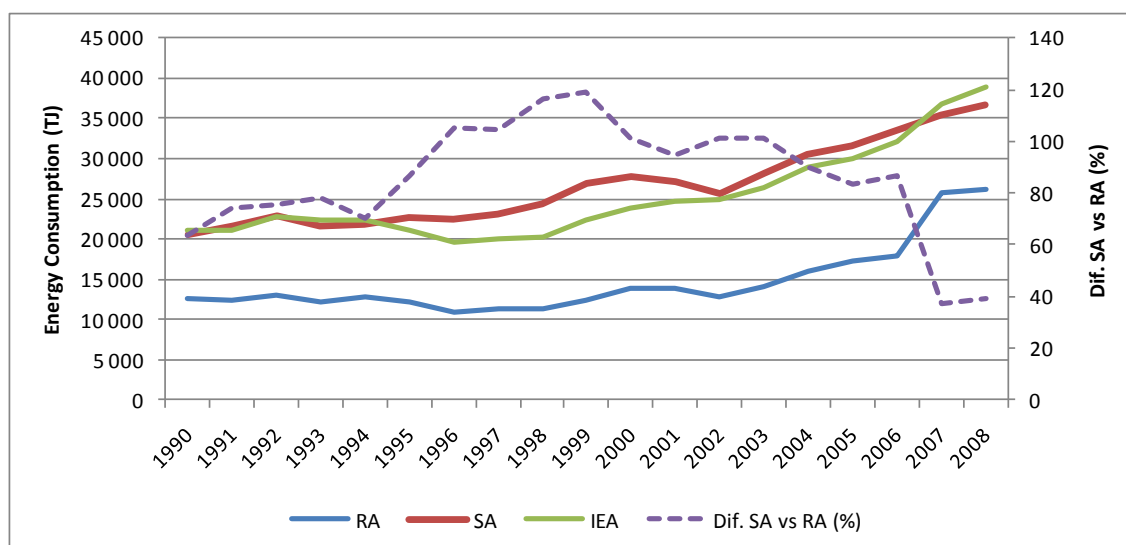


Figure 3.8 – International aviation bunkers

3.2.2 International marine bunkers

In 2008 the energy consumption for international navigation was about 90% of the total energy used in marine navigation. This percentage was estimated according with the origin and destiny of the flight as recommended by 2006 IPCC guidelines.

The international fuel classification used by the national fuel authority (DGEG) is different from the one used in national inventory. DGEG split is based in the flag of the ship rather than in the origin and destiny of the movement. As consequence the international consumption from the reference approach (RA) differs from the consumption estimated using the sectoral approach (SA).

The international navigation energy consumption data from the IEA differ to some extent from the DGEG fuel balance. This discrepancy results from a reporting error to the IEA. The data from IEA includes consumption from domestic navigation and this occurs because domestic consumption is missed classified as international bunkers when reported to the IEA. DGEG is developing efforts to correct this reporting error.

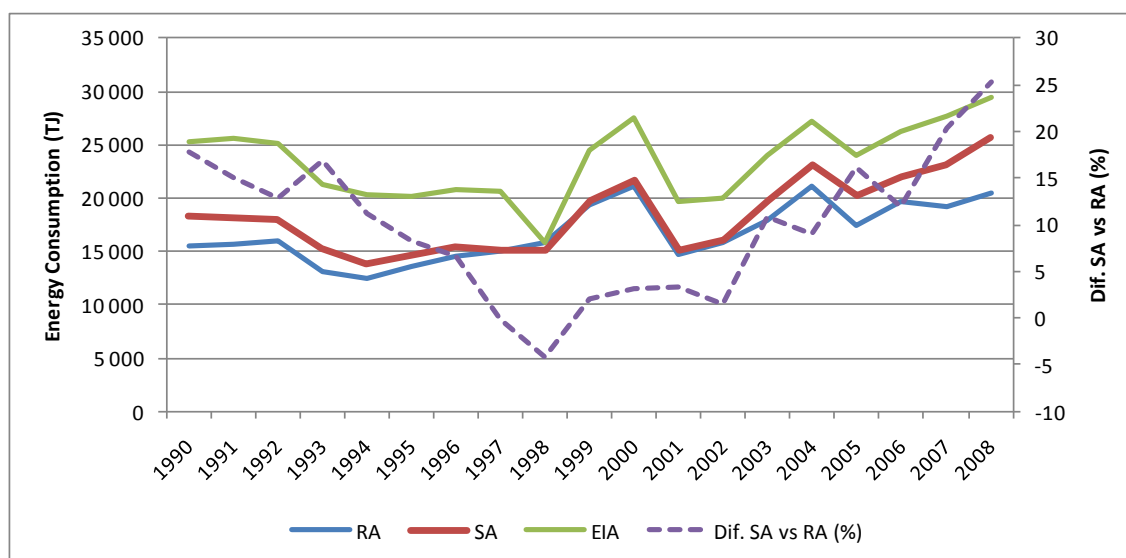


Figure 3.9 – International marine bunkers

3.3 Category Sources

3.3.1 Energy Industries

3.3.1.1 Public Electricity and Heat Production (CRF 1.A.1.a.)

3.3.1.1.1 Overview

Until 1950 electric energy production in Portugal was based in small power plant units using coal as energy source. In the 50s increase in the demand for industry consumers induced the development of hydro-electric production units and the built of *Tapada do Outeiro* power plant using low energy coal (lignite) obtained from Portuguese mines. The next decade saw the entrance of petroleum products as the main energy sources, and three additional power plants were built: *Carregado*, *Barreiro* and *Setúbal*. After the energy crisis of 1973/74 and 1979/81 there was a political shift towards the preference for imported coal (*Sines* and *Pêgo* power plants, started in 1985 and 1993 respectively) and, more recently, towards natural gas (*Turbogás* power plant already in operation and the new TER⁵ unit, build near the old unit in *Carregado* entered its final testing period at the end of 2003). In the islands of Azores and Madeira, the discontinuity in territory caused the prevalence of smaller units, basically one per island, working on fuel-oil or diesel-oil.

Apart from the dedicated electric power plants, auto-producers generate electric energy for own consumption and to sales to the public system. However not all combustion from these sources are included here because, according to the Revised 1996 IPCC Guidelines, emissions from auto-producers are to be reported under the industrial or commercial branch in which their main economic activity occurs. The present source sector includes only emissions resulting from main power producers⁶.

⁵ TER – Termoelétrica do Carregado

⁶ Main Power Producers generate and sell electricity or heat as their main activity (primary activity) either public owned or private owned. In contrast there are other Auto-producers of electricity or heat, that also are agents producing or selling electricity or heat, but as a secondary activity and not as main business.

Several components of the electricity and heat producing sector were arbitrarily individualized in the inventory of air emissions from the energy sector for the sake of making explanation easier and they are discussed separately in the following paragraphs.

This category includes also the emissions associated with the incineration of municipal solid wastes (MSW) with energy recovery.

3.3.1.1.1 Large Point Source Energy Plants in Mainland Portugal

The number of Large Point Source Energy Plants (LPS-EP) in continental Portugal has increased from 6 units in 1990 to 19 units at present. Power plants and installed power are listed in table below together with their main relevant characteristics.

Table 3.1 – Large Point Sources in the sector of Public Electricity and Heat Production

Power Plant	Location	Start	Situation	Fuel***	Power	Technology	Treatment of Gas Effluents****	Stack Height (m)	Comments
Tapada do Outeiro	Gondomar	1959	Deactivated (2003)	LIG + FO	150/100/47* MWe	Boiler + Steam Turbine.	ESP	60 (x3)	Lignite use stopped in 1997
Portgen (new Tapada do Outeiro)	Gondomar	1998	Working	NG + GO + LPG	990 (3x330) MWe	Combined Cycle.	DLE (only for one group)	60 (x3)	-
Soporgen	Lavos	2001	Working	NG	67 (44+23) MWe	Co-generation. Combined Cycle	DLE	50 (x2)	-
Energim	Alhambra	2002	Working	NG	43.7 MWe	Co-generation. Combined Cycle	-	31 (x1)	-
Mortágua	Mortágua	1999	Working	WW + NG + GO	30 MWe	Boiler + Steam Turbine.	ESP	-	-
Pêgo	Abrantes	1993	Working	HC + FO + GO + LPG	628 MWe	Boiler + Steam Turbine.	ESP + LNOX + WFGD + SCR	225 (x1)	WFGD after 2008 SCR after 2008
Pêgo (Elecgás)	Abrantes	2010	Working	NG + GO	800 MWe	Combined Cycle	DLE	80 (x2)	
Carregado	Alenquer	1968	Working	FO + NG + GO + LPG	750 (6x125) MWe	Boiler + Steam Turbine.	ESP	100 (x3)	Natural gas introduced in 1997
TER	Alenquer	2004	Working	NG + GO	1170 MWe	Combined Cycle.	-	75 (x3)	-
Carriço	Sines	2006	Working	NG + GO	487 MWe	Co-generation.	-	30 (x1)	-
Alto do Mira	Amadora	1975	Deactivated (2003)	GO	132 MWe	Gas Turbine.	-	13.5 (x1)	-
Barreiro	Barreiro	1978	Deactivated (2010)	FO + LPG	65 (32+33) MWe	Co-generation.	-	104 (x1)	-
Fisigen	Barreiro	2009	Working	NG	121 MWt	Co-generation.	-	-	-
Setúbal	Setúbal	1979	Working	FO + GO + LPG	1000 (4x250) MWe	Boiler + Steam Turbine.	ESP	201 (x2)	-

Power Plant	Location	Start	Situation	Fuel***	Power	Technology	Treatment of Gas Effluents****	Stack Height (m)	Comments
Sines	Sines	1985	Working	HC + FO	1256 (4X314) MWe	Boiler + Steam Turbine.	ESP + LNOX + WFGD + SCR	225 (x2)	WFGD after 2008 SCR after 2011
Tunes	Silves	1973	Working	GO	199.2 (2x16.3 + 2x83.3) MWe	Gas turbine.	-	13.5	Groups 1 and 2 deactivated in 2007.
Lares	Figueira da Foz	2009	Working	NG + GO	1428 MWt	Combined Cycle.	-	-	-
Constância	Constância	2009	Working	WW + FO + LPG	39.2 MWt	Boiler + Steam Turbine.	-	-	-
Figueira da Foz	Figueira da Foz	2009	Working	WW + NG	31.2 MWt	Boiler + Steam Turbine.	DLE + ESP	80	-
Cacia	Cacia	2009	Working	WW + NG + GO	49.75 MWt	Boiler + Steam Turbine.	-	-	-
CB Setúbal	Setúbal	2009	Working	WW + NG + GO	49.75 MWt	Boiler + Steam Turbine.	-	-	-
Rodão	Vila Velha do Rodão	2008	Working	WW + FO + LPG + GO	39.1 MWt	Boiler + Steam Turbine.	-	-	-

* 250 MW in 2 groups using fuel oil and natural gas.

** The smaller power value refers to situation after 2 of the 3 initial groups where closed. The intermediate value refers to the situation when 2 groups where operating.

*** HC - hard-coal; LIG - Lignite; FO - fuel-oil; GO - Diesel oil; NG - Natural Gas; WW – Wood Waste

**** WFGD – Wet Flue Gas Desulfurization; DLE – Dry Low Emissions; ESP – Electrostatic Precipitators; LNOx – Low Nox Burners; SCR - Selective Catalytic Reduction

There are two small gas turbine power plants included in the public service: one near Lisbon to sustain peak power demands and another in Tunes, in the southern province of Algarve, which is used to support the increase of demand during touristic seasonal peak demands. The unit near Lisbon (Alto do Mira) has interrupted its activity in 2003.

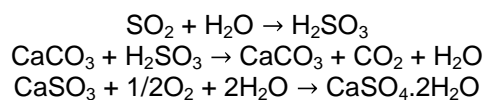
There has also been a change in the production structure along the 1990-2005 period, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase in the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was Orimulsion, that was used as fuel in Setúbal power plant but only in 1994 and its use had no continuation.

- In 1990 three units (Carregado, Setúbal and Barreiro) were using fuel-oil, one unit (Sines) was consuming imported hard coal and another unit (Tapada do Outeiro) was using lignite coal and fuel-oil;
- A new build coal unit (Pêgo) using hard coal, started producing electricity in 1993 and doubled its production capacity in 1995;
- The old unit in northern Portugal (Tapada do Outeiro) that was burning low heating value lignite coal, partly mined in Portugal, stopped using this fuel in 1997 but was kept producing electricity with a small consumption of fuel-oil since;
- Between 1995 and 1997 Carregado power plant shifted part of its production groups from residual fuel-oil to natural gas;
- A new unit (Portgen) consuming natural gas was built in northern Portugal near the old unit of Tapada do Outeiro and started producing in 1998;
- A new unit - TER - also using natural gas was installed, and started activity in the end of 2003, near the old unit of Carregado;
- The Mortágua unit in central Portugal initiated production in 1999 using a combination of natural gas and wood wastes;
- Soporgem and Energin, in central Portugal and Carriço (in the south) start production (Soporgem in 2001, Energin in 2002 and Carriço in 2006) using natural gas. They exist in close connection, respectively, with an industrial paper pulp plant, a chemical industry plant and a crude oil refinery;
- In 2009 a new power plant was built in Lavradio – Fisigen. This new plant replaced the Barreiro plant in 2010. Also in 2009 a new power plant was built in Figueira da Foz – Lares, which burn NG as fuel;
- In later years (2008 and 2009) new small power plants were built that burn wood waste;
- In 2010 a new combined cycle plant was inaugurated in Abrantes.

3.3.1.1.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

From the information gathered only two plants in Portugal implement this kind of abatement system: Pêgo and Sines. Both plants use hard coal and fuel oil in the combustion processes. The abatement equipments operate since 2008 (for both plants).

In a wet flue gas desulfurization the SO₂ emissions are absorbed by lime, forming CO₂ and plaster (gypsum + H₂O) as by-products:



These equations show that the wet flue gas desulfurization reduces the SO₂ emissions but increment de CO₂ emissions.

Since there is no CRF category specific for desulfurization, total CO₂ emissions from this abatement system were included together with combustion emissions.

3.3.1.1.1.3 *Energy Plants in Azores and Madeira Autonomous Regions*

Electricity production in the autonomous regions of Madeira and Azores islands depends mostly on small and medium scale power plants using imported residual fuel oil and/or diesel oil.

Table 3.2 - Electricity Power Plants in the Azores and Madeira

Power Station	Location	Fuel*	Power
Porto Santo	Porto Santo	FO + GO	51.9 MWt
Câmara de Lobos	Câmara de Lobos	FO + GO	326.4 MWt
Canical	Canical	FO + GO + LPG	144 MWt
Santa Bárbara	Faial	FO + GO	41.16 MWt
Belo Jardim	Terceira	FO + GO	158.8 MWt
Caldeirão	São Miguel	FO + GO	254.84 MWt
Pico	Pico	FO + GO	26.28 MWt
Graciosa	Graciosa	GO	4.26 MWe
São Jorge	São Jorge	GO	7.03 MWe
Flores	Flores	GO	2.31 MWe
Corvo	Corvo	GO	0.56 MWe
Santa Maria	Santa Maria	GO	5.68 MWe

* HC - hard-coal; LIG - Lignite; FO - fuel-oil; GO - Diesel oil; NG - Natural Gas; WW – Wood Waste

3.3.1.1.1.4 *Non public co-generation Energy Producers*

Auto-producers not included in their industrial and commercial branches were considered non public co-generation energy producers. These smaller private owned co-generation units started after 1993 and although working actually in close association with other industrial activities, are independent companies, in legal terms, which the main activity is defined as electric and heat production. Consequently they were included in this source sector and not in industry sector as emissions from other co-generation units are.

3.3.1.1.1.5 *Municipal Solid Waste incineration*

This issue is considered in the Waste (CRF 6) chapter in order to avoid repetition.

3.3.1.1.2 Methodology

3.3.1.1.2.1 Thermo-electricity Power Plants

A bottom-up sectoral Tier 2 approach was used to estimate emissions of CO₂ and other air pollutants from this activity. For carbon dioxide, a mass balance approach could be used in principle to estimate emissions from the carbon content of fuels. But because that information is not available from most power plants, the IPCC recommendation of using emission factors based on energy consumption was used: "Emission factors for CO₂ from fossil fuel combustion are expressed on a per unit energy basis because the carbon content of fuels is generally less variable when expressed on a per unit energy basis than when expressed on a per unit mass basis" (IPCC, 1996).

Total CO₂ and ultimate CO₂ emissions from fossil origin were estimated from:

$$\begin{aligned}
 U_{CO_2(u,f,y)} &= EF_{CO_2} * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3} \\
 Fossil_{CO_2(y)} &= \sum_u \sum_f [U_{CO_2(u,f,y)} * C_{Fossil(f)} * 10^{-2}]
 \end{aligned}$$

$U_{CO_2(y)}$ – Total carbon liberated to atmosphere from consumption of fuel f in unit plant u, expressed in total carbon dioxide emissions (ton);

$Fossil_{CO_2(y)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

EF_{CO_2} – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ – Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f,y)}$ - Consumption of energy (Low Heating Value) from fuel f in power plant u in year y (GJ).

This formula reflects the fact that some carbon in fuel is not oxidized and not emitted to atmosphere. Although, some carbon in the fuel is not released directly as carbon dioxide but instead in the form of carbon monoxide, methane, volatile organic compounds and even in soot, ash and particulate matter as consequence of the incomplete combustion of fuel. Emissions of these compounds in airborne fraction are transformed sooner or later into CO₂ in the atmosphere or after deposition on soil. Emissions of CO₂ at stack exhaust (End-of-pipe emissions) may be estimated from final CO₂ emissions from:

$$Stack_{CO_2} = U_{CO_2} - 44/12 * (NMVOC * C_{NMVOC} + CO * 12/28 + CH_4 * 12/16 + TPM * C_{TPM}) * 10^{-3}$$

where

$Stack_{CO_2}$ - end of pipe emissions of carbon dioxide (kton);

NMVOC - Emissions of non-methanic Volatile Organic Compounds (ton);

CO - carbon monoxide emissions (ton);

CH₄ - Methane emissions (ton);

TPM - Total Particulate Matter emissions (ton);

C_{NMVO}C - Carbon content in NMVOC (w/w);

C_{TPM} - Carbon content of Total Particulate Matter (w/w).

Since EU-ETS data is available for inventory use plants specific carbon content was use in those cases where fuel analysis were made by the plant operator.

For methane and nitrous oxide, emission estimates were based on the application of emission factors to energy consumption (GJ/yr). The following equation was used:

$$\text{Emission}_{(u,f,y,p)} = \text{Energy}_{\text{Cons}(u,f,y)} * \text{EF}_{(u,f,y,p)} * 10^{-6}$$

where:

Emission_(u,f,y,p) - Emission of pollutant p estimated from consumption of fuel f in power plant u in year y (ton);

Energy_{Cons(u,f,y)} - Consumption of energy (Low Heating Value/ Net Calorific Value) from fuel f in power plant u in year y (GJ);

EF_(u,f,y,p) - Emission factor pollutant p, for fuel f consumed in power plant u in year y (g/GJ).

3.3.1.1.2.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

In the desulfurization processes it's important to determine the emission of CO₂ and the reduction of SO₂. For both determinations the lime consumption was used as activity data:

$$\begin{aligned} \text{CO}_2 \text{ Emission}_{(u,y)} &= \text{CaCO}_3\text{Cons}(u,y) * \text{CO}_2\text{Ratio} * 10^{-3} \\ \text{SO}_2 \text{ Removal}_{(u,y)} &= \text{CaCO}_3\text{Cons}(u,y) * \text{SO}_2\text{Ratio} * 10^{-3} \end{aligned}$$

CO₂ Emission_(u,y) – Emission of CO₂ estimated from CaCO₃ consumption in power plant u in year y(ton);

SO₂ Removal_(u,y) – Quantity of SO₂ not emitted estimated from CaCO₃ consumption in power plant u in year y(ton);

CaCO₃Cons_(u,y) – Consumption of CaCO₃ in power plant u in year y(ton);

CO₂Ratio – Ratio between CO₂ emitted and CaCO₃ consumption;

SO₂Ratio – Ratio between the SO₂ removed and CaCO₃ consumption;

Since both energy plants are included in the EU-ETS the CO₂ ratio reported under this scheme was used in the inventory – 0.44 ton CO₂/ton Ca. Monitoring data from the two plant was used for determining the SO₂ ratio: estimation based in CaCO₃ consumption and the difference between the expected SO₂ emissions without abatement system (based in the fuel sulphur content) and what was actually emitted. Because of this the SO₂ ration is plant specific and varies over time.

Since the methodology for determining combustion SO₂ does not consider the use of abatement systems, the quantity of SO₂ removed in the desulfurization equipment will be subtracted to the total SO₂ emissions.

3.3.1.1.3 Emission Factors

3.3.1.1.3.1 Large Point Source Energy Plants

Emission factors presented in next table are only function of fuel type and they were established from available emission factors from international bibliography, while trying as much as possible to choose those that best match national circumstances:

- IPCC 1996 Revised Guidelines (IPCC,1997);
- IPCC Good Practice Guidebook (IPCC,2000);
- EMEP/ CORINAIR Emission Factor Handbook (EEA,2002; EEA, 2009);
- AP-42 (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c);
- EU-ETS.

Table 3.3 – Emission Factors for energy production sector. Greenhouse Gases

Fuel	UCO ₂ ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1	FossilC %	CH ₄ ⁽ⁱ⁾ g/GJ	N ₂ O ⁽ⁱ⁾ g/GJ
Lignite	101.2	0.980	100	1.0	1.4
Hard Coal	92.0 ⁽ⁱⁱ⁾	0.980	100	0.7	1.4
Fuel-oil	77.4	0.990	100	0.7 ^(ii,iii)	0.6
Orimulsion	80.7	0.990	100	0.7 ^(ii,iii)	0.6
Natural Gas	56.1	0.995	100	0.1 - 1.4 ^(i,ii)	1.4
LPG	63.1	0.995	100	1.4	1.4
Biomass	109.6	1.000	0	15	4.3 ⁽ⁱⁱ⁾
Diesel (GT) ⁷	74.1	0.990	100	0.14	2.5 ⁽ⁱⁱ⁾
Diesel (Engine)	74.1	0.990	100	0.14	0.6

(i) IPCC (1997); (ii) EEA (2002); (iii) AP-42

The following table shows the plant specific CO₂ emission factors obtained in the EU-ETS.

Table 3.4 – CO₂ Emission Factors for energy production sector – Plant specific.

Fuel	UCO ₂ ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1
Hard Coal	93.5 - 95.2	0.995
Fuel-oil	79.2 - 79.5	0.990 - 0.995
Natural Gas	56.1 – 57.3	0.990 - 0.995

3.3.1.1.3.2 Other Thermo-electricity Power Plants

The other smaller - non LPS - power plants are seldom subjected to the continuous *Autocontrolo* program and the scarce available information does not allow the establishment of

⁷ Mainly used in Gas Turbine plants.

plant specific emission factors. Therefore emission factors reflect an expert best guess from the available bibliography, which again is available from:

- IPCC 1996 Revised Guidelines (IPCC,1997);
- IPCC Good Practice Guidebook (IPCC,2000);
- EMEP/ CORINAIR Emission Factor Handbook (EEA,2002);
- AP-42 (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c)

The emission factors that were used in the inventory are shown in Table 3.5 for the power plants belonging to the public system in Azores and Madeira, and in Table 3.6 for the non public co-generation self producers⁸.

Table 3.5 – Emission Factors for thermo-electricity production in Azores and Madeira. Greenhouse Gases

Region	Fuel	U _{CO2} ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1	Fossil _c %	CH ₄ g/GJ	N ₂ O ⁽ⁱ⁾ g/GJ
Azores	Fuel-oil	77.4	0.990	100	⁽ⁱⁱ⁾ 2.9	0.6
Azores	Diesel oil	74.1	0.990	100	0.14	0.6
Madeira	Fuel-oil	77.4	0.990	100	⁽ⁱⁱ⁾ 2.9	0.6
Madeira	Diesel oil	74.1	0.990	100	0.14	0.6
Madeira	LPG	63.1	0.995	100	1.4	1.4

(i) IPCC (1997); (ii) EEA (2002)

Table 3.6 – Emission Factors for non public co-generation self producers. Greenhouse Gases

Fuel	U _{CO2} ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1	Fossil _c %	CH ₄ g/GJ	N ₂ O ⁽ⁱ⁾ g/GJ
LPG	63.1	0.995	100	⁽ⁱⁱⁱ⁾ 0.06	1.4
Fuel –oil	77.4	0.990	100	⁽ⁱⁱ⁾ 2.9	0.6
Diesel oil	74.1	0.990	100	⁽ⁱ⁾ 5	0.6
Natural Gas	56.1	0.995	100	⁽ⁱⁱ⁾ 1.4	1.4

(i) IPCC (1997); (ii) EEA (2002); (iii) EEA (2002) NG EF corrected to LPG

3.3.1.1.4 Activity Data

Activity data has different origins according to specific energy plants:

3.3.1.1.4.1 Large Point Source Energy Plants

Data on fuel consumption, by fuel type, for LPS are available from these sources:

- Large Combustion Plants (LCP) directive - which relies in direct information reported from the individual plant producer to the Environment Ministry;
- Self-control program (*Programa Autocontrolo*)⁹;

⁸ Power producers as main activity only.

⁹ The *Auto-controlo* program is a legal obligation for major emitters.

- Plant activity reports from EDP;
- EU-ETS – European Union Emission Trading System.

For the latest years (mainly 2009 onwards) the EU-ETS completely replaced the other sources of information. Although different information sources have been used the consistency in time series is guaranteed considering that the same original source (power plant companies) is ultimately used.

As a general rule power plant units report information about consumption in tons or cubic meters of gas together with the Low Heating Value ¹⁰ for that specific year from where consumption of fuels in energy units are calculated from:

$$\text{Energy (GJ)} = \text{Consumption (ton/year)} * \text{LHV (MJ/kg)}$$

or

$$\text{Energy (GJ)} = \text{Consumption (Nm}^3\text{/year)} * \text{LHV (MJ/Nm}^3\text{)}$$

When LHV/NCV was not available it was estimated from interpolation or extrapolation from the remaining available time series. The average value and range of the reported LHV per fuel type is presented in next table.

Table 3.7 – Low Heating Value per fuel type

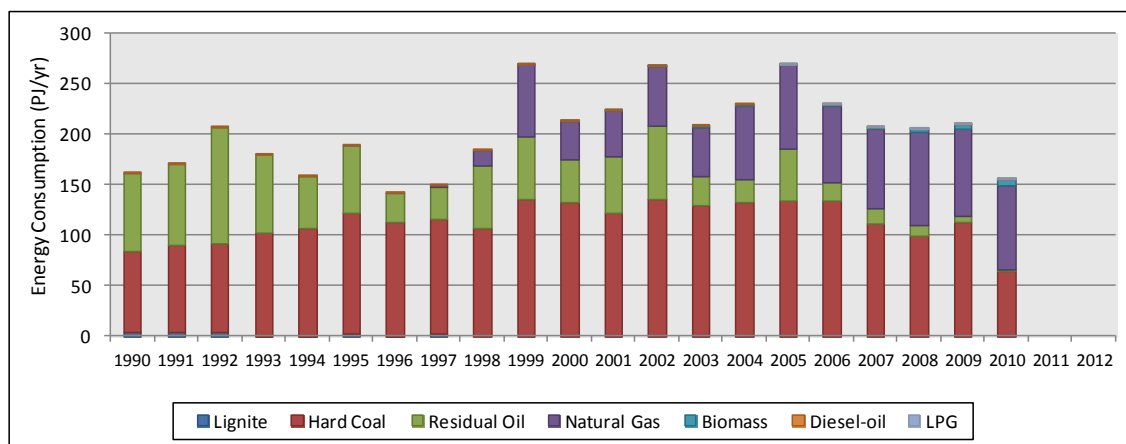
Fuel	LHV/NCV	
Lignite	16.42 (15.57 - 17.02)	MJ/kg
Hard Coal	25.70 (24.51 - 27.23)	MJ/kg
Fuel-oil	40.22 (39.42 - 41.61)	MJ/kg
Orimulsion	28.00	MJ/kg
Diesel oil	43.30	MJ/kg
Natural Gas	38.06 (36.02 - 39.16)	MJ/kNm ³
GPL	47.44 (47.28-48.55)	MJ/kg
Biomass	7.8	MJ/kg

Source: The same as for the fuel consumption (including in some cases plants specific information)

Total consumption per fuel type in comparable energy units (GJ) may be verified in Figure 3.10.

¹⁰ Low Heating Value (LHV) or Net Calorific Values (NCV) measure the quantity of heat liberated by the complete combustion of a unit volume or mass of a fuel, assuming that the water resulting from combustion remains as a vapour and the heat of the vapour is not recovered (GPG). In contrast, Gross Calorific Value (GCV) or Gross Heating Value (GHV) are estimated assuming that this water vapour is completely condensed and the heat is recovered (GPG). The default in IPCC Guidelines is to use the NCV.

Figure 3.10 – Trends of fuel consumption per fuel type



Not visible in the graph is the increase in biomass consumption (wood waste) from 1999 to 2010. The consumption of diesel-oil presents no clear trend since 1990 even though we can identify a slight crease in the later years of the time series. LPG represents only a small fraction of total fuel consumption in this sector (less than 0.001 per cent). The relevancy of residual oil has been decreasing since 2005, representing only a fraction of total consumption in 2010 due to Barreiro power plant deactivation.

3.3.1.1.4.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

Values for the total lime consumed for desulfurization in each plant were obtained in the EU-ETS. For confidentiality constrains and since there are only two plants in Portugal that use this kind of abatement system, the CaCO_3 consumption cannot be reported.

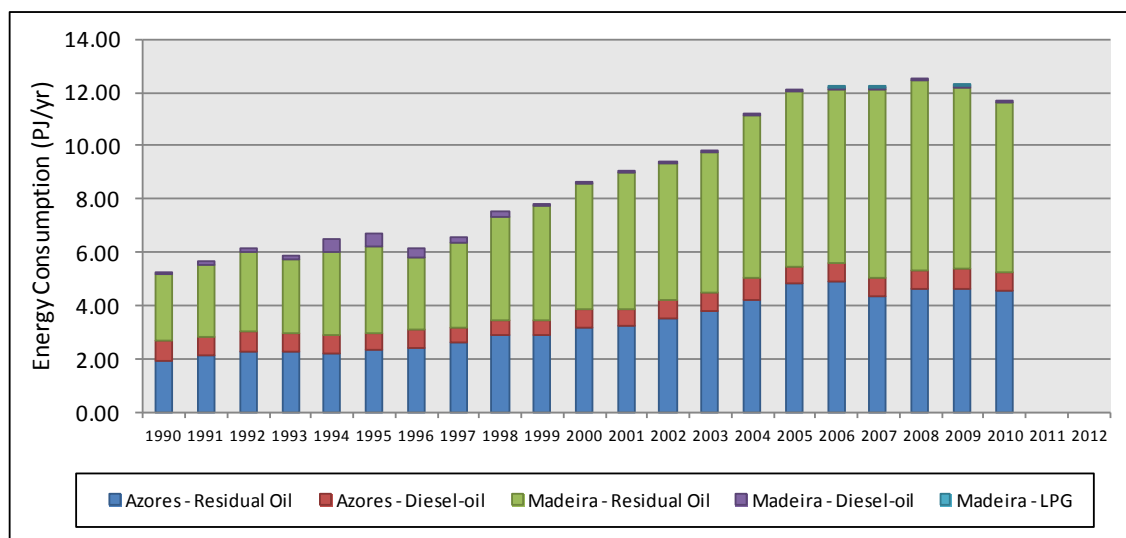
3.3.1.1.4.3 Energy Plants in Azores and Madeira Autonomous Regions

The quantity of residual fuel-oil, diesel oil and GPL used in Madeira and Azores in electricity production is available from the following two sources:

- Madeira and Azores Regional Environmental entities;
- EU-ETS.

Full fuel consumption time series can be observed in the figure below:

Figure 3.11 – Trends of fuel consumption in Azores and Madeira Archipelagos



Note: Consumption of diesel oil and LPG in Madeira represent a very small quantity and is barely visible in the figure.

Consumption of fuels expressed in energy units was estimated from the above consumption figures assuming the Low Heating Value (LHV/NCV) values presented in the following table.

Table 3.8 - LHV per fuel type

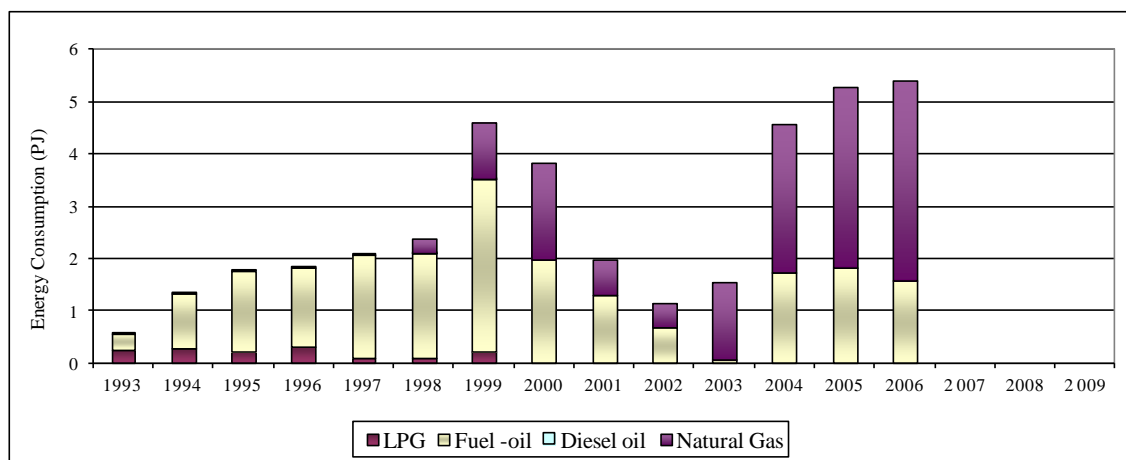
Region	Fuel type	LHV/NCV (MJ/kg)
Azores	Residual fuel oil	40.17
	Diesel oil	43.30
Madeira	Residual fuel oil	40.17
	Diesel oil	43.30
	LPG	47.28

Source: The same as for the fuel consumption

3.3.1.1.4.4 Non-public co-generation Energy Producers

Consumption of fuels in the auto-producers co-generation units (classified as energy producers) are reported in toe units in the Energy Balance (DGEG). These values can be observed in Figure 3.12.

Figure 3.12 – Trends in consumption of fuels in non-public co-generation plants



The growing tendency to create different companies to manage the energy production aspect of industrial co-generation plants led to the necessity, by DGEG, to shift these units from the energy-production co-generation category back to their industrial co-generation category in the Energy Balance. As a result of this shift, from 2007 onwards the energy-production co-generation category in the Energy Balance considers only two units already included, because of their size, in the LPS estimations. Because of this and to avoid double-counting fuel consumption from 2007 onwards was made 0. Since DGEG transferred fuel consumption to the industrial co-generation category, which is used for estimating combustion emissions in the industrial sector (CRF 1A2), the emission inventory maintains its completeness.

Assumed values for LHV per fuel type are presented in next table.

Table 3.9 - LHV per fuel type used for non-public co-generation plants estimates

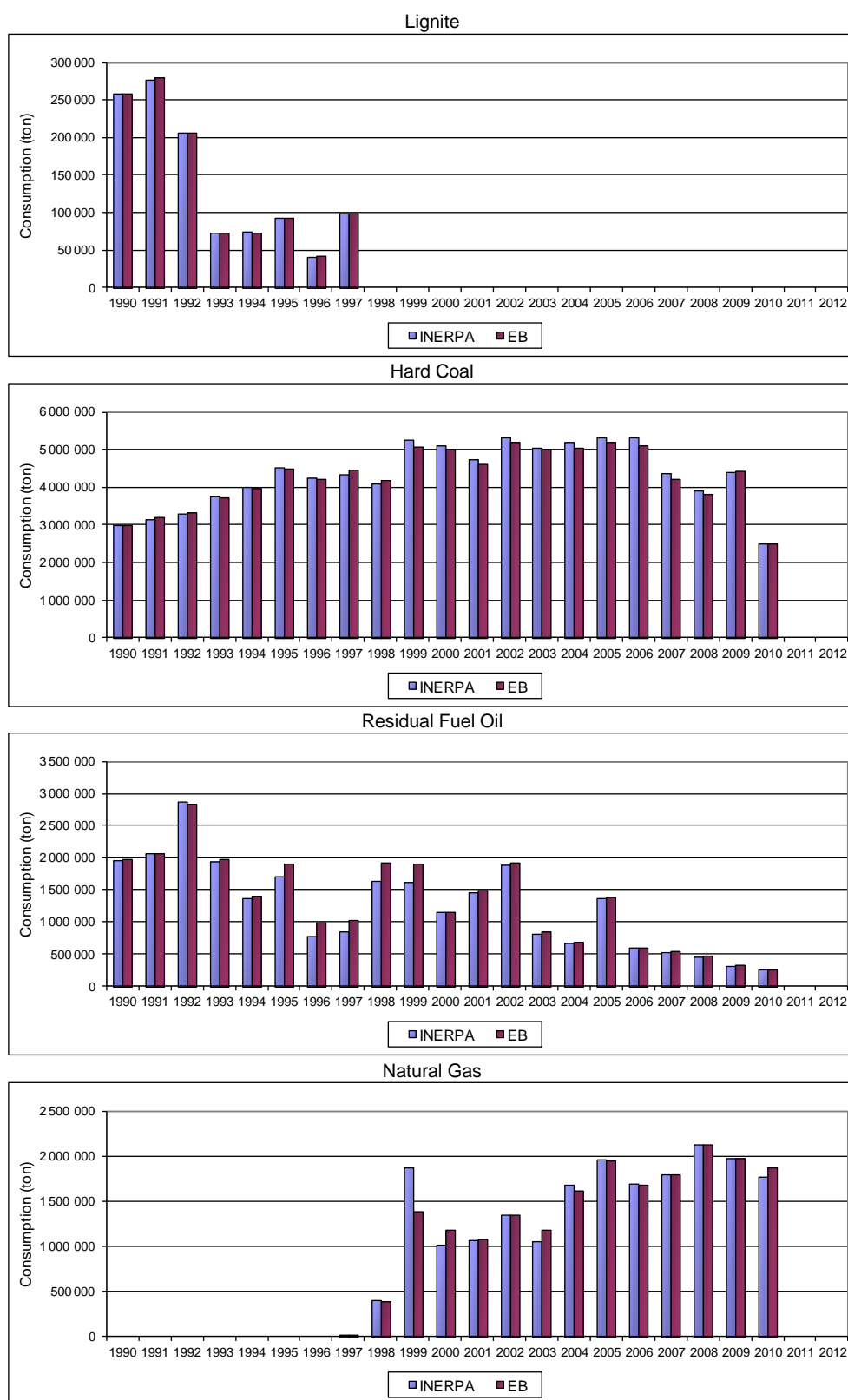
Fuel	LHV (MJ/kg)
LPG	49.76
Fuel -oil	40.00
Diesel oil	42.60
Natural Gas	38.72 (MJ/Nm ³)

Source: The same as for the fuel consumption

3.3.1.1.4.5 Comparison of LPS data vs. National Statistics

Consumption of fuel for electricity production in large units is also published in the Energy Balance of DGEG. Total consumption in all units was compared between the data in the inventory (INERPA) and the Energy Balance (EB) and graphs for the most important energy sources are presented in the figure below. For this analyses contacts were made with DGEG to obtained the complete list of installations covered in each energy production category of the last energy balance (small differences with previous EB are expected due to reclassification). Generally, there is an acceptable agreement between the two sources of information and, because data was acquired in an independent mode, this match gives a high degree of confidence to the results.

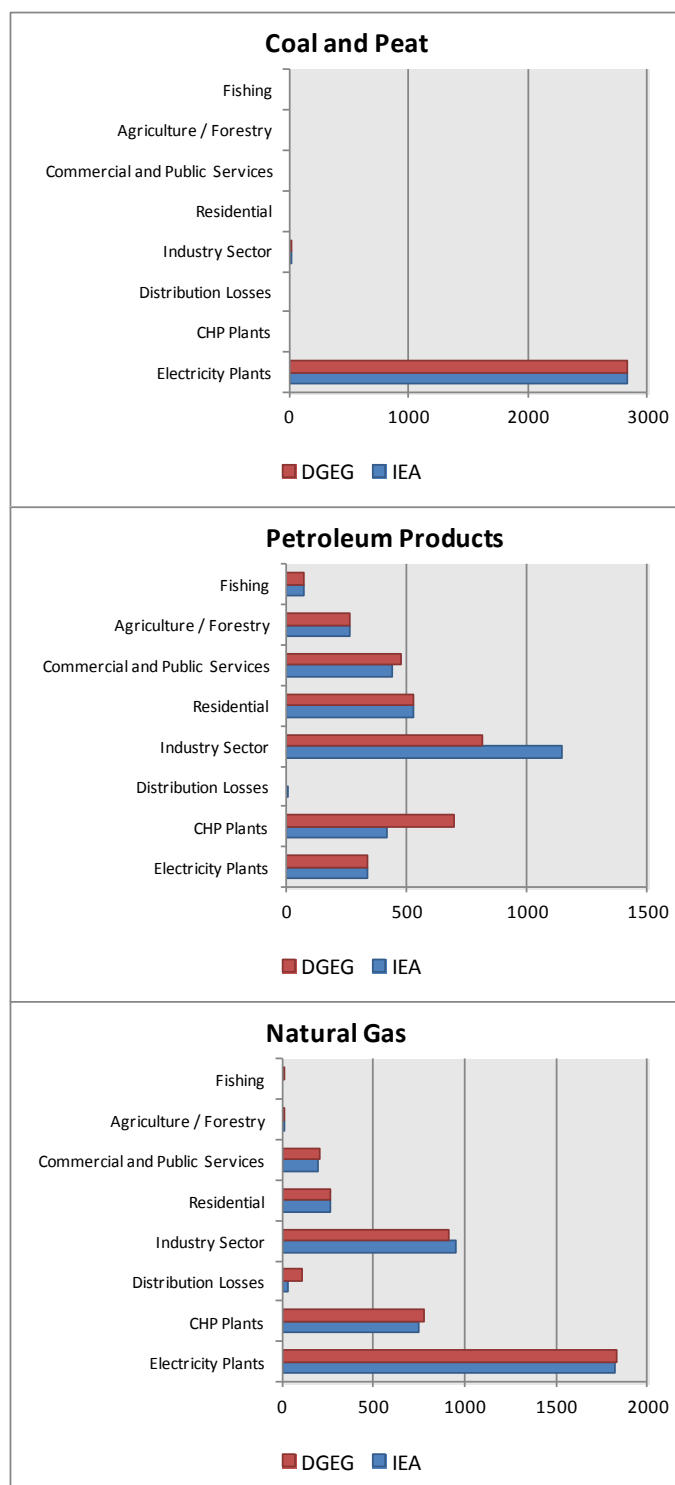
Figure 3.13 – Comparison of total fuel consumption in large power plants, between values used in the inventory (INERPA) and in the Energy Balance



3.3.1.1.4.6 Comparison of Energy Balance vs. IEA Energy Statistics

Total energy consumption reported in DGEG energy balance was compared with IEA (International Energy Agency) energy statistics values. This comparison is included in the QA/QC procedures applied to this inventory. The energy statistic values from IEA were collected from their website. Unfortunately IEA data is only publicly available for the n-1 year (n being the latest inventory year). Following the fuel classification presented in the IEA energy statistics, three fuel types were analyzed: coal and peat, petroleum products and natural gas, connected to 8 emission sources: Electricity Plants, CHP Plants, Industry, Residential, Commercial and Public Services, Agriculture/Forestry, Fishing and Distribution Losses. The comparison between DGEG energy balance and IEA energy statistics, for 2009, is shown in the figure below.

Figure 3.14 – Comparison of fuel consumption between DGEG energy balance and IEA energy statistics



For natural gas and coal and peat the differences between the two data sources are very small. The consumption of petroleum products shows discrepancies for five of the eight analysed sectors: CHP Plants, Industry, Commercial and Public Services, Fishing and Distribution Losses. These differences are greater for CHP Plants and Industry which may imply a problem in the fuel consumption classification. Upon our contact DGEG reported that there were

compilation errors in the information sent to IEA, which may explain the differences found between the two data sources.

3.3.1.1.5 Uncertainty Assessment

The accuracy of activity data collected from direct reporting (LPS data) is expected to have a lower error than data collected in an aggregated form for the elaboration of the energy balances, in particular for those categories in the energy balance comprehending units small, multiple and dispersed. Therefore, different uncertainty values were considered in accordance with different provenience of data:

- for LPS the uncertainty value was set at 1 per cent, which is in the higher range of the uncertainty considered in GPG when good quality surveys are considered, which is the case;
- for area sources an uncertainty of 4 per cent was considered for this sector, which is fixed according to a conservative approach, considering the double of the upper range of the values that IPCC proposes when data was obtained from surveys in a less developed statistical system. This conservativeness factor is used because the surveys were made indirectly to industrial plants via fuel suppliers.

The uncertainty associated with the CO₂ emission factor is 5 per cent, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 per cent for CH₄ and 1000 per cent for N₂O.

The EU-ETS defines a maximum uncertainty value of 7.5 per cent for the CaCO₃ consumption data reported by each plant.

Since 2009 submission, the use of plant specific data for the power plants in Azores and Madeira has decreased uncertainty.

3.3.1.1.6 Category-specific QA/QC and verification

QA/QC procedures were implemented primarily to check the time series consistency for fuel consumption data collected from different information sources. There were also made general checks to the emission compilation spreadsheets from which resulted several small corrections to reported emission.

For large combustion plants a comparison between fuel consumption collected by the inventory team and data reported in the energy balance was made (as described in Comparison of LPS data vs. National Statistics chapter). Also a comparison between the energy balance and IEA statistics has been made to strengthen the QA/QC procedures. For this source category no major differences were found in this comparison between data sources.

3.3.1.1.7 Recalculations

The major recalculations for this sector were:

- Revised data for Caniçal power plant was obtained from Madeira Regional Environmental entities (2000-2009);

- Revised CO₂ emission factors and oxidation factors for several power plants. This revision resulted from a consistency issue raised by the review team (2011 UNFCCC Centralised Review Process);
- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series for auto-producers (1990-2006). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small. This revision only affected auto-producers (fuel consumption obtained from DGEGs energy balance);
- Update of the energy balance fuel consumption data for 2005 and 2006 (previous values came from provisional data). This update only affects Non-public co-generation Energy Producer.

3.3.1.1.8 Further Improvements

Even though efforts were made to increase the percentage of units treated as LPS in this year inventory, the inclusion of more LPS plants is an ongoing objective for this sector as well as for industrial combustion. These efforts are in accordance with the goals that the EC¹¹ has set to streamline data collection for the inventories and for the EU-ETS¹². In the same sense on-going efforts should be maintained for the compatibilization of data acquisition by APA and DGEG in order for a better consistency of the data that is used for the Energy Balance and for the LPS data used in the inventory.

3.3.1.2 *Petroleum Refining (CRF 1.A.1.b.)*

3.3.1.2.1 Overview

In 1990 there were three oil refining plants in Portugal: Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed for most of its activity and only two units remain now in operation.

Oporto refinery, located in Matosinhos in northern Portugal since 1966, converts crude oil and other intermediate materials received from Sines refinery by atmospheric and vacuum distillation, cracking, platforming and several treatments processes (desulphurization). This refinery unit has also units for the production of oils, lubricants and aromatics (Benzene, Hexane, toluene, xylene, etc). Sines refinery, installed in 1978 in southern Portugal, has also extensive transformation of crude products after atmospheric and vacuum distillation, which are subjected to Fluid Catalytic Cracking (FCC), platforming, hydrocracking, alkylation and asphalts blowing. The nowadays closed refinery at Lisbon performed mostly cracking. Refinery gas from this unit was used as combustible gas for domestic, service and industry use in Lisbon city.

Following the UNFCCC source categories classification, only emissions resulting from combustion in boilers and furnaces are included in this source sector. Process fugitive emissions, including combustion emissions realized in the FCC unit are included elsewhere.

SO_x and NMVOC emissions also result from sulphur that is removed from intermediate or final products, mostly to respect environmental regulations, and conveyed in final flux gases.

¹¹ European Commission.

¹² European CO₂ trading scheme.

Elemental sulphur from the refining process is later recovered in both Sines and Oporto refineries but emissions from this source are considered under Emissions from Flaring and Venting in part 3.2.B.

3.3.1.2.2 Methodology

A bottom-up sectoral Tier 2 approach was used to estimate emissions of CO₂ and other air emissions from combustion in refineries, either in boilers or process furnaces. Emissions were estimated individually for each combustion equipment when discrimination was possible.

As explained in more detailed for the sector “Public Electricity and Heat Production”, emissions to atmosphere of total CO₂ and of ultimate CO₂ from fossil origin were estimated using the following equation set:

$$U_{CO2(y)} = 44/12 * EF_C * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3}$$

$$Fossil_{CO2(y)} = U_{CO2(y)} * C_{Fossil(f)} * 10^{-2}$$

where,

$U_{CO2(y)}$ - Emissions to atmosphere of total carbon dioxide emissions (ton);

$Fossil_{CO2(y)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

EF_C – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (percent);

$Fac_{OX(f)}$ – Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f,y)}$ - Consumption of energy (Low Heating Value) from fuel f in power plant u in year y (GJ).

For all other pollutants the following equation was applied to estimate air emissions:

$$Emission_{(e,f,y,p)} = Energy_{Cons(e,f,y)} * EF_{(e,f,y,p)} * 10^{-6}$$

Where

$Emission_{(e,f,y,p)}$ - Emission of pollutant p estimated from consumption of fuel f in combustion equipment e in year y (ton);

$Energy_{Cons(e,f,y)}$ - Consumption of energy (Low Heating Value) from fuel f in combustion equipment e in year y (GJ);

$EF_{(e,f,y,p)}$ - Emission factor pollutant p, for fuel f under burning conditions in combustion equipment e in year y (g/GJ).

3.3.1.2.3 Emission Factors

The same set of emission factors was used for all three refineries and was derived from international bibliography such as IPCC (1997), EMEP/CORINAIR (EEA,2002) and AP-42

(USEPA,1996b; USEPA, 1998b; USEPA,1991e; USEPA,1995c). The chosen Emission Factors are presented in the table below.

Table 3.10 – Emission Factors for combustion sources in Refining of Petroleum Products. Greenhouse Gases.

Fuel	Equipment	U _{CO2} ⁽ⁱ⁾ kg/GJ	Fa _{COx} ⁽ⁱ⁾ 0..1	Fossil _c %	CH ₄ g/GJ	N ₂ O ⁽ⁱ⁾ g/GJ
Fuel-oil	Boilers	77.4	0.990	100	2.9	0.6
	Furnaces	77.4	0.990	100	2.9	0.6
Fuel gas	Boilers	⁽ⁱⁱ⁾ 60.0	0.990	100	2.5	1.4
	Furnaces	⁽ⁱⁱ⁾ 60.0	0.990	100	2.5	1.4
LPG	Boilers	63.1	0.995	100	4	1.4
	Furnaces	63.1	0.995	100	4	1.4
Diesel oil	Engines	74.1	0.990	100	9.9	0.6

(i) IPCC (1997); (ii) EEA (2002)

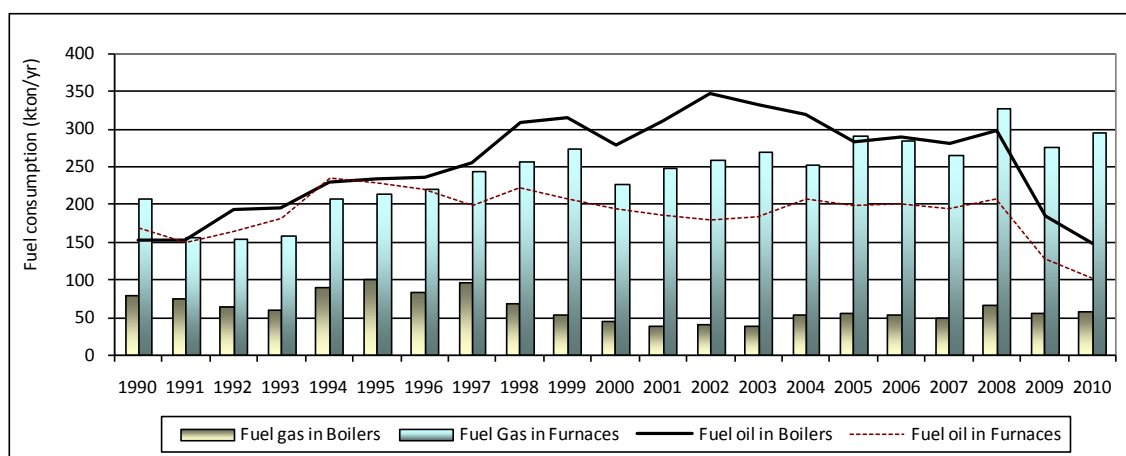
3.3.1.2.4 Activity Data

Emissions from this source sector include combustion air pollutants resulting from boilers and furnaces.

The three refinery units consume self produced residual fuel-oil¹³, fuel-gas, liquefied petroleum gases (LPG) and diesel oil.

The quantities of fuel consumption from 1990 to 2004 in boilers and furnaces were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in the next figure for fuel oil and fuel gas. Since 2005 data source was EU-ETS. Use of other fuels such as diesel oil and LPG although included in inventory estimates are not at all significant and do not need to be reported here.

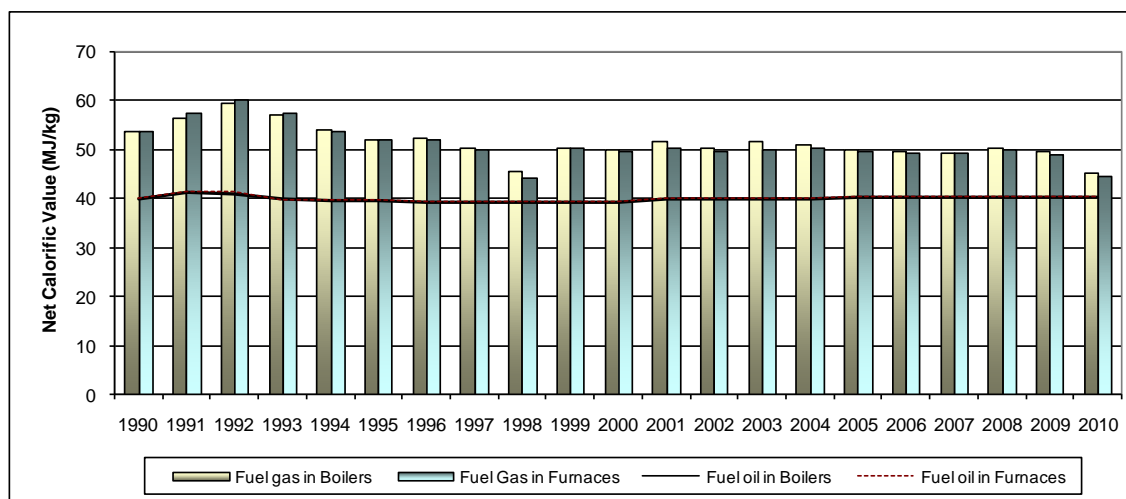
Figure 3.15 – Fuel consumption per year by type of equipment



¹³ In strict terms this fuel is not traded and must not be named fuel-oil, to avoid confusion to traded fuel oil.

Consumption expressed in energy was calculated with the following time series of Low Heating Values. This time series reflects actual information given by each refinery also under LCP directive (1990-2004) or EU-ETS (since 2005) and are weighted averages for all three plants.

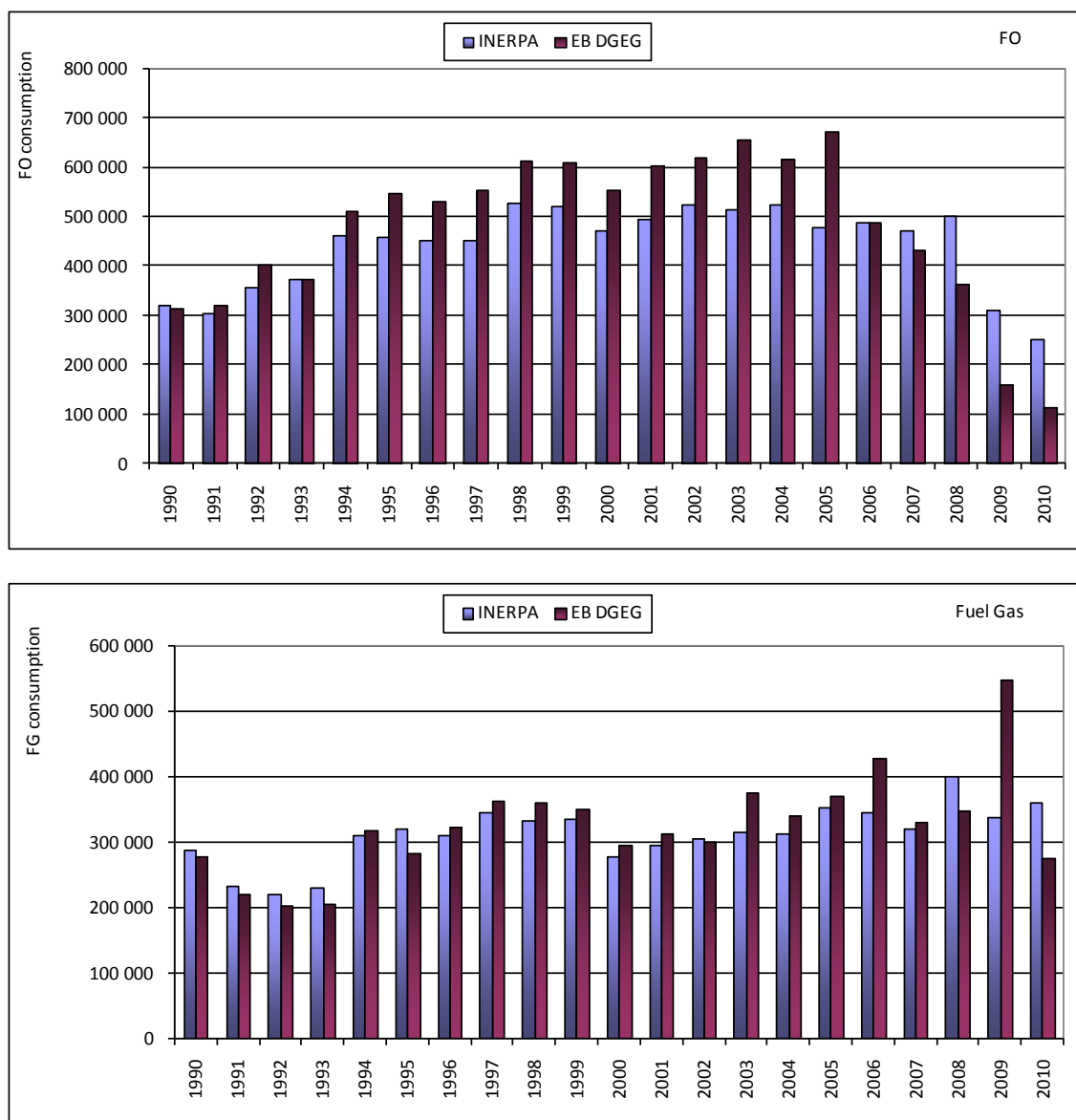
Figure 3.16 – Net Calorific Value (NCV) or Low Heating Value (LHV) expressed in MJ/ kg by type of equipment



3.3.1.2.4.1 Comparison of LPS data vs. National Statistics

In a similar mode to what was done for large power plants, and according to the explanations provided before, a comparison was done for total consumption in all refinery units between the data in INERPA (from EU-ETS) and the Energy Balance and graphs for residual fuel oil (FO) and fuel gas are presented in the next figure. There is an agreement between the two sources of information for the initial years of the period, although not so good for the last years. -

Figure 3.17 – Comparison of total fuel consumption in crude oil refineries, between values used in the inventory (INERPA) and in the Energy Balance.



3.3.1.2.5 Uncertainty Assessment

The uncertainty value was established at 1 percent, in accordance with the fact that all data was obtained from direct inquiry to refinery units.

The uncertainty associated with the CO₂ emission factor is 5 percent, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 percent for CH₄ and 1000 percent for N₂O.

3.3.1.2.6 Recalculations

No recalculations were made.

3.3.1.3 *Other Energy Industries (CRF 1.A.1.c)*

3.3.1.3.1 Overview

The following two sub-sources are included in this category:

- External fuel consumption realized in the coquerie unit, that existed within the only integrated iron and steel plant in Portugal, and that was closed in 2001. Coke gas was the only fuel combustion used as energy source in the coquerie unit;
- Combustion emissions done for the production of city gas that was consumed in the city of Lisbon. This activity was being replaced as consequence of substitution of this energy source by Natural Gas, and was fully deactivated in 2001.

3.3.1.3.2 Methodology

Emissions to atmosphere of total CO₂ and of ultimate CO₂ from fossil origin were estimated using the following equation set:

$$\begin{aligned}
 U_{CO_2(y)} &= EF_{CO_2} * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3} \\
 Fossil_{CO_2(y)} &= U_{CO_2(y)} * C_{Fossil(f)} * 10^{-2}
 \end{aligned}$$

where,

$U_{CO_2(y)}$ - Emissions to atmosphere of total carbon dioxide emissions (ton);

$Fossil_{CO_2(y)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

EF_{CO_2} – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ – Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f,y)}$ - Consumption of energy (Low Heating Value) from fuel f in power plant u in year y (GJ).

For CH₄ and N₂O the following equation was applied to estimate emissions:

$$Emission_{(y,p)} = Energy_{Cons(y)} * EF_{(y,p)} * 10^{-6}$$

where

$Emission_{(y,p)}$ - Emission of pollutant p in year y (ton except CO₂ in ton);

$Energy_{Cons(y)}$ - Consumption of energy in coke gas (Low Heating Value) in year y (GJ);

$EF_{(f,p)}$ - Emission factor pollutant p from coke gas combustion (g/GJ except CO₂ in kg/GJ).

3.3.1.3.3 Emission Factors

Emissions factors for combustion of coke gas in the coquerie unit and in the city gas factory were set from IPCC96, EMEP/CORINAIR and AP-42. They are reported in Table 3.11.

Table 3.11 – Emission Factors used for the coquerie and city gas production

Source	Coquerie	City Gas Production			Unit
Fuel	Coke Gas	FO	Naphta	NG	
$U_{CO_2}^{(i)}$	⁽ⁱⁱⁱ⁾ 41	77	77	56	kg/GJ
$Fac_{Ox}^{(i)}$	0.995	0.990	0.990	0.995	ratio
FossilC	100	100	100	100	%
CH ₄	2.5	⁽ⁱⁱ⁾ 2.9	⁽ⁱⁱⁱ⁾ 2.9	⁽ⁱ⁾ 1.4	g/GJ
N ₂ O ⁽ⁱ⁾	1.40	0.60	0.60	1.40	

(i) IPCC (1997); (ii) EEA (2002); (iii) from plant information

3.3.1.3.4 Activity Data

3.3.1.3.4.1 Coke Production

Consumption of coke gas in the coquerie unit was available directly from the industry plant for 1991-1994. For the remaining years, the use of coke in coquerie was estimated from total consumption of coke gas in the all plant, which information was collected from the energy balances of DGEG. Therefore, except for 1991 to 1994, annual consumption of coke in the integrated iron and steel plant was estimated from:

$$Coquerie_{CONS(y)} = Coquerie_{CONS(91-94)} / Total_{CONS(91-94)} * Total_{CONS(y)}$$

where

$Coquerie_{CONS(y)}$ - consumption of coke gas in the coquerie in year y;

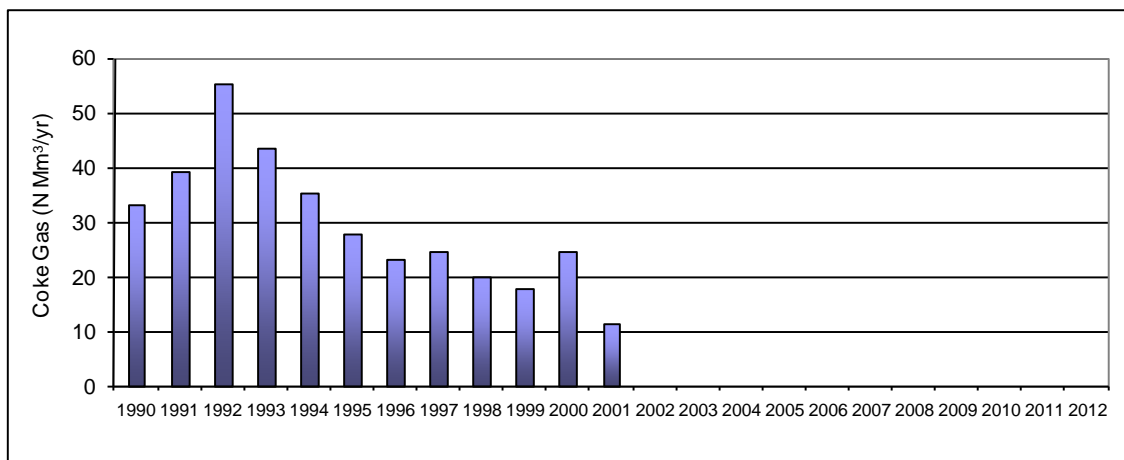
$Coquerie_{CONS(91-94)}$ - consumption of coke gas in the coquerie from 1990 till 1994;

$Total_{Plant_{CONS(91-94)}}$ - total consumption of coke gas in the iron and steel sector, from 91 to 94, as reported in DGEG's energy balance;

$Total_{Plant_{CONS(y)}}$ - total consumption of coke gas in year y.

The coquerie has interrupted operations in 2001 and was later dismantled. The complete time series may be seen in Figure 3.18. Conversion in energy units was calculated using a LHV of 18.78 MJ/Nm³, the value that is reported under LCP directive.

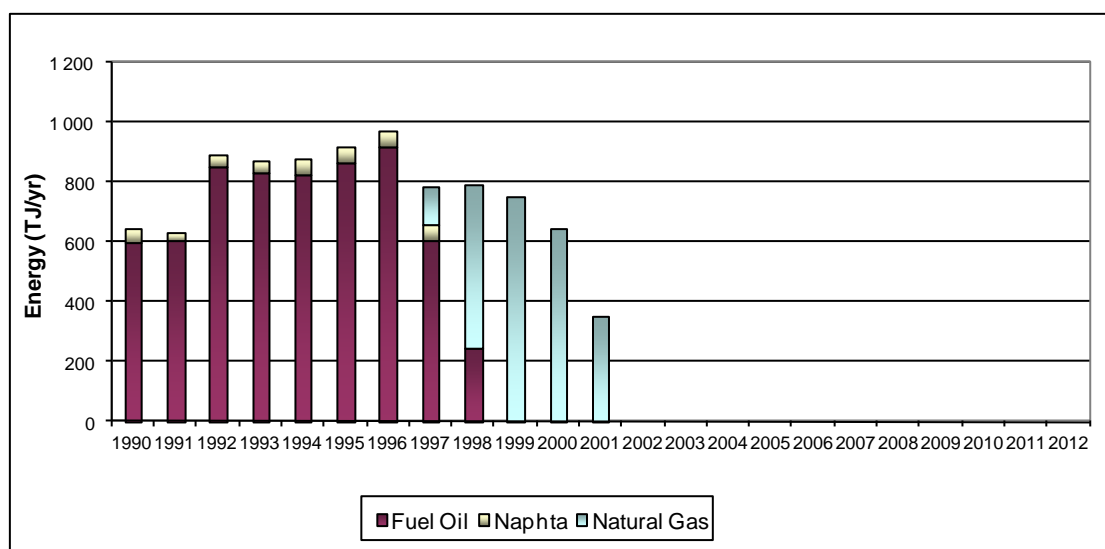
Figure 3.18 – Coke gas consumption in the coquerie



3.3.1.3.4.2 City Gas Production

According to the energy balances from DGE, this activity has used fuel oil, naphtha and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001¹⁴. The available time series is presented in Figure 3.19.

Figure 3.19 – Consumption of fuels in co-generation in city gas production



The following Net Calorific Values (NCV) or Low Heating Values (LHV) values were used.

¹⁴ This activity uses also fuel gas, LPG, fueloil, naphta and natural gas as feedstocks. These quantities, separated in the energy balance, are not included in the inventory at this point but in use of city gas as fuel

Table 3.12 – NCV/LHV per fuel type for city gas production

Fuel	NCV (MJ/kg)
Fuel-oil	40.0
Naphta	44.0
Natural Gas	46.0

3.3.1.3.5 Uncertainty Assessment

Coke production is based extensively in extrapolations from a reduced time-series. Therefore 10 per cent uncertainty was assumed for the activity data, which is in the higher range of the uncertainty values proposed by IPCC (2000) when data of an energy intensive industry was obtained from low quality surveys. In the case of city gas production, in a consistent way to what was used for power plant units an uncertainty of 4 per cent was considered adequate.

In a similar way to all other stationary combustion sources, the uncertainty associated with the CO₂ emission factor was set at 5 per cent, which is the value proposed for traded fuels (IPCC, 2000), and the uncertainty values for methane and nitrous oxide, are in accordance with the GPG proposed values, 150 per cent for CH₄ and 1000 per cent for N₂O.

3.3.1.3.6 Recalculations

Recalculations for this source category comprise the revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (in the case of city gas 1990-2001). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small

3.3.1.3.7 Further Improvements

No further improvements are planned for this sector.

3.3.2 Manufacturing Industries and Construction (CRF 1.A.2.)

Emissions covered in this source category are those resulting from combustion activities in manufacturing industry and building and construction industry. Excluded are the emissions of CO₂ from decarbonising in the cement and glass industries, which are covered under production processes (Chapter 4.2.A). The following sub-source categories are considered individually: Iron and Steel, Metallurgic industry, Chemicals, Pulp and Paper, Food Processing, Beverages and Tobacco, Textile, Ceramic, Glass and glass products, Cement, Clothing, shoes and leather industry, Wood, Rubber, Metal Equipment and Machines, Extractive industry, Construction and Building and Other Transformation Industry.

Total emissions for this sub-sector comprehend the sum of different industrial activities, using diverse fuels and combustion technologies and refer to the full combustion emissions of the industry sector: boilers, process dedicated fuel combustion in furnaces and kilns and all emissions originated in co-generation units¹⁵.

¹⁵ Only when the co-generation activity is reported in the energy balance as referring to the manufacturing industry. When economic activity is referred as Energy Production then emissions are included in source category CRF 1A1a (See chapter 3.2.A.1 for further explanations).

3.3.2.1 Methodology

Air emissions from combustion of manufacturing industries and construction are estimated using a Tier 2 methodology, but two basic approaches are used: energy approach or production approach.

According to the energy based approach, emissions are estimated multiplying emission factors by the energy consumption according to the following equations.

For Carbon Dioxide (CO₂), total emissions and ultimate fossil emissions are estimated using:

$$\begin{aligned}
 U_{CO_2(y)} &= EF_{CO_2} * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3} \\
 Fossil_{CO_2(y)} &= U_{CO_2(y)} * C_{Fossil(f)} * 10^{-2}
 \end{aligned}$$

where,

$U_{CO_2(y)}$ - Emissions to atmosphere of total carbon dioxide emissions (ton);

$Fossil_{CO_2(y)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

EF_{CO_2} - Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ - Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f,y)}$ - Consumption of energy (Low Heating Value) from fuel f in power plant u in year y (GJ).

For CH₄, N₂O and other GHG when the energy consumption approach is used the equation simplifies to:

$$Emi_{(p)} = \sum_f \sum_s \sum_t [EF_{(p,f,s,t)} * Energy_{(f,s,t)}] * 10^{-6}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p (ton/yr except CO₂ in kton/yr);

$EF_{(p,f,s,t)}$ - Emission Factor for pollutant p, specific of fuel type f, sector activity s and technology/ combustion equipment t (g/GJ except CO₂ in kg/GJ);

Activity $_{(f,s,t)}$ - Energy Consumption of fuel type f, sector activity s and technology/ combustion equipment t (GJ).

When in the production process occurs contact between combustion gases and product, which is the case of sintering and lime kilns in the iron and steel industry, cement kilns, glass ovens, ceramic ovens and dryers and lime kilns in paper pulp industry, or when combustion occurs also with the purpose of recovery of combustion products, which is the case for the recovery boiler in paper pulp industry (green liquor), emissions are more appropriately estimated using produced quantities as activity data, and the associated emission factor is expressed in kg/ton. For these situations, where the production approach is used, emissions from combustion activities are estimated using the following equation:

$$Emi_{(p)} = EF_{(p)} * Production * 10^{-3}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p (ton/yr except CO₂ in kton);

$EF_{(p)}$ - Emission Factor for pollutant (kg/ton);

Production – Production activity rate (ton/yr).

It's important to point out that following a meeting with the energy balance team from DGEG new procedures were established to include biodiesel in the INERPA estimates. Hence all estimates derived from the energy balance now have biodiesel. This new approach for obtaining biodiesel results from the fact that from 2006 forward the gas oil reported in the energy balance contained a percentage of biodiesel. The methodology for obtaining the total pure biodiesel and pure gas oil consumed in each industrial sector follows the steps¹⁶:

- Total pure gas oil consumed was obtained by subtracting the total biodiesel produced (that is going to be incorporated in gas oil) to the gas oil reported in the energy balance;
- With the pure gas oil and the pure biodiesel values an incorporation rate was derived;
- For each industrial sector this incorporation rate was applied to obtain value for total gas oil and total biodiesel consumed;
- Not all the gas oil reported has biodiesel. Because of this, before applying the incorporation rate the total gas oil for heating was subtracted;
- In the end we have, for which industrial sector, the total gas oil consumed (heating gas oil plus gas oil with biodiesel removed) and the total biodiesel consumed (biodiesel from gas oil plus pure biodiesel purchased directly by the industrial unit).

The table below represents the incorporation rate derived for the period 2006-2010.

Table 3.13 – Incorporation rate of biodiesel (% toe/toe)

	1990-2005	2006	2007	2008	2009	2010	2011	2012
Incorporation rate	0	1.33	2.50	2.43	4.34	6.40	-	-

Emissions from the following industries were estimated based only on fuel consumption as activity data (energy approach): metallurgy; chemical and plastic industry; food, beverages and tobacco, textile industry; clothing, shoes and leather manufacturing; wood industry; rubber manufacturing; machines manufacturing industry and other metal equipment industry; extractive industry; building and construction and all other unspecified industry. Following the recommendation made by the review team, since the 2011 inventory all emissions from lime

¹⁶ Note: This procedure does not apply to gas oil reporter under co-generation in the energy balance. The DGEG has no documentation to differentiate this fuel as heating gas oil or as gas oil with biodiesel.

production are reported in 2.A.2. For the following industrial sectors specific estimation procedures were taken.

3.3.2.1.1 Paper and Pulp Production

Emissions of SO_x, NO_x, NMVOC and methane from the recovery boilers and lime kilns in the Kraft and Acid Sulphide paper pulp plants were estimated using production data, for each industrial plant, as activity data (production approach). The remaining pollutants emitted from these combustion equipments and all pollutants for the remaining combustion equipments of this industry sector were estimated using energy consumption as activity data (energy approach).

3.3.2.1.2 Clinker Production

Emissions from combustion in clinker kilns were estimated based on production data or consumption of energy obtained for each individual industrial plant, according to the original units of the emission factors. For this sector most emission factors are plant specific and obtained from information monitored at industrial plants. The remaining fuel use in this sector that is consumed in equipments other than kilns is converted into emission using the general purpose emission factors (energy approach). Carbon dioxide originated from decarbonising limestone and dolomite is quantified in production processes and reported in CRF sector 2A.

3.3.2.1.3 Ceramic Industry

Emissions of SO_x, NO_x, NMVOC, CH₄ and CO from combustion processes in furnaces in the ceramic industry are estimated using the production approach. Emissions estimates from combustion in other equipment, boilers and engines, and emission estimates for the other pollutants, also for furnaces, are based on the energy approach

3.3.2.1.4 Glass Production

Similarly to ceramic industry, emissions of SO_x, NO_x, CH₄ and CO are estimated using production information as activity data (production approach). Emissions for the remaining pollutants, CO₂ and N₂O from furnaces and for all pollutants from other combustion equipments are estimated using energy consumption as activity data indicator. Carbon dioxide emissions from glass production comprehend both oxidation of carbon, that are estimated using the general emission factors based on energy consumption, and decarbonising or materials, which are included in production process and reported in CRF sector 2.

3.3.2.1.5 Iron and Steel Production

Air emissions from sintering (SO_x, NO_x, NMVOC and CO) and production of lime (SO_x, NO_x, CO and CO₂) integrated in the iron and steel production sector are estimated using production as activity data (production approach). The remaining pollutants resulting from the iron and steel industry were estimated using the energy approach. For simplicity, activity data and emission factors for this source are discussed in chapter 4.3.3.1 – Industrial Processes: Iron and Steel Production.

3.3.2.2 Activity data

Activity data comprehends consumption of fuels and industrial production rates. The subsequent chapters will follow this division.

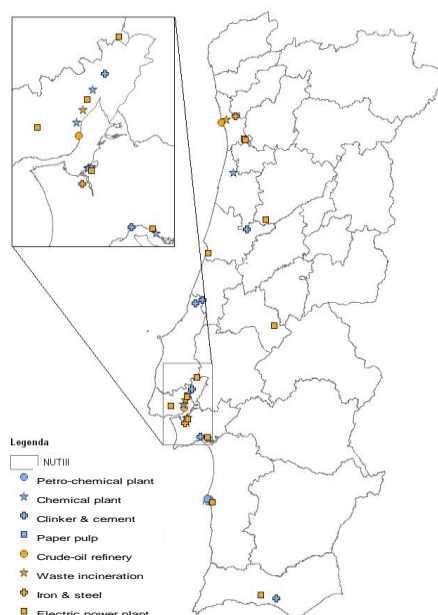
3.3.2.2.1 Combustion Data

Data on fuel consumption for LPS were obtained from several sources:

- directly from Large Combustion Plants (LCP) submitted to APA under the provisions of the LCP Directive;
- information received by APA from special surveys;
- from EPER/PRTR inventory;
- from Self-control program (*Programa Autocontrolo*);
- from direct request to the LCP operators;
- since 2009 inventory from EU-ETS.

Presently LPS comprehend one iron and steel industry, one petrochemical unit, one carbon black industrial plant, eight paper pulp plants (in most cases divided in different fiscal entities) and six cement plants (covering all clinker producing units).

Figure 3.20 – Distribution of Large Point Sources in continental Portugal¹⁷



The remaining national energy consumption for each sector was estimated subtracting LPS consumption data from the figures reported in the energy balance compiled annually by DGEG and with detailed consumption data for each industrial sector and for each fuel. This procedure is synthesized in Figure 3.21 and in the following formula set:

$$\text{Cons}_{\text{EB}}(f,s) = \sum_c \{ \text{Energy}_{\text{EB}}(f,s,c) / \text{LHV}_{\text{EB}}(f,s) \}$$

$$\text{Energy}_{\text{AREA}}(f,s,e) = \{ \text{Frac}_{\text{Equi}}(s,f) * [\text{Cons}_{\text{EB}}(f,s) - \sum_u \text{Cons}_{\text{LPS}}(u,f,e)] \} * \text{LHV}_{\text{AREA}}(f,s,e)$$

$$\text{Energy}_{\text{LPS}}(u,f,e) = \text{Cons}_{\text{LPS}}(u,f,e) * \text{LHV}_{\text{LPS}}(u,f,e)$$

Where,

¹⁷ This map includes also LPS that are accounted as process emissions (CRF 2).

$Energy_{EB(f,s,c)}$ – Reported energy consumption of fuel f in activity sector s , according to the energy balance, either in co-generation or not (index c) (toe/yr);

$Cons_{LPS(u,f,e)}$ – Reported consumption of fuel f consumed by LPS unit u in equipment e (ton/yr or Nkm^3/yr);

$Cons_{EB(f,s)}$ – Calculated consumption of fuel f consumed in sector s , in both co-generation or non-cogeneration (c index), according to the Energy Balance (ton/yr or Nkm^3/yr);

$Energy_{AREA(s,f,e)}$ – Remaining energy consumption of fuel f in non-LPS – Area Sources - in activity sector s and in equipment e (GJ/yr);

$Energy_{LPS(u,f,e)}$ – Energy consumption of fuel f estimated for LPS unit u in equipment e (GJ/yr);

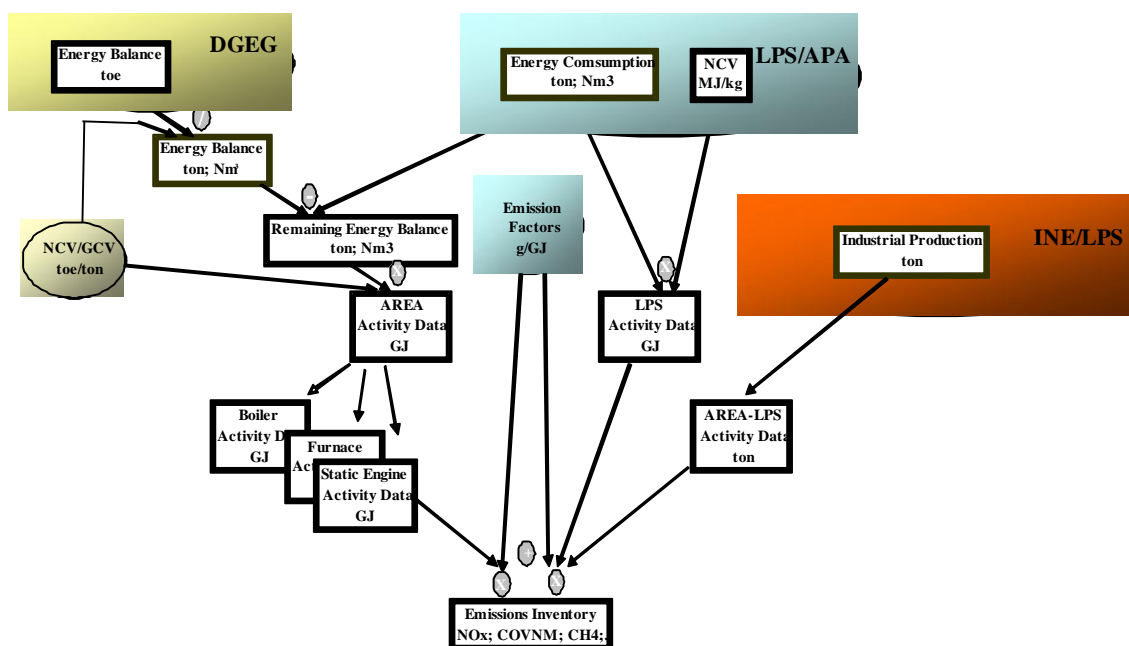
$Frac_{Equi(s,f)}$ – Fraction of consumption of fuel f in sector s that is used in equipment e (0..1);

$LHV_{LPS(u,f,e)}$ – Low Heating Value/ Net Calorific Value, reported by LPS unit u , for fuel f in combustion equipment e (MJ/kg or MJ/Nm^3);

$LHV_{EB(f,s)}$ – Low Heating Value/ Net Calorific Value used by DGEG in the compilation of the Energy Balance for fuel f in activity sector s (toe/ton or toe/Nkm^3);

$LHV_{AREA(f,s,e)}$ - Low Heating Value/ Net Calorific Value used in the Inventory for fuel f in equipment e for area sources (combustion in non LPS) (MJ/kg or MJ/Nm^3)¹⁸.

Figure 3.21 – General procedure for emissions estimate



¹⁸ In most cases similar values to Energy Balance are used

Characterization of the combustion equipments was also taken from LPS sources, as well as some characteristics of the fuels. For the non LPS sources, or the remaining energy consumed that are accounted in the energy balances, there is no detailed information about in which equipment combustion takes place, apart from division between co-generation and non co-generation. Hence separation of fuel consumption among boilers, furnaces and engines was made by expert judgment according to each economic sector, and also considering that the original data of fuel consumption in the DGE's energy balances make a separation between quantities used in co-generation and quantities used without co-generation.

3.3.2.2.1.1 The Energy Balance

The Portuguese Energy Balance (EB) is published annually by DGE covering all national territory and without any disaggregation at regional level. The structure of the report table is summarized in the next tables. The Energy Balance for 2010 is presented in annex to the NIR.

Table 3.14 – Structure of the Portuguese Energy Balance. Sectoral categories

Primary	Imports	Co-generation	Electric producers	Final Consumption	Agriculture
	Indigenous Production		Barreiro power plant		Fisheries
	Stock variations		Crude oil refineries		Mining Industry
For production of secondary energy sources	Exports		City gas		Food and Beverages
	Foreign ships		Agriculture		Textile
	Foreign aircraft		Food and Beverages		Paper pulp and paper
Consumption in the Energy sector	Primary Energy Consumption		Textile		Chemical and Plastics
			Paper pulp and paper		Ceramic
			Chemical and Plastics		Glass
Feedstocks	Briquettes		Ceramic		Cement
	Coke		Glass		Metalurgy
	Crude oil products		Cement		Iron and steel
Corrections	City gas		Metalurgy		Cloth, shoes, leather
	Petro-chemical		Iron and steel		Wood
	Electricity		Cloth, shoes, leather		Rubber
			Wood		Equipment
			Rubber		Other Manufacturing Industries
			Equipment		
			Other Manufacturing Industries		Construction and Public Works
			Extractive		Transport
			Services		National airplanes
					National ships
					Railways
					road
					Domestic
					Services

Table 3.15 – Structure of the Portuguese Energy Balance. Fuel categories

Coal	Imported coal	Non Energy Products	Lubricants
	National coal		Asphalts
	coal coke		Paraffin
Oil	Intermediate refinery products	Electricity	Solvents
	LPG		Propylene
	Gasoline		
Gases	Kerosene	Hydro-electricity	Wind and Geothermal
	Jets		Thermo-electricity
	Diesel oil		
Other	Residual fuel oil		
	Naphta		
	Petro coke		
	Natural gas		
	City Gas		
	Coke oven gas		
	Blast Furnace gas		
	Petrochemical gas		
	Hydrogen		
	Tar		
	Wood and vegetable wastes		
	Solid Urban Waste		
	Industrial Waste		
	Biogas		
	Biodiesel		
	Liquors		
	Other		

The sub classes presented below represent the most detailed information available limited by the detail reported in the National Energy Balances from DGEG. Each group represents an aggregation of specific Categories of Economic Activities (CAE).

Table 3.16 – Definition of Sectors in accordance with Economic Activity Classes

Sub sector	EAC (1977)
Agriculture	111, 112, 113, 121, 122
Fisheries	130
Extractive Industry	220, 230, 290
Food processing, beverages and tobacco	311, 312, 313
Textile	321
Paper and paper pulp	341
Chemical and Plastic Industry	351, 352, 356
Ceramic	361, 3691
Glass	362
Cement	369 except 3691
Metallurgy	271, 272 except Iron and Steel
Iron and Steel Industry	Iron and Steel
Clothing, shoes and leather	322, 323, 324
Wood & wood products	331, 332
Rubber	355
Manufacturing of machines and metallic Equipments	381, 382, 383, 384
Other	390, 314, 342, 385
Construction & Building	500

3.3.2.2.1.2 Tables of consumption per activity

For confidential reasons, LPS data on fuel consumption for the iron and steel industry, the petrochemical and carbon black units are presented lumped together with data in energy balances, with no separation from the other non-LPS sources within the respective sector. Data on paper pulp plants are presented for the eight LCP units summed together with non-LPS sources (like paper production). In the cement industry since only two companies represent the six factories that exist in Portugal, for confidential reasons no activity data can be presented in this report.

3.3.2.2.1.2.1 Iron and Steel Industry

Table 3.17 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Iron and Steel Industry

Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm ³
30.95	46.04	43.8	42.6	40 - 40.4	38.7

Coke Oven Gas	Blast Furnace Gas	Tar	Waste Oil	Gasoline	Biodiesel
MJ/Nm ³	MJ/Nm ³	MJ/kg	MJ/kg	MJ/kg	MJ/kg
18.8	2.9	34.1	40.4	44.0	37.0

Table 3.18 – Fuel consumption in the Iron and Steel Industry in boilers and furnaces (GJ) (1/2)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
1990	0	461 351	1 343	23 000	1 231 825	0
1991	0	452 225	1 631	14 960	324 431	0
1992	0	520 545	1 349	16 404	340 311	0
1993	0	598 970	1 788	18 819	1 373 593	0
1994	0	595 001	2 891	16 268	1 138 766	0
1995	0	603 060	2 916	15 681	942 280	0
1996	0	558 857	2 811	17 344	984 206	0
1997	0	408 945	3 295	5 667	941 755	200 080
1998	0	280 672	3 158	6 796	623 019	654 945
1999	0	326 230	2 927	6 902	712 221	703 241
2000	0	410 633	586	7 801	821 346	911 513
2001	0	395 280	0	8 004	748 872	965 759
2002	0	351 377	0	9 587	738 232	959 082
2003	0	239 689	0	13 904	641 052	1 302 103
2004	0	241 663	0	16 354	646 431	1 184 871
2005	0	240 812	0	17 365	682 803	1 445 936
2006	0	241 773	0	19 389	1 028 631	1 540 860
2007	266 699	241 368	0	23 533	666 360	1 908 283
2008	264 313	237 977	0	17 770	40 611	1 858 920
2009	153 279	237 809	84	18 203	0	1 387 104
2010	165 085	238 689	126	17 771	0	1 710 957
2011	-	-	-	-	-	-
2012	-	-	-	-	-	-

Table 3.19 – Fuel consumption in the Iron and Steel Industry in boilers and furnaces (GJ) (2/2)

Year	Coke oven gas	Blast furnace gas	Tar	Waste Oil	Biodiesel
1990	1 041 796	1 460 387	341 000	40 348	0
1991	1 525 059	1 244 462	357 845	1 210	0
1992	1 943 130	2 079 874	388 263	0	0
1993	1 753 741	2 158 502	311 278	0	0
1994	1 562 652	1 981 945	227 791	0	0
1995	1 175 219	1 343 038	272 878	7 318	0
1996	1 211 854	1 306 474	198 643	5 608	0
1997	1 715 874	1 585 069	300 377	8 282	0
1998	1 655 684	1 396 770	251 115	7 196	0
1999	1 626 560	1 453 276	281 529	8 401	0
2000	1 856 360	1 746 675	333 420	10 255	0
2001	1 455 916	1 547 215	333 420	10 255	0
2002	0	0	333 420	10 255	0
2003	0	0	333 420	10 255	0
2004	0	0	333 420	10 255	0
2005	0	0	333 420	10 255	0
2006	0	0	333 420	10 255	262
2007	0	0	333 420	10 255	604
2008	0	0	333 420	10 255	443
2009	0	0	333 420	10 255	826
2010	0	0	333 420	10 255	1 216
2011	-	-	-	-	-
2012	-	-	-	-	-

Table 3.20 – Fuel consumption in the Iron and Steel Industry in Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	1 674	23 000	0
1991	1 100	14 960	0
1992	1 728	16 404	0
1993	1 049	18 819	0
1994	1 807	16 268	0
1995	1 463	15 681	0
1996	2 253	17 344	0
1997	235	5 667	0
1998	142	6 796	0
1999	177	6 902	0
2000	151	7 801	0
2001	3 404	8 004	0
2002	164	9 587	0
2003	46	13 904	0
2004	0	16 354	0
2005	0	17 365	0
2006	0	19 389	262
2007	0	23 533	604
2008	0	17 770	443
2009	0	18 203	826
2010	0	17 771	1 216
2011	-	-	-
2012	-	-	-

The expressive decrease in fuel consumption that can be observed from 2001 to 2002 is explained by the significant changes in the only integrated iron and steel plant that existed in Portugal, particularly the closure and dismantling of the production of coke, sinter and of the blast furnace. Presently iron and steel is produced from scrap and metallic foils. This changed has also caused substantial changes in the contribution of fuels, with the disappearance of coke oven gas and blast furnace gas, and the increase in the use of natural gas, that not only was used to replace the other by product gases, but also partially the use of LPG and residual fuel oil.

Figure 3.22 – Total Energy Consumption in the Iron and Steel Industry

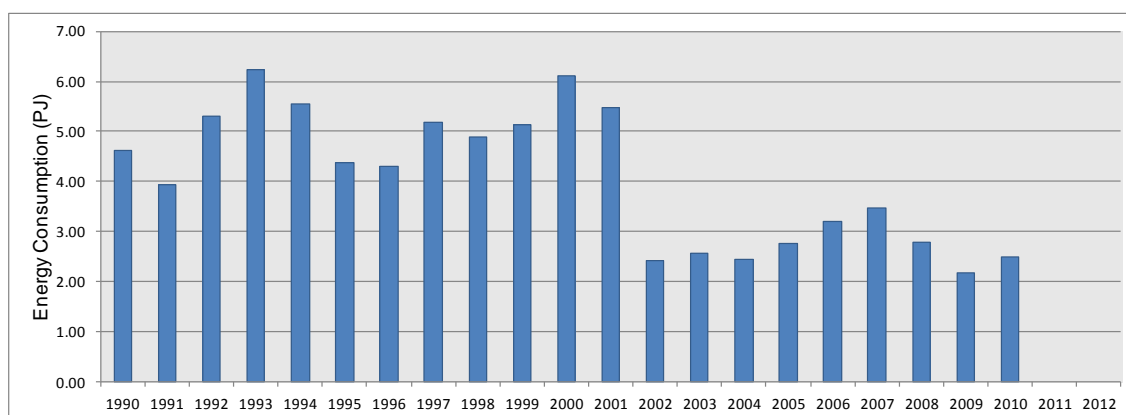
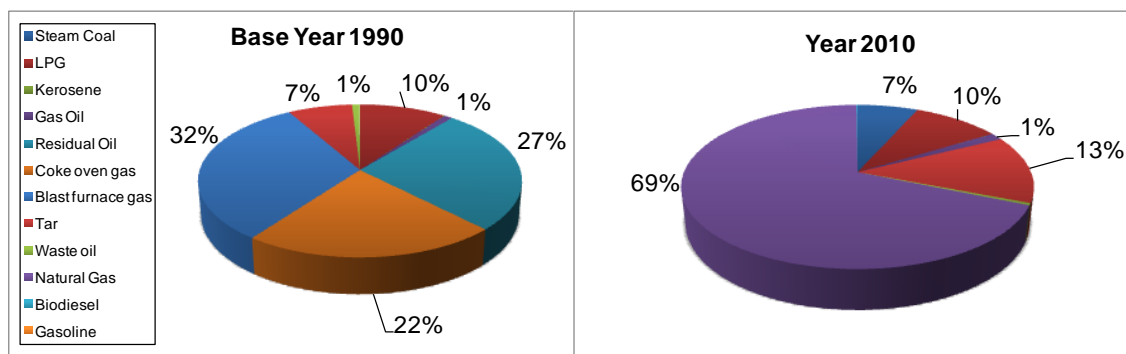


Figure 3.23 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2010



3.3.2.2.1.2.2 Metallurgy Industry

Table 3.21 – Low Heating Values/ Net Calorific Value (LHV/NCV) in Metallurgy Industry

Steam Coal	Coal Coke	LPG	Kerosene	Gas Oil	Residual Oil
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
31.0	29.4	46.0	43.8	42.6	40.0

Natural Gas	Wood	Gasoline	Biodiesel
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg
38.7	12.6	44.0	37.0

Table 3.22 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Coal Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	132 971	381 617	526 189	372	14 487	1 163 364	0	142 678	0
1991	121 117	240 375	520 732	3	19 589	958 702	0	140 167	0
1992	30 903	240 324	596 796	0	19 789	1 059 801	0	138 033	0
1993	50 879	0	495 350	0	20 301	721 327	0	135 272	0
1994	6 196	0	526 400	0	22 392	554 653	0	135 314	0
1995	0	0	588 598	0	18 324	387 450	0	135 314	0
1996	0	0	634 908	0	32 228	480 184	0	143 515	0
1997	0	0	549 121	0	28 725	78 987	1 057	143 515	0
1998	0	0	492 290	545	28 176	75 075	30 324	143 818	0
1999	0	0	375 702	1 578	44 187	66 686	173 263	144 351	0
2000	0	0	241 885	7	43 885	81 208	429 171	143 515	0
2001	0	0	317 853	8	77 634	99 082	473 486	143 515	0
2002	0	0	340 702	0	70 961	68 532	496 868	143 515	0
2003	0	0	332 094	0	54 573	60 430	597 323	223 898	0
2004	0	0	325 208	0	56 593	67 819	569 369	227 897	0
2005	0	0	298 108	16	83 207	64 698	616 193	232 894	0
2006	0	0	286 208	16	68 027	68 884	645 638	235 893	899
2007	19 176	0	276 452	42	60 639	80 846	671 152	239 874	1 534
2008	0	0	261 129	0	5 841	15 700	641 007	239 874	146
2009	0	0	181 789	0	11 535	35 420	395 992	239 874	523
2010	0	0	154 868	0	15 166	21 729	429 697	239 874	1 036
2011	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-

Table 3.23 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	0	14 487	0
1991	254	19 589	0
1992	678	19 789	0
1993	3 604	20 301	0
1994	6 465	22 392	0
1995	7 124	18 324	0
1996	8 210	32 228	0
1997	8 409	28 725	0
1998	7 047	28 176	0
1999	3 191	44 187	0
2000	311	43 885	0
2001	10 979	77 634	0
2002	729	70 961	0
2003	808	54 573	0
2004	332	56 593	0
2005	350	83 207	0
2006	199	68 027	899
2007	0	60 639	1 534
2008	0	5 841	146
2009	0	11 535	523
2010	0	15 166	1 036
2011	-	-	-
2012	-	-	-

Emissions from this sector cover both the industry producing iron products and non iron products. The original information source does not allow the separation of these activities. Here too is noticeable the partial shift from the use of residual fuel oil and LPG to natural gas, after 1997. Also observable is the abandonment of the use of coal and coke, already in 1994.

Figure 3.24 – Total Energy Consumption in the Metallurgy Industry

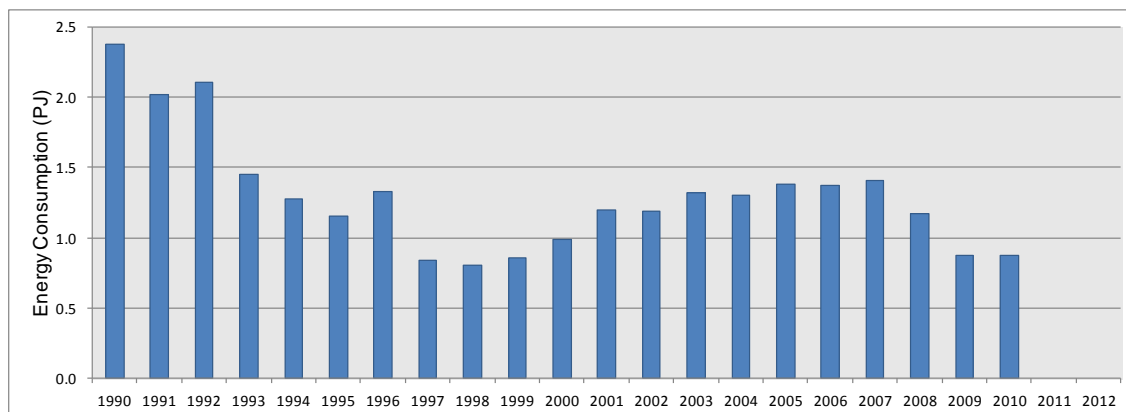
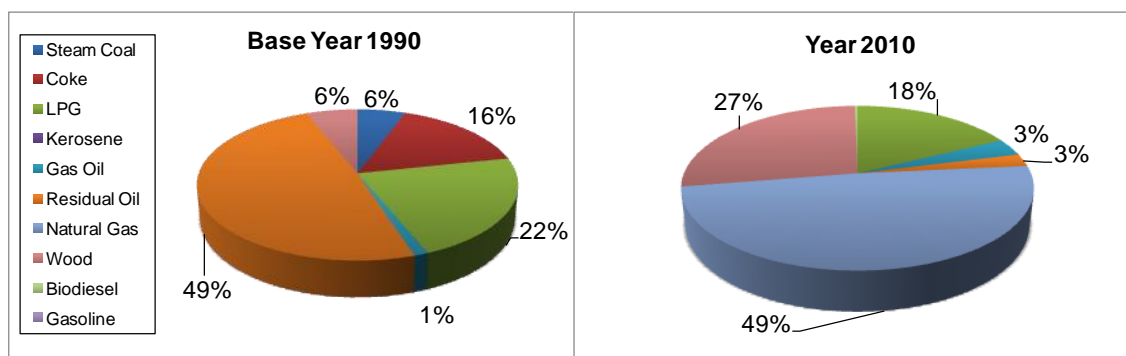


Figure 3.25 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2010



3.3.2.2.1.2.3 *Chemical and Plastics Industry*

Table 3.24 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Chemical and Plastics Industry

Steam Coal	Coal Coke	LPG	Kerosene	Gas Oil	Residual Fuel Oil*
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
31.0	29.4	46 - 52.7	43.8	42.6	39.3 - 41.2

Natural Gas	Wood	Fuel Gas ¹⁹	Gasoline	Flare Gas ²⁰	Biodiesel
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
38.7	12.6	47.7 - 52.8	44.0	47.8 - 53.1	37.0

* Including Pyrolysis fuel oil and non traded similar sub-products

¹⁹ Several streams of intermediate gaseous products and tail gases that are used as energy source

²⁰ Several streams of intermediate gaseous products and tail gases that are used as energy source

Table 3.25 - Fuel consumption in Chemical and Plastics Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Coal Coke	LPG	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas	Wood	Fuel Gas	Biodiesel
1990	261 248	196 840	292 721	1 180	77 663	9 970 391	0	1 051 213	11 323 991	0
1991	198 793	276 731	128 258	516	122 917	11 692 840	0	1 032 803	9 038 284	0
1992	0	467 372	126 750	333	107 330	10 363 974	0	1 017 238	10 866 527	0
1993	0	427 819	223 856	118	99 347	7 793 157	0	996 904	10 235 911	0
1994	0	460 864	1 128 784	97	148 592	8 463 649	0	996 904	9 395 006	0
1995	0	492 226	1 609 725	54	167 034	10 502 784	0	996 904	10 383 744	0
1996	0	469 840	1 034 702	88	209 665	10 207 277	0	1 058 033	9 106 036	0
1997	0	404 872	873 379	9 758	166 955	10 766 995	0	1 058 033	11 604 809	0
1998	0	521 287	475 166	19 453	212 439	11 152 909	633 709	1 060 272	12 315 071	0
1999	0	521 287	420 476	45 564	212 027	11 199 606	1 853 939	1 343 390	12 667 516	0
2000	0	2 141 169	342 273	12 395	115 944	11 712 200	2 306 654	1 360 854	13 109 705	0
2001	0	576 830	585 682	5 892	173 761	11 274 543	2 615 706	1 360 837	9 085 408	0
2002	0	581 290	1 525 777	3 677	120 445	9 531 464	2 833 029	1 360 837	8 958 054	0
2003	313 523	283 436	790 348	3 093	99 646	8 058 174	3 580 649	1 414 358	10 140 940	0
2004	413 918	238 253	2 069 796	2 774	92 573	7 683 769	4 277 635	1 442 345	11 773 371	0
2005	482 572	135 743	1 184 269	2 360	98 055	7 811 818	3 904 240	1 471 332	12 972 282	0
2006	688 025	99 984	3 595 052	2 339	70 575	6 403 846	4 210 833	1 493 322	12 330 903	796
2007	533 566	118 697	4 688 952	2 177	42 045	6 150 193	4 512 653	1 536 318	13 975 868	915
2008	536 622	106 848	5 899 883	879	24 669	5 950 938	4 269 714	1 536 318	10 701 814	603
2009	448 239	86 123	1 814 218	837	30 493	3 788 755	6 430 930	1 536 318	7 150 397	1 294
2010	423 327	91 315	351 153	377	35 615	4 290 703	8 810 445	1 536 318	8 820 626	2 102
2011	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-	-

Table 3.26 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Fuel oil	Biodiesel
1990	7 803	80 157	160 712	0
1991	24 211	129 048	274 906	0
1992	66 734	115 720	425 762	0
1993	67 461	105 835	588 618	0
1994	107 787	151 737	203 808	0
1995	166 006	173 141	379 018	0
1996	131 720	214 851	321 823	0
1997	190 848	172 353	334 966	0
1998	188 291	218 213	358 303	0
1999	161 623	219 922	489 977	0
2000	48 157	123 786	486 645	0
2001	72 112	180 016	378 123	0
2002	56 488	127 377	418 988	0
2003	47 944	106 665	424 255	0
2004	32 195	98 984	387 512	0
2005	12 349	104 913	414 539	0
2006	3 747	77 014	389 226	796
2007	2 052	49 143	429 050	915
2008	293	30 488	351 723	603
2009	0	34 132	220 004	1 294
2010	0	39 455	232 103	2 102
2011	-	-	-	-
2012	-	-	-	-

Table 3.27 - Fuel consumption in Chemical and Plastics Industry – Flares (GJ)

Year	Flare Gas
1990	859 031
1991	538 730
1992	574 865
1993	1 217 549
1994	1 223 447
1995	1 011 512
1996	858 870
1997	893 948
1998	956 229
1999	1 307 636
2000	1 298 744
2001	1 036 071
2002	1 148 041
2003	1 162 474
2004	1 061 797
2005	1 135 850
2006	1 066 494
2007	1 175 611
2008	963 732
2009	602 818
2010	635 969
2011	-
2012	-

Two industrial plants in this sector were treated as Large Point Sources, representing a substantial component of total energy consumption, but for confidentiality constraints plant specific information cannot be published individually. In the beginning of the period under analysis, fuel consumption²¹ was based on residual fuel oil, traded or by-product of the unit, and residual gases, also obtained as a by-product from the production processes. More recently, natural gas has gained a relevant importance as the third energy source. An increasing trend in total energy consumption - although irregular - is verifiable in Figure 3.26. The consumption of coke time series presents an anomalous value in 2000. When questioned about this, the energy balance team at DGE could not justify the inconsistent value.

Figure 3.26 – Total Energy Consumption in the Chemical and Plastic Industry

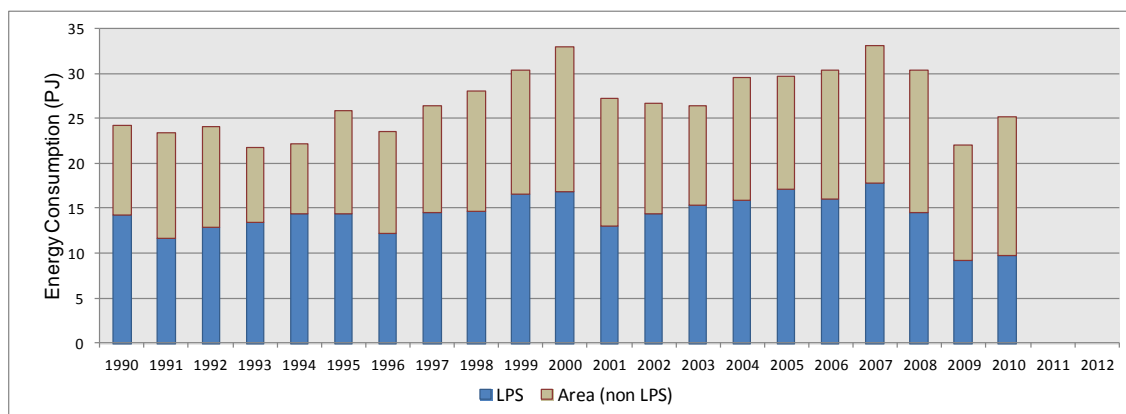
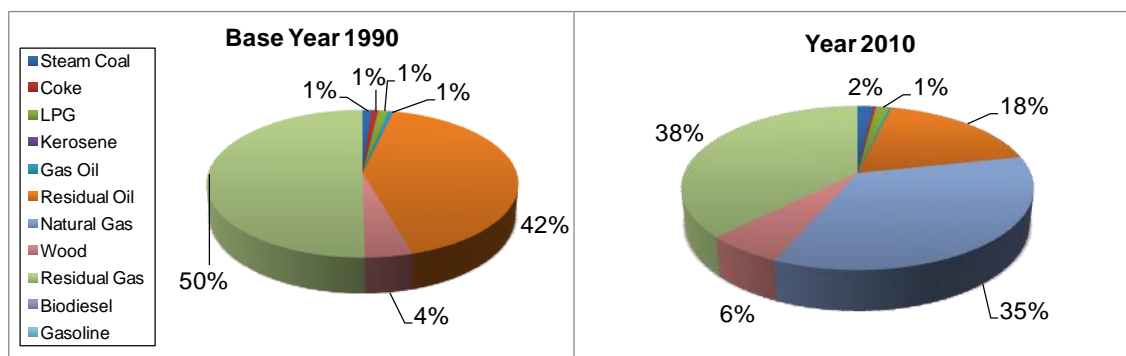


Figure 3.27 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2010



²¹ Not considering feedstocks. Emissions from feedstock use are only included when by products (pyrolysis fuel or and fuel gas) are generated and reported explicitly in the industrial plant as fuels.

3.3.2.2.1.2.4 Paper and Paper Pulp Industry

Table 3.28 – LHV/NCV in the Paper and Paper Pulp Industry

Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3
31.0	46 - 52.7	43.8	42.6 - 43.3	37.9 - 41.8	37.9 - 39.1

Gasoline	Biodiesel	Biogas	Wood	Black Liquor	Bisulphite Liquor
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
44.0	37.0	34.7	6.3 - 20.5	7.4 - 16.7	7.2 - 15.8

Gasified Biomass	Methanol	NCG	Tall-oil
MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
14.7 - 14.7	17 - 19.5	0.0069 - 0.0074	34 - 35.7

Table 3.29 - Fuel consumption in the Paper and Paper Pulp Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood & Wood Wastes ²²	Liquors	Biodiesel
1990	103 423	7	90 172	9 478 929	0	5 148 908	25 397 844	0
1991	192 057	51	78 864	10 289 568	0	5 717 707	28 352 132	0
1992	238 921	32	76 196	11 262 506	0	7 061 105	28 706 113	0
1993	201 008	7	70 972	11 651 070	0	7 681 878	27 159 242	0
1994	274 229	4	66 319	13 401 753	0	6 740 066	26 600 496	0
1995	283 226	23	72 544	11 038 222	0	7 360 136	27 222 347	0
1996	301 955	5	71 744	11 558 997	0	6 810 970	27 096 395	0
1997	326 409	6	80 331	10 885 350	0	7 373 382	30 025 613	0
1998	346 368	0	61 032	10 974 744	7 823	7 298 265	29 876 259	0
1999	265 576	0	59 618	10 809 553	337 903	7 854 467	30 739 205	0
2000	249 182	26	54 762	11 559 810	2 375 644	6 489 241	33 489 524	0
2001	240 268	109	79 638	8 501 738	957 152	6 183 349	31 461 749	0
2002	103 178	78	76 889	7 711 112	1 574 938	6 613 112	30 748 133	0
2003	99 506	79	77 148	6 710 693	2 244 300	5 837 012	27 846 161	0
2004	96 983	81	75 053	6 655 151	2 349 430	7 973 839	31 101 753	0
2005	92 399	55	81 294	4 988 837	3 579 288	7 431 556	31 534 746	0
2006	60 855	107	81 501	4 696 112	4 601 484	7 838 096	32 933 200	1 088
2007	55 223	84	76 761	4 012 043	4 835 397	7 604 510	33 204 529	1 970
2008	54 972	126	75 940	4 803 253	5 108 904	6 924 471	32 351 803	1 892
2009	84 991	126	71 986	3 972 499	6 820 546	6 115 997	33 017 163	3 249
2010	93 532	126	74 474	4 712 406	12 691 733	6 259 701	36 429 196	5 081
2011	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal from 1990 to 2010 (six Kraft plants and two bisulphite smaller plants), but also smaller units dedicated to paper production. The increasing trend in total fuel consumption is evident and was

²² Wood waste includes methanol, NCG, tall-oil, biogas and gasified biomass.

almost continuous in the period, except for 2010 where the increase is significant (20 per cent). The lower temporary value in 2003 reflects a re-qualification period for one unit. Considering the share of energy sources, there is a dominance of liquor, followed by residual fuel oil, wood waste and natural gas - this last only recently - as auxiliary primary energy sources.

Table 3.30 - Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ)

Year	Gasoline	Diesel Oil	Biogas	Biodiesel
1990	2 678	90 172	0	0
1991	6 339	78 864	0	0
1992	8 809	76 196	0	0
1993	4 835	70 972	0	0
1994	11 005	66 319	0	0
1995	6 137	72 544	0	0
1996	5 363	71 744	0	0
1997	9 484	80 331	0	0
1998	8 928	61 032	0	0
1999	7 702	59 618	0	0
2000	796	54 762	9 705	0
2001	24 311	79 638	17 804	0
2002	1 069	76 889	19 632	0
2003	1 283	77 148	19 056	0
2004	891	75 053	24 469	0
2005	911	81 294	28 895	0
2006	591	79 898	33 047	1 088
2007	335	76 761	31 230	1 970
2008	167	75 940	40 780	1 892
2009	167	71 329	38 815	3 249
2010	335	74 213	34 055	5 081
2011	-	-	-	-
2012	-	-	-	-

Figure 3.28 – Total Energy Consumption in the Paper and Paper Pulp Industry

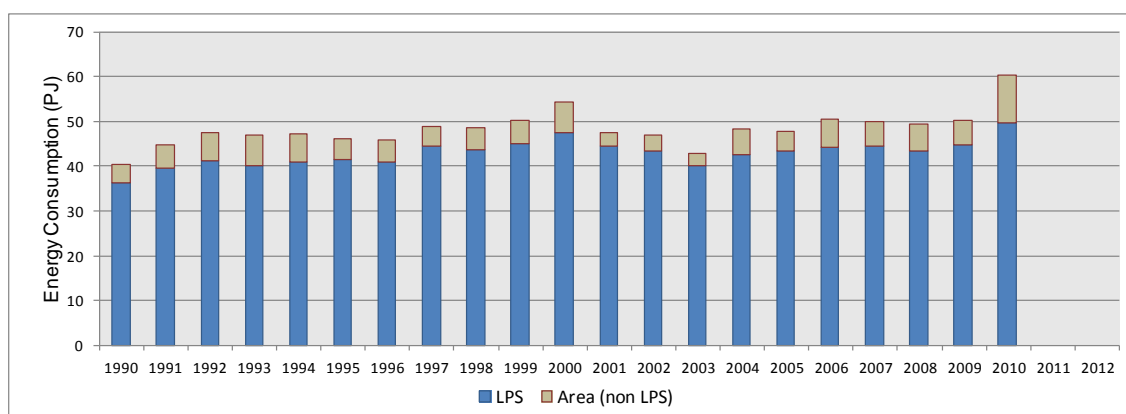
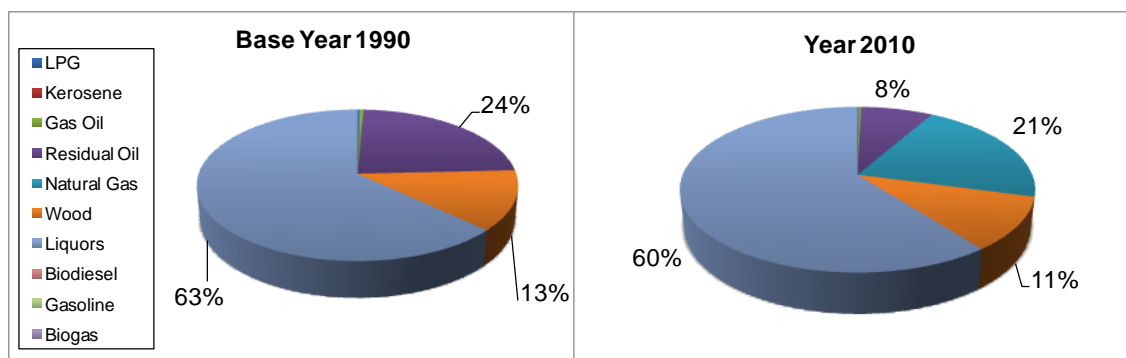


Figure 3.29 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2010



3.3.2.2.1.2.5 Food Processing, Beverages and Tobacco Industries

Table 3.31 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Food Processing, Beverages and Tobacco Industries

Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3
31.0	46.0	43.8	42.6	40.0	38.7

Wood	Gasoline	Biodiesel	Biogas
MJ/kg	MJ/kg	MJ/kg	MJ/kg
12.6	44.0	37.0	34.7

Table 3.32 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas	Wood	Biodiesel
1990	12 416	906 272	13 318	545 639	8 902 333	0	3 981 464	0
1991	6 641	1 043 157	6 716	590 698	9 657 033	0	3 911 799	0
1992	432	1 147 678	7 586	683 319	9 558 680	0	3 852 887	0
1993	0	1 217 112	7 662	688 426	9 014 368	0	3 775 816	0
1994	0	1 363 652	6 223	728 505	8 945 629	0	3 775 858	0
1995	0	1 462 813	5 078	735 940	9 399 512	0	3 775 858	0
1996	0	1 626 766	2 130	798 673	9 403 558	0	4 006 695	0
1997	0	1 965 948	4 595	747 839	11 124	3 872	4 006 695	0
1998	0	1 944 223	5 540	720 126	11 360	393 130	4 015 170	0
1999	0	1 899 755	6 938	813 351	10 595	1 197 675	3 391 460	0
2000	0	1 699 805	1 729	669 262	9 384 736	1 800 049	3 435 549	0
2001	0	1 812 025	906	738 713	9 505 627	2 563 079	3 435 146	0
2002	0	1 703 146	802	650 597	9 554 549	3 839 367	3 435 146	0
2003	0	1 632 065	802	634 089	9 039 749	5 104 930	3 652 342	0
2004	0	1 438 067	742	678 022	6 543 490	4 916 845	3 642 346	0
2005	0	1 231 248	5	753 087	5 798 837	4 518 401	3 714 314	0
2006	0	1 117 981	0	660 586	6 983 886	4 632 098	3 769 289	8 694
2007	0	1 031 535	0	645 959	6 479 213	6 798 818	3 883 222	16 194
2008	0	1 009 136	42	530 191	5 969 479	6 442 308	3 883 222	12 682
2009	0	920 042	126	497 523	5 823 278	6 357 399	3 883 222	21 445
2010	0	913 427	209	487 144	7 033 326	7 046 973	3 883 222	31 384
2011	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-

Table 3.33 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biogas	Biodiesel
1990	17 588	545 639	0	0
1991	27 172	590 698	0	0
1992	68 262	683 319	0	0
1993	50 904	688 426	0	0
1994	103 964	728 505	0	0
1995	109 277	735 940	0	0
1996	118 108	798 673	0	0
1997	192 149	747 839	0	0
1998	174 625	720 126	0	0
1999	171 514	813 351	0	0
2000	117 945	669 262	0	0
2001	224 544	738 713	0	0
2002	101 376	650 597	0	0
2003	89 323	634 089	0	0
2004	73 178	678 022	0	0
2005	68 883	753 087	0	0
2006	53 825	660 586	0	8 694
2007	40 110	645 959	0	16 194
2008	27 089	530 191	0	12 682
2009	27 801	497 523	61	21 445
2010	23 782	487 144	61	31 384
2011	-	-	-	-
2012	-	-	-	-

In 1990 the dominant fuel source of this sector was residual fuel oil, followed by biomass and also with a representative use of propane and gasoil. After 1997, natural gas has been replacing the use of former fuels.

Figure 3.30 – Total Energy Consumption in the Food Processing, Beverages and Tobacco Industry

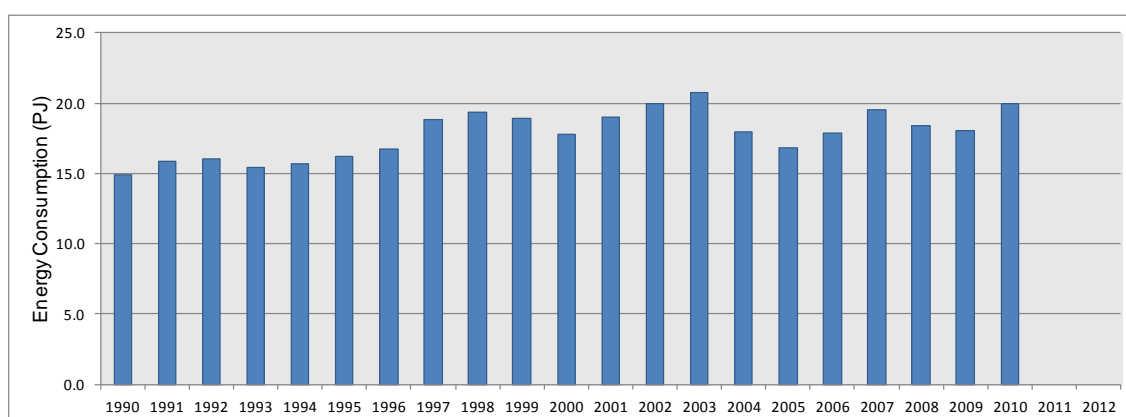
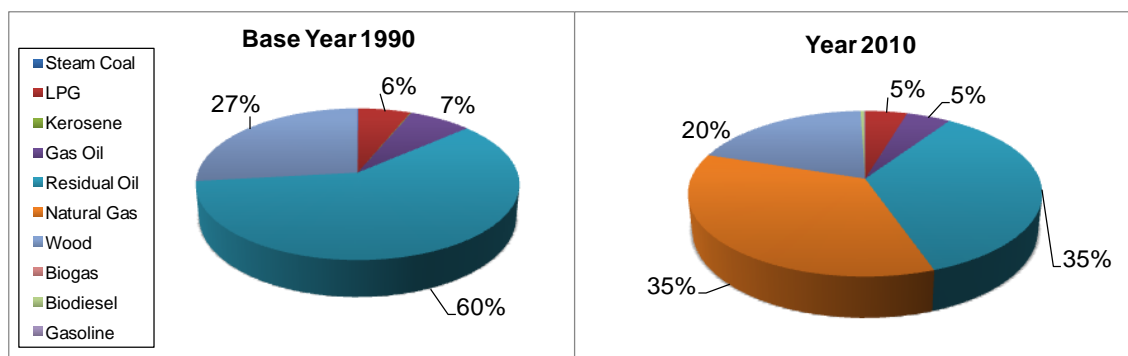


Figure 3.31 - Fuel consumption per fuel type in the Food Processing, Beverages and Tobacco Industries in 1990 and 2010



3.3.2.2.1.2.6 Textile Industry

Table 3.34 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Textile Industry

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	43.8	42.6	40.0	38.7	12.6

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3.35 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	211 214	125	27 579	10 404 993	0	1 136 569	0
1991	260 205	113	28 151	8 875 482	0	1 116 695	0
1992	313 552	104	31 073	8 143 021	0	1 099 874	0
1993	309 144	65	31 631	7 372 887	0	1 077 866	0
1994	327 132	24	37 277	8 360 703	0	1 077 866	0
1995	375 912	4	37 333	8 878 803	0	1 077 866	0
1996	446 600	6	40 491	11 406 256	0	1 143 933	0
1997	554 936	180	50 856	14 719 583	0	1 143 933	0
1998	658 786	175	52 487	14 167 006	15 730	1 146 353	0
1999	714 642	8	51 568	11 703 715	626 486	2 033 077	0
2000	508 000	0	75 347	11 337 089	4 196 267	2 059 507	0
2001	450 644	0	67 973	9 263 701	6 182 150	2 059 498	0
2002	406 246	0	91 024	9 179 144	7 928 276	2 059 498	0
2003	394 650	0	100 415	7 739 570	9 060 539	2 140 028	0
2004	415 336	0	114 222	7 117 438	8 621 090	2 183 009	0
2005	362 613	4	108 672	7 295 236	7 979 698	2 225 989	0
2006	311 168	6	87 504	7 214 990	8 293 655	2 258 974	1 084
2007	250 704	84	62 987	5 990 496	8 093 100	2 328 954	1 426
2008	159 223	42	53 845	4 417 459	9 100 456	2 328 954	1 211
2009	140 927	42	20 224	4 055 097	8 279 038	2 328 954	354
2010	127 822	42	19 588	4 033 368	7 529 131	2 328 954	634
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Table 3.36 – Fuel consumption in Textile Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	4 315	27 579	0
1991	4 726	28 151	0
1992	12 066	31 073	0
1993	9 231	31 631	0
1994	18 629	37 277	0
1995	18 913	37 333	0
1996	19 253	40 491	0
1997	21 802	50 856	0
1998	22 731	52 487	0
1999	18 443	51 568	0
2000	66 391	75 347	0
2001	60 135	67 973	0
2002	59 054	91 024	0
2003	63 476	100 415	0
2004	50 115	114 222	0
2005	43 123	108 672	0
2006	37 732	87 504	1 084
2007	30 355	62 987	1 426
2008	2 638	53 845	1 211
2009	670	20 224	354
2010	0	19 588	634
2011	-	-	-
2012	-	-	-

Figure 3.32 – Total Energy Consumption in the Textile Industry

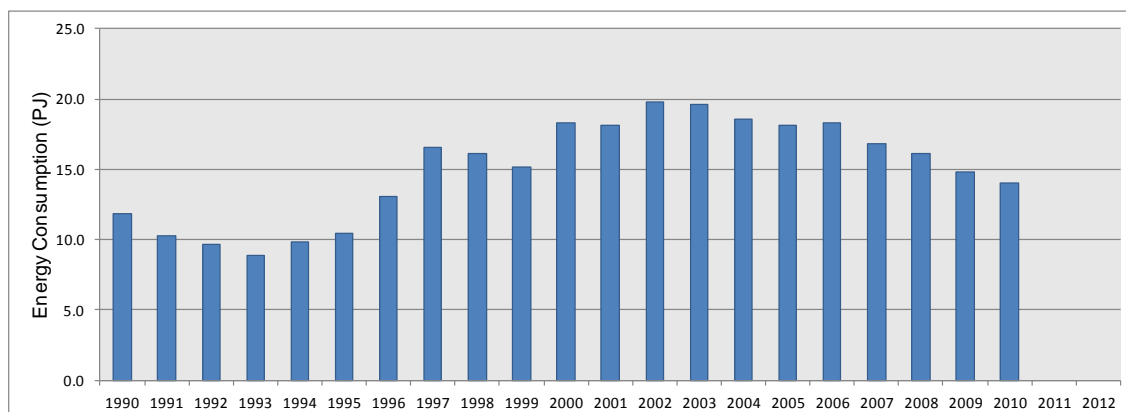
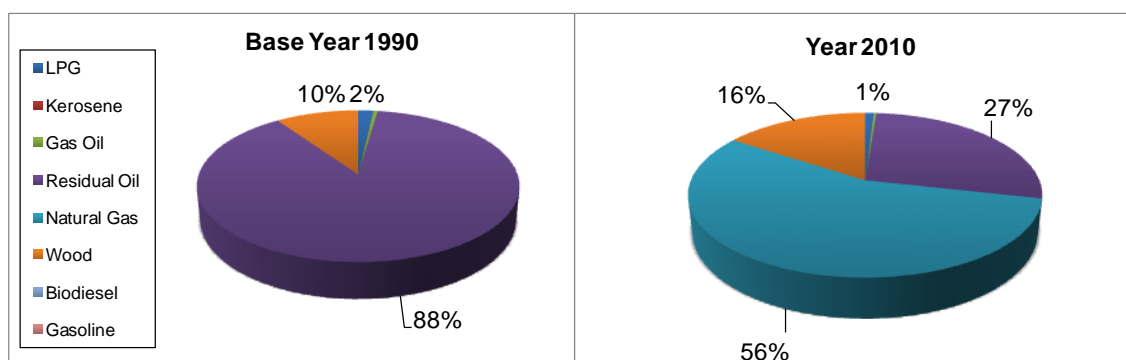


Figure 3.33 – Fuel consumption per fuel type in Textile Industry in 1990 and 2010



3.3.2.2.1.2.7 Ceramic Industry

Table 3.37 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Ceramic Industry

Steam Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
31.0	32.0	46.0	43.8	42.6	40.0

Natural Gas	Wood	Gasoline	Biodiesel
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg
38.7	12.6	44.0	37.0

Table 3.38 - Fuel consumption in the Ceramic Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	6 556	0	6 150 865	28	128 086	3 301 796	0	12 476 234	0
1991	2 256	0	6 723 830	214	156 820	3 540 690	0	12 257 950	0
1992	0	0	7 327 807	4 322	157 373	3 342 813	0	12 073 347	0
1993	0	0	7 659 325	1 396	131 411	3 190 911	0	11 831 925	0
1994	0	0	8 226 958	109	133 584	3 288 727	0	11 831 883	0
1995	0	0	8 792 146	0	130 307	3 727 408	0	11 831 883	0
1996	0	0	9 082 825	1	135 921	3 923 131	0	12 556 485	0
1997	0	0	8 148 126	0	188 157	6 037 204	1 399 983	12 556 485	0
1998	0	0	4 500 669	0	199 676	5 884 312	6 409 816	12 583 047	0
1999	0	0	2 507 757	7	177 792	4 478 322	11 301 103	13 336 945	0
2000	0	0	1 410 200	347	181 234	3 754 710	13 870 688	13 510 325	0
2001	0	0	1 459 289	244	215 231	3 038 583	15 367 705	13 510 335	0
2002	0	0	1 120 472	256	171 444	2 074 805	16 154 316	13 510 335	0
2003	0	0	839 455	299	155 544	912 791	17 545 611	13 782 248	0
2004	0	843 393	691 344	193	157 760	826 023	15 478 571	14 059 122	0
2005	0	539 058	540 176	166	126 016	810 594	14 790 354	14 022 734	0
2006	0	0	439 528	220	98 605	549 847	14 256 194	14 355 156	1 329
2007	0	191 791	419 849	167	86 320	813 104	14 346 622	14 860 837	2 209
2008	0	319 414	365 881	209	80 663	692 694	15 632 823	14 824 895	2 004
2009	0	685 152	274 066	293	191 690	385 221	11 016 903	14 824 895	8 394
2010	0	462 743	252 964	251	57 751	348 964	11 364 956	14 824 895	3 899
2011	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-

Table 3.39 – Fuel consumption in the Ceramic Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	38 533	128 086	0
1991	41 482	156 820	0
1992	51 461	157 373	0
1993	50 728	131 411	0
1994	53 076	133 584	0
1995	48 847	130 307	0
1996	34 960	135 921	0
1997	30 044	188 157	0
1998	30 588	199 676	0
1999	20 682	177 792	0
2000	17 199	181 234	0
2001	17 688	215 231	0
2002	19 150	171 444	0
2003	21 423	155 544	0
2004	19 920	157 760	0
2005	435	126 016	0
2006	135	98 605	1 329
2007	0	86 320	2 209
2008	0	80 663	2 004
2009	8 374	191 690	8 394
2010	377	57 751	3 899
2011	-	-	-
2012	-	-	-

The figure below shows two periods: the first goes from 1990 to 2001 and characterizes a steady increase in fuel consumption, after that total energy consumption has declined each year until 2010 (except for 2007). The pattern of fuel consumption has also changed, with the abandonment of residual fuel oil and LPG and their substitution by natural gas in more recent years. This sector, together with the glass industry, is in fact one in which the substitution was more visible. The decrease in use of biomass is only apparent in per cent, because values of consumption of these fuels did in fact increased slightly. Since 2004 the gasoline consumption has been dropping significantly. In 2009 an increase in gasoline and gas oil consumption was reported in the energy balance.

Figure 3.34 – Total Energy Consumption in the Ceramic Industry

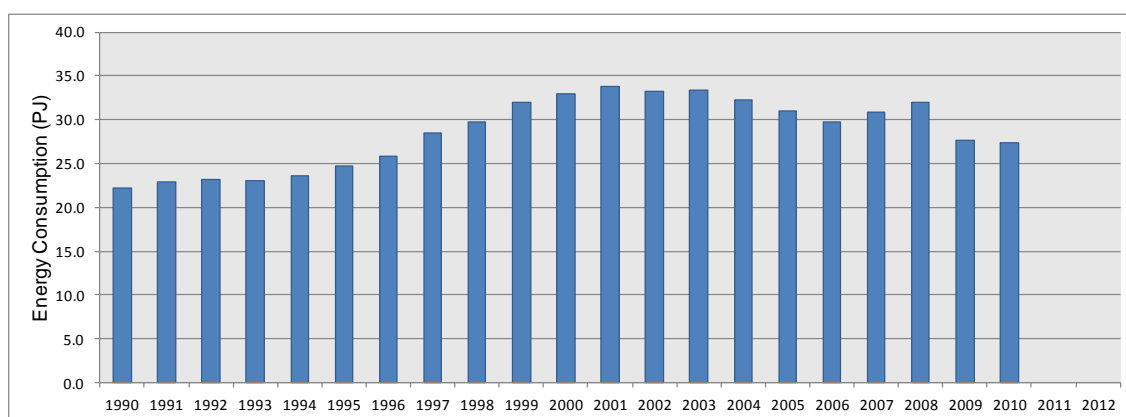
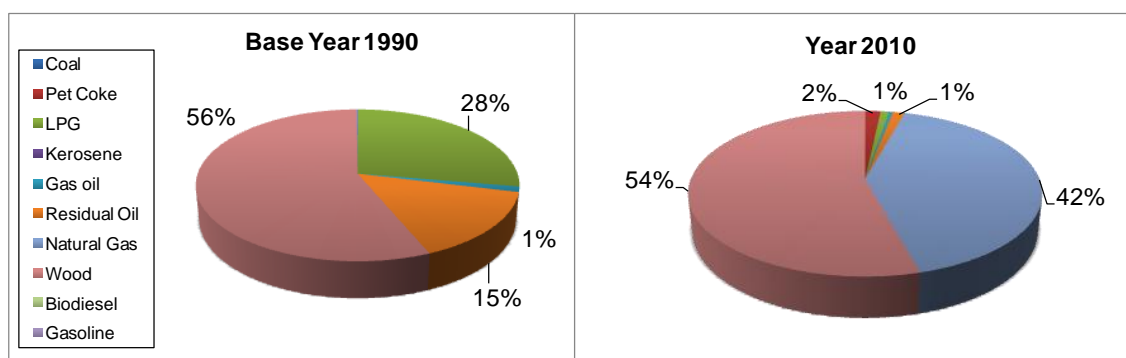


Figure 3.35 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2010



3.3.2.2.1.2.8 *Glass Industry*

Table 3.40 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Glass Industry

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	43.8	42.6	40.0	38.7	12.6

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3.41 – Fuel consumption in the Glass Industry – Boilers and Furnaces (GJ)

Year	LPG	Gas Oil	Residual Oil	Kerosene	Natural Gas	Wood	Biodiesel
1990	1 160 597	25 181	4 404 014	0	0	1 381	0
1991	1 248 720	23 622	5 443 854	0	0	1 339	0
1992	1 142 419	24 975	5 501 239	0	0	1 339	0
1993	1 133 167	16 947	6 020 464	0	0	1 297	0
1994	1 265 445	14 541	6 351 112	0	0	1 297	0
1995	1 381 339	21 325	6 496 385	0	0	1 297	0
1996	1 549 033	35 682	6 786 940	0	0	1 381	0
1997	1 733 878	29 344	7 568 657	0	28 312	1 381	0
1998	1 109 931	27 061	8 074 747	0	799 595	1 384	0
1999	567 235	31 090	5 592 341	0	2 833 514	1 381	0
2000	343 895	23 576	3 448 203	7	5 280 281	1 381	0
2001	240 774	35 096	3 057 398	0	6 048 776	1 381	0
2002	156 518	24 374	2 624 789	0	6 348 540	1 381	0
2003	134 353	25 996	1 990 481	0	7 220 017	1 381	0
2004	45 382	30 303	1 851 946	0	6 751 721	1 381	0
2005	20 881	19 281	1 734 777	0	6 677 624	0	0
2006	25 736	9 409	929 530	0	7 104 015	0	121
2007	21 981	8 368	546 870	0	8 508 687	0	215
2008	22 106	25 551	386 226	0	8 247 385	0	637
2009	14 193	25 833	150 932	0	7 849 802	0	1 172
2010	13 272	26 787	116 810	0	7 753 002	0	1 830
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Table 3.42 – Fuel consumption in the Glass Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	4 001	25 181	0
1991	3 989	23 622	0
1992	5 229	24 975	0
1993	5 589	16 947	0
1994	4 933	14 541	0
1995	3 648	21 325	0
1996	3 816	35 682	0
1997	3 579	29 344	0
1998	4 315	27 061	0
1999	2 702	31 090	0
2000	1 030	23 576	0
2001	1 123	35 096	0
2002	283	24 374	0
2003	152	25 996	0
2004	171	30 303	0
2005	174	19 281	0
2006	123	9 409	121
2007	0	8 368	215
2008	0	25 551	637
2009	0	25 833	1 172
2010	0	26 787	1 830
2011	-	-	-
2012	-	-	-

The consumption of energy in this sector has suffered stagnation in the most recent years after 1999, showing a slight increase in 2007 and 2008 and a decrease in 2009 and 2010. The introduction of natural gas has almost fully replaced the consumption of LPG and most of the consumption of residual fuel oil that was in dominance in 1990.

Figure 3.36 – Total Energy Consumption in the Glass Industry

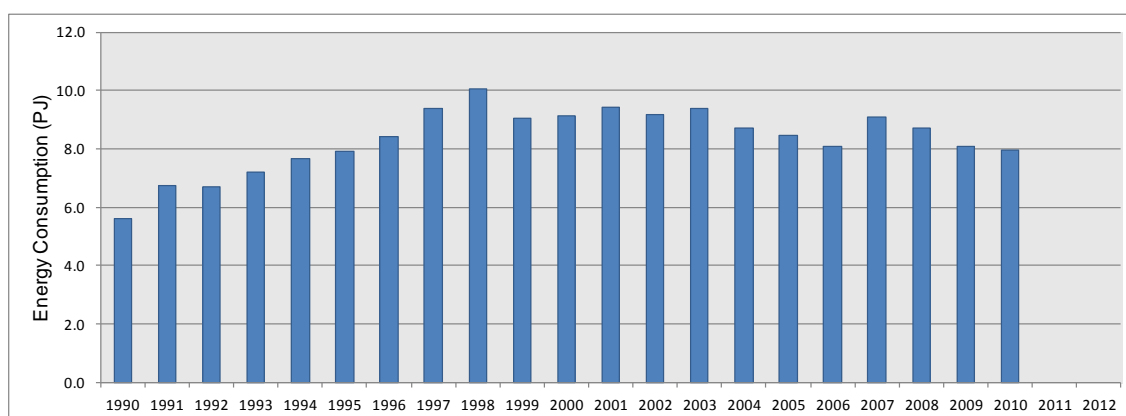
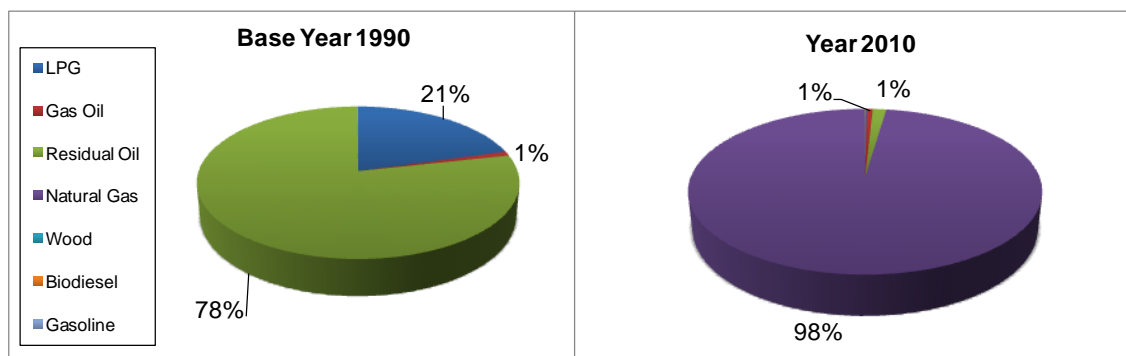


Figure 3.37 – Fuel consumption per fuel type in Glass Industry in 1990 and 2010



3.3.2.2.1.2.9 Cement Industry

In the 2009 inventory new data concerning fuel consumption in the Cement Industry was obtained through the LCP operator. In this new data batch, previously unreported fuels were accounted. These fuels were:

- Industrial waste – Fluff (fiber residue) and RDF (unrecycled cardboard and plastics)
- Hazardous industrial waste – composition unknown;
- Animal and wood waste – animal carcass and general wood waste;

Even though there are six clinker units in Portugal they only belong to two companies. Because of this, fuel consumption for the Cement Industry is considered confidential and will not be reported desagregated by fuel type.

Table 3.43 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry

Steam Coal	Petcoke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
22.5 - 31	30.9 - 34.6	46.0	44.0	43.8	42.6	39.8 - 40.4

Natural Gas (MJ/Nm3)	Biodiesel	Tires	Industrial Waste	Hazardous Industrial Waste	Animal + Wood Waste	Natural Gas (MJ/Nm3)
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3
38.7	37.0	23.8 - 31.4	10.7 - 32.3	12.3 - 23.5	9.8 - 20.8	38.7

Six units produce clinker and cement in Portugal, representing the majority of fuel combustion in this economic sector. Petroleum coke has been, in recent years, gradually replacing the use of imported coal in the kilns. Relevant is also to note the use of old tires and other industrial waste as energy source.

Figure 3.38 – Total Energy Consumption in the Cement Industry

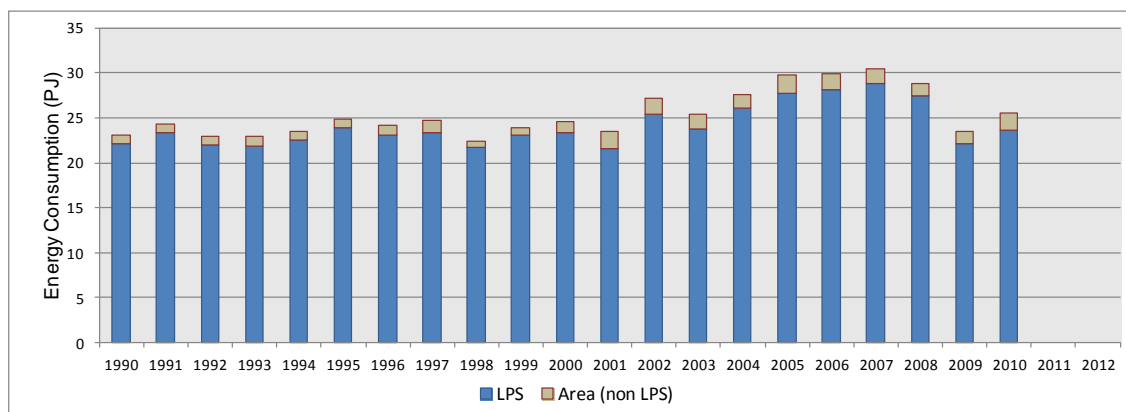
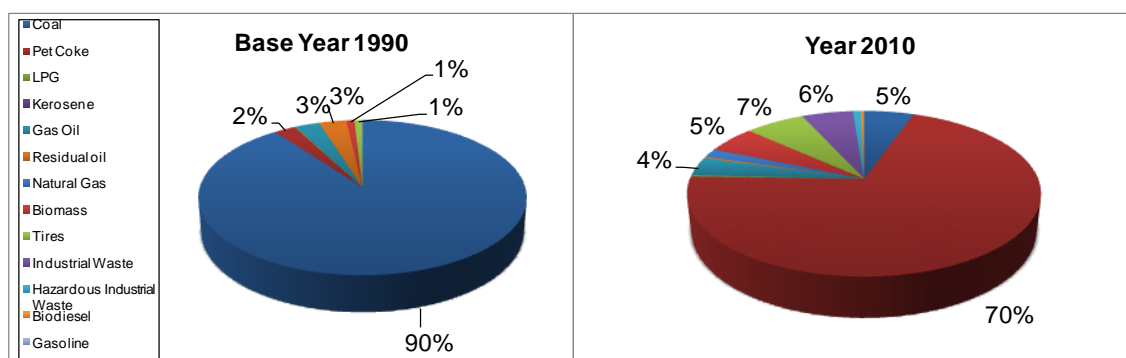


Figure 3.39 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2010



3.3.2.2.1.2.10 Clothing, Shoes and Leather Industries

Table 3.44 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Clothing, Shoes and Leather Industries

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	43.8	42.6	40.0	38.7	12.6

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3.45 – Fuel consumption in the Clothing, Shoes and Leather Industries – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	56 737	28	27 665	766 086	0	279 958	0
1991	111 352	42	27 365	857 780	0	275 063	0
1992	162 183	35	25 769	1 392	0	270 921	0
1993	206 219	7	24 420	1 826	0	265 523	0
1994	222 108	0	25 347	1 336	0	265 481	0
1995	239 172	0	22 330	704 818	0	265 481	0
1996	305 659	0	24 048	791 568	0	281 590	0
1997	314 163	0	19 948	776 058	0	281 590	0
1998	330 170	0	20 230	714 889	7 699	282 186	0
1999	312 995	0	19 271	646 835	33 699	282 427	0
2000	226 044	0	15 078	350 076	148 574	282 636	0
2001	315 192	0	17 804	370 528	400 440	282 636	0
2002	297 487	0	14 775	466 430	259 662	282 636	0
2003	259 993	0	12 902	333 378	439 812	0	0
2004	242 081	0	11 756	323 717	478 350	0	0
2005	231 177	8	11 608	241 561	471 677	0	0
2006	212 729	0	8 234	244 972	508 823	0	111
2007	183 757	0	3 980	244 296	576 320	0	102
2008	202 053	0	4 672	263 261	664 663	0	100
2009	172 997	0	4 792	391 417	763 975	0	169
2010	154 994	0	7 379	401 968	748 818	0	408
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Table 3.46 – Fuel consumption in the Clothing, Shoes and Leather Industries – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	1 962	27 665	0
1991	2 752	27 365	0
1992	7 815	25 769	0
1993	7 118	24 420	0
1994	9 400	25 347	0
1995	8 668	22 330	0
1996	8 252	24 048	0
1997	7 989	19 948	0
1998	7 529	20 230	0
1999	6 189	19 271	0
2000	3 836	15 078	0
2001	13 200	17 804	0
2002	2 321	14 775	0
2003	1 363	12 902	0
2004	801	11 756	0
2005	465	11 608	0
2006	211	8 234	111
2007	0	3 980	102
2008	0	4 672	100
2009	0	4 792	169
2010	0	7 379	408
2011	-	-	-
2012	-	-	-

Figure 3.40 – Total Energy Consumption in the Clothing, Shoes and Leather Industries

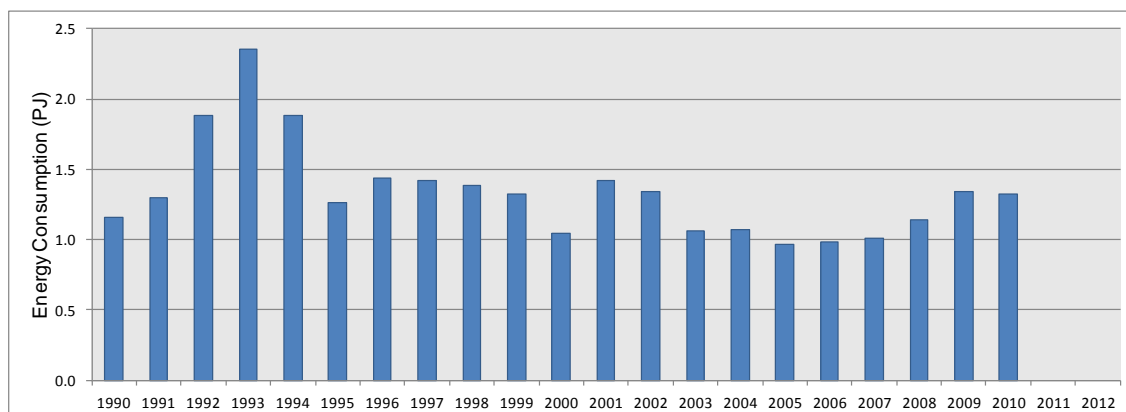
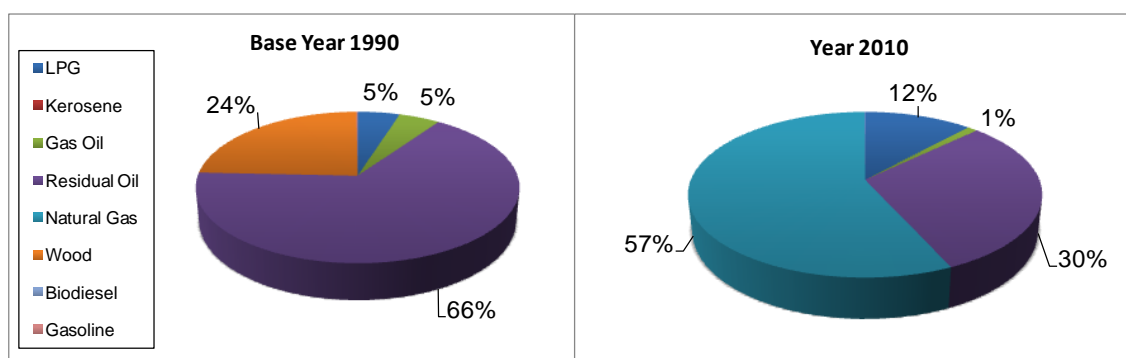


Figure 3.41 - Fuel consumption per fuel type in the Clothing, Shoes and Leather Industries in 1990 and 2010



3.3.2.2.1.2.11 Wood Industry

Table 3.47 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Wood Industry

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	43.8	42.6	40.0	38.7	12.6

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3.48 – Fuel consumption in the Wood Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	85 312	69	250 404	1 346 386	0	1 309 205	0
1991	100 217	57	246 445	1 276 646	0	1 286 318	0
1992	96 645	11	208 220	689 356	0	1 266 946	0
1993	110 716	22	179 511	1 075 448	0	1 241 590	0
1994	115 891	21	185 097	1 786 302	0	1 241 590	0
1995	115 297	0	192 250	3 036 372	0	1 241 590	0
1996	131 603	0	204 648	3 087 875	0	1 317 573	0
1997	330 329	1 913	479 921	2 899 400	0	1 317 573	0
1998	343 536	2 902	578 339	2 839 822	12	1 320 360	0
1999	378 477	74	498 230	2 844 661	34 865	895 593	0
2000	467 887	85	206 253	2 939 646	237 203	907 236	0
2001	444 997	81	255 386	1 742 151	306 935	903 766	0
2002	426 701	84	208 273	2 119 550	345 245	618 075	0
2003	382 080	73	202 288	1 999 425	439 877	1 637 257	0
2004	303 590	57	323 109	2 071 844	525 719	1 693 231	0
2005	260 611	1 127	215 627	1 998 707	524 181	1 632 259	0
2006	208 727	1 653	239 281	2 032 255	513 476	1 656 248	3 097
2007	183 590	1 507	235 849	2 024 450	559 363	1 706 234	5 559
2008	54 763	42	158 228	1 645 049	293 205	1 706 234	3 694
2009	47 478	42	134 140	1 893 071	257 826	1 706 234	5 801
2010	59 326	0	123 705	1 659 828	791 399	1 706 234	8 135
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Table 3.49 – Fuel consumption in the Wood Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	793	250 404	0
1991	1 833	246 445	0
1992	3 554	208 220	0
1993	3 625	179 511	0
1994	9 248	185 097	0
1995	11 017	192 250	0
1996	11 956	204 648	0
1997	132 910	479 921	0
1998	169 240	578 339	0
1999	129 639	498 230	0
2000	4 050	206 253	0
2001	30 957	255 386	0
2002	3 233	208 273	0
2003	2 503	202 288	0
2004	1 595	323 109	0
2005	1 373	215 627	0
2006	399	239 281	3 097
2007	0	235 849	5 559
2008	0	158 228	3 694
2009	0	134 140	5 801
2010	0	123 705	8 135
2011	-	-	-
2012	-	-	-

Although total consumption of energy from combustion has increased from 1990 to 2010, there is not a constant trend along periods, but instead oscillations along the period. The share of fuels has been maintained fairly constant, dominated by the use of residual fuel oil and biomass, and the introduction of natural gas was less important than for other sectors.

Figure 3.42 – Total Energy Consumption in the Wood Industry

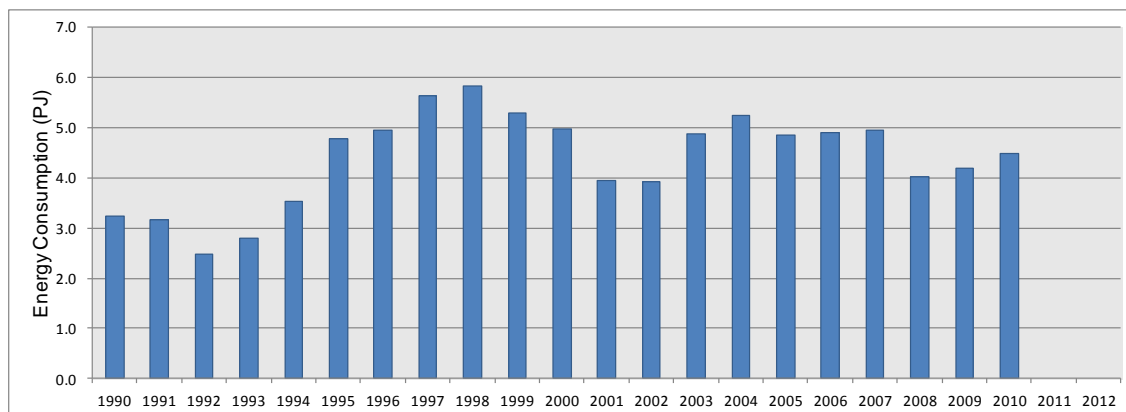
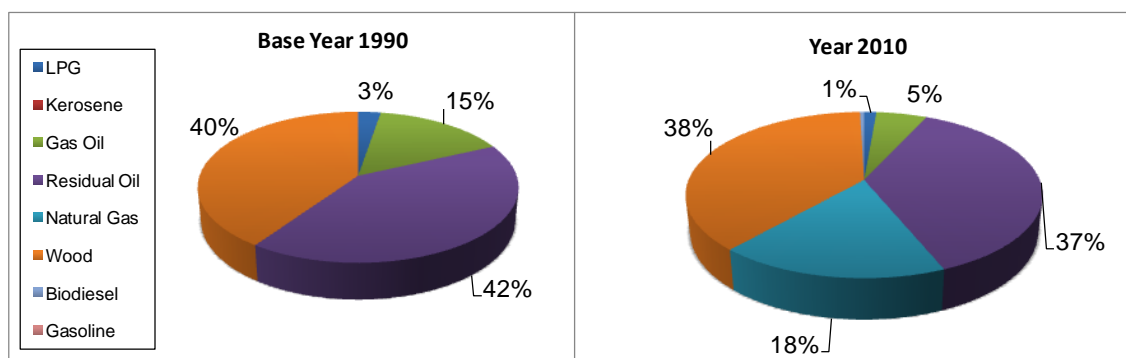


Figure 3.43 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2010



3.3.2.2.1.2.12 Rubber Industry

Table 3.50 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Rubber Industry

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	43.8	42.6	40.0	38.7	12.6

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3.51 – Fuel consumption in the Rubber Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	27 688	240	5 481	571 475	0	46 820	0
1991	30 088	268	6 785	462 494	0	45 983	0
1992	28 326	223	13 612	344 254	0	45 314	0
1993	27 900	188	13 630	286 945	0	44 393	0
1994	30 756	118	14 585	262 613	0	44 393	0
1995	33 286	135	13 470	270 653	0	44 393	0
1996	39 209	168	14 017	268 187	0	47 280	0
1997	71 154	60	11 593	281 383	0	47 280	0
1998	28 011	28	11 876	307 699	362	47 380	0
1999	26 034	13	16 811	352 972	1 570	47 322	0
2000	28 111	48	29 578	379 923	34 818	47 280	0
2001	35 400	15	33 386	203 323	137 687	47 280	0
2002	29 357	0	29 342	87 481	270 925	47 280	0
2003	27 680	1	24 560	67 653	346 960	0	0
2004	19 803	0	25 403	50 879	402 280	0	0
2005	20 546	0	1 314	27 107	419 238	0	0
2006	17 453	16	270	17 474	482 839	0	4
2007	11 932	42	3 131	11 430	475 626	0	9
2008	6 113	0	3 122	17 919	111 873	0	18
2009	3 140	42	1 957	21 352	672 827	0	32
2010	4 145	42	0	32 112	733 704	0	0
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Table 3.52 – Fuel consumption in the Rubber Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	0	5 481	0
1991	0	6 785	0
1992	1 643	13 612	0
1993	2 361	13 630	0
1994	3 488	14 585	0
1995	4 728	13 470	0
1996	5 174	14 017	0
1997	7 285	11 593	0
1998	6 993	11 876	0
1999	20 492	16 811	0
2000	57 450	29 578	0
2001	53 119	33 386	0
2002	48 425	29 342	0
2003	43 570	24 560	0
2004	44 012	25 403	0
2005	48	1 314	0
2006	9	270	4
2007	0	3 131	9
2008	0	3 122	18
2009	0	1 957	32
2010	0	0	0
2011	-	-	-
2012	-	-	-

The figure below shows a significant decrease in the total fuel consumption in 2008 and a increase in 2009 and 2010, mainly due to fluctuations in natural gas consumption. The sharp increase in natural gas consumption from 2008 to 2009 results from a reclassification of a co-generation plant in the energy balance (previously accounted in another sector).

Figure 3.44 – Total Energy Consumption in the Rubber Industry

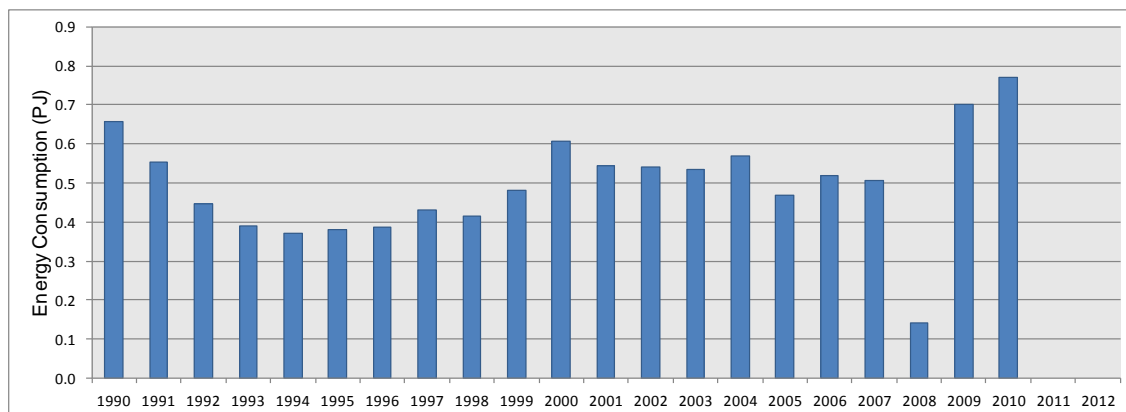
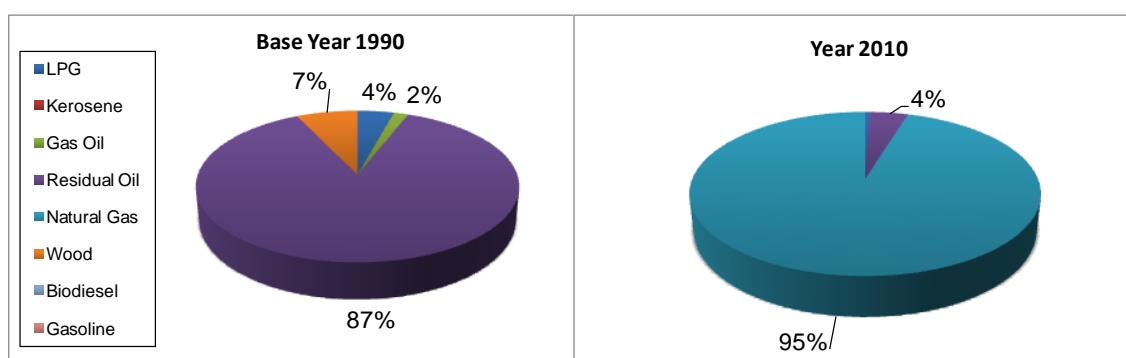


Figure 3.45 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2010



3.3.2.2.1.2.13 Manufacturing of Machines and Metallic Equipments Industry

Table 3.53 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Manufacturing of Machines and Metallic Equipments Industry

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	43.8	42.6	40.0	38.7	12.6

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3.54– Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	1 464 554	5 901	166 018	885 983	0	28 368	0
1991	1 513 346	2 697	163 453	815 255	0	27 866	0
1992	1 535 201	1 233	176 195	863 221	0	27 448	0
1993	1 513 218	430	159 884	536 037	0	26 904	0
1994	1 620 994	106	154 892	648 010	0	26 904	0
1995	1 606 517	77	210 899	508 561	0	26 904	0
1996	1 629 591	206	254 712	1 022 150	0	28 452	0
1997	2 371 790	208	217 413	728 381	163 341	28 452	0
1998	2 457 574	238	250 399	976 233	433 677	28 512	0
1999	2 270 274	378	238 928	651 408	718 264	15 993	0
2000	1 785 009	324	117 664	770 616	1 196 668	16 201	0
2001	1 675 701	136	175 273	494 750	1 568 925	16 192	0
2002	1 422 586	182	170 618	401 471	1 715 171	16 192	0
2003	1 331 127	110	151 366	331 391	2 074 957	16 992	0
2004	1 327 801	111	135 563	281 902	2 059 217	17 992	0
2005	1 293 735	296	142 488	215 524	2 120 763	16 992	0
2006	1 224 299	225	169 726	250 084	2 153 805	17 992	2 253
2007	1 102 250	126	164 957	213 732	2 218 445	16 987	4 145
2008	1 074 031	42	159 514	4 145	2 443 698	16 987	3 538
2009	934 528	42	139 572	9 713	2 097 361	16 987	5 771
2010	926 824	921	108 547	107 222	1 804 658	16 987	6 568
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Table 3.55 – Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	43 723	166 018	0
1991	50 451	163 453	0
1992	84 308	176 195	0
1993	70 038	159 884	0
1994	95 158	154 892	0
1995	101 341	210 899	0
1996	165 367	254 712	0
1997	162 969	217 413	0
1998	157 213	250 399	0
1999	139 014	238 928	0
2000	45 687	117 664	0
2001	100 614	175 273	0
2002	49 746	170 618	0
2003	104 229	151 366	0
2004	20 195	135 563	0
2005	10 951	142 488	0
2006	37 414	169 726	2 253
2007	31 109	164 957	4 145
2008	31 904	159 514	3 538
2009	28 596	139 572	5 771
2010	90 353	108 547	6 568
2011	-	-	-
2012	-	-	-

Figure 3.46 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry

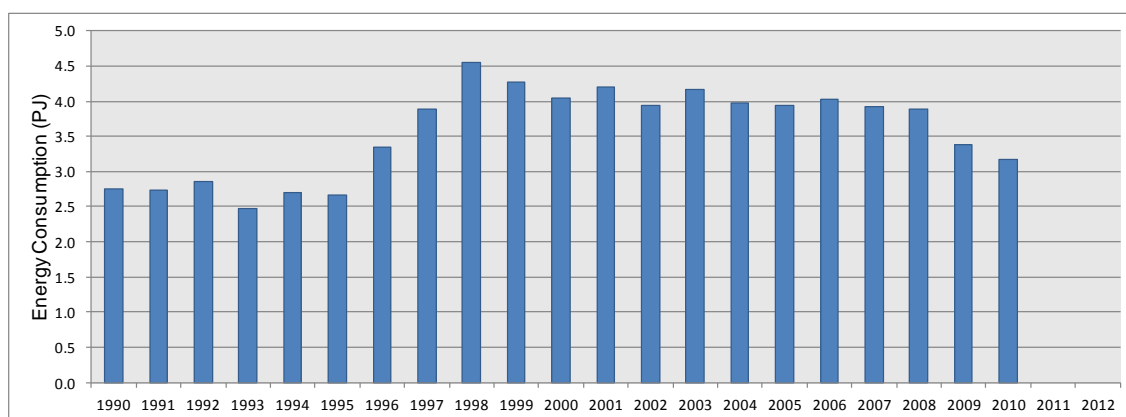
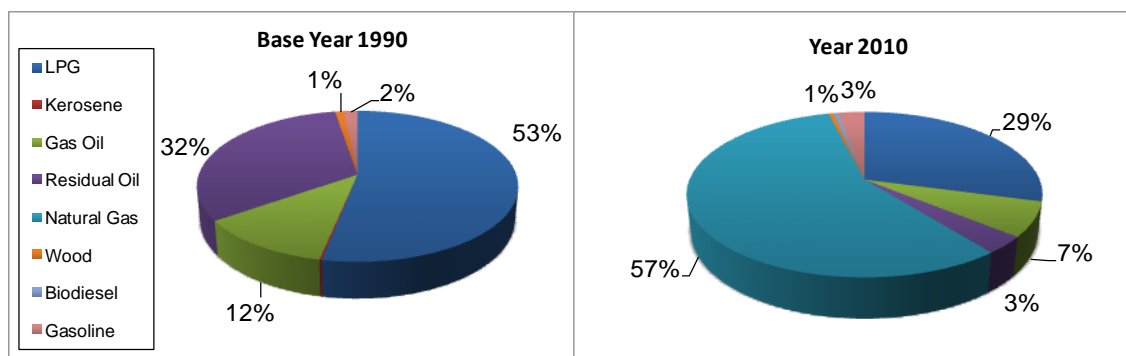


Figure 3.47 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2010



3.3.2.2.1.2.14 Other Transformation Industry

Table 3.56 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Other Transformation Industry

Lignite	LPG	Kerosene	Gas Oil	Residual Oil	City Gas
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
17.2	46.0	43.8	42.6	40.0	15.7

Natural Gas	Wood	Gasoline	Biodiesel	Biogas
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg	MJ/kg
38.7	12.6	44.0	37.0	34.7

Table 3.57 – Fuel consumption in Other Transformation Industry – Boilers and Furnaces (GJ)

Year	Lignite	LPG	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas	Wood	Biodiesel
1990	446	152 483	4 090	169 380	1 450 485	78	0	6 234	0
1991	206	203 577	3 984	219 362	1 386 959	2 746	0	6 109	0
1992	34	234 705	3 312	238 688	1 261 446	6 360	0	6 025	0
1993	463	341 042	2 198	363 689	939 151	64 686	0	5 900	0
1994	711	396 156	1 009	292 321	811 687	55 941	0	5 900	0
1995	0	431 055	37	180 662	168 426	55 690	0	5 900	0
1996	0	490 976	1 052	262 445	179 210	61 914	0	6 276	0
1997	0	114 740	0	20 034	332	72 929	0	6 276	0
1998	0	96 699	0	31 781	0	68 724	418	6 289	0
1999	0	128 819	0	27 421	0	60 544	18 177	6 276	0
2000	0	79 493	0	17 846	0	44 451	108 897	6 276	0
2001	0	50 002	30	24 959	0	6 056	144 787	6 276	0
2002	0	40 482	0	8 169	0	0	150 667	6 276	0
2003	0	33 289	0	7 453	0	0	204 165	33 985	0
2004	0	37 680	0	9 790	0	0	192 551	32 985	0
2005	0	33 769	0	8 023	0	0	198 241	34 984	0
2006	0	37 155	0	3 766	0	0	203 719	35 984	51
2007	0	36 509	0	0	0	0	227 513	34 979	0
2008	0	87 420	167	19 656	79 004	0	379 287	34 979	441
2009	0	108 730	84	259 607	116 391	0	402 105	34 979	11 631
2010	0	114 382	0	385 646	95 499	0	321 676	34 979	26 078
2011	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-

Table 3.58 – Fuel consumption in Other Transformation Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biogas	Biodiesel
1990	307	169 380	0	0
1991	4 852	219 362	0	0
1992	221 240	238 688	0	0
1993	896 540	363 689	0	0
1994	503 827	292 321	0	0
1995	51 541	180 662	0	0
1996	88 126	262 445	0	0
1997	28 535	20 034	0	0
1998	32 781	31 781	0	0
1999	23 952	27 421	0	0
2000	2 621	17 846	0	0
2001	14 207	24 959	0	0
2002	3 594	8 169	0	0
2003	3 248	7 453	0	0
2004	3 022	9 790	0	0
2005	2 706	8 023	0	0
2006	1 050	3 766	0	51
2007	0	0	0	0
2008	0	19 656	0	441
2009	0	259 607	9 120	11 631
2010	0	385 646	26 347	26 078
2011	-	-	-	-
2012	-	-	-	-

An increase in fuel consumption is noticeable from 2008 to 2009. This is mainly due to gas oil and natural gas fuel consumption.

Figure 3.48 – Total Energy Consumption in Other Transformation Industry

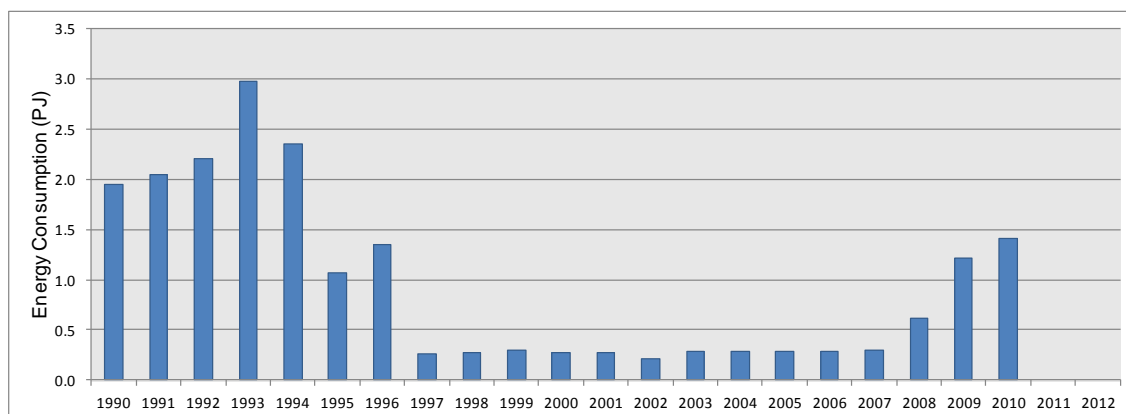
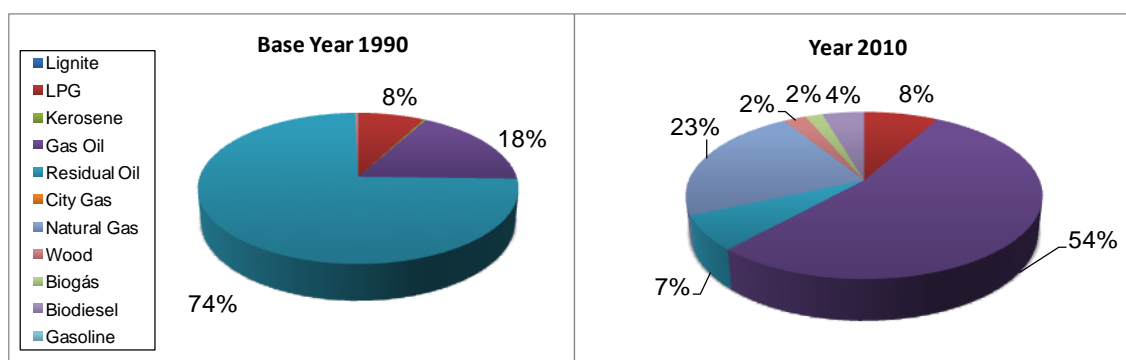


Figure 3.49 – Fuel consumption per fuel type in Other Transformation Industry in 1990 and 2010



3.3.2.2.1.2.15 Extractive Industry

Table 3.59 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Extractive Industry

Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
17.2	46.0	44.0	43.8	42.6	40.0

Natural Gas	Biodiesel
MJ/Nm3	MJ/kg
38.7	37.0

Table 3.60 – Fuel consumption in the Extractive Industry – Boilers and Furnaces (GJ)

Year	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	2 402	77 429	0	1 929	496 778	119 777	0	0
1991	2 608	78 386	0	14	537 249	269 792	0	0
1992	1 904	77 081	18	1 274	612 710	169 204	0	0
1993	1 184	86 266	24	605	640 432	87 648	0	0
1994	412	103 715	8	625	481 293	54 018	0	0
1995	0	106 523	0	625	497 405	53 492	0	0
1996	0	127 644	0	202	598 901	57 225	0	0
1997	0	188 025	0	553	940 789	134 366	0	0
1998	0	205 347	0	520	838 773	112 400	0	0
1999	0	197 600	6	213	844 300	87 417	10 497	0
2000	0	176 933	29 133	0	1 054 333	103 471	14 477	0
2001	0	215 503	0	4	1 005 478	150 538	432 229	0
2002	0	142 695	7 376	0	947 979	120 050	55 611	0
2003	0	105 275	4 850	0	1 014 418	89 687	53 914	0
2004	0	67 562	2 992	0	1 011 786	0	832 783	0
2005	0	72 128	2 932	0	971 618	435 410	277 500	0
2006	0	73 799	2 552	0	899 911	140 809	267 350	10 940
2007	0	120 188	711	2 050	923 163	353 180	271 070	22 134
2008	0	162 134	0	0	1 014 406	45 913	289 993	24 864
2009	0	134 603	0	0	958 486	33 468	329 820	43 761
2010	0	78 748	0	0	821 490	42 129	321 491	70 484
2011	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-

Table 3.61– Fuel consumption in the Extractive Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	16 538	466 146	0
1991	16 109	505 626	0
1992	10 626	547 043	0
1993	8 795	544 413	0
1994	6 541	462 454	0
1995	2 073	495 098	0
1996	3 183	596 232	0
1997	5 833	937 636	0
1998	20 260	835 859	0
1999	30 793	842 952	0
2000	21 042	756 662	0
2001	83 596	1 005 478	0
2002	39 463	901 089	0
2003	25 593	900 097	0
2004	58 526	898 758	0
2005	22 861	880 964	0
2006	20 576	827 986	10 940
2007	31 439	890 527	22 134
2008	17 594	1 013 652	24 864
2009	23 643	958 486	43 761
2010	341	821 490	70 484
2011	-	-	-
2012	-	-	-

Figure 3.50 – Total Energy Consumption in the Extractive Industry

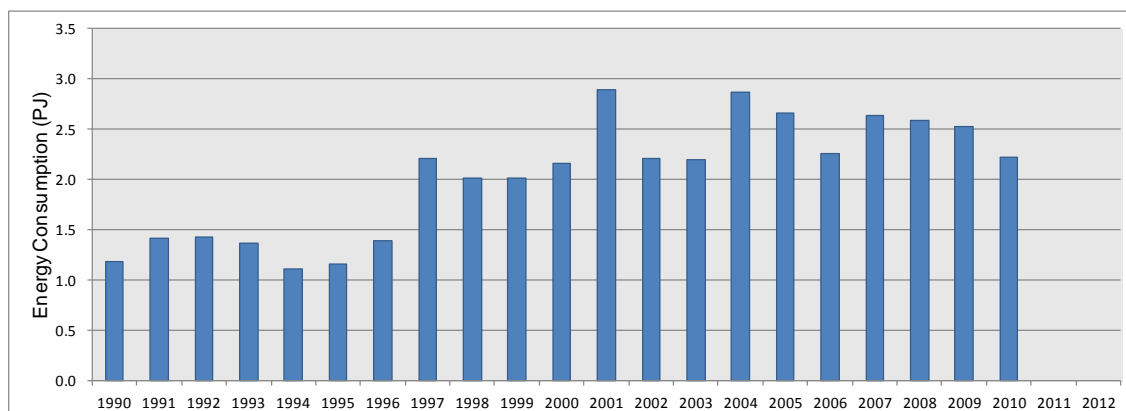
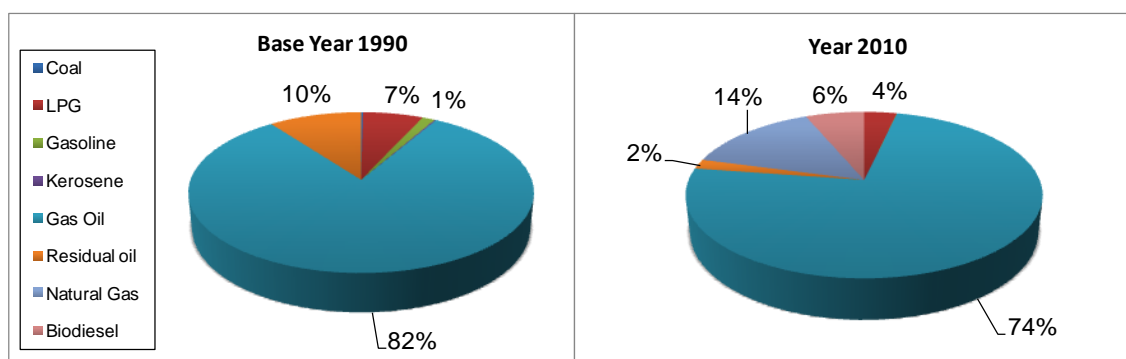


Figure 3.51– Fuel consumption per fuel type in the Extractive Industry in 1990 and 2010



3.3.2.2.1.2.16 Construction and Building Industry

Table 3.62 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Construction and Building Industry

LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3	MJ/kg
46.0	44.0	43.8	42.6	40.0	38.7	37.0

Table 3.63 – Fuel consumption in the Construction and Building Industry (GJ)

Year	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	226 695	27 676	6 859	5 864 312	668 507	0	0
1991	200 517	53 330	333	6 641 723	881 020	0	0
1992	257 260	165 177	2 108	6 358 531	872 358	0	0
1993	449 705	213 777	2 774	6 482 578	1 768 570	0	0
1994	677 512	357 378	1 180	7 037 664	1 407 088	0	0
1995	887 678	447 712	640	7 580 456	1 756 467	0	0
1996	1 037 883	670 960	178	7 799 976	1 348 200	0	0
1997	628 759	373 819	1 797	8 120 774	1 884 264	0	0
1998	558 547	349 408	11 050	8 117 508	1 999 855	612	0
1999	562 634	296 398	228	7 984 363	1 423 115	2 725	0
2000	545 639	72 532	130	7 548 443	1 467 006	7 654	0
2001	820 530	389 328	390	9 370 392	1 630 972	302 795	0
2002	532 463	60 560	280	9 309 392	1 848 438	602 459	0
2003	481 822	56 703	104	8 631 057	1 289 941	870 508	0
2004	482 645	54 850	93	10 025	1 565 488	856 864	0
2005	412 087	67 399	184	9 135 498	1 717 788	847 286	0
2006	396 618	67 850	1 465	7 107 254	1 301 958	768 432	95 913
2007	353 915	59 832	84	6 445 370	1 085 000	851 961	176 218
2008	502 051	90 262	167	5 856 674	1 133 792	614 028	151 884
2009	489 106	95 525	293	5 223 352	1 253 471	796 619	232 360
2010	491 834	117 073	126	5 655 695	1 124 990	1 058 509	479 803
2011	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-

Figure 3.52 – Total Energy Consumption in the Construction and Building Industry

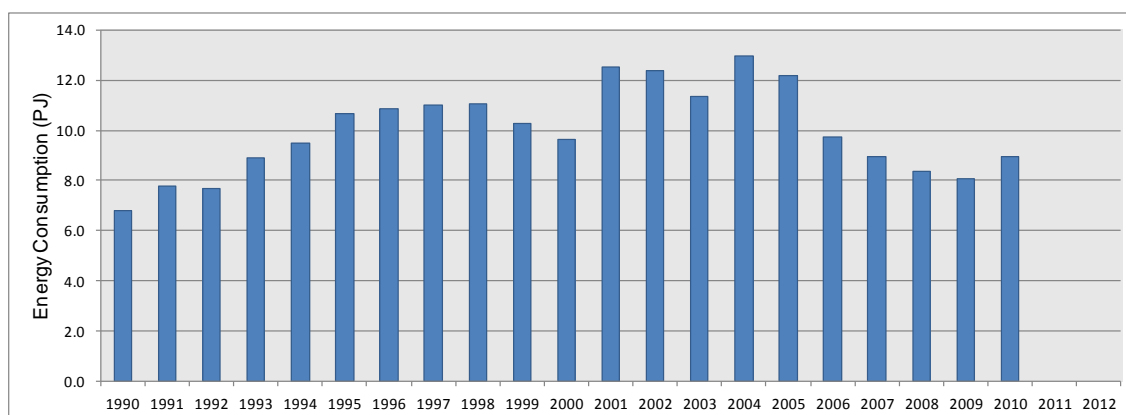
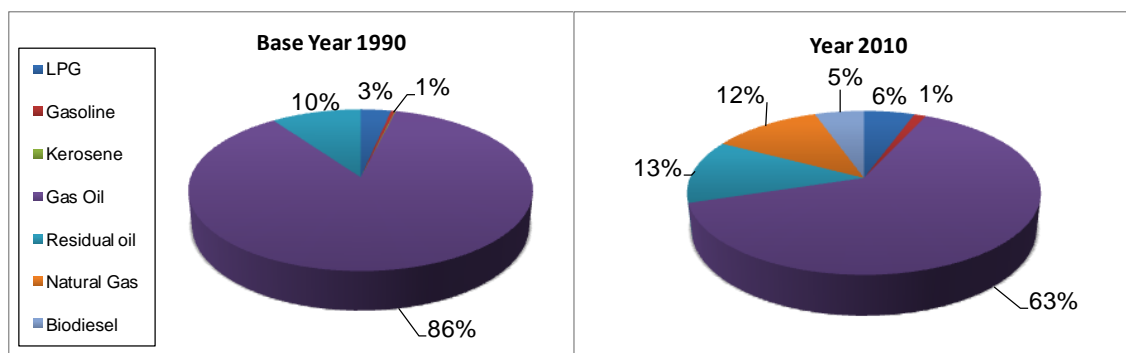


Figure 3.53 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2010

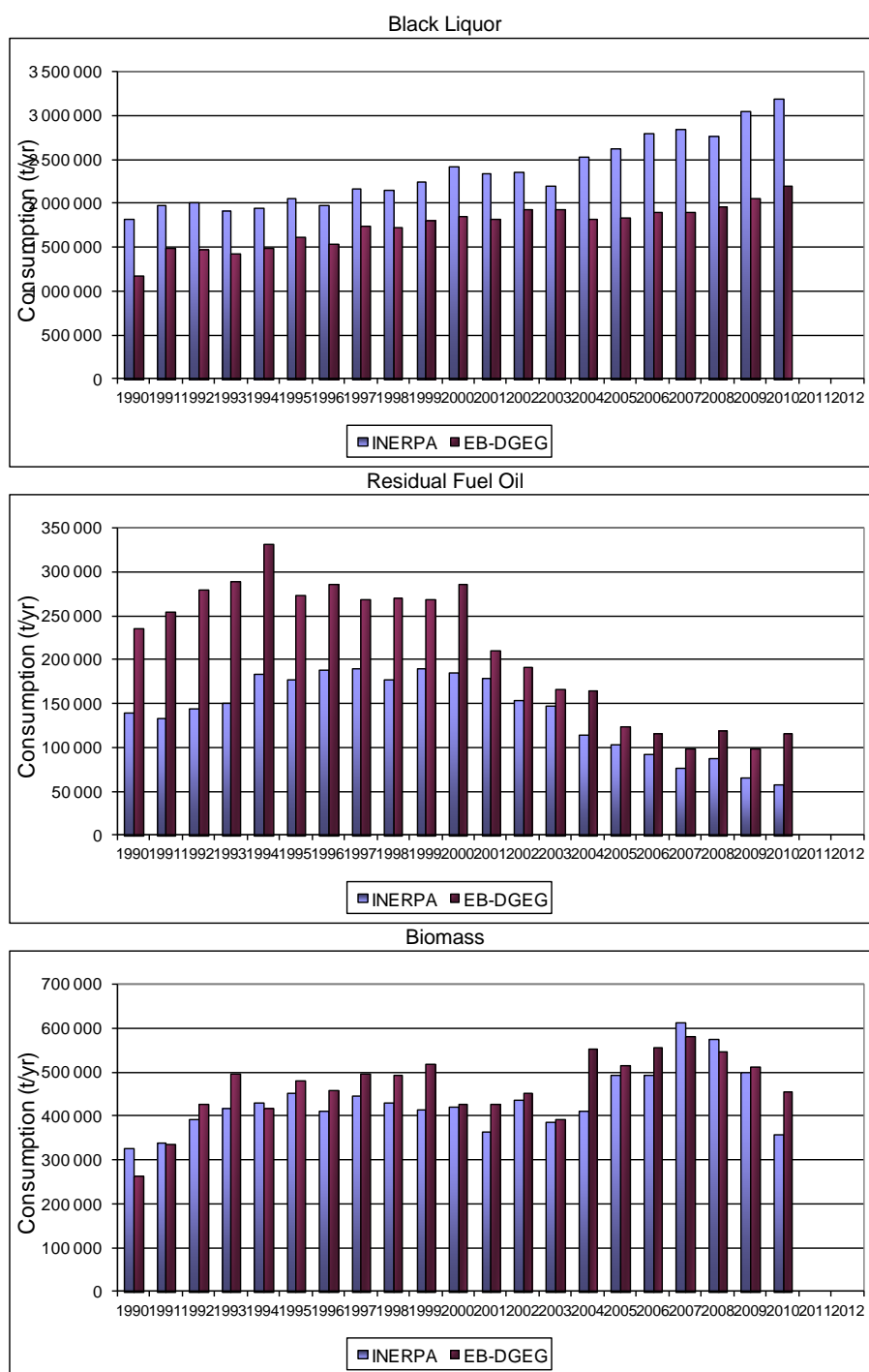


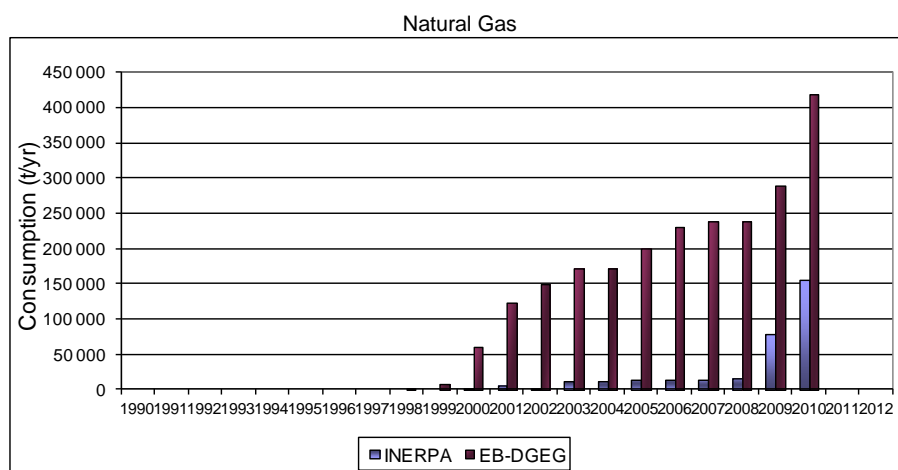
3.3.2.2.1.3 Comparison of LPS data vs. Energy Balance

Total consumption in LPS per sector was compared with the correspondent value in the energy balance for the most important fuels, in order to verify the applicability of the methodology in use, which mixes a top-down approach (EB) with a bottom-up approach (LPS data). The following figures present the comparison done for sectors: (1) Paper Pulp; (2) Chemical Manufacturing; (3) Cement Industry and (4) Iron and Steel Plants.

Before hand, it must be realized that to conclude for consistency between both distinct datasets, the comparison should result in higher or equal consumption in the EB than in the inventory, because apart from specific fuels (black liquor in the paper and pulp industry, coke oven gas and blast furnace gas in the iron industry, and coal, coke and tires in the cement industry) the universe considered by the Energy Balance covers more units than the set of LPS (E.g. the paper and paper pulp sector also includes consumption in the manufacturing of paper, for which there are several small units).

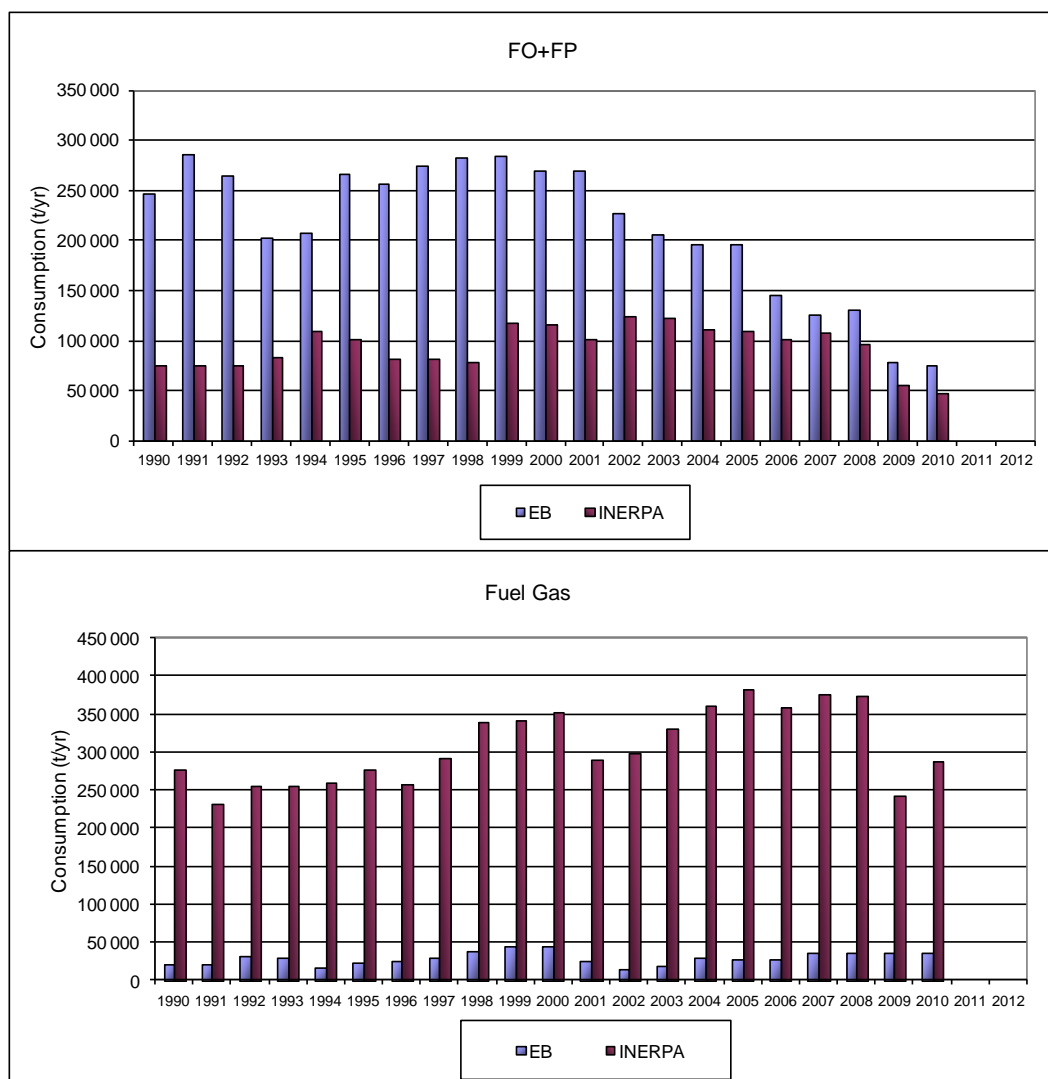
Figure 3.54 – Comparison of total LPS consumption in Paper Pulp units with the reported consumption in the EB for the sector “Paper pulp and paper production”





The comparison made for the paper and pulp industry shows that differences occur, but are not substantial for the major fuels: black liquor and biomass. Part of the differences were analysed before (DGEG,2003) and could be explained by the use of different LHV in the Energy Balance, which occurs commonly for biomass fuels, given the variability in water content. It's important to point out that in 2007 and 2008 the total Biomass considered in INERPA is slight superior to that reported in the EB. Careful estimations were made not double count the emissions.

Figure 3.55 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector “Chemical and Plastics”²³



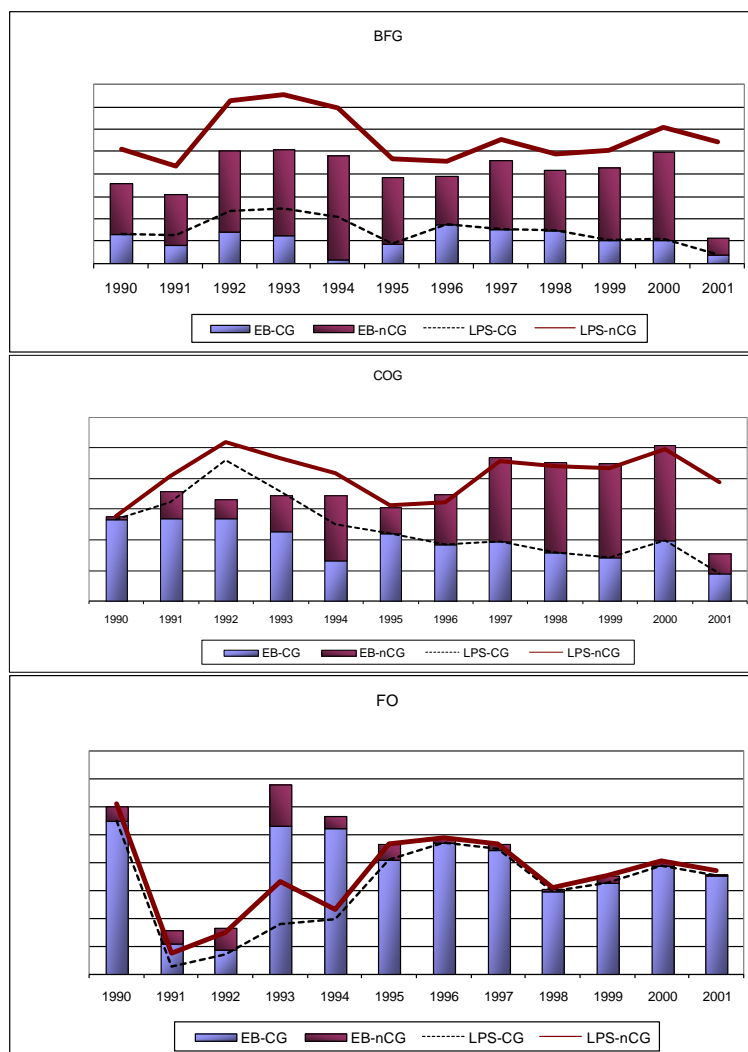
For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil²⁴ is about 50 per cent until 2005. The two values show a tendency to converge in the later years. Consumption of fuel gas as reported from the LPS data shows much higher values than in the EB. After consultation with DGEG it was realized that the EB does not covers consumption of fuel gas that is not traded or used in co-generation.

The match for the iron and steel industry show a good consistency, except for intermediate years, and for the slightly higher consumption of Blast Furnace Gas. This last difference may result from the use of different LHV values.

²³ Units in the vertical axis are not indicated due to confidentiality issues.

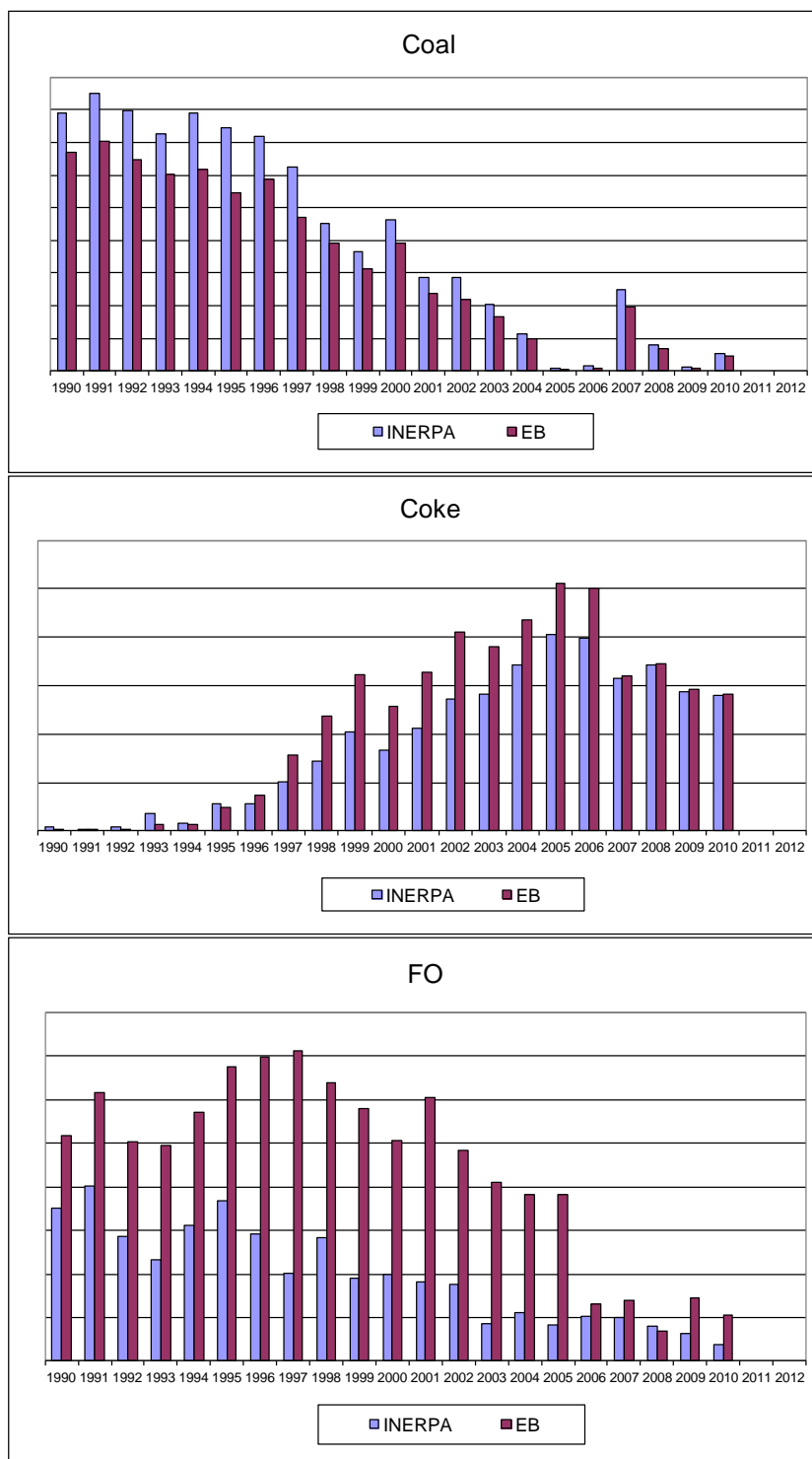
²⁴ This category includes residual fuel oil, a traded fuel, and fuel pyrolysis, a non-traded by product fuel, used inside the industrial unit that produces it.

Figure 3.56 – Comparison of total LPS consumption in the only Integrated Iron and Steel Plant with the reported consumption in the EB for the sector “Iron and Steel”²⁵ (1990-2001)



²⁵ Units in the vertical axis are not indicated due to confidentiality issues.

Figure 3.57 – Comparison of total LPS consumption in Cement Plant with the reported consumption in the EB for the sector “Cement and Lime” (Due to confidentiality issue y axis values are not shown)



Concerning the cement industry, an acceptable coherence exists between both information sources, except for fuel oil consumption which can be explained by the inclusion of lime production in this energy balance category.

In conclusion, the analysis indicates that albeit certain differences, there is an acceptable agreement between both data sets. Nevertheless, efforts should be maintained in order for the streamlining of data between the inventory and the energy balance, and for the inclusion of all fuels, either traded or not, in the energy balance.

3.3.2.2.2 Production Data

The production activity rates that were used to estimate of air emissions (production approach) are present in next tables. Although for some activities, such as cement production, emissions were estimated at plant level with plant specific emission factors this information was considered confidential and may not be published in NIR.

Total production of paper pulp is reported in Table 3.64. Production data for Kraft paper pulp was obtained from the following data sources:

- LCP Directive – 1990 to 2000;
- CELPA – 2003 to 2009 (Kraft paper pulp);
- INE industrial production data – 2003 to 2009 (Acid sulphite paper pulp);
- EU-ETS – 2010 onwards.

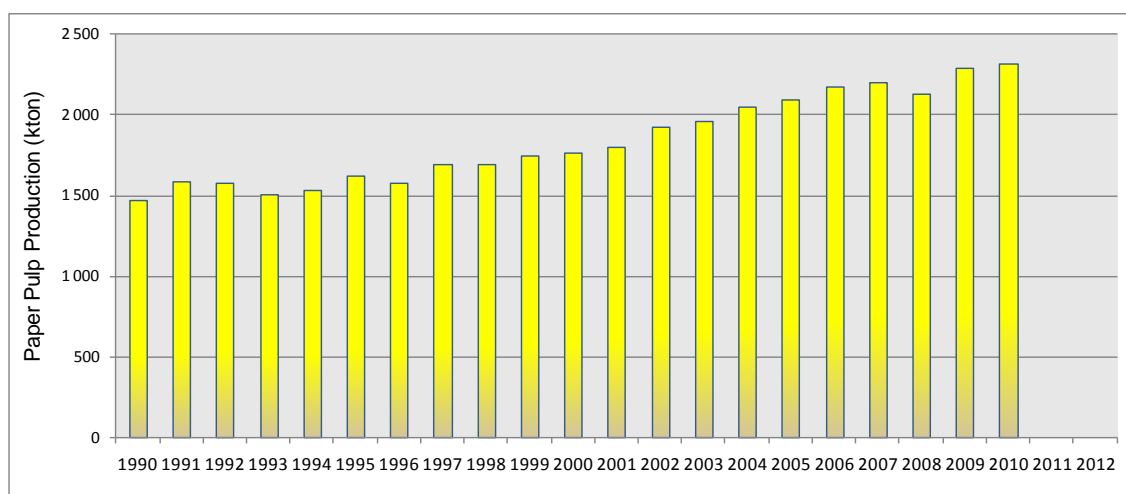
Even though different sources were used the ultimate data source was the same: the industrial plants.

Table 3.64 – Total Paper Pulp Production (Kraft and sulphide paper pulp)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Pulp Production (kton)	1 471	1 591	1 577	1 511	1 540	1 626	1 577	1 694	1 698	1 752	1 772	1 805

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pulp Production (kton)	1 929	1 960	2 054	2 098	2 174	2 204	2 135	2 297	2 316	-	-

Figure 3.58 – Total paper pulp production: Kraft and sulphide paper pulp



Clinker production values cannot be shown in this reported because of confidentiality issues.

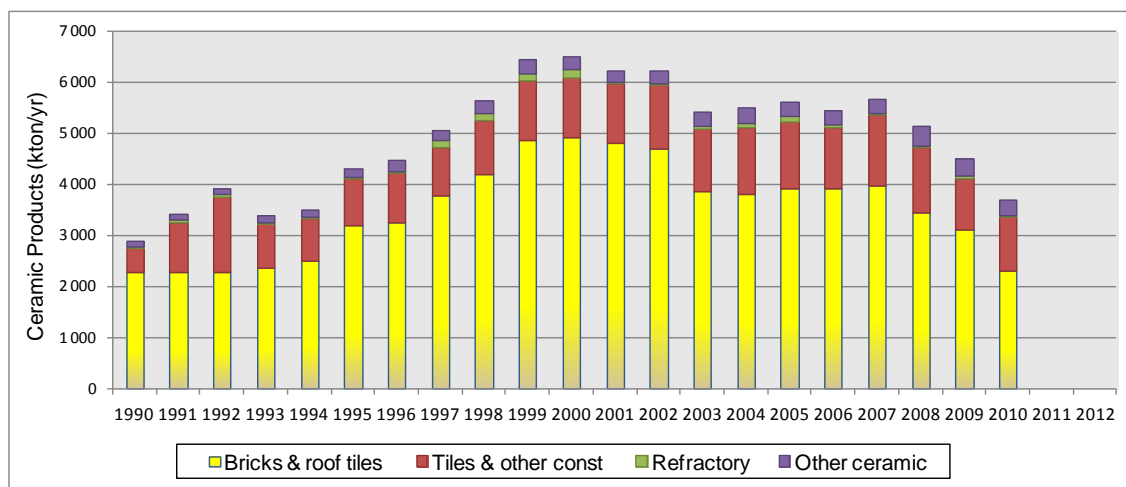
Data on annual manufacturing of ceramic products is available from 1990 to 2010 from INE statistical database. The time series for total production is shown in Table 3.65 and Figure 3.59, according to type of ceramic.

Table 3.65 – Ceramic Production according to type of ceramic (kton)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Bricks & roof tiles	2 290	2 290	2 290	2 367	2 513	3 200	3 261	3 786	4 203	4 874	4 932	4 834
Tiles & other const	478	980	1 483	856	822	921	982	958	1 077	1 170	1 170	1 155
Refractory	31	33	34	28	26	27	32	125	134	153	167	32
Other ceramic	104	115	127	146	154	185	200	212	236	255	260	234

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bricks & roof tiles	4 697	3 873	3 831	3 923	3 917	3 993	3 453	3 122	2 321	-	-
Tiles & other const	1 253	1 221	1 289	1 327	1 224	1 377	1 276	1 013	1 043	-	-
Refractory	30	49	103	100	39	40	35	32	25	-	-
Other ceramic	258	282	290	278	277	270	399	339	310	-	-

Figure 3.59 – Ceramic Production according to type of ceramic



The Production values for container glass, lead crystal glass and other glass are presented in Figure 3.60 and in Table 3.66, and they were established from the INE statistical databases and information received from Technology Centre for Ceramics and Glass (CTCV). More detailed discussion of the origins of data sources should be consulted in chapter 4.2.A.5. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 3.60 - Glass production by glass type (excluding flat glass production)

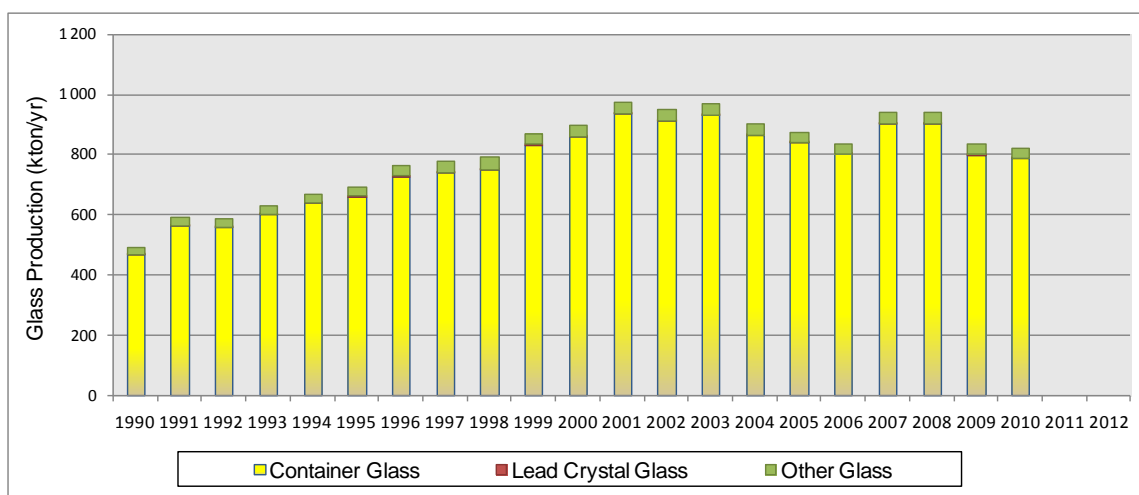


Table 3.66- Glass production by glass type (kton/yr) excluding flat glass production

Type of Glass	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Container Glass	470	564	560	602	640	663	730	741	751	835	864	936
Lead Crystal Glass	0.15	0.23	0.23	0.25	0.27	0.27	0.29	0.33	0.35	0.31	0.32	0.33
Other Glass	26	28	28	30	32	33	35	39	42	38	38	40

Type of Glass	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Container Glass	913	934	866	842	803	904	906	802	789	-	-
Lead Crystal Glass	0.32	0.33	0.30	0.29	0.28	0.32	0.32	0.28	0.28	-	-
Other Glass	39	39	37	36	34	38	38	34	33	-	-

Sinter and lime production in iron and steel integrated plan are reported in chapter 4.2.C.1 – Industrial Processes: Iron and Steel Production.

3.3.2.3 *Emission Factors*

The emissions factors that were used are dependent, in the majority of cases, on the fuels characteristics and do not vary with the typology of equipments, except in what concerns the division between fuel use in boilers/furnaces and static engines. It is still not possible to differentiate emission factors for boilers and process furnaces. These emission factors are presented in a separate table where relevant.

In the great majority of cases emission factors were taken from international sources:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- EMEP/EEA Air Pollutant Emission Inventory Guidebook – 2009 (EEA, 2009);
- 1996 IPCC Guidelines (IPCC,1997);
- US EPA AP-42 and EIIP (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

The set of following tables present the emission factors that were used as default national emission factors in all cases where no specific emission factors may be used, either because there are no specific methodologies and emission factors available in the bibliography or either because country specific emission factors were not developed from national studies and monitoring data. They are presented in the subsequent tables.

The CO₂ emission factors presented in the next tables correspond to values prior multiplication with the corresponding oxidation factor, unless specified otherwise.

Table 3.67 – Default emissions factors of Greenhouse gases for combustion equipments in Manufacturing Industry

Equipment	Fuel		Code	CO ₂ ⁽ⁱ⁾ (kg/GJ)	Oxidation factor ⁽ⁱ⁾ (ratio)	% C fossil	CH ₄ ⁽ⁱⁱ⁾ (g/GJ)	N ₂ O ⁽ⁱ⁾ (g/GJ)
Boilers	Steam Coal	S	102	96.1	0.980	100	2.4	⁽ⁱⁱ⁾ 0.7
	Brown Coal/Lignite	S	105	101.2	0.980	100	2.4	⁽ⁱⁱ⁾ 0.7
	Coke from Coal	S	107	⁽ⁱⁱ⁾ 102.0	0.980	100	2.4	⁽ⁱⁱ⁾ 0.7
	LPG	L	303	63.1	0.995	100	1.4	1.4
	City Gas	G	308	⁽ⁱⁱ⁾ 60.0	0.995	100	2.4	0.7
	Coke Oven Gas	S	304	⁽ⁱⁱ⁾ 46.5	0.995	100	2.4	0.7
	Blast Furnace Gas	S	305	⁽ⁱⁱ⁾ 102.5	0.995	100	2.4	0.7
	Fuel Gas, Hydrogen	G	399	63.1	0.995	100	1.4	1.4
	Biomass Wood	B	111	109.6	1.000	0	⁽ⁱ⁾ 15.0	⁽ⁱⁱ⁾ 4.3
	Kerosene	L	206	71.9	0.990	100	0.1	0.6
	Diesel Oil	L	204	74.1	0.990	100	0.1	0.6
	Residual Oil	L	203	77.4	0.990	100	2.9	0.6
	Natural Gas	G	301	56.1	0.995	100	1.4	1.4
	Biodiesel	B	223	74.1	1.000	0	0.1	0.6
Static Engines	Gasoline	L	208	69.3	0.990	100	9.9	0.6
	Gas Oil	L	204	74.1	0.990	100	9.9	0.6
	Biogas	B	309	⁽ⁱⁱ⁾ 52.0	1.000	0	1.4	1.4
	Biodiesel	B	223	74.1	1.000	0	9.9	0.6

(i) IPCC (1997); (ii) EEA (2002); (iii) AP-42

Table 3.68 –Emission factors of Greenhouse gases in the extractive industry

Equipment	Fuel		NAPFUE	CO ₂ (kg/GJ)	Oxidation factor (ratio)	% C fossil	CH ₄ (g/GJ)	N ₂ O (g/GJ)
Boilers	LPG	L	303	63.1	0.995	100	1.5	1.4
	Gasoline	L	208	68.6	0.990	100	0.1	0.6
	Kerosene	L	206	71.9	0.990	100	0.6	0.6
	Diesel Oil	L	204	74.1	0.990	100	0.6	0.6
	Residual Oil	L	203	76.6	0.990	100	1.4	0.6
	Natural Gas	G	301	56.1	0.995	100	1.4	1.4
	Lignite	S	105	101.2	0.980	100	2.4	0.7
Static Engines	Gasoline	L	208	69.3	0.990	100	60	0.6
	Gas Oil	L	204	74.1	0.990	100	60	0.6

Table 3.69 – Emission factors for Greenhouse gases in the building and construction industry

Fuel		NAPFUE	LHV	CO ₂			CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.17	77.4	0.990	100	1.6	0.6
Gas Oil	L	204	43.31	74.1	0.990	100	5.0	0.6
Kerosene	L	206	43.72	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.77	69.3	0.990	100	9.9	0.6
LPG	L	303	47.28	63.1	0.995	100	1.5	1.4
Natural Gas	G	301	45.97	56.1	0.995	100	9.9	1.4

Other specific emission factors were used for some industrial units, several of them obtained from direct measurements in LPS or as a result from bibliographic references specific of the industrial sector. Some of the emission factors are used in the process approach and are applied to production data instead of fuel consumption data. These emission factors are listed in the tables below, arranged by sector and indicating if they only apply to LPS.

Table 3.70 – Emission factors for use in LPS units in the Iron and steel Industry: Greenhouse Gases from combustion

Equipment	Fuel		NAPFUE	CO ₂			CH ₄ (g/GJ)	N ₂ O (g/GJ)
				kg/GJ	Oxidation Factor (ratio)	% C fossil		
Coquerie	Coke oven gas	S	304	41.0	0.995	100	2.5	1.4
Sintering	Coke oven gas	S	304	41.0	0.995	100	2.5	1.4
Blast Furnace Cowpers	Coke oven gas	S	304	41.0	0.995	100	2.5	1.4
	Blast furnace gas	S	305	297.7	0.995	100	2.5	1.4
Rolling mills	Residual oil	L	203	77.4	0.990	100	3.0	0.6
	Coke oven gas	S	304	41.0	0.995	100	2.5	1.4
Thermo-Electric Power plant	Coke oven gas	S	304	41.0	0.995	100	2.5	1.4
	Blast furnace gas	S	305	297.7	0.995	100	2.5	1.4
	Residual oil	L	203	77.4	0.990	100	3.0	0.6
	Tar	L	299	80.7	0.990	100	3.0	0.6
Heat power plant	LPG	L	303	63.1	0.995	100	4.0	1.4
	Tar	L	299	80.7	0.990	100	3.0	0.6
	Waste oils	O	115	77.4	0.990	100	3.0	0.6
Lime kiln	Residual Oil	L	203	77.4	0.990	100	3.0	0

Table 3.71 – Emission factors for use in LPS units in the Chemical Industry: Greenhouse Gases from combustion

Equipment	Fuel		NAPFUE	CO ₂ (kg/GJ)	Oxidation Factor (ratio)	% C fossil	CH ₄ (g/GJ)	N ₂ O (g/GJ)
Boilers	Residual Fuel Oil	L	203	77.4	0.990	100	3	0.6
	Pyrolysis Fuel Oil	L	203	77.4	0.990	100	3	0.6
	Fuel Gas	L	307	50.1	0.995	100	2.5	1.4
Furnaces	Fuel Gas	L	307	50.1	0.995	100	2.5	1.4
	Propane	L	303	63.1	0.995	100	2.5	1.4
Static Engines	Residual Fuel Oil	L	203	77.4	0.990	100	60	0.6
	Diesel Oil	L	204	74.1	0.990	100	60	0.6
Flares	Flare Gas	L	307	59.2-65.6	0.995	100	-	-

In the 2012 inventory, for the paper and pulp industrial sector, efforts were made to improve the emission estimation by reviewing and update emission factors when possible. To this end new EF data sources were used (EEA, 2009) as well as an in depth revision of the plant specific emission factors for non-direct GHG. The EF used for this industrial sector (LPS estimation only) can be found in the next tables.

Table 3.72 – Emission factors used in LPS units in the Paper Pulp Industry: Greenhouse Gases from combustion – Energy Approach

Equipment	Fuel	NAPFUE		CO ₂ ⁽ⁱ⁾		CH ₄	N ₂ O
				EF (kg/GJ)	%C fossil	EF (g/GJ)	EF (g/GJ)
Auxiliary Boilers	Residual Oil	L	203	76.6	0	3.0	0.6
	Natural Gas	G	301	55.8	0	1.4	1.4
Biomass Boilers	Wood Waste	B	111	109.6	100	30.0	4.3
	Residual Oil	L	203	76.6	0	3.0	0.6
	Natural Gas	G	301	55.8	0	1.4	1.4
	LPG	L	303	62.8	0	1.4	1.4
Recovery Boilers	Residual Oil	L	203	76.6	0	3.0	0.6
	Natural Gas	G	301	55.8	0	-	1.4
	Gas Oil	L	204	73.3	0	-	0.6
	Bisulfite Liquor	B	215	73.3	100	30.0	0.6
	Black Liquor	B	215	73.3	100	-	0.6
	Methanol	B	111	62.8	100	-	1.4
Flare	LPG	L	303	62.8	0	1.4	1.4
Lime Kiln	Gasified Biomass	B	111	109.6	100	-	4.3
	Residual Oil	L	203	76.6	0	-	0.6
	Natural Gas	G	301	55.8	0	-	1.4
	Gas Oil	L	204	73.3	0	-	0.6
	NCG	B	111	55.8	100	-	1.4
	Tall-oil	B	111	73.3	100	-	0.6
Static Engine	Gas Oil	L	204	73.3	0	9.9	0.6
Gas Turbine	Natural Gas	G	301	55.8	0	1.4	1.4

(i) The CO₂ emission factors presented in this table include the corresponding oxidation factor.
NCG- Non-condensable gases

Table 3.73 – Emission factors used in LPS units in the Paper Pulp Industry: Greenhouse Gases from combustion – Production Approach

Equipment	CH ₄ ⁽ⁱ⁾
	EF (kg/ton pulp)
Recovery Boilers	0.23
Lime Kiln	0.029

(i)Source EEA, 2002.

For the cement source, sector emissions were estimated using either activity data as energy consumption (energy approach) or either cement produced (production approach), although both represent similar emissions in cement kiln. Emission factors will not be presented in this report because of confidentiality issues (please see Activity Data chapter for more explanations). Most emission factors result from plant specific emission factors developed from monitoring at each installation, as reported to EPER exercise.

Table 3.74 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Greenhouse gases

Ceramic	CO ₂ ^(b) (kg/ton)	CH ₄ ^(a) (kg/ton)
Bricks and roof tiles	0.14	0.029
Tiles & other construction materials	18.57	0.022
Refractory	-	0.029
Other ceramic	-	0.022

Source: (a) 10 per cent of VOC emissions; (b) EU-ETS

Table 3.75 – Emission Factors for glass production using the Production Approach: SO_x and Indirect Precursor gases (kg/ton glass)

Type of Glass	SO _x	NO _x	NMVOC	CO
Flat Glass	1.5	4	0.1	0.1
Container Glass	1.7	3.1	4.5	0.1
Lead Crystal Glass	2.8	4.3	4.7	0.1
Other Glass	2.8	4.3	4.7	0.1

Source: USEPA (1986)

Table 3.76 – Emission Factors for glass production using the Production Approach: Greenhouse Gases

Type of Glass	CO ₂ kg/ton	CH ₄ kg/ton
Flat Glass	126	0.01
Container Glass	130	0.45
Lead Crystal Glass	239	0.47
Other Glass	239	0.47

Source: CH₄ USEPA (1986); CO₂ EUTS data

Emission factors for sinter and lime production in iron and steel integrated plan are reported in chapter 4.2.C.1 – Industrial Processes: Iron and Steel Production.

3.3.2.4 *Uncertainty Assessment*

Different uncertainty values were attributed to different types of sub-sources considering that different sources of information have diverse error and also assuming that industries for which energy consumption is a more important factor (Energy intensive industries) tend to have and report more accurate data. Consequently, in concordance to what is proposed in IPCC (2000) but always assuming a conservative posture, the following rules were used to establish the uncertainty associated with activity data:

- when fuel consumption was obtained directly from a Large Point Source (LPS) the uncertainty of activity data was set at 3 per cent for energy intensive industrial sectors (iron and steel, cement, paper pulp, glass and ceramics) and 5 per cent for all other sources;
- if fuel consumption, other than biomass, results from statistical information gathered from the National Energy balances then uncertainty is 5 per cent for energy intensive sectors and 10 per cent for all other sectors;
- the uncertainty in biomass consumption is always higher, at least because the moisture content is always doubtful, and the uncertainty was set in all area sources as 60 per cent.

The uncertainty of CO₂ emission factors is 5 per cent for all situations, which is consistent with GPG recommendations. Finally the uncertainty for methane is 150 per cent and an order of magnitude for N₂O.

3.3.2.5 *Category-specific QA/QC and verification*

Similar to 1.A.1.a the majority of the QA/QC procedures were implemented to check consistency between years for the fuel consumption time series of all industrial sectors. Since LHV for several industries show variability between years, a general consistency check was also made.

For industrial sectors where fuel consumption data for individualized plants was available: Paper Pulp, Chemical Manufacturing, Cement Industry and Iron and Steel Plants, a comparison between plant specific data and energy balance fuel consumption was made (see the appropriate chapter for more information).

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Several differences were identified between data sources for this sector, which may imply problems in the fuel consumption classification for IEA values. Also DGEG reported that there were compilation errors in the information sent to IEA, which may explain the differences found.

3.3.2.6 *Recalculations*

There were several recalculations to this source category:

- In depth revision of the Pulp and Paper industrial sector resulted in revised fuel consumption and pulp production data, and more extensive use of plant specific emissions factors. This revision affected all years of the 1990-2009 time series (mostly the latest 7 years);

- For the Cement industrial sector several small revisions/updates were made to the emission estimation (2006-2009). These updates resulted from data (fuel consumption and LHV) received from the EU-ETS for several secondary fuels;
- Updated fuel consumption values for the Chemical industrial sector were obtained from LCP directive (2004-2009);
- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small. This revision had more impact in emission estimated from energy balance fuel consumption data;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates;
- Corrections made to the energy balance compilation procedure which resulted in an increase in other fuel (industrial waste) consumption (2005, 2006-2009);
- Fuel consumption for gas oil used for heating was revised by DGEG for some industrial sectors (2006-2009).

3.3.2.7 *Further Improvements*

The most important improvement in this sector is the continuing streamline with EU-ETS and DGEG's energy balance, mainly for sectors like Steel production and Chemical industry. Also efforts should be made to expand the estimation and use of plant specific emission factors with data from Self-Control Program (*Programa Autocontrolo*).

3.3.3 Transport (CRF 1.A.3.)

3.3.3.1 Civil Aviation (CRF 1.A.3.a)

3.3.3.1.1 Overview

Civil aviation under business-as-usual is likely to generate a global sharp increase in future greenhouse gas emissions.

In 2010 emissions from civil aviation in Portugal amounted to 3,026 Gg CO₂e., from which 401 Gg CO₂e are from domestic flights and 2,625 Gg CO₂e are from international flights.

Emissions from aviation come from the combustion of jet fuel and aviation gasoline. Emissions from combustion in aircraft mobile activities comprehend all air emissions associated with fuel combustion in airplanes, either realized in passenger or freight planes, and either realized during flight or in land activities: idle and taxi. Aircraft operations are divided into

Landing/Take-off cycle and;

Cruise.

Emissions from military aircraft are included in sector 1.A.5.b Other Mobile Sources.

The method to estimate emissions from jet fuel consumption is a Tier 2b method according with IPCC Good Practice Guidance. This method uses data from individual flights with information on the origin and destination, aircraft type, engines type, and date of the flight. This method provides a good accurate separation between domestic and international flights.

The method to estimate emissions from aviation gasoline is a Tier 1 method which is based primarily in energy statistics.

The choice of methods allows the harmonisation between inventories covering greenhouse gas emissions and inventories covering other air pollutants.

For the elaboration of the greenhouse gases emissions inventory which is reported to the EU²⁶ and to the UNFCCC, emissions from flights to and from the autonomous regions of Azores and Madeira islands are included in national totals.

Data on air traffic from 2009 and 2010 was made available late 2011. Therefore emissions from 2009 were recalculated. Recalculation were also made for all time series since updated LHV were available from the energy authority.

Emissions of domestic and international flights must be reported separately to UNFCCC. In order to strictly follow UNFCCC good practice the separation is done according to the following table.

²⁶ Decision 2004/280/CE

Table 3.77 – IPCC 2006 source categories

Source Category	Coverage
1 A 3 a i International Aviation (International Bunkers)	Emissions from flights that depart in one country and arrive in a different country. Include take-offs and landings for these flight stages.
1 A 3 a ii Domestic Aviation	Emissions from civil domestic passenger and freight traffic that departs and arrives in the same country (commercial, private, agriculture, ...), including take-offs and landings for these flight stages.
1 A 5 (aviation component)	Emissions from military aviation.

3.3.3.1.2 Methodology

The methodology that is used in the inventory is coherent with good practices from IPCC and is equivalent to the Tier 2b for jet fuel and Tier 1 for aviation gasoline. Emissions are calculated separately for:

- Landing and Take-off emissions (LTO). Emissions from activities realized near airport in the ground and on flight under an altitude of 3000 feet (914 m): idle, taxi-in, taxi-out, take-off, climbing and descending;
- Cruise emissions. All emissions realized above 3000 feet, including ascend and descend between cruise altitude and 3000 feet
- Fuel type: jet fuel and aviation gasoline. Jet fuel is used mostly in large commercial aircraft. Aviation gasoline is used in piston engine aircrafts;
- Origin and destination of the flight;
- Movement type: arrival and departure
- Aircraft type.

3.3.3.1.2.1 Landing/Take-off

The general approach to estimate emissions during LTO is:

$$\begin{aligned} \text{Emission}_{\text{LTO}(p,d,a,s,y)} &= \text{Emission}_{\text{Arrival}(p,d,a,s,y)} + \text{Emission}_{\text{Departure}(p,d,a,s,y)} \\ \text{Emission}_{\text{Arrival}(p,d,a,s,y)} &= N_{\text{Arrival}(d,a,s,y)} \times EF_{\text{Arrival}(p,s)} \times 10^{-3} \\ \text{Emission}_{\text{Departure}(p,d,a,s,y)} &= N_{\text{Departure}(d,a,s,y)} \times EF_{\text{Departure}(p,s)} \times 10^{-3} \end{aligned}$$

where

$\text{Emission}_{\text{LTO}}(p,d,a,s,y)$ – Emissions of pollutant p from origin/destiny d in airport a performed by aircraft s during year y (ton/yr);

$\text{Emission}_{\text{Arrival}}(p,d,a,s,y)$, $\text{Emission}_{\text{Departure}}(p,d,a,s,y)$ – Arrival and departure emissions of pollutant p from, respectively, origin and destiny d in airport a performed by aircraft s during year y (ton/yr);

N_{arrival} , $N_{\text{departure}}$ – Number of arrival and departure movements performed in year y , by aircraft s in airport s from origin/destiny d .

EF_{Arrival(p,s)} – Sum of approach and taxi-in emission factor for pollutant p and aircraft s (kg/movement);

EF_{Departure(p,s)} – Sum of taxi-out, take-off and climb emission factor for pollutant p and aircraft s (kg/movement);

p – pollutant;

d – origin/destination;

a – airport;

s – aircraft;

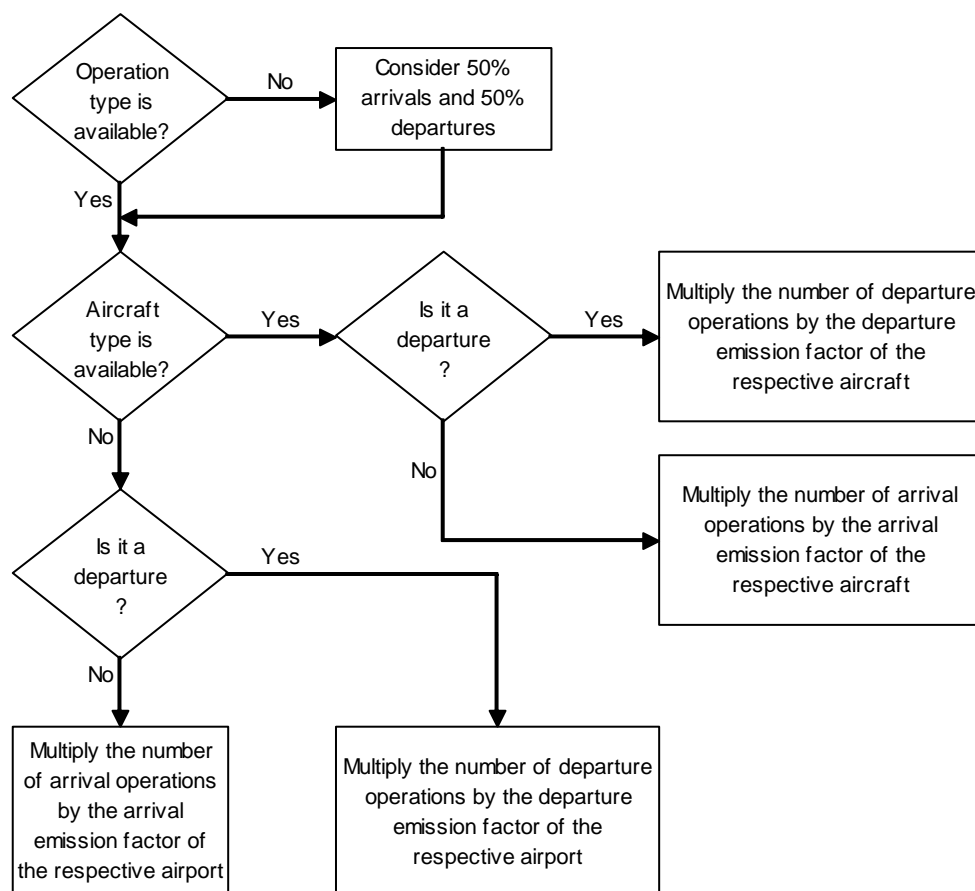
y – year.

However the aircraft type is not always available. For these cases the approach is based on an airport specific emission factor as follows:

$$\begin{aligned}
 \text{Emission}_{\text{LTO}(p,d,a,y)} &= \text{Emission}_{\text{Arrival}(p,d,s,y)} + \text{Emission}_{\text{Departure}(p,d,a,y)} \\
 \text{Emission}_{\text{Arrival}(p,d,a,y)} &= N_{\text{Arrival}(p,a,y)} \times \text{EF}_{\text{Arrival}(p,a)} \times 10^{-3} \\
 \text{Emission}_{\text{Departure}(p,d,a,y)} &= N_{\text{Departure}(p,a,y)} \times \text{EF}_{\text{Departure}(p,a)} \times 10^{-3}
 \end{aligned}$$

Figure 3.61 outlines the process whereby LTO emissions are estimated.

Figure 3.61 – Decision tree for LTO emission calculation



3.3.3.1.2.2 Cruise

Domestic cruise emissions are estimated based on aircraft movement data. The approach relies on a origin and destination matrix. The distances between airports are calculated from an airport coordinates database (Partow, 2003) applied to a great circle distance algorithm (GCD) assuming the Earth as a perfect sphere. Emission factors are given for each aircraft type and for a specific flight distance. International cruise emissions are estimated from fuel consumption. The international fuel consumption is estimated by subtracting the LTO and the domestic cruise fuel from the total fuel sales.

$$\text{Emission}_{\text{cruise}(p,d,a,s,y)} = N_{\text{LTO}(d,a,s,y)} \times EF_{\text{cruise}(p,d,s,t,y)} \times 10^{-3}$$

where

$\text{Emission}_{\text{cruise}(p,d,a,s,y)}$ – Domestic cruise emissions of pollutant p resulting from flight with origin/destiny d in airport a performed by aircraft s during year y (ton/yr);

$N_{\text{LTO}(d,a,s,y)}$ – number domestic LTO from origin/destiny d in airport a performed by aircraft type s during year y ;

$EF_{\text{cruise}(p,d,a,s,t,y)}$ – Emission factor for pollutant p specific for flight with origin/destination d taking time t performed by aircraft type s in year y (kg/LTO).

In national airports the same national flight is registered in origin airport as a departure and in destiny airport as an arrival therefore the number of national movements must be divided by two to avoid double counting.

3.3.3.1.3 Emission Factors

3.3.3.1.3.1 LTO

3.3.3.1.3.1.1 Aircraft Based LTO Emission Factors

Emissions factors for LTO were set for each aircraft type according to information from ICAO Emission Factor Databank which contains emission factors for each operation condition: idle, take off, climb out and approach conditions. Emissions factors for arrival and departure were than set from the default time in mode proposed by FAEED table and from the emission factor for each operation condition where:

Departure includes taxi-out (idle), take off and climb out modes;

Arrival includes approach and taxi in (idle) conditions.

Table 3.78 - Emissions factors for most common aircraft movements in national airports.

Aircraft	Take-off (kg/movement)					Land (kg/movement)				
	FC	HC	CO	NOx	PM	FC	HC	CO	NOx	PM
Airbus A318/319/320/321	674.7	1.8	15.6	26.5	6.3	273.0	0.7	6.1	4.7	3.0
Airbus A320-100/200	674.7	1.8	15.6	26.5	6.3	273.0	0.7	6.1	4.7	3.0
Airbus A319	546.4	0.8	8.7	15.1	5.1	224.6	0.3	3.7	2.9	2.4
British Aerospace ATP	813.2	1.4	15.5	27.3	7.6	354.5	0.6	6.6	5.7	3.9
Boeing 737 all pax models	685.2	4.4	16.3	13.4	6.3	287.4	1.9	7.8	2.9	3.1
Fokker 100	481.0	1.9	12.4	9.5	4.4	202.8	0.8	5.3	1.7	2.1
Shorts SD.360	63.9	8.7	10.0	0.5	0.6	34.1	4.0	4.9	0.2	0.4
Embraer RJ135 / RJ140 / RJ145	232.5	0.8	5.3	4.9	2.2	105.2	0.4	2.4	1.2	1.1
Airbus A321-100/200	674.7	1.8	15.6	26.5	6.3	273.0	0.7	6.1	4.7	3.0
Embraer RJ145 Amazon	232.5	0.8	5.3	4.9	2.2	105.2	0.4	2.4	1.2	1.1
Boeing 757 all pax models	804.2	1.4	15.5	27.3	7.5	328.7	0.6	6.5	5.2	3.6
Boeing 737-800 (winglets) pax	581.4	1.3	11.3	16.7	5.4	243.2	0.5	4.7	3.9	2.6
Airbus A310-200 Freighter	996.1	4.7	20.7	37.3	9.4	421.2	1.9	8.9	6.9	4.7
Airbus A310 all pax models	1136.9	1.3	9.0	50.1	10.5	499.0	0.5	3.8	8.0	5.4
Cessna 172 Mescalero	2.5	0.1	2.2	0.0	0.0	1.4	0.0	1.5	0.0	0.0
Boeing 757 Mixed Configuration	804.2	1.4	15.5	27.3	7.5	328.7	0.6	6.5	5.2	3.6
Fairchild Dornier Do.228	111.3	5.4	14.7	2.3	1.0	54.2	2.4	7.7	0.6	0.6
Boeing 737-300 Freighter	548.5	1.2	18.4	11.3	5.1	235.0	0.5	7.6	3.1	2.5
McDonnell Douglas MD80	656.6	2.7	9.3	16.5	6.1	281.9	1.5	4.6	3.8	3.0
Beechcraft 1900/1900C/1900D	131.6	16.2	16.2	1.5	1.2	60.5	6.8	8.7	0.4	0.6
Boeing 737-700 (winglets) pax	505.6	1.5	12.1	12.1	4.7	215.5	0.5	5.2	3.2	2.3
CASA / IPTN 212 Aviocar	378.0	4.2	14.2	11.0	3.5	171.1	1.9	7.0	2.3	1.9
Boeing 737-500 pax	548.5	1.2	18.4	11.3	5.1	235.0	0.5	7.6	3.1	2.5
Beechcraft 1900/1900C	131.6	16.2	16.2	1.5	1.2	60.5	6.8	8.7	0.4	0.6
Aerospatiale Fennec (AS-550)	94.1	1.5	3.4	1.3	1.0	94.1	1.5	3.4	1.3	1.1
Dassault (Breguet Mystere) Falcon	42.2	0.4	2.0	0.9	0.4	34.1	0.4	2.4	0.3	0.3
Airbus A340 all models	1376.4	11.8	74.4	106.1	12.8	557.3	4.4	28.6	18.2	6.1
Boeing 767 all pax models	996.1	4.7	20.7	37.3	9.4	421.2	1.9	8.9	6.9	4.7
Mooney M-20	3.0	0.1	3.1	0.0	0.0	2.1	0.0	2.5	0.0	0.0

3.3.3.1.3.1.2 Airport Based LTO Emission Factors

Specific airport LTO emission factors were needed for movements where information about the aircraft type was not available. Therefore weighted averaged departure and arrival emission factors were estimated from the fleet composition for each airport and year. This set of averaged airport based LTO emission factors, was used mainly in movements from 1990 to 1999 since this was the period for which information on aircraft characteristics was scarce.

Table 3.79 – Airport based LTO emission factors (kg/movement).

Airport	Operation	Parameter	1990	1995	2000	2005	2008	2009	2010
Lisboa (LIS)	Take-off	Fuel Consumption	670.2	608.9	567.4	452.6	435.2	446.0	451.6
		VOC	16.4	14.9	15.2	9.3	7.0	2.8	2.8
		CO	37.1	33.7	35.4	21.5	18.2	12.9	13.8
		NO _x	26.3	23.9	23.6	16.2	15.1	15.6	15.9
		PM ₁₀	6.2	5.6	5.2	4.2	4.0	4.1	4.2
	Landing	Fuel Consumption	291.0	264.4	240.2	204.2	199.1	204.9	206.6
		VOC	7.0	6.4	6.0	4.4	2.9	1.5	1.5
		CO	17.8	16.2	16.3	11.1	8.9	6.7	7.0
		NO _x	4.9	4.4	4.3	3.3	3.2	3.4	3.4
		PM ₁₀	3.1	2.8	2.6	2.2	2.1	2.2	2.2
Porto (OPO)	Take-off	Fuel Consumption	530.0	481.5	401.1	374.4	369.3	395.9	427.6
		VOC	8.2	7.5	6.5	4.1	3.7	3.1	3.3
		CO	26.3	23.9	23.0	13.7	12.6	12.5	12.8
		NO _x	19.1	17.3	15.0	11.9	12.2	13.4	14.7
		PM ₁₀	4.9	4.5	3.7	3.5	3.4	3.7	4.0
	Landing	Fuel Consumption	236.2	214.6	181.3	172.9	169.4	173.6	191.7
		VOC	3.7	3.3	2.9	2.2	1.8	1.6	1.6
		CO	12.7	11.5	11.1	7.2	6.6	6.3	6.3
		NO _x	3.8	3.5	3.0	2.6	2.7	2.7	3.2
		PM ₁₀	2.5	2.3	1.9	1.9	1.8	1.9	2.1
Faro (FAO)	Take-off	Fuel Consumption	514.8	467.7	443.6	348.7	304.8	326.6	339.1
		VOC	5.3	4.8	4.9	3.0	2.5	2.3	2.4
		CO	19.2	17.4	17.2	12.2	10.3	10.5	11.0
		NO _x	17.4	15.8	16.0	11.0	8.7	9.8	10.0
		PM ₁₀	4.8	4.3	4.1	3.2	2.8	3.0	3.1
	Landing	Fuel Consumption	231.8	210.6	198.9	158.2	140.5	152.9	161.1
		VOC	2.7	2.5	2.5	1.7	1.5	1.4	1.4
		CO	10.0	9.1	9.0	6.5	5.7	5.7	5.9
		NO _x	3.5	3.2	3.1	2.3	2.0	2.3	2.4
		PM ₁₀	2.5	2.3	2.1	1.7	1.5	1.6	1.7

3.3.3.1.3.2 Cruise Emissions

3.3.3.1.3.2.1 Aircraft Based Cruise Emissions

Cruise emissions were estimated from EMEP/EEA Guidebook detailed methodology. Cruise emissions are given for typical cruise distances (see EMEP/CORINAIR Emission Inventory Guidebook, December 2001: ppB851-22, Table 8.4; Annex 1; Annex 2). This information was used to derive emissions for specific distances according with a trend line established between discrete samples provided in the EMEP/CORINAIR Emission Inventory Guidebook

The table below shows an example of cruise emission for Airbus and Boeing models.

Table 3.80 – Cruise emissions and fuel consumption.

Aircraft	Distance (km)	Fuel Consumption (kg)	NOX (kg)	HC (g)	CO (g)
Airbus A310 all pax models	0	0	0	0	0
	232	1 270	30	290	1587
	463	2 359	49	490	2651
	926	4 450	64	763	3848
	1389	6 541	89	1026	4913
	1852	8 632	113	1288	5977
	2778	12 992	166	1836	8193
	3704	17 441	214	2378	10345
	4630	22 159	273	2960	12678
	5556	27 135	340	3585	15206
	6482	32 223	408	4223	17790
Airbus A318/319/320/321	0	0	0	0	0
	232	842	17	149	1096
	463	1 695	27	267	1742
	926	2 858	45	508	3108
	1389	3 903	56	684	3571
	1852	5 225	73	915	4688
	2778	7 530	99	1311	6166
	3704	10 064	130	1747	7849
	4630	12 639	159	2189	9532
Boeing 727 all pax models	0	0	0	0	0
	231.5	1303.9	11	907	3459
	463	2341.8	17	2206	5869
	926	4247.3	43	2311	8837
	1389	6080.4	58	3072	11842
	1852	8058.3	74	3746	14568
	2778	12131.4	108	5279	20688
	3704	16459.4	147	6871	27075
	4630	20825.2	185	8477	33515

Source: EMEP/CORINAIR

3.3.3.1.3.2.2 Airport Based Cruise Emissions

Averaged airport cruise emission factors were needed for movements where information about the aircraft type was not available. For this purpose, weighted averaged cruise emission factors were estimated from the fleet profile in each airport, year and origin/destination.

Again, this set of averaged airport based cruise emissions, were used mainly in movements from 1990 to 1999 since this was the period for which information on aircraft characteristics was scarce.

3.3.3.1.3.3 Correspondence between aircraft type and representative aircraft

The availability of emissions factor is limited to a certain number of engines and frames. Therefore a representative aircraft is needed when an emission factor is not available for a specific airplane. The table below shows the correspondence between aircrafts and representative aircrafts for LTO and cruise emissions factors.

Table 3.81 – Aircraft type and representative aircraft for LTO and cruise emission factors.

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
100	Fokker 100	L JeK	L2J	100	100
146	BAe 146 all pax models	L JeK	L4J	146	146
310	Airbus A310 all pax models	L JeK	L2J	310	310
321	Airbus A321-100/200	L JeK	L2J	321	320
330	Airbus A330 all models	L JeK	L2J	330	330
340	Airbus A340 all models	L JeK	L4J	342	340
707	Boeing 707/720 all pax models	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
727	Boeing 727 all pax models	L JeK	L3J	727	727
737	Boeing 737 all pax models	L JeK	L2J	731	731
747	Boeing 747 all pax models	L JeK	L4J	747	741
757	Boeing 757 all pax models	L JeK	L2J	752	757
767	Boeing 767 all pax models	L JeK	L2J	767	767
777	Boeing 777 all pax models	L JeK	L2J	772	777
14F	BAe 146 Freighter (-100/200/300QT & QC)	L JeK	L4J	146	146
31F	Airbus A310 Freighter	L JeK	L2J	310	310
32S	Airbus A318/319/320/321	L JeK	L2J	320	320
70F	Boeing 707 Freighter	L JeK	L4J	70F	340
70M	Boeing 707 Combi	L JeK	L4J	707	340
72F	Boeing 727 Freighter (-100/200)	L JeK	L3J	72F	727
72M	Boeing 727 Combi	L JeK	L3J	727	727
73F	Boeing 737 all Freighter models	L JeK	L2J	731	731
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
74F	Boeing 747 all Freighter models	L JeK	L4J	74F	741
74M	Boeing 747 all Combi models	L JeK	L4J	747	741
75F	Boeing 757 Freighter	L JeK	L2J	75F	757
76F	Boeing 767 all Freighter models	L JeK	L2J	767	767
A109	Agusta A-109	L JeK	H2T	S61	NA
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
AB4	Airbus Industrie A300B2/B4/C4 pax	L JeK	L2J	AB4	310
31X	Airbus A310-200 Freighter	L JeK	L2J	312	310
319	Airbus A319	L JeK	L2J	319	320
A32	Antonov AN-32	L JeK	L2T	A32	NA
320	Airbus A320-100/200	L JeK	L2J	321	320
321	Airbus A321-100/200	L JeK	L2J	321	320
332	Airbus A330-200	L JeK	L2J	330	330
333	Airbus A330-300	L JeK	L2J	330	330
342	Airbus A340-200	L JeK	L4J	342	340
343	Airbus A340-300	L JeK	L4J	343	340

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
346	Airbus A340-600	L JeK	L4J	346	340
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
A660	Ayres Turbo Thrush (S-2R-T660)	L JeK	L1T	C208	C208
AA5	Gulfstream American AA-5 Traveler	L AvG	L1P	AA5	DHO
AB3	Airbus Industrie A300 pax	L JeK	L2J	AB3	310
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
ABB	Airbus Industrie A300-600ST Beluga Freighter	L JeK	L2J	AB6	310
ABF	Airbus Industrie A300 Freighter	L JeK	L2J	AB3	310
AC11	Rockwell Commander	L AvG	L1P	C150	DHO
ACT	Gulfstream/Rockwell (Aero) Turbo Commander	L JeK	L2T	ACT	NA
ACD	Gulfstream/Rockwell (Aero) Commander/Turbo Commander	L JeK	L2T	ACD	NA
AEST	Aerostar 600	L AvG	L2P	AEST	DHO
AJET	Dassault Alpha Jet	L JeK	L2J	FA10	S20
ALO3	Aerospatiale Alouette 3	L JeK	H1T	ALO3	NA
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
A26	Antonov AN-26	L JeK	L2T	A26	AN6
AN4	Antonov AN-24	L JeK	L2T	AN4	NA
AN6	Antonov AN-26 / AN-30 /AN-32	L JeK	L2T	A26	AN6
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
APH	Eurocopter (Aerospatiale) SA330 Puma / AS332 Super Puma	L JeK	H2T	S61	NA
ARJ	Avro RJ70 / RJ85 / RJ100 Avroliner	L JeK	L4J	ARJ	146
AS32	Aerospatiale Super Puma	L JeK	H2T	S61	NA
AS50	Aerospatiale Fennec (AS-550)	L JeK	H1T	S61	NA
AS65	Aerospatiale Dolphin (AS-366)	L JeK	H2T	AS65	NA
ASTR	IAI Gulfstream G100	L JeK	L2J	WWP	S20
AT3	AIDC AT-3 Tzu-Chung	L JeK	L2J	AT3	NA
AT43	Aerospatiale/Alenia ATR 42-300 / 320	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5T	Air Tractor AT-502	L JeK	L1T	C208	C208
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT8T	Air Tractor AT-802 Fire Boss	L JeK	L1T	C208	NA
ATP	British Aerospace ATP	L JeK	L2T	ATR	AT42
ATR	Aerospatiale/Alenia ATR 42/ ATR 72	L JeK	L2T	ATR	AT42
B06	Agusta AB-206 LongRanger	L JeK	H1T	S61	NA
MBH	Eurocopter (MBB) Bo.105	L JeK	H2T	S61	NA
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
B12	British Aerospace (BAC) One Eleven 200	L JeK	L2J	B12	B11
BES	Beechcraft 1900/1900C	L JeK	L2T	BE1	BE1
B200	Beech 200 Super King Air	L JeK	L2T	BE20	BE20
B350	Beech Super King Air 350	L JeK	L2T	BE30	B350
B36T	Allison 36 Turbine Bonanza	L JeK	L1T	C208	C208
70M	Boeing 707 Combi	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
B72	Boeing 720B pax	L JeK	L4J	B72	NA
72X	Boeing 727-100 Freighter	L JeK	L3J	721	727
72S	Boeing 727-200 Advanced pax	L JeK	L3J	722	727
731	Boeing 737-100 pax	L JeK	L2J	731	731
73M	Boeing 737-200 Combi	L JeK	L2J	732	731
73Y	Boeing 737-300 Freighter	L JeK	L2J	733	731
735	Boeing 737-500 pax	L JeK	L2J	735	734
B735	Boeing 737-500	L JeK	L2J	735	734
736	Boeing 737-600 pax	L JeK	L2J	736	734
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
73H	Boeing 737-800 (winglets) pax	L JeK	L2J	73H	734
739	Boeing 737-900 pax	L JeK	L2J	739	734
741	Boeing 747-100 pax	L JeK	L4J	741	741
74C	Boeing 747-200 Combi	L JeK	L4J	742	741
74U	Boeing 747-300 / 747-200 SUD Freighter	L JeK	L4J	743	741
74J	Boeing 747-400 (Domestic) pax	L JeK	L4J	744	74J
B74S	Boeing 747SP	L JeK	L4J	B74S	741
75M	Boeing 757 Mixed Configuration	L JeK	L2J	752	757
753	Boeing 757-300 pax	L JeK	L2J	752	757
76X	Boeing 767-200 Freighter	L JeK	L2J	762	767
76Y	Boeing 767-300 Freighter	L JeK	L2J	763	767
764	Boeing 767-400 pax	L JeK	L2J	764	767
772	Boeing 777-200 pax	L JeK	L2J	772	777
773	Boeing 777-300 pax	L JeK	L2J	773	777
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
BE1	Beechcraft 1900/1900C/1900D	L JeK	L2T	BE1	BE1
BE10	Beech King Air 100	L JeK	L2T	BE10	B350
BE18	Beech 18	L AvG	L2P	BE18	DHO
BE19	Beech 19 Sport	L AvG	L1P	BE19	DHO
BE2	Beechcraft twin piston engines	L AvG	L2P	BE55	DHO
BE20	Beech Huron	L JeK	L2T	BE20	BE20
BE30	Beech Super King Air 300	L JeK	L2T	BE30	B350
BE33	Beech Bonanza 33	L AvG	L1P	BE33	DHO
BE35	Beech Bonanza 35	L AvG	L1P	BE33	DHO

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
BE36	Beech Bonanza 36	L AvG	L1P	BE33	DHO
BE4	Beech Beechjet	L JeK	L2J	BE40	LOH
BE40	Beech Beechjet	L JeK	L2J	BE40	LOH
BE55	Beech Baron	L AvG	L2P	BE55	DHO
BE58	Beech Baron 58	L AvG	L2P	BE55	DHO
BE76	Beech Duchess	L AvG	L2P	BE55	DHO
BE9L	Beech King Air 90	L JeK	L2T	BE10	B350
BEC	Beechcraft light aircraft	L AvG	L1P	BE19	DHO
BEH	Beechcraft 1900D	L JeK	L2T	BE1	BE1
BEP	Beechcraft light aircraft - single engine	L AvG	L1P	BE19	DHO
BET	Beechcraft light aircraft - twin turboprop engine	L JeK	L2T	BE20	BE1
BH2	Bell Helicopters	L JeK	H1T	BH2	NA
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
C130	Lockheed Hercules	L JeK	L4T	C130	LOH
C150	Cessna 150	L AvG	L1P	C150	DHO
C160	Transall C-160	L JeK	L2T	C160	NA
C17	Boeing Globemaster 3	L JeK	L4J	C17	NA
C172	Cessna 172 Mescalero	L AvG	L1P	C150	DHO
C177	Cessna 177 Cardinal	L AvG	L1P	C150	DHO
C182	Cessna 182 Skylane	L AvG	L1P	C150	DHO
C185	Cessna 185 Skywagon	L AvG	L1P	C150	DHO
C206	Cessna 206 Stationair	L AvG	L1P	C150	DHO
C208	Cessna 208 Caravan	L JeK	L1T	C208	C208
C210	Cessna 210 Centurion	L AvG	L1P	C150	DHO
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
C303	Cessna T303 Crusader	L AvG	L2P	C404	DHO
C310	Cessna 310	L AvG	L2P	C337	DHO
C337	Cessna 337 Super Skymaster	L AvG	L2P	C337	DHO
C402	Cessna 402 Businessliner	L AvG	L2P	C404	DHO
C404	Cessna 402 Titan	L AvG	L2P	C404	DHO
C414	Cessna 414 Chancellor	L AvG	L2P	C404	DHO
C421	Cessna 421 Executive Commuter	L AvG	L2P	C404	DHO
C425	Cessna 425 Conquest	L JeK	L2T	C425	NA
C441	Cessna 441 Conquest	L JeK	L2T	C441	NA
C500	Cessna 500 Citation	L JeK	L2J	C500	DHO
C501	Cessna 501 Citation 1SP	L JeK	L2J	C500	DHO
C525	Cessna 525 Citation	L JeK	L2J	C500	DHO
C550	Cessna 550 Citation 2	L JeK	L2J	C550	DHO
C551	Cessna 551 Citation 2SP	L JeK	L2J	C551	DHO
C560	Cessna 560 Citation 5	L JeK	L2J	C560	S20

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
C56X	Cessna 560XL Citation Excel	L JeK	L2J	C560	S20
C650	Cessna 650 Citation 3	L JeK	L2J	C680	SH6
C680	Cessna 680 Citation Sovereign	L JeK	L2J	C680	SH6
C750	Cessna 750 Citation 10	L JeK	L2J	C750	F50
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ
CL4	Canadair CL-44	L JeK	L4T	CL4	F28
CL4	Canadair CL-44	L JeK	L4T	CL4	F28
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CN2	Cessna light aircraft - twin piston engines	L AvG	L2P	C404	DHO
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CNA	Cessna light aircraft	0	0	C150	DHO
CNJ	Cessna Citation	L JeK	L2J	C500	DHO
CNT	Cessna light aircraft - twin turboprop engines	L JeK	L2T	CNT	NA
CRJ	Canadair Regional Jet	L JeK	L2J	CR1	FRJ
CRV	Aérospatiale (Sud Aviation) Se.210 Caravelle	L JeK	L2J	CRV	D94
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CVF	Convair CV-240 / 440 / 580 / 600 / 640 Freighter	L JeK	L2T	CVF	NA
CVY	Convair CV-580 / 600 / 640 Freighter	L JeK	L2T	CVY	BE1
CVR	Convair CV-240 / 440 / 580 / 600 / 640 pax	L JeK	L2T	CVR	NA
D10	Douglas DC-10 pax	L JeK	L3J	D10	D10
D1F	Douglas DC-10 all Freighters	L JeK	L3J	D10	D10
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D8F	Douglas DC-8 all Freighters	L JeK	L4J	D8T	340
D8M	Douglas DC-8 all Combi models	L JeK	L4J	DC8	340
D9F	Douglas DC-9 all Freighters	L JeK	L2J	D9F	D91
D1X	Douglas DC-10-10 Freighter	L JeK	L3J	D11	D10
DC3T	Douglas DC-3	L JeK	L2T	DC3T	NA
DC8	Douglas DC-8 all pax models	L JeK	L4J	DC8	340
D8T	Douglas DC-8-50 Freighter	L JeK	L4J	D8T	340
D8L	Douglas DC-8-62 pax	L JeK	L4J	D8X	340
D8Y	Douglas DC-8-71 / 72 / 73 Freighters	L JeK	L4J	D8Y	340
DC9	Douglas DC-9 all pax models	L JeK	L2J	DC9	D91
DF3	Dassault (Breguet Mystere) Falcon 50 / 900	L JeK	L3J	FA50	F50
DFL	Dassault (Breguet Mystere) Falcon	0	0	FA10	S20
DHR	De Havilland Canada DHC-2 Turbo-Beaver	L AvG	L1P	DHB	DHO

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DH8	De Havilland Canada DHC-8 Dash 8 all models	L JeK	L2T	DH8	DH8
DH1	De Havilland Canada DHC-8-100 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH3	De Havilland Canada DHC-8-300 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH4	De Havilland Canada DHC-8-400 Dash 8Q	L JeK	L2T	DH8	DH8
DHB	De Havilland Canada DHC-2 Beaver / Turbo Beaver	L AvG	L1P	DHB	DHO
DHP	De Havilland Canada DHC-2 Beaver	L AvG	L1P	DHB	DHO
DHS	De Havilland Canada DHC-3 Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DHO	De Havilland Canada DHC-3 Otter / Turbo Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DR40	Robin DN-400	L AvG	L1P	C150	DHO
EMB	Embraer EMB.110 Bandeirante	L JeK	L2T	EMB	EMB
EM2	Embraer EMB.120 Brasília	L JeK	L2T	EM2	NA
E121	Embraer 121 Xingu	L JeK	L2T	E121	B350
ER3	Embraer RJ135	L JeK	L2J	ERJ	ERJ
ER4	Embraer RJ145 Amazon	L JeK	L2J	ERJ	ERJ
E70	Embraer 170	L JeK	L2J	EMJ	FRJ
E3CF	Boeing Sentry	L JeK	L4J	E3CF	NA
EM2	Embraer EMB.120 Brasília	L JeK	L2T	EM2	NA
EMB	Embraer EMB.110 Bandeirante	L JeK	L2T	EMB	EMB
EMJ	Embraer 170/190	L JeK	L2J	EMJ	FRJ
ERJ	Embraer RJ135 / RJ140 / RJ145	L JeK	L2J	ERJ	ERJ
100	Fokker 100	L JeK	L2J	100	100
F16	Lockheed F-16 Fighting Falcon	L JeK	L1J	F16	NA
F27	Fairchild FH.227	L JeK	L2T	FK7	NA
F28	Fokker F.28 Fellowship 3000	L JeK	L2J	F24	F28
F2TH	Dassault Falcon 2000	L JeK	L2J	F2TH	NA
F406	Cessna F406 Caravan 2	L JeK	L2T	F406	F406
F50	Fokker 50	L JeK	L2T	F50	F50
F70	Fokker 70	L JeK	L2J	F70	NA
F900	Dassault Falcon 900	L JeK	L3J	F900	F50
FA10	Dassault Falcon 10	L JeK	L2J	FA10	S20
FA20	Dassault Falcon 20	L JeK	L2J	FA20	S20
FA50	Dassault Falcon 50	L JeK	L3J	FA50	F50
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
GALX	IAI Galaxi	L JeK	L2J	WWP	S20
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
GLF2	Grumman Gulfstream 2	L JeK	L2J	GLF3	NA
GLF3	Grumman Gulfstream 3	L JeK	L2J	GLF3	NA
GLF4	Grumman Gulfstream 4	L JeK	L2J	GLF4	NA
GLF5	Grumman Gulfstream 5	L JeK	L2J	GLF5	NA
GRG	Grumman G.21 Goose	L AvG	A2P	GRG	B350
GRJ	Gulfstream Aerospace G-1159 Gulfstream II / III / IV / V	L JeK	L2J	GLF3	NA
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25B	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H60	Sikorsky Black Hawk	L JeK	H2T	S61	NA
HS7	Hawker Siddeley HS.748	L JeK	L2T	HS7	FRJ
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL8	Ilyushin IL18	L JeK	L4T	IL8	NA
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
ILW	Ilyushin IL86	L JeK	L4J	ILW	340
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
J41	British Aerospace Jetstream 41	L JeK	L2T	J41	J41
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
L10	Lockheed L-1011 Tristar pax	L JeK	L3J	L10	D10
L11	Lockheed L-1011 1 / 50 / 100 / 150 / 200 / 250 Tristar pax	L JeK	L3J	L10	D10
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
L1F	Lockheed L-1011 Tristar Freighter	L JeK	L3J	L10	D10
L29	Aero (2) L-29 Delfin	L JeK	L1J	F16	NA
L4T	LET 410	L JeK	L2T	L4T	NA
LJ31	Learjet 31	L JeK	L2J	LJ31	S20
LJ35	Learjet 35	L JeK	L2J	LJ35	S20
LJ45	Learjet 45	L JeK	L2J	LJ35	S20
LJ60	Learjet 60	L JeK	L2J	LJ35	S20
LOE	Lockheed L-188 Electra pax	L JeK	L4T	LOE	NA
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
LOH	Lockheed L-182 / 282 / 382 (L-100) Hercules	L JeK	L4T	C130	LOH
LOM	Lockheed L-188 Electra Mixed Configuration	L JeK	L4T	LOM	NA
LRJ	Gates Learjet	L JeK	L2J	LJ23	S20
LYNX	Westland Lynx	L JeK	H2T	S61	NA

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
M11	McDonnell Douglas MD11 pax	L JeK	L3J	M11	D10
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M1M	McDonnell Douglas MD11 Mixed Configuration	L JeK	L3J	M11	D10
M20P	Mooney M-20	L AvG	L1P	M20P	DHO
M20T	Mooney TLS	L AvG	L1P	M20P	DHO
M80	McDonnell Douglas MD80	L JeK	L2J	M81	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M82	McDonnell Douglas MD82	L JeK	L2J	M82	M82
M83	McDonnell Douglas MD83	L JeK	L2J	M83	M82
M88	McDonnell Douglas MD88	L JeK	L2J	M88	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MU2	Mitsubishi Mu-2	L JeK	L2T	MU2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
NDC	Aerospatiale SN.601 Corvette	L JeK	L2J	NDC	DHO
P180	Piaggio P-180 Avanti	L JeK	L2T	P180	B350
P28A	Piper Archer 2	L AvG	L1P	P28A	DHO
PN6	Partenavia P.68	L AvG	L2P	PN6	DHO
PA18	Piper Super Club	L AvG	L1P	PA18	DHO
PA2	Piper light aircraft - twin piston engines	L AvG	L2P	PA31	DHO
PA24	Piper Comanche	L AvG	L1P	PA24	DHO
PA27	Piper Aztec	L AvG	L1P	PA27	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA31	Piper Navajo	L AvG	L2P	PA31	DHO
PA32	Piper Saratoga	L AvG	L1P	PA32	DHO
PA34	Piper Seneca	L AvG	L2P	PA44	DHO
PA44	Piper Seminole	L AvG	L2P	PA44	DHO
PA46	Piper Malibu	L AvG	L1P	PA46	DHO
PAG	Piper light aircraft	L AvG	L1P	P28A	DHO
PAT4	Piper T-1040	L JeK	L2T	PAT4	SWM
PL2	Pilatus PC-12	L JeK	L1T	PL2	C208
PL6	Pilatus PC-6 Turbo Porter	L JeK	L1T	PL6	C208
PL2	Pilatus PC-12	L JeK	L1T	PL2	C208
PL6	Pilatus PC-6 Turbo Porter	L JeK	L1T	PL6	C208
PN6	Partenavia P.68	L AvG	L2P	PN6	DHO
PUMA	Aerospatiale Puma	L JeK	H2T	S61	NA
S05F	Siai-Marchetti S-205-20F	L AvG	L1P	C150	DHO

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
S20	Saab 2000	L JeK	L2T	S20	S20
S58	Sikorsky S-58T	L JeK	H1T	S58	NA
S58P	Sikorsky S-58	L AvG	H1P	S61	NA
NDC	Aerospatiale SN.601 Corvette	L JeK	L2J	NDC	DHO
S61	Sikorsky S-61	L JeK	H2T	S61	NA
S76	Sikorsky S-76	L JeK	H2T	S61	NA
SA3	Stits Playboy	L AvG	L1P	SA3	DHO
S20	Saab 2000	L JeK	L2T	S20	S20
SBR1	North American Sabreliner	L JeK	L2J	SBR1	NA
SF3	Saab SF340A/B	L JeK	L2T	SF3	SF3
SF3	Saab SF340A/B	L JeK	L2T	SF3	SF3
SH3	Shorts SD.330	L JeK	L2T	SH3	SH3
SH3	Shorts SD.330	L JeK	L2T	SH3	SH3
SH6	Shorts SD.360	L JeK	L2T	SH6	SH6
SH6	Shorts SD.360	L JeK	L2T	SH6	SH6
SHB	Shorts SC-5 Belfast	L JeK	L4T	SHB	NA
SR20	Cirrus SR-20	L AvG	L1P	C150	DHO
SR22	Cirrus SR-22	L AvG	L1P	C150	DHO
SSC	Aerospatiale/BAC Concorde	L JeK	L4J	SSC	NA
SW2	Swearingen Merlin 2	L JeK	L2T	SW2	NA
SW3	Swearingen Merlin 3	L JeK	L2T	SW3	SHS
SW4	Swearingen Merlin 4	L JeK	L2T	SW4	NA
SWM	Fairchild (Swearingen) SA26 / SA226 / SA227 Metro / Merlin / Expediter	L JeK	L2T	PA31	SWM
TU3	Tupolev Tu134	L JeK	L2J	TU3	NA
TU5	Tupolev Tu154	L JeK	L3J	TU5	727
T20	Tupolev Tu-204 / Tu-214	L JeK	L2J	T20	NA
T20	Tupolev Tu-204 / Tu-214	L JeK	L2J	T20	NA
TBM	Grumman Avenger	L AvG	L1P	C150	NA
TBM7	Socata TBM-700	L JeK	L1T	TBM7	C208
TOBA	Socata Tobago	L AvG	L1P	C150	DHO
TRIN	Scata Pashosh	L AvG	L1P	C150	DHO
TU3	Tupolev Tu134	L JeK	L2J	TU3	NA
TU5	Tupolev Tu154	L JeK	L3J	TU5	727
VC10	Bac VC-10	L JeK	L4J	VC10	NA
VCV	Vickers Viscount	L JeK	L4T	VCV	NA
WG30	Westland WG-30	L JeK	H2T	S61	NA
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK5	Yakovlev Yak 50	L AvG	L1P	C150	DHO

3.3.3.1.3.4 Fuel dependent emission factors

Fuel dependent emission factors were set for CO₂ and N₂O. Emission factors for CO₂ and N₂O are IPCC default. The LHV were obtained from the national energy authority (DGEG).

Table 3.82 – Fuel dependent emission factors.

Pollutant	Aviation Gasoline	Jet Fuel
LHV (MJ/kg)	44.0	43.0
CO ₂ (t/TJ) ²⁷	69.5	70.6
N ₂ O (kg/TJ)	2.00	2.00

Source: IPCC; DGEG

3.3.3.1.4 Activity Data

3.3.3.1.4.1 Flight movements in Airports

Very important activity data for this source activity is the number of arrival and departure movements. The number of movements by airport, aircraft, origin/destiny and movement type (arrival or departure) for the period between 1990 and 2010 was provided by the *Instituto Nacional de Aviação Civil* (INAC). This database is being improved and the coverage of it is increasing as new airports (mostly regional and local airports) are connected to the movements database from INAC.

Table 3.83 – LTO per airport

Region	Airport Code	1990	1995	2000	2005	2008	2009	2010
Mainland	LIS	30 862	34 932	56 073	68 168	72 324	70 433	73 783
	OPO	11 574	13 348	23 280	25 910	29 002	27 079	28 502
	FAO	11 252	13 067	18 243	20 397	22 835	21 897	22 359
	TOTAL	53 688	61 347	97 596	114 475	124 161	119 409	124 644

Region	Airport Code	1990	1995	2000	2005	2008	2009	2010
Islands	FNC	6 475	9 460	12 040	15 952	12 949	12 477	12 697
	TER	3 801	4 049	4 501	4 875	5 005	5 343	4 988
	PDL	2 954	3 382	4 134	7 196	6 405	8 314	8 182
	PXO	2 403	4 243	3 788	3 688	2 207	2 173	2 325
	HOR	1 237	1 542	1 756	2 964	2 516	3 137	2 919
	SMA	634	893	1 557	1 649	1 591	1 623	1 275
	FLW	281	357	552	1 101	776	1 271	1 136
	TOTAL	17 785	23 926	28 328	37 425	31 449	34 338	33 522

Source: INAC

²⁷ The CO₂ emission factor takes into account an oxidation factor of 0.99.

Data concerning aircraft operation characteristics, particularly, the origin/destiny, the aircraft type and the movement type was sometimes not included in the records database. The worse case refers to the period between 1990 and 1994, for this period the only information available was the number of operations, all other information was missing. There is also the period between 1995 and 1999 with missing data on aircraft type. For all these cases an alternative approach had to be set.

An alternative database was however available with information on the number of operations and the aircraft types. This data was very useful to determine the aircraft fleet profile in each airport between 1990 and 1999 whereby airport representative arrival and departure emission factors were determined.

On the other hand, for records with missing information on origin and destiny, an yearly fraction of international, domestic and European flights was derived for each airport relying on the movements which had this information. This was necessary to differentiate emissions between domestic and international.

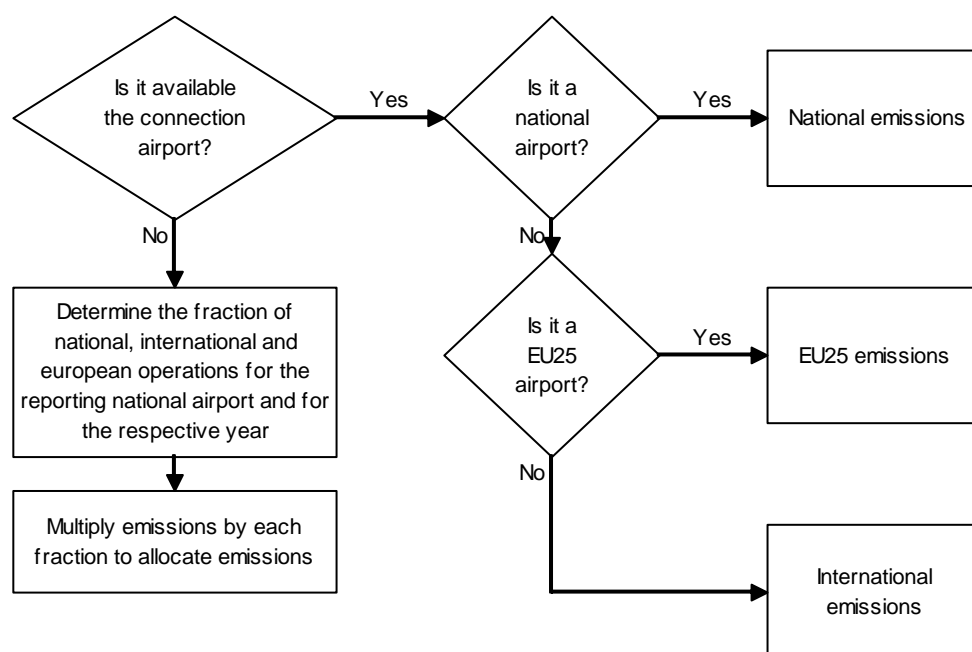


Figure 3.62 – Decision tree for distinction between domestic and international emissions.

3.3.3.1.4.2 Fuel Consumption

Fuel consumption is available from fuel sales statistics from DGEG for main territory and islands. LTO and domestic cruise fuel consumption is estimated with a bottom-up approach. International cruise consumption is estimated as the difference to the total fuel sales. This approach guarantees that the total fuel for aviation equals the fuel sales.

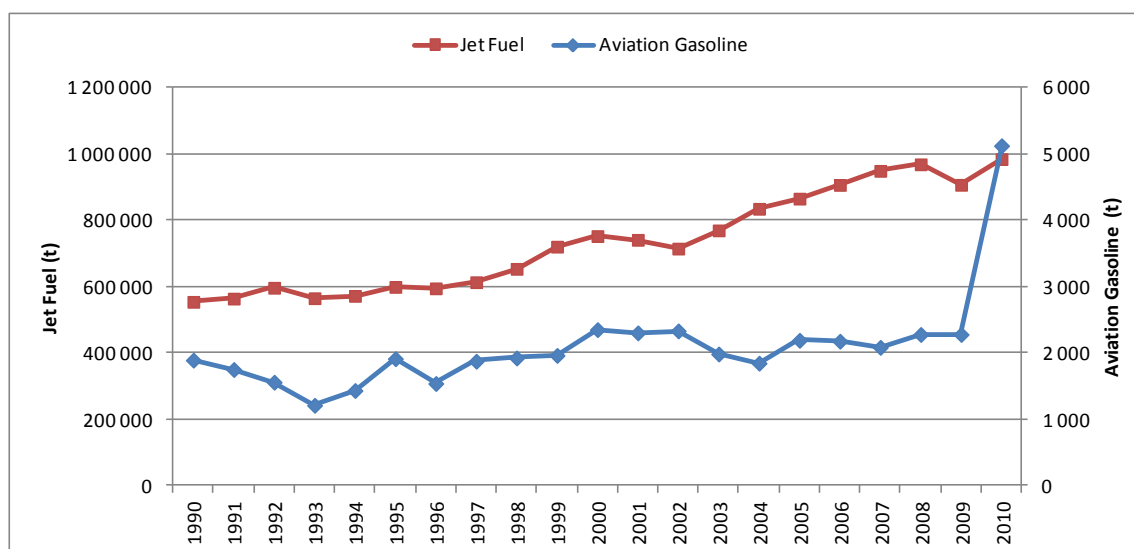


Figure 3.63 – Total Fuel consumption of aviation gasoline and jet fuel (Source: DGEG)

3.3.3.1.5 Uncertainty Assessment

Activity level refers to the fuel domestic consumption which was estimated for LTO and Cruise separately according with the following couple equations.

$$U_{cruise} = \sqrt{U_{movements}^2 + U_{time}^2 + U_{FCcruise}^2}$$

$$U_{lto} = \sqrt{U_{movements}^2 + U_{FClto}^2}$$

The activity level uncertainty (U_{global}) is therefore obtained from:

$$U_{global} = \frac{\sqrt{E_{cruise} \times U_{cruise}^2 + E_{lto} \times U_{lto}^2}}{E_{cruise} + E_{lto}}$$

Where,

E_{cruise} , E_{lto} = domestic energy consumption under cruise and LTO (GJ).

Table 3.84 – Aviation activity level uncertainty.

Source	Parameter	Unit	1990	1995	2000	2005	2010
All	U_{global}	%	74	72	35	36	35
Cruise	U_{cruise}	%	99	99	47	49	48
LTO	U_{lto}	%	100	100	48	49	48

The uncertainties of emissions factors were set at 5% for CO₂, 100% for methane and one order of magnitude for N₂O, following the recommendations from GPG.

3.3.3.1.6 Category-specific QA/QC and verification

Energy consumption was compared with data from the energy balance reported by DGEG. No differences were found between total fuel estimated with the described methodology and total fuel reported in the energy balance.

ANA Aeroportos is a public enterprise that manages the majority of the national airports, i.e., Lisbon, Oporto, Faro, Ponta Delgada, Santa Maria, Horta e Flores, concerning about 88% of the total LTOs. The 2010 ANA Traffic Yearbook reports 8.6% less flights than the value used in the inventory which was obtained from the national civil airtraffic authority (*Instituto Nacional de Aviação Civil*, INAC) and adjusted to include flights from piston engines aircrafts. Therefore traffic data is considered fairly closed in both sources.

3.3.3.1.7 Recalculations

During the preparation of the previous submission (2011) data on air traffic was not available for the year 2009. Emissions for 2009 were then calculated based on the fuel consumption obtained from the energy balance for 2009. All emission factors and O/D matrices were assumed equal to year 2008.

The 2009 air traffic data was made available in late 2011, together with the 2010 data. Therefore emissions from 2009 were recalculated. Recalculation was also made for all time series since updated LHV were available from the energy authority.

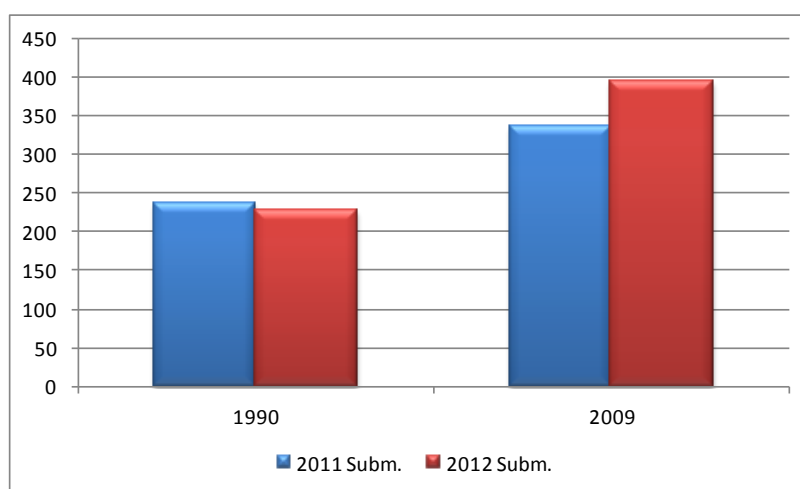


Figure 3.64 – Recalculation of domestic CO₂ emissions including LTO and cruise emissions (kt CO₂)

3.3.3.2 Road Transportation (CRF 1.A.3.b)

3.3.3.2.1 Overview

Road transportation is one of the most important emitter of greenhouse gases (GHG) such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O).

Exhaust greenhouse gases emissions from road transportation were estimated at about 18 255.3 kton CO₂e. in 2010 representing an increase of 89.6% when compared to 9 628.1 kton CO₂e., estimated for 1990 (see Table 3.85).

Emissions of N₂O have increased by a factor of 2.6 since 1990 due to the introduction of catalytic converters. As could be observed the introduction of catalytic converters have some disadvantages including also the increase of CO₂ and NH₃ emissions which contribute to climate change and acid deposition. It is difficult to assess the extent to which CO₂ emissions have increased as a result of fitting catalytic converters, because improvements in fuel economy have been made at the same time as development of the engine management systems that are required to minimize NO_x and VOC emissions

Table 3.85 – Estimated emissions from road transport

Pollutant	Unit	1990	2010	Var (%)
CO2 Fossil	kt	9 475.8	18 046.5	90.4
CH4	t	4 064.6	1 591.8	-60.8
N2O	t	215.9	565.9	162.1
CO ₂ e.	kt	9 628.1	18 255.3	89.6

3.3.3.2.2 Methodology

Emissions from road transportation are estimated using the latest version of COPERT IV (version 9.0 - November 2011). An additional tool was developed by APA to calculate the vehicle fleet. This estimates annual fleet from long-time series of vehicle sales and abatements. Activity level, expressed in km/vehicle/year, was obtained from a model based on data from vehicle inspection centers. The fuel consumption is provided by the national energy authority and this information is used to correct fuel consumption using bottom-up approach in conjunction with top-down approach.

Emissions from heavy duty vehicles, buses and coaches were estimated from vehicle-kilometers obtained from national statistics. Disaggregation by vehicle technology was then obtained using the data from the vehicle inspection centers.

Estimated emissions from road transport are based in Tier 2 method for CO₂ emissions and Tier 3 for non-CO₂ emissions.

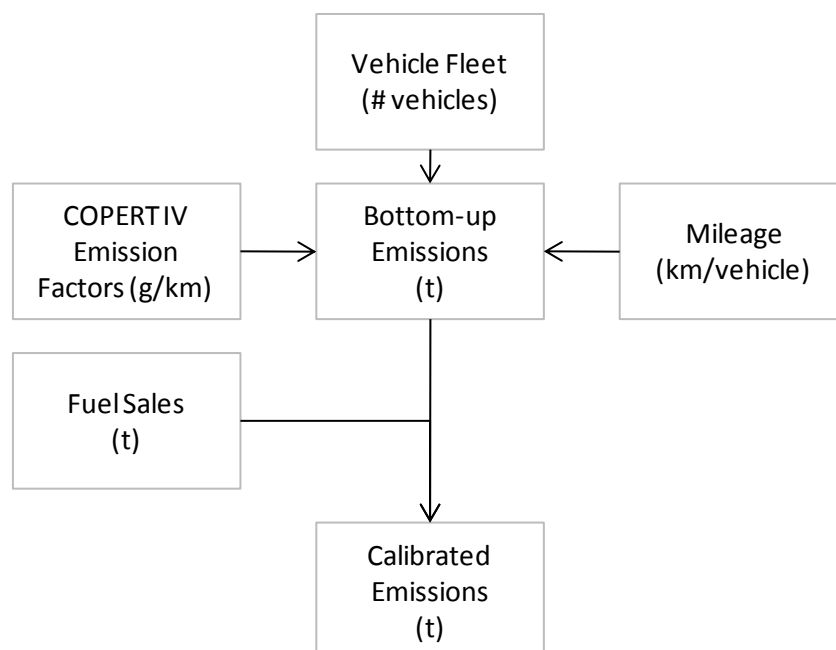


Figure 3.65 – General scheme of methodology applied for road transport emissions estimates (Passenger cars, light duty vehicles and motorcycles)

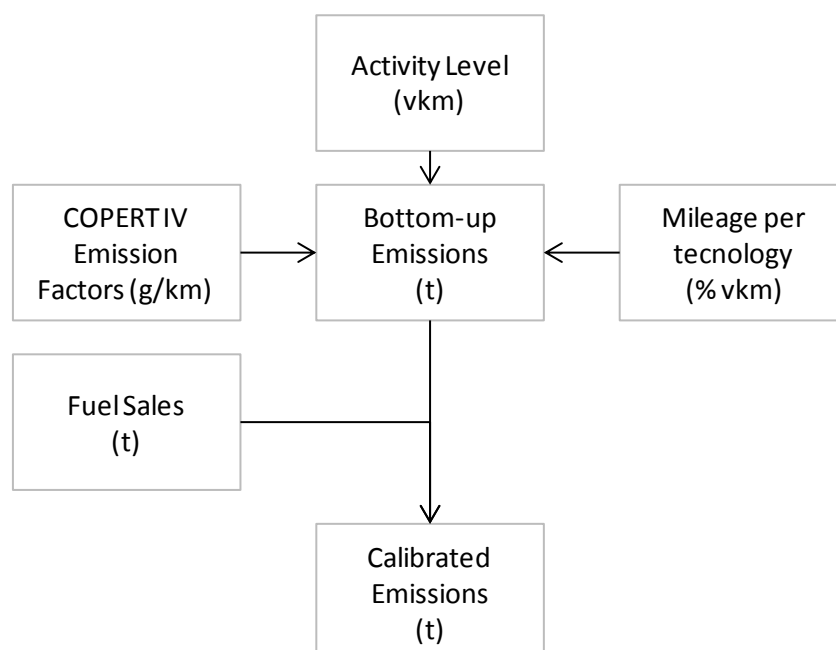


Figure 3.66 – General scheme of methodology applied for road transport emissions estimates (Heavy duty vehicles, buses and coaches)

3.3.3.2.2.1 Vehicle Fleet

A function for vehicle abatement based on vehicle age was applied to vehicle sales in order to determine the active fleet per year. This function derives from *Associação Automóvel de Portugal* (ACAP) data and is valid for passenger cars, light duty vehicles and motorcycles and is summarized in the following couple equations:

$$T_{c,a,f,y1} = S_{c,y2} \times \left[1 - \frac{0.0477 \times e^{(0.6003 \times A_{c,y1-y2})}}{100} \right]; A < 10$$

$$T_{c,a,f,y1} = S_{c,y2} \times \left[1 - \frac{0.2721 \times A_{c,y1-y2} - 35.199}{100} \right]; 10 \leq A \leq 20$$

Where,

$T(c,a,y1)$ = number of vehicles of class c, with age a, using fuel f in year y1;

$S(c,y2)$ = sales of vehicles of class c, using fuel f in year y2;

$A(c,y1-y2)$ = age of vehicles of class c, using fuel f in year y1.

The number of mopeds was obtained from the insurance institute as information on mopeds sales and abatements is not available.

National statistics institute provides information on the total activity level for heavy duty trucks, Buses and Coaches. The activity level is then disaggregated by technology using the information from vehicle inspection centers.

3.3.3.2.2.2 Distance Travelled

Distance driven was established using a model based on data from vehicle inspection centers.

Distance travelled by heavy duty vehicles, buses and coaches was established from national statistics. Disaggregation by vehicle technology was then obtained using the data from the vehicle inspection centres.

Mopeds and motorcycles are excluded from the vehicle maintenance program therefore it was assumed an average mileage of 12000 km/year for motorcycles (Bennetts, 2009) and 5000 for mopeds.

Table 3.86 – Km per year per vehicle as function of vehicle age for passenger cars and light duty vehicles.

Vehicle Category	Sub Categories	Mileage Function	Parameters
Passenger Cars	Gasoline <1,4 l Hybrid Gasoline <1,4 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 11059.2452 A2 = -2885.12141 x0 = 23.28806 p = 2.56847
	Gasoline 1,4 - 2,0 l Hybrid Gasoline 1,4 - 2,0 l	$\text{km/year} = y0 + A * \text{Exp}(-0.5 * ((\text{age} - xc) / w) ^ 2)$	y0 = 13010.25545 xc = 26.65915 w = 8.63531 A = -8623.92117
	Gasoline >2,0 l LPG 2-Stroke Hybrid Gasoline >2,0 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 13354.66789 A2 = 737.09264 x0 = 19.69152 p = 2.4209
	Diesel <2,0 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 19241.06557 A2 = 6603.86725 x0 = 17.45625 p = 2.53695
	Diesel >2,0 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 20445.94606 A2 = 9728.01464 x0 = 14.25834 p = 3.25053
Light Duty Vehicles	Diesel <3,5 t	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 20800.21535 A2 = 2597.42606 x0 = 15.44257 p = 2.32592

Table 3.87 – Km per year per vehicle type

Sector	Subsector	Technology	1990	1995	2000	2005	2010
Passenger Cars	Gasoline <1,4 l	PRE ECE	5 145	3 720	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	7 731	5 637	3 989	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/02	9 316	7 268	5 098	3 454	0
Passenger Cars	Gasoline <1,4 l	ECE 15/03	10 457	9 009	6 941	4 895	3 454
Passenger Cars	Gasoline <1,4 l	ECE 15/04	11 021	10 655	9 478	7 561	5 523
Passenger Cars	Gasoline <1,4 l	Improved Conventional	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	Open Loop	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	PC Euro 1 - 91/441/EEC	0	11 049	10 692	9 452	7 455
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	0	0	11 036	10 541	9 134
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	10 982	10 252
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	11 059	10 949
Passenger Cars	Gasoline <1,4 l	PC Euro 5 (post 2005)	0	0	0	0	11 059
Passenger Cars	Gasoline <1,4 l	PC Euro 6	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	6 277	4 721	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	9 583	6 875	4 938	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	11 401	9 112	6 237	4 544	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	12 332	10 969	8 515	5 888	4 544
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	12 877	12 584	11 621	9 591	6 917
Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	0	12 898	12 551	11 477	9 262
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	0	0	12 880	12 430	11 172
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	12 803	12 173
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	12 937	12 758
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 (post 2005)	0	0	0	0	12 937
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	PRE ECE	6 686	5 485	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	9 082	7 059	5 670	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/02	10 921	8 664	6 640	5 272	0

Sector	Subsector	Technology	1990	1995	2000	2005	2010
Passenger Cars	Gasoline >2,0 l	ECE 15/03	12 190	10 208	7 997	6 197	5 272
Passenger Cars	Gasoline >2,0 l	ECE 15/04	13 288	12 723	11 154	8 992	7 027
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	0	13 331	12 735	11 050	8 816
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	0	0	13 312	12 549	10 726
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13 211	12 109
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 171
Passenger Cars	Gasoline >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	13 355
Passenger Cars	Gasoline >2,0 l	PC Euro 6	0	0	0	0	0
Passenger Cars	Diesel <2,0 l	Conventional	18 516	18 089	16 360	14 000	11 863
Passenger Cars	Diesel <2,0 l	PC Euro 1 - 91/441/EEC	0	19 198	18 445	16 380	13 803
Passenger Cars	Diesel <2,0 l	PC Euro 2 - 94/12/EEC	0	0	19 196	18 299	16 092
Passenger Cars	Diesel <2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	19 127	17 943
Passenger Cars	Diesel <2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	19 241	19 031
Passenger Cars	Diesel <2,0 l	PC Euro 5 (post 2005)	0	0	0	0	19 241
Passenger Cars	Diesel <2,0 l	PC Euro 6	0	0	0	0	0
Passenger Cars	Diesel >2,0 l	Conventional	18 690	17 521	15 735	13 871	12 317
Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	0	20 428	19 808	17 394	14 327
Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	0	0	20 433	19 762	17 201
Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	20 381	19 230
Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	20 446	20 333
Passenger Cars	Diesel >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	20 446
Passenger Cars	Diesel >2,0 l	PC Euro 6	0	0	0	0	0
Passenger Cars	LPG	Conventional	13 109	12 455	10 806	8 689	6 816
Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	0	13 294	12 546	10 769	8 551
Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	0	0	13 295	12 442	10 554
Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13 166	11 942
Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 330
Passenger Cars	LPG	PC Euro 5 (post 2005)	0	0	0	0	13 355
Passenger Cars	LPG	PC Euro 6	0	0	0	0	0
Passenger Cars	2-Stroke	Conventional	0	0	0	0	0

Sector	Subsector	Technology	1990	1995	2000	2005	2010
Passenger Cars	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	10 228	9 879	9 134	9 121	10 174
Passenger Cars	Hybrid Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	12 937	12 914	12 843
Passenger Cars	Hybrid Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	13 355	13 242	13 191
Light Duty Vehicles	Gasoline <3,5t	Conventional	10 433	8 828	6 292	4 092	2 460
Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	0	13 331	12 735	11 050	8 816
Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	0	0	13 312	12 549	10 726
Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	13 211	12 109
Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 171
Light Duty Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards	0	0	0	0	13 355
Light Duty Vehicles	Gasoline <3,5t	LD Euro 6	0	0	0	0	0
Light Duty Vehicles	Diesel <3,5 t	Conventional	17 571	16 481	13 978	11 295	9 067
Light Duty Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	0	20 733	19 497	16 114	12 248
Light Duty Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	0	0	20 741	19 246	15 618
Light Duty Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	20 649	18 597
Light Duty Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	0	20 491
Light Duty Vehicles	Diesel <3,5 t	LD Euro 5 - 2008 Standards	0	0	0	0	0
Light Duty Vehicles	Diesel <3,5 t	LD Euro 6	0	0	0	0	0

3.3.3.2.2.3 Allocation of distance travelled

Vehicle-kilometers (vkm) were allocated to urban, rural and highway driving modes. Information on vkm driven under highways derive from the *Instituto Mobilidade e dos Transportes Terrestres* (IMTT) which is the national authority for terrestrial transportation. Originally this data is communicated to IMTT by the highway service providers. The remaining vkm are allocated to urban and rural driving modes according with the population living in each area.

3.3.3.2.2.4 Speed

Three driving modes where individualized in accordance with source categories SNAP97 from CORINAIR/EMEP methodology: urban, rural and highway. For each driving mode average speeds had to be set by vehicle type whereas vehicle fuel consumption and exhaust emissions are strongly dependent on speed.

Table 3.88 – Assumed vehicle speeds by driving mode and vehicle type.

Driving Mode	Vehicle Type	Assumed Speed (km/h)	Source
Highway	Passenger Car	124	Lemonde, 2000
	Light Duty Vehicles	124	Lemonde, 2000
	Heavy Duty Vehicles	103	LNEC, 2002
	Coaches	103	LNEC, 2002
	Motorcycles	124	Lemonde, 2000
Rural	Passenger Car	61	LNEC, 2002
	Light Duty Vehicles	61	LNEC, 2002
	Heavy Duty Vehicles	56	LNEC, 2002
	Coaches	56	LNEC, 2002
	Mopeds	40	Maximum Legal Value
	Motorcycles	61	LNEC, 2002
Urban	Passenger Car	24.9	Gois et al., 2005
	Light Duty Vehicles	24.9	Gois et al., 2005
	Heavy Duty Vehicles	24.9	Gois et al., 2005
	Buses	14.8	Carris, 2005
	Coaches	24.9	Gois et al., 2005
	Mopeds	24.9	Gois et al., 2005
	Motorcycles	24.9	Gois et al., 2005

3.3.3.2.2.5 Fuel consumption

Fuel consumption was estimated for each fuel type according with the kilometers travelled.

$$FC_{f,y} = \sum_m \sum_c \sum_t vkm_{c,t,m,f,y} \times FC_{c,t,m,f} \times 10^{-6}$$

where,

$FC_{f,y}$ = fuel consumption of fuel type f by all vehicles in year y (km/y) using bottom-up approach;

$vkm_{c,t,m,f,y}$ = total kilometres driven by vehicles of class c, with technology t, under driving mode m using fuel f in year y (km/y);

$FC_{c,t,m,f}$ = EMEP/CORINAIR fuel consumption factor for vehicle type c, with technology t, under driving mode m, using fuel f (g/km);

c = vehicle class or type: light passenger, LDV, HDV, etc;

t = vehicle technology: PRE-ECE, ECE, Euro I, Euro II, etc;

m=driving mode: highway, rural, urban

f = fuel type (gasoline, diesel or LPG);

y = civil year.

3.3.3.2.2.6 Adjustment of bottom-up and top-down approaches

Fuel adjustments are necessary so that the sum of estimated fuel consumption equals the total fuel sales from the DGGE. Fuel consumption estimates were corrected with the following factor for car type c, technology t, fuel f, driving mode d and year y.

$$Correc_{Factor_{f,y}} = \frac{FuelSales_{f,y}}{FuelEstimates_{1stFC_{f,y}}}$$

Correction factors are later applied to the first approach fuel consumption and emissions. This correction guarantees that emission estimates are in accordance with the good practices (IPCC, 2000; IPCC, 1996). Although emissions were derived from estimate of vehicle kilometres travelled and from fuel consumption per kilometre (bottom-up approach), they were corrected for total national fuel sales (top-down correction).

3.3.3.2.7 Emission Factors

Ultimate CO₂ emission factors were established according with IPCC guidelines.

Energy content was first estimated using national specific LHV provided by DGEG.

Table 3.89 – National specific LHV

Fuel	GJ/ton
Gasoline	44.00
Diesel	42.60
LPG	46.00
CNG	45.97
Biodiesel	37.00

Source: DGEG

Then IPCC default CO₂ emission factors (kgCO₂/GJ) were multiplied by the energy consumption.

Table 3.90 - CO₂ emission factors

Fuel	EF _{CO2} (kg CO ₂ /GJ)
Gasoline	73.00
Diesel	74.00
LPG	63.00
CNG	64.10

Source: IPCC, 1996

Emissions factors for CH₄ and N₂O, expressed in g/km, were determined using COPERT IV (version 9.0 - November 2011).

This set of equations allows the estimation of emission factors as function of driving conditions and vehicle properties:

- Vehicle class: light passenger vehicles, LDV, HDV, Mopeds with cylinder capacity under 50 cc and; Motorcycles with cylinder capacity greater than 50 cc;
- Fuel type: gasoline, diesel and LPG;
- Technology standard;
- Vehicle dimensions: motor size (cubic centimetres) for light vehicles and two wheelers and vehicle weight for heavy vehicles;
- Average vehicle speed under each driving mode.

European technology standards were determined according with the vehicle built year as present in table below.

Table 3.91 – Technology classification according to built year

Vehicle Category	Legislation	Built year	
		from	to
Passenger Cars	PRE ECE	...	1971
	ECE 15/00-01	1972	1977
	ECE 15/02	1978	1980
	ECE 15/03	1981	1985
	ECE 15/04	1986	1991
	Euro 1	1992	1996
	Euro 2	1997	2000
	Euro 3	2001	2004
	Euro 4	2005	2008
	Euro 5 ⁽²⁸⁾	2009	2014
	Euro 6 ⁽¹⁾	2014	...
Light Duty Vehicles	Conv	...	1991
	Euro 1	1992	1997
	Euro 2	1998	2001
	Euro 3	2002	2006
	Euro 4	2006	2009
	Euro 5 ⁽¹⁾	2010	2015
	Euro 6 ⁽¹⁾	2015	...
Heavy Duty Vehicles	Conv	...	1991
	Euro I	1992	1995
	Euro II	1996	2000
	Euro III	2001	2005
	Euro IV	2006	2008
	Euro V	2009	...
Mopeds	Conv	...	1999
	Euro 1	2000	2002
	Euro 2	2003	2005
	Euro 3	2006	...
Motorcycles	Conv	...	1999
	Euro 1	2000	2003
	Euro 2	2004	2005
	Euro 3	2006	

²⁸ Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information. (OJ L 171 29.6.2007, p. 1).

According with COPERT IV method, driving condition parameters, such as the average trip length, must be set in order to derive adequate emission factors.

There is no available updated data regarding L_{trip} for Portugal. Therefore it was decided to use an European average value of 12 km (L_{trip}) as proposed by COPERT IV. The European average value is closed to the value for Spain which is assumed to be adequate also for Portugal

Emissions factors for SO_2 and heavy metals were estimated from the fraction S and heavy metals in the fuel. For LPG, CNG and Biodiesel it was assumed a 0% sulphur content.

Table 3.92 – Sulphur content in gasoline and diesel (%)

Fuel	1990-1999	2000-2004	2005-2008	2009-2010
Gasoline	0.100	0.015	0.005	0.001

Fuel	1990-1994	1995	1996-1999	2000-2004	2005-2008	2009-2010
Diesel	0.300	0.200	0.050	0.035	0.005	0.001

Source: National Legislation (Portaria n.º125/89, Portaria n.º1489/95, Decreto-Lei n.º104/2000);

For evaporative emission calculations, monthly maximum and minimum average ambient temperatures were inputted into COPERT IV. Meteorological data was received from 9 climatological stations of the National Meteorological Institute (IM). The data concerns a long period average from 1971 to 2000 and is the most updated long period average available from the IM. The same values were used for all years in analysis.

Table 3.93 – Monthly average ambient temperatures (°C)

Month_	Max.	Min.
January	14.0	6.6
February	15.2	7.4
March	17.3	8.5
April	18.4	9.7
May	20.8	11.9
June	24.5	14.7
July	27.7	16.8
August	28.0	16.8
September	26.0	15.6
October	21.6	12.8
November	17.5	9.8
December	14.9	7.3

Source: IM (<http://www.meteo.pt/pt/oclima/normais/>)

Monthly values of fuel volatility (RVP - Reid Vapour Pressure) were established from Portuguese legislation (Decreto-lei n.º 104/2000; Portaria 1489/95; Portaria 125/89). RVP values considered in national legislation 104/2000 are applicable since the beginning of year 2000 although the regulatory document was valid only after May 2000.

Table 3.94 – Reid Vapour Pressure (kPa)

Month	1990 to 1995	1996 to 1999	2000 to 2010
January	98	95	90
February	98	95	90
March	98	95	90
April	83	80	90
May	83	80	60
June	70	70	60
July	70	70	60
August	70	70	60
September	70	70	60
October	83	95	90
November	98	95	90
December	98	95	90

Emissions from biofuels

Use of biodiesel as a blend with diesel may also lead to some change in emissions. The following table proposes differences in emissions caused by different fuel blends on fossil diesel and correspond to a Euro 3 vehicle/engine technology.

Table 3.95 – Effect of biodiesel blends on diesel vehicles emissions

Pollutant	Vehicle Type	B10	B20	B100
CO ₂	Passenger Cars	-1.5%	-2.0%	
	Light duty vehicles	-0.7%	-1.5%	
	Heavy duty vehicles	0.2%	0.0%	0.1%
NO _x	Passenger Cars	0.4%	1.0%	
	Light duty vehicles	1.7%	2.0%	
	Heavy duty vehicles	3.0%	3.5%	9.0%
PM	Passenger Cars	-13.0%	-20.0%	
	Light duty vehicles	-15.0%	-20.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-47.0%
CO	Passenger Cars	0.0%	-5.0%	
	Light duty vehicles	0.0%	-6.0%	
	Heavy duty vehicles	-5.0%	-9.0%	-20.0%
HC	Passenger Cars	0.0%	-10.0%	
	Light duty vehicles	-10.0%	-15.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-17.0%

Source: (EEA/EMEP, 2009)

The effect of biodiesel may vary with the vehicle technology but the extent of the variation is difficult to estimate in the absence of detailed literature data. With regard to NO_x, CO₂ and CO, any effect of technology should be negligible, given the marginal effect of biodiesel on these pollutants in general. The effect of biodiesel on PM for different technologies is more difficult to assess (EEA/EMEP, 2009).

Considering that detailed literature data on biodiesel effects is scarce and that the actual blend used for road transportation in Portugal was about 7.4% in 2010 (Table 3.96), emission factors from biodiesel use were assumed to be the same as for diesel.

Table 3.96 – National biodiesel blends with diesel (%v/v)

2006	2007	2008	2009	2010
1.6	3.0	2.9	5,1	7,4

Source: (DGEG, 2011)

Fuel consumption factors here presented are developed in a similar manner as for emission factors.

3.3.3.2.3 Implied Emission Factors

The implied emission factors are estimated by dividing the estimated emissions by the energy consumption.

Table 3.97 – Road transportation emission factors (kg/GJ)

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010
CO ₂	Passenger Cars	Gasoline	73.000	73.000	73.000	73.000	73.000
		Diesel	74.000	74.000	74.000	74.000	74.000
		LPG	63.000	63.000	63.000	63.000	63.000
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.000
	Light Duty Vehicles	Gasoline	-	-	-	-	-
		Diesel	74.000	74.000	74.000	74.000	74.000
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.000
	Heavy Vehicles	Gasoline	-	-	-	-	-
		Diesel	74.000	74.000	74.000	74.000	74.000
		LPG	-	-	-	-	-
		CNG	-	-	64.100	64.100	64.100
		Biodiesel	-	-	-	-	0.000
	Motorcycles	Gasoline	73.000	73.000	73.000	73.000	73.000
		Diesel	-	-	-	-	-
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	-
CH ₄	Passenger Cars	Gasoline	0.044	0.036	0.026	0.019	0.014
		Diesel	0.006	0.005	0.003	0.002	0.001
		LPG	0.021	0.022	0.020	0.018	0.015
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.001
	Light Duty Vehicles	Gasoline	-	-	-	-	-
		Diesel	0.004	0.004	0.003	0.002	0.001
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.001
	Heavy Vehicles	Gasoline	-	-	-	-	-
		Diesel	0.007	0.007	0.007	0.006	0.005
		LPG	-	-	-	-	-
		CNG	-	-	0.095	0.097	0.092
		Biodiesel	-	-	-	-	0.005
	Motorcycles	Gasoline	0.179	0.169	0.146	0.107	0.081
		Diesel	-	-	-	-	-
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	-

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2009
N ₂ O	Passenger Cars	Gasoline	0.003	0.012	0.006	0.005	0.002
		Diesel	0.000	0.001	0.001	0.002	0.003
		LPG	0.000	0.004	0.005	0.005	0.004
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.003
	Light Duty Vehicles	Gasoline	-	-	-	-	-
		Diesel	0.000	0.000	0.001	0.001	0.002
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.002
	Heavy Vehicles	Gasoline	-	-	-	-	-
		Diesel	0.002	0.002	0.002	0.002	0.001
		LPG	-	-	-	-	-
		CNG	-	-	0.000	0.000	0.000
		Biodiesel	-	-	-	-	0.001
	Motorcycles	Gasoline	0.001	0.001	0.001	0.001	0.001
		Diesel	-	-	-	-	-
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	-

The implied emission factors expressed in grams per kilometer were also derived.

Table 3.98 – Road transportation distance based implied emission factor (MJ/km; g/km)

Pollutant	Fuel	Vehicle Type	1990	1995	2000	2005	2009
Energy Consumption (MJ/km)	Diesel	Passenger Cars	2.689	2.606	2.671	2.570	2.524
		Light Duty Vehicles	3.518	3.424	3.276	3.200	3.167
		Heavy Vehicles	9.993	9.864	11.624	11.605	11.238
	Gasoline	Passenger Cars	2.729	2.679	2.655	2.585	2.559
		Light Duty Vehicles	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-
		Mopeds	1.100	1.100	1.050	0.789	0.572
		Motorcycles	1.722	1.752	1.757	1.662	1.599
	CNG	Heavy Vehicles	-	-	21.574	21.623	21.514
	LPG	Passenger Cars	2.602	2.635	2.644	2.603	2.580
		Light Duty Vehicles	-	-	-	-	-
CO ₂ (g/km)	Diesel	Passenger Cars	199.022	192.845	197.670	190.182	174.693
		Light Duty Vehicles	260.340	253.397	242.388	236.825	219.159
		Heavy Vehicles	739.491	729.970	860.154	858.784	777.743
	Gasoline	Passenger Cars	199.187	195.575	193.782	188.675	186.780
		Light Duty Vehicles	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-
		Mopeds	80.298	80.298	76.682	57.592	41.739
		Motorcycles	125.670	127.894	128.297	121.319	116.705
	CNG	Heavy Vehicles	-	-	1 382.922	1 386.016	1 379.050
	LPG	Passenger Cars	163.946	165.991	166.542	163.993	162.547
		Light Duty Vehicles	-	-	-	-	-
CH ₄ (g/km)	Diesel	Passenger Cars	0.017	0.014	0.009	0.005	0.002
		Light Duty Vehicles	0.014	0.014	0.010	0.006	0.003
		Heavy Vehicles	0.068	0.067	0.077	0.073	0.054
	Gasoline	Passenger Cars	0.121	0.097	0.069	0.048	0.035
		Light Duty Vehicles	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-
		Mopeds	0.219	0.219	0.199	0.106	0.045
		Motorcycles	0.192	0.192	0.188	0.159	0.131
	CNG	Heavy Vehicles	-	-	2.050	2.106	1.979
	LPG	Passenger Cars	0.054	0.058	0.053	0.046	0.040
		Light Duty Vehicles	-	-	-	-	-
N ₂ O (g/km)	Diesel	Passenger Cars	0.000	0.002	0.003	0.006	0.007
		Light Duty Vehicles	0.000	0.001	0.003	0.004	0.006
		Heavy Vehicles	0.019	0.019	0.019	0.019	0.014
	Gasoline	Passenger Cars	0.008	0.033	0.015	0.012	0.006
		Light Duty Vehicles	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-
		Mopeds	0.001	0.001	0.001	0.001	0.001
		Motorcycles	0.002	0.002	0.002	0.002	0.002
	CNG	Heavy Vehicles	-	-	0.000	0.000	0.000
	LPG	Passenger Cars	0.000	0.010	0.012	0.012	0.011
		Light Duty Vehicles	-	-	-	-	-

3.3.3.2.4 Activity Data

3.3.3.2.4.1 Vehicle Fleet

The following table shows the number of vehicles between 1990 and 2010 was based in data available from ACAP, *Instituto de Seguros de Portugal* (ISP) and INE.

Table 3.99 – Vehicle fleet synthesis

Vehicle Type	1990	1995	2000	2005	2010
Passenger Cars	1 616 142	2 702 220	3 743 313	4 185 544	4 191 284
Light Duty Vehicles	449 918	545 091	684 953	751 144	718 869
Mopeds	834 675	682 031	529 387	330 528	283 369
Motorcycles	66 129	92 239	144 595	157 055	215 987

The growth of gasoline passenger cars has decreased over the last years. It was observed a decrease in the number of this type of vehicles while diesel passenger cars have increased. After an initial growth, LPG fuelled vehicles have stabilised as a small percentage of passenger cars. The number of mopeds is decreasing according with data from ISP.

3.3.3.2.4.2 Distances Travelled

Total road traffic activity has increased 115% since 1990.

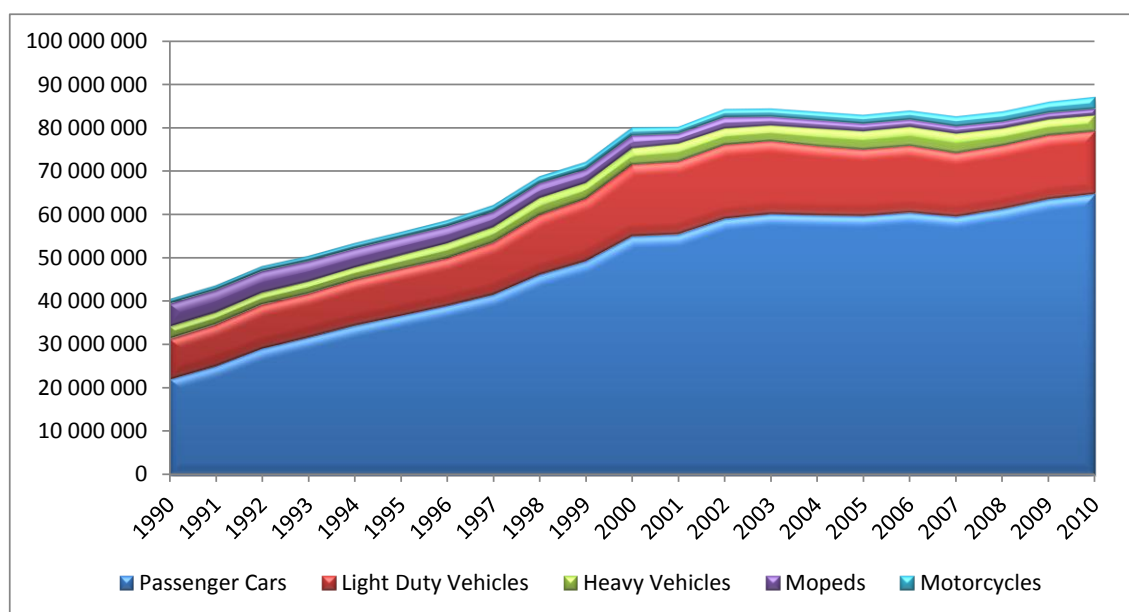


Figure 3.67 – Kilometers travelled by vehicle type (vkmx10³)

Table 3.100 – Kilometers travelled per vehicle type (vkmx10³)

Tipo Veículo	1990	1995	2000	2005	2010
Passenger Cars	22 206 741	36 791 100	55 019 287	59 665 057	64 767 041
Light Duty Vehicles	9 236 067	10 705 643	16 461 643	15 239 750	14 381 465
Heavy Vehicles	2 839 603	3 194 763	3 851 053	4 332 297	3 761 875
Mopeds	5 265 495	4 047 894	2 883 789	1 759 306	1 505 049
Motorcycles	1 001 210	1 313 865	1 890 404	2 006 301	2 753 197
TOTAL	40 549 115	56 053 266	80 106 175	83 002 711	87 168 627

3.3.3.2.4.3 Fuel Consumption

Fuel consumption from road transport sector is available from the revised energy balances from DGEG. Total consumption of petrol, diesel-oil and LPG are shown in Table 3.101.

Table 3.101 – Fuel consumption from road transport sector

Fuel	Unit	1990	1995	2000	2005	2010
Gasoline	t	1 376 217	1 885 861	2 052 007	1 791 425	1 379 897
Diesel	t	1 603 658	2 110 210	3 759 009	4 167 113	4 281 331
LPG	t	21	289	22 329	20 935	28 944
CNG	t	0	0	648	9 572	11 459
Biodiesel	t	0	0	0	0	341 586

Source: DGEG

Fuel consumption was also estimated from the fuel consumption factors given from COPERT IV. The bottom-up versus top-down correction factor was derived from the differences between estimated and real fuel consumption as explained.

3.3.3.2.5 Uncertainty Assessment

In accordance with the chapter of Road Vehicles in the GPG, the uncertainty of methane emission factor is 40% and the uncertainty for nitrous oxide should be at least 50%. The uncertainty in CO₂ is 5%, also in accordance with the same source of information. The uncertainty of activity data was assumed to be 10%.

3.3.3.2.6 Category-specific QA/QC and verification

Differences were found in fuel consumption time series taken as a sum from COPERT IV compared to total fuel sales data taken from the energy balance. In 2010 the estimated fuel consumption compared to sales are: Gasoline -5.9%; Diesel -10.3%; LPG -73.3%; CNG -97.3%. These differences are corrected in COPERT IV to equal fuel sales in order to ensure full consistency between Energy Statistics and GHG inventory. Corresponding CO₂ emissions are corrected as well.

3.3.3.2.7 Recalculations

Recalculations for this sector comprise:

- Use of the updated version of COPERT IV (version 9.0 - November 2011);
- Update of km/vehicles for passenger cars and light duty vehicles using a model based on data from the vehicle inspection centers;
- Update activity data for HDV and Buses according with data from national statistics.
- Update of sulphur content in gasoline and diesel according to DL 235/2004 (Directive 2003/17/CE).
- Adoption of CO₂ default emission factor to calculate emissions from the combustion of gasoline.

Figure 3.68 – Recalculation of CO₂ for road transportation

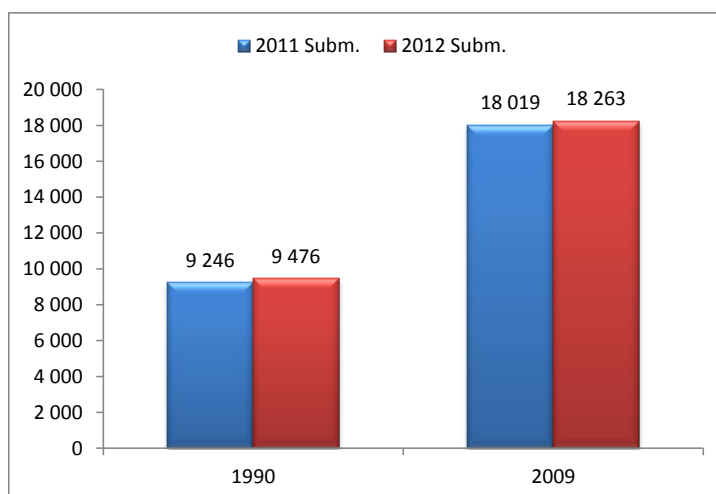


Figure 3.69 – Recalculation of CH₄ for road transportation

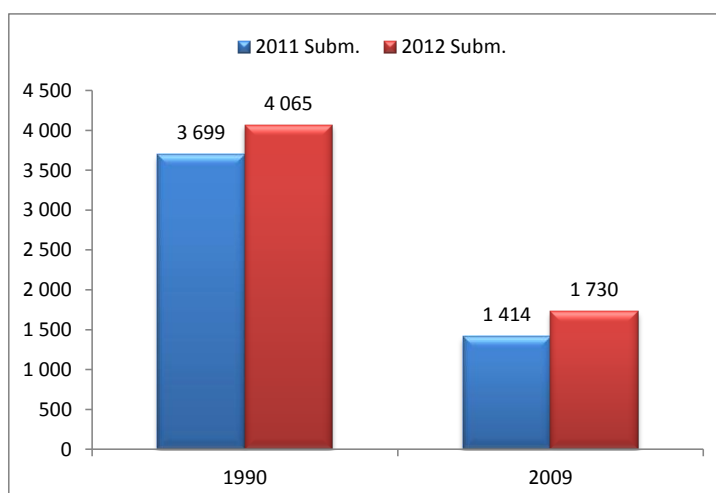
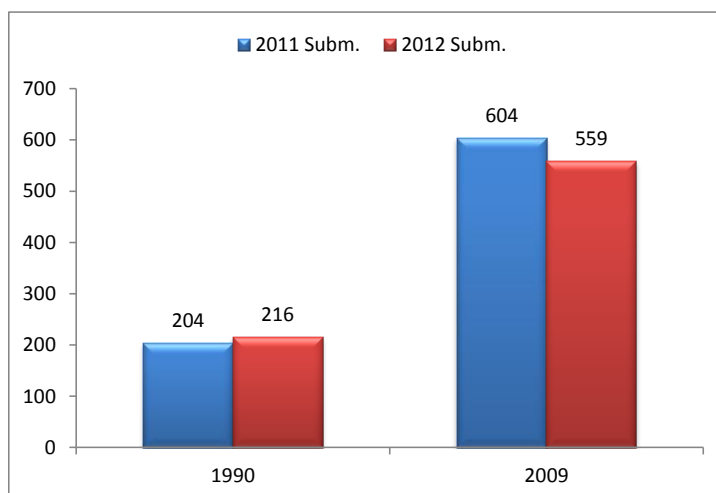


Figure 3.70 – Recalculation of N₂O for road transportation



3.3.3.2.8 Further Improvements

No further improvements are planned for this sector.

3.3.3.3 Railways (CRF 1.A.3.c)

3.3.3.3.1 Overview

Although there has been a growing electrification of railway lines in Portugal during latest years, locomotives, shunting locomotives and railcars are still responsible for substantial part of rail transport and consequent emission of GHG in exhaust.

3.3.3.3.2 Methodology

Emissions to atmosphere of ultimate CO₂ from fossil origin were estimated from CO₂ total emissions by:

$$\text{Fossil}_{\text{CO}_2(y)} = \sum_f [\text{EF}_{\text{CO}_2(f)} * \text{Fac}_{\text{OX}(f)} * \text{C}_{\text{Fossil}(f)} * \text{Cons}_{\text{Fuel}(f,y)} * \text{LHV}_{(f)}] * 10^{-5}$$

where

$\text{Fossil}_{\text{CO}_2(y)}$ - Emissions of carbon dioxide to atmosphere from combustion of fossil fuel f (ton);

$\text{EF}_{\text{CO}_2(f)}$ – Total carbon content of fuel expressed in total CO₂ emissions (kgCO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$\text{Fac}_{\text{OX}(f)}$ – Oxidation factor for fuel f (ratio 0..1);

$\text{Cons}_{\text{Fuel}(f,y)}$ - Consumption of fuel f in year y (ton/yr);

$\text{LHV}_{(f)}$ - Low Heating Value (MJ/kg).

For all other pollutants the following formula was used:

$$\text{Emission}_{(p,y)} = \sum_f [\text{EF}_{(f,p)} * \text{Cons}_{\text{Fuel}(f,y)}] * 10^{-3}$$

where

Emission_(p,y) - Emission of pollutant p in year y (ton/yr);

EF_(f,p) - Quantity of pollutant p emitted from fuel f (kg/ton);

Cons_{Fuel(n,f,y)} - consumption of fuel f during in year y (ton/yr).

3.3.3.3.3 Emission Factors

Emission factors, expressed in kg/ton of fuel, were set from available proposed emission factors in EMEP/CORINAIR Handbook (EEA,2002), IPCC 1996 Revised Guidelines (IPCC,1997) and MEET project, and are presented in next table.

Table 3.102 - Emission factors in Railways (in kg/ton of fuel)

	Coal	Coke	Diesel-oil	Biodiesel	Fuel-oil
LHV ^(a)	31.3	29.4	42.6	37.0	40.0
CH ₄	0.22 ^(iv)				
U _{CO2}	3 168 ^(v)				
% C fossil	100			0	100
FAC _{OX} ^(b)	0.980	0.990		1.000	0.990
N ₂ O	0.66 ^(iv)				

(a) LHV/NCV expressed in MJ/kg; (b) Oxidation Ratio expressed as ratio

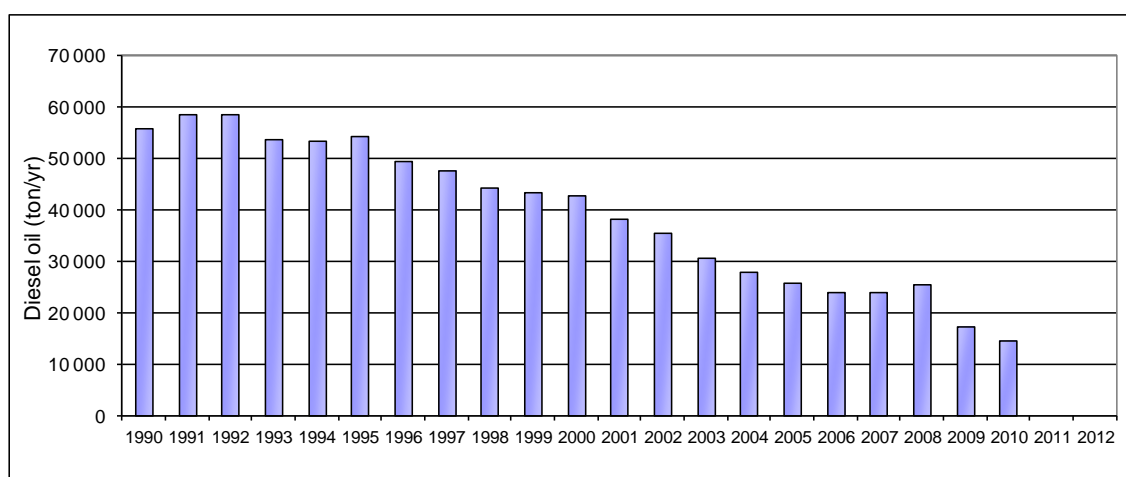
(iv) Average of EMEP/CORINAIR (European values) and IPCC (US values);

(v) Average of EMEP/CORINAIR, IPCC and MEET;

3.3.3.3.4 Activity Data

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2010 from the energy balance. Besides some very small use of coal and coke until 1996, the majority of combustible energy refers to use of gas oil²⁹. The quantities that were consumed have been decreasing steadily since 1992, as can be seen in Figure 3.71.

Figure 3.71 - Consumption of diesel oil in the railway transport sector



²⁹ Gas oil represents no less than 98.4 per cent of total annual use of combustible energy.

3.3.3.3.5 Uncertainty Assessment

The uncertainty of fuel consumption was set equal to the uncertainty that was also considered for road traffic: 5 per cent. In a similar way the uncertainties in methane and nitrous oxide emission factors were set at 40 per cent and 50 per cent respectively, the same values that were used for road traffic. The general error of 5 per cent, set for most combustion sources, was used for the calculation of uncertainties of carbon dioxide emissions.

3.3.3.3.6 Category-specific QA/QC and verification

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

3.3.3.3.7 Recalculation

Recalculations in this source category result from:

- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates;
- Revision of coal consumption (2003-2009).

3.3.3.3.8 Further Improvements

No further improvements are planned for this sector.

3.3.3.4 *Water Borne Navigation (CRF 1.A.3.d)*

3.3.3.4.1 Overview

This sector refers to domestic ship transport between Portuguese ports including traffic to the Azores and Madeira islands.

3.3.3.4.2 Methodology

Statistics on fuel used in shipping activities is available at national level as an aggregated figure provided in the energy balance from the energy authority. Detailed ship movements are also available as well as some technical information on the ships such as gross tonnage and ship type.

The methodology used for the calculation of emissions from shipping activities is in accordance with the ship movement methodology from the detailed methodology of EEA/EMEP air pollutant emission inventory guidebook (version from August 2002).

The methodology takes into account the fuel used as well as the type of ship, the distance travelled and the speed of vessel. Therefore, according with IPCC Guidelines, this approach consists in a detailed method (tier 2 or 3). Since fuel consumption is used for top-down calibration, tier 2 method could be regarded as the method used to estimate emissions from shipping activities.

The general approach could be described as follows:

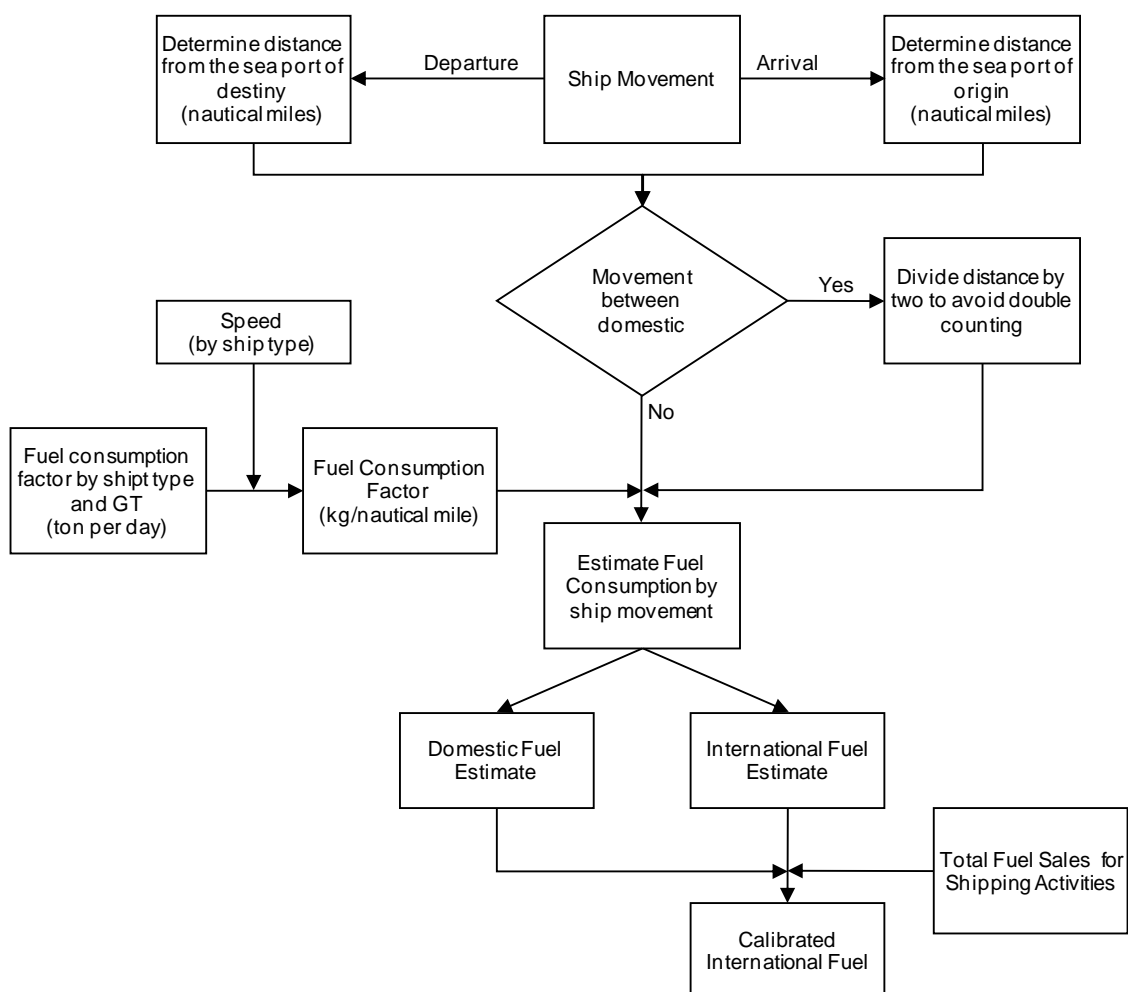
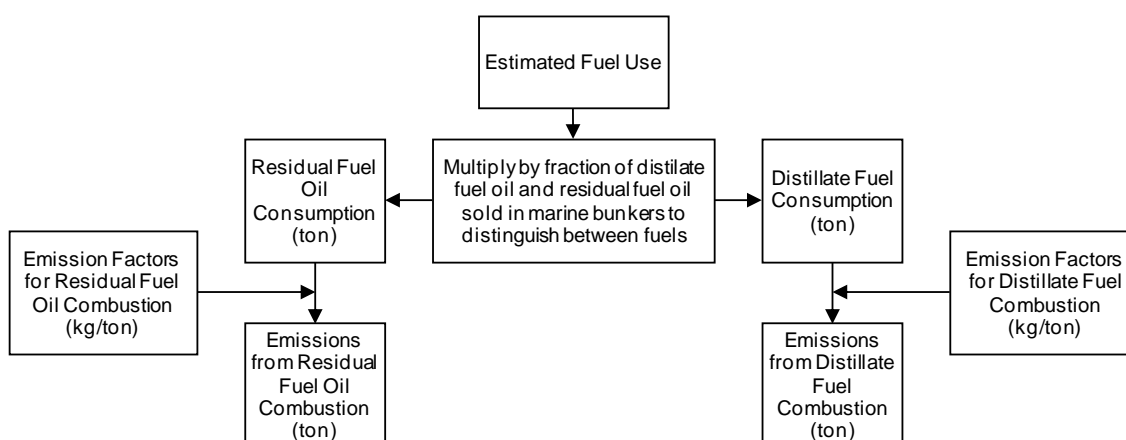


Figure 3.72 – Generic methodology flowchart.

Emissions factors vary according with the type of fuel used. To distinguish between residual and distilled fuel an additional calculation step is required:



3.3.3.4.3 Emission Factors

Emission factors and energy content were obtained from several sources. The energy content of residual and distillate fuels was provided by the energy authority (DGEG). The carbon emission factors, expressed in t C/TJ are from IPCC (IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual). Emission factors for CH₄ and N₂O were obtained from EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook.

When estimating CO₂, it was assumed that a fraction of carbon (0,01) remains unoxidized and stored indefinitely, as follows:

$$CO_2 \frac{t}{year} = Energy \frac{TJ}{year} \times CarbonContent \frac{tC}{TJ} \times 0.99 \times \frac{44}{12}$$

Table 3.103 – Emission factors for navigation

Pollutant	Unit	Gas-oil	Residual fuel oil
LHV	MJ/kg	42.60	40.00
Carbon	t C/TJ	20.20	21.10
CO ₂	t CO ₂ /TJ	73.33	76.59
CH ₄	kg/tonne fuel	0.050	0.050
N ₂ O	kg/tonne fuel	0.080	0.080

Source: EMEP/CORINAIR, IPCC, DGEG.

The fuel consumption factors (expressed in tonne per day) are dependent from the ship type and from the gross tonnage. The equations used to derive fuel consumption factors were obtained from EMEP/CORINAIR.

Table 3.104 – Consumption factors

Ship Type	Consumption at fuel power (tonne/day) ^(a)
Solid bulk	20.186 + 0.00049 × gt
Liquid bulk	14.685 + 0.00079 × gt
General cargo	9.8197 + 0.00143 × gt
Container	8.0552 + 0.00235 × gt
Passenger/Ro-Ro/Cargo	12.834 + 0.00156 × gt
Passenger	16.904 + 0.00198 × gt
High speed ferry	39.483 + 0.00972 × gt
Inland cargo	9.8197 + 0.00143 × gt
Sail ships	0.4268 + 0.00100 × gt
Tugs	5.6511 + 0.01048 × gt
Fishing	1.9387 + 0.00448 × gt
Other ships	9.7126 + 0.00091 × gt
All ships	16.263 + 0.001 × gt

Legend:

gt – gross tonnage

^(a) – a factor of 0.8 was applied to obtain consumption for cruise.

Source: (EEA/EMEP, 2005)

3.3.3.4.4 Activity Data

3.3.3.4.4.1 *Ships movements in national sea ports*

The activity data from navigation is based on ship movement for individual ships in each national seaport comprehending nine ports in Portugal mainland and four in islands of Madeira and Azores.

The data provided by national seaports reports to the years 1990 and 1995; and to the period between 2000 and 2010. The number of movements and the distances travelled for the period 1991-1994 and 1996-1999 were estimated according with an interpolation established between years with available data.

For most cases, data on origin and destiny was also available per movement which allowed to estimate the distances travelled and to distinguish between domestic and international movements.

Table 3.105 – Ship docks

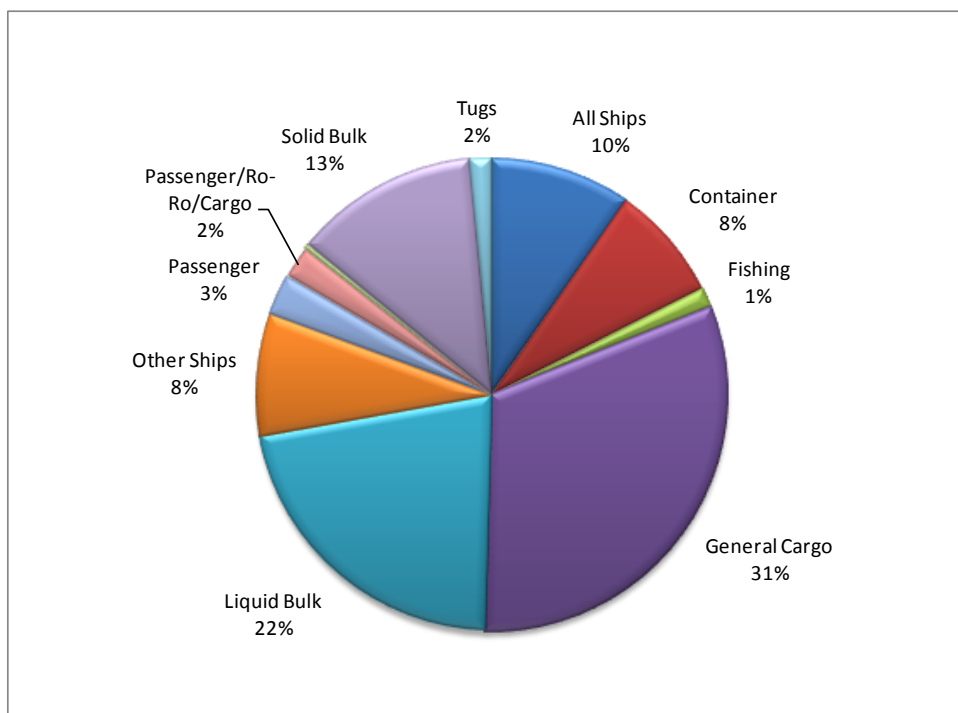
Sea Port	Location	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Aveiro	Mainland	docks	876	920	965	1 009	1 054	1 098	1 080	1 062	1 045	1 027	1 009
Canical	Madeira	docks	76	76	76	76	76	76	76	76	76	76	76
Faro	Mainland	docks	163	163	163	163	163	163	163	163	163	163	163
Figueira da Foz	Mainland	docks	315	311	308	304	301	297	299	301	303	305	307
Funchal	Madeira	docks	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063
Leixões	Mainland	docks	2 742	2 773	2 804	2 834	2 865	2 896	2 927	2 958	2 988	3 019	3 050
Lisboa	Mainland	docks	5 586	5 586	5 586	5 586	5 554	4 993	5 332	4 927	4 776	4 323	3 869
Ponta Delgada	Azores	docks	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080
Portimão	Mainland	docks	34	34	34	34	34	34	34	34	34	28	37
Porto Santo	Madeira	docks	402	402	402	402	402	402	402	402	402	402	402
Setúbal	Mainland	docks	1 453	1 453	1 453	1 453	1 453	1 453	1 502	1 551	1 601	1 650	1 699
Sines	Mainland	docks	1 038	1 026	1 014	1 003	991	979	945	911	876	842	808
Viana do Castelo	Mainland	docks	254	315	310	228	247	293	304	315	326	337	348

Sea Port	Location	Unit	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Aveiro	Mainland	docks	1 042	1 021	1 013	1 053	1 028	1 002	977	1 010	848	961
Canical	Madeira	docks	76	57	76	94	76	76	76	76	347	390
Faro	Mainland	docks	89	69	51	36	32	27	23	17	15	12
Figueira da Foz	Mainland	docks	309	260	262	292	271	271	271	406	359	476
Funchal	Madeira	docks	1 063	1 076	1 090	1 022	1 063	1 063	1 063	1 063	800	758
Leixões	Mainland	docks	3 113	3 090	2 952	2 815	2 814	2 814	2 813	2 727	2 637	2 612
Lisboa	Mainland	docks	3 597	3 735	3 713	3 473	3 474	3 474	3 475	3 455	3 251	3 129
Ponta Delgada	Azores	docks	1 080	1 047	1 125	1 067	1 080	1 080	1 080	1 112	1 095	1 035
Portimão	Mainland	docks	24	28	33	56	42	29	15	42	97	136
Porto Santo	Madeira	docks	402	402	399	398	400	400	400	400	405	392
Setúbal	Mainland	docks	1 625	1 603	1 609	1 669	1 592	1 516	1 439	1 389	1 404	1 632
Sines	Mainland	docks	728	806	753	927	1 124	1 321	1 518	1 518	1 458	1 632
Viana do Castelo	Mainland	docks	369	315	262	208	214	220	226	246	179	179

3.3.3.4.4.2 Ship Fleet

The fleet is composed mainly by general cargo ships. The fleet from the figure below refers to all ships that docked in national seaports irrespective of domestic or international movements.

Figure 3.73 – Ship fleet.



3.3.3.4.4.3 Fuel consumption

Fuel consumption is estimated with a bottom-up approach using fuel consumption factors combined with a top-down calibration with the energy balance. In a first step, domestic and international consumption are estimated with the bottom up approach. Then the international consumption is re-calculated by subtracting the estimated domestic consumption from the total sales reported in the energy balance, this is considered the top down calibration. This calibration does not affect the domestic fuel consumption calculated with the bottom-up approach.

$$FuelConsumption_{International} = FuelSales - FuelConsumption_{Domestic}$$

Table 3.106 – Total fuel sales³⁰

Fuel Sales	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
L ResO	t	407 823	406 206	403 591	334 853	305 775	290 920	306 451	311 196	320 960	416 843	475 743
L GasD	t	126 903	123 797	123 902	120 747	114 490	141 272	148 771	137 420	132 235	142 877	125 554

Fuel Sales	Unit	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
L ResO	t	331 358	366 423	444 170	529 904	457 115	516 191	552 950	590 249	547 252	506 320
L GasD	t	104 612	94 901	110 683	108 590	110 197	97 014	88 729	114 495	105 133	94 064

Source: DGEG

³⁰ L ResO – Residual fuel oil; L GasD - Diesel

Table 3.107 – Estimated fuel consumption (t)

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
L ResO	Domestic	61 244	60 348	59 288	58 035	57 009	53 023	55 409	57 417	58 675	52 793	46 988
L ResO	International	431 554	440 413	447 537	452 636	451 432	448 716	456 698	442 048	427 584	429 029	430 253
L ResO	Total	492 797	500 762	506 825	510 672	508 441	501 739	512 107	499 465	486 259	481 822	477 242
L GasD	Domestic	23 132	22 794	22 394	21 921	21 533	20 027	20 929	21 687	22 162	19 940	17 748
L GasD	International	163 002	166 349	169 039	170 965	170 510	169 485	172 499	166 966	161 503	162 049	162 511
L GasD	Total	186 135	189 143	191 433	192 886	192 043	189 512	193 428	188 653	183 665	181 989	180 259

Fuel	Region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
L ResO	Domestic	45 396	47 600	47 939	48 931	48 804	48 828	48 852	49 836	52 816	53 458
L ResO	International	412 368	420 785	415 054	423 117	411 428	399 120	386 812	402 246	479 587	515 738
L ResO	Total	457 764	468 384	462 993	472 048	460 233	447 948	435 664	452 082	532 403	569 196
L GasD	Domestic	17 147	17 979	18 107	18 482	18 434	18 443	18 452	18 824	19 949	20 192
L GasD	International	155 756	158 935	156 770	159 816	155 401	150 752	146 103	151 932	181 145	194 799
L GasD	Total	172 902	176 914	174 877	178 297	173 835	169 195	164 555	170 756	201 094	214 991

Table 3.108 – Estimated fuel consumption after top-down calibration (t).

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
L ResO	Domestic	61 244	60 348	59 288	58 035	57 009	53 023	55 409	57 417	58 675	52 793	46 988
	International	346 579	345 858	344 303	276 817	248 766	237 897	251 042	253 780	262 285	364 051	428 754
	Total	407 823	406 206	403 591	334 853	305 775	290 920	306 451	311 196	320 960	416 843	475 743
L GasD	Domestic	23 132	22 794	22 394	21 921	21 533	20 027	20 929	21 687	22 162	19 940	17 748
	International	103 770	101 003	101 508	98 826	92 957	121 244	127 843	115 733	110 073	122 936	107 806
	Total	126 903	123 797	123 902	120 747	114 490	141 272	148 771	137 420	132 235	142 877	125 554

Fuel	Region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
L ResO	Domestic	45 396	47 600	47 939	48 931	48 804	48 828	48 852	49 836	52 816	53 458	
	International	285 962	318 823	396 231	480 974	408 311	467 363	504 098	540 413	494 436	452 862	
	Total	331 358	366 423	444 170	529 904	457 115	516 191	552 950	590 249	547 252	506 320	
L GasD	Domestic	17 147	17 979	18 107	18 482	18 434	18 443	18 452	18 824	19 949	20 192	
	International	87 465	76 922	92 576	90 109	91 763	78 571	70 277	95 672	85 184	73 872	
	Total	104 612	94 901	110 683	108 590	110 197	97 014	88 729	114 495	105 133	94 064	

3.3.3.4.4.3.1 Tugs Fuel consumption

Data concerning tugs assistance operations within the national seaports allowed the incorporation of these emissions in the inventory. Tug fuel consumption was estimated for each manoeuvring ship in a seaport following the criteria shown in the Table 3.109. Specific tug fuel consumption factors were supplied by IPTM.

Table 3.109 – Criteria employed in the tugs fuel consumption estimation.

Ship Type	Seaport	Assisted Arrivals (%)	Assisted Departures (%)	N.º Of Tugs/Arrival	N.º Of Tugs/Departure
Small Size	All	20	0	1	0
Medium Size	All	50	25	1	1
Large Size	All	100	100	2	1
Super Large Size	Sines and Leixões	100	100	3	2
Super Large Size	All except Sines and Leixões	100	100	2	2

This estimation required the ship size classification expressed in table below.

Table 3.110 – Ship type classification for tugs fuel consumption estimation.

Ship Type	gt
Small Size	gt≤1000
Medium Size	10000≤gt<1000
Large Size	50000≤gt<10000
Super Large Size	gt>50000
gt: gross tonnage	

Finally the fuel consumption was added to the ship that needed the tugs service. The fuel tables presented above include fuel consumption in tugs operations.

3.3.3.4.5 Uncertainty Assessment

Activity level uncertainty refers to the fuel consumption uncertainty which depends on the number of movements, the distance travelled and fuel consumption factors. The global uncertainty is therefore obtained from:

$$U_{global} = \sqrt{U_{movements}^2 + U_{distance}^2 + U_{FC}^2}$$

Movement's uncertainty was assumed to be 5% as suggested in IPCC Good Practice Guidance and Uncertainty Management. The distance uncertainty was calculated assuming that ships speeds were constant between origin and destiny seaports. This allows the indirect assessment of the uncertainty trough the travelling time between seaports. For the same OD it is possible to estimate uncertainty according with differences between travelling times performed by the same type of ships. Finally, it

was assumed an uncertainty of 50% for fuel consumption factors proposed by EMEP/CORINAIR. Activity level uncertainty was estimated about 51% as referred in Table 3.111.

Table 3.111 – Navigation activity level uncertainty.

Source	Parameter	Value
All	Uglobal	50%
Movements	Umovements	5%
Distance Travelled	Udistance	15%
Fuel Consumption Factor	Ufc	48%

Following the recommendations of GPG the uncertainties of emission factor for CH₄ and N₂O, and for all types of vessels and navigation, were set respectively to 100% and 1000%.

3.3.3.4.6 Category-specific QA/QC and verification

Energy consumption was compared with data from the energy balance reported by DGEG. The difference in total fuel was around 0.4% in 2008 which could result from rounding values.

3.3.3.4.7 Recalculations

Recalculations for this sector comprise update of activity data from Madeira and update of LHV according with the energy balance.

Figure 3.74 – Recalculation of CO₂ for national navigation (kt)

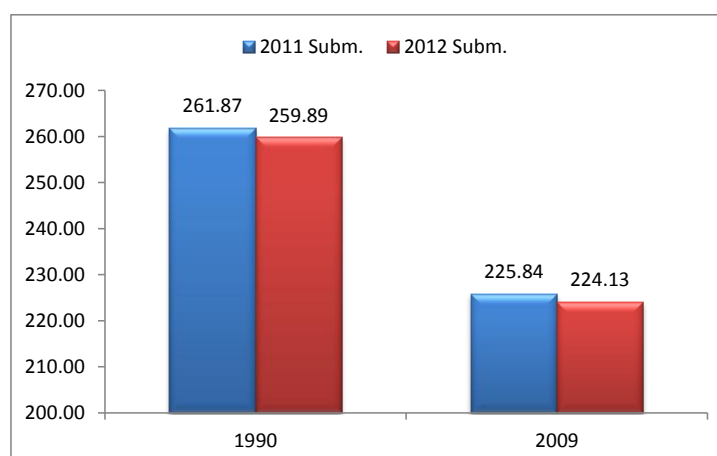


Figure 3.75 – Recalculation of CH₄ for national navigation (t)

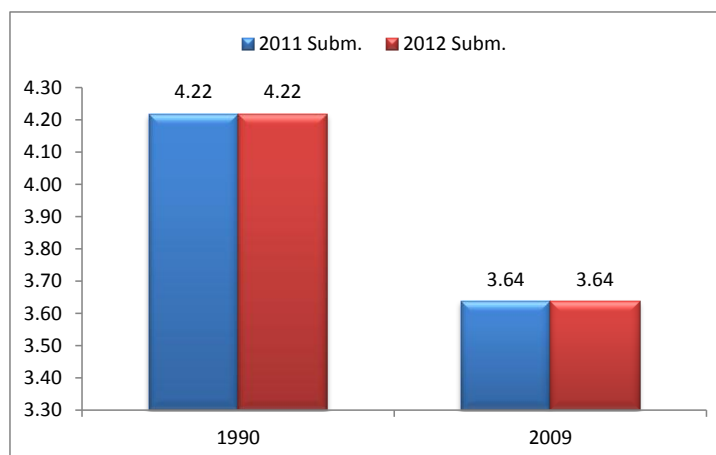
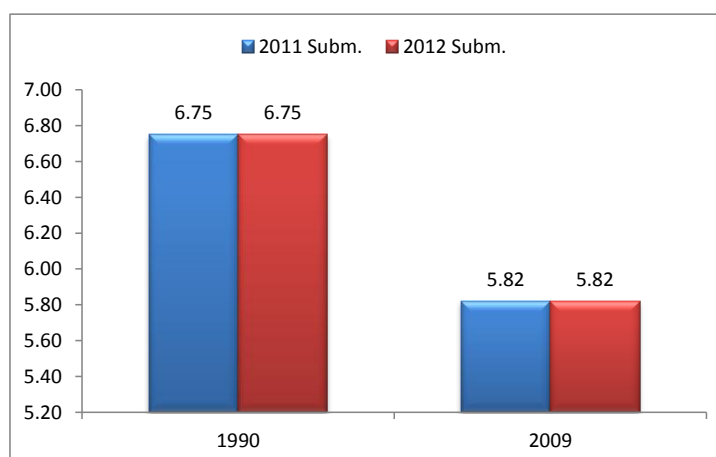


Figure 3.76 – Recalculation of N₂O for national navigation (t)



3.3.3.4.8 Further Improvements

No further improvements are planned for this sector.

3.3.3.5 Other Mobile Sources (CRF 1.A.3.e)

3.3.3.5.1 Overview

There is not much information allowing the estimation of emissions from off-road vehicles and machines, mainly because they are not individualized in the energy balances from DGEG. The only exceptions is the agriculture/forestry sector, where it is more or less evident that all gas-oil is used as energy source to vehicles and mobile machines, and the fishing vessels.

Emissions from off-road vehicles and machines from other sectors: industry, residential and institutional, are however quantified and included in emission totals but under activity-specific emission estimates. The fact that they are different equipments with different emission factors is also considered in the inventory because when emission factors were established for all those activities some assumptions were made concerning where the fuel was used. For instance, it was assumed that all petrol/gasoline and half of the diesel-oil was used in engines, and these may be either static or mobile.

Since there is very little information to completely characterize 1 A 3 e Other Transportation the notation key “Included Elsewhere” was associated with this source category:

- off-road vehicles and machines from manufacturing industries, residential and commercial/institutional are included together with the other combustion equipment of these source categories;
- emissions from off-road vehicles and machines from agriculture/forestry and fishing sectors are included in 1 A 4 c Agriculture/Forestry/Fisheries.

All methodologic descriptions associated with each of these sources are presented in the appropriate chapter (1.A.2 and 1.A.4).

3.3.4 Other Sectors (CRF 1.A.4.)

3.3.4.1 Overview

This source category refers to combustion in stationary and mobile sources (off-road) equipments that occur in commercial/institutional, residential, and agriculture/forestry/fishing activity sectors. The following stationary combustion equipments were included in this sector: boilers, co-generation equipment, machines and static engines are included in sector. Also included in 1.A.4 are emissions from fisheries bunkers and off road-road vehicles in agriculture/ forestry sector (both will have their own sub chapter in this report). As explained in 1.A.3.e due to contrains in DGEG’s energy balance off-road vehicles and machines from commercial/institutional and residential sectors could not be individualized from stationary combustions.

3.3.4.1.1 Commercial/Institutional (CRF1.A.4.a)

3.3.4.1.1.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in commercial, services and institutional sector. In this sector small other mobile sources are considered because no separation between fuel consumption is possible in the energy balance.

3.3.4.1.1.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance (CO₂) or emission factors, according to the pollutant, and using an IPCC Tier 2 methodology.

For Carbon Dioxide (CO₂), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$\begin{aligned}
 U_{CO_2(s,f)} &= EF_{CO_2(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3} \\
 Fossil_{CO_2(s,f)} &= U_{CO_2(s,f,y)} * C_{Fossil(f)} * 10^{-2}
 \end{aligned}$$

where,

$U_{CO_2(s,f)}$ - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

$Fossil_{CO_2(s,f)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

$EF_{CO_2(f)}$ – Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ – Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

$$Emi_{(p,s)} = \sum_f \sum_t [EF_{(f,s,t,y,p)} * Activity_{(f,s,t,p)}] * 10^{-3}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p for sub-sector s (ton/yr except CO₂ in kton/yr);

$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO₂ in kg/GJ);

$Activity_{(f,s,t)}$ - Energy Consumption of fuel f in sub-sector s and in equipment/technology t (GJ).

3.3.4.1.1.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following table and figures.

Table 3.112 - Fuels consumed in the commercial, services and institutional sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	2 377 775	2 082 473	1 987 019	2 067 733	3 669 386	4 274 308	3 304 671	1 388 428	2 838 261	3 440 598	3 314 158	3 449 183
Diesel/Gas Oil	L	204	5 639 815	6 917 498	8 280 078	8 445 426	8 591 550	7 888 815	8 726 269	13 105 635	16 719 028	18 351 231	18 391 384	21 956 952
Kerosene	L	206	74 919	33 396	64 201	73 783	24 510	13 467	12 685	25 068	27 142	17 200	6 137	7 572
Motor Gasoline	L	208	579 621	638 690	617 687	605 093	1 036 563	1 174 935	1 419 347	2 593 860	3 262 569	3 219 051	2 217 473	2 854 812
LPG	L	303	1 198 048	1 373 765	1 580 371	1 897 820	1 870 938	1 268 113	2 562 028	3 836 555	4 010 705	4 233 884	4 414 101	5 206 806
City Gas	L	308	504 399	556 773	528 075	643 808	647 871	732 803	785 507	777 866	908 944	1 044 085	732 238	69 195
Natural Gas	G	301	0	0	0	0	0	0	0	15 281	545 827	1 542 075	2 497 381	3 913 556
Biogas	B	309	0	0	0	0	0	0	0	0	0	49 887	102 121	54 482
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	3 534 234	2 907 217	3 152 344	3 182 777	3 540 956	3 560 519	2 220 557	1 905 882	3 678 836	-	-
Diesel/Gas Oil	L	204	24 194 942	29 771 236	33 061 615	28 690 066	14 637 324	14 949 743	12 587 345	12 093 159	4 712 368	-	-
Kerosene	L	206	9 494	7 344	7 216	6 334	8 228	4 563	1 298	5 191	879	-	-
Motor Gasoline	L	208	2 486 947	2 364 277	2 426 561	1 637 165	1 025 939	797 979	28 471	27 801	30 062	-	-
LPG	L	303	5 113 787	5 287 262	5 413 453	4 806 060	4 349 043	4 487 167	5 143 317	4 804 021	2 196 378	-	-
City Gas	L	308	0	0	0	0	0	0	0	0	0	-	-
Natural Gas	G	301	4 987 653	6 358 284	6 381 245	6 286 200	7 109 398	8 163 460	7 646 085	9 918 423	10 007 179	-	-
Biogas	B	309	60 612	48 531	100 962	135 768	128 814	108 242	173 604	180 362	209 357	-	-
Biodiesel	B	223	0	0	0	0	98 637	176 804	128 939	199 180	66 413	-	-

The Diesel/Gas Oil time series show a drop in consumption from 2005 to 2006. This fact results from reallocation, in the energy balance, of road gas oil from services not specified to agriculture (DGEG). There is a decrease in diesel oil consumption in 2010 for the services sector that results from the incorporation of data from the 2010 Survey on Energy Consumption in the Residential Sector. This decrease is coupled with an increase in diesel consumption in the residential sector.

Figure 3.77 – Total Energy Consumption in fuels in the commercial, services and institutional sector

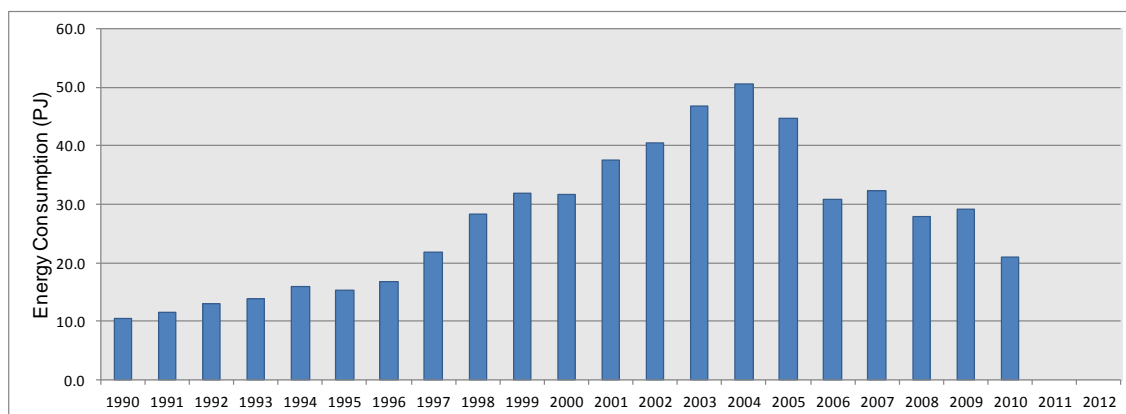
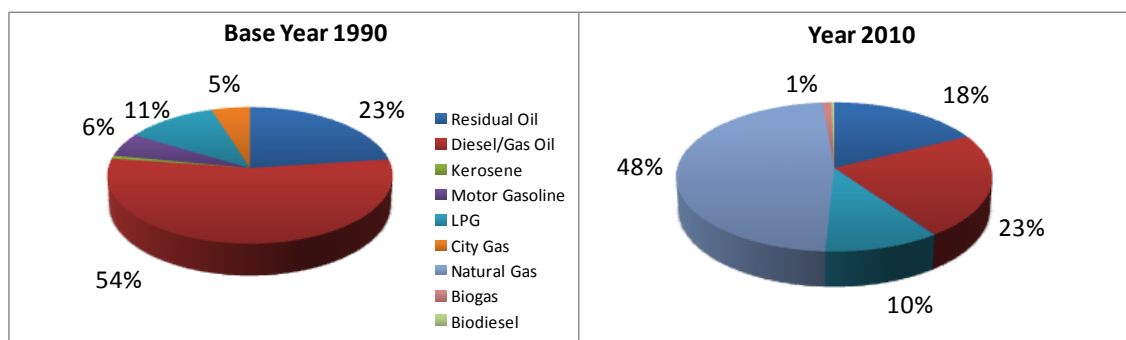


Figure 3.78 – Consumption of energy in fuels in the commercial, services and institutional sector in 1990 and 2010



3.3.4.1.1.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3.113 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Commercial, services and institutional sector

Fuel		NAPFUE	LHV	CO ₂			CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	1.6	0.6
Gas Oil	L	204	42.6	74.1	0.990	100	5.0	0.6
Diesel Oil	L	205	42.6	74.1	0.990	100	0.6	0.6
Kerosene	L	206	43.8	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.0	69.3	0.990	100	9.9	0.6
LPG	L	303	46.0	63.1	0.995	100	1.5	1.4
City Gas	L	308	15.7	60.0	0.995	100	1.5	1.4
Natural Gas	G	301	46.1	56.1	0.995	100	1.2	1.4
Biogas	B	309	34.7	52.0	1.000	0	0.72	1.4
Biodiesel	B	223	37.0	73.9	1.000	0	5.0	0.6

3.3.4.1.1.5 Uncertainty Assessment

The uncertainty in activity data was established from the knowledge of the way that activity data information was collected in the inventory but nevertheless trying as much as possible to make an assessment consistent to what is proposed in the GPG. Therefore, for fuel consumption except biomass, uncertainty was set at 10 per cent. For biomass fuels, considering that the quantification error is higher, namely due to lack of clarification of the actual moisture content in which biomass is reported, the uncertainty was assumed to be 60 per cent.

The uncertainty of CO₂ emission factors was assumed to be 5 per cent for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N₂O were set respectively at 150 per cent and an order of magnitude.

3.3.4.1.1.6 Category-specific QA/QC and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Only minor differences in natural gas consumption between data sources were identified for Commercial and Public Services sector (less than 10 per cent). For petroleum product the differences between data sources are greater than natural gas (around 30 per cent). DGEG reported that there were compilation errors in the information sent to IEA, which may explain the differences found.

3.3.4.1.1.7 Recalculations

Recalculations for this source category comprise:

- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all time series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates;

- Error correction in the estimation spreadsheet concerning CO₂ emission factor for biogas (1999-2009).

3.3.4.1.1.8 Further Improvements

No further improvements are planned for this sector.

3.3.4.1.2 Residential (CRF1.A.4.b)

3.3.4.1.2.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in the residential sector. In this sector small other mobile sources are considered because no separation between fuel consumption is possible with DGEG's energy balance data.

3.3.4.1.2.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance (CO₂) or emission factors, according to the pollutant, and using an IPCC Tier 2 methodology.

For Carbon Dioxide (CO₂), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO_2(s,f)} = EF_{CO_2(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

$$Fossil_{CO_2(s,f)} = U_{CO_2(s,f,y)} * C_{Fossil(f)} * 10^{-2}$$

where,

$U_{CO_2(s,f)}$ - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

$Fossil_{CO_2(s,f)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

$EF_{CO_2(f)}$ - Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ - Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

$$Emi_{(p,s)} = \sum_t [EF_{(f,s,t,y,p)} * Activity_{(f,s,t,p)}] * 10^{-3}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p for sub-sector s (ton/yr except CO₂ in kton/yr);

$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO₂ in kg/GJ);

$Activity_{(f,s,t)}$ - Energy Consumption of fuel f in sub-sector s and in equipment/technology t (GJ).

3.3.4.1.2.3 *Activity Data*

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following table and figures. Charcoal consumption was obtained from an inquiry made to the residential sector by DGEG.

Table 3.114 - Fuels consumption in the residential sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	63 570	62 136	55 570	51 491	66 733	42 592	43 339	40 296	10 922	3 883	2 596	0
Diesel/Gas Oil	L	204	158 313	210 952	285 685	205 156	190 401	201 062	132 690	91 954	106 045	144 312	90 483	82 460
Kerosene	L	206	793 847	753 503	626 435	530 823	514 054	356 029	416 128	728 737	761 963	705 693	365 545	194 522
Motor Gasoline	L	208	6 189	7 791	5 904	5 653	6 256	9 584	13 758	14 908	14 701	6 081	773	93
LPG	L	303	23 458 865	24 712 407	26 379 429	27 970 640	28 407 682	28 700 786	30 988 266	30 036 100	31 626 170	33 487 398	34 345 777	31 576 352
City Gas	L	308	1 923 876	1 950 110	1 984 435	2 073 096	1 984 456	1 929 958	1 977 160	1 991 632	2 106 088	2 039 388	1 212 913	156 763
Natural Gas	G	301	0	0	0	0	0	0	0	34 275	387 929	1 458 114	3 090 090	4 769 698
Wood	B	111	53 770 921	51 344 184	49 611 501	48 513 399	48 000 716	48 033 473	48 172 943	46 841 627	45 510 311	44 178 995	42 847 679	41 516 363
Charcoal	B	112	749 950	738 791	727 632	716 473	705 314	694 155	682 996	671 837	660 678	626 132	591 586	557 041
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	0	0	0	0	0	0	0	0	0	-	-
Diesel/Gas Oil	L	204	120 375	380 360	667 243	600 226	1 439 028	574 557	332 928	395 813	5 218 169	-	-
Kerosene	L	206	147 927	89 834	88 654	50 117	30 792	25 203	28 678	22 398	27 213	-	-
Motor Gasoline	L	208	24 864	36 183	37 371	57	79	0	0	0	0	-	-
LPG	L	303	31 565 739	30 542 812	30 029 737	29 312 438	27 074 925	25 417 104	22 777 808	21 795 551	23 214 739	-	-
City Gas	L	308	0	0	0	0	0	0	0	0	0	-	-
Natural Gas	G	301	5 967 854	7 117 191	7 374 400	8 125 511	8 239 604	8 954 314	12 165 959	10 747 536	11 453 606	-	-
Wood	B	111	40 185 047	38 853 731	37 522 415	36 191 099	34 859 783	33 528 467	32 197 151	30 865 835	29 534 519	-	-
Charcoal	B	112	522 495	487 949	453 404	418 858	384 312	349 767	315 221	280 675	246 130	-	-
Biodiesel	B	223	0	0	0	0	1 566	2 794	1	42	7	-	-

There is an increase in diesel oil consumption in 2010 for the residential sector that results from the incorporation of data from the 2010 Survey on Energy Consumption in the Residential Sector. This increase is coupled with a decrease in diesel consumption in the services sector.

Figure 3.79 – Total Energy Consumption in fuels in the residential sector

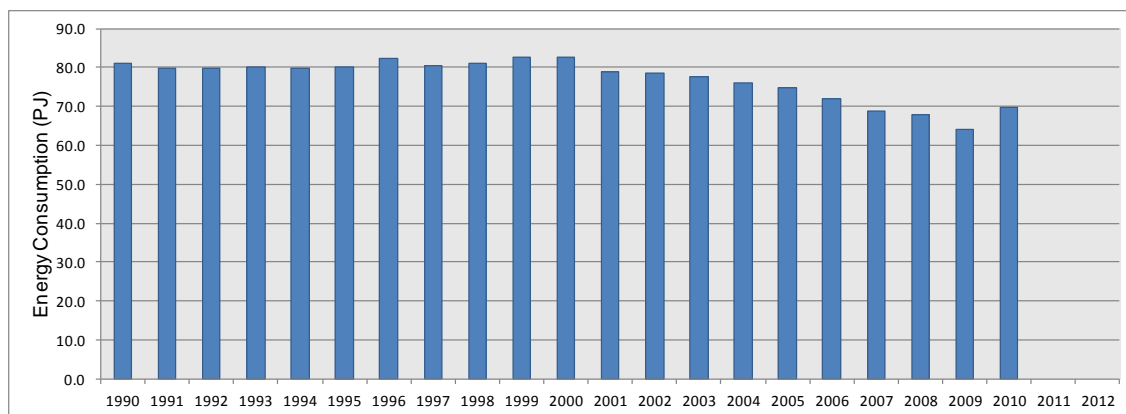
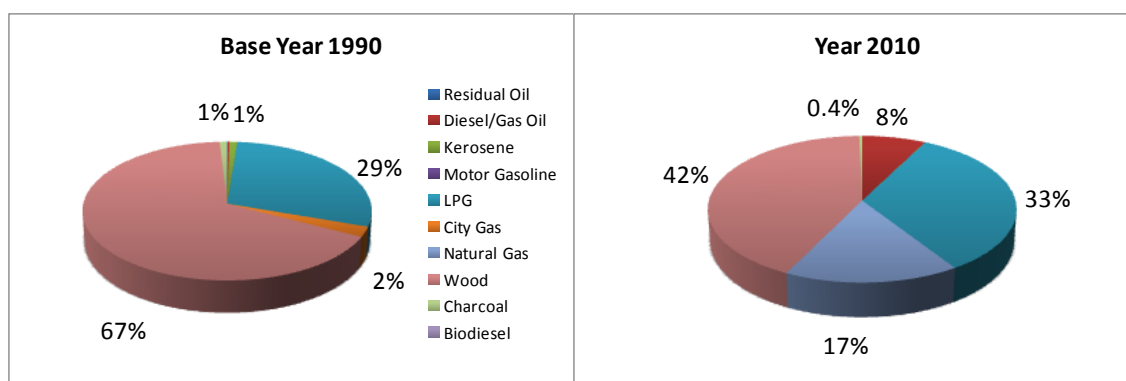


Figure 3.80 – Consumption of energy in fuels in the residential sector in 1990 and 2010



3.3.4.1.2.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3.115– Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Residential sector

Fuel		NAPFUE	LHV	CO ₂		CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	5.1
Diesel/Gas Oil	L	204	42.6	74.1	0.990	100	5.0
Kerosene	L	206	43.8	71.9	0.990	100	5.0
Motor Gasoline	L	208	44.0	69.3	0.990	100	9.9
LPG	L	303	46.0	63.1	0.995	100	1.5
City Gas	L	308	15.7	60.0	0.995	100	1.5
Natural Gas	G	301	46.1	56.1	0.995	100	2.5
Wood	B	111	12.6	109.6	1.000	0	300
Charcoal	B	112	25.1	109.6	1.000	0	300
Biodiesel	B	223	37.0	73.8	1.000	0	5.0

3.3.4.1.2.5 Uncertainty Assessment

The uncertainty in activity data was established from the knowledge of the way that activity data information was collected in the inventory but nevertheless trying as much as possible to make an assessment consistent to what is proposed in the GPG. Therefore, for fuel consumption except biomass, uncertainty was set at 10 per cent. For biomass fuels, considering that the quantification error is higher, namely due to lack of clarification of the actual moisture content in which biomass is reported, the uncertainty was assumed to be 60 per cent.

The uncertainty of CO₂ emission factors was assumed to be 5 per cent for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N₂O were set respectively at 150 per cent and an order of magnitude.

3.3.4.1.2.6 Category-specific QA/QA and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). There is a general agreement between data source for this source category.

3.3.4.1.2.7 Recalculations

Recalculations for this source category comprise:

- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates;
- Correction of an estimation error concerning N₂O emission from gaseous fuels (1997-2009). Previously no N₂O emissions were reported for this pollutant associated with consumption of gaseous fuels;
- Correction of inconsistencies identified in the consumption time series of biomass (1997-2009);
- Revision of the charcoal fuel consumption time series from 1999 to 2009. This resulted from a report made by DGEG concerning fuel consumption in the residential sector;
- Error correction in the estimation spreadsheet concerning CO₂ emission factor for biogas (1999-2009).

3.3.4.1.2.8 Further Improvements

No further improvements are planned for this sector.

3.3.4.1.3 Agriculture / Forestry / Fishing – Stationary (CRF1.A.4.c.i)

3.3.4.1.3.1 Overview

Emission considered in this source category cover stationary combustion in the agriculture and forestry sectors. Stationary combustion in the fishing industry was included together with fishing bunker in 1.A.4.c.iii.

3.3.4.1.3.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance (CO₂) or emission factors, according to the pollutant, and using an IPCC Tier 2 methodology.

For Carbon Dioxide (CO₂), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO_2(s,f)} = EF_{CO_2(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

$$Fossil_{CO_2(s,f)} = U_{CO_2(s,f)} * C_{Fossil(f)} * 10^{-2}$$

where,

$U_{CO_2(s,f)}$ - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

$Fossil_{CO_2(s,f)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

$EF_{CO_2(f)}$ – Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO_2/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ – Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

$$Emi_{(p,s)} = \sum_f \sum_t [EF_{(f,s,t,y,p)} * Activity_{(f,s,t,p)}] * 10^{-3}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p for sub-sector s (ton/yr except CO_2 in kton/yr);

$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO_2 in kg/GJ);

$Activity_{(f,s,t)}$ - Energy Consumption of fuel f in sub-sector s and in equipment/technology t (GJ).

3.3.4.1.3.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following table and figures.

Table 3.116 - Fuels consumed in agriculture and forestry sector (GJ) (excluding mobile sources)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	524 617	376 193	286 335	343 681	488 068	426 845	511 483	547 071	474 723	677 941	889 643	799 840
Kerosene	L	206	350 338	311 043	272 158	207 862	200 980	191 157	183 421	427 000	494 010	24 166	44 397	47 082
Motor Gasoline	L	208	33 650	35 681	47 407	44 936	134 763	129 648	162 646	197 586	174 417	159 737	42 723	119 538
LPG	L	303	329 856	405 427	478 962	575 900	580 807	572 444	826 953	560 179	713 861	674 638	496 882	673 259
Natural Gas	G	301	0	0	0	0	0	0	0	0	35	169	4 740	198 384
Biogas	B	309	0	0	0	0	0	0	0	0	0	0	9 294	7 773

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	1 207 470	1 083 548	755 230	867 118	608 637	298 917	278 584	125 240	221 062	-	-
Kerosene	L	206	50 284	47 237	48 915	54 581	56 434	32 446	38 935	45 173	39 061	-	-
Motor Gasoline	L	208	106 820	116 977	117 435	208 555	153 501	100 611	36 091	32 407	23 740	-	-
LPG	L	303	639 651	532 506	523 451	541 228	493 957	449 407	362 700	296 549	305 383	-	-
Natural Gas	G	301	265 961	286 824	276 322	305 044	299 780	340 073	284 165	365 414	392 663	-	-
Biogas	B	309	5 939	6 344	11 122	29 039	26 931	20 251	13 766	19 833	23 013	-	-

Figure 3.81 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources)

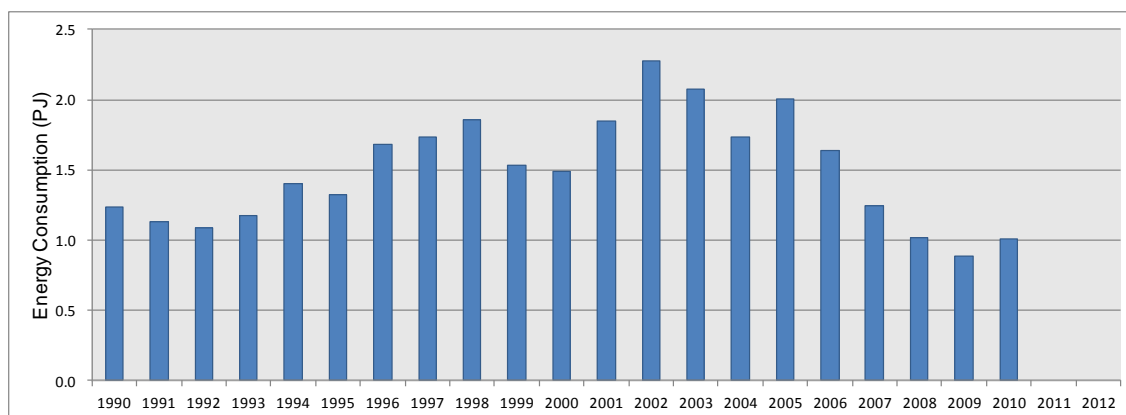
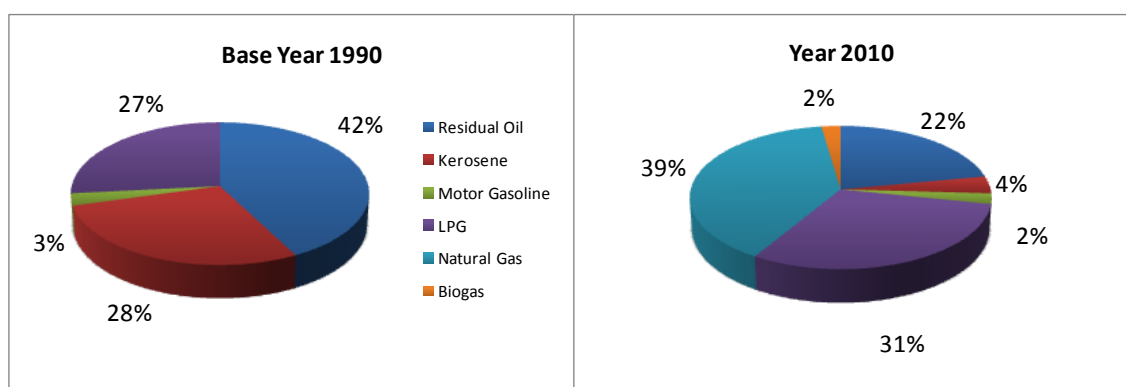


Figure 3.82 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2010



3.3.4.1.3.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3.117 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Commercial, services and institutional sector - Agriculture / Forestry / Fishing – Stationary sector

Fuel		NAPFUE	LHV	CO ₂			CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	1.6	0.6
Kerosene	L	206	43.8	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.0	69.3	0.990	100	9.9	0.6
LPG	L	303	46.0	63.1	0.995	100	1.5	1.4
Natural Gas	G	301	46.1	56.1	0.995	100	1.2	1.4
Biogas	B	309	34.7	52.0	1.000	0	0.72	1.4

3.3.4.1.3.5 Uncertainty Assessment

The uncertainty in activity data was established from the knowledge of the way that activity data information was collected in the inventory but nevertheless trying as much as possible to make an assessment consistent to what is proposed in the GPG. Therefore, for fuel consumption except biomass, uncertainty was set at 10 per cent. For biomass fuels, considering that the quantification error is higher, namely due to lack of clarification of the actual moisture content in which biomass is reported, the uncertainty was assumed to be 60 per cent.

The uncertainty of CO₂ emission factors was assumed to be 5 per cent for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N₂O were set respectively at 150 per cent and an order of magnitude.

3.3.4.1.3.6 Category-specific QA/QA and Verification

Following the same procedure as in other 1.A.4 source categories where energy balance was used as the main data source, a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Only minor differences between data sources were identified for this source category.

3.3.4.1.3.7 Recalculations

Recalculations for this source category comprise:

- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (1990-2009). These new values were accompanied by

revised LHV which were also updated in the INERPA. The difference between newer and older values is small;

- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data).

3.3.4.1.3.8 Further Improvements

No further improvements are planned for this sector.

3.3.4.1.4 Agriculture / Forestry / Fishing – Off-road Vehicles and Other Machinery (CRF1.A.4.c.ii)

3.3.4.1.4.1 Overview

Due to typical operation in vast land areas, agriculture and forestry activities are heavily dependent on machines and off-road vehicles: tractors from 5 kW up to 250 kW, harvesters, sprayers, mowers, tillers, chain saws, haulers, shredders and log loaders among others.

Only gas-oil is assumed to be an energy source for mobile equipments in this activity. Consumption of biodiesel with gas oil was assumed in the energy balance data, in accordance with the explained in 1A2 methodology chapter.

3.3.4.1.4.2 Methodology

Emissions to atmosphere of ultimate CO₂ from fossil origin were estimated from CO₂ total emissions by:

$$\text{Fossil}_{\text{CO}_2(y)} = \sum_f [\text{EF}_{\text{CO}_2} * \text{Fac}_{\text{OX}} * \text{Cons}_{\text{Fuel}(y)} * \text{LHV}] * 10^{-5}$$

where

Fossil_{CO₂(y)} - Emissions of carbon dioxide to atmosphere from combustion of diesel oil in agriculture off road vehicles and machinery (ton);

EF_{CO₂} – Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

Fac_{OX} – Oxidation factor for diesel oil (ratio 0-1);

Cons_{Fuel(f,y)} - Consumption of diesel oil in year y (ton/yr);

LHV_(f) - Low Heating Value (MJ/kg).

Emissions for other pollutants are estimated with the following formula:

$$\text{Emission}_{(p,y)} = \text{EF}_{(p)} * \text{Cons}_{\text{Fuel}(y)} * 10^{-3}$$

where

Emission_(p,y) - Emission of pollutant p in year y (ton/yr);

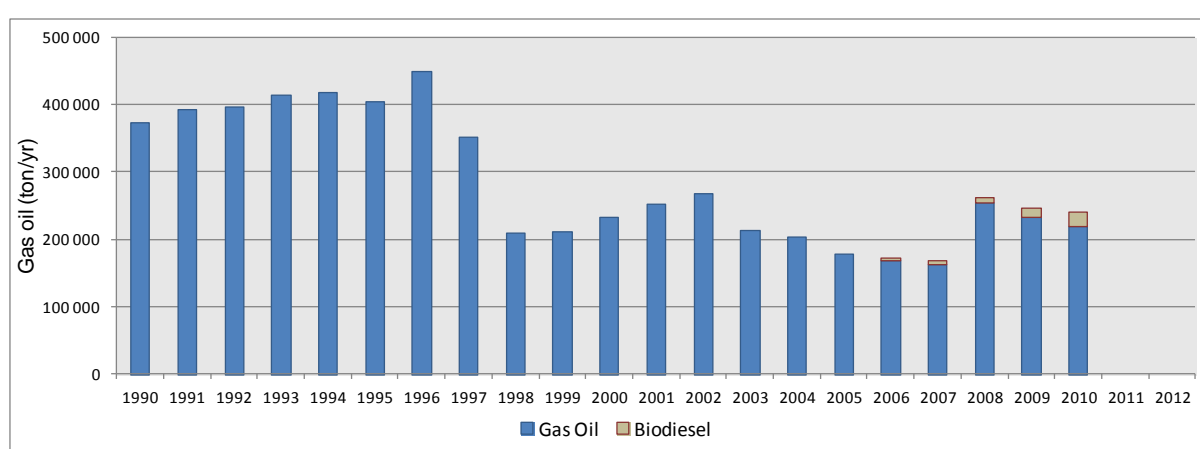
EF_(p) - Emission factor for pollutant p (kg/ton);

$Cons_{Fuel(y)}$ - consumption of gas oil in agriculture machines and off-road vehicles during in year y (ton/yr).

3.3.4.1.4.3 Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to the latest inventory year from DGEG in the energy balance. Although there is no clear specification, in the original database, in which combustion equipment each fuel is used it was assumed that all gas-oil is used in machines and other off-road vehicles. The same suppositions were made for biodiesel since both are used together. Quantities that were consumed are presented in figure below. The increase in gas oil from 2007 to 2008 results from a fuel reclassification in the energy balance.

Figure 3.83 - Consumption of gas-oil in machines and other off-road vehicles



3.3.4.1.4.4 Emission Factors

The set of emission factors utilized to estimate air emissions from use of gas oil in agriculture machines and other off-road vehicles were determined as the average value of the values proposed in tables I-47 and I-49 of the Revised 1996 IPCC Guidelines (IPCC,1997). In general for biodiesel EF were considered the same as for gas oil, with the exceptions shown in the following table.

Table 3.118 – Emission factors for gas oil use in agriculture machines and other off-road vehicles

Parameter	EF		Unit
	Gas oil	Biodiesel	
LHV	42.6	37.0	MJ/kg
SOx	0.3	0	%
NOx	56.9	56.9	g/kg
NMVOC	8.4	8.4	
CH4	0.3	0.3	
CO	20.7	20.7	
CO2	73.3	74.1	kg/GJ
%CO2 Fossil	100	0.0	%
Fac _{ox}	0.990	1	0..1
N2O	1.3	1.3	g/kg

3.3.4.1.4.5 *Uncertainty Assessment*

The time trend of diesel oil consumption in this activity shows a sharp and unexpected decrease between 1996 and 1998. Although future developments are expected to correct this situation, in this year the uncertainty in activity data was set as the maximum inter-annual variation, 80 per cent. Concerning emission factors, because there is no specific information for this activity in the GPG, the same uncertainty values that were used for road transportation were used to estimate uncertainty from off-road emissions of CO₂, CH₄ and N₂O.

3.3.4.1.4.6 *Category-specific QA/QA and Verification*

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

3.3.4.1.4.7 *Recalculations*

Recalculations for this source category comprise:

- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates.

3.3.4.1.4.8 *Further Improvements*

No further improvements are planned for this sector.

3.3.4.1.5 *Agriculture / Forestry / Fishing – Fishing (CRF1.A.4.c.iii)*

3.3.4.1.5.1 *Overview*

Emission in this source category include both stationary and other mobile source (fisheries bunkers). Stationary equipments included those associated with fishing industry, aquaculture or sea ports that are realized inland and not in water vessels. Fishing bunker represent emission from local costal fishing, deep-sea fishing and cod-fish fishing vessels.

In the inventory process it was assumed that marine diesel engines are the main power source for ships either for transport or shipping activities. Small local fishing and sport ships do in fact use petrol-engines but they represent a small proportion of total consumption and for most situations their fuel consumption cannot be individualised from road traffic consumption. Again consumption of biodiesel was determined as a part of the gas oil since 2006.

3.3.4.1.5.2 *Methodology*

3.3.4.1.5.2.1 *Stationary Equipment*

Emissions were estimated from fuel/energy consumption using either mass balance (CO₂) or emission factors, according to the pollutant, and using an IPCC Tier 2 methodology.

For Carbon Dioxide (CO₂), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$\begin{aligned}
 U_{CO_2(s,f)} &= EF_{CO_2(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3} \\
 Fossil_{CO_2(s,f)} &= U_{CO_2(s,f,y)} * C_{Fossil(f)} * 10^{-2}
 \end{aligned}$$

where,

$U_{CO_2(s,f)}$ - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

$Fossil_{CO_2(s,f)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

$EF_{CO_2(f)}$ - Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$Fac_{OX(f)}$ - Oxidation factor for fuel f (ratio 0..1);

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

$$Emi_{(p,s)} = \sum_t [EF_{(f,s,t,y,p)} * Activity_{(f,s,t,p)}] * 10^{-3}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p for sub-sector s (ton/yr except CO₂ in kton/yr);

$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO₂ in kg/GJ);

$Activity_{(f,s,t)}$ - Energy Consumption of fuel f in sub-sector s and in equipment/technology t (GJ).

3.3.4.1.5.2.2 Fishing Bunker

Emissions for all pollutants other than CO₂ are estimated for each ship type using the following formula:

$$Emission_{(n,p,y)} = \sum_f [EF_{(n,f,p)} * Cons_{Fuel(n,f,y)}] * 10^{-3}$$

where

$Emission_{(n,p,y)}$ - Total emission of pollutant p in year y from ships of class n (ton/yr);

$EF_{(n,f,p)}$ - Quantity of pollutant p emitted, variable with fuel type f and ship class n (kg/ton);

$Cons_{Fuel(n,f,y)}$ - consumption by ships of type n of fuel f during year y (ton/yr).

Emissions of carbon dioxide are estimated from:

$$\text{Fossil}_{\text{CO}_2(n,y)} = \sum_f [\text{EF}_{\text{CO}_2(f)} * \text{Fac}_{\text{OX}(f)} * \text{C}_{\text{Fossil}(f)} * \text{Cons}_{\text{Fuel}(n,f,y)} * \text{LHV}_{(f)}] * 10^{-5}$$

Where,

$\text{Fossil}_{\text{CO}_2(y)}$ - Emissions of carbon dioxide to atmosphere from combustion of fossil origin from ships of class n (ton);

$\text{EF}_{\text{CO}_2(f)}$ – Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO_2/GJ);

$\text{Fac}_{\text{OX}(f)}$ – Oxidation factor for fuel f (ratio 0..1);

C_{Fossil} - Percentage of carbon from fossil origin in fuel f (%);

$\text{Cons}_{\text{Fuel}(n,f,y)}$ - Consumption of fuel f in year y from ship type n (ton/yr);

$\text{LHV}_{(f)}$ - Low Heating Value (MJ/kg).

3.3.4.1.5.3 Activity Data

Data on fuel consumption in the fishing sector was obtained from DGEG's energy balance. Since there is no distinction between fishing vessels and static equipment in this data source (situation similar to that found in other 1.A.4 and 1.A.2 source categories), new data was obtained concerning bunker fuel sales (source: DGEG). With this new data a separation between fuel consumption in mobile and non-mobile equipment was possible. The resulting fuel consumption for static equipment can be found in the following table and figures.

Table 3.119 - Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	4 004	5 415	7 458	9 303	7 681	12 145	5 132	8 888	6 383	49 680	6 483	18 055
Diesel/Gas Oil	L	204	99 086	95 355	84 795	74 186	77 645	84 915	64 556	209 384	597 882	0	1 081 354	2 179 005
Kerosene	L	206	7	0	7	7	0	0	0	0	2 652	74 960	10 079	94
Motor Gasoline	L	208	1 406	0	214	85	278	707	985	728	4 040	61 587	279 165	286 314
LPG	L	303	2 847	5 792	4 077	1 499	2 148	0	110	3 902	2 531	8 434	20 809	32 648
Natural Gas	G	301	0	0	0	0	0	0	0	0	0	0	0	0
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	28 129	25 341	0	0	13 012	0	48 147	0	91 620	-	-
Diesel/Gas Oil	L	204	1 097 824	596 445	568 387	587 681	692 877	445 143	519 129	0	1 052 313	-	-
Kerosene	L	206	47	47	320	15	0	0	0	0	0	-	-
Motor Gasoline	L	208	280 882	278 706	260 910	29 919	31 819	26 126	5 569	30 062	19 971	-	-
LPG	L	303	21 140	20 708	91 294	5 903	5 967	2 303	5 778	3 014	1 675	-	-
Natural Gas	G	301	0	0	0	0	1 319	2 188	1 945	2 999	4 255	-	-
Biodiesel	B	223	0	0	0	0	48 124	73 390	70 525	117 356	235 064	-	-

Figure 3.84 – Total Energy Consumption in fuels in fisheries (excluding consumption in fishing vessels)

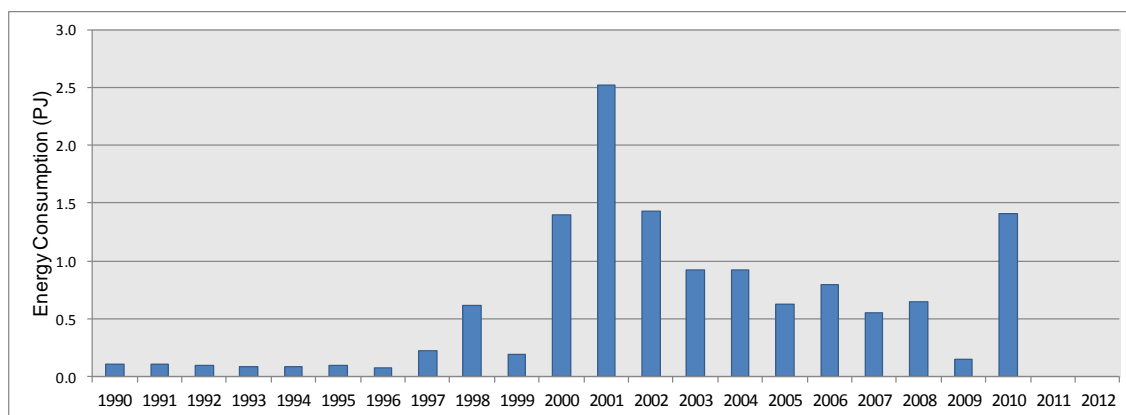
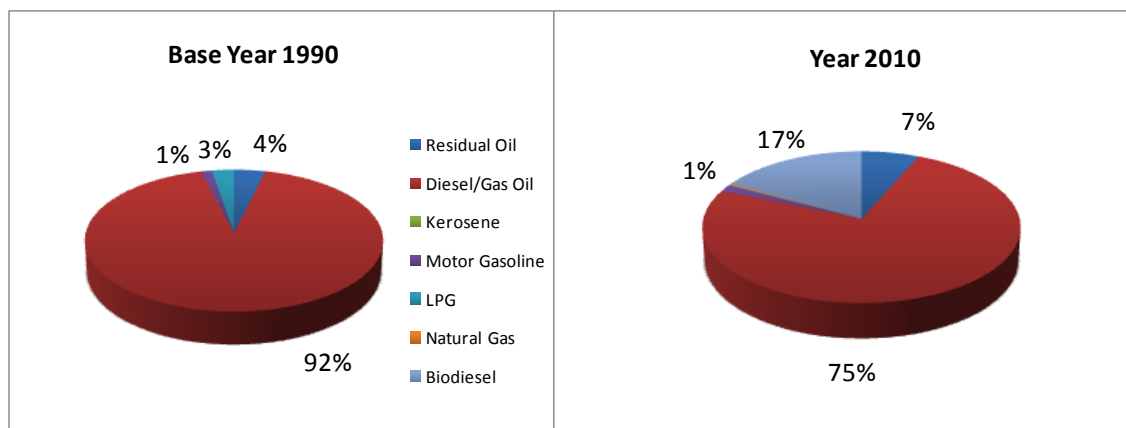


Figure 3.85 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2010



Total fuel consumption in fishing bunkers can be seen in the following table and figure.

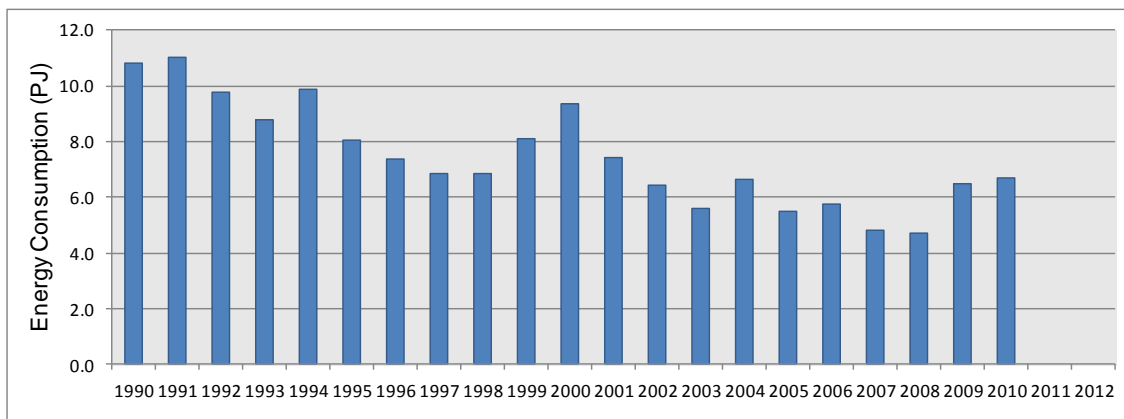
Table 3.120 - Fuels consumed in fishing bunkers (GJ)³¹

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Thin Fuel-oil	L	203	0	6 000	0	81 600	552 240	53 520	32 000	19 520	21 760	12 880	4 000	0
Thick Fuel-oil	L	203	0	0	0	0	413 200	96 000	24 000	22 400	42 240	21 120	0	0
Diesel/Gas Oil	L	204	10 783 849	11 035 700	9 752 418	8 671 656	8 912 346	7 898 551	7 321 406	6 789 503	6 794 700	8 072 743	9 350 785	7 398 427
NATO's Nafta	L	203	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Thin Fuel-oil	L	203	0	0	0	0	0	0	0	0	0	-	-
Thick Fuel-oil	L	203	0	0	0	0	0	0	0	714 669	765 555	-	-
Diesel/Gas Oil	L	204	6 446 147	5 591 932	6 630 905	5 496 620	5 749 321	4 798 240	4 694 265	5 765 758	5 916 129	-	-
NATO's Nafta	L	203	0	0	0	0	0	0	0	0	0	-	-

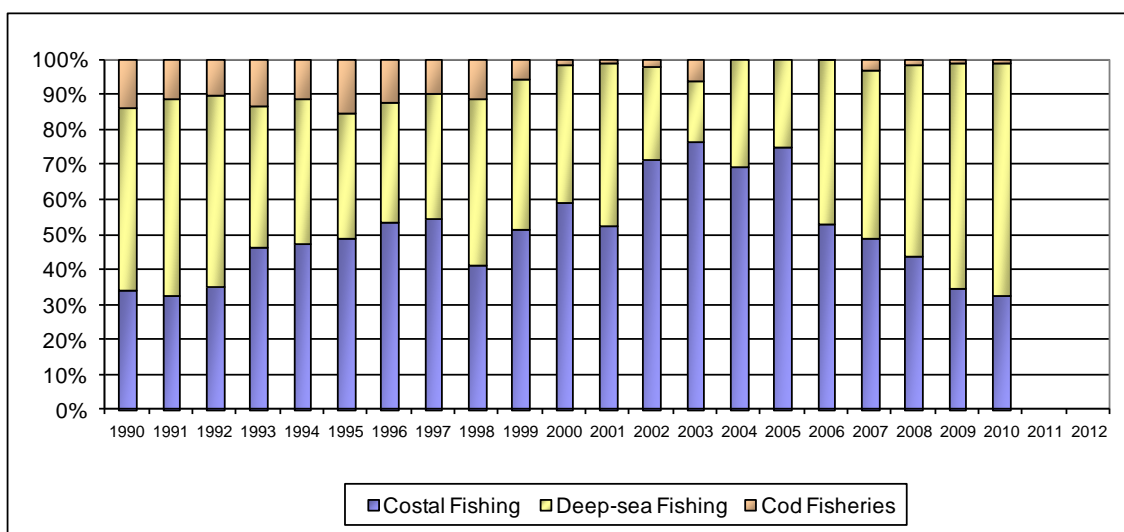
³¹ The same situation that was described for transport navigation is true here. It was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha, gas-oil and diesel oil, but available emission factors again do not distinguish these fuel types

Figure 3.86 – Consumption of fuel oil in fishing bunkers



Additional information in DGEG annual reports, allows for the division of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels³². Percentage for each type of fisheries is presented in next figure.

Figure 3.87 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries



3.3.4.1.5.4 Emission Factors

3.3.4.1.5.4.1 Stationary Equipment

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);

³² All fishing activities were allocated to national total although it is true that some may not be realized in territorial waters or EMEP area. That is clearly the case of cod-fish fishing and it is also partly true for deep-sea fishing.

- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3.121 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Fisheries – stationary equipment sector

Fuel		NAPFUE	LHV	CO ₂			CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	1.6	0.6
Gas Oil	L	204	42.6	74.1	0.990	100	5.0	0.6
Diesel Oil	L	205	42.6	74.1	0.990	100	0.6	0.6
Kerosene	L	206	43.8	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.0	69.3	0.990	100	9.9	0.6
LPG	L	303	46.0	63.1	0.995	100	1.5	1.4
Natural Gas	G	301	46.0	56.1	0.995	100	1.2	1.4
Biodiesel	B	223	37.0	73.9	1.000	0	5.0	0.6

3.3.4.1.5.4.2 Fishing Bunker

Except for carbon dioxide and sulphur oxide, emissions were estimated using default emission factors (kg/ton) from IPCC 1996 Revised Guidelines (table I-47 in IPCC,1997) for most pollutants. The following criteria were used to choose the most suitable emission factors:

- “Ocean-going ships” for national and international transport navigation, deep-sea fishing and cod fishing;
- “Boat” in the case of coastal fishing vessels.

For carbon dioxide emission factors are in kg/GJ in a similar mode to other combustion activities. Sulphur oxide emissions are dependent on sulphur content of fuel. Emission factors are presented in next table.

Table 3.122 – Emission factors for Water Borne Navigation and Fishing Vessels

EF	Units	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries
		Gas-oil		Biodiesel		Fuel-oil	
LHV	MJ/kg	42.6		37.0		40.0	
SO _x	%	0.3		0.0		3	
NO _x	g/kg	67.5	87	67.5	87	67.5	87
NMVOC	g/kg	4.9					
CH ₄	g/kg	0.23					
CO	g/kg	21.3	1.9	21.3	1.9	21.3	1.9
EF _{CO2}	kg/GJ	74.07		74.05		77.37	
C _{Fossil}	%	100		0.0		100	
Fa _{COX}	0..1	0.99		1.0		0.99	
N ₂ O	g/kg	0.08					

3.3.4.1.5.5 *Uncertainty Assessment*

3.3.4.1.5.5.1 *Stationary Equipment*

The uncertainty in activity data was established from the knowledge of the way that activity data information was collected in the inventory but nevertheless trying as much as possible to make an assessment consistent to what is proposed in the GPG. Therefore, for fuel consumption except biomass, uncertainty was set at 10 per cent. For biomass fuels, considering that the quantification error is higher, namely due to lack of clarification of the actual moisture content in which biomass is reported, the uncertainty was assumed to be 60 per cent.

The uncertainty of CO₂ emission factors was assumed to be 5 per cent for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N₂O were set respectively at 150 per cent and an order of magnitude.

3.3.4.1.5.5.2 *Fishing Bunkers*

Concerning the uncertainty in fishing bunkers activity data the uncertainty was set as 5 per cent in accordance to what was done for the other mobile sources.

Following the recommendations of GPG the uncertainties of emission factors for CH₄ and N₂O, and for all types of vessels and navigation, were set respectively to 100 per cent and 1000 per cent.

3.3.4.1.5.6 *Category-specific QA/QA and Verification*

For this sector the comparison between DGED and IEA fuel consumption values was also made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). There are major differences between the two data sources for this source category. No precise justification for this difference was found, apart from the reported compilation errors made by DGEG in the information sent to IEA.

3.3.4.1.5.7 *Recalculations*

Recalculations for this source category comprise:

- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all time series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small;
- Update of fuel consumption in bunkers for the period 2004-2009. The new data that supports this update comes from DGEG;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates.

3.3.4.1.5.8 *Further Improvements*

No further improvements are planned for this sector.

3.3.5 Other (Not Else-where specified) (CRF 1.A.5.)

3.3.6 Mobile (CRF 1.A.5.b)

3.3.6.1.1 Military Use

Emissions from military reported under category 1 A 5 b include only military aviation.

The energy balance does not provide a specific fuel consumption classification for military operations. Fuel consumed in military operations is reported under category “Serviços”. Therefore emissions from military operations, except military aviation, are reported under category NFR 1 A 4 Small Combustion. For military aviation it was assumed that all jet fuel reported under category “Serviços” was used for military aviation since jet fuel could be considered as an aviation specific fuel.

According with the IPCC Good Practice Guidelines, all the jet fuel for military operations was considered to be domestic since there is no information available regarding origins and destinies of the military aircraft movements that could be used to distinct domestic from international consumption.

The following table shows the amount of jet fuel used for military operations provided by the national energy balance under the *Serviços* classification. All fuels under *Serviços* were already considered in the inventory besides jet fuel. Energy was estimated using a country specific LHV of 43.00 MJ/kg reported by the national energy authority.

Table 3.123 – Activity data.

Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	TJ	1 344	1 504	1 127	1 065	1 188	1 149	1 471	1 413	1 474	1 127	1 338

Parameter	Unit	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Energy	TJ	1 338	939	749	570	1 025	1 064	1 026	1 200	1 205	1 208

The emission factors used to estimate emissions are IPCC default emission factors. CO₂ emission factor was obtained from:

$$EF_{CO_2}[t/TJ] = EF_C[t/TJ] \times 44/12[tCO_2/tC] \times \text{Carbon Oxidized Fraction}$$

$$EF_{CO_2}[t/TJ] = 19.5 \times 44/12 \times 0.99$$

$$EF_{CO_2}[t/TJ] = 70.79$$

The carbon emission factor (EF_C) and the carbon oxidized fraction are from IPCC Reference Manual, 1996.

Table 3.124 – Emission factors.

Parameter	EF	EF Unit
CO ₂	70.79	tCO ₂ /TJ
CH ₄	0.5	kg/TJ
N ₂ O	2	kg/TJ

No recalculations were made for this subsector.

No further improvements are planned for this sector.

3.3.6.1.1.1 *Uncertainty Assessment*

3.3.7 Fugitive Emissions From Fossil Fuels (CRF 1.B.)

3.3.7.1 *Fugitive Emissions from Solid Fuels (CRF 1.B.1.)*

3.3.7.1.1 Coal Mining and Handling

3.3.7.1.1.1 *Overview*

Coal contains some proportion of methane trapped in its structure that it is usually emitted to atmosphere during and after extraction of coal from mines to open air. Emissions at extraction result from ventilation of mine gas which is done for safety reasons at underground mines. Emissions at open cast mines are usually lower and result from coal mobilization and blasting operations. Post-mining emissions result from the slower liberation of methane still entrapped in coal after it is extracted and stored at surface in piles, or from crushing and drying operations applied to modified and ameliorate coal characteristics. In underground mines, post-mining emissions may occur in fact during extraction if degasification systems are installed but, nevertheless, total emissions remain more or less unaffected.

Since 1990 in Portugal there was extraction of coal at only two coal mines, but both were latter closed down in 1992 and 1994 and did not resume activity since. Both mines - *Pejão* and *S. Pedro da Cova* - are located in northern region of Portugal. Coal from these mines is classified as lignite, it has a low energy value and it was used mainly as fuel for one public power energy plant near Oporto (*Tapada do Outeiro* power plant). Moreover the coal production during the exploration period was of small importance (less than 300 kt in 1990, see figure below). One mine - *Pejão* - is an underground mine and the other is an open cast type.

Emissions of carbon dioxide and sulphur oxides may occur from mining activity when burning of coal deposits occurs or when flaring is used to control air emissions or recover energy. Because the occurrence of coal burning on-site or flaring is unknown for both Portuguese mines, emissions of these pollutants from this source are not included in the inventory.

Emissions of methane from abandoned mines may still continue after mine closure, even if mines are sealed. However most available evidence indicates that methane flow rates decay rapidly once deep mine coal production ceases. Because no methodology is available to calculate present day flux from abandoned mines - which would require knowledge of all abandoned mines, not only *Pejão* and *S. Pedro da Cova* - no estimates are included in the inventory.

Emissions from fuel combustion for coal extraction are included under category 1.A.1.c.1.

3.3.7.1.1.2 *Methodology*

Emission estimates include both emissions occurring during extraction of coal as well as those resulting from processing.

A simple tier 1 approach was used to estimate emissions, which is considered a sufficient approach being present the scarcity of technical information about these mines and because

this emission source is no key source and has small relevance. The following equation is similar to the methodology proposed in IPCC96 (IPCC,1997):

$$Emi_{CH_4} = [(EF_U^{ex} + EF_U^{post}) * Coal_U + (EF_S^{ex} + EF_S^{post}) * Coal_S] * 0.67 * 10^{-3}$$

where

Emi_{CH_4} - Methane emissions in year y (ton);

$Coal_U, Coal_S$ - quantity of coal extracted from underground mines and open cast/surface mines, respectively (ton/yr);

EF_U^{ex} - emission factor for extraction emissions in underground mining (m^3/ton);

EF_U^{post} - emission factor for post-extraction emissions in underground mining (m^3/ton);

EF_S^{ex} - emission factor for extraction emissions in surface mining (m^3/ton);

EF_S^{post} - emission factor for post-extraction emissions in surface mining (m^3/ton);

0.67 is the conversion factor, the density of methane at 20°C and at atmospheric pressure (kg/m^3).

Ultimate carbon dioxide emissions, also in ton/yr, are calculated the carbon emitted as methane:

$$Emi_{CO_2} = 44 / 16 * Emi_{CH_4}$$

3.3.7.1.1.3 Emission Factors

Although it is known that high rank coals contain usually more methane than lower rank coals such as lignite, average emission factors from IPCC96 (IPCC,1997) defaults were used for both mines, which are presented in next table. The same emission factor range was maintained in GPG (IPCC,2002).

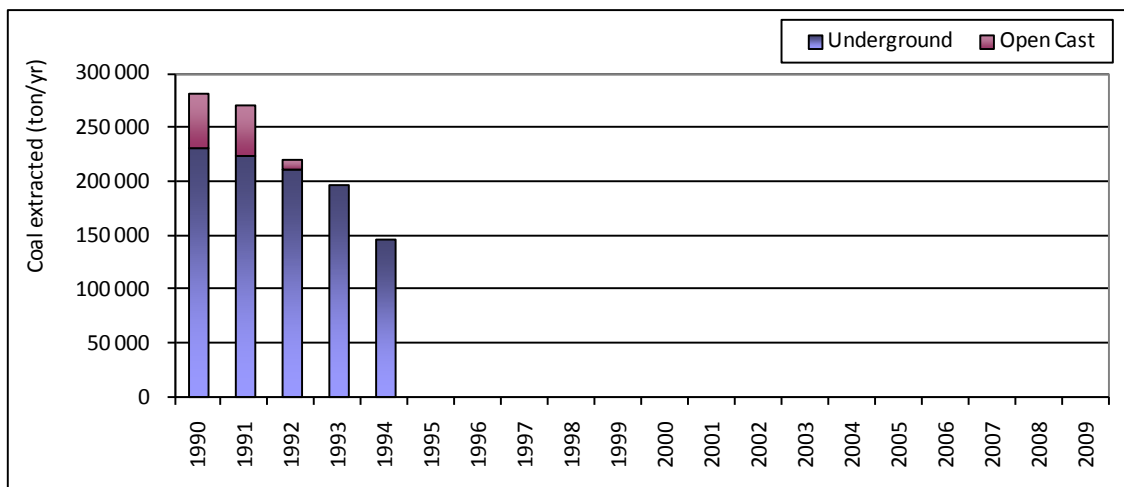
Table 3.125– Emission Factors for coal extraction and processing

Mine	Type of Emission	Emission Factor	Value (m^3/ton)
Underground	Extraction	EF_U^{ex}	11.73
	Post-mining	EF_U^{post}	1.64
Open cast	Extraction	EF_S^{ex}	0.77
	Post-mining	EF_S^{post}	0.07

3.3.7.1.1.4 Activity data

The quantity of extracted coal was always more expressive in underground mining but, nevertheless has decreased as a whole towards the final closure of both mines in 1994, as may be seen in next figure. Statistical information is from annual energy reports from DGEG.

Figure 3.88 – Quantities of coal extracted from mines in Portugal (1990-2010)



3.3.7.1.1.5 Uncertainty Assessment

A value of 5 percent was considered for the uncertainty of coal production (activity data) which is a conservative factor according to the proposed values by IPCC (2000). Also in accordance with table 2.14 of the GPG, the uncertainty values for methane emission factors were set at 100 percent for underground mines and 200 percent for surface mines. The uncertainty in CO₂ emission factors were set equal to uncertainties of CH₄ emission factor, considering that CO₂ emissions are simply atmospheric conversion of methane emissions.

3.3.7.1.1.6 Recalculations

No recalculations of emissions were made on this source sector.

3.3.7.1.1.7 Further Improvement

Although this activity has stopped in 1994 it is possible that emissions after closure may continue for some time. Efforts will be done in next submissions to improve estimates of that origin, although it is probable that they will not affect substantially the inventory during the commitment period of the Kyoto Protocol.

3.3.7.2 Fugitive Emissions from Oil Production and Refining (CRF 1.B.2.a.)

3.3.7.2.1 Overview

Extraction and production of crude oil did never occur in the Portuguese territory. Therefore, fugitive emissions comprehend only those resulting from refining, storage and transport of crude oil, other raw materials, intermediate products and final products - particularly gasoline - from terminal receiving of crude oil and other petroleum products till delivering to final consumer. According to available methodologies air emissions considered include:

- Marine Terminals and Ballast water;
- Emissions from refinery operations not including emissions from combustion of fuels, such as: Flaring and venting in oil refining and; Emissions due to storage of raw materials, intermediate products and final products in the refinery;
- Emissions from refinery dispatch station;

- Emissions from the transport and distribution of petroleum products in the Portuguese Territory, including transport depots and service stations.

3.3.7.2.2 Transport of Crude/ Marine Terminals

3.3.7.2.2.1 Overview

Emissions from this source consist mainly of volatile organic compounds, including methane, that escape to atmosphere during transport of crude oil to refineries for processing. The three oil refineries considered in the inventory were all located at a small distance from the sea coast. Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

3.3.7.2.2.2 Methodology

Emissions of CH₄ and NMVOC were estimated from:

$$\text{Emission} = \text{Source}_{\text{InFlow}} * \text{EF} * 10^{-9}$$

where

Emission - CH₄ or NMVOC emissions (ton/y);

Source_{InFlow} - is total crude oil, gasoline, naphta, residual oil or distillate oil received at each marine terminal (L/y);

EF - emission factor for CH₄ or NMVOC (mg/ton crude oil).

Emissions of VOC will ultimately be oxidized in atmosphere and contribute to ultimate carbon dioxide, which estimates are also included in the inventory. Emissions of ultimate carbon dioxide result from conversion of carbon in NMVOC and CH₄:

$$\text{Emi}_{\text{CO}_2\text{U}} = 44/12 * (\text{Emi}_{\text{NMVOC}} * 0.85 + \text{Emi}_{\text{CH}_4} * 12/16)$$

3.3.7.2.2.3 Emission Factors

Table 3.126– Total Organic Emission Factors for Marine Vessel Loading Operations

Loading Operations	Gasoline (mg/L)	Crude ³³ (mg/L)	Jet Naphta – JP-4 (mg/L)	Jet Kerosene (mg/L)	Distillate Oil n°2 (mg/L)	Residual Oil n°6 (mg/L)
Ships/ocean barges	215	73	60	0.63	0.55	0.004

Source: Tables 5.2-2 and 5.2-6 of USEPA AP-42 Emission Factors

The chosen Emission factor for Gasoline is the “Typical overall situation”. For other petroleum products it is used “Ships/ocean barges” emission factors.

For products for which there are not emission factors available, they were estimated using the following expression:

³³ VOC Emission Factors for a typical crude oil are 15% lower than the total organic factors shown, in order to account for methane and ethane. All products other than crude oil can be assumed to have VOC factors equal to total organic factors.

$$EF_{LL} = 12.46 \times \frac{F_s \times P_v \times M_v}{T} \times \left(1 - \frac{eff}{100}\right)$$

Where,

EF_{LL} - Emission Factor associated to Loading Losses (lb/1000 gal);

F_s - Saturation Factor (0 to 1);

P_v - True Vapour Pressure (psia);

M_v - Molecular Weight (lb/mol);

T - Temperature of Petroleum Product (520 °R – Rankin);

eff - Overall Reduction Efficiency (Both Recovery and Collection Efficiencies);

True Vapour Pressure and Molecular Weight Values were obtained from “International Chemical Safety Cards”.

CH₄ emission factor (60 g/ton of Crude) is obtained from EMEP/Corinair.

3.3.7.2.2.4 Activity data

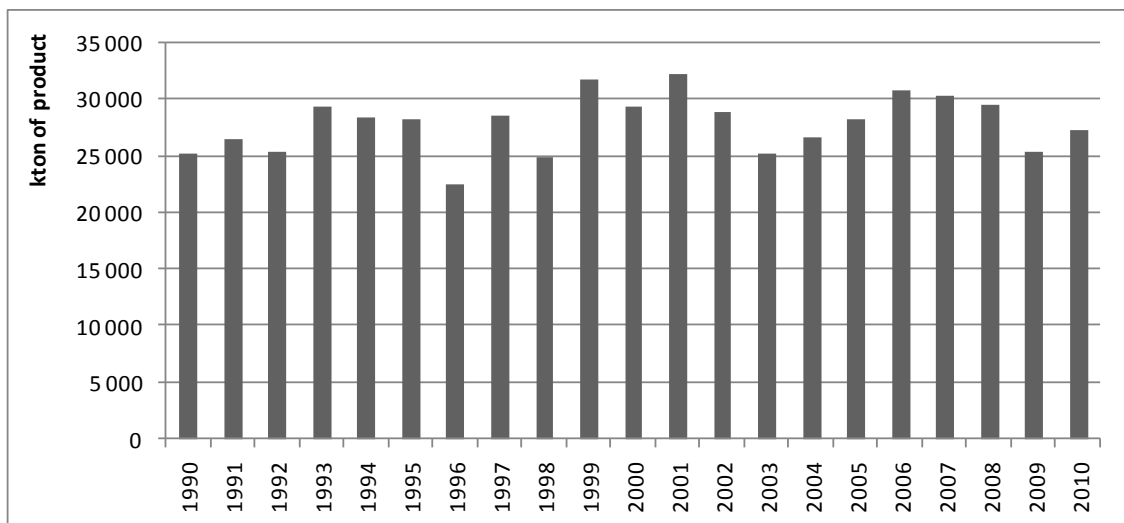
Data was obtained for year 2005, from:

- Ports Authorities (Port of Sines, Port of Lisbon, Port of Leixões, Port of Setúbal);
- Depots Companies (BP, Cepsa, CLCM, Esso, ETC, LBC Tanquipor, Petrogal, Repsol, Saaga, Sapec Química);
- Responsible company for the transport of Petroleum Products between Mainland and Madeira and São Miguel (Azores) Islands – Galpenergia;
- Responsible company for the transport of Petroleum Products between São Miguel Island (Azores) and other Azores Islands – BP (the transport is made by a ship rented by the Regional Government of Azores and is assured by BP company).

For the period 1990-2004 and 2006-2010 data was extrapolated using Crude Oil stock changes obtained from DGEG energy balance.

It was made a cross-check between data obtained from different sources.

Figure 3.89 – Total amounts of loaded and unloaded crude and fuels in Marine Terminals (kton)



3.3.7.2.2.5 Uncertainty Assessment

An uncertainty value (3 percent) similar to that that was considered for fuel consumption data in industrial LPS was also used for quantification of uncertainty of activity data for this source sector reflecting the fact that in this case data was also collected directly from refinery plants, where crude oil is uploaded, and used to build the energy balance of DGEG. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO₂ emissions, was considered to be 50 percent, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases. The uncertainty of methane emission factor was set to 100 percent, the double of the emission factor for CO₂/NMVOC in accordance with the fact that methane is obtained as a VOC fraction and hence with double uncertainty.

3.3.7.2.2.6 Recalculations

No recalculations were made.

3.3.7.2.3 Refining and Storage

3.3.7.2.3.1 Overview

In 1990 there were three oil refining plants in Portugal, located in Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed for all activity and only two units remain now operating.

The refining process converts crude oil - which is a complex mixture of hydrocarbon compounds with impurities of sulphur, nitrogen, oxygen and heavy metals - into oil products used as fuels, asphalts, lubricants or feedstock for the organic and inorganic chemical industry. Processes included in Portuguese refineries include:

- Separation process: isolation of individual constituents of crude using differences in boiling-point, using atmospheric and vacuum distillation and recovery of light end gases;
- Conversion process. These may be also classified as:

- Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular weight into smaller ones, including visbreaking;
- Polymerisation of small molecules combined in bigger molecules with different characteristics. Alkylation has similar objectives;
- Chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing
- Treatment processes. Operations which include hydrodesulfurization, hydrotreating, chemical sweetening, acid gas removal, deasphalting and desalting, that are used to remove impurities, the most important is sulphur;
- Blending of individual fractions and intermediate products to obtain final commercial products with characteristics as desired.

Emissions of storage of crude oil and other materials, intermediate products and final products are also included in this source sector as they are fugitive emissions occurring as part of the refining process. Because emissions from organic liquids in storage occur both from the evaporative loss of the liquid as well as from changes in the liquid level, the emission sources vary significantly with tank design. Six basic tank designs are usually used for organic liquid storage vessels: fixed roof (vertical and horizontal), external floating roof, domed external (or covered) floating roof, internal floating roof, variable vapor space, and pressure (low and high).

NM VOC and methane emissions may also result from “normal” leaks³⁴ scattered through the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NM VOC emissions resulting from non-condensable fraction at the steam ejectors or vacuum pumps of the Vacuum distillation. Emissions in flares are discussed in “Venting and Flaring in Oil Industry” below.

Use of some catalytic converters, such as Fluid Catalytic Cracking and Platforming units, are used to convert heavy oils into lighter products, by action of heat, pressure and catalysts. Fluidized-bed Catalytic Cracking (FCC) use finely divided catalysts suspended in a riser with hot vapour from the fresh feed. Catalytic processes result in operations emissions, when the coke that is deposited in the catalytic bed over time has to be burned in the regenerator equipment. Emissions from catalyst regeneration are also included in this source category.

3.3.7.2.3.2 Methodology

3.3.7.2.3.2.1 Storage and Tanks

GALP, the company operating all refineries in Portugal, made annually estimates of emissions from storage in the tanks existing inside the refineries. The estimates, relying on the TANKS4.0 model, are available from 2002 till 2005. This detailed information lead to the establishing of plant specific emission factors, and its evolution, for NM VOC losses from crude oil and oil products storage. Annual emissions of NM VOC (ton/yr) for the remaining time series are

³⁴ Sometimes only these emissions are referred as fugitive emissions from refineries.

estimated using the emission factor (EF in g/ton) and relying in the time series of total throughput petroleum materials processed (ton/yr) as an indicator of activity³⁵.

$$\text{Emission}_{\text{NMVOC}} = \text{EF}_{(y)} * \text{Throughput} * 10^{-6}$$

3.3.7.2.3.2.2 Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations where estimated from:

$$\text{Emission}_{(p,r)} = \text{ActivityRate} * \text{EF}_{(p,r)} * 10^{-6}$$

where

Emission (p,r) - annual emissions of pollutant p occurring from refining operation r (ton/yr);

ActivityRate - is a suitable activity indicator, specific of each pollutant and refining operation (ton/yr);

EF (p,r)- emission factor for a particular pollutant p and a specific refining operation (g/ton).

Total crude use was used as activity data to estimate fugitive emissions from leakages, according to the available emission factors in literature. Concerning Catalyst recovery activity data is coke burnt during catalyst regeneration.

3.3.7.2.3.2.3 Ultimate CO₂ Emissions

All carbon in emitted compounds, such as CO, NMVOC and methane, have fossil origin and must be included in ultimate emissions inventory. Individual pollutants (ton/yr) are converted into ultimate CO₂ (kton/yr) by:

$$U_{\text{CO}_2} = 44/12 * (0.85 * \text{NMVOC} + 12/16 * \text{CH}_4 + 12/28 * \text{CO}) * 10^{-3}$$

3.3.7.2.3.3 Emission Factors

3.3.7.2.3.3.1 Storage/ Tanks

For the period 2002-2005, GALP, the single petroleum refinery operator in Portugal, in collaboration with APA, performed a detailed inventory of NMVOC emissions from tanks in Oporto and Sines refineries using TANKS 4.0 (USEPA,1990). The inventory has been extended to marketing terminal storage tanks (including data from all companies operating in the Portuguese territory). For the period 1990-2001, data was estimated using stock changes values from DGE's energy balance.

TANKS4.0 software was designed to estimate air emissions from organic liquids in storage tanks, according to the methodology proposed in "Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources" (AP-42), Section 7.1, Organic Liquid Storage Tanks (USEPA,1997).

³⁵ This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

Determination of emission factors for Oporto and Sines refineries were performed for each tank, considering the following detailed information:

- Site information: meteorological data such as the daily average ambient temperature, the annual average minimum and maximum temperatures, the annual average wind speed, the annual average solar insolation factor, and the atmospheric pressure;
- Liquid characterization: For individual substances the model requires chemical nomenclature, average liquid temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. For mixtures, the information may be as detailed as the mixture name, average, minimum and maximum liquid surface temperatures, bulk temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights;
- Tank information is slightly different according to tank type, but in general terms comprehends: shell and roof colour and condition, height, diameter, average and maximum liquid height, working volume, turnover rate and net output, heating conditions and pressure and vacuum settings and the existence and type of seals³⁶.

Emissions were determined relying on methodologies that vary according to each tank type. The possible type of tanks, a very short description of their characteristics and the percentage of each tank type in existence in 2005 in Oporto and Sines refineries are presented in the table below.

Table 3.127 – Type of tanks classes distinguished in TANKS4.0 model and percentage of tanks per tank type in Oporto and Sines refineries in 2005 (percent).

Tank Type	Description	Oporto	Sines (a)
External Floating Roof Tank	cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid	55	170
Horizontal Tank	above-ground or underground storage with the axis parallel to the foundation	4	0
Internal Floating Roof Tank	permanent fixed roof and a floating deck	30	58
Vertical Fixed Roof Tank	cylindrical shells with permanently affixed roofs; the tank axis is perpendicular to the foundation. The fixed roof may be dome-shaped or coneshaped	206	235
Domed External Floating Roof.	external floating roof tank that has been retrofit with a domed fixed roof	0	0

(a) Inventory covers only tanks for storage of liquids with Vapor Pressure above 27kPa

TANKS4.0 methodology differentiates the following emissions, according to the cause of release:

³⁶ This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

Table 3.128 – Types of losses from tanks for storage of organic compounds and petroleum products

Tank	Loss	Description
Fixed Roof	Breathing	Expulsion of vapour from a tank through vapour expansion and contraction, which are the results of changes in temperature and barometric pressure
	Working	Combined loss from filling and emptying. Evaporation during filling operations is a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapours are expelled from the tank. Evaporative loss during emptying occurs when air drawn into the tank during liquid removal becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space.
Floating Roof	Rim Seal	The majority of rim seal vapour losses have been found to be wind induced.
	Withdrawal	Occur as the liquid level, and thus the floating roof, is lowered. Some liquid remains on the inner tank wall surface and evaporates.
	Deck Fitting	Deck fittings can be a source of evaporative loss when they require openings in the deck, such as: access hatches, gauges, rim vents, deck drains, guide-poles, columns, wells, vacuum breakers and ladders.
Internal Floating	Deck Seam	Seams may not be completely vapor tight if the deck is not welded

Finally the resultant emission factors, obtained dividing total tank emissions by total throughput³⁷ in each refinery, are presented in next table. After 2005 the emission factors were forecasted.

Table 3.129 – Final emission factor for evaporation of NMVOC from storage and tank in refineries

Refinery	Emission Factor			
	(g NMVOC/ton throughput)			
	2002 and before	2003	2004	2005
Sines	0.118	0.198	0.205	0.222
Oporto	0.057	0.041	0.040	0.039
Lisbon	0.088 ^(a)	NA	NA	NA

(a) Average value from Sines and Oporto refineries

3.3.7.2.3.3.2 Fugitive Emissions

The following emission factors were used to estimate emissions from other processes, mainly leaks. These emission factors were still established from Corinair90 Emission Factor Handbook (EMEP/CORINAIR 3rd ed).

Table 3.130 – Emission Factors for fugitive emissions of NMVOC in operation processes in petroleum refineries

Pollutant	EF kg NMVOC/ ton crude
NMVOC	0.9
CH ₄	0.1

³⁷ Crude oil input added to input of other materials.

3.3.7.2.3.3.3 Recovery of Catalysts

From information collected at the refinery of Sines (quantities of coke burnt in FCC unit during 2002 plant specific emission factors were established for this process). For carbon monoxide emission factors from USEPA (1995) were used, but because original emission in the original reference source are expressed in volume of fresh feed – and this activity rate it is not available from the refinery – the original emission factor was corrected, by multiplication by the ratio of the NO_x emission factor in both information sources (monitoring data and USEPA). Carbon dioxide emission factor was set assuming that coke is 92 percent carbon. Final emission factors may be verified in the next table.

This set of emission factors was also applied to coke burning in the platforming unit, also in Sines refinery, and regeneration of catalysts at Oporto refinery.

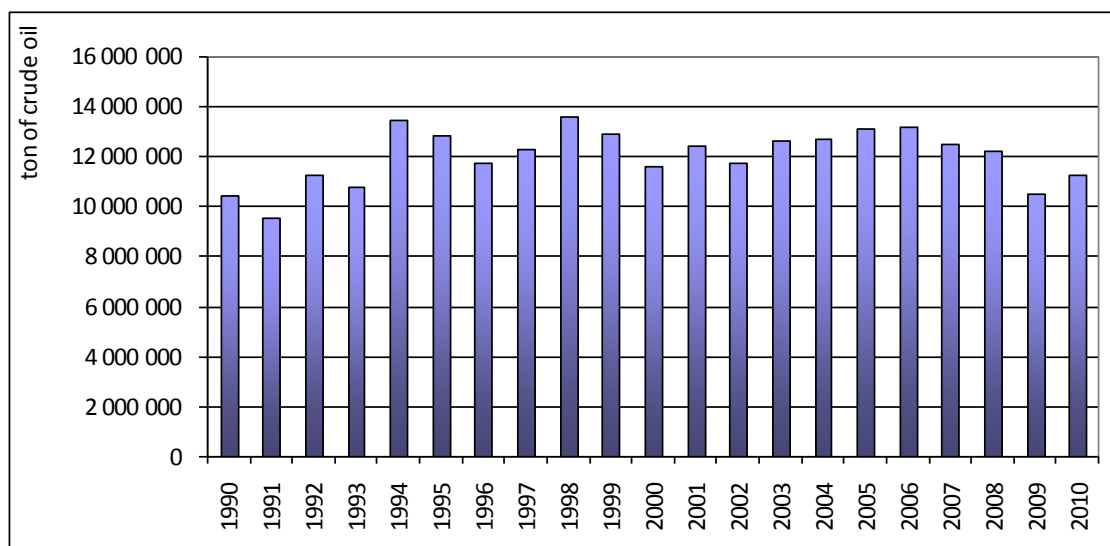
Table 3.131 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Parameter	Emission Factor kg/ton coke
UCO ₂	3 373

3.3.7.2.3.4 Activity data

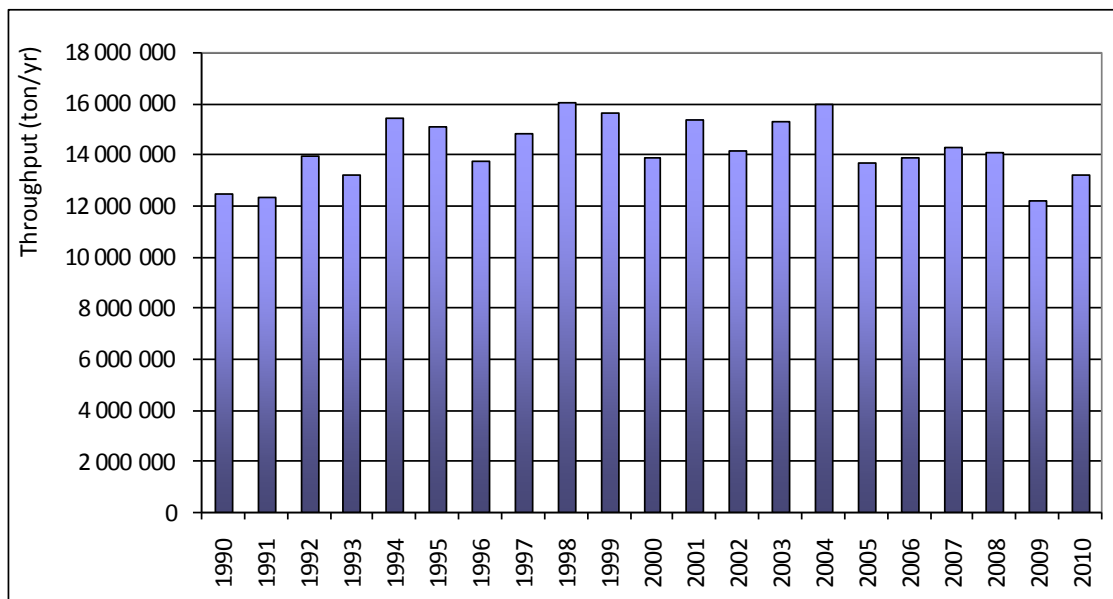
The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed (see next figure).

Figure 3.90 – Total Crude Oil Processed in Refineries (ton)



Total throughput in each refinery was used to estimate NMVOC emissions from storage and tanks. Total throughput represents not only crude oil entered into the refinery but also other petroleum products that are imported or moved between refineries. This indicator was considered the most suitable variable to be multiplied by the national emission factor. Total throughput for all refineries, according to information delivered by GALP, is presented in the next figure.

Figure 3.91 – Total throughput entered in Lisbon, Oporto and Sines refineries: 1990-2010



For FCC, and other processes where there happens recovery of catalysts, activity data is total coke burnt. Annual burning of coke in Sines refinery, both in FCC and in platforming is available from PETROGAL up to 2003. Combustion of coke from catalysts in Oporto refinery was only available for 2001-2002, and was assumed constant over the all 1990-2010 period. Total coke burning was obtained from the industrial units and it is considered confidential data.

3.3.7.2.3.5 Uncertainty Assessment

Most of the activity data that was obtained to estimate emissions come directly from the refinery units or indirectly by the Energy Balance of DGEG (which is based also in information surveyed from the industrial plants). Therefore a low uncertainty of 3 percent may be assumed for this sub-source in a similar mode to other LPS combustion data.

Uncertainty of emission factors for NMVOC³⁸ were set as 50 percent, at the higher range of possible uncertainties proposed by IPCC (2000), although the fact that some emission factors use plant specific information. Estimates of methane emissions were assumed to have the double uncertainty that was determined for CO₂ (100 percent)

3.3.7.2.3.6 Recalculations

No modifications were made to this source sector.

3.3.7.2.3.7 Further Improvements

The efforts that the refineries are doing together with APA, in order to ameliorate emission estimates of storage in tanks, fugitive emissions, emissions from catalysts regeneration and from sulphur recovery, were developed, and, after the application of validation procedures, will be used for the improvement in the inventory methodologies and emission factors for the coming years.

³⁸ The uncertainty of NMVOC was considered to be the uncertainty of CO₂ emission factor.

3.3.7.2.4 Distribution of Oil Products

3.3.7.2.4.1 Overview

This sub-source sector include emissions of volatile organic compounds resulting from distribution of refinery products, mainly gasoline:

- (1) Terminal Dispatch Stations in Refineries. Emissions of volatile organic compounds occurring inside refineries during filling of transport equipments - trucks, rail cars - when dispatching products of the refining unit. Most emissions occur when light products with high level of volatile compounds are dispatched;
- (2) Transport and Depots, occurring in storage tanks outside the refineries and over the country;
- (3) Service Stations, including emissions from tank loading from trucks and when refuelling consumer cars.

Emissions may result from:

- Leakage. Evaporation of liquid products by flaws and seal leakage, pumps and valve systems;
- Displacement emissions, due to displacement of air in tanks by the incoming liquid;
- Breathing emissions in tanks;
- Vapours emitted when filling vehicles in result of displacement of filling air and from splashing and turbulence during filling;
- Unwanted spillage.

3.3.7.2.4.2 Methodology

Ultimate carbon dioxide emissions, are calculated assuming that emitted VOC have on average 85 percent of carbon:

$$Emi_{CO_2} = 0.85 * Emi_{NMVOC}$$

3.3.7.2.4.2.1 Filling Underground Tank

From “Portaria 646/97” it is assumed that since 2005 it is used “bottom loading with vapour return” (Stage IB) for latter recovering (VRU) or destruction (VDU). Before 2005 it is not known the type of filling used and it is assumed that 50% of the service stations had vapour return and 50% hadn’t the Stage IB in place.

Before 2005 emissions estimates are based on:

$$E_{FUT} = V_{StageIB} \times TVP \times EF_{StageIB} + V_{other} \times TVP \times EF_{other}$$

Where,

E_{FUT} - Emissions Filling Underground Tanks (kg)

TVP – True Vapour Pressure (kPa)

$V_{StageIB}$ - Gasoline throughput at Service Stations with Stage IB (m^3)

$EF_{StageIB}$ - Emission Factor for Filling Underground Tanks at Service Stations with Stage IB ($kg/m^3/kPa$ TVP)

V_{other} - Gasoline throughput at Service Stations without Stage IB (m^3)

EF_{other} – Emission Factor for Filling Underground Tanks at Service Stations without Stage IB ($kg/m^3/kPa$ TVP)

Since 2005, the emissions estimates are based on:

$$E_{FUT} = V_{StageIB} \times EF_{StageIB}$$

Where,

E_{FUT} - Emissions Filling Underground Tanks (kg)

$V_{StageIB}$ - Gasoline throughput at Service Stations with Stage IB (m^3)

$EF_{StageIB}$ – Emission Factor for Filling Underground Tanks at Service Stations with Stage IB ($kg/m^3/Kpa$ TVP)

3.3.7.2.4.3 Emission Factors

3.3.7.2.4.3.1 Filling Underground Tanks

Emission factors were obtained from “Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1”.

Table 3.132 – Filling Underground Tanks NMVOC Emission Factors

Filling Underground Tank	Emission Factor ($kg/m^3/kPa$ TVP)
Without Stage IB	$2.44E^{-02}$
With Stage IB	$1.1E^{-03}$

3.3.7.2.4.3.2 Underground Tank Breathing and Emptying

The NMVOC emission factor source is “Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1” ($=3.30E^{-03} kg/m^3/kPa$ TVP).

3.3.7.2.4.3.3 Vehicle Refuelling Operations

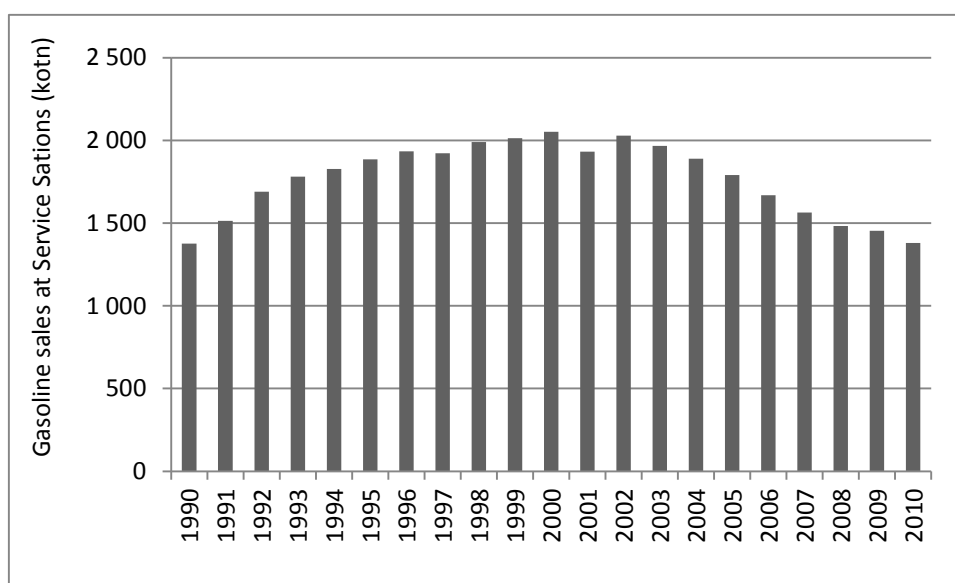
Table 3.133 – Vehicle Refuelling Operations NMVOC Emission Factors

Vehicle Refuelling Operations	Emission Factor (kg/m ³ /kPa TVP)
Drips and Minor Spillage	2.20E ⁻⁰³
Refuelling with no emission controls in operations (without Stage II measures)	3.67E ⁻⁰²

3.3.7.2.4.4 Activity data

Data on gasoline sales was obtained from DGEG Energy Balance.

Figure 3.92 – Fuel Sales in Service Stations



3.3.7.2.4.5 Recalculations

We start using gasoline sales as AD and not all fuel sales. We have changed emission factors in order to accomplish “Portaria n.º 646/97”. We assumed that there is no stage II implementation in service stations in Portugal.

3.3.7.2.4.6 Further Improvements

Efforts should be addressed in order to verify stage II implementation in service stations in Portugal.

3.3.7.2.5 Venting and Flaring in Oil Industry

3.3.7.2.5.1 Overview

In the three refineries in Portugal flares were used to control and burn non-condensable gases recovered from leakages and blow down operations, that would otherwise be emitted as volatile organic compounds. Although smokeless and complete combustion is always an objective, sometimes the gas influx exceeds flare combustion capacity and partly unburned organic compounds are emitted: NMVOC, CH₄ and CO.

3.3.7.2.5.2 Methodology

All carbon emitted in compounds, such as CO, NMVOC and methane, has fossil origin and must be included in the estimate of ultimate carbon dioxide emissions. Individual pollutants (end of pipe carbon dioxide, NMVOC, methane and carbon monoxide) are converted into ultimate CO₂ according to:

$$U_{CO_2} = \text{EndofPipe}_{CO_2} + 44/12 * (0.85 * \text{NMVOC} + 12/16 * \text{CH}_4 + 12/28 * \text{CO}) * 10^{-3}$$

Air emissions in flaring, resulting from combustion of gas collected from leaks and blowdown system, and were estimated either from the quantity of gas flared or total feed to refinery.

When the quantity of gas flared was used as activity data, emissions are estimated from:

$$\text{Flare}_{(p,y)} = \text{EF}_{(p)} * \text{LHV}_{\text{GAS}(y)} * \text{Flare}_{\text{GAS}(y)} * 10^{-6}$$

Where,

Flare_(p,y) – Emission of pollutant p in year y (ton/yr);

EF_(p) – Emission factor for pollutant p (g/GJ);

LHV_{GAS(y)} – Low Heating Value of flared gas in year y (MJ/kg);

Flare_{GAS(y)} – Quantity of gas flared in year y (ton/yr).

N₂O emissions are estimated from:

$$\text{Emis}_{(p,y)} = \text{EF}_{(p)} * \text{Dens}_{\text{Crude}(y)} * \text{Crude}_{\text{Cons}(y)} * 10^{-6}$$

Where,

Flare_(p,y) – Emission of pollutant p in year y (ton/yr);

EF_(p) – Emission factor for N₂O (ton/m³ of crude oil);

Dens_{crude(y)} – Density of crude oil in year y (ton/m³);

Crude_{Cons(y)} – Consumption of Crude Oil in year y (ton/yr).

3.3.7.2.5.3 Emission Factors

Emission factors for CO₂, NMVOC and CH₄ were set from US-EPA (1991).

Emission factor for N₂O was set from IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Feed density was assumed as of 0.85 kg/l.

Table 3.134 – Emission Factors for flaring in refineries

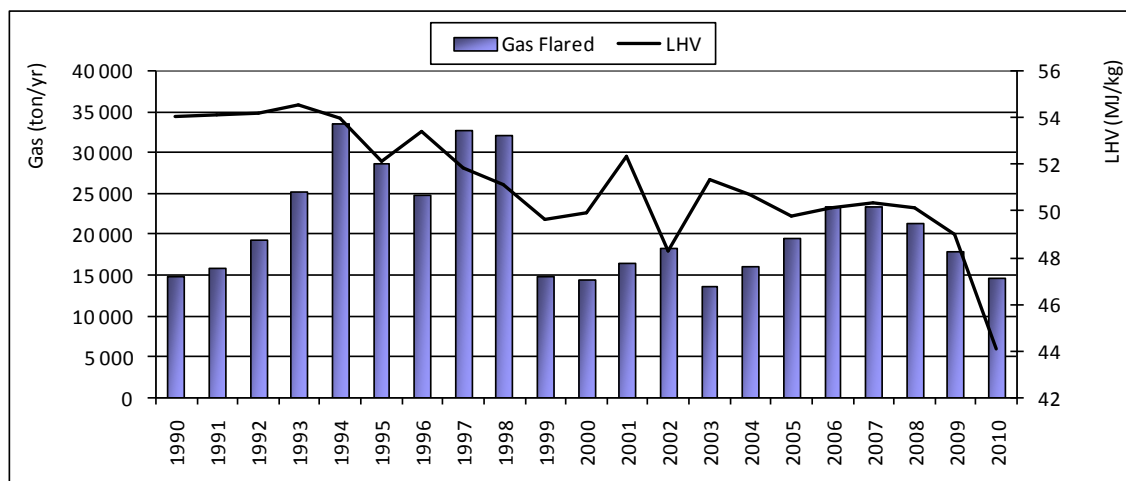
Pollutant	EF Unit	EF
CO ₂ (kg/GJ)	Kg/GJ	60
NMVOC	g/GJ	12
CH ₄	g/GJ	15
N ₂ O ³⁹	ton/m ³ oil	6.4x10 ⁻⁷

3.3.7.2.5.4 Activity data

Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL and it is presented in the next figure.

Total amount of crude oil processed in refineries was obtained from Refineries Safety Databooks.

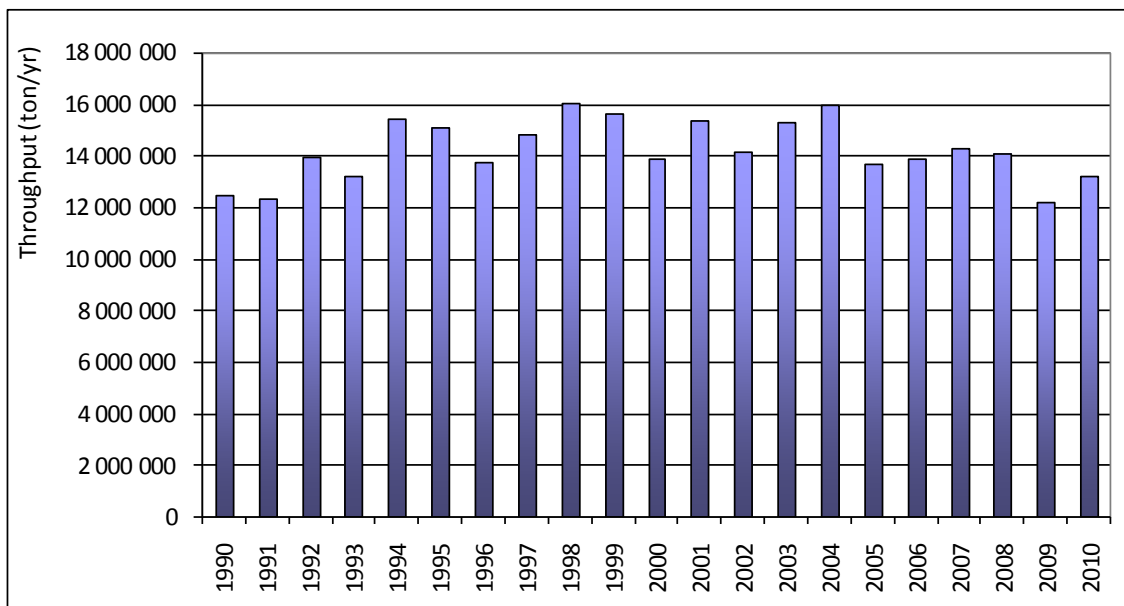
Figure 3.93 – Total consumption of flare gas in Portuguese refineries and Low Heating Value: (1990-2010)



Total throughput (feed) entered in refinery units is available from annual energy publications of (DGEG), and is again presented in the next figure.

³⁹ Table 2.16 of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Oil Production – Conventional Oil – Flaring)

Figure 3.94– Total throughput entered in Lisbon, Oporto and Sines refineries (1990-2010)



3.3.7.2.5.5 Uncertainty Assessment

The uncertainty in activity data was considered to be 5 percent, the same value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in NMVOC/CO₂ emission factor is 50 percent and the double of that value for methane emissions.

3.3.7.2.5.6 Recalculations

No recalculations were made.

3.3.7.3 Fugitive Emissions from Natural Gas (CRF 1.B.2.b.)

3.3.7.3.1 Overview

There is no production of natural gas in Portugal. The use of natural gas in Portugal was initiated only in 1997 (DGEG). At that time this energy source was received by ship from Algeria and used mainly in electric power production and in combustion in industry. Since then its use has become more widespread and its now consumed also in the manufacturing industry, domestic, service, institutions, commerce, building and construction, agriculture and even a small quantity in road transport. All natural gas is imported and received through shipping transport from Algeria and Nigeria as Liquefied Natural Gas (LNG). There are also no major processing operations in Portugal.

Natural gas pipelines may be classified in two different sub-groups:

- Transmission lines. Operating at high pressure, are used to transport natural gas in bulk over large distances till distribution centres;
- Distribution networks. Comprehend the network of extensive pipelines that convey natural gas to the end-user. They tend to work on lower pressure and with smaller diameter lines. There are distribution networks of natural gas distributing for industrial consumers, services and domestic users.

The gas received from Algeria in ships is re-gasified in a plant in Sines, in southern Portugal.

Methane emissions from natural gas result mostly from leaks of unmodified natural gas, in pipes or in the plant. Although these losses happen as result of maintenance operations or abnormal accident situations (pressure surges due to failure of equipment that controls pressure), they occurs also constantly as result of normal operations of the system in operation valves or in chronic leaks due to seal failure, flawed valves, small cracks and holes in the lines or reservoirs.

3.3.7.3.2 Methodology

Losses of Natural Gas are estimated equal to the quantity of gas that is lost in transport and distribution, according to the energy balance of DGEG. Therefore, total emissions are determined from:

$$Emi_{GHG(y)} = Losses_{NG(y)}$$

Where,

$Emi_{GHG(y)}$ – Emissions of total GHG from natural gas leakage, in year y;

$Losses_{NG(y)}$ – Losses of Natural Gas from the system and reported in the energy balance, in year y.

Emissions of methane, direct CO₂ and ultimate CO₂, from transmission of Natural Gas in major pipelines is estimated from:

$$\begin{aligned} Emi_{CH_4} &= Pipeline_{Lenght} * EF_{CH_4} \\ Emi_{CO2direct} &= Pipeline_{Lenght} * EF_{CO2direct} \\ Emi_{CO2} &= Emi_{CH_4} * 44/16 + Emi_{CO2direct} \end{aligned}$$

Where,

Emi_{CH_4} – Emissions of CH₄ from losses of natural gas during transmission, t/yr;

$Emi_{CO2direct}$ – Direct emissions of CO₂ from leakages, t/yr;

Emi_{CO2} – Total emissions of CO₂, including conversion of carbon in methane and other gases in atmosphere, t/yr;

EF_{CH_4} , $EF_{CO2direct}$ – Emission factors, t/km;

$Pipeline_{Lenght}$ – Extension of pipeline in year y, km.

A similar procedure is used to estimate emissions in the re-gasification plant, although using total natural gas processes⁴⁰ as activity data:

$$\begin{aligned} Emi_{CH_4} &= Import_{NG} * EF_{CH_4} / 100 \\ Emi_{CO2direct} &= Import_{NG} * EF_{CO2direct} \\ Emi_{CO2} &= Emi_{CH_4} * 44/16 + Emi_{CO2direct} \end{aligned}$$

⁴⁰ Equals imports in Portugal

Where,

EF_{CH_4} , $EF_{CO_2direct}$ – Emission factors, per cent;

$Import_{NG}$ – Import of Natural Gas, t/yr.

Finally emissions during distribution (Emi_{DIST}) are estimated from total losses (Emi_{TOTAL}), after removal of transmission emissions (Emi_{TRANS}) and emissions occurring at the re-gasification plant (Emi_{GAS}):

$$Emi_{DIST} = Emi_{TOTAL} - Emi_{TRANS} - Emi_{GAS}$$

3.3.7.3.3 Emission Factors

The emission factors are based on the IPCC Good Practice (IPCC, 2000), and are reported in Table 3.135.

Table 3.135 – Net Calorific Value and Emission Factor for fugitive emissions from natural gas

-	Transmission (t/km) [#]	NGL Plant (%) ^{\$}
CH ₄	2.5	0.05
CO ₂	0.016	0.00032

- IPCC (2000), table 2.16

\$ - IPCC (2000), table 2.18, assuming same CO₂/CH₄ ratio in transmission

The implicit emission factor from emissions from distribution was calculated in the end. It corresponds to the annual loss of about 1.1 per cent of the natural gas consumed in the distributive systems.

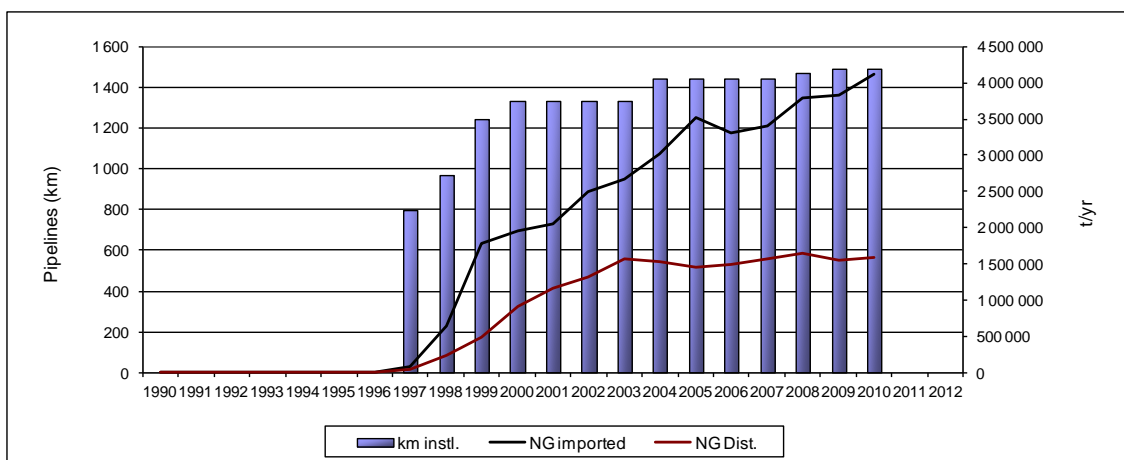
3.3.7.3.4 Activity data

According to the above explained methodology, activity data comprehends:

- extension of pipelines for transmission. Total extension of pipelines in kilometres was estimated from data concerning the operational launch of each pipeline. Because of this the activity data for transmission for each year since 1997 represents the new pipeline extension added to the total length from previous years. This pipeline data was received via DGEG from TRANSGAS;
- importation of natural gas, obtained from the DGEG's Energy Balances;
- consumption of Natural Gas. Distribution emissions were assumed to result only from small and medium size units. Therefore, total consumption was subtracted from consumption in sectors characterized for high consumptions per unit: Paper pulp; Chemical Industry; Ceramics; Cement; Glass and related products and Iron and Steel.

All three variables used as activity data are represented in the next figure.

Figure 3.95 – Activity data used to estimate GHG emissions from Natural gas transmission, distribution and transformation

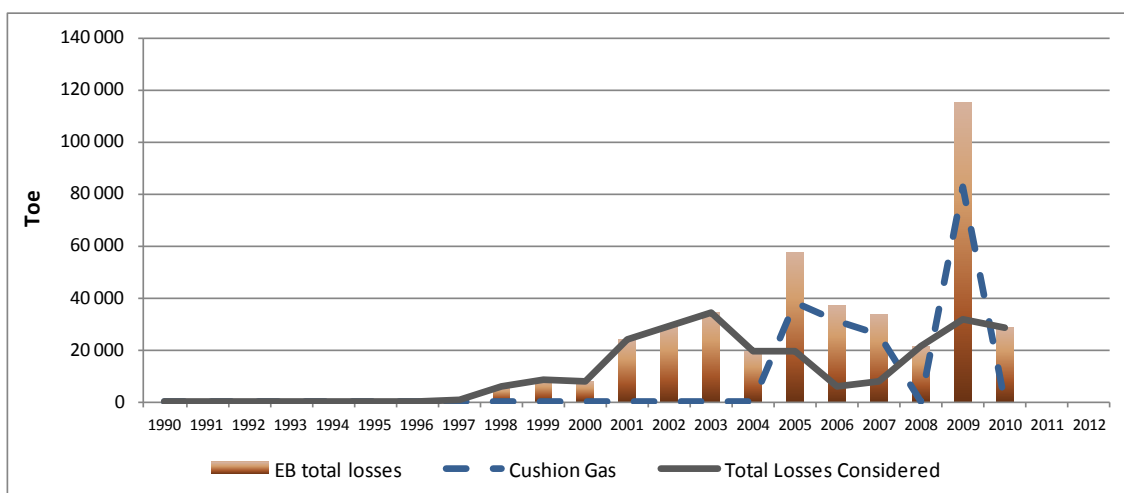


In 2009 new data was obtained from DGE concerning the consumption of cushion gas. This gas is used for maintaining constant pressure within underground storage tanks and it is considered to be confined within the tank only resulting in emissions when the tank is deactivated. Because there is no specific category in the energy balance for this type of consumption, DGE reports cushion gas together with natural gas Losses in Transmission and Distribution. This led to an overestimation of CH₄ emission in previous inventories.

The following figure shows both the total natural gas losses reported in the energy balance and the consumption of cushion gas. Also shown is the final time series considered for CH₄ emission estimation purposes (cushion gas subtracted to the total losses reported in the energy balance).

Please note that the consumption of cushion gas is only made when a storage tank begins its operation which results in a large interannual variation in the consumption of this gas.

Figure 3.96 – Natural gas losses reported in the energy balance compared with the consumption of cushion gas



After contacting DGE, the following explanations were provided concerning the variations in the natural gas losses:

The rapid increase from 2000 to 2003 results from the increase expansion of the natural gas distribution network to sectors with more ramifications (domestic and services);

The decline from 2004 to 2007 results from the stabilization in the pipeline extension in residential and service sectors coupled with improvements in pipeline quality and other general gains in efficiency;

The increase in 2008 results mainly from corrections done to the natural gas losses values reported to DGEG. For this year no Cushion Gas consumption was reported;

The increase in 2009 results from consumption of Cushion Gas in new natural gas storage facilities;

There was no consumption of Cushion Gas in 2010.

There is only one compressor station in Portugal that works at the entrance of an underground storage facility. This equipment has no fuel consumption for combustion. Throughout the pipeline network there are small pressure regulation and measurement stations used for monitoring and small pressure adjustments. These equipments also have no fuel consumption for combustion. Natural gas losses from both the large compressor station and the small pressure regulation station are included in this source category (reported as total natural gas losses in the energy balance). This information was obtained from DGEG.

3.3.7.3.5 Uncertainty Analysis

The uncertainty in activity data was considered to be 5 per cent, the value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in CH₄ emission factor, considering a low quality inventory, was assumed to be 150 per cent, and the same value was considered for CO₂ emissions which were determined simply from simple conversion of emissions in methane form.

3.3.7.3.6 Category-specific QA/QC and verification

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). No significant differences were found between data sources for this category.

3.3.7.3.7 Recalculations

Recalculations for this source category comprise:

- Revised values for pipeline extension were given by DGEG (2008 and 2009). These new values do not change emissions from 1B2d since emissions from distribution are calibrated using total losses reported in the energy balance - emissions from transmission rise while emissions from distribution fall;
- Update of the energy balance fuel consumption data for 2005, 2006 and 2008 (previous values came from provisional data).

3.3.7.3.8 Further Improvements

A new update on pipeline extension is expected in the next inventory, mainly for low pressure pipelines. This new data will not be given by DGEG which explains the fact that it was not included in this year inventory exercise.

Efforts are being done with DGEG⁴¹ and the major Portuguese company responsible for gross transport of natural gas⁴², in order to increase the tier level of the methodology. Results and changes in estimates are expected in the coming years.

3.3.7.4 *Other Fugitive Emissions (Geothermal Electricity Production) (CRF 1.B.2.d.)*

3.3.7.4.1 Overview

A small amount of electricity is produced from two geothermic sources in Azores archipelago: *Pico Vermelho* and *Ribeira Grande* Plants, and they are assumed to increment the release of carbon dioxide to atmosphere.

The available reporting (CRF) categories do not consider a specific place to report CO₂ emissions from geothermal electricity production. Nevertheless, emissions from these activity are clearly related to sector 1 (Energy) and must be better considered as fugitive emissions. However, for fugitive emissions the CRF nomenclature allows only the classes Solid Fuels (1B1) and Oil and Natural Gas (1B2), which are not exactly suitable for this activity. Sector 7 (Other) could be used in principle, but would imply that emissions from this category would be no longer included in the energy sector.

Fugitive emissions from geothermal electricity production are therefore reported in category 1B2d (Other fugitive emissions from oil and natural gas).

3.3.7.4.2 Methodology

From 1994 till 1999, the Regional Authority of Economy (Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia) performed estimates of carbon dioxide released to atmosphere from geothermic units and these were considered in the National Inventory.

For the years prior to 1994, and for the years after 1999, emissions of CO₂ were estimated from electricity production reported by DGEG, and using the emission factors estimated for the 1994-1999 period. Since the 2010 inventory all data concerning geothermal production is obtained from the Azores environmental entity (this time series starts in 2003).

3.3.7.4.3 Emission factors

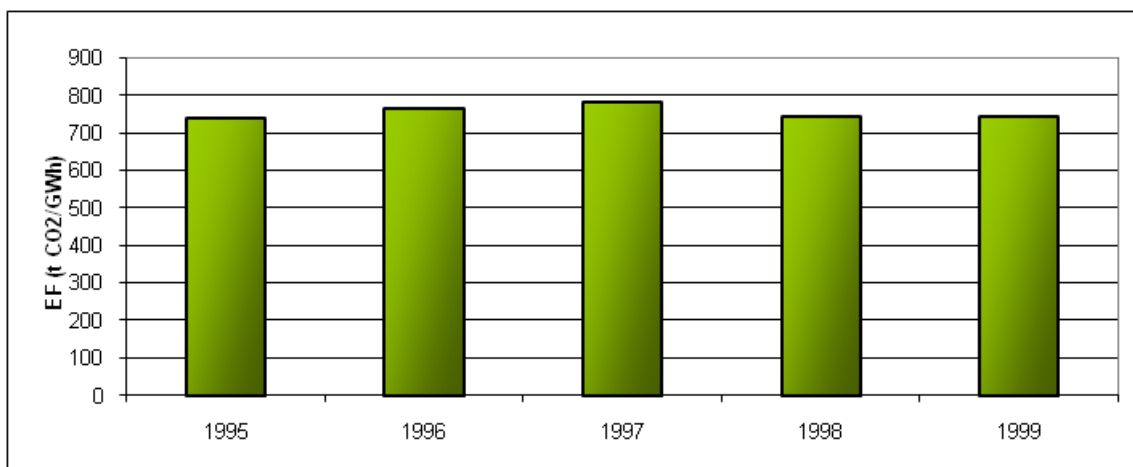
Measurements of carbon dioxide emissions are available from one plant (*Pico Vermelho*) from 1994 till 1999 and provided by the regional authority of the Autonomous Region of Azores⁴³. These results were used to estimate an average emission factor applied to the whole period.

⁴¹ Direcção Geral de Energia e Geologia/ General Directorate of Energy and Geology

⁴² TRANSGAS

⁴³ Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia.

Figure 3.97 – Emission Factor of CO₂ emissions calculated for Ribeira Grande Power Plant (1995-1999)

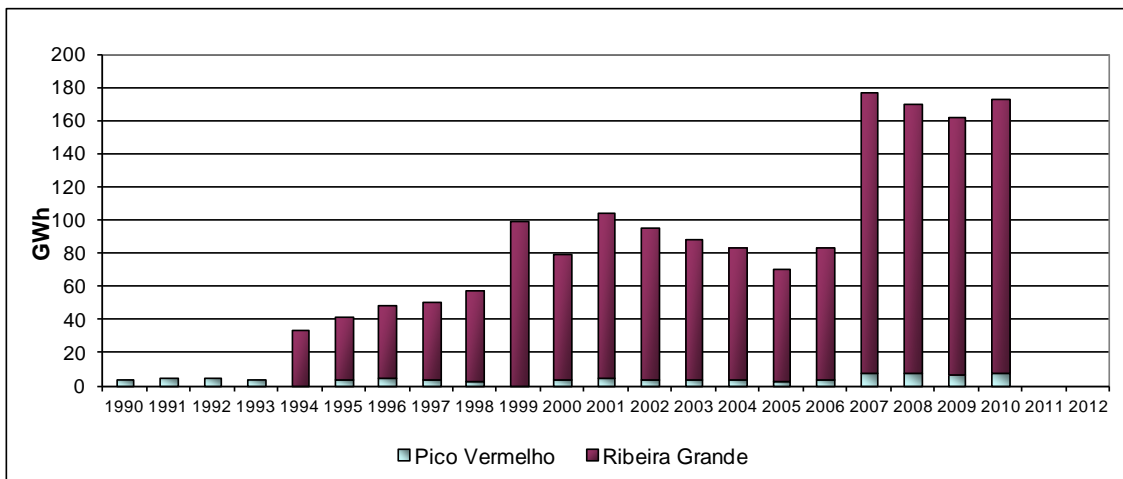


For the other power plant, Pico Vermelho, the regional authority provides estimates that indicate a common emission factor of 500 ton CO₂/GWh.

3.3.7.4.4 Activity Data

Activity data consists of geothermal production. The time series was constructed using data from the regional authority in Azores (1994-1999), where detailed data is available for each plant, and total geothermal production from DGEG for the period 1990-2002, and Azores regional environmental authority for the period 2003-2010. The ratio of production for each plant in the period 1994-1999 was used to estimate production at each plant for the whole period.

Figure 3.98 – Total Geothermal Production in Azores



Geothermal production in 2010 doubles the 2006 value.

3.3.7.4.5 Uncertainty Analysis

The uncertainty of the activity data is 5 per cent considering that the statistical information is reliable but some extrapolations have been performed for earlier years, namely to separate data per power plant.

The uncertainty in the emission factor has to be considered high. Comparing the emission factor derived to Azores with similar EF set for other regions (Iceland, New Zealand) it appears uncertainty could be about one order of magnitude.

3.3.7.4.6 Recalculations

No recalculations were done for this source sub-sector since last year's submission.

3.3.7.4.7 Further Improvements

Efforts will be made with Azores Regional Authority of Economy to obtain revised carbon dioxide released to atmosphere from geothermic units.

3.4 Recalculations

The main recalculations that are affecting this comparison are:

- Revised data for Caniçal power plant was obtained from Madeira Regional Environmental entities (2000-2009);
- Revised CO₂ emission factors and oxidation factors for several power plants. This revision resulted from a consistency issue raised by the review team (2011 UNFCCC Centralised Review Process);
- In depth revision of the Pulp and Paper industrial sector resulted in new and revised fuel consumption and pulp production data and more extensive use of plant specific emissions factors. This revision affected all years of the 1990-2009 time series (mostly the latest 7 years);
- For the Cement industrial sector several small revisions/updates were made to the emission estimation (2006-2009). These updates resulted from data (fuel consumption and LHV) received from the EU-ETS for several secondary fuels;
- Updated fuel consumption values for the Chemical industrial sector were obtained from LCP directive (2004-2009);
- Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series (1990-2009). These new values were accompanied by revised LHV which were also updated in the INERPA. The difference between newer and older values is small. This revision had more impact in emission estimated from energy balance fuel consumption data;
- Update of the energy balance fuel consumption data from 2005 to 2008 (previous values came from provisional data). This update also resulted in a revision of the biodiesel incorporation rates;
- Fuel consumption for gas oil used for heating was revised by DGEG for some industrial sectors (2006-2009);
- Revision of coal consumption in railways (2003-2009);
- Error correction in the estimation spreadsheet concerning CO₂ emission factor for biogas in the services sector (1999-2009);
- Correction of an estimation error in the residential sector concerning N₂O emission from gaseous fuels (1997-2009). Previously no N₂O emissions were reported for this pollutant associated with consumption of gaseous fuels;
- Correction of inconsistencies identified in the consumption time series of biomass in the residential sector (1997-2009);
- Revision of the charcoal fuel consumption time series from 1999 to 2009. This resulted from a report made by DGEG concerning fuel consumption in the residential sector;

- Update of fuel consumption in bunkers for the period 2004-2009. The new data that supports this updates comes from DGEG;
- Revised values for pipeline extension were given by DGEG (2008 and 2009). These new values do not change emissions from 1B2d since emissions from distribution are calibrated using total losses reported in the energy balance - emissions from transmission rise while emissions from distribution fall.

Figure 3.99 – Differences between 2011 and 2012 submissions (CO₂, CH₄ and N₂O)

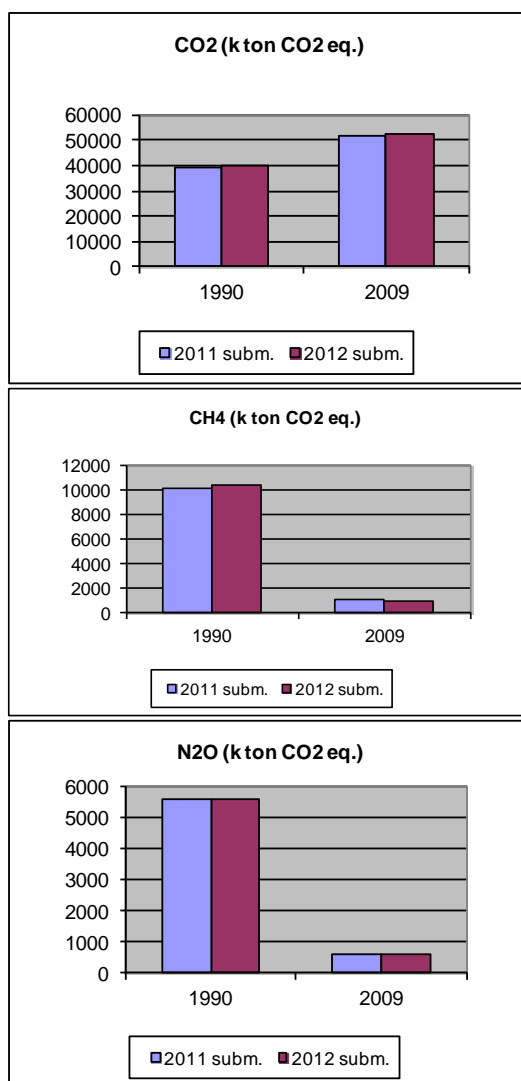


Table 3.136 – Recalculations (differences between 2011 to 2012 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2			CH4			N2O		
		2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Difference (1)
		CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)
1990										
1. Energy		39 320.89	39 936.79	1.57	10 188.33	10 429.78	2.37	5 619.45	5 601.78	-0.31
1.A.	Fuel Combustion Activities	39 156.68	39 785.19	1.61	588.31	589.29	0.17	447.18	454.04	1.54
1.A.1.	Energy Industries	15 948.10	16 303.32	2.23	470.53	471.51	0.21	444.73	451.60	1.54
1.A.2.	Manufacturing Industries and Construction	9 163.10	9 170.80	0.08	4.33	4.33	0.00	61.05	61.05	0.00
1.A.3.	Transport	9 917.07	10 139.78	2.25	38.82	32.04	-17.45	67.26	67.45	0.28
1.A.4.	Other Sectors	4 025.13	4 067.60	1.05	78.92	86.59	9.73	78.66	82.50	4.88
1.A.5.	Other	103.28	103.69	0.41	348.30	348.38	0.02	236.92	239.75	1.20
1.B.	Fugitive Emissions from Fuels	164.21	151.60	-7.68	0.17	0.17	4.74	0.85	0.85	0.11
1.B.1.	Solid fuel	8.65	8.65	0.00	117.78	117.78	0.00	2.44	2.44	0.00
1.B.2.	Oil and Natural Gas	155.56	142.95	-8.11	66.02	66.02	0.00	NO	NO	
2009										
1. Energy		51 991.95	52 522.79	1.02	1 066.70	954.29	-10.54	612.05	580.11	-5.22
1.A.	Fuel Combustion Activities	51 346.27	51 875.09	1.03	408.87	296.02	-27.60	609.60	577.66	-5.24
1.A.1.	Energy Industries	19 505.19	19 381.53	-0.63	8.08	8.08	0.00	137.51	137.51	0.00
1.A.2.	Manufacturing Industries and Construction	8 358.29	8 555.26	2.36	56.26	49.74	-11.59	93.07	91.31	-1.90
1.A.3.	Transport	18 635.88	18 937.20	1.62	30.17	36.88	22.26	195.71	182.25	-6.88
1.A.4.	Other Sectors	4 761.62	4 915.80	3.24	314.36	201.31	-35.96	182.57	165.84	-9.16
1.A.5.	Other	85.29	85.28	0.00	0.01	0.01	0.00	0.75	0.75	0.00
1.B.	Fugitive Emissions from Fuels	645.68	647.70	0.31	657.83	658.26	0.07	2.45	2.45	0.00
1.B.1.	Solid fuel	IE,NO	IE,NO		IE,NO	IE,NO		NO	NO	
1.B.2.	Oil and Natural Gas	645.68	647.70	0.31	657.83	658.26	0.07	2.45	2.45	0.00

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

3.4.1 Further Improvements

Considering that the energy sector is the most prevalent emission source, special efforts must always be made to improve emission estimates, even if they affect smaller energy sub-sectors. Future improvements to the inventory will depend on the conclusions of the MDP in the scope of SNIERPA's implementation, which is being made with direct contact with the main stakeholders of the energy sector, and in close collaboration of the inventory team from APA. Although the main conclusions from this report are still not set in a final report and plan, the following preliminary routes may be here identified.

- Better integration between activity data in the air emissions inventory and other surveys such as LCP directive, Autocontrolo program, EPER/E-PRTR, the EU-ETS and the energy surveys (co-generation) made annually by DGEG. Contacts are being made to implement it. Particular work is being done to streamline the collection of data and emission estimates between the inventory and the EU-ETS, following the promotion efforts that are being made by the European Commission;
- Determination of country-specific emission factors (SO_x and NO_x) from monitoring data collected from the Autocontrolo program and CO₂ emission factors for information collected under carbon market;
- Consistency Checks on Refining/Storage timeseries.

3.5 Reference Approach

3.5.1 Overview

The reference approach consists in the estimate of CO₂ emissions using the simple approach tier 1 of IPCC (1997). Although the Portuguese National Inventory uses an sectoral approach (National Approach) of higher tier level, nevertheless the UNFCCC reporting guidelines request that parties make also a top-down "reference approach"⁴⁴ for estimation of CO₂ emissions from fossil fuel combustion, in addition to the bottom-up sectoral methodology.

The Reference approach uses a very simple methodology, assuming that all carbon input to the national economy in fuel form, it is either stored in some way (fuel stocks, products or even left unoxidized in ash) or it must be released to the atmosphere. In order to calculate the carbon released it is not necessary to know exactly how and where the fuel was used or what intermediate transformations it underwent. In this respect the methodology may be termed a "top-down" approach compared with the "bottom-up" methods used for other gases (IPCC,1997).

The Reference Approach requires simple statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of values for the consumption of fossil products used for non-energy purposes, where carbon may be stored.

⁴⁴ This does not mean that a "bottom-up" approach should not be followed for estimating CO₂ emissions but the total emissions must be compared with those obtained from the Reference Approach.

3.5.2 Methodology

The following methodological steps were made in accordance with IPCC (1997):

- 1 Estimate consumption of fuels by fuel/product type;
- 2 Convert the fuel data to a common energy unit (TJ), if necessary;
- 3 Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels;
- 4 Estimate the amount of carbon stored in products for long periods of time;
- 5 Account for carbon not oxidized during combustion;
- 6 Convert emissions of carbon to full molecular weight of CO₂.

3.5.2.1 Fuel consumption

Apparent consumption was estimated from energy balances from DGEG according to:

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{Stock Change.}$$

for primary fuels and,

$$\text{Apparent Consumption} = \text{Imports} - \text{Exports} - \text{Bunkers} - \text{Stock Change.}$$

for secondary fuels.

National production is not considered because the carbon in these fuels was already included in the supply of primary fuels from which they were derived.

3.5.2.2 Energy Consumption

The Portuguese National Balance reports consumption in energy units (toe⁴⁵), apparent consumption needs only to be converted to TJ using the multiplier 41.868 GJ/toe.

3.5.2.3 Carbon Content of Fuels

Carbon content in apparent consumption is estimated in reference approach from:

$$\text{Apparent Consumption}_{(\text{Gg C})} = \text{Apparent Consumption}_{(\text{TJ})} * \text{Carbon Content}_{(\text{MgC} / \text{TJ})} * 10^{-3}$$

The carbon content of fuels was determined using the Carbon Emission Factors used in the sectoral approach, which are presented in Table 3.137.

⁴⁵ Ton of oil equivalent

Table 3.137 – Carbon content of fuels and Oxidation Factor used in the Reference Approach

Fuel			C content	FaC _{ox}
			(t C/TJ)	0 - 1
Liquid Fossil	Primary Fuels	Crude Oil	20.0	0.99
		Orimulsion	22.0	0.99
		Natural Gas Liquids	17.2	
	Secondary Fuels	Gasoline	19.4	0.99
		Jet Kerosene	19.9	0.99
		Other Kerosene	20.0	0.99
		Gas / Diesel Oil	19.9	0.99
		Residual Fuel Oil	20.7	0.99
		LPG	17.7	0.99
		Naphtha	20.0	0.99
		Bitumen	22.0	0.99
		Lubricants	20.0	0.99
		Petroleum Coke	27.5	0.99
		Refinery Feedstocks	20.0	0.99
		Other Oil	20.0	0.99
Solid Fossil	Primary Fuels	Anthracite (a)	26.8	0.98
		Coking Coal	25.8	0.98
		Other Bit. Coal	25.1	0.98
		Sub-bit. Coal	26.2	0.98
		Lignite	27.3	0.98
		Oil Shale	29.1	0.99
		Peat	28.9	0.99
	Secondary Fuels	BKB & Patent Fuel	27.0	0.98
		Coke Oven/Gas Coke	29.5	0.98
Gaseous Fossil		Natural Gas (Dry)	15.3	1.00
Biomass		Solid Biomass	29.9	1.00
		Liquid Biomass	20.0	1.00
		Gas Biomass	30.6	1.00

3.5.2.4 Carbon Stored in Products

For the IPCC Reference Approach, the suggested formula for estimating carbon stored in products for each country is:

$\begin{aligned} \text{Total Carbon Stored (Mg C)} &= \text{Non-Energy Use (toe)} \\ &\times \text{Conversion Factor (TJ/toe)} \\ &\times \text{Emission Factor (t C/TJ)} \\ &\times \text{Fraction Carbon Stored} \end{aligned}$

Presently the following products are taken from the National Energy Balance: lubricants, bitumen, and naphtha and residual fuel oils used as raw materials. Original statistical information was already expressed in toe. Emission factors and the fraction of carbon stored are reported in Table 3.138.

Table 3.138 – Reference Approach. Carbon Emission Factor and Fraction of carbon stored

Fuel	C content	FacOX
	(t C/TJ)	0..1
Naphtha	20.0	0.8
Lubricants	20.0	0.5
Bitumen	22.0	1.0
Fuel Oil	21.1	0.8

3.5.3 Actual Carbon Dioxide Emissions

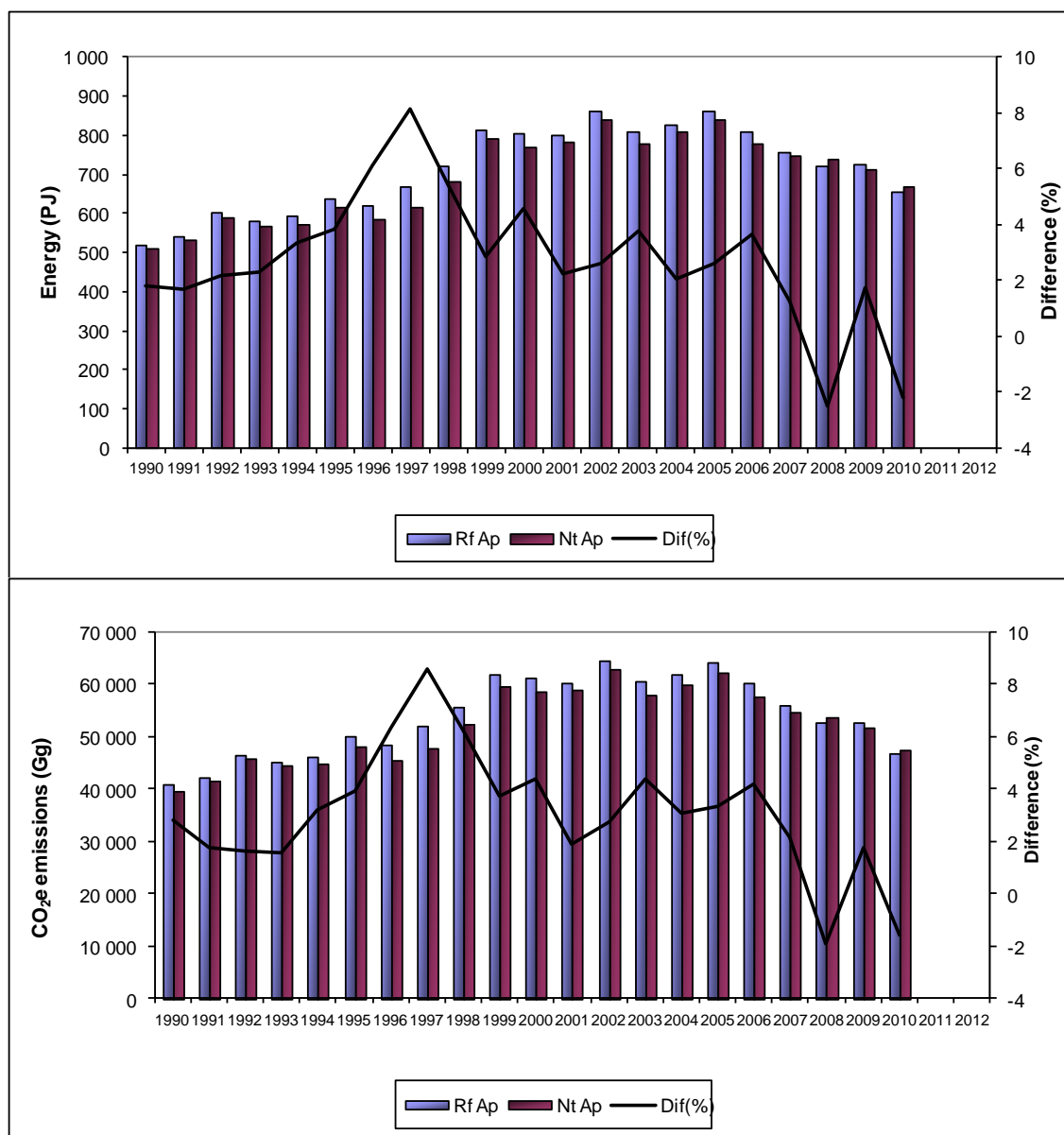
Estimated simply from:

$$\text{CO}_2 \text{ Emission} = 44/12 * (\text{Carbon Content} - \text{Carbon Stored}) * \text{Oxidation Factor}$$

3.5.4 Results - Comparison of Reference Approach and Sectoral Approach

Detailed data used in the reference approach calculation is reported in CRF tables and is not duplicated in NIR. The emissions estimated according to reference approach and national approach show differences in both energy consumption and carbon emissions, and are presented in Figure 3.100.

Figure 3.100 – Comparison of Energy Consumption and CO₂ emissions between the National approach and the Reference Approach



Differences are mostly explained by the following:

- differences in the Energy Balance and the energy activity data used by the inventory – where data collected directly from emission units (Large Point Sources) play a very representative role – and a different approach to account for emissions from carbon stored in products;
- specific LHV values for LPS are not always considered in the Energy Balance;
- the per cent of feed-stocks which carbon is stored in products are default values and not specific of the national conditions reflected in the inventory;
- the energy balance as been updated in order to follow the IPCC criteria to distinguish between domestic and international fuel use. This improvement

contributes to decrease the difference between the reference and the sectoral approach. Portugal is still developing efforts to further improve the split between domestic and international consumption in the energy balance;

The difference between the approaches in terms of CO₂, has been reduced after 2001, which is coincident with the efforts that were made by DGEG and APA in order to improve consistency between the different approaches. The slight increase in the difference between the two approaches from 2008 to 2009 may be due to the reclassification of lime production and the corrections of double counting for some co-generation power plants. The year 2010 keeps the general downward trend observed since 1997.

3.5.5 Feedstock

Emissions of greenhouse gas emissions from feedstock use are only clearly accounted in the inventory in the following situations:

- emission of CO₂ resulting from use of feedstock sub-products as energy sources. That is the case of emissions from consumption of fuel gas in refinery and petrochemical industry;
- emission of CO₂ liberated as sub-product in production processes such as ammonia production;
- emission of NMVOC from fossil fuel origin, and occurring from solvent use and evaporation. Although in this case it is not possible to establish which part results from feedstock consumption in Portugal in the energy balance;

However, some potential emissions are not estimated or are only partly estimated. Those that are estimated in the reference approach but not in sectoral approach are:

- emissions from mineral oil use as lubricants;
- emissions from wear of bitumen in roads.

It is evident that more efforts should be made to estimate other emissions from feedstock use, although it is expected that reporting guidelines should give more clear guidance in the future.

4 INDUSTRIAL PROCESSES (CRF 2.)

4.1 Overview

This source sector includes GHG emissions resulting from the chemical and physical transformation of raw materials in the industrial transformation processes, excluding emissions that result from combustion processes aiming for energy production⁴⁶. According to UNFCCC reporting guidelines, also are included in this sector the emissions of fluorinated compounds (HFC, PFC and SF₆) that are used in different applications - not solely industrial, but also in domestic and services sector - as substitutes to ozone depleting substances (ODS). Emissions occurring in production processes in industry, but involving the use of solvents or solvent bearing substances (such as paint), are included in source sector "Use of solvent and other uses – CRF 3" and discussed in chapter 5.

Industrial processes, either involving combustion or not, result also in the release of other atmospheric pollutants like acidifying gases and indirect GHG: NO_x, NMVOC and SO_x. Industrial processes are also relevant sources of particulate matter (PM, PM₁₀, PM_{2.5} and PM₁) and local air pollutants such CO and Heavy Metals. The methodologies and emission factors that are used in the Portuguese air emission inventory for the estimate of emission from these sources are discussed in the Inventory Informative Report⁴⁷.

In terms of total GHG, emissions from the industrial production sector have increased from about 4.7 Mton CO₂e in 1990 to 5.8 Mton CO₂e in 2010, as may be seen from the figure below, i.e. emissions estimated for 2010 are about 21.5 percent higher than the emissions estimated for 1990⁴⁸. The majority of emissions, expressed in CO₂e, are associated with mineral industry, responsible for 74.8 percent of total emissions from this sector in 1990, and 70.9 percent of total emissions from this sector in 2010, as may be seen in Figure 4.2. The remaining sub-source sectors (2B, 2C, 2D and 2F⁴⁹) have a lower importance, contributing to 29.1 percent of total emissions. This a relevant increase in sub-category 2F, consumption of Halocarbons and SF₆, which represents in 2010 about 21.5 percent of total GHG emissions from this source sector, and shows a fast grow over years.

⁴⁶ Emissions of combustion are considered in this sector if they are considered a production process and not as a way to obtain energy, even if the energy is used directly in the production process such as in a furnace. Emissions from combustion processes in industry with the sole aim of obtaining energy (boilers, furnaces, engines) are included in Energy sector.

⁴⁷ IIR is the report of emissions elaborated under the reporting obligations of the Convention on Long Range Trans-boundary Air Pollution (CLRTAP), of the UN-ECE. It will be available also in <http://www.apambiente.pt>.

⁴⁸ Base year for F-gases is however 1995.

⁴⁹ No emissions were allocated to sub-category 2G – Other. Emissions for category. Sector 2 F - Production of Halocarbons and SF₆ does not occur in Portugal.

Figure 4.1 – Total GHG emissions from Industrial Processes per source sub-sector (1990-2010)

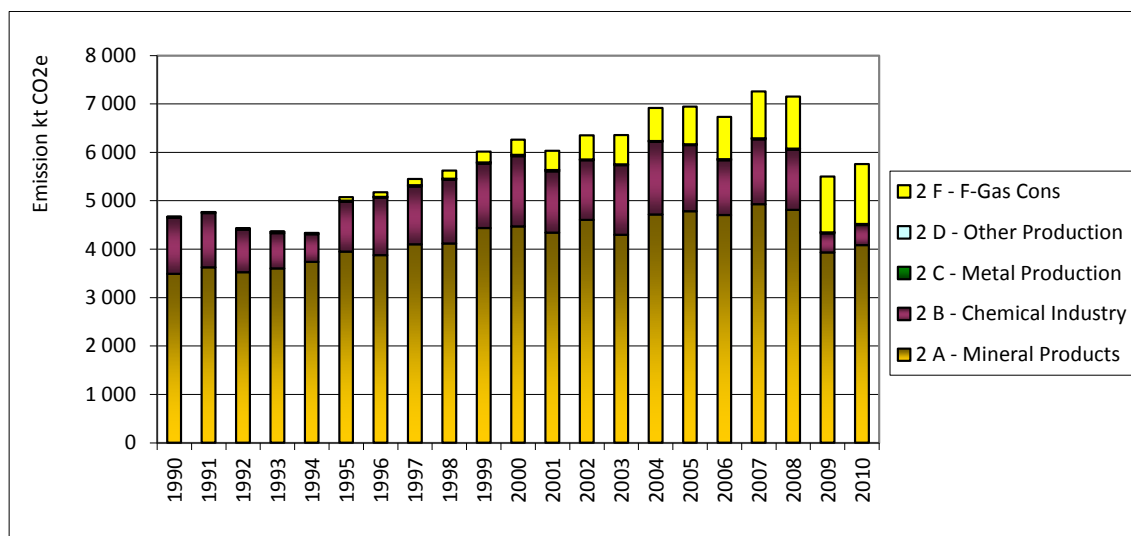
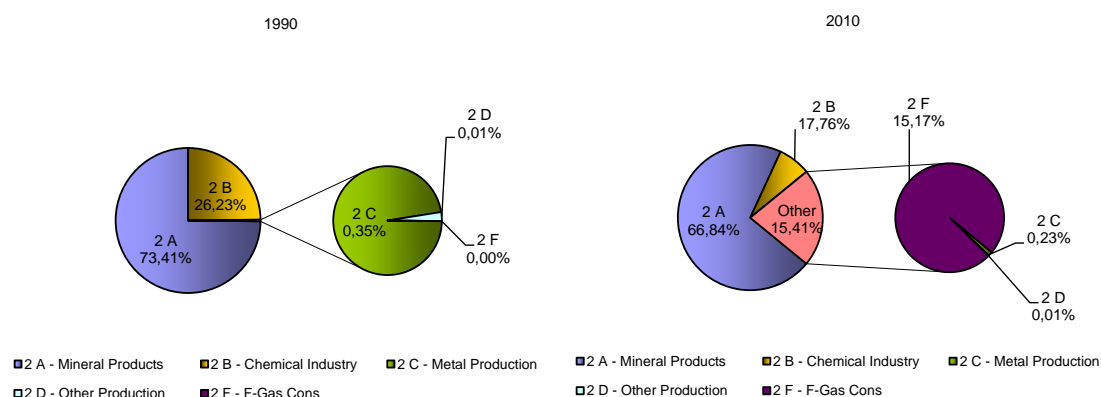
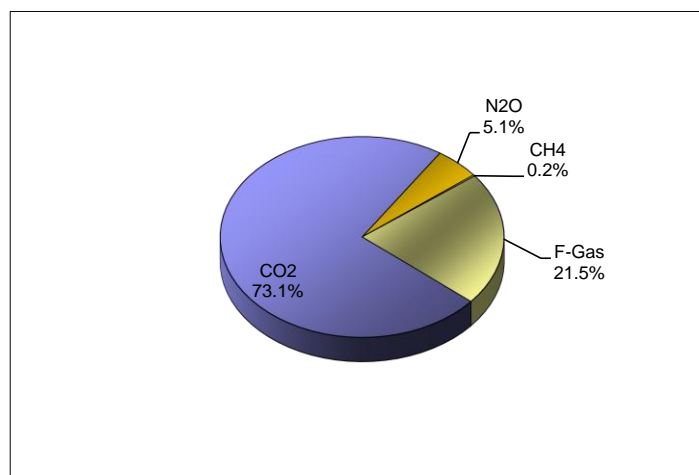


Figure 4.2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2010



The major part of greenhouse gas emissions are released directly as CO₂; while N₂O represents a smaller proportion of emissions and methane emissions are a non relevant part, as may be seen in the figure below for year 2010. Fluoride gases are becoming an important source and have already surpassed the relative importance of nitrous oxide.

Figure 4.3 - GHG emissions from Industrial Processes per greenhouse gas in 2010



4.2 Recalculations

Detailed explanation of the recalculations made will be presented for each category, and in broad terms they resulted from activity data time series revision from INE.

Figure 4.4 - Differences between 2011 and 2012 submissions for CO₂, CH₄ and N₂O emissions

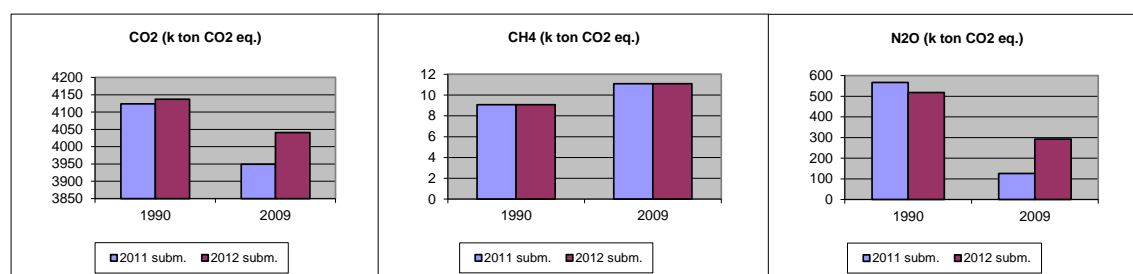


Table 4.1 - Recalculations (differences between 2011 and 2012 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Difference (1)
	CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)		
1990									
2. Industrial Processes	4 123.57	4 136.93	0.32	9.08	9.08	0.00	566.68	517.92	-8.60
2.A. Mineral Products	3 474.51	3 487.87	0.38	0.76	0.76	0.00	NO	NO	
2.B. Chemical Industry	632.69	632.69	0.00	8.32	8.32	0.00	566.68	517.92	-8.60
2.C. Metal Production	15.93	15.93	0.00	IE,NO	IE,NO		NO	NO	
2.D. Other Production	0.44	0.44	0.00						
2.G. Other	NO	NO		NO	NO		NO	NO	
2009									
2. Industrial Processes	3 949.45	4 040.79	2.31	11.09	11.09	0.00	126.37	292.52	131.48
2.A. Mineral Products	3 838.89	3 930.18	2.38	1.75	1.75	0.00	NO	NO	
2.B. Chemical Industry	92.18	92.18	0.00	9.34	9.34	0.00	126.37	292.52	131.48
2.C. Metal Production	18.05	18.15	0.55	IE,NO	IE,NO		NO	NO	
2.D. Other Production	0.32	0.27	-15.00						
2.G. Other	NO	NO		NO	NO		NO	NO	

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

4.3 Category Sources

4.3.1 Mineral Industry (CRF 2.A.)

4.3.1.1 *Cement Production (CRF 2.A.1.)*

4.3.1.1.1 Overview

During the 1990-2010 period there were six cement production plants operating in Portugal, mostly dedicated to Portland cement production⁵⁰ and almost all localized in the southern half of the country. Five of these clinker producing units use the dry process while the remaining one uses both the dry and the semi-wet process - although the dry process is prevalent in that unit too. All dry process units have short kilns with pre-heaters, and 5 kilns in four units are provided with pre-calciners⁵¹. The importance of clinker production for each one of the six plants is presented in the next table, from where it is evident that production of clinker and CO₂ decarbonising emissions are dominated by three plant units.

Portland cement is broadly a mixture of clinker and gypsum with some minor additives. Cement production is in essence a pyro-processing operation on calcium carbonate, aluminium-siliceous and iron-oxide materials to form a mixture of calcium silicates, aluminates and aluminoferrites that forms a binder with water.

Carbon dioxide emissions from cement production process result from the conversion of CaCO₃ and MgCO₃, the main constituents of limestone, to lime (CaO) and MgO, while leaving CO₂ as by product to atmosphere (Decarbonisation). Sulphur oxides emissions result from sulphur existence both in fuel and in some constituent materials such as clay. However contrary to what occurs with CO₂, usually most of the SO_x that is formed during calcination will be absorbed and long term immobilized in clinker and then in cement.

Only emissions of CO₂ from limestone decarbonising are reported here. Emissions of other pollutants, although they may result from both fuel and raw material, are reported in Energy (CRF 1A2) for simplicity sake. CO₂ emissions from liberation of carbon in fuel during combustion are reported also in Energy sector 1A2. However, although emissions are estimated separately from carbon originally present in fuel and carbon present in raw materials, they are in fact emitted at same place and are inseparable in concept.

4.3.1.1.2 Methodology

EU-ETS method A from Annex VII of Decision 2007/589/EC is used for the period 2005-2010. Calculation is based on the carbonate content of process inputs (including fly-ash or blast furnace slag) with cement kiln dust (CKD) and bypass dust deducted from raw material consumption (Tier 3). It is assumed a complete calcination (conversion factor = 1).

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to the following equation:

⁵⁰ There is also some production of white Portland cement, which is characterized by a lower iron and manganese content, than grey cement, and it is used mainly for decorative purposes (EPA,1995). There are also in Portugal smaller additional cement plants in Portugal but that do not produce clinker.

⁵¹ One calciner is a false pre-calciner.

$Emi_{CO_2} = Kiln\ input * EF * CF$ where Emi_{CO_2} – emissions of CO_2 from cement production, originated from carbon in kiln input materials (kton/yr);

Kiln input – Net amount of relevant kiln input (ton/yr);

EF – emission factor (kton CO_2 /ton of each relevant kiln input); CF – Conversion factor (0 to 1). For the period 1990-2004, emissions were estimated based on clinker production time series.

4.3.1.1.3 Emission Factors

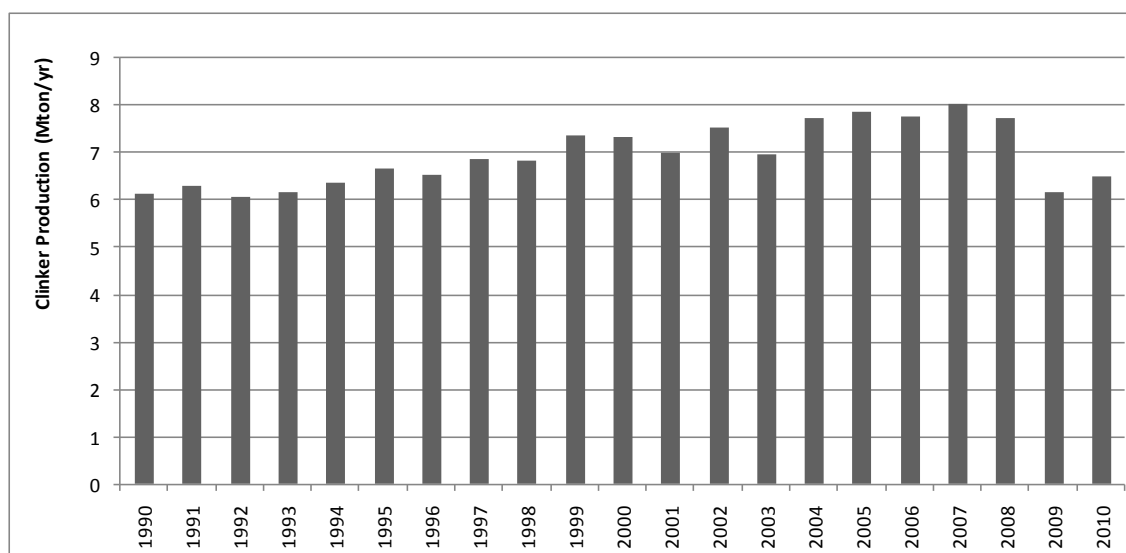
The CO_2 emission factors were estimated by converting kiln input materials composition data, using the following stoichiometric ratios (Table 1 of Annex VII of Decision 2007/589/EC):

Substance	Unit	Stoichiometric ratios
$CaCO_3$	t CO_2 /t $CaCO_3$	0.440
$MgCO_3$	t CO_2 /t $MgCO_3$	0.522
$FeCO_3$	t CO_2 /t $FeCO_3$	0.380
C	t CO_2 /t C	3.664

4.3.1.1.4 Activity Data

Data on consumption of raw materials, was obtained for the period 2005-2010 from EU-ETS. Clinker production for all the years from 1990 to 2010, was received directly from each industrial plant, and the correspondent time series may be observed in next figure. Total clinker production for 1990-2010 as reported in the National Statistical Database from INE is fully consistent with the sum of the information received from each individual plant.

Figure 4.5 – Total Production of cement clinker in Portugal (1990-2010)

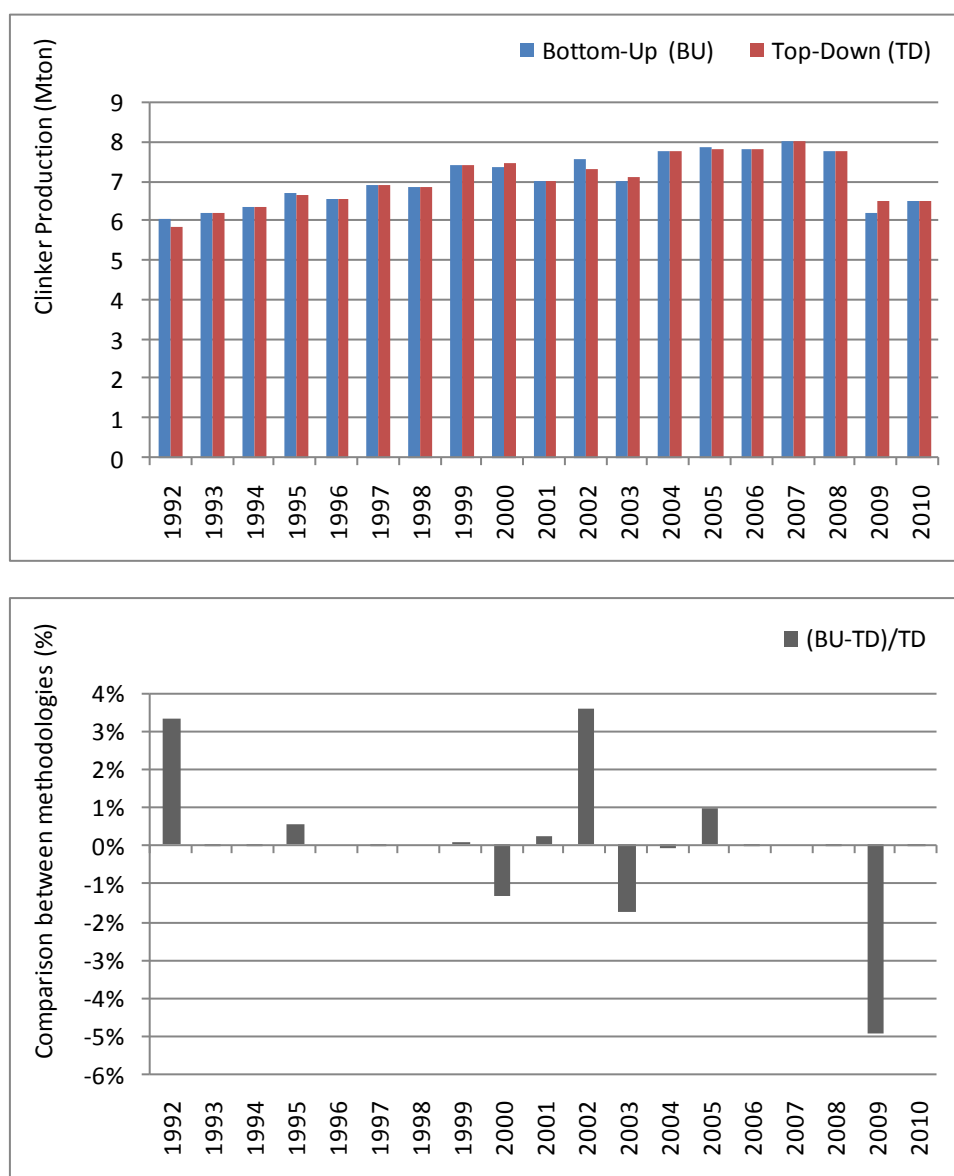


4.3.1.1.5 Uncertainty assessment

The uncertainty value of the emission factor was determined to be 10 percent for all years which results from the consideration of uncertainty error in the assumption that all CaO is from CaCO₃, CaO content of clinker and CKD parameter. In all cases the maximum values of uncertainty in the GP (IPCC,2000) was considered using a conservative approach. In a similar conservative mode the uncertainty associated with activity data was set at 2 percent.

4.3.1.1.6 Category-specific QA/QC and verification

Emissions estimates were based on a bottom-up approach with collection of plant specific clinker production data. A comparison was made using a top-down approach based on clinker production data obtained from national production statistics (IAP) for the period 1992-2010. There are slight differences using the two different approaches, but, generally, data is consistent.



4.3.1.1.7 Recalculations

No recalculations were made.

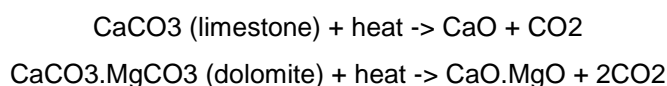
4.3.1.1.8 Further Improvements

There are no further improvements planned for this sector.

4.3.1.2 *Lime Production (CRF 2.A.2.)*

4.3.1.2.1 Overview

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200°C) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving calcium oxide (CaO) or magnesium oxide (MgO) as valuable products. The following chemical conversion equation applies, where for each mol of oxide a mol of carbon dioxide is emitted.



Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy CaCO_3 content (at least 50 percent) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of Na_2CO_3 , NaOH, steel, refractory material, SO_2 absorption, CaC_2 , glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;
- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45 percent in content). Dolomite quicklime is a mixture of CaO and MgO;
- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime: Ca(OH)_2 It is produced from CaO and water. When an equivalent quantity of water is used is called slaked lime, when an excess water is used is milk of lime and a clear solution of Ca(OH)_2 in water is limewater. It is used as an industrial alkali and in the preparation of mortar (slaked lime plus sand) which sets to solid by reconversion of the hydroxide to CaCO_3 (Sharp, 1981);
- Hydraulic Lime. A mixture of calcium oxide (CaO) and silicates, it is an intermediate product between lime and cement.

Besides the production of lime in the lime industry to furnish market requirements, lime is also produced and consumed inside industrial sectors. That is the case of the production of lime in Kraft paper pulp plants, where quicklime is produced from carbonates in lime kilns and it is used to regenerate green liquor to white liquor. That is also the case of iron and steel production whereas emissions from this activity are also reported in this source category.

4.3.1.2.2 Methodology

EU-ETS method A from Annex VIII of Decision 2007/589/EC is used for the period 2005-2010. Calculation is based on the amount of calcium carbonate and magnesium carbonate in the raw materials consumed (Tier 3).

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to the following equation:

$$Emi_{CO_2} = \text{Kiln input} * EF * CF$$

Where

Emi_{CO_2} – emissions of CO_2 from lime production, originated from carbon in kiln input materials (kton/yr);

Kiln input – Net amount of relevant kiln input (ton/yr);

EF – emission factor (kton CO_2 /ton of each relevant kiln input);

CF – Conversion factor (0 to 1).

For the period 1990-2004, emissions were estimated based on lime production time series.

4.3.1.2.3 Emission Factors

The CO_2 emission factors were estimated by converting kiln input materials composition data, using the following stoichiometric ratios (Table 1 of Annex VIII of Decision 2007/589/EC):

Substance	Unit	Stoichiometric ratios
$CaCO_3$	t CO_2 /t $CaCO_3$	0.440
$MgCO_3$	t CO_2 /t $MgCO_3$	0.522

4.3.1.2.4 Activity Data

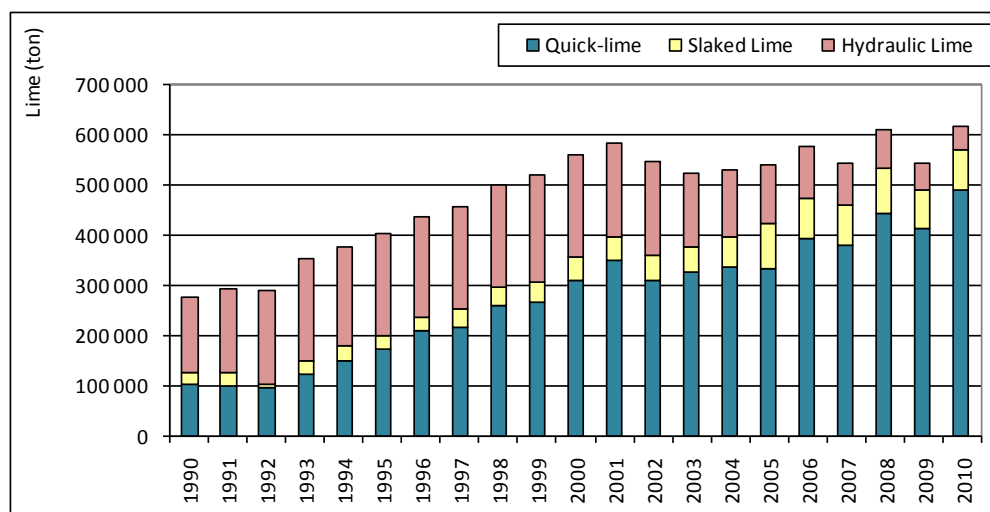
Data on consumption of raw materials, was obtained for the period 2005-2010 from EU-ETS. Lime production for the period 1990-2010, was obtained from National Statistics (INE) IAPI industrial survey.

Lime production in the iron and steel industry was available from information received from the industry for the period 1991-1994. For the remaining years 1990 and 1995-2001 annual lime production, which data was unavailable, was forecasted using energy consumption as surrogate indicator. After year 2002 production of lime in this unit was interrupted and the production line dismantled. All lime produced in the iron and steel plant was high calcium lime.

In the case of the paper pulp industry the IAIT/IAPIS surveys have no available information in lime production but only of limestone and dolomite consumption. Lime production had to be estimated from consumption of those carbon bearing materials and assuming the stoichiometric ratios of limestone and dolomite rock. Consumption of limestone and dolomite materials is available for the period 1989-2000 from National Statistics (INE): for the period 1989-1991 from IAIT industrial survey, and for 1992-2010 from the IAPI industrial survey.

The time-series of Lime production per lime type is presented in the figure below, from where it is clear the pattern of production increase (183 percent from 1990 to 2010), which is particular evident for quick-lime that has more than doubled in the period. Also evident is the minor importance of slaked lime production.

Figure 4.6 – Production of lime in Portugal per lime type (1990-2010)



4.3.1.2.5 Uncertainty assessment

According to the GP the uncertainty associated with the carbon dioxide emission factor for lime production is 15 percent for hydraulic lime and 2 percent for all other lime types (IPCC,2000). The resultant uncertainty value according to the share of each lime type in Portugal was set at about 8.5 percent.

The GP assumes that uncertainty in activity data is very high due to problems in gathering lime data. The national inventory recognizes that this is in fact the case for Portugal, particularly because in some situations lime is not produced for market but for internal consumption in the industrial plant, and may be not properly reported in statistical surveys. The maximum uncertainty value of 105 percent was therefore used in the uncertainty analysis.

4.3.1.2.6 Recalculations

Lime production estimates in the paper pulp industry have been revised due to an error on the stoichiometric ratios.

4.3.1.2.7 Further Improvements

There is still some possibility that the inventory is doubling the estimate of CO₂ emissions, if part of the quick-lime that is produced in an industrial unit is sold and used again to produce slaked lime or hydraulic lime in a different industrial plant. To correct this effect, emissions estimated from lime production should be cross checked with emission estimates from limestone and dolomite consumption. Another contribution factor to over-estimation of emissions is the possible use of calcium materials to other used than lime⁵² production in the paper pulp industry.

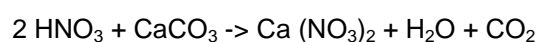
⁵² Or any other process not resulting in decarbonisation.

A better and detailed knowledge of the proportion of lime that is high calcium lime and which is dolomite lime should be achieved – however this separation cannot be done from National Statistical Databases except in the case of the paper pulp industry - allowing this differentiation to be used in activity data and not in emission factor as it was done in this submission.

4.3.1.3 *Limestone, Dolomite and Carbonate Use (CRF 2.A.3.)*

4.3.1.3.1 Overview

Carbon dioxide liberation to atmosphere occurs from several industrial activities that use limestone (CaCO_3), dolomite rock ($\text{CaCO}_3 \cdot \text{MgCO}_3$) or other carbonates, but only when original materials are not incorporated as inert components but suffer a chemical removal of carbon, as for example when calcium carbonate is added to nitric acid to form calcium nitrate:



Presently, in the inventory of GHG emissions, only CO_2 emissions resulting from production of calcium and magnesium nitrates and consumption of sodium carbonates in paper pulp production are reported in source category 2A3.

Use of carbonate materials in glass industry is covered in sector activity 2A7. Although the use of carbonates in iron and steel industry as flux in blast furnace result in CO_2 emissions, these were included in Energy (1A2), being assumed that the emission factor of CO_2 from blast furnace consumption⁵³ already includes the carbon from limestone that was liberated from the flux in the blast furnace. While consumption of carbonate materials is reported in the National Statistics Database (INE) for other industrial activities, some do not correspond to uses where carbon is liberated and no emissions are estimated: paint, soap, pharmaceutical and agrochemical products, cleaning products, perfumeries and hygiene products, glues and adhesives, tire and rubber products, plastic products and synthetic fibbers, and all food and beverage industry.

Lime production involves as well the consumption and decarbonising of carbonate materials, limestone or dolomite rock. Albeit the similitude of both process, carbon dioxide emissions from lime production, including production in the paper pulp industry and in the iron and steel industry, are reported in source category 2A2 and were already discussed.

Non- CO_2 process emissions in the paper pulp and fertilizer industry are reported in other source categories, respectively 2B and 2C. Combustion emissions from these industrial activities are reported in source category 1A2.

4.3.1.3.2 Methodology

CO_2 emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of CO_2 that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

$$\text{Emi}_{\text{CO}_2 (y)} = 44/12 * \text{Mat}_{\text{Carb} (m,y)} * \text{C}_{\text{content} (m)} * 10^{-3}$$

where

⁵³ Determined from composition of Blast Furnace Gas given by industry.

$Emi_{CO_2(y)}$ - emission of carbon dioxide in year y (kton/yr);

$Mat_{Carb}(m,y)$ - consumption of carbonate containing material m in year y (ton/yr);

$C_{content(m)}$ - carbon content of material m consumed in year y (ton C/ton).

4.3.1.3.3 Emission Factors

Carbon content of materials consumed in Portugal was set from molecular stoichiometry⁵⁴:

Table 4.2 - Carbon content of carbonate materials

Material	Ccontent
Sodium Carbonate	0.42
Barium Carbonate	0.22
Limestone*	0.44
Dolomite [#]	0.48
Magnesium Carbonate	0.52
Coal (Electrodes) to be removed	3.67

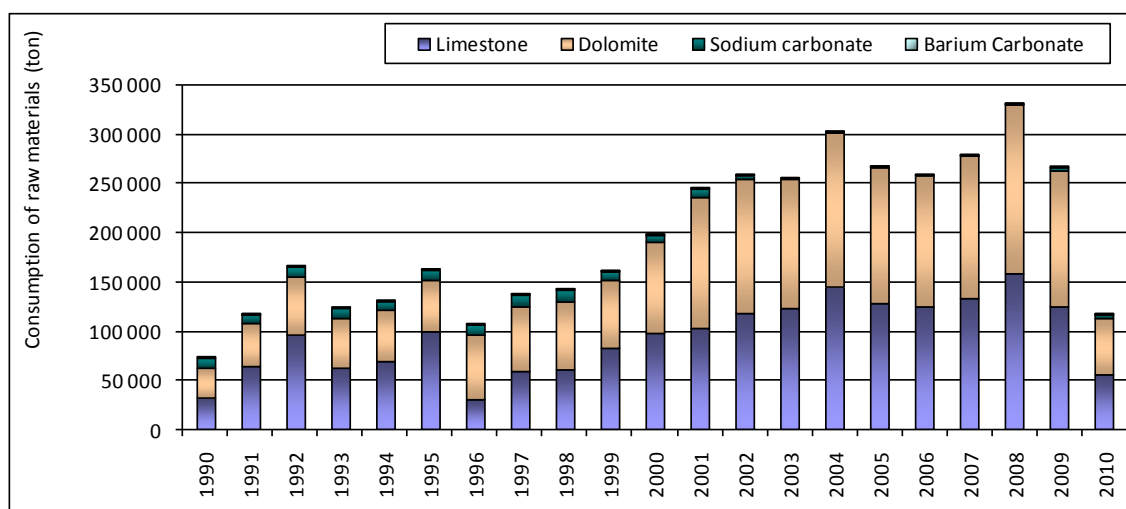
* assumed pure calcium carbonate; # Ca and Mg carbonate in equal share

4.3.1.3.4 Activity Data

The consumption of sodium carbonate in the paper and pulp industry was determined from the statistical information from INE from 1990 to 2010. Due to the unavailability of statistical information concerning consumption of carbonaceous materials in the fertilizer industry – for the production of calcium and magnesium nitrates – they had to be estimated from fertilizer production data and considering that stoichiometrically two moles of nitrogen require one mole of either $CaCO_3$ or $MgCO_3$. Fertilizer production data was also available from INE database from 1990 to 2010. Final total consumption of carbonaceous materials is presented in the figure below. The ceramic industry, more particularly the brick and tile industry and the pavement industry, consumes limestone, dolomite and the carbonates of sodium and barium, and all these substances were considered to result in decarbonisation. For this industry sector, although the consumption of carbonate bearing materials is not known for the whole period, a consumption factor was developed based on the information received under the European Emission Trading Scheme (EU-ETS), and production of construction ceramics and pavement ceramics, which is available from INE's industry surveys IAIT and IAPI, was used to obtain the full time series. In 2010 there is a strong decrease in limestone and dolomite consumption related to a decrease in calcium nitrate production.

⁵⁴ It was assumed that limestone was totally pure, which causes over-estimated emissions.

Figure 4.7 - Consumption of carbonate materials in industry (1990-2010)



4.3.1.3.5 Uncertainty Assessment

There are no proposed values in GPG for the consideration of uncertainty values for CO₂ emission factor from consumption of carbonate materials. The same uncertainty values that are proposed for lime production (non hydrated lime) were therefore assumed (2 percent), considering that the conversion is only a stoichiometric mass balance and that error results only from uncertainty in Calcium and Magnesium content of raw materials. The uncertainty value of activity data, also not referred to in GPG, was assumed also equal to the uncertainty set for lime production.

4.3.1.3.6 Recalculations

Activity data time series were updated for the period 2001-2010 based on data from INE (IAP). Emission values for the period 2001-2010 are due to the changes in activity data for that period.

Sodium carbonate consumption time series in paper pulp production has been revised based on data from INE (IAP).

4.3.1.3.7 Further Improvements

More efforts to obtain necessary statistical information or alternative methodologies will be envisaged to estimate emissions from emissions from carbonate use in the production of synthetic fertilizers (nitrates of calcium and magnesium and ammonium nitrate with calcium and magnesium).

4.3.1.4 Road Paving with Asphalt (CRF 2.A.6.)

4.3.1.4.1 Overview

Emission estimates reported in this source category include emissions occurring from paving road surfaces with asphalt materials as well as emissions occurring during operation of hot mix asphalt plants. Emissions from production of asphalt emulsions and cold asphalt mixtures are not included in the inventory estimates, being assumed that they are negligible.

Roads pavement with asphalt is done by the application of several layers over road bed. In volume, the majority of pavement is composed of layers of a compact aggregate and an asphalt binder (asphalt concrete). Asphalt concretes are classified either as hotmix or as coldmixes: cutback and emulsified asphalts. Liquefied asphalts – cutbacks and emulsions - are also used directly in seal and priming roadbed operations, sometimes in intermediate layers between applications of asphalt cement layers. Aggregate materials incorporated in asphalt concrete are usually composed of coarse unconsolidated rock fragments, either obtained from rock crushing, natural alluvial deposits or by products from metal ore refining.

Hot mix asphalts are made by mixing the aggregate material together with the asphalt cement using high temperatures (150°-160°)⁵⁵. Cold mix plants also involve mixing aggregate materials with an asphalt binder, but now the binder is an asphalt emulsion or is cutback cement, and this process takes place at much lower temperature (40-60°).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers⁵⁶. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphta (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12 percent of solvents. Hot mix asphalts in the other hand, result in minimum NMVOC emissions during application, because the organic component has high molecular weight and low vapour pressure (USEPA,2001 – EIIP Volume III Chapter 17).

Asphalt pavements dominate road paving activity in Portugal, whereas rigid cement pavements are only about 5 percent of total paved areas (APORBET).

Emissions during fabrication of asphalt concretes are estimated only for hot mix asphalt and comprehend NMVOC and Particulate Material that escape mostly from the drier. Other pollutants are also emitted but they result mostly from combustion of fuels and are considered in chapter Energy (1A2)⁵⁷. Emission estimates for hot-mix are only made here for pollutants NMVOC and PM, while emission of other pollutants are covered in emission estimates made for Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity⁵⁸.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible⁵⁹.

⁵⁵ That are needed to fluidize the asphalt cement.

⁵⁶ And also a solvent in several emulsion types.

⁵⁷ To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

⁵⁸ It is not possible to distinguish fuel combustion in hot mix production activity.

⁵⁹ Some emissions do occur in fact during mixing and stockpiling operations. However, because the methodology is based on mass balance, these emissions are in fact quantified under application of asphalt.

It was still not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation or asphalt roofing, and therefore all emissions from production of asphalts – except emissions from fuel combustion – are included in this source category.

4.3.1.4.2 Methodology

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100 percent composed of VOC (USEPA,2001) and that emitted VOC have on average 85 percent of carbon⁶⁰:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

Different methodologies were used to estimate emissions of NMVOC during asphalt application or from asphalt production.

4.3.1.4.2.1 Application of Asphalt Concretes and Liquefied Asphalts

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA,1997; USEPA,2001):

$$Emi_{NMVOC (y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Emi_{NMVOC (y)}$ - Emissions of NMVOC from asphalt application during year y (ton/yr);

$Binder_{(y)}$ – Total quantity of asphalt binder used in road paving during year y (ton/yr);

SLV_{Fac} - Fraction of distillate (solvent) in asphalt (m^3/m^3);

d_{SLV} - density of solvent added to liquefied asphalt (kg/l);

d_{BIN} - density of bitumen binder mixture (kg/l);

$Cure_{FC}$ - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

4.3.1.4.2.2 Hot Mix Asphalt Production

For calculation of hot mix production emissions, emission calculation is based on total product:

$$Emi_{(p,y)} = Hotmix_{Batch (y)} * EF_{(p)} + Hotmix_{Drum (y)} * EF_{(p)}$$

⁶⁰ Normal carbon content for medium linear simple hydrocarbons.

Where,

$Emi_{(p,y)}$ – Total emissions for pollutant p occurring in year y from Hot mix asphalt production (ton);

$Hotmix_{Batch(y)}$ and $Hotmix_{Drum(y)}$ – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

$EF_{(p)}$ and $EF_{(p)}$ – Emission Factors for pollutant p used respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

Although available methodologies allow the calculation of emissions of several other pollutants from Hot mix asphalt production, in order to avoid double counting – and because fuel consumption in this activity could not be individualized from total fuel use in construction and building – only emissions of NMVOC and PM were estimated here. Although double counting could nevertheless be made for these pollutants, it was considered that the production process results in specific emissions of these two pollutants, that would be under-estimated if they would be estimated solely from fuel combustion. Particulate matter is enhanced by manipulation of aggregate materials and some NMVOC result not from incomplete combustion of fuel but also from partial evaporation of bitumen components.

4.3.1.4.3 Emission Factors and Parameters

The following parameters were chosen to determine emission factors for application of emulsified and cutback asphalts. These values were chosen according to recommendations in AP-42, EMEP/CORINAIR or industrial expert guess.

Table 4.3 - Emission Parameters for road paving with asphalt

Parameter	Cutback	Emulsions
SLV_{Fac}	25 %	3 %
d_{SLV}	0.95 kg/l	0.85 kg/l
d_{Bin}	0.95 kg/l	0.85 kg/l
Cure type	Medium Cure (MC)	-
$Cure_{FC}$	0.75 kg/kg	1 kg/kg

Emission factors used to estimate NMVOC and PM emissions from Hot mix plants are from USEPA (2000) and are presented in next table.

Table 4.4 - Emission Parameters for Hot Mix asphalt production

Pollutant	Continuous	Batch	Unit EF
NMVOC	32.0	22.1	g/ton
CH4	12.0	7.4	g/ton

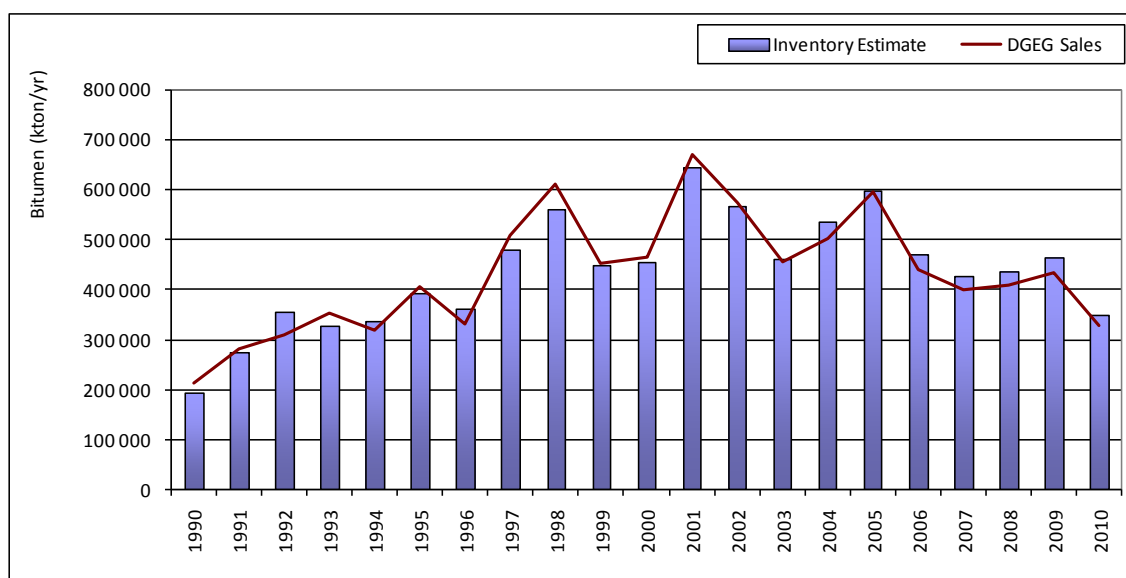
Source: USEPA (2000)

4.3.1.4.4 Activity Data

The total quantity of bitumen sold to construction and building economic sector is available from the Energy Balance and was collected by the General Directorate of Energy and Geology

(DGEG) based on surveys⁶¹, and it is presented in the figure below. Although this time series was not used in the inventory, it is nevertheless used for the verification that the estimates made for each asphalt materials, which are subsequently explained, are coherent with total sale statistics.

Figure 4.8 - Total consumption of bitumen in the construction sector according to sales from DGEG and sum of values of asphalt used, according to the inventory (1990-2010)



Cutback asphalt is seldom used in Portugal and it is sold only by two companies, according to information gathered at APORBET, the Portuguese Association of Producers of Bitumen Materials. Annual sales were assumed equal to annual consumption and may be seen in the table below and in the figure above. Total emulsions applied are available from EAPA for 1997 and beyond. For previous years use of emulsions was estimated from the total quantity of asphalt materials applied as road pavement, also from EAPA, and considering a percentage of that bitumen that is emulsions. It was also assumed that this percentage was zero in 1990 and has increased to 19 percent in 1996. Data for Hot mix concrete asphalt production is from EAPA for 1991-2010. Bitumen in hot mix asphalt was estimated considering that it equals 5 percent of hot mix asphalt. Although this last figure is not necessary for the inventory it was nevertheless estimated in order to verify if total bitumen sales, from DGEG, match the sum of individual estimates. Total production of Hot mix concrete asphalts is presented in the figure below.

Table 4.5 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (ton)

Asphalt	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cutback	ton	4 100	3 500	2 700	3 100	2 600	676	407	1 232	933	162	576
Emulsified	ton	0	10 567	21 133	36 576	49 852	65 025	100 517	110 000	130 000	95 000	86 000

Asphalt	Unit	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cutback	ton	824	501	340	0	0	0	0	0	0	0
Emulsified	ton	107 000	116 000	112 665	93 600	65 000	40 500	36 556	37 441	39 824	30 049

⁶¹ Original data from DGEG is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGEG

Figure 4.9 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (1990-2010)

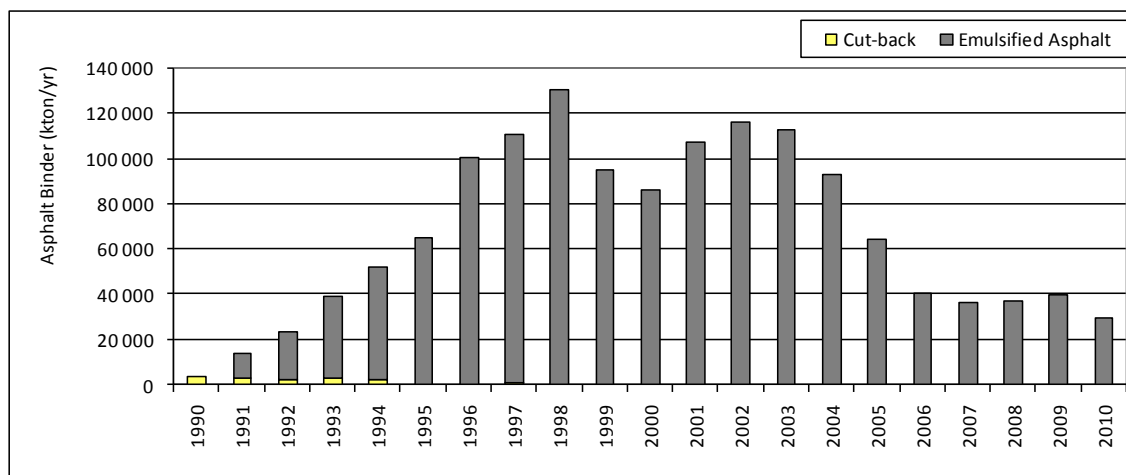
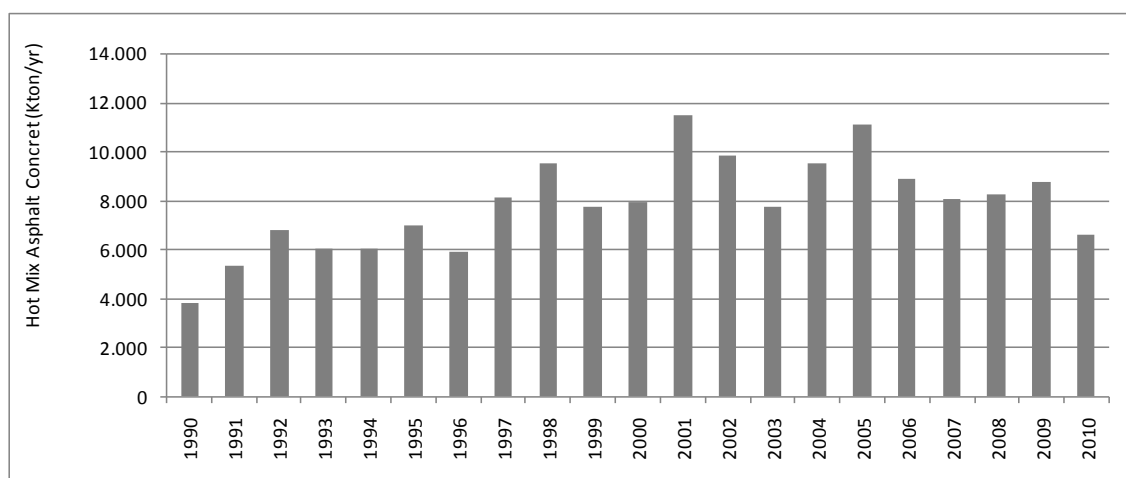


Figure 4.10 – Total Production of Hot Mix Asphalt (1990-2010)



Emissions of Hot Mix Production depend if the equipment is batch or continuous. Desegregation of Hot Mix production per equipment was done assuming a constant proportion of 46 percent continuous equipment and 54 percent batch, which is an expert guess (PTEN,2002).

4.3.1.4.5 Uncertainty Assessment

There is no specific information in the GPG concerning uncertainty values for this source sector. Uncertainty in activity data was estimated as the maximum difference between the total bitumen quantities estimated by the inventory and reported in the DGGE energy balance: 31 percent.

The uncertainty in the emission factor for NMVOC/CO₂ is higher and mostly associated with the uncertainty in the share of asphalt that is applied as cut-back, emulsion of as hot mix. Because of the very variable emission factor according to which asphalt type is being considered two

orders of magnitude was considered for the uncertainty value of the emission factors for NMVOC and CO₂.

4.3.1.4.6 Recalculations

No recalculations were made.

4.3.1.4.7 Further Improvements

It was still however not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation and asphalt roofing. Improvements in this separation are expected in following submissions.

4.3.1.5 *Glass Production (CRF 2.A.7.)*

4.3.1.5.1 Overview

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. It is made submitting these materials to a high temperature which are thereafter made solid without crystallization (semi-solid state).

Glass involves carbon dioxide emissions, from decarbonising of limestone and carbonate materials under high temperature conditions. Carbonate materials vary with the desired product and comprehend typically limestone, dolomite, soda ash (sodium carbonate) and other carbonate compounds of potassium, barium or strontium.

Combustion emissions from glass production were already considered in source sector 1A2, estimated from fuel consumption data or production data. Some anthracite coal is used also as additive in glass production. However, because the consumption of this material is already considered in the energy balance, to avoid double counting of emissions from coal use are not considered here⁶².

4.3.1.5.2 Methodology

Carbon dioxide emissions from glass production were estimated from:

$$\text{Emission}_{\text{CO}_2(t,y)} = \text{EF}_{\text{CO}_2(t)} * \text{ActivityRate}_{(t,y)} * 10^{-3}$$

where

Emission_{CO₂(t,y)} - annual emission of carbon dioxide from specific glass type t in year y (ton/yr);

ActivityRate_(t,y) - Glass of type t produced in a given year y (ton/yr);

EF_{CO₂(t)} - emission factor from production of glass of type t (kg/ton)

4.3.1.5.3 Emission Factors

The following emission factors were considered:

⁶² They were not used to derive the country specific emission factors for instance.

Table 4.6 - Carbon Dioxide Emission Factors for Glass Production

Material	EF	Unit EF	Reference
Flat Glass	126	kg/ton	CS
Container Glass	130	kg/ton	CS
Lead Crystal Glass	239	kg/ton	EMEP/CORINAIR
Other Glass	239	kg/ton	

Country specific emission factors were calculated using data from 10 industrial plants in Portugal under the studies for the development of the Allocation Plan for the implementation of the European Union Emission Trading Scheme (EU-ETS) and under the efforts to streamline both inventories. These units reported annual production quantities together with consumption of carbonate materials: limestone, dolomite, sodium, barium and potassium carbonates, from where average emission factors could be estimated.

4.3.1.5.4 Activity Data

Some problems with the use of statistical information from INE were detected, mainly because not all products are reported in weight, but instead are measured in area-units (m²) or number of produced pieces. Because the available emission factors are expressed on weight basis, an effort was made to build time series in common weight units, converting production estimates from INE databases and also making use of information collected directly from industrial plants. The following assumptions were made:

- Flat glass. Presently there is only one industrial unit producing flat glass in Portugal. Activity data was set for 1990 to 2001 from information collected directly from that unit. Statistical information from INE for the period 1992-2000 (IAPI industrial survey) was available in area units (m²) but was not used because conversion to weight units would lead to high uncertainties. Production values for 2002 to 2010 were forecasted by APA based on Energy Balance fuel consumption data;
- Container Glass. Also for this type of glass product the information available in INE databases (IAIT and IAPI industrial surveys) was not well suited to be used in the inventory because production was measured in produced object numbers units and not weight. Production of container glass was available from Technology Centre for Ceramics and Glass (CTCV) for the period 1994 to 2003. Production in the period 1990-1993 and 2004-2010 was estimated by APA extrapolating CTCV time series using Energy Balance fuel consumption data;
- Lead Crystal Glass production data was available for the period 1990-1991 from INE IAIT industrial survey and was extrapolated, based on Energy Balance fuel consumption data, for the period 2001-2010; Other glass. This category comprehends several parts such as blocks, bricks, tiles, kitchen-ware, medical and pharmaceutical equipment and decoration articles. Time series was set from INE IAIT industrial survey for the period 1990-1991 and forecasted for the period 1992-2010 based on Energy Balance fuel consumption data.

For some products original units were only available in number and had to be converted to weight. The following conversion table was assumed:

Table 4.7 – Unit conversion factors for glass products in INE statistical databases

Product	Conversion Factor (kg/unit)
Glasses	0.2
Bottles	0.5
Small containers (Jars)	0.2
Large Containers	3
Medical equipment	0.01
Other objects	0.5

Production values for container glass, lead crystal glass and other glass is presented in the figure below. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 4.11 - Glass production by glass type (excluding flat glass production)

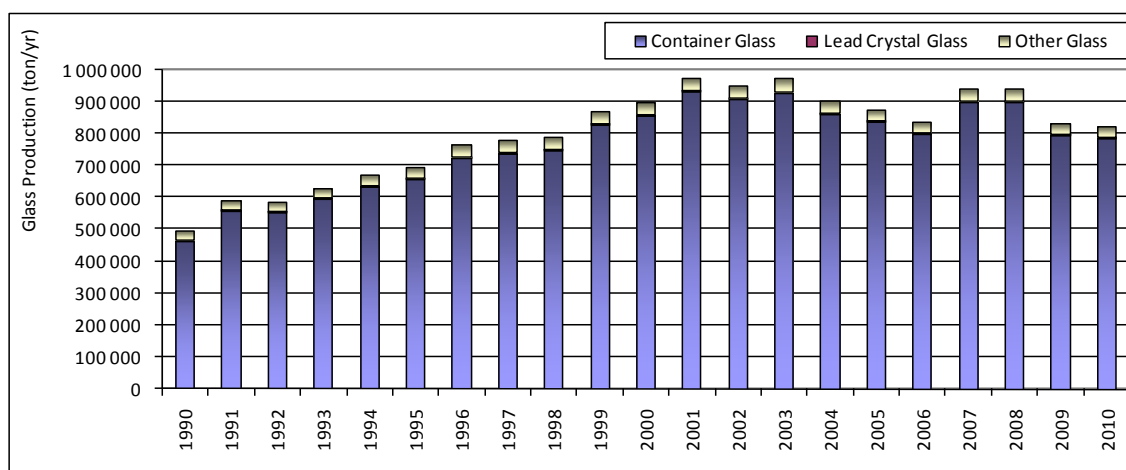


Table 4.8 - Glass production by glass type (excluding flat glass)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Container Glass	470 046	564 115	560 354	601 688	639 947	663 498	730 342	741 392	751 333	835 451	863 502
Lead Crystal Glass	149	234	232	250	265	275	292	326	348	314	316
Other Glass	26 224	28 311	28 122	30 196	32 117	33 264	35 309	39 431	42 157	38 024	38 287

Glass	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Container Glass	936 471	912 672	934 356	866 040	842 398	803 272	904 166	906 127	802 187	789 401
Lead Crystal Glass	327	318	326	302	294	280	315	316	280	275
Other Glass	39 536	38 532	39 447	36 563	35 565	33 913	38 172	38 255	33 867	33 327

4.3.1.5.5 Uncertainty Assessment

A 100 percent uncertainty value was set for activity data expressing the fact that for some glass types the activity data in statistical databases was expressed in non weight units, number of

pieces or area. The double value of the standard deviation of the set of emission factors available for Portuguese units, and estimated from carbon market data, allows the consideration of an uncertainty value of 54 percent.

4.3.1.5.6 Recalculations

Recalculations were made based on Energy Balance fuel consumption for the periods for which there was no real data available from the industrial units or from INE IAIT surveys.

4.3.1.5.7 Further Improvements

Estimates of emissions due to the production of glass wool and rock wool are still not available due to lack of statistical information for activity data. Although it is foreseen that this are minor emission sources, efforts are being made to obtain this information and establish emission estimates for this source.

Activity data based on IAPI survey needs further calculations, since data is reported in different units and it is necessary further integration.

4.3.2 Chemical Industry (CRF 2.B.)

4.3.2.1 Ammonia Production (CRF 2.B.1.)

4.3.2.1.1 Overview

In 2008 only one fertilizer industrial plant manufactures ammonia in Portugal, using Vacuum Residual Fuel Oil (VRF) as source of hydrogen (feedstock). In 2009, this plant has stopped activity and the ammonia production has been relocated to India.

Ammonia is formed after reaction of hydrogen with nitrogen from air. In the start of year 1990 there was another unit operating in Portugal, but has stopped activity already in the beginning of that year. The conversion of feedstock to hydrogen results in the liberation of the associated carbon as ultimate CO₂ which is vented to atmosphere. Although actually some part of CO₂ liberated from VRF, during ammonia production, is in fact used in urea production and it is not immediately emitted to atmosphere. However, because liberation to atmosphere is eventually achieved after the application of urea in agricultural soils as amendment, and also because some other sources of CO₂ may be used in urea manufacturing, the option was not to deduce this CO₂ fixation in feedstock.

Other pollutants result from the process, either from escape of ammonia (NH₃) or either from release of products from feedstock: CO and NMVOC.

4.3.2.1.2 Methodology

Carbon dioxide emissions were estimated from feedstock consumption using the following formulation:

$$\text{Emi}_{\text{CO}_2(y)} = 44/12 * \text{Feedstock}_{(y)} * C_{\text{Feed}(y)} * 10^{-5}$$

where

Emi_{CO₂(y)} - Emission of carbon dioxide (kton/yr);

FeedStock_(y) - Annual consumption of feedstock (ton/yr)

$C_{Feed(y)}$ - Carbon content of feedstock (%).

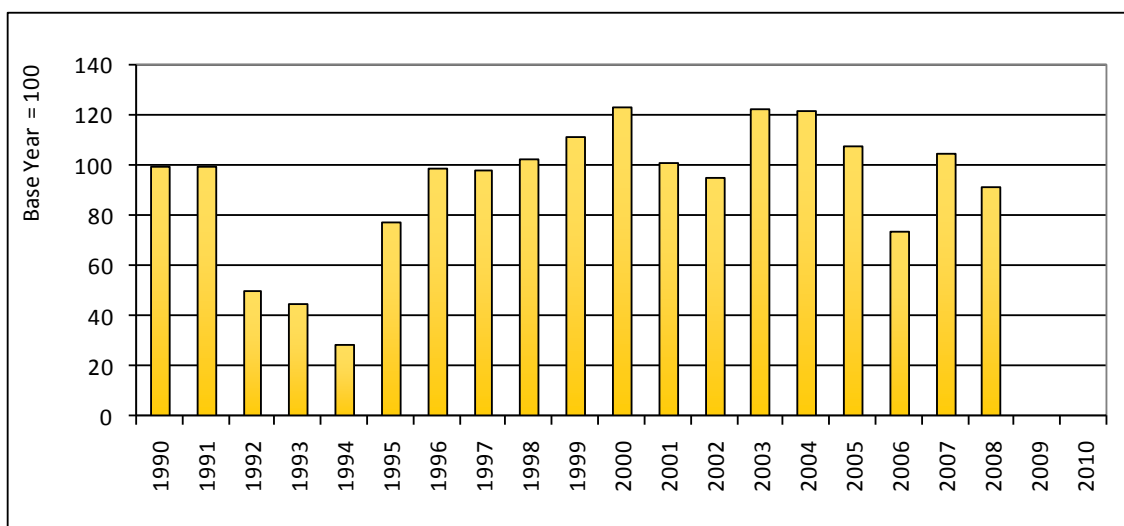
4.3.2.1.3 Emission Factors

Due to confidentiality constraints it is not possible to publish emission factors.

4.3.2.1.4 Activity Data

Because there is only one industrial plant in operation, it is not possible to present any absolute information concerning activity data for this source activity, neither ammonia production nor feedstock and methanol consumption. The overall trend in the amount of ammonia produced in the period may be however depicted in the figure below, from where it is evident the significant inter-annual changes in the period 1991-1996. In 2009 the only facility that produced ammonia in Portugal has stopped and the production was relocated to India.

Figure 4.12 - Trend in Ammonia production (1990-2010)



The following sources of information were used to construct the above full time-series.

- total production of ammonia in Portugal is available from the only existing facility for the period 1990-2008. In 2010 there is no ammonia production since the facility was stopped and the production relocated to India;
- consumption of VRF feedstock could not however be determined from INE statistical database, because differentiation of residual fuel oil for feedstock and energy source was not clarified for this economic activity. Therefore, as explained before, consumption of feedstock VRF was estimated from limited information and relying on linear correlations: the quantity of VRF that was used was set from data collected at the only industrial plant in Portugal for a limited number of years – 1990 till 1994 – and a strong linear relation between feedstock consumption and ammonia production could be established from available data;

- use of methanol was also estimated for the full time period from a linear regression which was determined from available information for a limited number of years.

4.3.2.1.5 Uncertainty Assessment

No specific guidelines exist in GPG (IPPC,2000) to estimate the uncertainty of this source sector. The greatest uncertainty of emission estimates for this source sector results from the uncertainty in knowledge of activity data (Feedstock consumption). Because the ratio of feedstock consumption over ammonia production was used to estimate feedstock consumption, the standard deviation of these ratios was used to estimate the error and then doubled to include an additional factor of conservativeness⁶³. The final uncertainty value for activity data was set as 31 percent.

With the methodology that was used the uncertainty in the emission factor refers only to the uncertainty in the carbon content of feedstock: 5 percent.

4.3.2.1.6 Recalculations

No recalculations were made.

4.3.2.1.7 Future Improvements

Information from Regional inventory surveys, EPER, E-PRTR and monitoring under *Autocontrolo* program may allow better insight of technologies of this sector and may possibly improve methodologies and emission factors for gases other than CO₂.

4.3.2.2 Nitric Acid (CRF 2.B.2.)

4.3.2.2.1 Overview

Only three industrial plants did produced nitric acid in Portugal between 1990 and 2010, located in Estarreja, Alverca and Lavradio. In all weak nitric acid (60 percent) is produced from ammonia, using catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to NO₂ at medium pressure, and subsequent absorption with water to form nitric acid in a dual-stage process.

Nitric Acid manufacture results in air emissions primarily of NO_x (NO and NO₂), trace amounts of HNO₃ acid mist, ammonia (NH₃) and Nitrous Oxide (N₂O). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of NO_x are controlled by catalytic reduction. Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

4.3.2.2.2 Methodology

For all pollutants emissions are estimated using the following equation:

$$\text{Emission}_{(p,y)} = \text{EF}_{(p)} * \text{ActivityRate}_{(y)} * 10^{-3}$$

where

Emission_(p,y) - annual emission of pollutant p in year y (ton/yr);

⁶³ A further doubling was used to convert from standart deviation to 95% confidence interval.

ActivityRate_(y) – production of Nitric Acid in year y (ton/yr);

EF_(p) - emission factor for pollutant p (kg/ ton)

4.3.2.2.3 Emission Factors

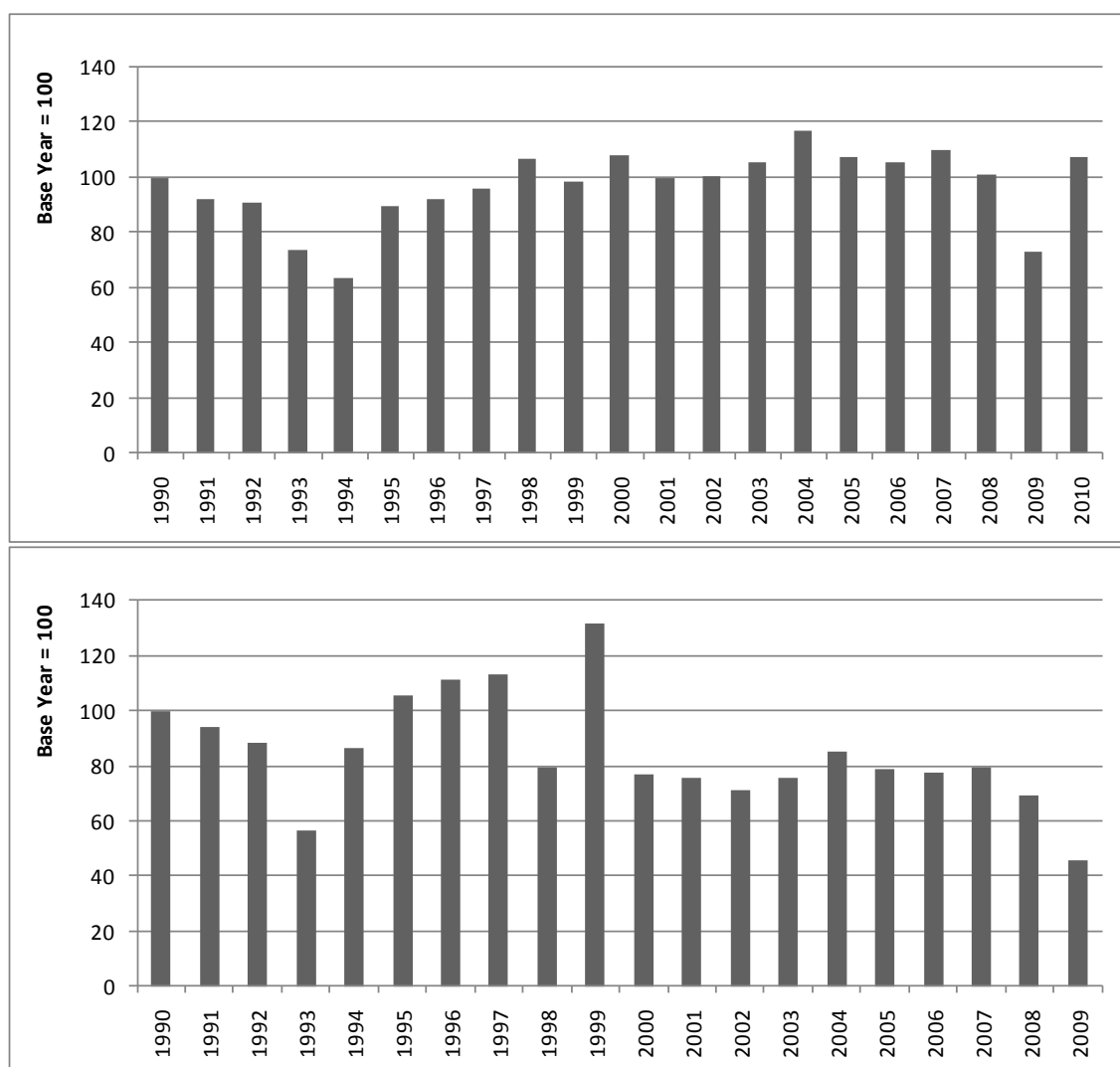
Due to confidentiality constraints it is not possible to publish the chosen emission factors. They were estimated based on monitoring data from the facilities.

4.3.2.2.4 Activity Data

The activity data that was used to estimate emissions from this sub-source sector is subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends).

Activity Data is obtained directly from the facilities. One of the plants was shutdown during year 2010 and replaced by a new facility.

Figure 4.13 - Trend in Nitric Acid production (1990-2010)



4.3.2.2.5 Uncertainty Analysis

The uncertainty value for activity data is 3 percent, considering that the restricted number of units allows a good knowledge of production data. The uncertainty value of the emission factor of Nitrous Oxide a value of 10 percent was chosen, which is in accordance with references to uncertainty ranges in GPG and also in accordance with the difference between the country specific emission factor determined from monitoring data and the proposed emission factor.

4.3.2.2.6 Recalculations

We have started to collect activity data directly from the facilities and estimated new emission factors using plant monitoring data for an extended period.

4.3.2.2.7 Future Improvements

No further improvements are planned for this sector.

4.3.2.3 *Organic Chemical Industry (CRF 2.B.5.)*

4.3.2.3.1 Overview

The organic chemical industry is responsible for greenhouse gas emissions in consequence of the release of carbon compounds that are transformed in carbon dioxide in the atmosphere. These emissions are mostly part of the carbon that is release from feed-stocks.

For this source sector emissions for some industrial units were estimated at individual unit plants – Large Point Sources (LPS) - and using detailed characterization of the plants and their industrial activities. Chemical organic industry in Portugal is not very extensive, however. The major organic chemical plant in Portugal is BOREALIS unit, a petrochemical unit situated in the southern part of the country, near Sines. The basic process in this unit is Ethylene production by Thermal Steam Cracking of petroleum feedstock. From ethylene this unit produces Low Density Poly Ethylene (LDPE) and High Density Poly Ethylene (HDPE). As by product of ethylene production other organic compounds are produced, such as propylene, butadiene and C4 fraction, aromatics and a residual fuel oil used in the unit as energy source.

The second chemical industry LPS is the sole Carbon Black plant in Portugal. It is also situated in the southern part of the country, near Sines. CARBOGAL unit produces Carbon Black by the Oil Furnace Process, a partial combustion process where feedstock with a high content of aromatic material is converted by incomplete combustion, thermal cracking and dehydrogenation to carbon black. Emissions result from Gas Vent, combined dryer vent and fugitive emission in the vacuum system vent.

Finally the last individualized unit (LPS) is an industrial plant located in Lisbon producing Phthalic Anhydride from aromatic compounds.

Apart from those individualized industrial plants other chemical industrial activities were included as area sources in this sub-source sector⁶⁴:

- Vinyl Chloride Monomer (VCM);

⁶⁴ This list is not extensive to chemical production in Portugal, but comprehends only those products for which there are emission estimate methodologies and emission factors

- Low Density Poly-ethylene (LDPE);
- Poly Vinyl Chloride (PVC);
- Poly propylene (PP);
- Poly styrene (PS);
- Formaldehyde;
- Explosives.

4.3.2.3.2 Methodology

For this sub-sector emissions estimates are extensively based on the use of emission factors multiplied by quantity of material produced:

$$\text{Emission}_{(p,y)} = \text{EF}_{(p)} * \text{ActivityRate}_{(y)} * 10^{-3}$$

where

$\text{Emission}_{(p,y)}$ - annual emission of pollutant p in year y (ton/yr);

$\text{ActivityRate}_{(y)}$ - Indicator of activity in the production process. Quantity of product produced per year is used as a general rule for this emission source sector (ton/yr);

$\text{EF}_{(p)}$ - emission factor (kg/ ton)

In the case of carbon black, where CO₂ emissions result from liberation of carbon in tail gas to atmosphere, emissions were estimated using a simple mass balance:

$$44 / 12 * C_{\text{TailGas}} = C_{\text{Feedstock}} + C_{\text{AuxFuels}} - C_{\text{CarbonBlack}}$$

Where,

C_{TailGas} – carbon emitted in tail gas (ton C/yr);

$C_{\text{Feedstock}}$ – Carbon entered in feedstock (ton C/yr);

C_{AuxFuels} – additional carbon entered into system in fuels (ton C/yr);

$C_{\text{CarbonBlack}}$ – carbon stored in carbon black and not emitted to atmosphere (ton C/yr);

4.3.2.3.3 Emission Factors

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994⁶⁵. Emissions estimated for this period were used to determine plant-specific process emission factors that were used to estimate emissions for all time series from 1990 to 2001 and using

⁶⁵ Unpublished.

ethylene production as activity rate indicator⁶⁶. Emissions from flares and flue gas combustor where included in the emission factors.

Table 4.9 – Emission Factors for determination of process emissions in Borealis (kg/ton)

Description	NM VOC	CH ₄
Ethylene	0.8	1.2
Butadiene	1.2	-
HDPE	9.6	-
LDPE	4.8	-
PP	8.0	-

In the same way, the carbon black industrial unit was subjected, also for period 1993-94, to a detailed survey and inventory exercise. Consequently mission factors were established for carbon black unit and emission estimates were extended for the rest of the time series using carbon black production as indicator of activity rate. Carbon Gas emissions include also emissions suffering partial combustion.

Table 4.10 – Emission Factors in calculation of Carbon Black process emissions

Pollutant	Main Process Vent Gas (kg/ton gas)	Combined Dryer Vent Gas (kg/ton gas)	Process and Fugitive (kg/ton Carbon Black)
NM VOC	33.3 ^(a)	2.50 ^(b)	-
CH ₄	0.80	0.8 + 1.4 ^(b)	-
CO	104	100 + 17 ^(b)	-
N ₂ O	-	1.40 ^(b)	-

(a) kg/ton Carbon Black

(b) g/GJ

(c) g/Nm³ tail gas

Emission factors for the Phthalic Anhydride Plant are from US-EPA (1983) and are presented in table 4.8:

Table 4.11 - Emission Factors for the production of Phthalic Anhydride

Pollutant	kg/ton
NM VOC	1.2
CO	151

Source: USEPA (1983)

4.3.2.3.4 Activity Data

Activity data used to estimate emissions may not be reported in NIR, due to confidentiality issues that result from the limited number of units concerned for each individual compound.

For BOREALIS Petrochemical Plant in Sines - produced quantities are available from 1990 to 1997 and were forecasted thereafter. Production of carbon black and explosives is available from 1990 to 2010 from INE Statistical Database (IAIT and IAPI surveys).

⁶⁶ This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Statistical information for all emissions sources other than Sines industrial Plants were obtained from the National Statistical Institute (INE).

4.3.2.3.5 Uncertainty Assessment

The uncertainty of activity data received from Large Point Sources was set as 10 percent. For area sources it depends if the data set is updated for the all time series or not. If it is not updated the uncertainty value was set as 100 percent and 20 percent if it is updated. The high uncertainty in the choice of emission factors from international references, which are themselves based in limited information and which conditions of determination are most of the time different from specific national conditions, lead to the choice of an uncertainty value of an order or magnitude for area sources and 100 percent for Large Point Sources⁶⁷.

4.3.2.3.6 Recalculations

No recalculations were made.

4.3.2.3.7 Further Improvements

Because emissions from production processes depend largely on specific conditions in each industrial plant, and because there are very few units in Portugal using a specific chemical manufacturing process, it is essential that the national inventory relays more and more in detailed plant information, i.e. increasing the number of Large Point Sources. Only deep knowledge of LPS units will allow quantification of air emission with reduced uncertainty, either using technology specific emission factors from literature or either using monitoring data. This improvement may imply coordination with EPER/PRTR exercises, the European carbon trading scheme, Regional Air Emission Inventories, cooperation with industry associations or specific inquiries.

Also, the quality of emission estimates from this sub-source sector will be improved in next submissions, following the on-going efforts to improve the inventory of NMVOC from industry, that are been done under the background works for the revision of the Ceiling Directive of the UE. Results will be however only available for the next submission. Other expected improvements include:

- Obtaining a deeper knowledge for the limited number of the most relevant industrial units and performing emission estimates with more detailed methodologies, similar to those performed for BOREALIS and CARBOGAL industrial units;
- Revision of emission methodologies and possible inclusion of more manufacturing processes, such as Styrene Butadiene latex or rubber; Acrylonitrile Styrene Butadiene (ABS); Acrylonitrile and MTBE. Efforts must be done to verify that production of these products, and others, did exist in Portugal;
- Estimate of emissions from storage and handling of organic liquids, which presently are only done for carbon black.

⁶⁷ The uncertainty of emission factors refers to uncertainty of NMVOC determination. Uncertainty for conversion from NMVOC to CO₂ is comparatively irrelevant.

4.3.3 Metal Production (CRF 2.C.)

4.3.3.1 Iron and Steel Production (CRF 2.C.1.)

4.3.3.1.1 Overview

Iron results from reduction of the iron element present in mineral ores by contact with coke - reducing agent - at high temperatures in the blast furnace. The resulting material, pig iron – and also scrap in some steel plants - is transformed into steel into subsequent furnaces which may be a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF). Coke, sinter and lime are intermediate materials necessary for iron and steel production.

Sintering modifies the structure of ore material making it more suitable for iron formation, by converting fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product. Sintering emissions occur from the windbox, discharge and sinter crusher, coolers and screens. Emissions from sintering, which result from a combustion process with contact, are reported under 1.A.2, although the emission factors are reported in this chapter.

Coke is produced by destructive distillation of imported fossil coal in coke ovens, where coal is subjected to heat in an oxygen-free atmosphere until all volatile components in the coal evaporate, forming a fuel used in industry, the Coke Gas. Process heat comes from the combustion of gases between the coke chambers. Excluding emissions associated with coke production resulting from use of fuels in under-fired heating furnaces (which are accounted in Energy source sector 1A1), air emissions from the coquerie result from coal preparation, coal charging, oven leakage during the coking period, coke removal and hot coke quenching. Leaks may also occur from poorly sealed doors, charge lids, off take caps, collecting main and from cracks that may develop in oven brickwork (USEPA, 2000)

Coke and sinter are added to the Blast Furnace where iron oxides, coke and fluxes react with blast air to form molten reduced iron, carbon monoxide (CO), and slag. Emissions occur during casting and in the blast furnace top. However the gas resulting from process in the blast furnace, which has a high CO content, is normally not emitted to atmosphere but used as fuel in integrated units (Blast Furnace Gas). Emissions from its combustion are also quantified and discussed under chapter 1A2 – Combustion in Manufacturing Industries and Construction. The emissions that are quantified here, in source 2.C, are only those resulting from casting operations and seal leaks at top of furnace.

In Basic Oxygen Furnace original material are re-melted with the addition of substantial source of oxygen which is lanced (injected) and oxidizes part of the carbon associated with iron: This carbon is emitted mostly as CO (contributing nevertheless to ultimate CO₂ emissions). Other emissions from BOF are iron oxides, oxides of other metals and sulphur and particulate matter. In EAF the original material, which is basically scrap, is subjected to an electric discharge that also reduces carbon content. Emissions in furnaces may also result from carbon additives such as limestone and coke.

Steel is finally finished in rolling mills. Emissions from this finishing process are mostly particulate matter besides combustion pollutants which is already included in emissions from the 1.A.2 sector.

Lime is necessary for the blast furnace charging and EAF mixtures. Production of lime from limestone in this unit results in CO₂ emissions from decarbonising.

Emissions of ultimate fossil CO₂ are the result of the oxidation of carbon in coke, anodes and electrodes. Part of the carbon may be sequestered in final product and not emitted to atmosphere as carbon dioxide. Only emissions of carbon that has origin in fossil fuels should be considered as emissions of final or ultimate CO₂ and not those from the use of biomass origin carbon - charcoal. Emissions of carbon may occur as CO and NMVOC but it is assumed that they are subsequently converted in atmosphere in carbon dioxide. Some carbon may remain in pig iron after initial reducing in blast furnace and partly may be emitted from oxidation in the BOF. Also EAF furnaces may result in carbon emission but from consumption of graphite anodes in the process.

Other pollutants may be emitted during steel production as result of its presence (or presence of its precursors) in original ore or in the material used to produce coke. That is the case of SO_x and heavy metals. But because combustion occurs with contact, emissions are modified - increase or decrease - by contact of combustion gases with products and emissions cannot be estimated by mass balance alone.

NO_x is formed from reaction of atmospheric nitrogen at high temperatures, which may result from fuel combustion or from high temperature generated at production processes.

Finally particulate materials result from handling and storage of materials, such as coal, ore, coke and scrap, crushers and screening in raw materials preparation and finishing operations in products such as teeming into ingots and scarfing. Particulate matter results also from blast furnace during casting and oxygen blow in BOF. Particulate materials are mostly composed of iron, sulphur and other metal oxides.

During the period 1990-2001 two main industrial plants in Portugal were associated with steel production which later turn into three units as result of the split of one of the units in two separate plants. Later, during 2001, the coquerie, blast furnace and sintering were closed and only steel furnaces and trimming remain as emission sources.

4.3.3.1.2 Methodology

Emissions are simply calculated from multiplication of activity levels by a suitable emission factor:

$$\text{Emission}_{(p,y)} = \sum_a [\text{EF}_{(p,a)} * \text{Activity}_{\text{Indicator}(p,a,y)}] * 10^{-3}$$

and,

Emission_(p,y) - Emission of pollutant p in a specific year y from all sector activities and equipments (ton/yr);

Activity_{Indicator(p,act,y)} - Most suitable indicator for emissions of a particular pollutant p resulting from a specific source activity or equipment a (ton/yr);

EF_(p,act) - Emission factor specific of pollutant and activity/ equipment a (kg/ton).

Emissions from sintering and lime production from limestone at iron and steel unit were also estimated using similar equation and using production of lime as activity data. Emissions for all pollutants from these two emission sources are reported however in source category Lime Production (2A2).

To avoid double counting, carbon dioxide emissions in coquerie and blast furnace, from oxidation of the carbon that was used as a reducing agent were not estimated from steel or coke production data but simply from use of coke derivative fuels (coke gas and blast furnace gas) in all combustion equipments. Methodology to estimate emissions from combustion of coke gas and blast furnace gas were already discussed in chapter 3.2A – Energy Industries and emissions are included in source sector 1A.2 - manufacturing industries and construction - and 1A.1.c.1 - Manufacture of Solid Fuels.

4.3.3.1.3 Emission Factors

Emissions factors for production process were set mostly from CORINAIR/EMEP also with contributions from IPCC96 and US-EPA AP42. Emission factors in kg/ton are present in next table.

Table 4.12 - Emission Factors for Iron and Steel Production

Pollutant	Coke Oven (kg/ton coke)	Sintering (kg/ton sinter)	Blast Furnace (kg/ton steel)	BOF (kg ton/steel)	EAF (kg/ton steel)
CO ₂ U ^(c)	7.5	52	2.6	22.5 ^(a)	7.4 -14.2 ^(f)

(a) carbon reduction from 4.25 to 2%; (b) Plant Specific Emission Factors (EU-ETS) (c) Ultimate CO₂, not all processes result in direct CO₂ emissions

The CO₂ emission factors for Electric Arc Furnace, and that were used for each one of the two iron and steel plants that are included in the European Union Emission Trading Scheme (EU-ETS), were determined from consumption of carbon bearing materials in these units: limestone, calcium carbide and coke for years 2002 and 2003. It was assumed that the same carbon content exists in both scrap and final steel produced in EAF furnaces and consequently no additional emissions are estimated apart from carbon in additives.

4.3.3.1.4 Activity Data

Activity data for estimation of emissions from iron and steel production comprehend coke, sinter, pig iron and steel production and also scrap consumption, and time series for each product may be seen in the figure below. The following sources of information were used to establish activity data time series:

- coke production is available from DGEG (Coquerie Balance) annually from 1990 to 2001. After 2002 the production of coke was interrupted;
- production time series for sinter, pig iron and steel production in blast furnace are available from industrial plant from 1990 to 1994 (APA direct survey). Thereafter annual values were estimated using coke production as surrogate data;
- steel resulting from BOF and EAF in Seixal Iron and Steel Plant were estimated from production data in both ovens types in 1990 and forecasted thereafter using fuel consumption in the electric power plant⁶⁸ as surrogate data⁶⁹, for the remaining time series;

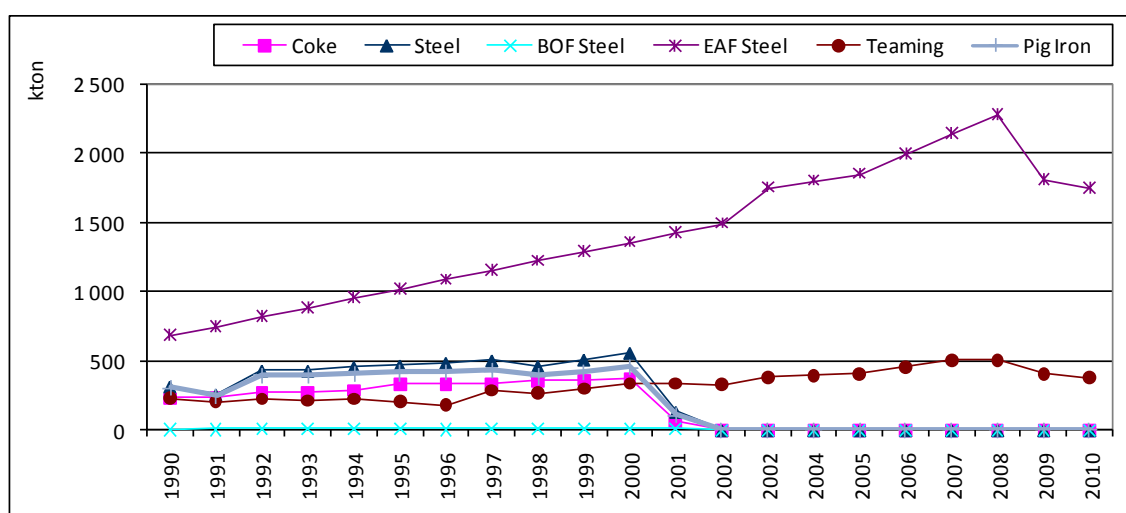
⁶⁸ Power plant that is part of the iron and steel plant

⁶⁹ They may result not from iron produced at this industrial plant

- the same procedure was used to establish the full time series of scrap use and lime consumption, although in this case information data from the industrial plant was available from 1990 to 1994;
- steel production and scrap use in the EAF oven in Maia steel plant was available for 1990, 2002 and 2003 and interpolated in between;
- scrap use for the period 2005-2010 in Maia and Seixal plants was obtained from EU-ETS data.

Production of total steel and intermediate products as they are presently considered may be seen in next figure. Details about specific products and origin by furnace technology (BOF and EAF) can not be reported due to confidentiality constrains.

Figure 4.14 - Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2010)



4.3.3.1.5 Uncertainty Assessment

The great majority of CO₂ emissions result from EAF and BOF furnaces with only a small contribution from coke oven and blast furnace, and hence furnaces data is what basically determines overall uncertainty. For year 1990 data information was collected directly from industrial plants and it is mostly probably of good quality. The same situation applies to the periods 2002-2003 and 2005-2010 (after the development of EU-ETS). In the intermediate period information had to be collected from statistical information from INE, DGEG or even estimated from surrogate data. Quality of activity data for this period decreased substantially but does not affect overall trend of the inventory. The uncertainty in activity data was set as 10 percent the major value in the range proposed in GPG. The uncertainty value for the emission factor was determined considering an uncertainty of 25 percent in the carbon content of both raw materials and final steel and additional 5 percent in the quantity of reducing agent for EAF.

4.3.3.1.6 Recalculations

No recalculations were made.

4.3.3.1.7 Further Improvements

Lack of information concerning activity data and possible double counting in steel production activities may be a problem to emission estimates for this source sector. Although this sector is undergoing deep changes with closure of main source activities (coquerie, blast furnace and sintering) an effort has to be made to clarify the situation and increase the quality of emission estimates for the base year. Because 2002 is a year with substantial changes for this source sector, care must be made to update appropriately the inventory thereafter.

Finally open dust sources of particulate matter are still not included in the inventory.

4.3.3.2 *Ferroalloys Production (CRF 2.C.2.)*

4.3.3.2.1 Overview

There is no ferroalloys production in Portugal in the period 1990-2010.

4.3.3.3 *Aluminium Production (CRF 2.C.3.)*

4.3.3.3.1 Overview and Recalculations

Aluminium production will result in carbon dioxide emissions when it is reduced using carbon electrodes in smelting pots and ultimate CO₂ emissions are the result of consumption of electrodes. This situation occurs when aluminium is manufactured from bauxite ore, using the Soderberg process, for example.

In Portugal, according to information received from the General Directorate of Economic Activities (DGAE), aluminium is produced from ingots and not from bauxite ore. Consequently emissions of CO₂ for this source sector were removed from emission inventory.

4.3.4 *Other Production (CRF 2.D.)*

4.3.4.1 *Wood Chipboard Production*

4.3.4.1.1 Overview

Chipboard manufacturing involves solvent emission but it is included in this source sector.

4.3.4.1.2 Methodology

Emissions were estimated by the use of emission factors multiplied by the quantity of material produced:

$$\text{Emission}_{\text{NMVOC}}(y) = \text{EF}_{\text{NMVOC}} * \text{ActivityRate}(y) * 10^{-3}$$

where

Emission_{NMVOC} - annual emission of NMVOC in year y (ton/yr);

ActivityRate - Indicator of activity in the production process (ton/yr);

EF_{NMVOC} - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents and these have fossil origin contributing to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85 percent of carbon:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

4.3.4.1.3 Emission Factors

Emission factor is 0.9 kg/ton, from Corinair90 Default Emission Factor Handbook.

4.3.4.1.4 Activity Data

Information about activity data for this sector is still scarce and limited to 1990, 2001-2007 and 2010 periods, from National Statistics Institute (INE). For the period 1991-2000 and 2008-2009 data has been interpolated.

4.3.4.1.5 Recalculations

No recalculations were made.

4.3.4.1.6 Further Improvements

The place where emissions from chipboard manufacture are located in the inventory should be subjected to revision and possibly moved to category "Solvent Use". Also, NMVOC emissions from this activity should be estimated according to methodologies for this source sector avoiding double counting of emissions that result in fact from solvent use.

4.3.5 Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2.F.)

4.3.5.1 Overview

Several simple halogenated organic compounds have high warming potentials and long atmospheric residence times. These include predominantly synthetic substances that have been used mostly as inert gases in such diverse applications as Refrigeration Fluid, aerosols propellants, foam fillers, gas insulation and fire suppressants. Chlorofluorocarbons (CFC), Hydrochlorofluorocarbons (HCFC), Perfluorinated hydrocarbons (PFC) and sulphur hexafluoride (SF₆)⁷⁰ are the most important among those compounds. CFC and HCFC are already under control and being phased out under the Montreal Protocol, as consequence of their role as Ozone Depleting Substances (ODS). Therefore, under the United Nations Convention on Climate Change it was decided to consider in the GHG inventory those substances not included in the Montreal Protocol: HFC, PFC and SF₆.

Some emission sources are still not included in the inventory:

- Aerosols. According to information from DGAE there are no fluorinated gases in the composition of produced or imported aerosols in Portugal; Solvents. According to information from DGAE there are no fluorinated gases in the composition of produced or imported solvents in Portugal;

Some emissions sources are not completely covered in the inventory, mainly as result of lack of adequate basic activity data, although there is a strong evidence that they are minor sources and thus do not decisively contribute to total emissions:

- some non-electrical use of SF₆ such as gas tracer in air dispersion and air emission studies.

⁷⁰ Other substances with greenhouse gas potential but less common are NF₃ and some halons. They are not included neither in Montreal Protocol neither in FCCC.

One source, HFC-23 emissions from HCFC-22 manufacture, did not exist in Portugal during the reporting period and is reported as Not Occurring (NO).

4.3.5.2 *General Methodology*

For those sources with sufficient available data, actual emissions were estimated with a Tier 2 (advanced or actual method) approach which is considered Good Practice in accordance with GPG. This approach allows the quantification of emissions in the year in which they actually occurred accounting for the time lag between consumption and emissions. On the contrary, the Tier 1, or potential approach, allocates emissions in the year that the chemical is sold into a particular end-user.

As a general rule, bottom-up methodologies were used, and thus overall methodology should be classified as Tier 2a. This approach departs from the knowledge of the number of equipments using Fluorinated compounds and estimates emissions to atmosphere from charge (amount of chemical used in the equipment), service life, emission rate during the various periods of the equipment life and possible recovery of emissions.

Whenever possible emission estimates include:

- assembly emissions - when equipment is first filled⁷¹;
- operation emissions - occurring during equipment lifetime or usage and resulting mainly from leaks;
- disposal emissions - the remaining charge that is released to the atmosphere at end of equipment life and where the remaining charge is neither recycled or destroyed.

4.3.5.3 *Recalculations*

The number of households (domestic refrigeration) was updated for the period 2001-2010 based on INE timeseries.

In hypermarkets, AD has been revised for the period 1990-2010.

Data on the opening date and total area of each shopping center (Industrial Stationary Air Conditioning) has been revised based on APCC timeseries.

Amounts of sold metered dose inhalers charged with F-gases have been revised for the period 2008-2010.

Electric equipment AD timeseries have been revised for the period 2007-2010.

4.3.5.4 *Further Improvements*

It is expected that emission estimates will improve as a consequence of the inclusion of non quantified sources and the upgrade of methodologies and parameters for the already quantified sources. The main aspects that will be subjected to future improvements include:

- It is known that SF₆ was used in Portugal as a tracer in scientific studies, even in the development of air emission methodologies (VOC from forest). But the quantities used in this activity remain unknown;

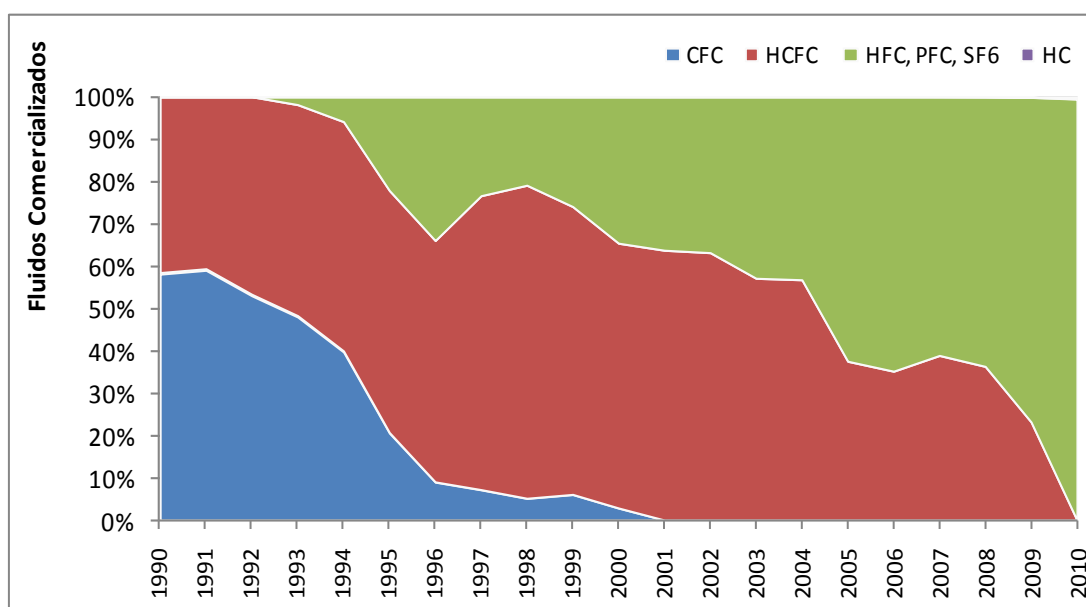
⁷¹ Assembly emissions could include also emissions during refilling but no data was available to make this distinction

- The consideration of refilling of refrigeration equipments should be better addressed in the inventory;
- Emissions from certain source sectors rely in less accurate activity data, which was estimated from surrogate data and assumptions. Efforts will be made to reduce uncertainty on activity data and parameters.

4.3.5.5 Importers Data

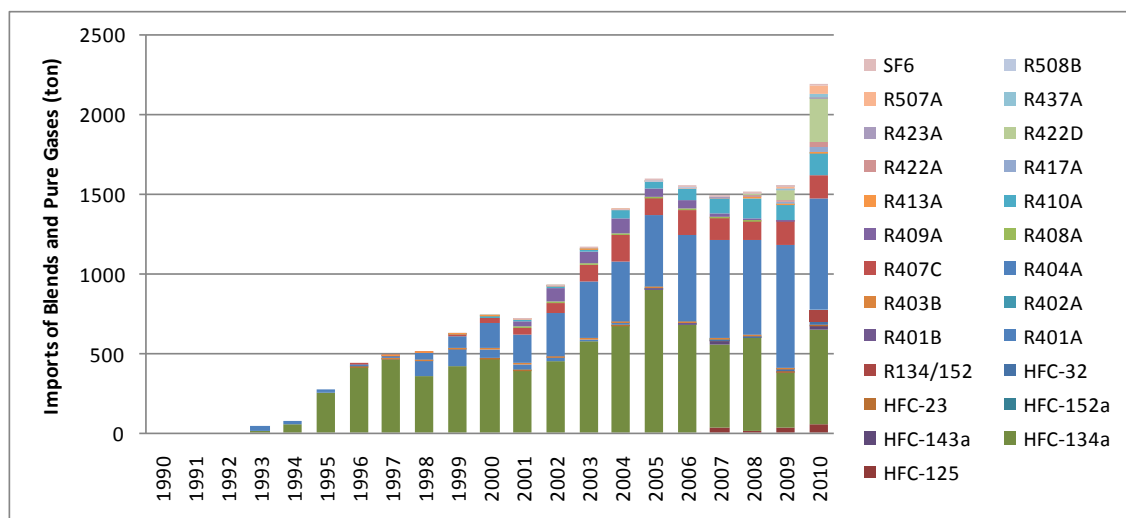
The share of each F-gas used in the assembling of refrigeration equipments was estimated for each year relying on imports data from the major national suppliers of assembled units. Although data from suppliers does not cover the total national market, it was assumed to represent 60 percent (value agreed upon with suppliers) and there were made corrections to the total value in order to obtain a well representative situation. Fluorinated Gases have been imported since 1993 and have been increasingly replacing HCFC imports. The share of imports of each gas can be checked in the following figure.

Figure 4.15 - Percentage of imported fluorinated gases (F-Gases) in Portugal by gas type



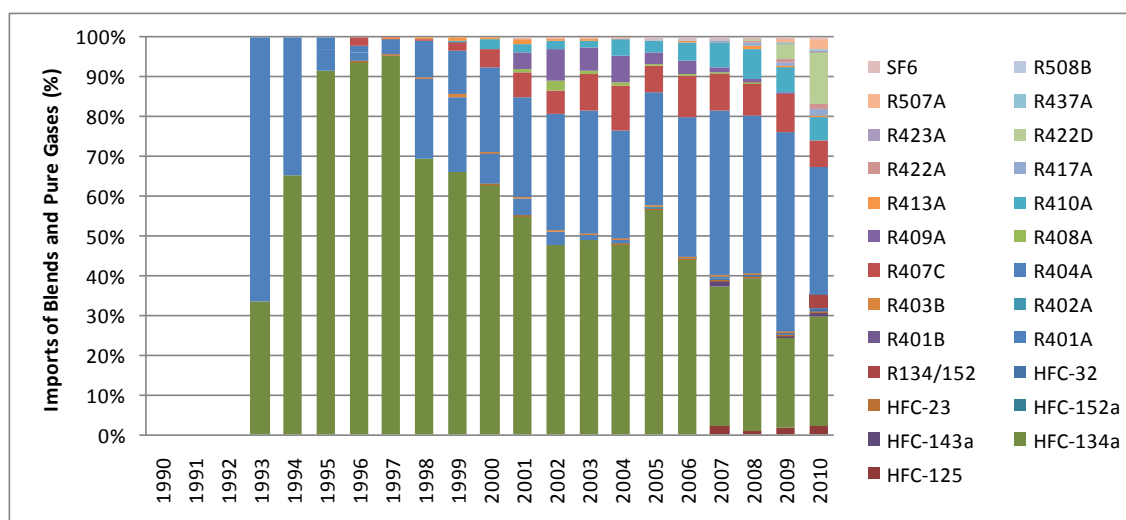
Source: Fluid Suppliers

Figure 4.16 – Imported amounts of pure HFC, PFC, SF₆ and Blends containing HFC and PFC



Source: Fluid Suppliers

Figure 4.17 – Percentual Distribution of pure HFC, PFC, SF₆ and Blends containing HFC and PFC



Source: Fluid Suppliers

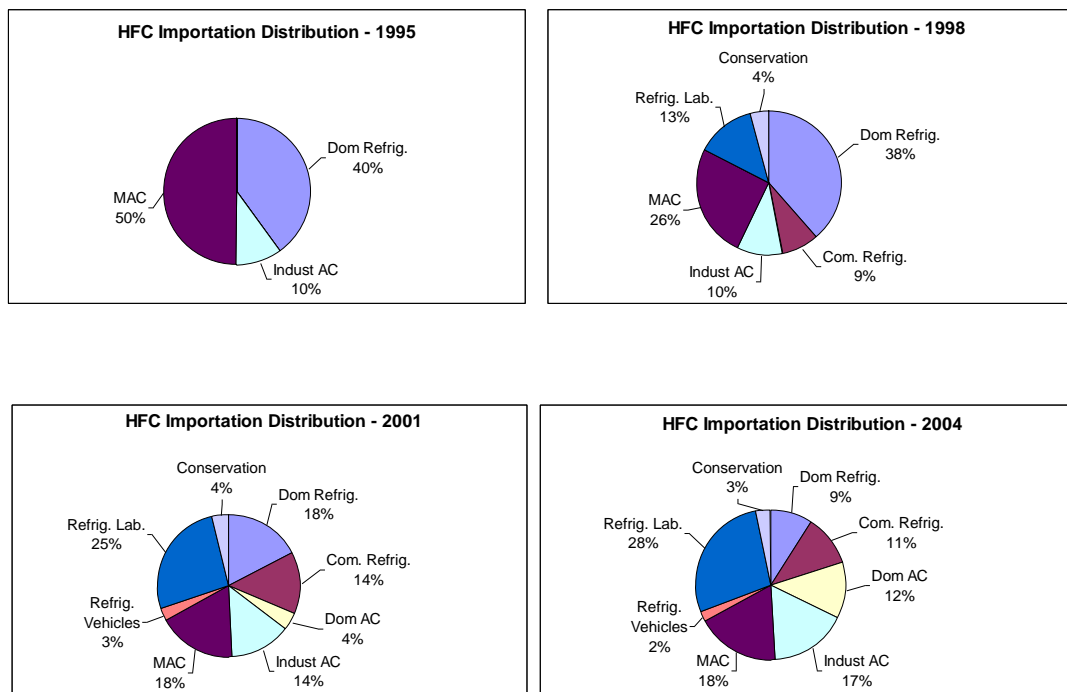
Table 4.13 – Constitution of each blend

Blend Name	Gases in the Blend	% of each gas
R-134/R152	HFC-134a	87%
	HFC-152a	13%
R-401a	HCFC-22	53%
	HCFC-124	34%
R-401b	HFC-152a	13%
	HCFC-22	61%
	HCFC-124	28%
R-402a	HFC-125	60%
	HCFC-22	38%
	HC-290 (propane)	2%
R-403a	HCFC-22	75%
	PFC-218	20%
	HC-290 (propane)	5%
R-404a	HFC-143a	52%
	HFC-125	44%
	HFC-134a	4%
R-407c	HFC-134a	52%
	HFC-125	25%
	HFC-32	23%

Blend Name	Gases in the Blend	% of each gas
R-408a	HCFC-22	47%
	HFC-143a	46%
	HFC-125	7%
R-409a	HCFC-22	60%
	HCFC-124	25%
	HCFC-142b	15%
R-410a	HFC-32	50%
	HFC-125	50%
R-413a	HFC-134a	88%
	PFC-218	9%
	HC-600a (iso-butane)	3%
R-502	CFC-115	51%
	HCFC-22	49%
R-507	HFC-125	50%
	HFC-143a	50%
R-508b	HFC-23	46%
	PFC-116	54%

Source: HRP – Supplier to the Refrigeration and Air Conditioning Equipment

Figure 4.18 - Percentage of imported F-Gases in Portugal by sub sector



Source: Importers

4.3.5.6 Domestic Refrigeration

4.3.5.6.1 Methodology

CFC, HCFC and F-Gases emissions from operation and disposal of Domestic Refrigeration Equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

The emissions were estimated according to the following set of equations from GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

F-Gases emissions for each particular compound were estimated from total Refrigeration Fluid emissions and considering the percentage of F-Gas use in total Refrigeration Fluid use in each year according to the following equations:

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * F-Gas_{\%(j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\%(t,y)} * F-Gas_{\%(j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} [Equip_{\%(t,t-lifetime)} * F-Gas_{\%(j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$, $Oper_{Emi(t)}$, $Disp_{Emi(t)}$ - total F-Gas emissions at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$, $Oper_{Emi(t,j)}$, $Disp_{Emi(t,j)}$ - F-Gas emissions of compound j at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$ - Equipments assembled at year t ;

$Equip_{Stock(t)}$ - Existing stock of equipment at year t ;

$Equip_{Disposal(t)}$ - Number of equipments disposed at year t ;

$Initial_{Charge(t)}$ - Initial charge of Refrigeration Fluid filled at year t ;

$Equip_{\%(t,y)}$ - Percentage of equipments assembled at year y in the existing stock at year t ;

$F-Gas_{\%(j,t)}$ - Percentage of use of Fluorinated compound j at year t ;

K - percentage of initial charge that it is released during assembly;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

4.3.5.6.2 Emission Factors

The following emission factors were considered for this activity corresponding to the average values from the proposed range in IPCC GPG table 3.22.

Table 4.14 - Emission Factors of F-gases from Domestic Refrigeration

Emission Factor (percentage of initial charge)	
Charging	Lifetime emission
0.60	0.20

Source: IPCC GPG (table 3.22)

No recovery of gas was considered at the end of product life ($z=0$). The emitted quantity to the atmosphere is therefore the residual product remaining in equipment (variable y) which was set at 90 percent, according to *1996 IPCC Revised Guidelines*.

4.3.5.6.3 Activity Data

The stock of domestic refrigeration equipments was estimated from the number of households and from the percentage of households with refrigeration equipments, available for years 1990, 1995 and 2000, according to an unpublished report from INE. From year 2000 onward the percentage of equipments per household was forecasted by APA based on gross domestic product behaviour. The number of households refers to INE-Family Survey.

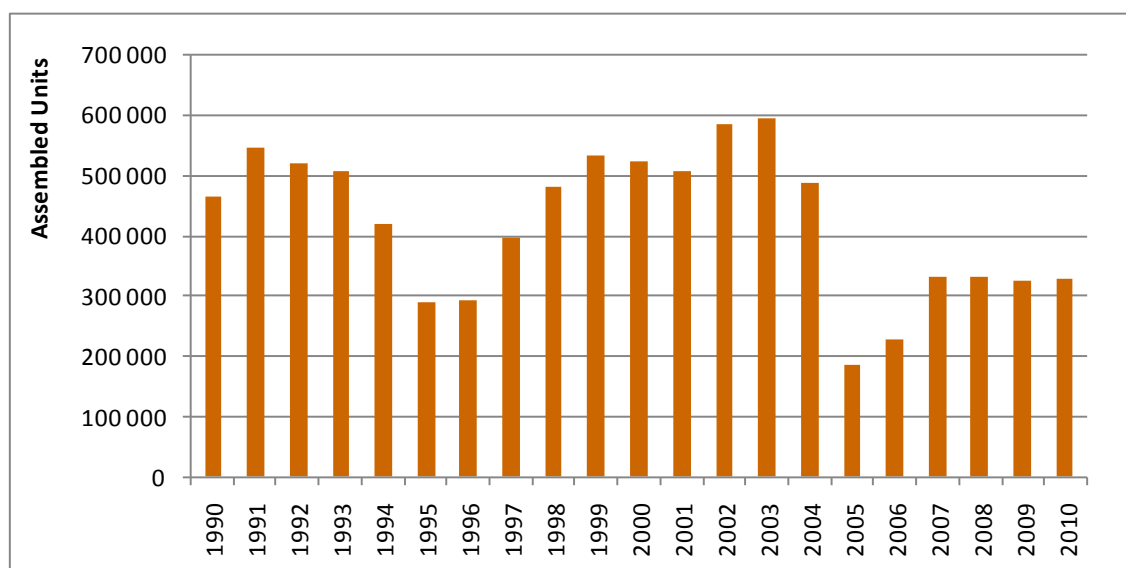
Table 4.15 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000	2010
Combined (Fridge and Freezer)	91.9	95.7	97.1	100.0
Freezers	34.4	49.5	53.5	55.0

Source: INE – National Statistics Institute

Time series of the number of assembled domestic refrigeration units in Portugal available from the National Statistic Institute (INE), are presented in next figure. Values for year 2010 were forecasted by APA based on previous years data.

Figure 4.19 – Number of assembled refrigeration units



Source: INE – National Statistics Institute

The number of disposed units (scrap rate) is not available in Portugal. It was assumed that 10 percent of the stock is removed every year.

4.3.5.6.4 Other Relevant Data and Parameters

According to data from fluid suppliers, F-gases used in Portugal in domestic refrigeration equipments include only HFC-134a. The percentage of each gas in the existing stock for each year was estimated considering an average of the percentage of gas in assembled units during the lifetime of the equipment. For disposal calculations, it was considered that the F-gas composition equals that of the year when the equipment was assembled, i.e. that of emission year less the lifetime of the equipment⁷². Prior to 1993 no F-gas was used in the assembling of refrigeration units. Lifetime of domestic equipments was set at 12 years to combined equipments (fridge+freezer) and 14 years to freezers.

The amount of Refrigeration Fluid charged into the equipment was assumed to be 110g/equipment for combined equipments (fridge+freezer) and 170 g/equipment unit for freezers, which are well within the range set in GPG table 3.22.

4.3.5.6.5 Recalculations

No recalculations were made.

⁷² In consequence no emissions of HFC from disposal are estimated for the reported period.

4.3.5.6.6 Uncertainty Assessment

An uncertainty of 10 percent was considered for the number of assembled units each year, and 15 percent was assumed as the number of existing equipment units. The number of disposed units was estimated from expert guess and a higher uncertainty of 35 percent was assumed. Uncertainty values for emission factors, or F gas liberation, incorporate the uncertainty in initial charge, emission factors and also a component for time of discharge – expressing the uncertainty in lifetime. Each individual value was determined from the range of default emission factors in GPG, except the uncertainty in initial charge that was established from the maximum range obtained from expert guess from the direct (bulk) importers of fluoride gases in Portugal. Individual uncertainty values are presented in next table.

Table 4.16 – Uncertainty of Emission Factors for F-gases emissions from Domestic Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	73	67	5	0	99
Operation	73	67	13	0	99
Disposal	73	6	13	0	74

The revision of the methodology, particularly the improvements on the knowledge of initial charge, has improved substantially the overall uncertainty since last submission (combined uncertainty was estimated to vary between 227 and 235 percent).

4.3.5.7 Commercial Refrigeration

4.3.5.7.1 Methodology

In a similar mode to other Stationary Refrigeration Equipments, CFC, HCFC and F-gases emissions from operation and disposal of non domestic Refrigeration Equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

Lifetime and disposal emissions were estimated according to the following set of equations from GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

F-gases emissions for each particular compound were estimated from total Refrigeration Fluid emissions and considering the percentage of F-gas use in total Refrigeration Fluid use in each particular year (data collected from importers), according to the following equations:

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} \cdot F-gas_{\% (j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\% (t,y)} \cdot F-gas_{\% (j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} [Equip_{\% (t,t-lifetime)} \cdot F-gas_{\% (j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$, $Oper_{Emi(t)}$, $Disp_{Emi(t)}$ - total F-gas emissions at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$, $Oper_{Emi(t,j)}$, $Disp_{Emi(t,j)}$ - F-gas emissions of compound j at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$ - Equipments assembled at year t;

$Equip_{Stock(t)}$ - Existing stock of equipment at year t;

$Equip_{Disposal(t)}$ - Number of equipments disposed at year t;

$Initial_{Charge(t)}$ - Initial charge of Refrigeration Fluid filled at year t;

$Equip_{\% (t,y)}$ - Percentage of equipments assembled at year y in the existing stock at year t;

$F-gas_{\% (j,t)}$ - Percentage of use of Fluorinated compound j at year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

4.3.5.7.2 Emission Factors

In a similar way to domestic equipments, emission factors were set as the average values from the proposed range in IPCC GPG table 3.22.

Table 4.17 - Emission Factor for F-gas emissions from commercial, industry and services refrigeration equipments

	Charging (kg/unit)	Lifetime Emission (%)
Mini-Fridge	0.05	0.20
Fridge	0.11	0.20
Horizontal Freezer	0.87	5.50
Congelation Chamber	1.20	5.50
Refrigeration Chamber	1.20	5.50
Supermarket Vertical Freezer Showcase	0.87	5.50
Vertical Freezer	0.87	5.50
Under Bench Refrigerator	1.31	5.50
Supermarket Horizontal Freezer Showcase	1.31	5.50
Fridge (Bottles)	1.31	5.50
Wine Fridge Showcase	0.87	5.50
Ice Machine	0.05	5.50
Juice Machine	0.05	5.50
Ice Cream Machine	0.05	5.50
Chantilly Machine	0.05	5.50
Tap drink cooler	0.05	5.50
Can Vendor	0.11	0.20
Tap beer cooler	0.05	5.50

It was considered that 80 percent of the gas remaining in the equipment at the end of lifetime was recovered ($z=0.8$) and the emitted quantity to the atmosphere is therefore the residual product remaining in equipment (variable y) which was set at 90 percent (data from importers).

4.3.5.7.3 Activity Data

There are no available national statistics concerning the number and dimension of non-domestic refrigeration equipments used in commerce, industry, tourism, services and institutional activities. A survey to Hotels, Hostels and Camping Parks was conducted with the support of "Turismo de Portugal, ip" and "AHP – Associação da Hotelaria de Portugal", in order to obtain real data concerning the number and dimension of non-domestic refrigeration equipments. Data pertaining to other commerce and services activities was estimated with the technical support of APIRAC, Importers and DGAE (Economic Activities General Directorate). Calculations for Hypermarkets were made separately.

The number of refrigeration equipments was estimated based on the unit numbers available from National Statistics Institute (INE), for the following economic activities:

Table 4.18 - Number of commercial installations in Portugal provided with refrigeration equipments

Activity	Number	Period
Hotels	406	1995
Hostels (Boarding Houses)	1131	1995
Other Establishments	379	1995
Campgrounds	181	1997
Restaurants	21 370	1996
Liquor stores	38 855	1996
Cafeterias	333	1996
Retail Commerce	49 135	1995
Gross Commerce	7 774	1995

Source: INE – National Statistics Institute

The following assumptions were made by APA:

- Retail Commerce and Gross Commerce do not include Hypermarkets (large, medium or small);
- For Hotels, Hostels, Boarding Houses, Other Establishments and Campgrounds, the following data was considered:

Table 4.19 - Number of refrigeration equipments per commercial unit in Portugal

	Hotels	Hostels and Boarding Houses	Campgrounds
Mini-Fridge	71	14	40
Fridge	5	2	5
Horizontal Freezer	3	2	4
Congelation Chamber	1	1	1
Refrigeration Chamber	3	2	1
Supermarket Vertical Freezer Showcase	2	2	2
Vertical Freezer	1	1	2
Under Bench Refrigerator	4	2	2
Supermarket Horizontal Freezer Showcase	1	1	2
Fridge (Bottles)	1	1	3
Wine Fridge Showcase	1	1	3
Ice Machine	2	1	1
Juice Machine	0	0	1
Ice Cream Machine	0	1	1
Chantilly Machine	0	1	0
Tap drink cooler	1	1	2
Can Vendor	0	1	2
Tap beer cooler	2	1	2

Source: Survey with the support of "Turismo de Portugal, IP" and "AHP – Associação da Hotelaria de Portugal"

When it was not possible to use real data, the number of equipments per activity was set by expert judgement and through visits to some installations, according to the following table:

Table 4.20 - Number of refrigeration equipments per commercial unit in Portugal

Activity	Equipment			
	Frigorific/Congelation Chamber (unit)	Fridge Showcase (m/unit)	Freezer (unit)	Fridge (unit)
Restaurants	1	4	2	1
Liquor stores	-	4	-	-
Cafeterias	2	4	3	-
Retail Commerce	2	10	-	-
Gross Commerce	2	50	-	-

Source: Expert Judgement based on local survey

For Hypermarkets, calculations were made using data on average numbers of specific equipment (showcase fridges/freezers, frigorific chambers, congelation chambers) for each category (Big, Medium and Small).

Table 4.21 – Classification of refrigeration equipments by area

Area (m ²)	Category	Showcase Fridge/Freezer (m)		Refrigeration Chambers (m ²)	Congelation Chambers (m ²)
		Positive Temp.	Negative Temp.		
Area >4500	Big	218	110	550	180
1000 ≤ Area ≤ 4500	Medium	96	48	75	82
Area < 1000	Small	40	38	10	20

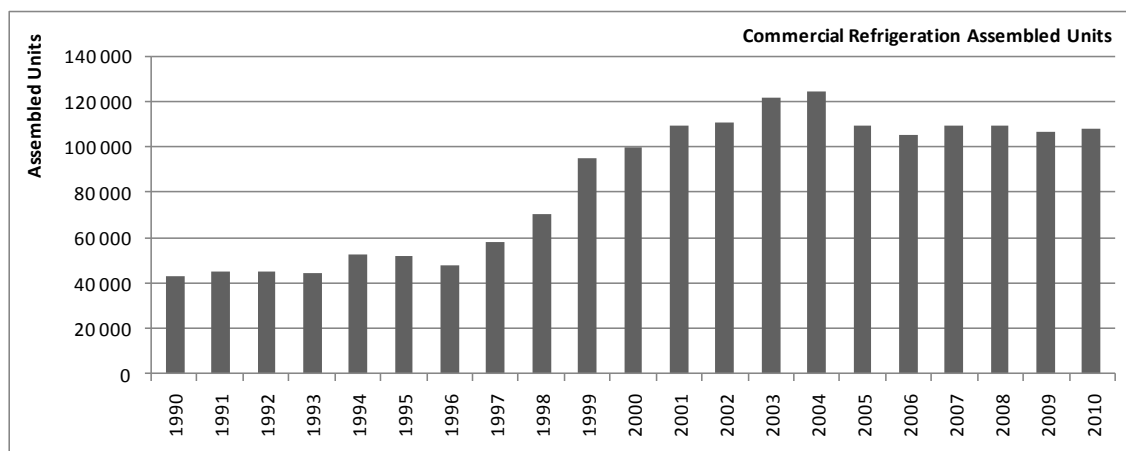
Source: Hypermarket Company

Table 4.22 – Number of installations using F-Gas as Refrigeration Fluid

Category		Number of Units using HFC as Refrigeration Gas															
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Positive Temperature	Big	0	0	0	0	2	3	5	6	7	7	10	10	20	23	35	36
	Medium	0	0	0	0	12	22	36	42	44	52	73	111	154	220	257	269
	Small	0	0	0	0	33	76	105	133	147	156	214	270	357	490	542	573
Negative Temperature	Big	0	0	0	0	0	1	3	4	5	5	8	8	18	21	33	34
	Medium	0	0	0	0	0	10	24	30	32	40	61	99	142	208	245	257
	Small	0	0	0	0	0	43	72	100	114	123	181	237	324	457	509	540

Data on the assemblage of commercial and industrial refrigeration units from the new Industrial Survey (IAP) is only available after 1992 and refers to refrigeration units with a viewing monitor. The number of these units is comparatively smaller than domestic ones (see Figure 4.6). The number of units for 1990 and 1991 were estimated concerning the Gross Domestic Product (GDP) values for each year.

Figure 4.20 - Number of commercial and industrial refrigeration assembled units in Portugal



In a similar way to domestic refrigeration equipments, the number of disposed units is not available and it was assumed that 10 percent of the stock is removed yearly (value confirmed by equipment manufacturers associations).

4.3.5.7.4 Other Relevant Data and Parameters

The percentage of F-gases in assembled equipments, existing stock and disposed units follows the same procedure and background data used for domestic equipments. However, lifetime was set at 14 years (average of values proposed by equipment manufacturers and suppliers).

IPCC GPG considers an excessive wide range of values for the charge in commercial stand-alone refrigeration equipments. The adopted value, 440 g per linear meter of equipment unit, is based upon information from equipment manufacturers and suppliers in Portugal.

4.3.5.7.5 Uncertainty Assessment

The uncertainty in the refrigeration equipment stock estimates was considered higher than that for domestic refrigeration. Using the same arguments that were used to derive activity data numbers, the actual values could be underestimated by 50 percent or overestimated by 200 percent. The uncertainty on the number of disposed units per year is probably even higher, reflecting the uncertainty in the lifetime of the equipment. That results in 16 percent uncertainty for stock and 75 percent for disposal. In the other hand, the uncertainty in new units estimates results from the same source of information than that for domestic equipments and the uncertainty value of 10 percent was considered.

In a similar mode to what was assumed for domestic refrigeration, uncertainty values for emission factors incorporate the uncertainty in the: initial charge; emission factor; composition of the F gas mixture⁷³, which affects the overall GWP; and also an uncertainty component for the time of discharge – expressing the uncertainty in lifetime. Individual uncertainty values are presented in the next table.

⁷³ This factor was not considered in the 2006 submission. It represents the change in final CO₂e values given the possible range in the gas composition that is used in the final mixture.

Table 4.23 – Uncertainty of Emission Factors for HFC emissions from Commercial Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	183	69	5	96	218
Operation	183	264	21	96	336
Disposal	183	11	21	96	208

4.3.5.8 *Transport Refrigeration*

4.3.5.8.1 Methodology

In a similar way to other Stationary Refrigeration Equipments, CFC, HCFC and F-gases emissions from operation and disposal of transport refrigeration equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG. Lifetime and disposal emissions⁷⁴ were estimated according to the following set of equations from GPG:

Operation/Lifetime

$$\text{Oper}_{\text{Emi}(t)} = \text{Equip}_{\text{Stock}(t)} * \text{Initial}_{\text{Charge}(t)} * (x/100)$$

Disposal

$$\text{Disp}_{\text{Emi}(t)} = \text{Equip}_{\text{Disposal}(t)} * \text{Initial}_{\text{Charge}(t-\text{lifetime})} * (y/100) * (1-z/100)$$

F-gases emissions for each particular F-gas compound were estimated from total Refrigeration Fluid emissions, and considering the percentage of F-gas use in total Refrigeration Fluid use in each particular year, according to the following equations:

Operation/ Lifetime

$$\text{Oper}_{\text{Emi}(t,j)} = \text{Oper}_{\text{Emi}(t)} \sum_{y=t}^{t-\text{Lifetime}} [\text{Equip}_{\% (t,y)} * \text{F-gas}_{\% (j,y)}]$$

Disposal

$$\text{Disp}_{\text{Emi}(t,j)} = \text{Disp}_{\text{Emi}(t)} [\text{Equip}_{\% (t,t-\text{lifetime})} * \text{F-gas}_{\% (j,t-\text{lifetime})}]$$

Where

$\text{Oper}_{\text{Emi}(t)}$, $\text{Disp}_{\text{Emi}(t)}$ - total F-gas emissions at year t from during Operation (Oper) and Disposal (Disp);

⁷⁴ Assembly emissions are not estimated and they are included in the assembling of other refrigeration equipments

$Oper_{Emi(t,j)}, Disp_{Emi(t,j)}$ – F-gas emissions of compound j at year t from during Operation (Oper) and Disposal (Disp);

$Equip_{Stock(t)}$ - Existing stock of equipment at year t;

$Equip_{Disposal(t)}$ - Number of equipments disposed at year t;

$Initial_{Charge(t)}$ - Initial charge of Refrigeration Fluid filled at year t;

$Equip_{\%(t,y)}$ - Percentage of equipments assembled at year y in the existing stock at year t;

$F-gas_{\%(j,t)}$ - Percentage of use of F-gas compound j at year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

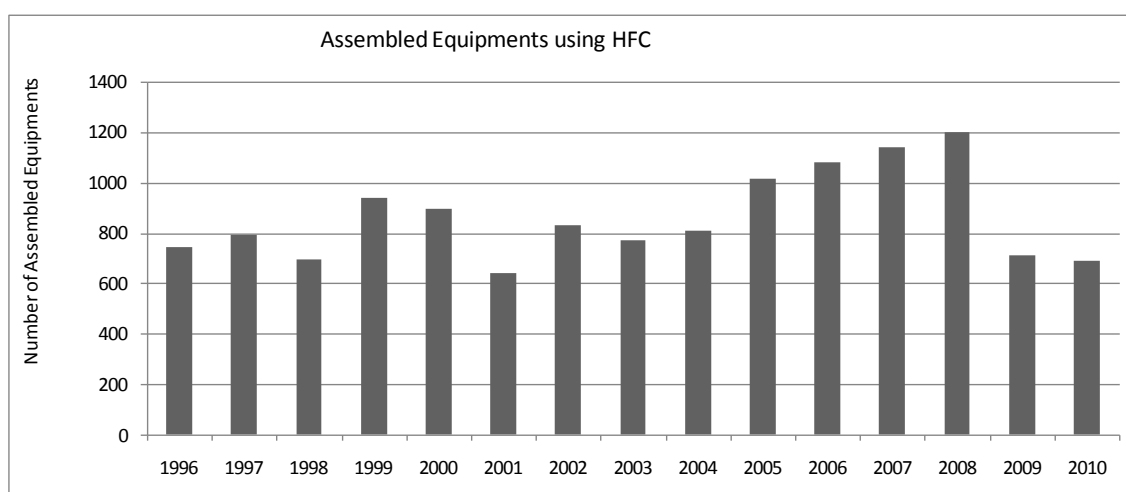
4.3.5.8.2 Emission Factors

Lifetime emissions were assumed to occur with a yearly rate of 32.5 percent of initial charge per year in accordance with the average rate proposed in table 3.22 of the GPG. The quantity emitted to the atmosphere is the residual product remaining in equipment (variable y) which was set at 90 percent (*1996 IPCC Revised Guidelines*) and no recovery is assumed at disposal.

4.3.5.8.3 Activity Data

It was assumed that, before 1996, CFC-12 was used instead of HFC as Refrigeration Fluid in Portugal. Data on the number of equipments produced in Portugal was collected from equipment manufacturers.

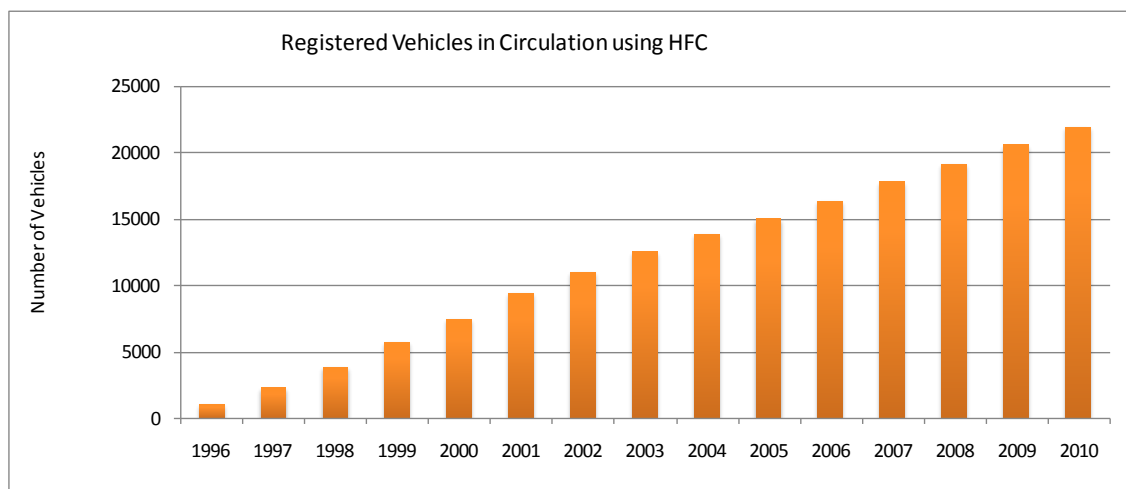
Figure 4.21 – Number of Equipments produced in Portugal (1990-2010)



Source: Frigorific and Refrigerated Chambers Manufacturers

Data on the number of existing registered vehicles was provided by the Portuguese Authority on Vehicles (ex-DGV).

Figure 4.22 – Number of Registered Vehicles in circulation in Portugal (1990-2010)



Source: DGV – National Entity responsible for road traffic

4.3.5.8.4 Other Relevant Data and Parameters

The value for initial charge was assumed to be 5.35 kg/unit (average of the values proposed by manufacturers and suppliers) which is within the recommended IPCC range (3 to 8 kg/unit). Lifetime was set at 10 years (average of the values proposed by manufacturers and suppliers). It was assumed an yearly disposal of 10 percent of the vehicles (value agreed upon with Manufacturers Association).

4.3.5.8.5 Uncertainty Assessment

For this source category there is also a high level of uncertainty in the determination of refrigeration equipment stock and it was assumed that the uncertainty varies from 10 percent (new units), 20 percent (stock) and up to 50 percent (disposal).

Uncertainty values for emission factors, in a similar way as for domestic refrigeration, incorporate the uncertainty in the: initial charge; emission factor; composition of the F gas mixture, which affects the overall GWP; and also an uncertainty component for the time of discharge – expressing the uncertainty in lifetime. Each value was determined in accordance with the range of default emission factors in GPG, except the uncertainty in the initial charge that was determined from the range of values referred from the three most important providers of the refrigeration equipment for vehicles in Portugal. Individual uncertainty values are presented in the next table.

Uncertainties in the previous submission were found to be underestimated.

Table 4.24 – Uncertainty of Emission Factors for F-gas emissions from Transport Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	86	67	5	47	119
Operation	86	54	19	47	114
Disposal	86	6	19	47	101

4.3.5.9 Domestic Stationary Air conditioning

4.3.5.9.1 Methodology

In a similar way to other Stationary Refrigeration Equipments, fluorine gas emissions from operation and disposal of Stationary Air conditioning equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

Emissions were estimated according to the following set of equations from GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * F-gas_{\%(j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\%(t,y)} * F-gas_{\%(j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} [Equip_{\%(t,t-lifetime)} * F-gas_{\%(j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$, $Oper_{Emi(t)}$, $Disp_{Emi(t)}$ - total F-gas emissions at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$, $Oper_{Emi(t,j)}$, $Disp_{Emi(t,j)}$ – F-gas emissions of compound j at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$ - Equipments assembled at year t;

$Equip_{Stock(t)}$ - Existing stock of equipment at year t;

$Equip_{Disposal(t)}$ - Number of equipments disposed at year t;

$Initial_{Charge(t)}$ - Initial charge of Refrigeration Fluid filled at year t ;

$Equip_{\%(t,y)}$ - Percentage of equipments assembled at year y in the existing stock at year t ;

$F-gas_{\%(j,t)}$ - Percentage of use of Fluorinated compound j at year t ;

K - percentage of initial charge that it is released during assembly;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

4.3.5.9.2 Emission Factors

Lifetime emission factor was set as 3 percent of initial charge per year, which is the average value from the proposed range in IPCC GPG table 3.22.

It was assumed a recovery of the gas of 10 percent (data from importers) at end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90 percent (IPCC 1996 Revised Guidelines).

4.3.5.9.3 Activity Data

From available data on industry statistics it is not possible to have a clear estimate of the number of assembled units over time, as consequence of the change that occurred in the industrial survey in 1992, when IAIT was replaced by IAPI, as the latter uses different products categories. IAIT survey categories are not detailed enough to differentiate the production of refrigeration components - from which no emissions occur - from their final assembling. The closedown of an important factory in that period further complicates the determination of the time series. This situation is nonetheless irrelevant for the inventory because F-gases emissions in the assembling of AC equipments did not occur in that period.

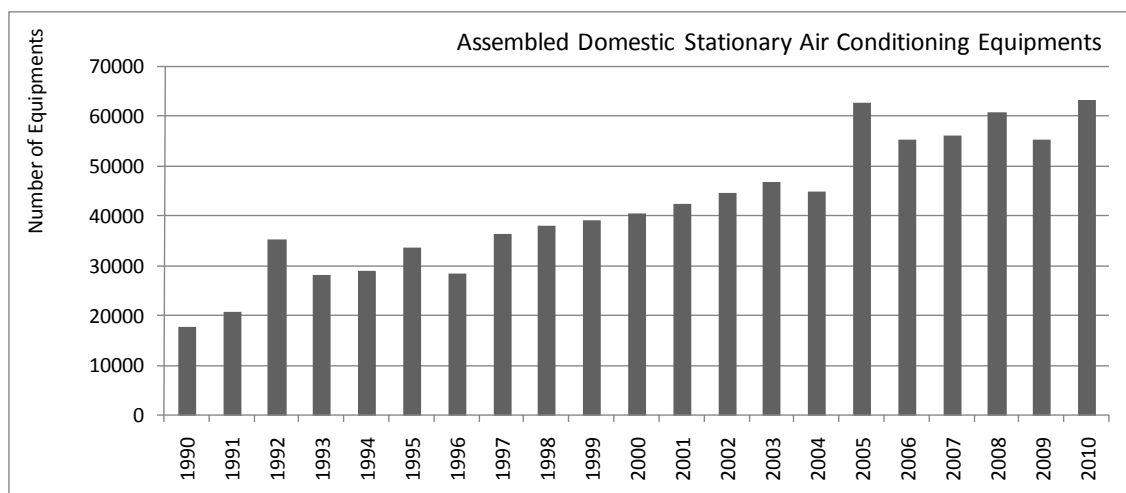
According to the available data from Luís Roriz at Higher Technical Institute (IST-UTL), the following time series (Figure 4.23), from 1990 to 2010, was adopted by the inventory. According to IAIT, 50 821 and 63 108 units were assembled, respectively, in 1990 and 1991⁷⁵.

It was assumed that 90 percent of stocks and assembled air conditioning equipments are domestic equipments.

The number of assembled domestic stationary air conditioning equipments was available from unpublished information received from IST-UTL (see Figure 4.23).

⁷⁵ Due to difference in magnitude order these values from IAIT are not shown in the graph

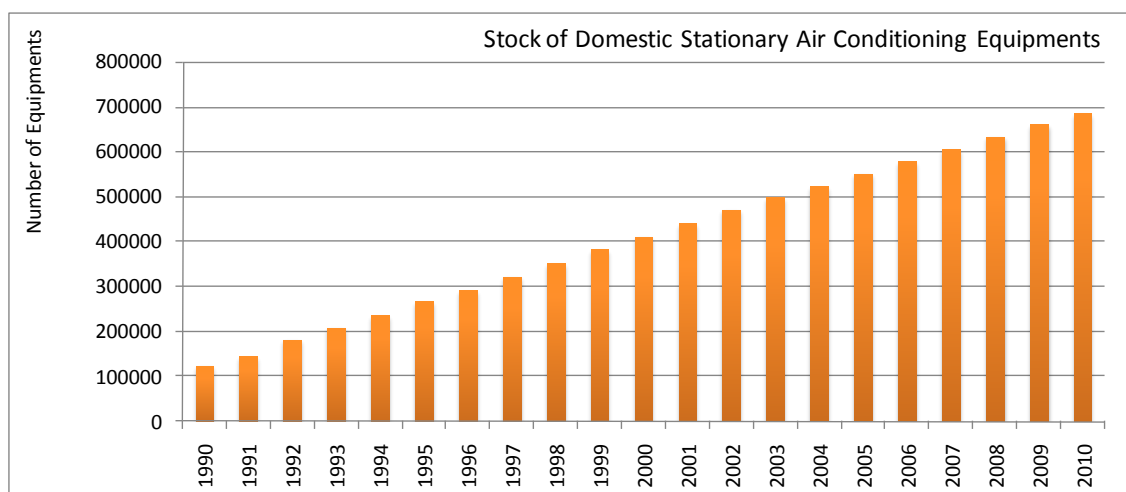
Figure 4.23 - Number of Domestic Stationary Air Conditioning Equipments assembled in Portugal in the period 1990-2010



Source: Prof. Luís Roriz (IST-UTL – Technical Superior Institute)

Annual stock of domestic stationary air conditioning equipments (see Figure 4.24) and yearly disposed units were also available from the same unpublished information received from IST-UTL.

Figure 4.24 - Annual Stock of Domestic Stationary Air Conditioning Equipments in Portugal (1990-2010)



Source: Prof. Luís Roriz (IST-UTL – Technical Superior Institute)

4.3.5.9.4 Other Relevant Data and Parameters

The amount of initial gas charged per equipment, set at 300 g/unit, is based upon information collected from the Portuguese Association of Refrigeration Equipment Providers (APIRAC) by Seixas et al (2000). The F-gas composition was obtained by data from importers. It was assumed that during the first filling, 0.6 percent of the initial charge of gas is lost (arithmetic average of the values 0.2 and 1 recommended by the IPCC Good Practice Guidance).

4.3.5.9.5 Uncertainty Assessment

The uncertainty in the number of newly assembled AC units is higher than the value that was considered for domestic refrigeration due to the incomplete time series data. An uncertainty value of 20 percent was assumed. Regarding stock in existence, an uncertainty of 30 percent was considered, and a higher value of 75 percent was used for disposal.

Similarly to domestic refrigeration, uncertainty values for emission factors incorporate the uncertainty in the: initial charge; emission factor; composition of the F gas mixture; and also an uncertainty component for time of discharge. The uncertainty in the initial charge of the equipments is based on the expert guess from APIRAC. The uncertainty associated to other parameters was established based on the range of default emission factors in GPG. Individual uncertainty values are presented in the following table. Overall, due to the methodological improvements achieved since 2007, the uncertainty in this sector was reduced by about one order of magnitude with regards to operation and disposal, and by half in what concerns assembly.

Table 4.25 – Uncertainty of Emission Factors for F-gases emissions from A/C stationary equipments

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	20	67	5	83	108
Operation	20	67	19	83	110
Disposal	20	6	19	83	87

4.3.5.10 Industrial Stationary Air Conditioning

4.3.5.10.1 Methodology

The methodology used for Industrial Refrigeration Air Conditioning is the same as for Domestic Refrigeration Air Conditioning.

4.3.5.10.2 Emission Factors

The charging emission factor was set to 0.6 percent (average of the values suggested by IPCC Guidelines for Chillers). A lifetime emission factor of 3 percent of initial charge per year, corresponding to the average value from the proposed range in IPCC GPG table 3.22, was considered.

It was assumed a recovery of the gas of 10 percent (data from importers) at the end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90 percent (IPCC 1996 Revised Guidelines). It was assumed a lifetime of 15 years for the equipments (values suggested by manufacturers and importers).

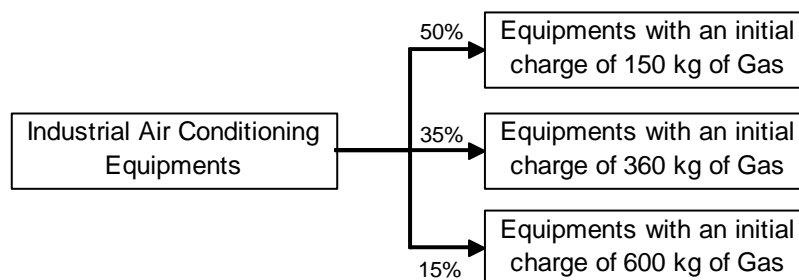
4.3.5.10.3 Activity Data

From available data on industry statistics it is not possible to have a clear estimate of the number of assembled units over time, as consequence of the change that occurred in the industrial survey in 1992, when IAIT was replaced by IAPI, as the latter uses different products categories. IAIT survey categories are not detailed enough to differentiate the production of refrigeration components – from which no emissions occur - from their final assembling. The closedown of an important factory in that period further complicates the determination of the

time series. This situation is nonetheless irrelevant for the inventory because F-gases emissions in the assembling of AC equipments did not occur in that period.

It was assumed that 10 percent of stocks and assembled air conditioning equipments are included in the industrial category (see Figure 4.25).

Figure 4.25 – Subdivision of Industrial Air Conditioning Equipments by type



According to the available data from Luís Roriz (IST-UTL), the following time series (figure below), from 1993 to 2010, was considered in the inventory.

Figure 4.26 – Number of Industrial Stationary Air Conditioning Equipments Assembled in Portugal using F-gases in the period 1993-2010

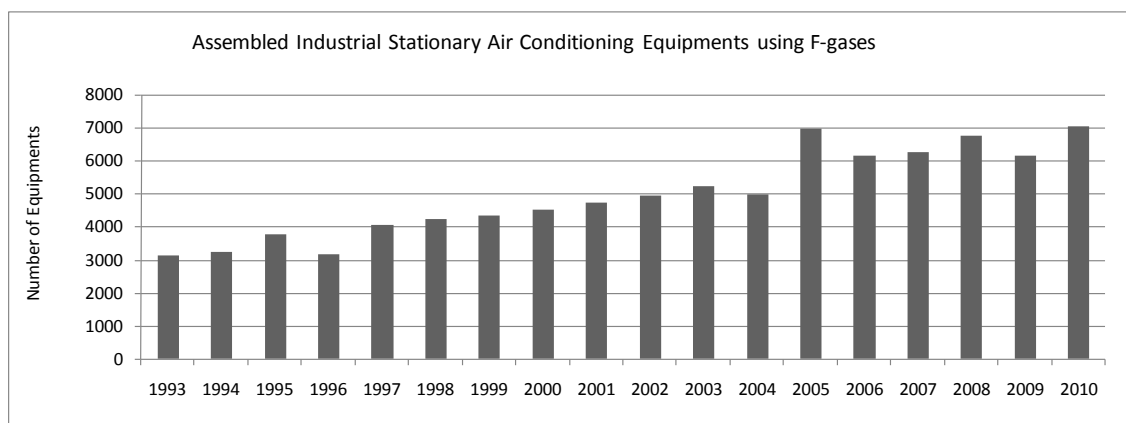
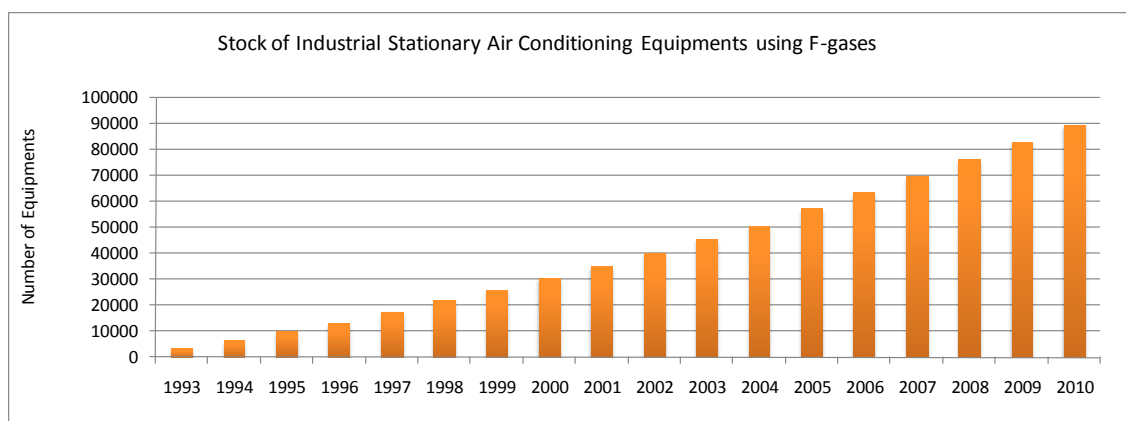


Figure 4.27 – Annual Stock of Industrial Stationary Air Conditioning Equipments in Portugal (1993-2010) using F-gases



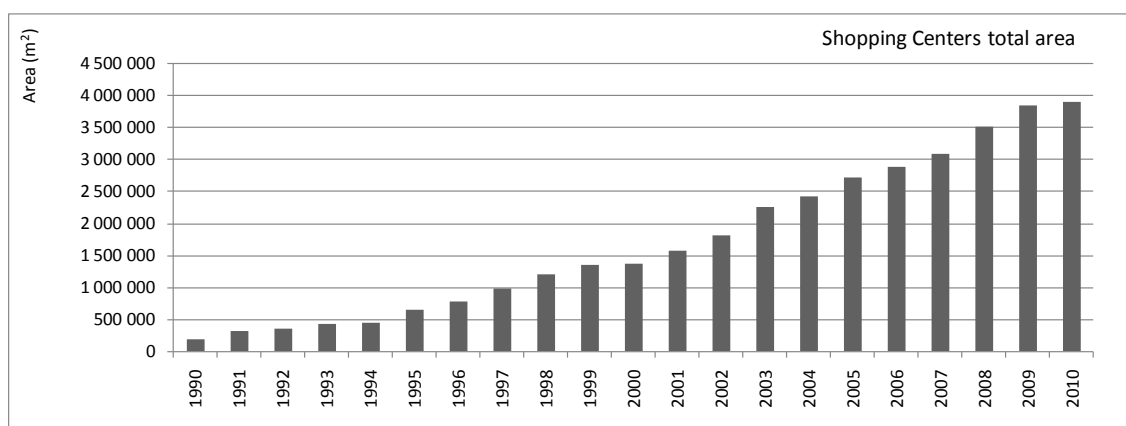
Data on the Temporal Distribution by type of gas was obtained from fluid suppliers.

4.3.5.10.4 Air conditioning equipments from Shopping centers

When considering shopping centers with centralized air conditioning systems, a different methodology was used, considering specific data from each commercial area.

Data on the opening date and total area of each shopping center was provided by APCC (Portuguese Association of Shopping Centers). The figure below shows shopping centers total area.

Figure 4.28 – Shopping Centers total area (m²)



Source: APCC - Portuguese Association of Shopping Centers

Some Shopping Centers provided data on the amount of gas used to charge the air conditioning equipments. Based on the available information, the ratio between the shopping center area and the amount of initial charge of gas was determined. This ratio was used to estimate the initial amount of gas used to fill air conditioning equipments in the Shopping Centers for which such information was not available. A ratio that relates the area and the annual loss of gas was also estimated. Based on collected information on the type of gas, it was assumed that after year 2000 (included) the gas used in assembled equipments was R-407c (HFC mixture), and before 2000 HCFC-22 was used.

4.3.5.10.5 Uncertainty Assessment

The uncertainty assessment is explained in the chapter describing Domestic Stationary Air Conditioning.

4.3.5.11 Mobile Air Conditioning

4.3.5.11.1 Methodology

CFC, HCFC and F-gases emissions from operation and disposal of Mobile Air Conditioning (MAC) systems were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.5.1 of the GPG. The chosen methodology and emission factors are in accordance with the decision tree in GPG figure 3.16.

Emissions were estimated according to the following set of equations from GPG:

Operation/Lifetime

$$\text{Oper}_{\text{Emi}(t)} = \text{Equip}_{\text{Stock}(t)} * \text{Initial}_{\text{Charge}(t)} * (x/100)$$

Disposal

$$\text{Disp}_{\text{Emi}(t)} = \text{Equip}_{\text{Disposal}(t)} * \text{Initial}_{\text{Charge}(t-\text{lifetime})} * (y/100) * (1-z/100)$$

Emission values for each particular F-gas compound were estimated from total Refrigeration Fluid emissions, and considering the percentage of F-gas use in total Refrigeration Fluid used in each particular year, according to the following equations:

Operation/ Lifetime

$$\text{Oper}_{\text{Emi}(t,j)} = \text{Oper}_{\text{Emi}(t)} \sum_{y=t}^{t-\text{Lifetime}} [\text{Equip}_{\% (t,y)} * \text{F-gas}_{\% (j,y)}]$$

Disposal

$$\text{Disp}_{\text{Emi}(t,j)} = \text{Disp}_{\text{Emi}(t)} [\text{Equip}_{\% (t,t-\text{lifetime})} * \text{F-gas}_{\% (j,t-\text{lifetime})}]$$

Where

$\text{Oper}_{\text{Emi}(t)}$, $\text{Disp}_{\text{Emi}(t)}$ - total HFC emissions at year t related to equipments Operation (Oper) and Disposal (Disp);

$\text{Oper}_{\text{Emi}(t,j)}$, $\text{Disp}_{\text{Emi}(t,j)}$ - HFC emissions of compound j at year t related to equipments Operation (Oper) and Disposal (Disp);

$\text{Equip}_{\text{Stock}(t)}$ – Number of equipments in stock at year t;

$\text{Equip}_{\text{Disposal}(t)}$ - Number of equipments disposed at year t;

$\text{Initial}_{\text{Charge}(t)}$ - Initial charge of Refrigeration Fluid filled at year t;

$\text{Equip}_{\% (t,y)}$ - Percentage of assembled equipments at year y in the existing stock at year t;

$\text{HFC}_{\% (j,t)}$ - Percentage of use of HFC compound j at year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

4.3.5.11.2 Emission Factors

Operation emission factors were estimated at an annual rate of 15 percent, corresponding to the average of the updated default range (10-20 percent) in IPCC GPG (table 3.23). Lifetime was set to 12 years, also corresponding to the default value both in IPCC 96 and IPCC GPG.

Variable y was set to 40 percent (default value in IPCC GPG). Variable z was set to 40 percent (value agreed upon with Gas Importers).

4.3.5.11.3 Activity Data

Estimates for Road Transportation and Railways were made separately.

The number of light vehicles with MAC was estimated from the total number of light vehicles sold each year, using the same information used to establish the time series of car sales and fleet in chapter 1A3, and the percentage of new cars sold with MAC at each year was estimated according to data provided by manufacturers. The total number of vehicles equipped with MAC is presented in Figure 4.30.

Figure 4.29 - percent of Assembled Vehicles with AC by class of vehicle (1995-2010)

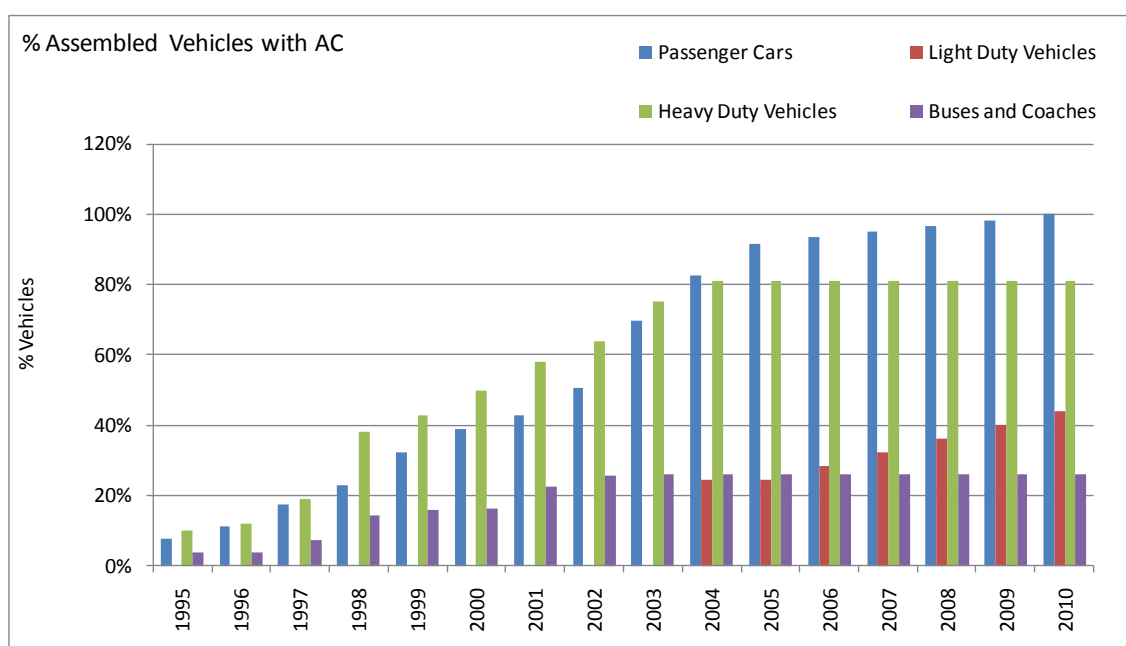
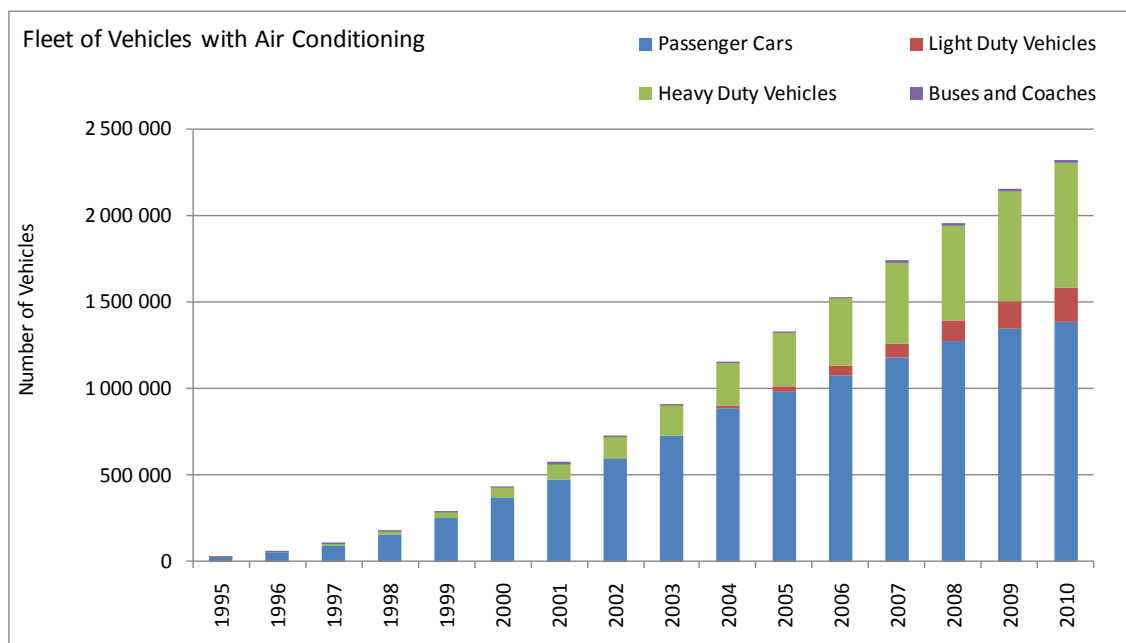


Figure 4.30 – Fleet of Vehicles equipped with AC systems (1995-2010)



4.3.5.11.4 Other Relevant Data and Parameters

The amount at initial charge of 0.77 kg/MAC unit for Passenger Cars and Light Duty Vehicles was considered. The initial charge values of 1.2 kg/MAC unit and 7.5 kg/MAC unit were considered for Heavy Duty Vehicles and for Buses and Coaches, respectively (these values were agreed upon with equipment manufacturers).

It was assumed that HFC-134a is the only HFC replacing CFC and HCFC in MAC associated to Road Transportation, which is in accordance with IPCC GPG. In Portugal the use of HFC-134a associated to MAC equipments reports to year 1993.

In MAC equipments associated to Trains and Subway, both HFC-134a and R-407C are used. For trains, the initial charge amount was considered 1.05-1.5 kg/MAC unit and 4-20 kg/MAC unit, on the crew room and on passenger rooms, respectively.

4.3.5.11.5 Uncertainty Assessment

The uncertainty in new units is higher than that of other refrigeration equipments due to the lack of specific national statistics information concerning the installation of these equipments in vehicles. Moreover, a survey directed to vehicle sellers, was only partially implemented. There is also a high level of uncertainty associated with the determination of MAC units, which are estimated based on sales, vehicle fleet and life time, and it was determined that the actual values could be up to twice higher than the number of new equipment entering the market. The number of units disposed annually is even harder to establish and an uncertainty of 75 percent was assumed.

Similarly to what was done for domestic refrigeration, uncertainty values for emission factors incorporate the uncertainty in the initial charge, in the emission factor and also a component for time of discharge – expressing the uncertainty in lifetime. Only one gas is mentioned in MAC systems and, therefore, no uncertainty in gas composition was considered. The uncertainty in the remaining parameters was established in accordance with the range of default emission factors in GPG, except the initial charge, that was established by comparing the information

delivered by the major car sellers in Portugal. Individual uncertainty values are presented in the next table.

Table 4.26 – Uncertainty of Emission Factors for HFC emissions from MAC

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	20	11	5	0	24
Operation	20	33	19	0	44
Disposal	20	44	19	0	52

4.3.5.12 *Foam Blowing*

4.3.5.12.1 Overview

Fluorinated gases are nowadays used as blowing agents in the manufacture of foams that are used as insulating, cushioning and packaging materials.

The foams blowing agent is eventually ventilated to the atmosphere, but at a rate dependent on the type of foam and its structure. Open cell foams emit virtually all blowing agent at the time of manufacture. Closed-cell foams emit the HFC blowing agent during their lifetime at three distinct phases:

- Foam Manufacturing emissions, occurring during the first year at the location where the foam is manufactured;
- Annual losses, occurring where the foam is applied, result from the slow release of the blowing agent trapped inside the foam.
- Disposal. Emissions occurring when foam is removed and destroyed. The remaining gas in cells is emitted to atmosphere.

Activity data on the use of HFC in foam manufacturing in Portugal is available, allowing the estimation of manufacturing emissions. Annual losses are, however, harder to estimate because it is not known neither the quantity of closed-cells imported that were manufactured with F gases, nor the quantities of foams that were exported with HFC. Nonetheless, assumptions are based on expert judgements.

In Portugal, there is production of Polystyrene closed-cell foams and Polyurethane open-cell foams, associated to the use of HFC-134a and HFC-152a as blowing agents.

4.3.5.12.2 Methodology

Methodology is classified as Tier 2a, using national data, but considering default emission factors. Therefore, emissions include:

First year losses from Foam Manufacture and Installation

$$F_{Gas_{Emi(t,j)}} = F_{FillGas_{Consumption(t)}} * HFC_{\%(j,t)} * (k/100)$$

Annual losses.

$$F_{Gas_{Emi}(t)} = F_{Gas_{inFoam}(t)} * (x/100)$$

$$F_{Gas_{inFoam}(t,j)} = \sum_{y=t}^{t-Lifetime} [Fill_{Gas_{Consumption}(y)} * HFC_{\%}(j,y)]$$

Where:

$F_{Gas_{Emi}(t,j)}$ - gas emission at year t of fluorine gas j;

$F_{Gas_{Consumption}(t)}$ - Total F gas consumption at year t used in closed-cell manufacturing;

$HFC_{\%(j,t)}$ - Percentage of Fluorine gas J used at year t in closed-cell manufacturing;

$F_{Gas_{inFoam}(t,j)}$ - quantity of F gas j in closed-cell existing in the country at year t⁷⁶;

K - first year loss emission factor;

X - annual loss emission factor.

This formulation is similar to equation 3.38 of the GPG.

Emissions due to decommissioning of foams were not included in estimates due to the lack of necessary information about foam stock and the expected lifetime of foams. It was assumed that the lifetime period is larger⁷⁷ than the time between the first use of HFC and 2010.

4.3.5.12.3 Emission Factors

Due to unavailability of country-specific information, default emission factors from GPG (table 3.17) shown in the following table were used:

Table 4.27 - Emission Factors to estimate F gas emissions from foam losses

Type of Foam	Emission Factor		EF (% Original Charge)
Open Cell	K	First Year Losses	100
Closed Cell	K	First Year Losses	10
Closed Cell	x	Annual Losses	4.5

4.3.5.12.4 Activity Data

Data on amounts of imported and exported foams by type of product were obtained from DGAE (Economic Activities General Directorate) and data on produced amounts of foam were provided by DGAE and manufacturers.

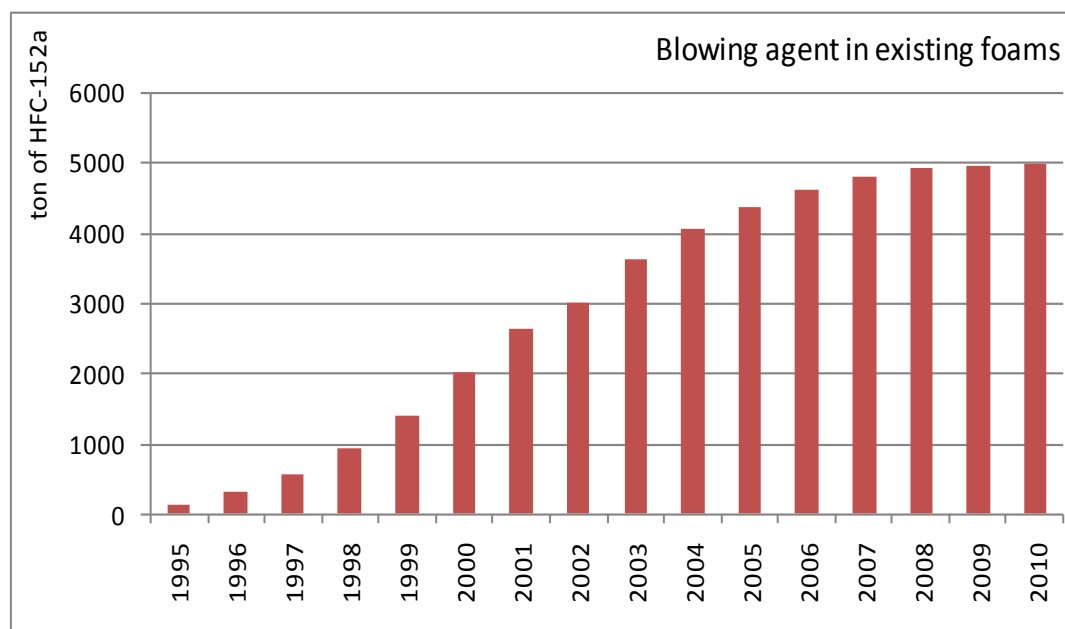
It was considered that the use of F-gases as foam blowing agents in foams produced in Portugal was introduced in 2003. For foams imported and applied in Portugal it was considered the use of F-gases since 1995. Foam industry is shifting to the use of non-HFC agents. The

⁷⁶ For the time being the stock is restricted to foam filled in Portugal;

⁷⁷ Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

amount of F-gas blowing agent associated to existing foams, from 1995 to 2010, is presented in the figure below.

Figure 4.31 – Amount of blowing agents used in Existing Foams in Portugal (ton/yr)



4.3.5.12.5 Uncertainty Assessment

According to recommendations of GPG for country-specific top-down information, the uncertainty in fill gas consumption was maintained at 50 percent, but the establishment of a better foam stock time series allowed the reduction of uncertainty in operation from one order of magnitude to 100 percent.

The uncertainty in emission factors result from the uncertainty in the release rate (emission), the life time, and also gas composition. The values set from the range in GPG (IPCC, 2000) are shown in the next table.

Table 4.28 – Uncertainty of Emission Factors for HFC emissions Foams

Origin	Uncertainty			
	Emission	Time of Release	Gas Composition	Combined
Blowing	425	5	81	433
Leakage	44	19	81	94

4.3.5.13 Metered Dose Inhalers

4.3.5.13.1 Overview

Fluorinated gases are used as propellants in pressurized solutions (metered dose inhalers) in the treatment of asthma.

4.3.5.13.2 Methodology

It is assumed that the gas is partly emitted during the same year the inhaler is sold and in the subsequent year. The method is similar to the equation 3.35 of GPG (2000), but an arithmetic average was used in this case.

$$Emi_{HFCt} = [\Sigma(\text{Sold MDI}_{t-1} * K_{t-1}) + \Sigma(\text{Sold MDI}_t * K_t)] / 2 * 10^{-6}$$

Where

Emi_{HFCt} - Emission of F-gas in year t

Sold MDI_{t-1} - Number of Sold units of each MDI in year t-1

K_{t-1} - Charge of gas of each equipment sold in year t-1

Sold MDI_t - Number of Sold units of each MDI in year t

K_t - Charge of gas of each equipment sold in year t

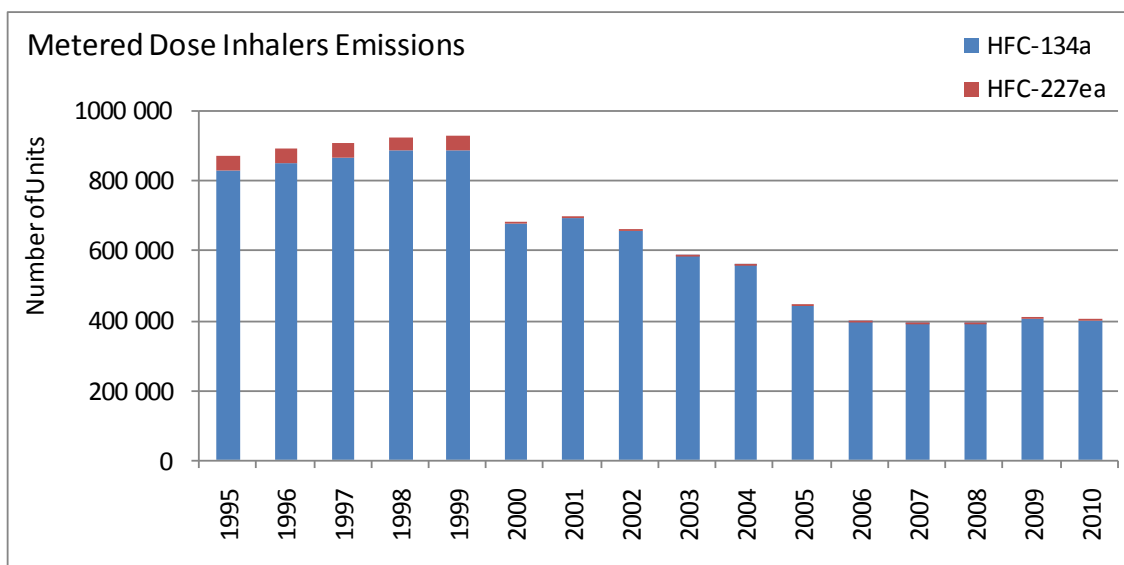
4.3.5.13.3 Emission Factors

Each manufacturer provided charge values for each type of inhaler. However, the yearly average emission factor lies in the range [12.05-14.75] g/inhaler.

4.3.5.13.4 Activity Data

Information was gathered on the amounts of sold inhalers charged with F-gases in the period 1995-2010. Information on the percent of propellant (F-gas) for each type of inhaler was also provided. The two F-gases in inhalers are HFC-134a and HFC-227ea.

Figure 4.32 – Sold Metered Dose inhalers using F-gases as propellant



Source: Infarmed and Pharmaceutical Laboratories

4.3.5.13.5 Further Improvements

More detailed information should be provided by manufacturers in the future, in order to obtain a better characterization of the inhalers market.

4.3.5.13.6 Uncertainty Analysis

The uncertainty in MDI was assumed as 80 percent, due to yearly changes.

4.3.5.14 *Fire Protection*

4.3.5.14.1 Overview

The most used equipments for fire protection in Portugal are the streaming (portable) ones. They contain HFC-23 and HFC-227ea gases.

4.3.5.14.2 Methodology

A Tier 2 comparable Top-Down approach from the IPCC Good Practice Guidance was considered.

$$\text{Emissions} = \text{F-gas}_{\text{a.s.}} - (\text{F-gas}_{\text{n.e.}} - \text{F-gas}_{\text{r.e.}})$$

Where:

$\text{F-gas}_{\text{a.s.}}$ – F-gas annual sales (ton)

$\text{F-gas}_{\text{n.e.}}$ – F-gas used to charge new fire protection equipments (ton)

$\text{F-gas}_{\text{r.e.}}$ – F-gas used to charge retiring fire protection equipments (ton)

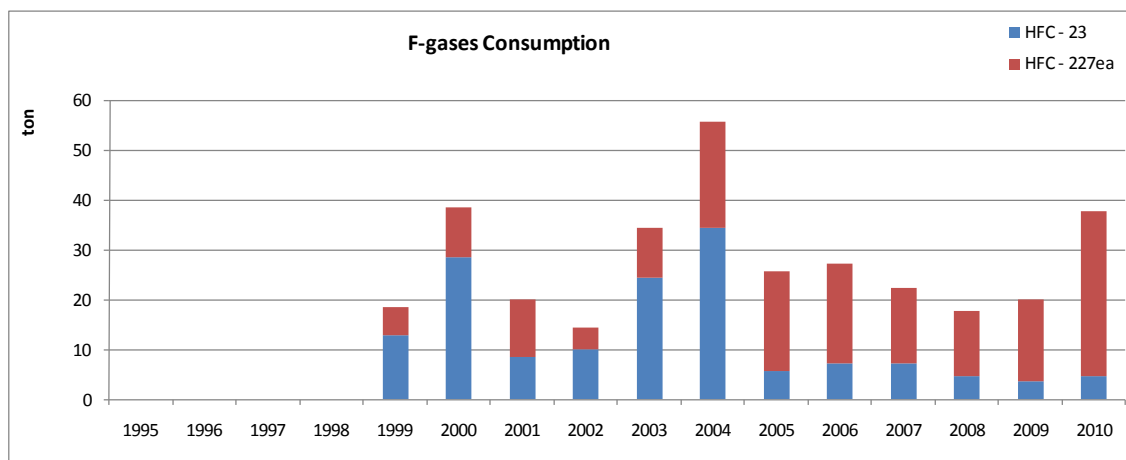
4.3.5.14.3 Emission Factors

It was assumed y equal to 99.99 percent and z equal to 99 percent. Annually, 4 percent of the existing equipments are dismissed.

4.3.5.14.4 Activity Data

Data on amounts of used gases in fire extinguishing equipments was provided by sellers and responsible enterprises on equipments filling. These equipments contain HFC-23 and HFC-227ea gases (see the figure below). The replacement of halons by HFC during 2004 in order to fulfil Regulation (EC) No 2037/2000 is reflected in the consumption increase of HFC-23 and HFC-227-ea. In the 2005-2009 period there is a decrease in consumption values associated to market saturation. In 2010 it occurred a pontual large dimension installation which is reflected in an activity data increase.

Figure 4.33 – HFC consumption on Fire Extinguishing Equipments by type of gas (ton)



4.3.5.14.5 Uncertainty Assessment

The uncertainty from fire protection equipment data was assumed as 20 percent, given that only one company is importing this kind of equipment to Portugal. The uncertainty in the type of gas, either HFC-23 or HFC-227ea, and differences in their GWP value, amount to an uncertainty of 60 percent. The final uncertainty value was set at 64 percent.

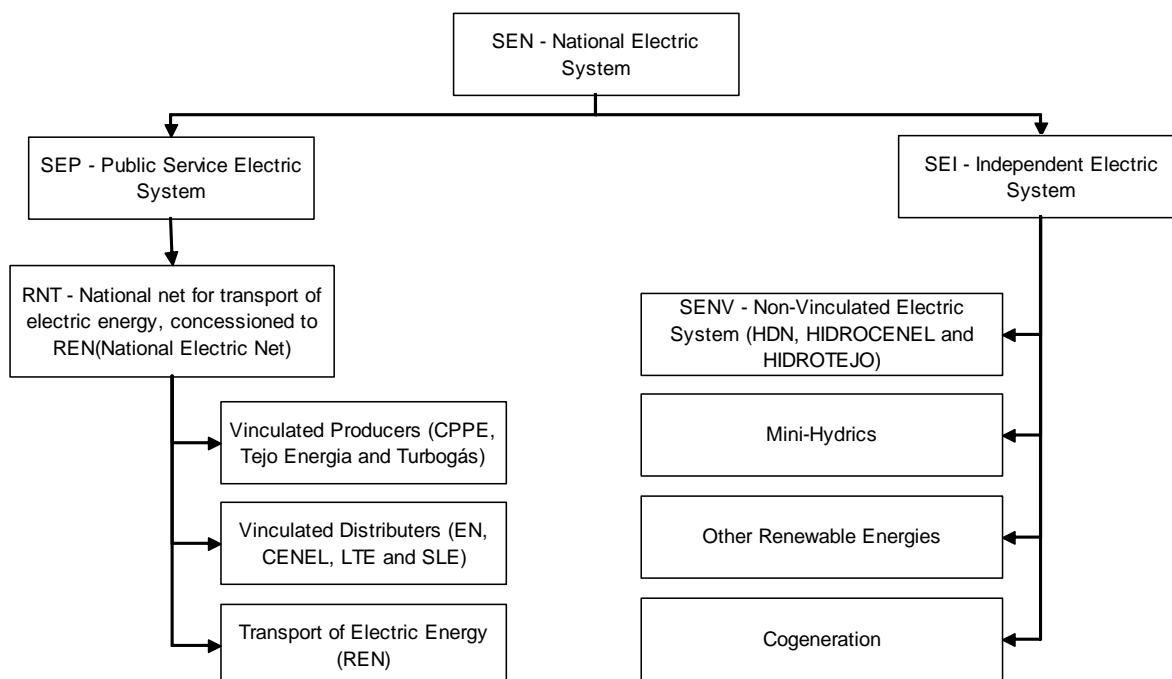
4.3.5.15 *Electric Equipment*

4.3.5.15.1 Overview

In Portugal, sulphur hexafluoride (SF₆) is used in the electrical sector, both as insulation gas in substations and as current interruption media, mostly in switch-gear and in circuit breakers. While most gas is recovered at equipment disposal, emissions occur annually as consequence of leaks and equipment failure.

The Portuguese National Electric System (SEN) is comprised by the Public Service Electric System (SEP) and by the Independent Electric System (SEI). In the second semester of 2000 the separation between the network for electricity transport at very high voltage (concession to REN – National Electric Net) and the network for electricity distribution at low, medium and high voltage (EDP Distribuição) took place.

Figure 4.34 - Flowchart of the National Electric System



In SEP (Public Service Electric System), “REN (National Electric Net)” is responsible for electricity distribution at Very High Voltage (>110 kV), “EDP Distribuição” is responsible for distribution at Low (≤ 1 kV), Medium (>1 kV and ≤ 45 kV) and High Voltage (>45 kV and ≤ 110 kV) and includes vinculated distributors. “EDP Produção” includes vinculated producers “CPPE” units and great part of SEI (Independent Electric System). “Tejoenergia” and “Turbogás” are SEP (Public Service Electric System) vinculated producers.

Figure 4.35 – Map of National Network of Electric Energy Transport



4.3.5.15.2 Methodology

There are different estimates methodologies for:

- REN;
- EDP Distribuição, EDP Produção, Tejoenergia and Turbogás.

4.3.5.15.2.1 REN

In this case, a methodology based on “Correspondent States Principle” was used:

$$P \times V = Z \times n \times R \times T$$

Where “Z” is the compressibility factor that can be obtained from tabled values for Reduced Pressure and Temperature.

$$n_i = \frac{P_i \cdot V}{R \cdot T_i} \cdot \frac{1}{Z_i}$$

$$n_f = \frac{P_f \cdot V}{R \cdot T_f} \cdot \frac{1}{Z_f}$$

$$m = (n_f - n_i) \cdot M$$

Source: REN – Rede Eléctrica Nacional (www.ren.pt)

where:

Ti and Pi - Measured Temperature and Pressure at the beginning of reposition of lost SF₆;

Tf and Pf - Measured Temperature and Pressure at the end of reposition of lost SF₆;

R - Gases Constant;

V - Compartment volume filled with SF₆ inside the equipment;

Zi - Compressibility Factor at Pressure Pi and Temperature Ti;

Zf - Compressibility Factor at Pressure Pf and Temperature Tf;

ni - Mole number of SF₆ at pressure Pi and Tf before the reposition of gas;

nf - Mole number of SF₆ at pressure Pf and Tf after the reposition of gas;

M - SF₆ molecular mass;

m - SF₆ mass emitted;

There are two alarm situations that require an intervention and reposition of SF₆:

- Loss of SF₆ slightly above Service Pressure (≈70 percent of Maximum Pressure);
- Loss of SF₆ below Service Pressure (<70 percent of Maximum Pressure) - in this situation the equipment doesn't work at all;

Besides these two situations there is a team that does regular gas repositions (each 15 days) after temperature and pressure measurements on containers. Each intervention is registered in a database and the equipment used is identified.

4.3.5.15.2.2 EDP Distribuição

In EDP Distribuição separate estimates were made for:

- Gas Circuit Breakers;
- Outdoor Gas Insulated Switchgears;
- Gas Insulated Switchgears;
- High and Medium Voltage Sectioning Posts;

Actual emissions of SF₆ from electrical equipment were estimated with a tier T3b, based on data provided by “EDP Distribuição”, excluding the details in life-cycle and using a country-specific emission factor. Emissions were determined using the following equation:

$$Emi_{SF_6(t)} = Stock_{SF_6(t)} * (EF/100)$$

where:

$Emi_{SF_6(t)}$ - Equipment use emissions, including leakage emissions, servicing and maintenance;

$Stock_{SF_6(t)}$ - total SF_6 gas in existence at year t in all electrical equipments;

EF – Emission Factor, corresponding to the percentage of SF_6 in stock at year t that is emitted to atmosphere.

4.3.5.15.2.3 EDP Produção, Tejoenergia and Turbogás

The used methodology was identical to the one described in “EDP Distribuição”.

Disposal or retiring units were not included in the inventory as emission sources because, according to industry experts, the collection of gas at end of lifetime is done in a systematic and efficient way. Manufacturing and installation emissions were assumed to be included in emissions from equipment usage.

4.3.5.15.3 Emission Factors

There are different emission factors for:

- REN;
- EDP Distribuição;
- EDP Produção;
- Tejoenergia;
- Turbogás.

4.3.5.15.3.1 REN

The database on SF_6 repositions by equipment was available for the period 2003-2010. For the period 1995-2002, an average of the estimated loss (0.38 percent) for the period 2003-2010 was considered.

4.3.5.15.3.2 EDP Distribuição

In EDP Distribuição different emission factors were considered for:

- Gas Circuit Breakers:

all circuit breakers are “Closed Pressure” equipments and the emission factor is 2.6 percent/year as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”;

- Outdoor Gas Insulated Switchgears;

all outdoor gas insulated switchgears are “Sealed Pressure” equipments and the emission factor is 0.2 percent/year as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment”;

- Gas Insulated Switchgears;

it is assumed by EDP expert judgment that 27 percent of equipments are “Sealed Pressure” and 73 percent are “Closed Pressure”;

the emission factors are 0.2 percent/year to “Sealed Pressure” as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment” and 2.6 percent/year to “Closed Pressure” as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”;

- High and Medium Voltage Sectioning Posts;

all high and medium voltage sectioning posts are “Sealed Pressure” equipments and the emission factor is 0.2 percent/year as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment”;

4.3.5.15.3.3 EDP Produção

Different emission factors are used for:

- Sealed Pressure Equipments;

emission factor is 0.2 percent/year as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment”

- Closed Pressure Equipments;

EDP Produção has a database on SF₆ stock amounts in “Closed Pressure” equipments in the period 2000-2010. There is no data related to SF₆ stock in the period 1995-1999 and it is used an average emission factor of 0.93 percent based on 2000-2006 data period.

4.3.5.15.3.4 Tejoenergia and Turbogás

It is assumed by “Tejoenergia” and “Turbogás” expert judgment that all equipments are “Closed Pressure” and that the emission factor is 2.6 percent/year as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”.

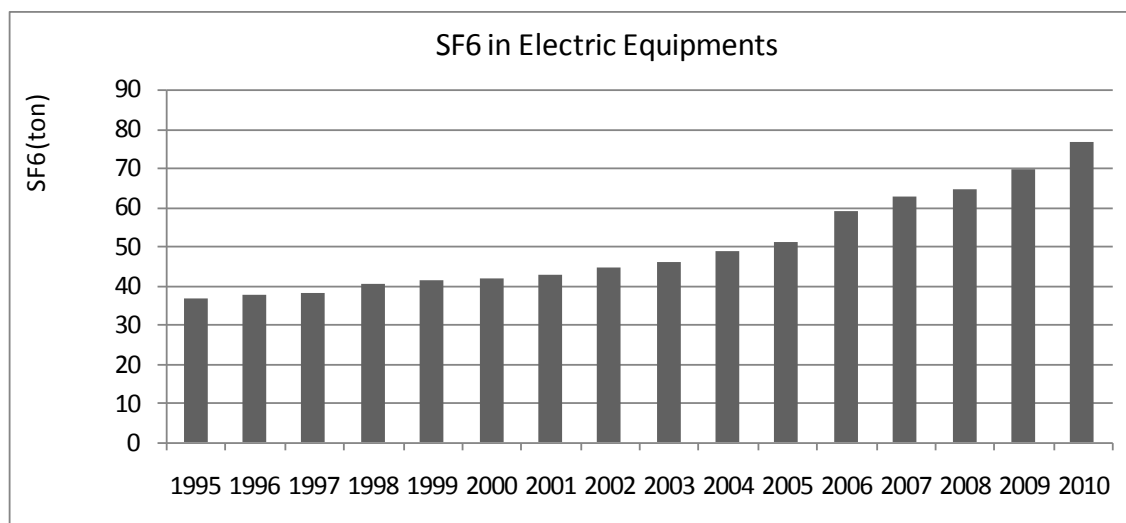
4.3.5.15.4 Activity Data

Although it is not possible to differentiate activity data in this report, the information on the yearly total amount of SF₆ in Electric Equipments is available (see the figure below).

Table 4.29 – Average SF₆ charge for each kind of equipment

Equipment	SF ₆ (kg)
Gas Circuit Breaker	1.200
Outdoor Gas Insulated Switchgear	0.720
Gas Insulated Switchgear	0.484

Figure 4.36 - Total SF6 in stock in electric equipments in Portugal (1995-2010)



4.3.5.15.5 Uncertainty Assessment

The uncertainty of 15 percent in the emission factor was obtained from statistical analysis of the emission factors determined for 1995, 1998, 1999 and 2000. The uncertainty in activity data was set at 10 percent.

4.3.5.15.6 Further Improvements

Further improvements should be addressed in order to obtain better quality activity data.

5 SOLVENTS AND OTHER PRODUCT USE (CRF 3.)

5.1 Overview

Solvents and related compounds are a significant source of emissions of non-methane volatile organic compounds (NMVOC). Emissions of N₂O from the use of anesthesia are also included in this sector. No emissions of methane are included in this source sector.

Some peculiarities apply to this source sector. In first place not all emissions occur directly to atmosphere when the production or use action takes place, as some solvents remain in product or are conveyed into wastewater. However, because eventually sooner or later these solvent fractions are liberated to atmosphere, all solvent losses may be assumed to contribute to air emissions. On the other hand, emissions of solvent may occur in three phases: during production of products containing solvents, during actual use of products containing solvent and during disposal.

NMVOC emissions estimates must be converted in CO₂ emissions whenever the carbon that is present in organic compounds has fossil fuel origin (originated from feedstocks from petroleum, coal or natural gas), and being assumed that NMVOC compounds are fully oxidized in air to carbon dioxide contributing thence to the atmospheric pool.

Figure 5.1 - NMVOC emissions from solvents and other product use

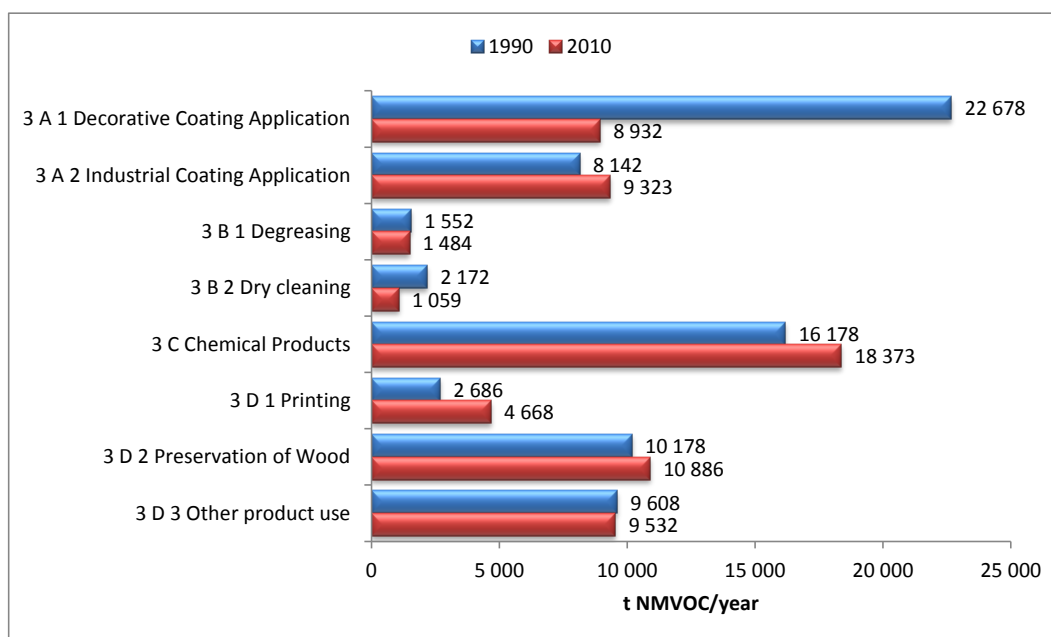
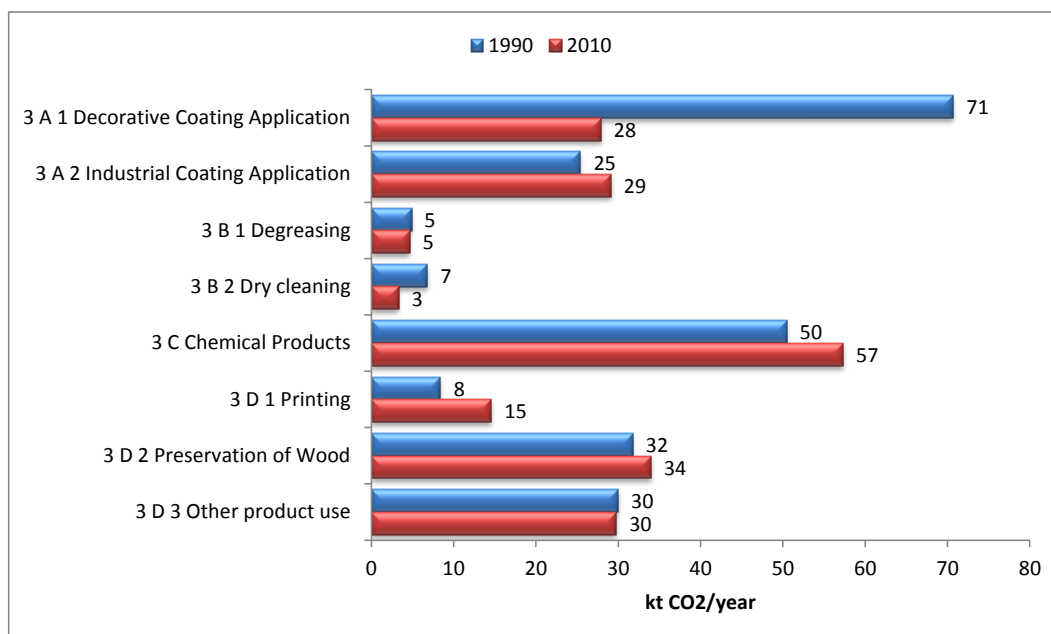


Figure 5.2 – CO₂ emissions from solvents and other product use



5.2 Recalculations

CO₂ emissions recalculations from solvent use are mainly related to the revision of AD time series from National Statistics which were made available during 2010. Methodology and emission factors for sector “3 D 2 Domestic Solvent Use including Fungicides” were updated according with EMEP/CORINAIR guidelines (EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009).

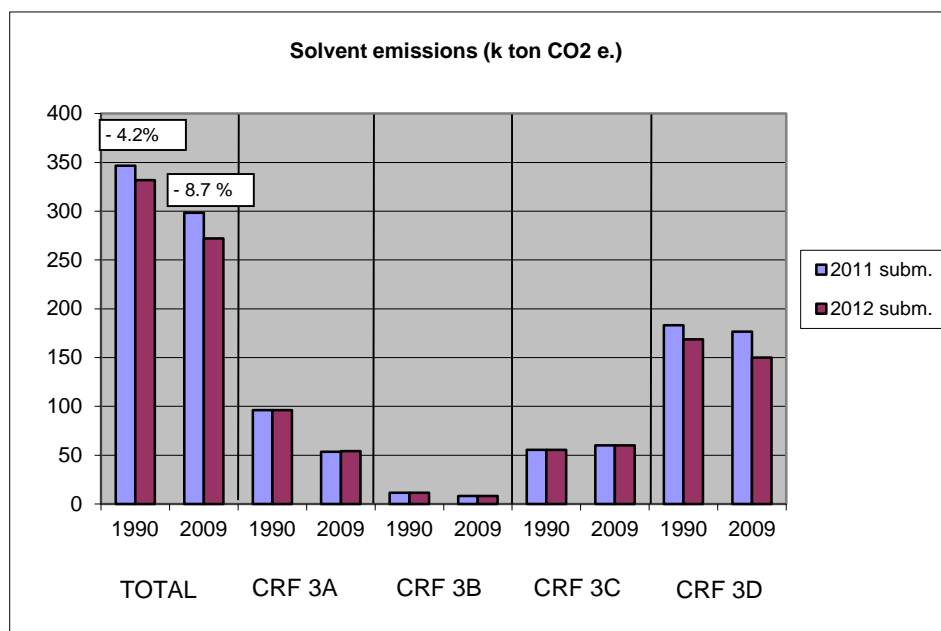


Figure 5.3 - Differences between submissions 2010 and 2011 for CO₂ emissions from solvent use

Table 5.1 - Recalculations of emissions of ghg from solvent use: differences between submissions 2010 and 2011

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2011	2012	Difference(1)	2011	2012	Difference(1)	2011	2012	Difference(1)
	subm.	subm.		subm.	subm.		subm.	subm.	
	CO ₂ equivalent (Gg)		(%)	CO ₂ equivalent (Gg)		(%)	CO ₂ equivalent (Gg)		(%)
1990									
3. Solvent and Other Product Use	247.89	233.30	-5.89				98.58	98.58	0.00
A. Paint Application	96.06	96.06	0.00						
B. Degreasing and Dry Cleaning	11.61	11.61	0.00				NO	NO	
C. Chemical Products, Manufacture and Proces	55.60	55.60	0.00						
D. Other	84.63	70.04	-17.24				98.58	98.58	0.00
2009									
3. Solvent and Other Product Use	212.73	197.59	-7.12				85.51	74.59	-12.77
A. Paint Application	53.58	54.16	1.08						
B. Degreasing and Dry Cleaning	8.22	8.11	-1.29				NO	NO	
C. Chemical Products, Manufacture and Proces	60.00	60.00	0.00						
D. Other	90.93	75.32	-17.17				85.51	74.59	-12.77

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

5.3 Category Sectors

5.3.1 Paint Application (CRF 3.A.)

5.3.1.1 Overview

This sub-source sector covers NMVOC emissions resulting from the use of coating materials – interpreted as the application of a continuous layer in a surface with the objective of protecting the surface or enhancing its appearance⁷⁸ – such as paints, stains, varnishes, enamels and lacquers, either in buildings or artifacts, and either from professional activities or domestic use. Emissions due to the use of inks and textile coloring are not included here. Emissions from paint manufacturing are discussed in sector CRF 3 C.

Emissions from paint use occur after paint is applied as a coating layer, irrespective of the application methodology: spraying (air pressure or electrostatic), spreading by roller or brush, dipping and electro-deposition, and happen from evaporation of solvent during paint cure. All organic compounds that evaporate are considered NMVOC emissions except if they are recovered and treated by any control equipment such as incineration or absorption.

All emissions from paint activity are included here, such as those arising from car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities and domestic use.

The distinction between coating operations in construction and building and domestic use is not very relevant because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

5.3.1.2 Methodology

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

⁷⁸ Non continuous applications of coatings is printing industry and is included in other sub-source category. Application of continuous layers for gluing materials, by the use of glues or adhesives is also considered elsewhere.

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from use/application of coating substances during year y (ton/yr);

$Coating_{CONS(a,p,y)}$ – Use of coating substance p in economic activity a during year y (ton coater/yr);

$EF_{(p)}$ – NMVOV emission factor (solvent content) resulting from application of substance p (kg/ton).

For specific sectors more detailed activity data and emissions factors were available a product base methodology was used. This is the case for:

- Cars manufacturing;
- Truck cabin coating;
- Leather finishing.

The product based methodology can be described as following.

$$Emi_{NMVOC(p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(p,y)}$ – NMVOC emissions resulting the production of product p during year y (t/yr);

$Product_{(p,y)}$ – Production units of product p during year y (cars/yr, truck cabins/yr, kg leather/yr);

$EF_{(p)}$ – NMVOV emission factor for production of product p (kg/car, kg/truck cabin, kg/kg leather)

p – product (cars, truck cabin, leather).

Ultimate CO₂ emissions were calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory as CO₂e.

$$U_{CO_2} = NMVOC * 0.85 * (44/12)$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

5.3.1.3 *Emission Factors*

Emission factors were taken from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC\ y} = \frac{CS_{t,y}}{100} \times \left(1 - \frac{AT_t}{100}\right) \times EF_{NMVOC\ default}$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatement technology t (%);

t – abatement technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

In cases where industrial detailed information was not available, Tier 1 emission factors for industrial paint application were used. This emission factor is based on the quantity of coating applied.

Table 5.2 – NMVOC Tier 1 emission factor for industrial application

NFR	NFR Title	Tier 1 EF	EF Unit
3 A 2	Industrial coating application	400	g/kg paint

Source: (EEA/EMEP, 2009)

5.3.1.3.1 Construction and buildings (SNAP 060103)

Table 5.3 – Default emission factor

SNAP	Unit	NMVOC
Construction and buildings	g/kg paint	230

Source: (EEA/EMEP, 2009)

Table 5.4 – Abatement technology

Abatement Technology	Efficiency
Substitution with dispersion/emulsion (2-3 wt-% solvent)	39
Substitution with water-based paints (efficiency 80%)	26
Substitution with high solids paints (efficiency 40-60%)	4
Substitution with dispersion/emulsion and water-based paints	65
Substitution with dispersion/emulsion and high solids paints	43
Substitution with dispersion/emulsion, water-based and high solids paints	70

Source: (EEA/EMEP, 2009)

Table 5.5 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010
Substitution with dispersion/emulsion (2-3 wt-% solvent)	%	0	0	100	50	0
Substitution with water-based paints (efficiency 80%)	%	0	100	0	0	0
Substitution with high solids paints (efficiency 40-60%)	%	100	0	0	0	0
Substitution with dispersion/emulsion and water-based paints	%	0	0	0	0	0
Substitution with dispersion/emulsion and high solids paints	%	0	0	0	0	0
Substitution with dispersion/emulsion, water-based and high solids paints	%	0	0	0	50	100

Source: (IIASA, 2009)

Table 5.6 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF	g/kg paint applied	221	170	140	105	98

5.3.1.3.2 Wood (SNAP 060107)

Table 5.7 – Default emission factor

SNAP	Unit	NM VOC
Wood	g/kg paint applied	960

Source: (EEA/EMEP, 2009)

Table 5.8 – Abatement technology

Abatement Technology	Unit	Efficiency
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 35%	%	75
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 75%	%	75
Wood coating-Coated surface-Combination of the above options	%	75
Wood coating-Coated surface-Low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping)	%	0
Wood coating-Coated surface-Medium solids systems (55% solvent content), application process with an efficiency of 75%	%	31
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 35%	%	94
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 75%	%	94
Uncontrolled	%	0

Source: (EEA/EMEP, 2009)

Table 5.9 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 35%	%	0.0	0.0	0.0	0.0	7.5
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 75%	%	0.0	0.0	0.0	0.0	20.3
Wood coating-Coated surface-Combination of the above options	%	0.0	0.0	0.0	0.0	0.0
Wood coating-Coated surface-Low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping)	%	38.1	38.1	38.1	38.4	20.0
Wood coating-Coated surface-Medium solids systems (55% solvent content), application process with an efficiency of 75%	%	0.0	0.0	0.0	0.0	0.0
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 35%	%	3.8	3.8	3.8	3.8	3.8
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 75%	%	44.1	44.1	44.1	44.1	44.1
Uncontrolled	%	14.0	14.0	14.0	13.7	4.4

Source: (IIASA, 2009)

Table 5.10 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF	g/kg paint applied	528	528	528	528	328
Final EF	t/t	0.5	0.5	0.5	0.5	0.3
Final EF	wt %	52.8	52.8	52.8	52.8	32.8

5.3.1.3.3 Manufacture of automobiles (SNAP 060101)

Table 5.11 – Default emission factor

SNAP	Unit	NM VOC
Manufacture of automobiles: Car coating	kg/car	8

Source: (EEA/EMEP, 2009)

Table 5.12 – Abatement technology

Abatement Technology	Unit	Efficiency
Water-based primer; solvent-based	%	10
Solvent-based primer; water-based basecoat	%	40
Water-based primer and basecoat	%	50
Add on: incinerator on drying oven	%	10
Add on: Incinerator on drying oven; activated carbon adsorption on spray booth & thermal incineration	%	40

Source: (EEA/EMEP, 2009)

Table 5.13 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010
Manufacture of automobiles-Vehicles-Process modification and substitution	% Efficiency of abatement technology mix	0	22.5	45	67.5	90

Source: (IIASA, 2009)

Table 5.14 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF Car coating	kg/car	8.0	6.2	4.4	2.6	0.8

5.3.1.3.4 Truck cabin coating (SNAP 060108)

Table 5.15 – Default emission factor

SNAP	Unit	NM VOC
Industrial coating application: Vehicle refinishing	kg/vehicle	8

Source: (EEA/EMEP, 2009)

Table 5.16 – Abatement technology

Abatement Technology	Unit	Efficiency
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	40
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	%	45
80% two layer - 20% one layer; waterborne primer and basecoat, high solid clear coat, waterborne solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	60
Uncontrolled	%	0

Source: (EEA/EMEP, 2009)

Table 5.17 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	0	0	0	0	0
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	%	0	0	0	0	0
80% two layer - 20% one layer; waterborne primer and basecoat, high solid clear coat, waterborne solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	0	0	0	0	0
Uncontrolled	%	100	100	100	100	100

Source: (IIASA, 2009)

Table 5.18 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0

5.3.1.3.5 Leather finishing (SNAP 060108)

Table 5.19 – Default emission factor

SNAP	Unit	NM VOC
Industrial coating application: leather finishing	g/kg leather	200

Source: (EEA/EMEP, 2009)

Table 5.20 – Abatement technology

Abatement Technology	Unit	Efficiency
Use of water based products (30 wt-% solvent content)	%	65
Add on: Thermal oxidation	%	81
Add on: Biofiltration	%	81
Uncontrolled	%	0

Source: (EEA/EMEP, 2009)

Table 5.21 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010
Use of water based products (30 wt-% solvent content)	%	0	0	0	10	30
Add on: Thermal oxidation	%	0	0	0	0	0
Add on: Biofiltration	%	0	0	0	0	5
Uncontrolled	%	100	100	100	90	65

Source: (IIASA, 2009)

Table 5.22 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF leather finishing	g/kg leather	200.0	200.0	200.0	187.0	152.9

5.3.1.4 Activity Data

The available and reliable information concerning the use of paints is restricted to a small number of activities in Portugal. From IAIT and IAPI industrial surveys, compiled by national statistics, it is only possible to determine consumption of paint in industrial activities, but the remaining, and larger part of consumption, is not known. Therefore total consume of paint and varnish in Portugal had first to be estimated from internal production, importation and exportation according to:

$$\text{Total}_{\text{Cons}(y)} = \text{Production}_{(y)} + \text{Imports}_{(y)} - \text{Exports}_{(y)}$$

where:

$\text{Total}_{\text{Cons}(y)}$ - Consumed paint and varnish in year y (t/yr);

$\text{Production}_{(y)}$ - National Produced paint and varnish in year y (t/yr);

$\text{Imports}_{(y)}$ - Imported paint and varnish in year y (t/yr);

$\text{Exports}_{(y)}$ - Exported paint and varnish in year y (t/yr).

Annual production of paints, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 5.23.

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 5.24.

Total consumption of paints was calculated and the resultant time series is presented in Table 5.25.

Table 5.23 – National production of paints (t)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Produced paints	115 892	117 358	109 426	93 969	101 145	95 328	114 015	124 512	141 700	137 979	142 082

Parameter	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Produced paints	154 210	154 992	155 081	154 221	149 706	148 908	165 048	161 165	135 826	155 209

Table 5.24 – Paint import and export (t)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Imports	7 679	10 340	12 211	14 431	21 986	25 084	27 845	28 980	31 912	32 230	35 434
Exports	5 336	5 626	5 785	5 415	7 534	8 130	12 854	11 614	14 670	13 622	13 823

Parameter	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Imports	36 885	37 990	36 398	38 680	37 097	37 371	35 624	35 883	34 466	33 044
Exports	16 171	20 545	23 827	25 973	34 089	40 749	43 510	42 435	36 546	39 398

Table 5.25 – Estimated paint consumption (t)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Apparent Consumption	118 236	122 073	115 853	102 984	115 596	112 282	129 006	141 878	158 941	156 587	163 694

Parameter	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Apparent Consumption	174 924	172 437	167 651	166 928	152 714	145 530	157 162	154 612	133 746	148 855

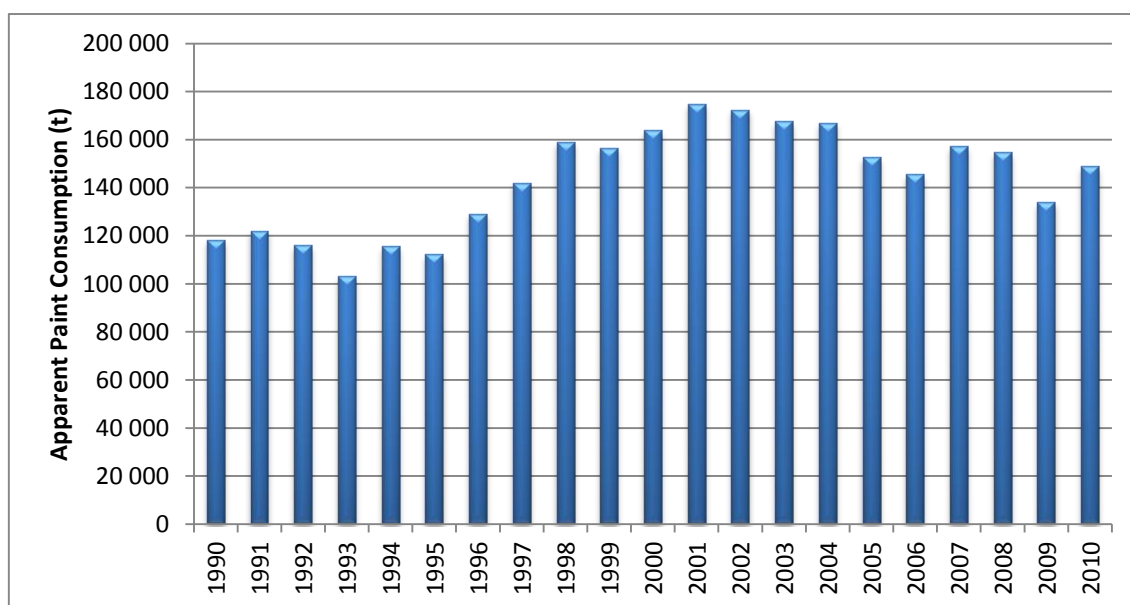


Figure 5.4 - Total consumption of paints in Portugal

Finally total consumption of paint was disaggregated by the economic activity where the paint is used. In first place, from IAIT and IAIP industrial surveys, it was possible to determine consumption of coating materials per economic activity but only for the industry sector: results from IAIT and IAPI are presented in Table 5.26. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction⁷⁹.

⁷⁹ No further disaggregation by this uses is possible from available statistical information

Table 5.26 - Paint and varnish consumption by snap (t paint)

SNAP	NFR Title	SNAP Title	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
060103	Decorative coating application	Paint application: construction and buildings	10 738	10 326	9 248	8 388	8 760	8 486	9 447	9 225	7 761	7 069	8 399
060104	Decorative coating application	Paint application: domestic use (except 060107)	91 969	95 902	92 001	79 659	92 249	90 715	102 421	111 519	129 668	125 779	130 608
060101	Industrial coating application	Paint application: manufacture of automobiles	111	111	111	111	111	249	709	1 142	1 143	1 130	2 595
060107	Industrial coating application	Paint application: wood	6 508	6 824	5 583	5 917	5 567	4 061	4 813	5 057	4 626	3 849	2 836
060108	Industrial coating application	Other industrial paint application	8 475	8 475	8 475	8 475	8 475	8 475	11 609	15 400	16 351	19 319	20 891
060108	Industrial coating application	Other industrial paint application: truck cabin coating	391	391	391	391	391	391	562	523	381	433	631
060108	Industrial coating application	Other industrial paint application: leather finishing	154	154	154	154	154	154	154	154	154	137	330

SNAP	NFR Title	SNAP Title	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
060103	Decorative coating application	Paint application: construction and buildings	7 866	7 524	7 328	8 613	9 242	10 373	10 374	11 120	8 385	9 846
060104	Decorative coating application	Paint application: domestic use (except 060107)	147 593	147 528	145 161	144 863	129 412	115 964	130 607	123 686	108 092	119 610
060101	Industrial coating application	Paint application: manufacture of automobiles	1 528	1 528	1 528	1 274	1 232	1 346	1 540	1 441	911	1 212
060107	Industrial coating application	Paint application: wood	3 862	3 872	3 740	4 333	4 493	5 078	5 257	5 402	4 244	5 018
060108	Industrial coating application	Other industrial paint application	14 867	12 827	10 787	8 746	9 074	13 489	10 061	13 324	11 952	13 110
060108	Industrial coating application	Other industrial paint application: truck cabin coating	534	534	534	320	363	489	242	158	99	113
060108	Industrial coating application	Other industrial paint application: leather finishing	201	152	102	52	130	137	621	923	973	1 159

Table 5.27 Final activity data used for paint application emission calculation

NFR	SNAP Title	Unit	1990	1995	2000	2005	2010
3 A 1	Paint application: construction and buildings	t paint	10 738	8 486	8 399	9 242	9 846
3 A 1	Paint application: domestic use (except 060107)	t paint	91 969	90 715	130 608	129 412	119 610
3 A 2	Paint application: manufacture of automobiles	n vehicles	134 109	100 170	195 309	146 340	157 552
3 A 2	Paint application: wood	t paint	6 508	4 061	2 836	4 493	5 018
3 A 2	Other industrial paint application	t paint	8 475	8 475	20 891	9 074	13 110
3 A 2	Other industrial paint application: truck cabin coating	n vehicles	9 608	2 557	6 929	6 203	4 396
3 A 2	Other industrial paint application: leather finishing	t leather	834	534	2 386	8 932	14 854

Table 5.28 Final NMVOC emission factors data used for paint application emission calculation

NFR	SNAP Title	Unit	1990	1995	2000	2005	2010
3 A 1	Paint application: construction and buildings	g/kg paint applied	220.8	170.2	140.3	104.7	69.0
3 A 1	Paint application: domestic use (except 060107)	g/kg paint applied	220.8	170.2	140.3	104.7	69.0
3 A 2	Paint application: manufacture of automobiles	kg/car	8.0	6.2	4.4	2.6	0.8
3 A 2	Paint application: wood	g/kg paint	527.9	527.9	527.9	527.9	328.1
3 A 2	Other industrial paint application	g/kg paint	400.0	400.0	400.0	400.0	400.0
3 A 2	Other industrial paint application: truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0
3 A 2	Other industrial paint application: leather finishing	g/kg leather	200.0	200.0	200.0	187.0	152.9

5.3.1.5 *Uncertainty Assessment*

The uncertainty factor of the emission factor for NMVOC and CO₂ was calculated from information obtained from EEA/CORINAIR Guidebook. The uncertainty value for CO₂/NMVOC emission factor was calculated to be 32.8% for all uses of paint.

The uncertainty associated with the activity data from INE was assumed to be 10%.

An overall uncertainty of 34.3% was calculated for the paint application sector.

5.3.1.6 *Recalculations*

Modifications have been made in emission estimates from this source sector since last year's submission. Recalculation are due to an update in the activity data series from National Statistics concerning national production, imports and exports.

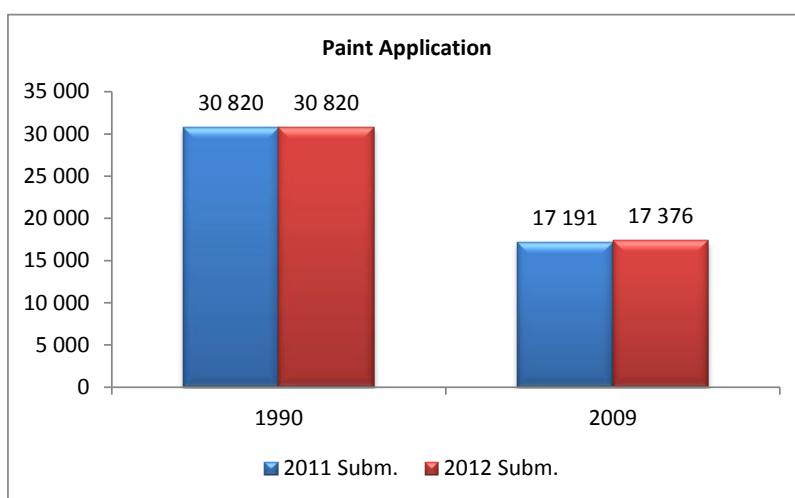


Figure 5.5 – Recalculations for NMVOC emissions from paint application (t)

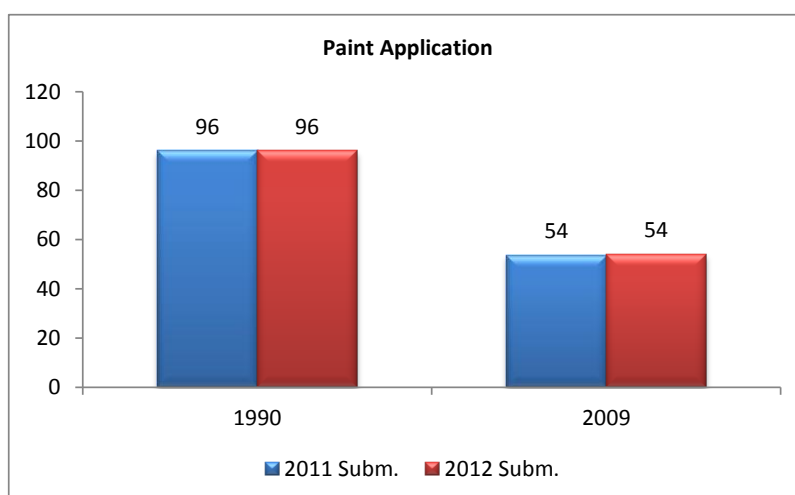


Figure 5.6 – Reclaculations for CO₂ emissions from paint application (kt)

5.3.1.7 *Further Improvements*

No further improvements are planned for this sector.

5.3.2 Degreasing and Dry Cleaning (CRF 3.B.)

5.3.2.1 Overview

Degreasing refers to operation processes, usually realized within industrial activities, where solvents are used as degreasers to clean products and materials from water insoluble substances (fats), such as oil, grease, wax or tars. This cleaning procedure precedes normally the application of other treatment processes and occurs mainly in metal industry, plastics products manufacturing, rubber⁸⁰, textiles, glass, paper and fiber-glass, etc. Usually solvents used to achieve degreasing are petroleum distillates, chlorinated hydrocarbons, ketones and alcohols, and the cleaning process is usually done in tanks, which may have some form of emissions control (solvent recovery).

In essence dry-cleaning has the same objective to degreasing, seeking to remove, by the aid of solvents, of contamination or dirt from cloths, textile, furs, leather, down leathers, textiles or other objects made of fibers.

5.3.2.2 Methodology

Assuming that all solvents consumed during degreasing and dry-cleaning evaporate, NMVOC emission will be equal to the amount of solvents used. If it is considered that annual consumption of solvents in an economic activity is used to replenish the quantity of solvent that was lost, then annual NMVOC emissions may be estimated from the annual consumption of solvent. This methodology overcomes the need of being aware of the portion of solvent that is recovered.

In the case of the dry-cleaning activity it was assumed that either the solvent is lost directly to atmosphere, or if it is conveyed to water or retained in clothes, but it will eventually reach atmosphere by evaporation.

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several sources (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

CO₂ emissions are derived by assuming that 85 percent of the mass emissions of NMVOC is carbon:

$$U_{CO_2} = NMVOC * 0.85 * (44/12)$$

where:

U_{CO_2} - Ultimate CO₂ (ton);

NMVOC - Global emissions of NMVOC (ton).

5.3.2.3 Activity Data

Statistical information concerning total solvent use, from the National Statistics Institute (INE), was used to estimate VOC emissions. Consumption of solvents, presented in Table 5.29, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

⁸⁰ Emissions from degreasing in this industry are included under rubber processing

Table 5.29 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	1992-2010
Metal Degreasing	1 552	1 415	1 484

Source: IAIT industrial survey (INE)

There is no available statistical information concerning consumption of solvents and other materials in dry-cleaning activity, because this activity is not included under IAIT and IAPI industrial surveys. Therefore, it was assumed that all PER (Tetra-chloro-ethylene)⁸¹ consumed in Portugal is used in dry-cleaning⁸² activity and that all PER used is imported (no national production). Annual apparent consumption was estimated from INE's statistical databases on external trade from 1990 to 2009 and assumed as equal to solvent use.

Table 5.30 - Annual consumption of PER (Tetra-chloro-ethylene) (t)

Parameter	1990	1995	2000	2005	2010
Imports	2 172	1 155	1 649	944	1 108
Exports	0	0	0	24	49
Apparent Consumption	2 172	1 155	1 649	920	1 059

Source: INE.

5.3.2.4 *Uncertainty Assessment*

The time trend of activity data for metal degreasing is very incomplete and an uncertainty of 100% was considered. Because emissions from PER use in dry cleaning were established from importation of this product the error is mostly due to incorrect allocation of emission, i.e. considering in dry cleaning a fraction of PER emissions that were realized in fact in other industrial activity. The final effect in inventory totals is therefore not significant and an error of 10% was used (USEPA). The uncertainty of emissions from both sectors are fully considered under activity data.

5.3.2.5 *Recalculations*

Recalculations were made due to an update of activity data on dry cleaning for 2009.

⁸¹ Other organic solvents may be also used in dry-cleaning, such as trichloroethylene, 1,1,1-trichloroethane(methyl chloroform), cichloromethane (methylene chloride), R113 (tri-chloro-trifluoroethane) and aliphatic hydrocarbon solvents C10 to C13.

⁸² There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

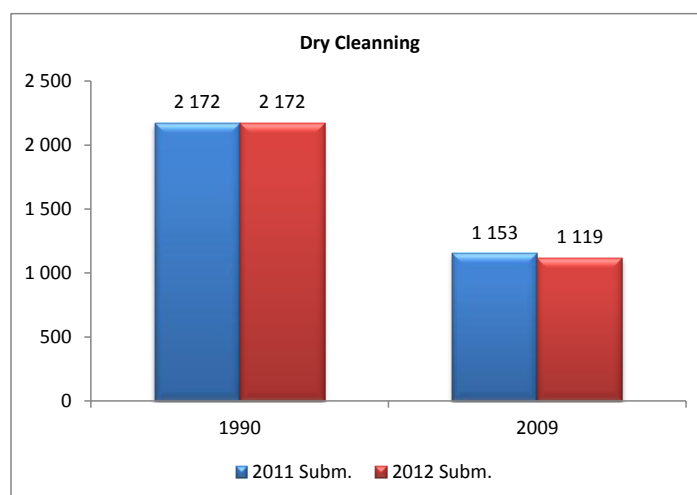


Figure 5.7 – Reclaculations for NMVOC emissions from dry cleaning (t)

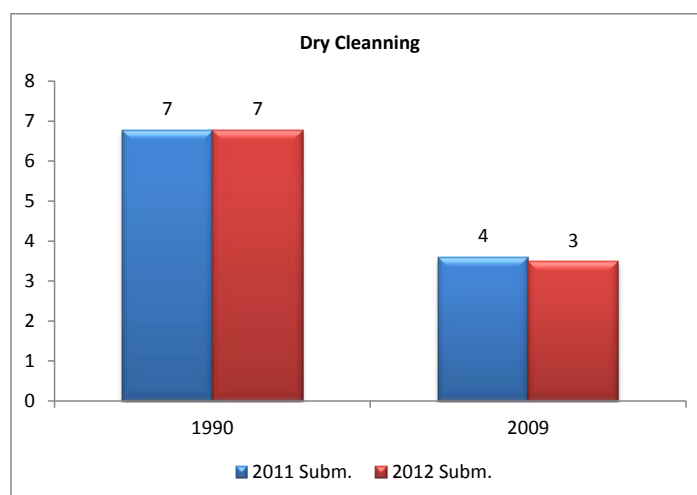


Figure 5.8 – Reclaculations for CO2 emissions from dry cleaning (kt)

5.3.2.6 *Further Improvements*

No further improvements are planned for this sector.

5.3.3 Chemical Products, Manufacture and Processing (CRF 3.C.)

5.3.3.1 *Overview*

This source sub-category comprehends several emission sources that are related to industrial processes involving manipulation of polymer. Although emissions for this source result mostly from the use of solvents, which are used as diluters or cleaning agents, some emissions result also from monomers leakage from the polymer, which means that these emissions should in fact be quantified under Production Processes. Nevertheless it was decided to include all those emissions here for simplicity in reporting and because it is not always possible to distinguish the part that is solvent from the part that has resulted from evaporation of monomers or from the degradation process of materials.

5.3.3.2 *Methodology*

Emissions were estimated by the use of emission factors that are multiplied by the quantity of material produced:

$$Emi_{NMVOC} = EF * Activity_{Rate} * 10^{-3}$$

where

Emi_{NMVOC} - annual emission of NMVOC (ton/yr);

$Activity_{Rate}$ - Indicator of activity in the production process. Quantity of product produced per year as a general rule for this emission source sector (ton/yr);

EF - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents with fossil origin, therefore contributing fully to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO_2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

5.3.3.3 Polyester processing

5.3.3.3.1 Methodology

Emissions from polyester processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). A tier 2 approach was used as activity data and emissions factors were stratified for polyester processing.

Emissions were estimated from the quantity of polyester processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} * Proc_{POYESTER(y)} * 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from polyester processing (t/yr);

EF_{NMVOC} – NMVOC emission factor for polyester processing (g/kg monomer used);

$Prod_{FOAM(y)}$ – Quantity of monomer used y (t/yr).

5.3.3.3.2 Emission Factors

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). The emissions factor was assumed constant for all covered period.

Table 5.31 – NMVOC foam processing emission factor

SNAP	Unit	NMVOC
Polyester processing	g/kg monomer used	50

Source: (EEA/EMEP, 2009)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO_2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

5.3.3.3.3 Activity Data

Data on polyester is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5.32 –Polyester processed

SNAP Title	Unit	1990	1995	2000	2005	2010
Polyester processing	t monomer	5	57	870	405	1 061

Source: INE

5.3.3.3.4 Uncertainty Assessment

The uncertainty associated with the emission factor from polyester processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 90% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyester processing was calculated to be 91%.

5.3.3.3.5 Recalculations

Activity data based on INE IAPI survey was updated for 2009.

5.3.3.3.6 Further Improvements

No further improvements are planned for this sector.

5.3.3.4 Polyvinylchloride processing

5.3.3.4.1 Methodology

Emissions from polyvinylchloride processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). A tier 1 approach was used as specific emissions factors from the EEA/EMEP guidebook were not available for polyvinylchloride processing.

Emissions were estimated from the quantity of polyvinylchloride resin processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RESIN(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from polyvinylchloride processing (t/yr);

EF_{NMVOC} – NMVOC emission factor for polyvinylchloride processing (g/kg resin);

$Prod_{RESIN(y)}$ – Quantity of polyvinylchloride resin (t/yr).

5.3.3.4.2 Emission Factors

The default emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). The emissions factor was assumed constant for all covered period.

Table 5.33 – Tier 1 emission factor for chemical product use

Source category	Unit	NMVOC
Chemical products, manufacture and processing	g/kg product	10

Source: (EEA/EMEP, 2009)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO_2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

5.3.3.4.3 Activity Data

Data on polyvinylchloride is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5.34 – Polyvinylchloride processed

SNAP Title	Unit	1990	1995	2000	2005	2010
Polyvinylchloride processing	t PVC	95 993	102 618	138 944	74 862	60 512

Source: INE

5.3.3.4.4 Uncertainty Assessment

The uncertainty associated with the emission factor from polyvinylchloride processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 300% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyvinylchloride processing was calculated to be 300%.

5.3.3.4.5 Recalculation

Activity data based on INE IAPI survey was updated for 2009.

5.3.3.4.6 Further Improvements

No further improvements are planned for this sector.

5.3.3.5 Polyurethane and polystyrene foam processing

5.3.3.5.1 Methodology

Emissions from polyurethane and polystyrene foam processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). A tier 2 approach was used as activity data and emissions factors were stratified for polyurethane and polystyrene foams.

Emissions were estimated from the quantity of foam processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{FOAM(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from foam processing (t/yr);

EF_{NMVOC} – NMVOC emission factor for foam processing (g/kg foam processed);

$Prod_{FOAM(y)}$ – Quantity of foam processed in year y (t/yr).

5.3.3.5.2 Emission Factors

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). The emission factor was assumed constant for all covered period.

Table 5.35 – NMVOC foam processing emission factor

SNAP	Unit	NMVOC
Polyurethane foam processing	g/kg foam processed	120
Polystyrene foam processing	g/kg foam processed	60

Source: (EEA/EMEP, 2009)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO_2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

5.3.3.5.3 Activity Data

Data on polyurethane and polystyrene foam is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5.36 –Foam processed

SNAP Title	Unit	1990	1995	2000	2005	2010
Polyurethane processing	t foam	5 700	6 322	11 704	16 989	10 038
Polystyrene processing	t foam	11 222	14 454	22 212	16 561	16 995

Source: INE

5.3.3.5.4 Uncertainty Assessment

The uncertainty associated with the emission factor from polyurethane processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 150% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyurethane processing was calculated to be 150%.

The uncertainty associated with the emission factor from polystyrene foam processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 58% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyurethane processing was calculated to be 59%.

5.3.3.5.5 Recalculations

Activity data based on INE IAPI survey was updated for 2009.

5.3.3.5.6 Further Improvements

No further improvements are planned for this sector.

5.3.3.6 Rubber processing

5.3.3.6.1 Methodology

Emissions from rubber processing was estimated according with EMEP/CORINAIR Guidebook. Rubber processed for tyre production is not included in this sector.

Statistical information for year 2008 was not yet available, therefore emissions were estimated according with a forecast based on historical emissions from the last five year period.

NM VOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times ProC_{RUBBER(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NM VOC total emissions from rubber processing (t/yr);

EF_{NMVOC} – NM VOC default emission factor for rubber processing (g/kg rubber produced);;

$Prod_{RUBBER(p,y)}$ – Production of rubber in year y (t/yr).

5.3.3.6.2 Emission Factors

The emission factor used for rubber processing was obtained from EMEP/CORINAIR guidebook. The same emission factor was used for year 1990 to 2008.

Table 5.37 – NM VOC rubber processing emission factor

SNAP	Unit	NM VOC
Rubber processing	g/kg rubber produced	8

Source: EMEP/CORINAIR 2009, 3.C Chemical products, table 3-5, pp18

5.3.3.6.3 Activity Data

Production data of rubber artefacts was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5.38 –Rubber processed

SNAP Title	Unit	1990	1995	2000	2005	2010
Rubber processed	t rubber	26 871	24 484	29 915	32 818	68 442

Source: INE

5.3.3.6.4 Uncertainty Assessment

The uncertainty associated with the emission factor for rubber processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 100% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyurethane processing was calculated to be 100%.

5.3.3.6.5 Recalculations

Activity data based on IATI survey was updated for 2009.

5.3.3.6.6 Further Improvements

No further improvements are planned for this sector.

5.3.3.7 *Paints, Inks and Glues Manufacturing*

5.3.3.7.1 Methodology

Emissions from paints, inks and glue manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(p,y)} = EF_{NMVOC(y)} \times ProductManuf_{(p,y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(p,y)}$ – NMVOC emissions from manufacturing of product p in year y (t/yr);

$EF_{NMVOC(y)}$ – NMVOC emission factor for production of paints, inks and glue during year y (g/kg product);

$ProductManuf_{(p,y)}$ – Quantity of product p manufactured in year y (t/yr);

p – product (paint, ink, glue)

y - year

5.3.3.7.2 Emission Factors

Emission factors were taken from EMEP/CORINAIR guidebook 2009. Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC\ y} = \frac{CS_{t,y}}{100} \times \left(1 - \frac{AT_t}{100}\right) \times EF_{NMVOC\ default}$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatement technology t (%);

t – abatement technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

Table 5.39 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Paints, Inks and Glue Manufacturing	g/kg product	11

Table 5.40 – Abatement technology (Source: EMEP/CORINAIR 2009)

Abatement Technology	Unit	Efficiency
Use of good practices	%	27

Table 5.41 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2010
Use of good practices	%	0	0	0	50	100
No control	%	100	100	100	50	0

Table 5.42 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF	g/kg product	11.0	11.0	11.0	9.5	8.0

5.3.3.7.3 Activity Data

Production data of paints, inks and glue was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in the following table.

Table 5.43 – Production of paints, inks and glue

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010
060307	Paints manufacturing	t paint	117 961	96 320	146 854	158 181	169 908
060308	Inks manufacturing	t ink	3 677	1 166	3 266	2 262	3 485
060309	Glues manufacturing	t glue	29 666	23 451	79 466	60 524	61 882

Source: INE

5.3.3.7.4 Uncertainty Assessment

The uncertainty associated with the emission factor for paints, inks and glues manufacturing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 36% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with paints, inks and glues manufacturing was calculated to be 38%.

5.3.3.7.5 Recalculations

Activity data based on INE IAPI survey was updated for 2009.

5.3.3.7.6 Further Improvements

No further improvements are planned for this sector.

5.3.3.8 *Manufacture of Tyres*

5.3.3.8.1 Methodology

Emissions from tyre manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NM VOC emissions were estimated from the number of tyres produced according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC(y)} \times Tyres_{(y)} \times 10^{-6}$$

Where:

$Emi_{NMVOC(y)}$ – NM VOC emissions from manufacturing of tyres during year y (t/yr);

$EF_{NMVOC(y)}$ – NM VOC emission factor for manufacturing of tyres in year y (g/tyre);

$Tyres_{(y)}$ – Number of tyres produced in year y (n./yr);

y - year

5.3.3.8.2 Emission Factors

Emission factors were taken from EMEP/CORINAIR guidebook 2009. Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC\ y} = \frac{CS_{t,y}}{100} \times \left(1 - \frac{AT_t}{100}\right) \times EF_{NMVOC\ default}$$

Where:

$EF_{NMVOC(y)}$ – NM VOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatement technology t (%);

t – abatement technology;

$EF_{NMVOC(default)}$ – Default NM VOC emission factor.

Table 5.44 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NM VOC
Tyre production	g/kg tyre	10

Table 5.45 – Abatement technology (Source: EMEP/CORINAIR 2009)

Abatement Technology	Unit	Efficiency
Process optimisation: Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent)	%	30
New processes: Use of 25% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvents)	%	75

Table 5.46 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2010
Process optimisation: Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent)	%	0	22	43	43	43
New processes: Use of 25% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvents)	%	0	29	57	57	57
No control	%	100	50	0	0	0

Since the final emission factor is expressed in g/kg tyre, a conversion factor was used to obtain emission factor expressed in g/tyre in order to use the activity data provided by INE. A conversion factor of 15kg/tyre was used.

Table 5.47 – Final NMVOC emission factor

Parameter	Unit	1990	1995	2000	2005	2010
Final EF	g/kg tyre	10	7	4	4	4
Final EF	g/tyre	150	108	67	67	67

5.3.3.8.3 Activity Data

Production data for tyres was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in the following table.

Table 5.48 – Production of tyres

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010
060314	Manufacture of tyres	tyres	4 218 714	5 891 971	11 605 755	14 748 990	15 595 153

Source: INE

5.3.3.8.4 Uncertainty Assessment

The uncertainty associated with the emission factor for manufacture of tyres was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 40% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with paints, inks and glues manufacturing was calculated to be 41%.

5.3.3.8.5 Recalculations

Activity data based on INE IAPI survey was updated for 2009.

5.3.3.8.6 Further Improvements

No further improvements are planned for this sector.

5.3.4 Other (CRF 3.D.)

5.3.4.1 *Use of N₂O for Anaesthesia (3.D.1)*

5.3.4.1.1 Methodology

The N₂O consumed in Portugal is primarily for medical use as anaesthesia. The new 2006 guidelines propose that emissions be estimated from supply "It is good practice to estimate N₂O emissions from data of quantity of N₂O supplied that are obtained from manufacturers and distributors of N₂O products". There will be a time delay between manufacture, delivery and use but this is probably small in the case of medical applications because hospitals normally receive frequent deliveries to avoid maintaining large stocks. Therefore, it is reasonable to assume that the N₂O products supplied will be used in one year.

5.3.4.1.2 Emission Factors

It is assumed that none of the administered N₂O is chemically changed by the body, and all is returned to the atmosphere. It is reasonable to assume an emission factor of 1.0

5.3.4.1.3 Activity Data

Consumption of N₂O emissions are calculated from statistics obtained from INE (1990 to 2009).

Table 5.49 – N₂O activity data (ton)

Year	1990	1995	2000	2005	2010
Production	108	151	0	57	0
Import	211	181	177	263	75
Export	1	2	5	5	3
Aparent Consumption	318	330	172	315	73

Source: INE, EUROSTAT

5.3.4.1.4 Uncertainty Assessment

The uncertainty is associated with the activity data from INE. It was assumed to be 10%.

5.3.4.1.5 Category-specific QA/QC and verification

No category-specific QA/QC has been made for this category.

5.3.4.1.6 Recalculations

Activity data based on INE IAPI survey was updated for 2009.

5.3.4.1.7 Further Improvements

No further improvements are under consideration at this time.

5.3.4.2 *Fire Extinguishers (3.D.2)*

Emissions from this category are included elsewhere (3.D.1).

5.3.4.3 *N₂O from Aerosol Cans (3.D.3)*

Emissions from this category are included elsewhere (3.D.1).

5.3.4.4 *Other Use of N₂O (3.D.4)*

Emissions from this category are included elsewhere (3.D.1).

5.3.4.5 *Other (3.D.5)*

5.3.4.5.1 Overview

In this chapter are included emission calculations for different activities, such as:

- printing;
- edible and non edible oil extraction;
- use of glue and adhesives;
- preservation of wood;
- other solvents use;
- use of perfume;
- use of waxes and polishing products;
- use of soaps and detergents;
- use of solvents from biomass.

5.3.4.5.2 Printing

5.3.4.5.2.1 Overview

Printing involves the application of an ink to several materials by presses, the most common of which is paper, but also cardboard, wood, plastics and metallic artifacts are subjected to this process. Emissions are very dependent of the printing technology because it (i.e., the type of press equipment) dictates the types of inks and coatings – and its solvent content - that can be used and defines, to a large extent, the emissions and the control techniques that are applicable (USEPA, 1985). The following technologies are available:

- lithography: the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellent to ink, by action of a dampener. In offset lithography the image is applied to a rubber-covered blanket cylinder and then transferred onto the substrate. This technique dominates the production of books and pamphlets and has been used increasing in newspapers;
- rotogravure: uses cylindrical image carrier, where the printing area is below the non printing area. The low relive is filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder. Used mostly in packaging, advertising, greeting cards, art books, catalogues, and directories;
- flexography: the image carrier, made of rubber or elastic photopolymers on which the printing areas are above the non printing areas. Used mostly in packaging, advertising newspapers, books, magazines, financial and legal document and directories;
- letterpress: similar to flexography, it uses a relief printing plate, but these plates differ from flexographic plates in that they have a rigid backing and are not

"flexible." Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to non-heatset web offset;

- screen: the ink is passed onto the surface to be printed by forcing it through a porous image carrier (stencil), in which the printing area is open and the non-printing area is sealed off. It is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles;
- plateless: Images printed on paper by laser printers, photo copiers, fax machines, and ink jets

NMVOC emissions from printing result from the evaporation of solvents that are components of the ink or that are added (dilution) just prior to printing activities. Emissions may also result from the use of cleaning products and dampeners. Emissions may occur during drying at air or at ovens (heat set).

5.3.4.5.2.2 Methodology

Emissions from printing industry was estimated according with Tier 1 methodology from EMEP/CORINAIR Guidebook.

$$Emi_{NMVOC(y)} = EF_{(i)} * INK_{CONS(y)} \times 10^{-3}$$

Where

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from printing activities during year y (t/yr);

$INK_{CONS(y)}$ – Use of printing ink during year y (t/yr);

$EF_{(i)}$ – NMVOC emission factor (solvent content) for ink use (g/kg ink).

Ultimate CO₂ emissions are calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory.

$$U_{CO_2} = NMVOC * 0.85 * (44 / 12)$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

5.3.4.5.2.3 Emission Factors

The emission factor used for printing activities was obtained from EMEP/CORINAIR guidebook. The same emission factor was used for year 1990 to 2010.

Table 5.50 – NMVOC emission factor for printing activities

SNAP	Unit	NMVOC
Printing	g/kg ink	500

Source: EMEP/CORINAIR 2009

5.3.4.5.2.4 Activity Data

Consumption of inks in printing industry according to printing product is available from the INE's statistical database, which is summarized in the following table.

Table 5.51 – Consumption of inks in printing industry

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010
060403	Printing Industry	t ink	5 372	5 372	9 290	8 722	9 336

Source: INE

5.3.4.5.2.5 Uncertainty Assessment

The uncertainty associated with the emission factor for printing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 207% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty was calculated to be 207%.

5.3.4.5.2.6 Recalculations

Activity data based on INE IATI survey was updated for 2009.

5.3.4.5.2.7 Further Improvements

No further improvements are planned for this sector.

5.3.4.5.3 Edible and non edible oil extraction

5.3.4.5.3.1 Overview

This sub-source comprehends emissions of NMVOC from extraction of edible and non-edible oils from seeds.

Extraction of oil in Portugal may be made using mechanical processes or solvent based processes. Mechanical processes, using presses, are used to extract first olive oil from olives⁸³. Extraction by solvents, usually using hexane and heat, is presently done in extraction from most oil seeds or secondary extraction of olive oil. Solvent recovery, where the oil is separated from the oil-enriched wash solvent and from the steamed out solvent, is an integral part of the production processes although leakages occur continuously leading to the need of solvent stock replenishment. Losses are either made directly to atmosphere through vents or leaks or indirectly through water and residues.

5.3.4.5.3.2 Methodology

Emissions of NMVOC were estimated considering that the annual hexane consumption by the industrial plant, hexane make-up, is due to losses to the air, and hence:

$$Emi_{NMVOC}(y) = MakeUp_{Solvents}(y)$$

where:

$Emi_{NMVOC}(y)$ - Emissions of NMVOC (ton/yr);

⁸³ Classified as virgin olive oil

$MakeUp_{Solvents(y)}$ - annual consumption of solvent in edible and non-edible oil industry, to replenish losses (ton/yr).

Ultimate CO₂ emissions are calculated assuming that 85 percent of the mass emissions of NMVOC is carbon⁸⁴ and is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory.

$$U_{CO_2} = NMVOC * 0.85 * (44 / 12)$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

5.3.4.5.3.3 Emission Factors

The national emission factor for NMVOC was calculated as the ratio of the amount of solvents consumed during manufacture processes to the quantities of edible and non edible oil manufactured. However, from the available data from INE, this emission factor could be only estimated from IAIT industrial survey, i.e. from 1989 to 1991, because solvent consumption is not available from IAPI survey. Statistical information used in actual calculations of annual emission factor are presented in Table 5.52, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole covered period.

Table 5.52 – Calculation of the National emission factor for edible and non-edible oils extraction (kg/ton).

Oil Type	Parameter	1989	1990	1991	Average
Edible	Oil refined (ton)	93 401	90 686	107 163	
non-edible		113 749	110 883	113 509	
Total		207 150	201 569	220 672	
Edible	Solvent Use (ton)	2 328	1 763	1 697	
non-edible		1 394	1 257	1 408	
Total		3 722	3 020	3 106	
Edible	Emission Factor NMVOC (kg/ton)	24.9	19.4	15.8	20.1
non-edible		12.3	11.3	12.4	12.0
Total		18.0	15.0	14.1	15.7

5.3.4.5.3.4 Activity Data

Oil refining data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2000. Annual values are reported in Table 5.53. Production of olive oil by mechanical pressure does not cause NMVOC emissions.

⁸⁴ From hexane chemical formula

Table 5.53 - Refining of edible and non-edible oils in Portugal

Parameter	1990	1995	2000	2005	2010
Oil refining	201 569	220 672	184 406	280 430	186 238

Source: National Statistics Institute (INE)

5.3.4.5.3.5 Uncertainty Analysis

The activity data time trend is reasonably complete and an uncertainty of 10% was considered. The uncertainty of NMVOC/CO₂ emission factor was established by comparison of the emission factors determined from the several available years: 26%.

5.3.4.5.3.6 Recalculations

Recalculations were made due to an update of activity data for 2009.

5.3.4.5.4 Industrial application of glues and adhesives

5.3.4.5.4.1 Methodology

$$\text{NMVOC} = \text{Cons}_{\text{Nat}} \times \text{FE}_{\text{Nat}} + \text{Imp} \times \text{FE}_{\text{imp}}$$

where:

NMVOC = Global emissions of NMVOC (ton)

Cons_{Nat} = Domestic consumption of glues and adhesives produced in Portugal (ton)

FE_{Nat} = Emission factor for glues and adhesives produced in Portugal (kg NMVOC/ton Ink)

Imp = Imported glues and adhesives (ton)

FE_{imp} = Emission factor associated with the use of imported glues and adhesives.

$$\text{Cons}_{\text{Nat}} = \text{Prod}_{\text{Nat}} - \text{Exp}$$

where:

Cons_{Nat} = Consumed glues and adhesives produced in Portugal (ton)

Prod_{Nat} = National production of glues and adhesives (ton)

Exp = Exported glues and adhesives (ton)

5.3.4.5.4.2 Emission Factors

To estimate the emission factor applied for the use of national glues and adhesives, the ratio of the amount of solvents consumed (Table 5.54 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5.55). The emission factor for VOC emission from the manufacture of glue and adhesives was subtracted from this value to obtain the emission factors for use of national produced glue and adhesives.

Table 5.54 - Solvents consumption in glue and adhesives manufacture (ton).

	1989	1990	1991
Methyl ketone	361	328	328
Dibutyl phthalate	97	134	143
Ethyl Acetate	373	351	355
Hexane	1 567	1 357	1 277
Benzene	295	354	335
Toluene	1 839	1 690	1 799
Other solvents	1 876	2 010	2 003
Total	6 408	6 224	6 240

Table 5.55 - National emission factors (kg/ton).

	1989	1990	1991	Average
For production and use of glue and adhesives	190	172	175	179
Only for use of glue and adhesives	170	152	155	159

For non-natural imported glues and adhesives the CORINAIR90 Default Emission Factor was used: 600 kg/ton. It is considered that natural based glue does not contribute to NMVOC emission.

5.3.4.5.4.3 Activity Data

Table 5.56 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	1992 - 2010
National Production (ton)	36 297	35 769	35 473
Importation (ton)	2 192	2 328	2 260
Exportation (ton)	707	532	620

Source: National Statistics Institute (INE)

5.3.4.5.4.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

5.3.4.5.4.5 Recalculations

No recalculations were made for this source sector.

5.3.4.5.5 Wood Preservation

5.3.4.5.5.1 Overview

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts and building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

5.3.4.5.5.2 Methodology

$$Emi_{NMVOC(y)} = Consumption_{(y)} * FE_{Consumption}$$

where:

$Emi_{NMVOC(y)}$ - Emissions of NMVOC associated to consumption of wood preservation products (ton)

$Consumption_{(y)}$ - Consumption of wood preservation products (ton)

$FE_{Consumption}$ - Emission factor associated to the consumption of wood preservation products.

5.3.4.5.5.3 Emission Factors

CORINAIR90 Emission Factor Handbook proposes three emission factors for VOC emission from wood preservation, depending on the type of product used. The emission factor is 100 kg/ton of product applied for creosote; 900 kg/ton for solvent based products and 0 for water based products. The available data do not discriminate the share of the several types of preservation products, therefore, it was assumed that the main product used in Portugal is creosote.

5.3.4.5.5.4 Activity Data

Table 5.57 - Wood preservation products consumption (ton)

Year	1990	1991	1992 - 2007
Wood Preservation products Consumption (ton)	2083	2900	2491

Source: National Statistics Institute (INE)

5.3.4.5.5.5 Uncertainty Assessment

The activity data and emission factors have a high level of uncertainty and errors therefore a uncertainty of 100% was assumed in both cases.

5.3.4.5.5.6 Recalculations

No recalculations were made for this source sector.

5.3.4.5.6 Domestic solvent use including fungicides

5.3.4.5.6.1 Methodology

This sector addresses emissions from the use of solvent containing products by the public in their homes. This sector does not include the use of decorative paints which is covered by source category 3.A. Paint Application.

NMVOC's are used in a large number of products sold for use by the public. These include:

- Cosmetics and toiletries; Products for the maintenance or improvement of personal appearance, health or hygiene.
- Household products; Products used to maintain or improve the appearance of household durables.
- Construction/Do-It-Yourself; Products used to improve the appearance or the structure of buildings such as adhesives and paint remover.
- Car care products; Products used for improving the appearance of vehicles to maintain vehicles or winter products such as antifreeze.

Pesticides such as garden herbicides and insecticides and household insecticide sprays may be considered as consumer products. Most agrochemicals, however, are produced for agricultural use and fall outside the scope of this section.

Emission from this sector were calculated using a Tier 1 approach. This approach uses a single emission factor expressed on a person basis which was multiplied by the population to derive emissions from domestic solvent use.

$$NMVOC_i = Population_i \times EF_{NMVOC} / 1000$$

where:

NMVOC_i - Emissions of NMVOC associated to the use of domestic products containing solvents [t]

Population_i – inhabitants in year i;

EF_{NMVOC} - Emission factor associated with the use of domestic products containing solvents [kg/person/year]

5.3.4.5.6.2 Emission Factors

Emission factor for NMVOC was obtained from EMEP/CORINAIR Guidebook, 2009. This default emission factor has been derived from an assessment of the emission factors presented in GAINS model developed by IIASA.

Table 5.58 – Default emission factor.

Description	Unit	Value
Emission factor for domestic solvent use including fungicides	kg/person/year	1

5.3.4.5.6.3 Activity Data

Table 5.59 - Activity data (inhabitants)

Description	1990	1995	2000	2005	2010
Inhabitants	9 970 441	10 043 180	10 256 658	10 569 592	10 636 979

Source: National Statistics Institute (INE)

5.3.4.5.6.4 *Uncertainty Assessment*

The uncertainty associated with the emission factor for domestic solvent use was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 125% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty was calculated to be 125%.

5.3.4.5.6.5 *Recalculations*

No recalculations were made for this source sector.

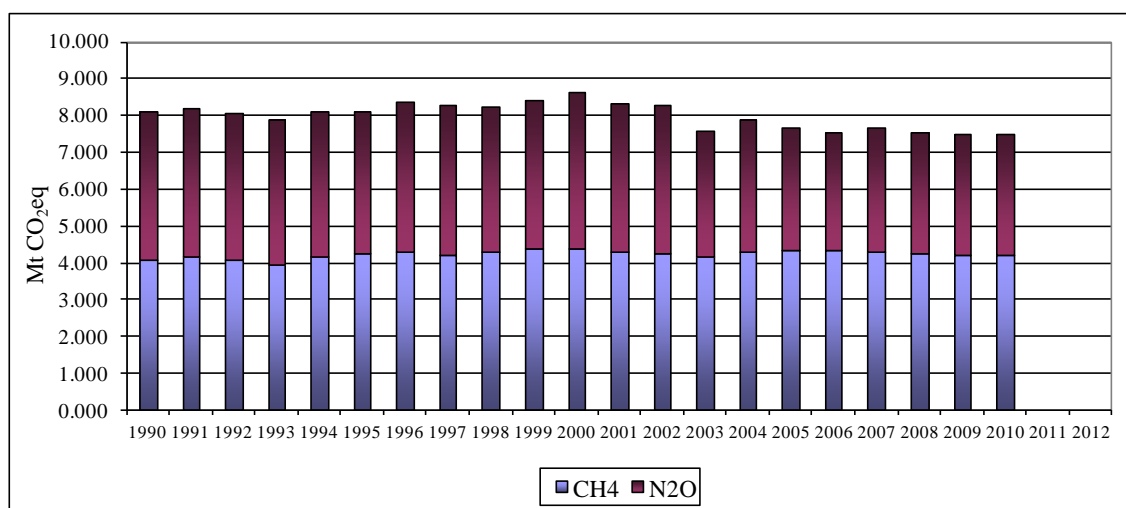
6 AGRICULTURE (CRF 4.)

6.1 Overview

Agriculture activities generate emissions of GHG from a variety of sources. This section refers to the quantification of: CH₄ emissions from enteric fermentation; CH₄ and N₂O emissions from manure management; direct and indirect N₂O emissions from agriculture soils; CH₄ from rice cultivation and CH₄ and N₂O emissions from field burning of agriculture residues. Also dealt here are the NH₃ emissions from agriculture, which are used as an intermediate step in the quantification of N₂O indirect emissions from soil, and all other non-greenhouse gas emissions from field burning of agriculture residues. There are no ecosystems in Portugal that could be considered natural savannas and no greenhouse gas emissions exist therefore for this sub-category. GHG emissions from combustion processes in agriculture are discussed in sector Energy: Other Sectors (CRF 1A4). Estimates of CO₂ release and uptake resulting from conversion of agriculture land and grazing land to other uses, conversion of other uses to agriculture land and grazing land, conversion of agriculture land to grazing land and vice versa, and substantial changes in agriculture practices, such as conversion of annual crops to perennial crops and the opposite, are estimated in the inventory but included in chapter Land Use, Land Use Change and Forestry (LULUCF).

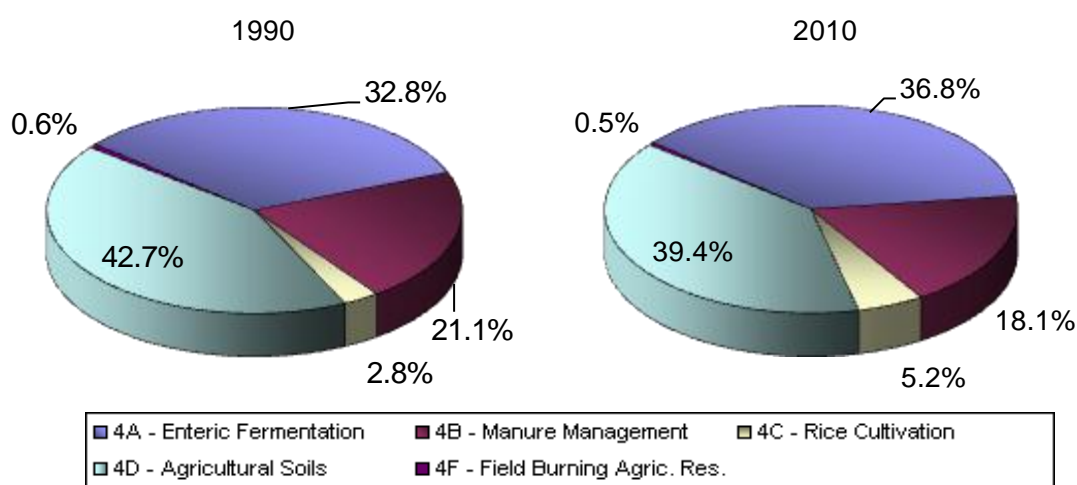
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 13.5 per cent in 1990 to 10.6 per cent in 2010. This decrease in importance is followed by a decrease of 7.36 per cent in the total emissions from 1990 to 2010: 8.0 Mton of CO₂eq in 1990 and 7.5 Mton CO₂eq in 2010 (Figure 6.1). Total GHG emissions show that nitrous oxide emissions have been decreasing in the last years while methane emissions were constant for the same time period. Because of these nitrous oxide variations, methane as increase its share on the total emissions from 50.6 per cent in 1990 to 56.5 per cent in 2010.

Figure 6.1 – Total Greenhouse Gas Emissions from Agriculture - trends by GHG



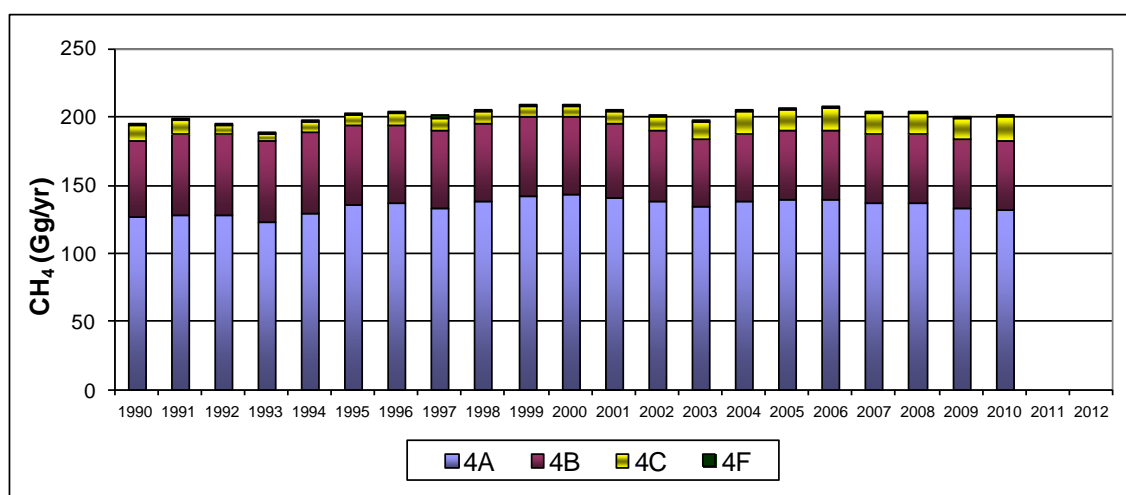
The majority of emissions in 2010 from agriculture are the result of only 3 sub-source sectors (figure below): Agriculture Soils, Enteric Fermentation, and Manure Management (hierarchically listed in order of the most prevalent).

Figure 6.2 - Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2010



Emissions of CH₄ from agriculture have increased 3.37 per cent from 1990 to 2010 (Figure 6.3). Enteric Fermentation was responsible, in 2010, for 65.2 per cent of the sectoral emissions and Manure Management accounted for 25.1 per cent of the sectoral emissions in the same year. The remaining 9.7 per cent of emissions result mostly from rice cultivation, with only a very small contribution from field burning of residues, only 0.5 per cent of total emissions in the same year.

Figure 6.3 - Methane emissions from agriculture

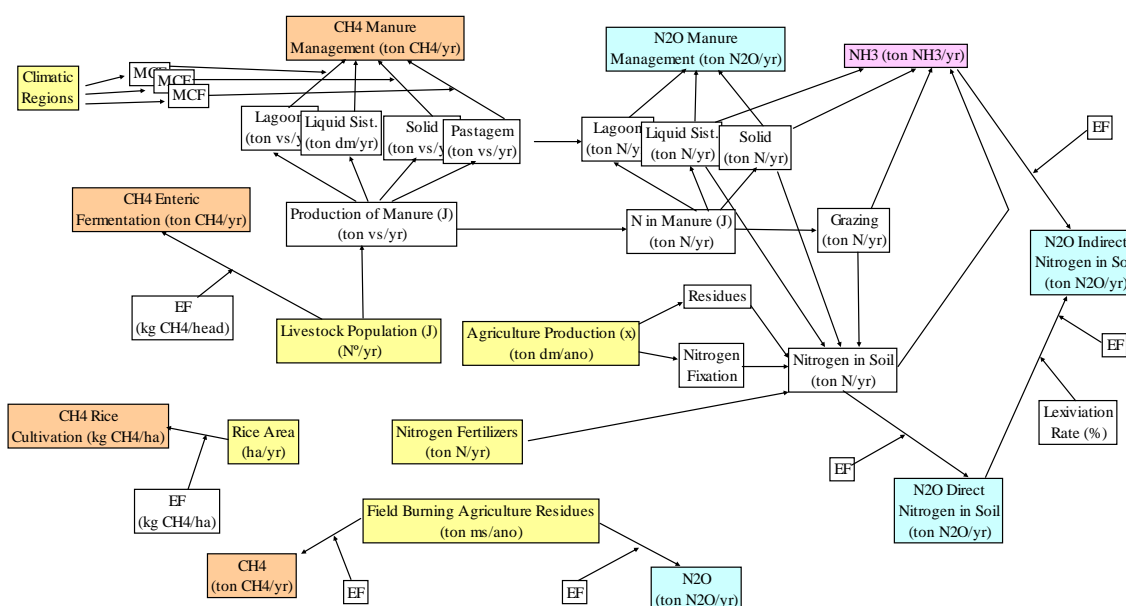


Following an opposite trend, N₂O emissions have decreased by 18.35 per cent from 1990 to 2010 (Figure 6.4). Nevertheless, it is visible a major increase from 1990 to 2002 while the subsequent decrease was the result of a drought period that occurred in 2003 and 2004, with the consequent decrease in agricultural production and use of fertilizers. The great majority of emissions in 2010 were associated with direct and indirect emissions from agricultural soils (90.4 per cent), manure management is responsible for 9.1 per cent of emissions, while the small remaining fraction results from field burning of agricultural residues (0.5 per cent).

The chart displays N₂O emissions in Gg/yr from 1990 to 2012. The y-axis ranges from 0 to 16 Gg/yr. The x-axis shows years from 1990 to 2012. The legend indicates three categories: 4B (dark blue), 4D (light blue), and 4F (dark blue). The emissions are dominated by category 4D, which shows a general downward trend from approximately 11 Gg/yr in 1990 to around 9 Gg/yr in 2012. Category 4B shows a slight increase from 1990 to 2000, peaking at about 1.5 Gg/yr, before declining. Category 4F remains relatively stable, contributing about 0.5 Gg/yr throughout the period.

Year	4B (Gg/yr)	4D (Gg/yr)	4F (Gg/yr)
1990	1.5	11.0	0.5
1991	1.5	11.0	0.5
1992	1.5	11.0	0.5
1993	1.5	11.0	0.5
1994	1.5	11.0	0.5
1995	1.5	11.0	0.5
1996	1.5	11.5	0.5
1997	1.5	11.5	0.5
1998	1.5	11.0	0.5
1999	1.5	11.0	0.5
2000	1.5	12.0	0.5
2001	1.5	11.5	0.5
2002	1.5	11.5	0.5
2003	1.5	10.0	0.5
2004	1.5	10.5	0.5
2005	1.5	10.0	0.5
2006	1.5	9.5	0.5
2007	1.5	10.0	0.5
2008	1.5	9.5	0.5
2009	1.5	9.5	0.5
2010	1.5	9.5	0.5
2011	1.5	9.5	0.5
2012	1.5	9.5	0.5

Figure 6.5 - Overview of Methodology



MAMAOT

6.2 Recalculations

The major changes between submissions result from the following actions:

- Introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types and crops (this revised series was given by INE). This also affected dairy cattle milk yield values;
- For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009);
- Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values;
- Revision of the estimation procedures for kids and lambs after the addition of the new data concerning livestock and slaughter numbers reported in the RGA 2009 (1990-2009);
- Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine. This revision was also supported by INE values;
- Revision of the procedure for adding a time trend to the estimated quantities of the CH₄ emission factor for sheep and goats (1990-2009 except 1998). This new procedure is more in line with the one already in use for non-dairy cattle;
- New data from GPP was obtained concerning rice areas in Techniques of Integrated Production and Protection. This new data revised the 1996-2009 time series;
- Revision of the 2009 value for apparent consumption of synthetic fertilizers.

These changes result in the differences between submissions shown in the following figure and table.

Figure 6.6 - Differences between submission 2011 and submission 2012 for CH₄ and N₂O emissions from agriculture

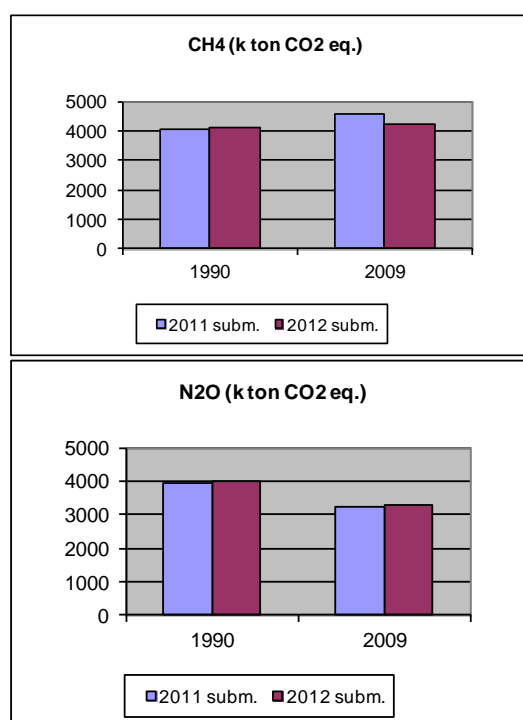


Table 6.1 – Recalculations. Differences between submission 2011 and submission 2012 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2			CH4			N2O		
	2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Difference (1)
	CO2 equivalent (Gg)			CO2 equivalent (Gg)			CO2 equivalent (Gg)		
1990									
4. Agriculture				4 076.04	4 104.56	0.70	3 959.96	4 008.28	1.22
4.A. Enteric Fermentation				2 637.22	2 663.81	1.01			
4.B. Manure Management				1 181.60	1 183.53	0.16	519.54	525.96	1.24
4.C. Rice Cultivation				226.76	226.76	0.00			
4.D. Agricultural Soils				NE,NO	NE,NO		3 418.63	3 460.52	1.23
4.E. Prescribed Burning of Savannas				NO	NO		NO	NO	
4.F. Field Burning of Agricultural Residues				30.46	30.46	0.00	21.80	21.80	0.00
4.G. Other				NO	NO		NO	NO	
2009									
4. Agriculture				4 558.28	4 218.70	-7.45	3 238.11	3 289.30	1.58
4.A. Enteric Fermentation				2 861.63	2 799.11	-2.18			
4.B. Manure Management				1 265.52	1 071.87	-15.30	316.77	306.84	-3.13
4.C. Rice Cultivation				410.94	325.34	-20.83			
4.D. Agricultural Soils ⁽²⁾				NE,NO	NE,NO		2 904.31	2 965.88	2.12
4.E. Prescribed Burning of Savannas				NO	NO		NO	NO	
4.F. Field Burning of Agricultural Residues				20.19	22.37	10.79	17.03	16.58	-2.64
4.G. Other				NO	NO		NO	NO	

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100 per cent x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

6.3 Source categories

6.3.1 CH4 Emissions from Enteric Fermentation in Domestic Livestock (CRF 4.A.)

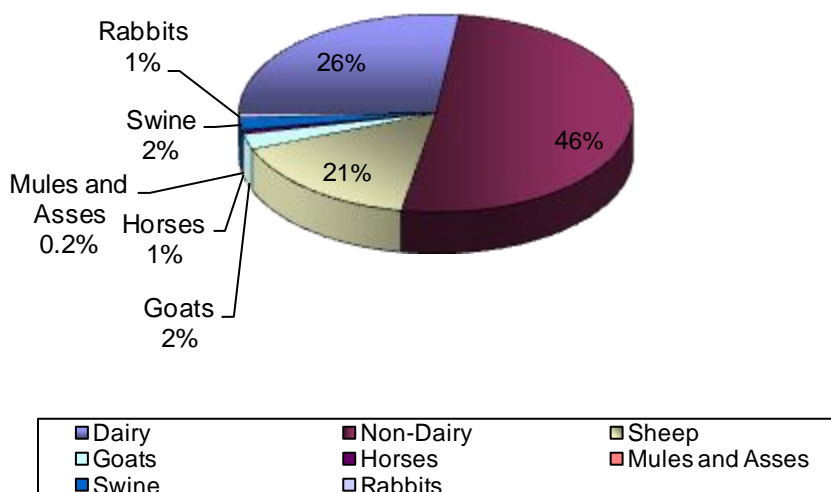
6.3.1.1 Overview

Methane emissions from enteric fermentation in animals result from this gas being produced as a by-product during the digestive process of carbohydrates by micro-organisms in the digestive system. This process occurs specially in ruminant animals, due to the activity of specific micro-

organisms in their upper digestive tracts, but also in smaller quantities in monogastric animals (swine, equines and rabbits). The estimates in this inventory include only emissions in domestic animals. Emissions from wild animals and semi-domesticated game are not quantified neither there is quantification of emissions from humans or pet animals.

CH₄ emissions from enteric fermentation are a key source, both by level and trend assessment. The share of each animal type is observable in Figure 6.7. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents, according to different years, 26 per cent to 30 per cent of total CH₄ emissions from Enteric Fermentation, while non-dairy cattle represents about 39 to 51 per cent of total CH₄ from enteric fermentation. Together, in 2010 cattle was responsible for about 78 per cent of total CH₄ emissions from enteric fermentation.

Figure 6.7 - Relative Importance of emissions of CH₄ from Enteric Fermentation per each animal species in 2010



Sheep is also an important source of methane, for which emissions have oscillated between 16.4 per cent and 23.9 per cent of total CH₄ from Enteric Fermentation. Emissions from goats were 2.4 to 4.6 per cent of total enteric fermentation and swine represented 1.9 to 3.0 per cent of emissions. Total emissions of methane for all other species varied between 1.4 and 2.8 per cent, for the same period and have less importance.

6.3.1.2 Methodology

Emissions were estimated for each animal type⁸⁵ by multiplication of the number of animals by the respective emission factor, in accordance to equation 4.12 of the Good Practice Handbook (Tier 2 method).

$$Emi_{CH_4}(y) = \sum_t [EF_{(i,y)} * N_{(i,y)}]$$

where, for each specie:

Emi_{CH_4} - methane emissions from enteric fermentation in year y, kg CH₄/year;

⁸⁵ For most animal types an enhanced characterization of livestock, with subdivision per age, sex and management conditions was used. This is discussed in more detail under activity data.

EF - emission factor for the specific population of animal type i in year y, kg/head/year;

N - the number of animals of type i in year y, head.

6.3.1.3 *Emission Factors*

Emission factors may be seen in Table 6.2, in which is presented the range of values according to time variation, which will be further discussed. In accordance with the unavailability of emissions factors in IPCC96 for broilers, laying hens, turkeys, ducks, geese, guinea fowl and other poultry, emissions from these classes were not estimated and were assumed as negligible. There are no livestock populations of Buffalo, Camels and Llamas in Portugal.

The default emission factors proposed by IPCC96 for West Europe (tables 4-3 and 4-4 in IPCC(1997)) were maintained for horses, mules and asses, due to the unavailability of a more detailed livestock characterization and specific characterization of national populations. For all other animal types the existence of an enhanced livestock population and animal characteristics allowed the use of a higher methodology level, tier 2.

Table 6.2 - Emission Factors for Enteric Fermentation (kg CH₄/head/year)

Animal type	sub-class	EF (kg CH ₄ /hd/yr)	
Dairy-Cattle	Dairy Cows	91-119	T2
non-dairy cattle	Beef calves (<1 yr)	32-36	T2
	Calves, Males for Replacements (<1 yr)	40-46	T2
	Calves, Females for Replacements (<1 yr)	34-39	T2
	Males 1-2 yrs	62-70	T2
	Beef Females 1-2 yrs	42-48	T2
	Females for Replacemet 1-2 yrs	48-55	T2
	Steers (>2 yrs)	77-88	T2
	Heifers for Beef (>2 yrs)	52-59	T2
	Heifers for Replacements (>2 yrs)	52-59	T2
	non-dairy cows	64-74	T2
Swine	Piglets (<20 kg)	0.3	T2
	Fattening Pigs (20-50 kg)	1.3	T2
	Fattening Pigs (50-80 kg)	1.9	T2
	Fattening Pigs (80-110 kg)	2.2	T2
	Fattening Pigs (> 110 kg)	2.5	T2
	Boars (>50 kg)	1.9	T2
	Sows, pregnant	1.8	T2
	Sows, non-pregnant	3.8	T2
Ovines	Ewes	8.1-10.7	T2
	Other: rams and young males	10-13.1	T2
	Lambs	4.3-5.6	T2
Caprines	Does	7.8-9.4	T2
	Other: bucks and young males	4.8-5.8	T2
	kids	2.6-3.1	T2
Equides	Horses	18	T1
	Asses, Mules and hynies	10	T1
Other	Rabbits	3.6	T2

6.3.1.3.1 Determination of tier 2 emission factors

Following the recommendations from previous review processes, a tier 2 analysis was sought for the most significant animal types.

According to the Good Practice Guidebook (IPCC,2000) equation 4.14, at tier 2, the emission factors for enteric fermentation are determined using the equation:

$$EF_{CH_4} = (GE * Y_m * 365 \text{ days/yr}) / (55.65 \text{ MJ/kg CH}_4)$$

Where:

EF_{CH_4} - emission factor, kg CH₄/hd/yr

GE - gross energy intake, MJ/hd/day

Y_m - methane conversion rate, the fraction of gross energy in feed that is converted to methane.

6.3.1.3.1.1 Dairy Cattle

The majority of cows used for milk production in Portugal belong to the Frisians race. Nevertheless there could not be found reliable records of animal feed intake or characteristics such as size. Therefore, emission factors were established using the following regression, which is based on the default IPCC emission factors per region and the value of annual milk production that was used in the determination of the default IPCC emission factors (Appendix A of the IPCC 1996 Guidelines (IPCC,1997)):

$$EF_{CH_4} = 0.0126 * Y + 40.207 \quad (r^2 = 0.961)$$

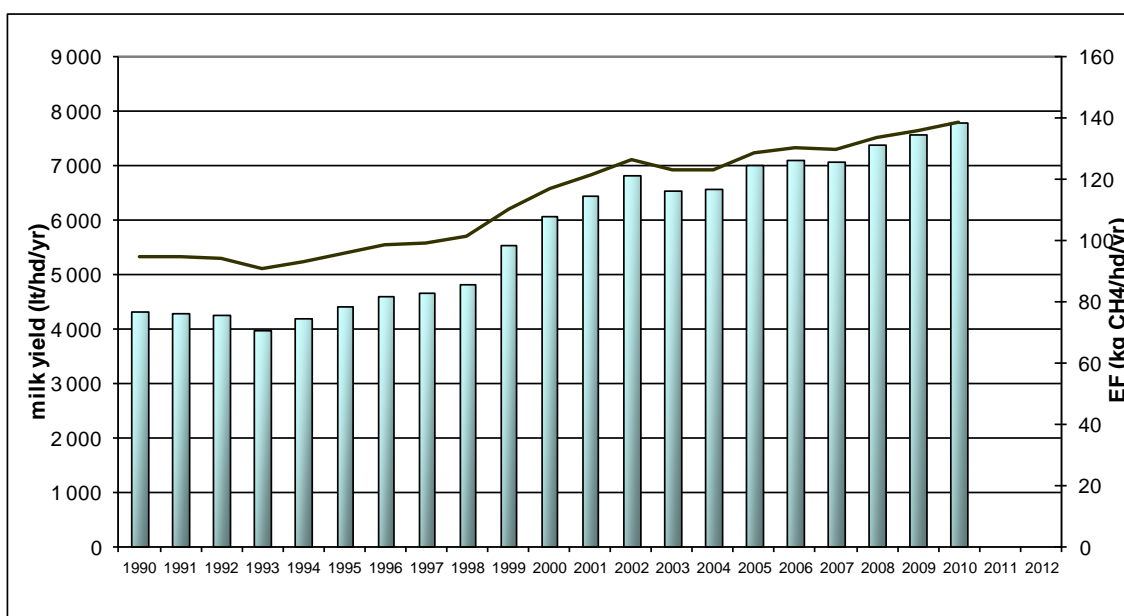
Where,

EF_{CH_4} is the Enteric Fermentation emission factor, kg CH_4 /hd/yr;

Y is average milk yield per cow, lt/yr.

Milk yield was estimated dividing the annual production of milk cow over the number of cows in production⁸⁶, both of which are published by the National Statistical Institute (INE). The calculated milk yield and the corresponding emission factor are shown in Figure 6.8. The improvement in breeding conditions caused the increase in milk yield in the overall period, while annual variations show sometimes decreases that are related to unfavorable climacteric conditions such as droughts, as can be seen in the temporary decreases in 1993, 2003 and 2004, and recover periods thereafter.

Figure 6.8 – Annual production of milk yield per dairy cow in Portugal (bars) and the estimated emission factor of CH_4 from Enteric Fermentation (line)



⁸⁶ The same time series used in the inventory but not averaged over 3 years.

Assuming a constant methane conversion rate of 6 per cent (default IPCC) and an energy density of the feed of 18.45 MJ/kg, the corresponding Feed Intake (FI) per day, was estimated to have increased from 13.1 kg dm/hd/day in 1990 to 19.1 kg dm/hd/day, in 2010. This trend in increase in the feed intake was used, in a consistent way, in the determination of the annual manure production per cow, in the estimation of CH₄ emissions from Manure Management (for more adequate explanation please see the chapter with the same name).

6.3.1.3.1.2 Non-dairy cattle

The Ministry of Agriculture compiled in 1998, and updated recently (GPPAA,2004), information from the eighteen breeders associations existing in Portugal, this database comprehending the number of registered producers, number of animals, age at weaning, age at slaughter, use as working animal, territorial range and biometric parameters such as weight at birth, at 7 months and at adult age. Thirteen breeds have national origin and four are imported breeds. The number of registered animals represents about 20 per cent of total reproductive animals. Some animals in the remaining livestock population are the result of cross-breeding and are not registered, but it was assumed that they attain the average characteristics of the progenitors.

The calculation was made individually for each sub-category, determined from the available statistical information:

Table 6.3.- Livestock population by age.

<1 yr	Beef Calfs
	Calfs, Males for Replacements
	Calfs, Females for Replacements
1-2 yr	Males
	Beef Females
	Females for Replacement
>2 yr	Steers
	Heifers for Beef
	Heifers for Replacements
	non-dairy cows

Feed intake estimates for each cattle sub-category was estimated using the energy model of the IPCC Good Practices (IPCC,2000), which is briefly presented here. First, net energy is determined from:

$$\begin{aligned}
 NE_m &= CF_i * (Weight)^{0.75} \\
 NE_a &= C_a * NE_m \\
 NE_w &= 0.10 * NE_m * W_{hour} \\
 NE_g &= 4.18 * \{0.0635 * [0.891 * (Weight * 0.96) * (478/(C_g * MW))]^{0.75} * (WG * 0.92)^{1.097}\} \\
 NE_l &= milk_{Yield} * (1.47 + 0.40 * Fat) \\
 NE_p &= C_{pregnancy} * NE_m
 \end{aligned}$$

Needs of digestible energy, and finally Gross Energy Intake (GE), expressed in energy, and Feed Intake (FI), expressed in dry matter ingested, are estimated from:

$$\begin{aligned} NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\ NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\ GE &= \{[(NE_m + NE_a + NE_l + NE_w + NE_p)/(NE_{ma}/DE)] + [NE_g / (NE_{ga}/DE)]\} / (DE/100) \\ FI &= GE / ED \end{aligned}$$

where, the following variables are estimated:

NE_m – net energy required by the animal for maintenance, MJ/day;

NE_a – net energy for animal activity, MJ/day;

NE_w – net energy for work, MJ/day;

NE_g – net energy needed for growth, MJ/day;

NE_l – net energy for lactation, MJ/day;

NE_p – net energy required for pregnancy, MJ/day;

GE – gross energy, MJ/day;

FI – Feed Intake, kg dm/day;

Based on the knowledge of the following parameters:

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

NE_{ga}/DE - ratio of net energy available for growth in a diet to digestible energy consumed;

DE - digestible energy expressed as a percentage of gross energy

Weight - live-weight of animal, kg/hd;

MW - the mature body weight of an adult animal, kg;

WG - the daily weight gain, kg/day;

Milk_{Yield} – milk production, kg/day;

W_{hour} - hours of work per day;

Fat - fat content of milk, %;

ED - energy density of the feed, MJ/kg dm;

C_{fi} - a coefficient for maintenance, specific of each animal class;

C_a – activity coefficient corresponding to the feeding situation of the animal;

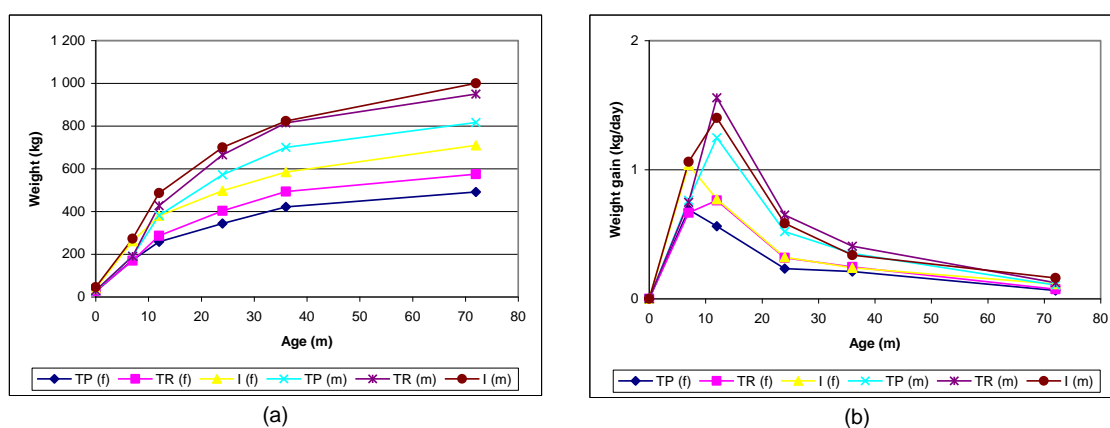
C_g – Coefficient for growth, dependent on the sex;

C_{pregnancy} = pregnancy coefficient.

For each cattle breed the values chosen for parameters, such as weight, weight gain and feeding situation, were established from the available information. Three different cattle types were considered: (1) Imported breeds; (2) Traditional breeds on pasture; (3) Traditional breeds on range⁸⁷. The difference between traditional animals on pasture and range depends on the type of terrain, being assumed the range situation for breeds mostly existing in the south plains (“Montados”) and pasture in small grazing plots (“Prados” and “Lameiros”) in central and northern continental Portugal and in the islands.

Given that the database did not have detailed information for all age classes a model had to be derived for each breed from information at birth, 7 months and adult weight. The model, based on information collected from other countries (Jarrige, 1988), considers the following evolution pattern.

Figure 6.9 – Grow model for cattle: (I) Imported breeds; (Tp) Traditional Pasture and (Tr) Traditional Range, for males (m) and females (f).



(a) Live-weight as function of age; (b) Weight gain as function of age.

The calculations for each individual breed were converted into a national average, using total non-dairy cattle population in the delimited territorial range as the weighting factor⁸⁸. The average values of the parameters and the average values of the values calculated are presented in Table 6.4 though Table 6.7.

⁸⁷ Imported breeds are Charolês; Limousine; Simmental Fleckvieh and Salers. Breeds in traditional pasture are: Arouquesa, Barrosã, Marinhola, Maronesa, Minhota/ Galega, Cachena, Ramo Grande and Mirandesa. Traditional range breeds are: Alentejana, Garvonesa, Brava, Mertolenga and Preta.

⁸⁸ The preference for this weighting factor other than number of animals results from the fact that the number of declared animals is probably over-estimated for traditional breeds.

Table 6.4 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of individual breed.

sub-class	W (kg)	WG (kg/day)	Cfi	NEm (MJ/day)	Ca ⁱ	NEa (MJ/day)	Cg	NEg (MJ/day)
Beef calves (<1 yr)	212	0.948	0.322	17.8	0.177	2.8	0.9	8.6
Calfs, Males Rep. (<1 yr)	230	1.139	0.322	19.0	0.177	3.2	1.0	8.9
Calfs, Fem. Rep. (<1 yr)	182	0.757	0.322	15.9	0.177	2.6	0.8	7.9
Males 1-2 yrs	543	0.589	0.322	36.2	0.177	6.3	1.0	8.2
Beef Fem. 1-2 yrs	366	0.295	0.322	26.9	0.177	4.4	0.8	4.7
Females for R. 1-2 yrs	366	0.295	0.322	26.9	0.177	4.4	0.8	4.7
Steers (>2 yrs)	789	0.249	0.322	47.9	0.177	8.4	1.2	3.7
Heifers for Beef (>2 yrs)	462	0.160	0.322	32.1	0.177	5.4	0.8	2.9
Heifers for Rep. (>2 yrs)	462	0.160	0.322	32.1	0.177	5.4	0.8	2.9
non-dairy cows	599	0.000	0.324	39.1	0.177	6.5	0.8	0.0

i) Weighted average for different feeding situations: Stall, Pasture and Grazing large areas.

Table 6.5 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Specific parameters for mother cows.

Parameter	Value
Per cent Pregnant	0.90
Milking Period (days/yr)	56
Milk Yield during milking period (kg/d) ⁱ	8.0
F (Fat content of Milk) (%)	4
NE _i (MJ/day)	3.8
C _{pregnancy}	0.1
NE _p (MJ/day)	3.5

i) Value considered for non-diary cows sub class. Milk yield for all other sub classes considered 0 kg/d.

Table 6.6 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of Mature Weight (MW).

MW	kg
Male	930
Female	600

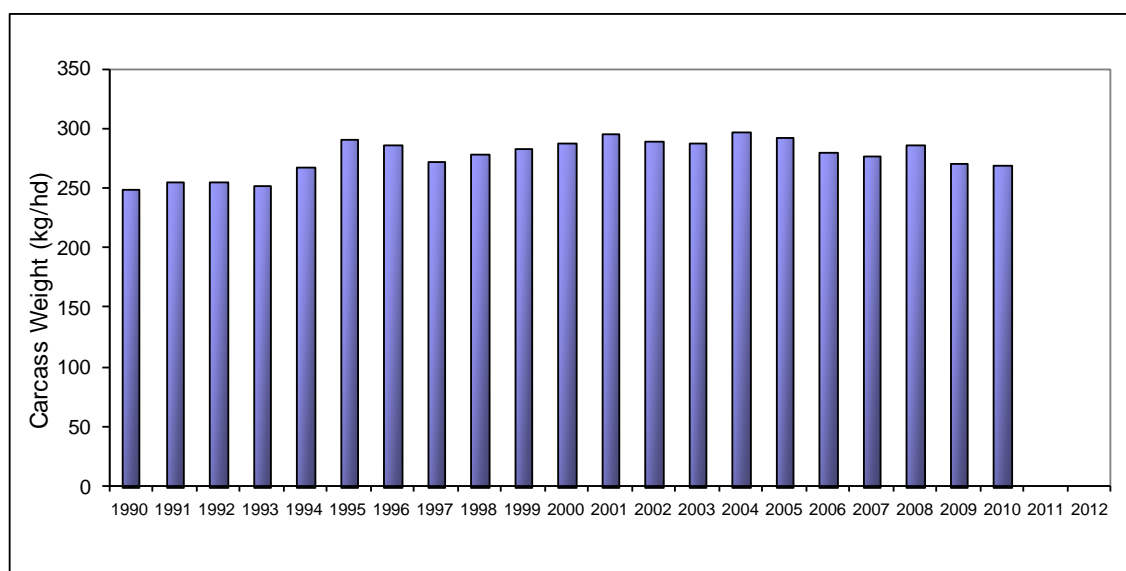
Table 6.7 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Y_m) and Emission Factor of CH₄ emissions from Enteric Fermentation for non-dairy cattle. Weighted averages from individual breeds.

sub-class	NE (MJ/day)	NE _{ma} /DE	NE _{ga} /DE	DE (%)	GE (MJ/day)	FI (kg dm/day)	Y _m	EF CH ₄ (kg/hd/yr)
Beef calves (<1 yr)	29.2	0.514	0.308	65	105	5.7	0.06	35
Calves, Males for Rep. (<1 yr)	31.1	0.514	0.308	65	111	6.0	0.06	44
Calves, Females for Rep. (<1 yr)	26.3	0.514	0.308	65	95	5.1	0.06	37
Males 1-2 yrs	50.7	0.495	0.278	60	192	10.4	0.05	67
Beef Fem. 1-2 yrs	36.0	0.495	0.278	60	134	7.2	0.05	46
Females for R. 1-2 yrs	36.0	0.495	0.278	60	134	7.2	0.06	53
Steers (>2 yrs)	60.2	0.495	0.278	60	212	11.5	0.06	84
Heifers for Beef (>2 yrs)	40.3	0.495	0.278	60	143	7.8	0.06	56
Heifers for Rep. (>2 yrs)	40.3	0.495	0.278	60	143	7.8	0.06	56
non-dairy cows	53.0	0.495	0.278	60	178	9.7	0.06	70
Average (1998)	41.3	0.502	0.289	62	146	7.9	0.06	56

These estimates were assumed representative of the situation when the database was compiled, in 1998. The evolution of the average carcass weight at slaughter, Figure 6.10, was used to add a time trend to the estimated quantities, assuming that overall parameters at a given year (Par_x) could be approximately related to carcass weight in the same year ($Cweight_x$), from the values of the parameters and weight at base year (Par_{base} and $Cweight_{base}$) by the power function used for NE_m . This procedure resulted in an average CH_4 emission factor per animal in 2010, 5.9 per cent higher than the corresponding 1990 value.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 6.10 – Average carcass weight at slaughtering. Total Cattle



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Following recommendations for clarification made by the 2010 review team, the next table shows C_{weight} values used for estimating CH_4 EF from 1990 to the last inventory year.

Table 6.8 – Determination of the methane emission factor – C_{weight}

Sub-class	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Carcass (numbers)	436 055	463 070	443 833	422 377	326 507	325 093	307 741	348 550	282 266	275 244	276 788	248 162
Carcass Weight (t)	108 650	118 676	113 782	106 710	87 367	94 568	88 368	95 210	78 927	77 948	79 818	73 318
Cweight (kg/hd)	249	256	256	253	268	291	287	273	280	283	288	295
Factor (%) ⁽ⁱ⁾	102.5	102.5	101.6	98.0	99.2	102.1	99.3	99.0	100.0	100.9	100.6	99.7

Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carcass (numbers)	284 058	283 612	320 336	314 255	302 520	283 281	306 031	294 226	270 810	-	-
Carcass Weight (t)	82 286	81 594	95 227	92 185	84 982	78 745	87 508	79 843	72 860	-	-
Cweight (kg/hd)	290	288	297	293	281	278	286	271	269	-	-
Factor (%) ⁽ⁱ⁾	102.3	103.7	106.0	104.8	112.6	109.6	113.6	109.2	104.5	-	-

Table 6.9 – Methane emission factor values (kgCH₄/hd/yr) per animal sub-class for all time series

Parameter	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Beef calves (<1 yr)	31.9	32.6	32.6	32.3	33.7	35.9	35.5	34.2	34.8	35.2	35.6	36.3
Calfs, Males for Rep.(<1 yr)	40.0	40.9	40.9	40.4	42.2	44.9	44.5	42.9	43.6	44.0	44.6	45.4
Calfs, Females for Rep.(<1 yr)	34.1	34.9	34.9	34.5	36.0	38.3	38.0	36.6	37.2	37.6	38.1	38.8
Males 1-2 yrs	61.7	63.0	63.0	62.4	65.1	69.3	68.6	66.1	67.3	67.9	68.9	70.1
Beef Fem. 1-2 yrs	42.4	43.4	43.4	42.9	44.8	47.7	47.2	45.5	46.3	46.7	47.4	48.2
Females for R. 1-2 yrs	48.3	49.3	49.3	48.8	50.9	54.2	53.7	51.7	52.6	53.1	53.8	54.8
Steers (>2 yrs)	76.7	78.3	78.3	77.5	80.9	86.1	85.3	82.1	83.6	84.4	85.5	87.1
Heifers for Beef (>2 yrs)	51.7	52.8	52.9	52.3	54.6	58.1	57.5	55.4	56.4	56.9	57.7	58.8
Heifers for Rep. (>2 yrs)	51.7	52.8	52.9	52.3	54.6	58.1	57.5	55.4	56.4	56.9	57.7	58.8
non-dairy cows	64.4	65.8	65.8	65.1	67.9	72.3	71.6	69.0	70.2	70.9	71.9	73.2
Average	50.0	51.1	50.9	50.5	53.0	56.8	56.7	54.9	55.9	56.2	56.9	57.8

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Beef calves (<1 yr)	35.8	35.6	36.5	36.1	34.9	34.7	35.4	34.1	33.8	-	-
Calfs, Males for Rep.(<1 yr)	44.8	44.6	45.7	45.2	43.8	43.4	44.3	42.6	42.4	-	-
Calfs, Females for Rep.(<1 yr)	38.2	38.0	39.0	38.6	37.3	37.0	37.8	36.4	36.1	-	-
Males 1-2 yrs	69.1	68.7	70.5	69.8	67.5	67.0	68.4	65.8	65.4	-	-
Beef Fem. 1-2 yrs	47.5	47.3	48.5	48.0	46.4	46.1	47.1	45.3	45.0	-	-
Females for R. 1-2 yrs	54.0	53.7	55.1	54.5	52.8	52.4	53.5	51.4	51.1	-	-
Steers (>2 yrs)	85.8	85.4	87.5	86.7	83.9	83.2	85.0	81.7	81.2	-	-
Heifers for Beef (>2 yrs)	57.9	57.6	59.1	58.5	56.6	56.2	57.4	55.2	54.8	-	-
Heifers for Rep. (>2 yrs)	57.9	57.6	59.1	58.5	56.6	56.2	57.4	55.2	54.8	-	-
non-dairy cows	72.1	71.7	73.5	72.8	70.5	69.9	71.4	68.7	68.2	-	-
Average	56.9	56.6	57.9	57.5	55.9	55.7	57.1	55.0	54.6	-	-

6.3.1.3.1.3 Sheep and Goats

The same database from the Ministry of Agriculture that was referenced previously for non dairy cattle, includes also information for the twelve⁸⁹ native Portuguese breeds of sheep and the five native Portuguese breeds of goats⁹⁰. Three imported breeds of sheep⁹¹ are also referenced, but no characterization data was available for them. The database includes information such as the number of registered animals, the number of producers, products (milk, meat or wool), dominant reproductive period, weaning age, age at slaughtering, weight (birth, 90 days and adult weight, distinguishing males from females), milk production, wool production (for sheep, males and females) and territorial distribution.

In a mode similar to that used for cattle, the energy model proposed in the IPCC Good Practices (IPCC,2000) for sheep was used. Net energy was estimated from the formulae set:

$$NE_m = CF_i * (Weight)^{0.75}$$

$$NE_a = C_a * Weight$$

$$NE_g = \{WG_{Lamb} * [a + b * BW]\}$$

⁸⁹ Campaniça, Churra Algarvia, Churra Badana, Churra da Terra Quente, Churra Galega Bragançana, Churra Galega Mirandesa, Merina Branca, Merina Preta, Merina da Beira Baixa, Mondegueira, Saloia and Serra da Estrela.

⁹⁰ Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

⁹¹ Assaf, Ile de France and Merino Precoco.

$$NE_l = \text{milk}_{\text{Yield}} * EV_{\text{milk}} / 365$$

$$NE_p = C_{\text{pregnancy}} * NE_m$$

$$NE_{\text{wool}} = \text{Wool}_{\text{Prod}} * EV_{\text{wool}} / 365$$

Needs of digestible energy, and finally Gross Energy Intake (GE), expressed in energy, and Feed Intake (FI), expressed in dry matter ingested, were estimated from:

$$NE_{\text{ma}}/DE = 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE)$$

$$NE_{\text{ga}}/DE = 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE)$$

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

$$FI = GE / ED$$

where, the following variables and parameters are estimated:

NE_m – net energy required by the animal for maintenance, MJ/day;

NE_a – net energy for animal activity, MJ/day;

NE_g – net energy needed for growth, MJ/day;

NE_l – net energy for lactation, MJ/day;

NE_p – net energy required for pregnancy, MJ/day;

NE_{wool} – net energy for wool production, MJ/day;

GE – gross energy, MJ/day;

FI – Feed Intake, kg dm/day;

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

NE_{ga}/DE - ratio of net energy available for growth in a diet to digestible energy consumed;

DE - digestible energy expressed as a percentage of gross energy

Weight - live-weight of animal, kg/hd;

WG_{Lamb} – weight gain of lamb, between weaning (Bi) and adult age or slaughter (Bf), kg/day;

BW – Average body weight of Lamb, between weaning and slaughter/ adult age, kg/hd;

Milk_{Yield} – milk production for lamb pre-weaning feeding and milk production, kg/year;

Wool_{Prod} – Wool production per animal and year, kg;

C_{fi} - a coefficient for maintenance, specific of each animal class;

C_a – activity coefficient corresponding to the feeding situation of the animal;

a, b – parameters dependent on sex of animal, used in the determination of $a + b * BW$, the Energy Value of the Weight gain, MJ/kg;

EV_{milk} - the energy value for milk, MJ/kg;

EV_{wool} - energy value of the wool produced, MJ/kg;

$C_{pregnancy}$ = pregnancy coefficient.

Estimates were done individually for each race and distinctly for ewes, does, lambs (for slaughtering), kids (slaughtering) and males (rams, bucks and young males). Parameters and final energy values were averaged using the number of registered animals as weighting factor and are presented in the next set of tables.

Table 6.10 – Parameters used in determination of Net Energy ingestion for sheep and goats. Weighted averages of individual breed per sub-class animal type.

Sub class	Sheep			Goats		
	Ram	Ewe	Lambs	Buck	Doe	Kids
Lifetime (day/year)	365	365	80	365	365	53
W (kg)	79.9	53.8	9.5	37.5	28.5	5.0
C_{fi}	0.250	0.217	0.254	0.315	0.315	0.315
NE_m (MJ/day)	6.64	4.30	1.36	3.57	2.97	0.93
C_a^i	0.017	0.017	0.017	0.024	0.024	0.024
NE_a (MJ/day)	1.39	0.93	0.17	0.90	0.68	0.12
WG (kg/day)	-	-	0.196	-	-	0.160
NE_g (MJ/day)	-	-	1.26	-	-	0.78
Wool (kg/yr)	6.5	3.6	-	-	-	-
NE_{wool} (MJ/day)	0.43	0.23	-	-	-	-
$C_{pregnancy}$	-	0.075	-	-	0.066	-
NE_p (MJ/day)	-	0.32	-	-	0.20	-

i) Sheep - Average for different feeding situations: grazing flat and hilly pasture. Goats – Grazing hilly pasture.

Table 6.11 – Parameters used in determination of Net Energy ingestion lactation for sheep and goats. Weighted averages of individual breed per sub-class animal type.

Specie	Ewe	Doe
Milk Production for suckling (kg/young/day)	0.981	0.802
Weaning age (days)	42	30
Offsprings (nr/female/yr)	0.97	0.85
Average Milk Production for off-spring suckling (kg/day)	0.104	0.056
Milk Production (kg/season)	55	427
Milking period (days/yr)	153	234
Milk Production (kg/day)	0.151	1.169
Total Avg. Milk Production (kg/day)	0.255	1.225
Energy Density of Milk (MJ/kg)	4.60	2.80
NE_l - Milk Production per day (MJ/day)	1.17	3.43

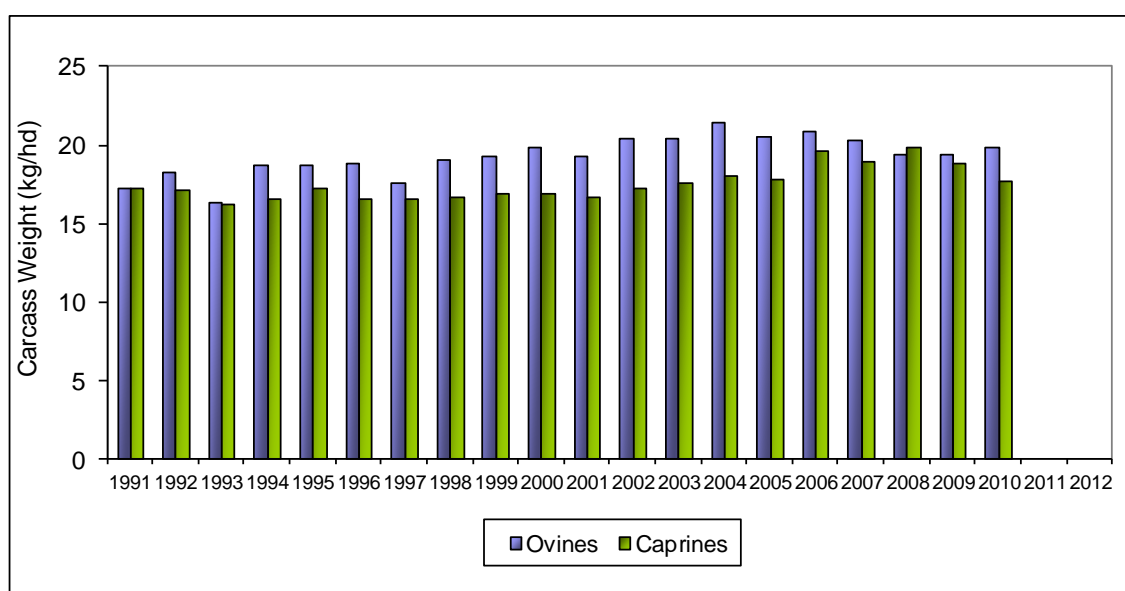
Table 6.12 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Ym) and Emission Factor of CH₄ emissions from Enteric Fermentation for sheep and goats. Weighted averages of individual breeds.

Sub-class	Sheep			Goats		
	Ram	Ewe	Lamb	Buck	Doe	Kid
NEma/DE	0.495					
NEga/DE	0.278					
DE (%)	60					
GE (MJ/day)	29.60	24.06	12.67	15.07	24.55	8.19
FI (kg dm/day)	1.60	1.30	0.69	0.82	1.33	0.44
Ym	0.06			0.05		
EF (kg CH ₄ /hd/yr)	11.6	9.5	5.0	4.9	8.1	2.7

Data on the average carcass weight at slaughter, Figure 6.11, is also available for Sheep and Goats. The time series for sheep shows a trend in animal size that was used, in a similar mode that was already explained for non-dairy cattle, to add a time trend to the estimated quantities, assuming that overall parameters at a given year (Par_x) could be approximately related to carcass weight in the same year ($Cweight_x$), from the values of the parameters and weight at base year (Par_{base} and $Cweight_{base}$). This procedure resulted in the CH₄ emission factors for ovine per animal being 15.2 per cent higher in 2010 than the corresponding values in 1990. An equivalent trend for goats is not visible, reflecting probably the lesser efforts made in the improvement of this specie.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 6.11 – Average carcass weight at slaughtering. Total sheep and total goats



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Following recommendations for clarification made by the 2010 review team, the next table shows C_{weight} values used for estimating CH₄ EF from 1990 to the last inventory year.

Table 6.13 – Determination of the methane emission factor - Ovines – C_{weight}

Sub-class	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Carcass (numbers)	183 478	177 547	141 768	233 548	153 228	145 499	129 211	144 632	100 041	76 177	68 700	74 903
Carcass Weight (t)	3 213	3 075	2 602	3 814	2 875	2 724	2 446	2 547	1 913	1 469	1 363	1 450
Cweight (kg/hd)	17.5	17.3	18.4	16.3	18.8	18.7	18.9	17.6	19.1	19.3	19.8	19.4
Factor (%) ⁽ⁱ⁾	91.6	90.6	96.0	85.4	98.1	97.9	99.0	92.1	100.0	100.8	103.8	101.2

Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carcass (numbers)	65 518	49 520	39 963	43 814	46 188	58 906	72 642	76 451	75 807	-	-
Carcass Weight (t)	1 337	1 011	860	903	965	1 198	1 410	1 484	1 512	-	-
Cweight (kg/hd)	20.4	20.4	21.5	20.6	20.9	20.3	19.4	19.4	19.9	-	-
Factor (%) ⁽ⁱ⁾	106.7	106.8	112.5	107.8	109.3	106.4	101.5	101.5	104.3	-	-

Table 6.14 – Determination of the methane emission factor - Caprines – C_{weight}

Sub-class	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Carcass (numbers)	42 687	42 687	53 063	38 729	47 363	45 980	50 121	45 604	38 997	28 457	22 192	16 348
Carcass Weight (t)	740	740	909	632	786	793	833	755	654	483	375	273
Cweight (kg/hd)	17.3	17.3	17.1	16.3	16.6	17.2	16.6	16.6	16.8	17.0	16.9	16.7
Factor (%) ⁽ⁱ⁾	103.4	103.4	102.1	97.3	99.0	102.8	99.1	98.7	100.0	101.2	100.8	99.6

Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carcass (numbers)	14 239	12 102	7 563	3 809	5 755	6 804	6 638	6 789	6 407	-	-
Carcass Weight (t)	246	213	137	68	113	129	132	128	114	-	-
Cweight (kg/hd)	17.3	17.6	18.1	17.9	19.6	19.0	19.9	18.9	17.8	-	-
Factor (%) ⁽ⁱ⁾	103.0	104.9	108.0	106.5	117.1	113.1	118.6	112.4	106.1	-	-

Table 6.15 – Methane emission factor values (kgCH₄/hd/yr) per animal sub-class for all time series - Ovines

Parameter	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Ewes	8.3	8.3	8.7	7.9	8.8	8.8	8.9	8.4	8.9	9.0	9.2	9.0
Rams and young males	10.8	10.8	11.3	10.3	11.5	11.5	11.6	10.9	11.6	11.7	12.0	11.8
Lambs	4.6	4.6	4.8	4.4	4.9	4.9	4.9	4.7	5.0	5.0	5.1	5.0
Average	8.5	8.5	8.9	8.2	9.1	9.1	9.2	8.7	9.2	9.3	9.4	9.0

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ewes	9.4	9.4	9.8	9.4	9.5	9.4	9.0	9.0	9.2	-	-
Rams and young males	12.2	12.2	12.7	12.3	12.4	12.2	11.8	11.8	12.0	-	-
Lambs	5.2	5.2	5.4	5.3	5.3	5.2	5.0	5.0	5.1	-	-
Average	9.2	9.1	9.5	9.3	9.4	9.2	8.9	8.9	9.0	-	-

Table 6.16 – Methane emission factor values (kgCH₄/hd/yr) per animal sub-class for all time series - Caprines

Parameter	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Does	8.0	8.0	8.0	7.7	7.8	8.0	7.8	7.8	7.9	7.9	7.9	7.8
Bucks and young males	5.1	5.1	5.0	4.8	4.9	5.0	4.9	4.9	4.9	5.0	5.0	4.9
Kids	2.8	2.8	2.7	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Average	6.9	6.9	6.8	6.6	6.7	6.9	6.7	6.7	6.7	6.8	6.8	6.9

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Does	8.0	8.1	8.3	8.2	8.8	8.6	8.9	8.6	8.2	-	-
Bucks and young males	5.1	5.1	5.2	5.2	5.6	5.4	5.6	5.4	5.2	-	-
Kids	2.7	2.8	2.8	2.8	3.0	2.9	3.1	2.9	2.8	-	-
Average	7.1	7.3	7.5	7.4	7.9	7.7	8.0	7.7	7.4	-	-

Swine and Rabbits

The methodology used by the French I.N.R.A. (INRA, 1984) was used to estimate feed intake for each swine sub-class, according to the following formula:

$$GE = \text{Feed}_{ED} / (DE / 100)$$

Where,

GE – gross energy, MJ/day;

Feed_{ED} – Recommended feed ingestion, expressed in digestible energy, MJ ED/day;

DE - digestible energy expressed as a percentage of gross energy, per cent.

The characteristics of each animal class as they were used to derive final emission factors for CH₄ emissions from enteric fermentation were obtained from INRA (1984) for each animal sub-class and are presented in Table 6.17.

Table 6.17 – Parameters used in determination of Gross Energy (GE) ingestion and enteric fermentation methane emission factor by swine and rabbits (all values INRA (1984))

sub-class	Weight (kg)	DE (MJ/day)	DE (% GE)	EF (kg CH ₄ /h/y)	Ym	Notes
Swine						
Piglets (<20 kg)	10	6.2	79.4	0.31	0.006	Avg. 22 d. to 20 kg
Fattening Pigs (20-50 kg)	35	23.4	72.6	1.27		Regression
Fattening Pigs (50-80 kg)	65	34.5	72.6	1.87		DE = 17.93*Ln(W)-40.13
Fattening Pigs (80-110 kg)	95	41.3	72.6	2.24		(r2 - 0.998)
Fattening Pigs (> 110 kg)	120	45.5	72.6	2.47		
Boars (>50 kg)	250	32.4	68.0	1.88		
Sows, pregnant	170	31.4	68.0	1.82		Sow in gestation
Sows, non-pregnant	195	64.9	68.0	3.75		Sow in lactation
Rabbits						
Reproductive Female	-	12.6	56.7	3.63	0.025	per female cage. The Ym is the IPCC default for Horses

6.3.1.3.1.4 Poultry⁹²

The methodology that was used to derive Gross Energy ingestion is similar to that used for swine and rabbits, albeit Metabolic Energy (ME) is used as indicator of feed ingestion, and digestibility is replaced by Metabolisability (McDonald et al, 2002; INRA, 1985):

$$GE = \text{Feed}_{ME} / (EM/GE / 100)$$

Where,

GE – gross energy, MJ/day;

Feed_{ME} – Recommended metabolic energy ingestion, MJ/day;

EM/GE - Metabolisability, metabolic energy expressed as a percentage of gross energy, per cent.

Table 6.18 – Parameters used in determination of Gross Energy ingestion by Poultry

Animal Type	Energy Intake (MJ EM/day)	Metabolizability (EM/GE)	GE (MJ/day)	Ym
Broiler	1.02	68.3	1.50	NA
Laying hens, eggs production	1.39	63.5	2.20	NA
Laying hens, reproduction	1.36	63.5	2.15	NA
Cocks	1.71	63.5	2.69	NA
Turkeys	3.23	68.0	4.75	NA
Ducks#	1.46	65.8	2.22	NA

used as reference for other fowl

It is importante to point out that for poultry there is no methane conversion rate and thus no enteric fermentation emissions. The choice to include the GE methodology for poultry in this chapter was made to maintaing coherency between animal types.

6.3.1.4 Activity Data

Periodic census to agriculture⁹³ and animal husbandry activities are realized by the National Statistical Institute. In accordance with the requirements of FAO and UE the census are realized with a 10 year interval. The first census was made in 1952/54, followed by exercises in 1968, 1979, 1989, 1999 and 2009. The census made in 1999, RGA99, considered:

- All national territory was surveyed at the same period, from October 1999 till March 2000. Reference year is 1988/89, starting in the 1st of November 1998 and ending in the 31 of October 1999;
- Inquiries were done at each installation by direct interview. Units are individual production units.

⁹² CH₄ emissions from Enteric Fermentation are not estimated for Poultry. Nevertheless GE is estimated for these animal types for the estimate of CH₄ emissions from Manure Management. GE is reported here for better comparison to the GE values for other animal types

⁹³ Referred in Portuguese as Recenseamento Geral da Agricultura (RGA)

The periodic agriculture census is subjected to Quality Control measures by INE. A set of interviews is made to a select number of explorations and the results from the “normal interview” are compared to the results from the “control interview”. The total number of “normal interviews” for the 1999 survey was 636 870 units whereas the sample for control was 15 000 units, 2.4 per cent. Data from 2009 survey was first introduced in the 2012 inventory.

Every two years about 40 000 agriculture explorations are surveyed. Annually livestock numbers for cattle, swine, sheep and goats are estimated using data from surveys made to a sample of about 9000 husbandry farms.

Using that data sources, the National Statistics Institute (INE), built consistent time series of annual livestock numbers from 1987 to 2010 for cattle, swine, sheep, goats, horses, mules and donkeys, disaggregated per region⁹⁴, age and sex.

For the 2010 inventory new activity was obtained concerning the number broilers, hens, turkeys, ducks and rabbits. This new data originated in the Survey of the Agriculture Explorations Structure, which is conducted every two years by INE. Even though data from these surveys are not as reliable as the RGA 99 (as pointed out by INE), they represent a good source of livestock numbers for Poultry and Rabbits. However INE recommended that data for duck and turkeys should not be used because of consistency issues.

Several procedures were undertaken to adjust this new data to our emission estimation requirement:

- Data provided comprises total livestock for Portugal. RGA 99 regional values were used for desagregations proposed;
- Gaps in the livestock time series were corrected with linear interpolation;
- Desegregation between hens for industrial egg production and hens for production of chicks had to be made since this new INE data reported only total hens. The number of hens for industrial egg production and for production of chicks was available in the Regional Agriculture Statistics (INE) from 1990 to 2000. The census made in 1999 (RGA99 from INE) found a substantially higher number of hens, 95 per cent higher than the values reported in the Regional Agriculture Statistics, reflecting the consideration, in the RGA99 census only, of animals in small farms. The original number of hens was corrected by the ratio of each kind of hens reported in the Regional Statistics.

For turkeys and duck the previously applied procedures for estimating the livestock number were maintained:

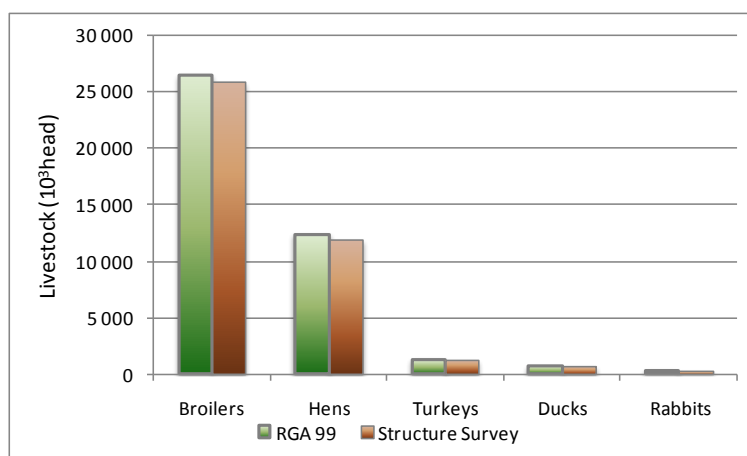
- Turkeys. The livestock from the 1999 census (RGA99) was considered to be the most representative of total population, including both animals in industrial units and in small farms. The full time series was constructed by extrapolation, using number of animals slaughtered as driver;

⁹⁴ A total of 9 regions were available: the 5 regions in Continental Portugal (NUT II level), Norte, Centro, Lisboa e Vale do Tejo, Alentejo and Algarve; subdivision of two of these regions in two sub-regions each (Norte divided in Entre-Douro-e-Minho and Trás-os-Montes, and Centro divided in Beira Litoral e Beira Interior); and the two Autonomous regions of Azores and Madeira.

- Ducks, geese, guinea - fowl and other poultry. Because the only available information concerns the Statistical census, RGA99, and also because there are no reliable information to establish a surrogate driver, a constant number of animals was assume in the all period.

In the following figure, a comparison between the data reported in RGA 99 and Explorations Structure Survey (for 1999) has been made (1999 is the only year with information for both data sources):

Figure 6.12 – Livestock numbers for different kind of Poultry and Rabbits – Comparison between RGA 99 and Explorations Structure Survey.



For all animal types the value that was considered as activity data is the average of the last three years, i.e: the activity data reported for year n (1990 given as example) is the average of livestock numbers for n-2, n-1 and n (1988, 1991 and 1992).

All original figures in statistical database represent stock numbers at a particular time of the year, mostly December and consequently for some species with strong seasonal reproducing periods, such as goats and sheep, these numbers had o be corrected and converted in average annual population. The seasonal correction was found not to be necessary for the other animal types.

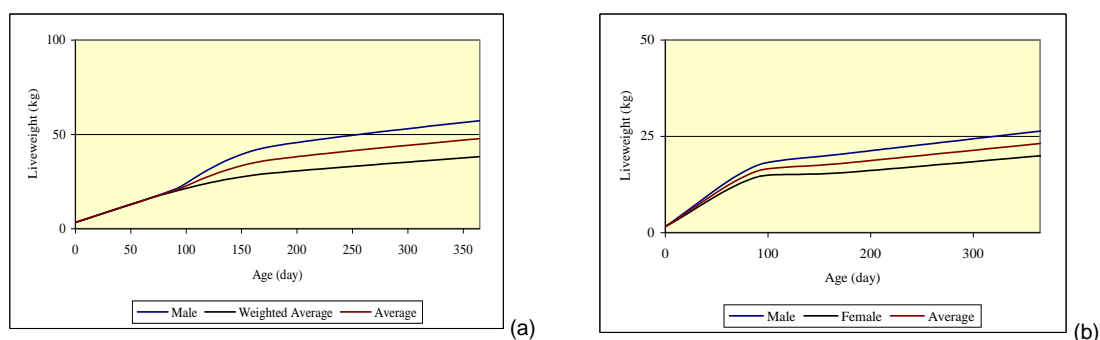
The annual number of lambs and kids was set from the number of registered slaughtered animals, as published by the Regional Statistics. The number of lambs and kids reported as activity data represents the equivalent annual average of animals, i.e.:

$$\text{lambs/kids (hd)} = \text{Annual Slaughter (hd/yr)} * \text{Age_Slaughter (days)} / 365$$

The age at which slaughter occurs (Age_Slaughter) was determined from the inverse function of the growth models⁹⁵ for both species, Figure 6.13, using the weight at slaughter that was determined from the information in the Regional Statistics (INE), which values are presented in Figure 6.14. Resultant average ages vary from 107 to 113 days for sheep and 73 to 102 days for kids.

⁹⁵ Model set from the information on the breeds existent in Portugal, complemented by information in Jarrige (1988) concerning growth pattern.

Figure 6.13 – Growth Model for Sheep (a) and Goats (b)



For both caprine and ovine animals there is a very appreciable variation of number of slaughtering according to months, as may be seen in Figure 6.15 for two subsequent years (GPPAA,2004). The importance of the periods of Christmas and Easter is evident. From this data, the population of lambs and kids was estimated for the beginning of each month (day 1), considering that at that moment were alive all animals killed in that same month and in the subsequent months according to the average age when young animals are killed. The ratio of population of young animals in the first of December (reference data for RGA99) to the average annual population, estimated to be 1.17 for sheep and 1.89 for goats, was used to estimate lamb and kids population in the moment of the RGA. The number of animals remaining from the total ovine and caprine numbers after subtraction of number of females (ewes and does) and the number of youngsters (lambs and kids) is reported as “Other Ovines” and “Other Caprines”. These animals are mostly adult males, but also young animals that are kept to reproductive functions and are not slaughtered.

Figure 6.14 – Average carcass weight at slaughtering. Lambs and Kids

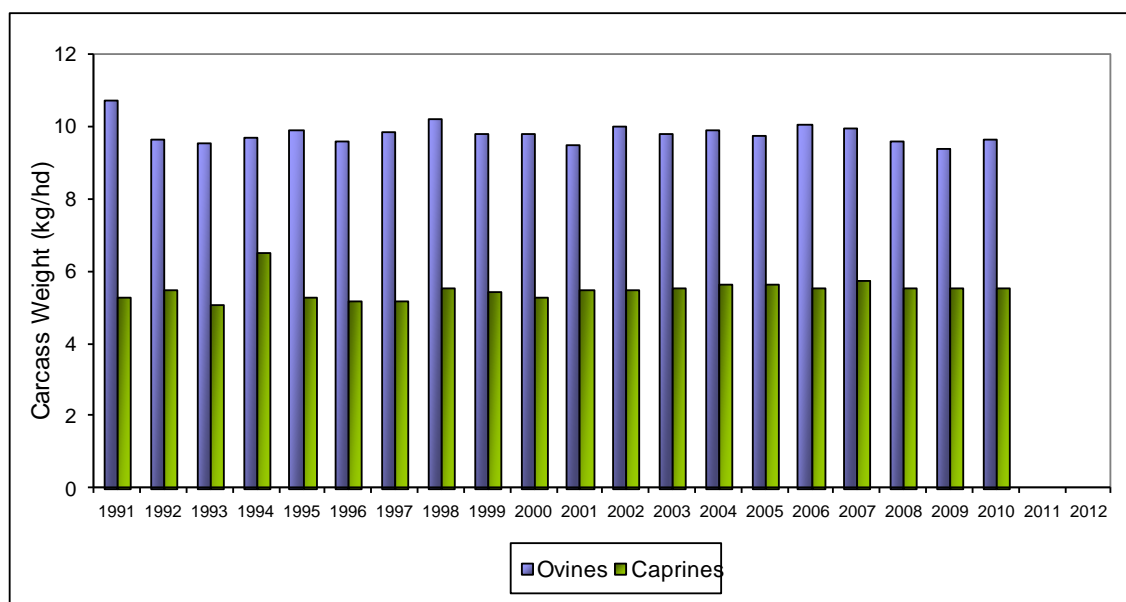


Figure 6.15 – Number of slaughtered young animals in each month for the years 2001 and 2002

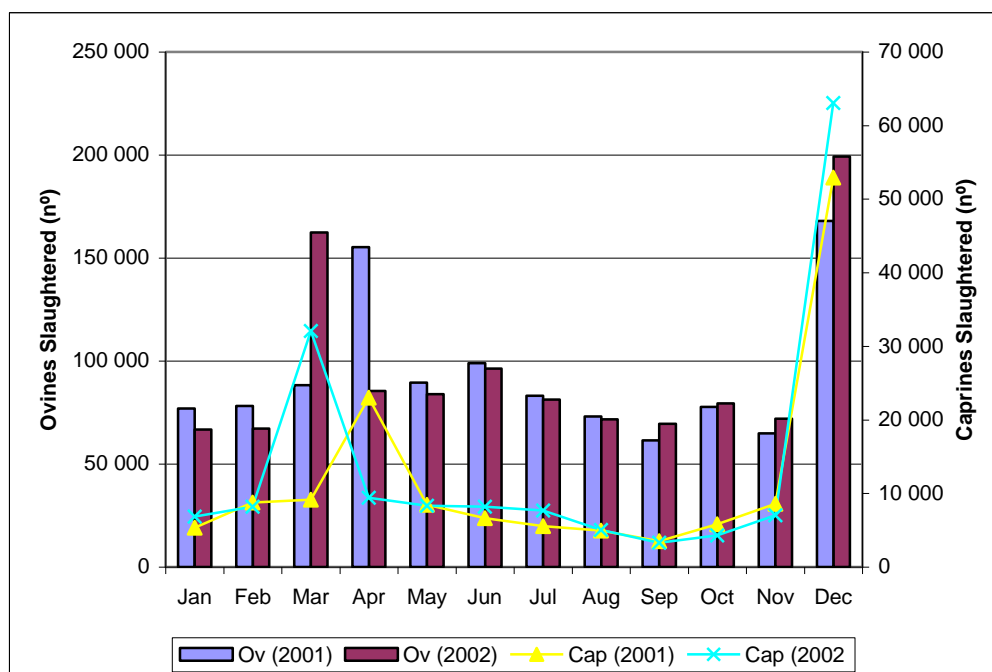


Table 6.19 - Livestock Numbers (Thousands)

Animal	Sub-class	1990	1995	2000	2005	2009	2010
Dairy-Cattle	Dairy cows	394	383	353	290	263	255
Non-dairy cattle	Beef calves (<1 yr)	46	60	67	104	109	114
	Calves M.Rep. (<1 yr)	186	162	144	136	123	123
	Calves F Rep. (<1 yr)	177	158	174	183	169	171
	Males 1-2 yrs	112	103	82	81	72	66
	Beef Fem. 1-2 yrs	18	22	17	17	18	20
	Females rep. 1-2 yrs	111	109	127	135	142	137
	Steers (>2 yrs)	38	33	26	25	34	38
	Heifers Beef (>2 yrs)	4	10	6	9	10	12
	Heifers rep. (>2 yrs)	45	52	67	94	102	110
	non-dairy cows	242	273	345	397	436	438
Swine	Piglets (<20 kg)	727	726	663	574	602	597
	Fatt. Pigs (20-50 kg)	662	660	585	467	460	448
	Fatt. Pigs (50-80 kg)	525	525	483	368	362	360
	Fatt. Pigs (80-110 kg)	218	198	174	214	237	244
	Fatt. Pigs (> 110 kg)	44	44	38	41	40	36
	Boars (>50 kg)	26	26	20	12	8	7
	Sows, pregnant	210	211	195	191	181	179
	Sows, non-pregnant	124	132	124	68	69	66
Ovines	Ewes	2 292	2 339	2 410	2 293	2 030	1 915
	Other Ovines	662	817	733	254	245	217
	Lambs	307	279	320	302	267	252
Caprines	Does	614	517	460	380	358	356
	Other Caprines	149	151	129	54	47	42
	kids	47	41	33	29	28	27
Equides	Horses	33	48	58	52	42	38
	Asses and Mules.	118	103	69	40	26	22
Poultry	Hens, reproductive	3 421	3 271	2 644	2 480	2 517	2 743
	Hens eggs	7 539	7 745	9 060	7 925	8 042	8 763
	Broilers	18 524	18 813	24 374	18 686	17 915	19 474
	Turkeys	603	827	1 283	1 019	1 140	1 114
	Ducks; Geese; Guinea Fowl	804	804	804	804	804	804
Other	Rabbits	475	401	336	289	255	263

6.3.1.4.1 Quality Assessment of Livestock Numbers

The decrease in dairy cows is consistent with the increase in productivity and the limits EU imposes on milk quotas (GPPAA,2004). More detailed information and critical analysis of the trends can be consulted in the Animal Production Yearbooks, published periodically by the Ministry of Agriculture including a detailed analysis of the animal production sector and the causes, both at national and EU level, which explain the trends⁹⁶.

Livestock numbers⁹⁷ as considered in the inventory, as collected from National Statistics, were compared to livestock numbers for years 1990-2004 for dairy cattle, non-dairy cattle, swine and ovine. Though FAO numbers are not presumably different from National Statistics – and should reflect these last.

Figure 6.16 – Comparison of Livestock numbers between national statistics and FAO database. Values represent the relative per cent difference to National Statistics



The only case where there appears to be a systematic situation is for sheep, whereas for all years FAO livestock numbers are much lower than the reported values in National Statistics. For other species the difference is of smaller relative importance and usually restricted to localized years. The number of horses, mules, asses and turkeys⁹⁸ is very different when comparing statistics from FAO and INE, but they have a small importance in the emissions inventory. The population of laying hens, also from National Statistics, include animals producing eggs for consumption as well as eggs used to obtain broilers and to replace other laying and reproductive animals. Poultry numbers include also animals kept in domestic rural houses and not only animals in farms and agro-industrial places. These two facts explain the

⁹⁶ Reports available at (<http://www.min-agricultura.pt/mediateca>)

⁹⁷ Annual values, not 3 year averages.

⁹⁸ While poultry numbers do not affect emissions of CH₄ from Enteric Fermentation they are discussed here to simplify NIR presentation.

constant higher numbers reported for birds in National Statistics than those reported in FAO database indicating that FAO time-series does not cover the all universe.

This issue has been considered in several review process, and in particular, during the review process of the 2006 Inventory Submission under UNFCCC and of the Informative Inventory Report under the Kyoto Protocol, which took place in 2007. A special effort was made to solve this issue to the Expert Review Team. The comment from Portugal is reproduced below.

“As explained in the FAO message in annex99, sheep numbers refer to an old official reported figure for 1994 (source: Production questionnaire) which is about 5 900 000 sheep. As mentioned by the FAO, the other years have been estimated (by FAO) reaching about 5 500 000 sheep in 2005. The contact person from the National Statistics is unable to confirm the previous sheep data (1994 value), but confirms that the level of magnitude of FAO sheep data is totally incorrect. On the other hand, as FAO states to be willing to change their whole time series in accordance with the INE/EUROSTAT data, this problem will be solved in the future.”

6.3.1.5 *Uncertainty Assessment*

The uncertainty of livestock numbers for cattle is expected to be lower than for other animal types, due to the longer growing period for this specie and also due to the strong control (tagging) that is made on this animals. An almost similar situation may be assumed to the swine population. Herd numbers of sheep and goats are probably less known, mostly because of the strong seasonal character of breeding, because of the younger age at which animals are sacrificed and finally due to the significant importance of auto-consumption. The need to estimate a time-series based on surrogate drivers, and the prevalence of dispersed animals in small farms, naturally causes higher uncertainty values for these animals. Finally, animals that are usually not considered as meat, such as equines, are less controlled and numbers tend to be known with less rigour.

A consistent pattern of values of uncertainty was obtained by making the comparison between values in the national statistics and the time series available from FAO, except for sheep, given the explanations provided in the description of the activity data.

The per cent differences between FAO data and INE time-series¹⁰⁰ was used as an indicator of the uncertainty of livestock numbers, and they are presented in table Table 6.20.

⁹⁹ In the original document to the UNFCCC only.

¹⁰⁰ The comparison was done without 3 year averages were calculated.

Table 6.20 - Uncertainty for livestock population.

Animal Type	U (%)
Dairy - Cattle	6
Non dairy cattle	6
Sheep	19
Goats	19
Pigs	11
Horses	71
Mules and Asses	272
Hens	64
Broilers	41
Turkeys	771
Other	771

The uncertainty of the emission factor was assumed to be 20 per cent for all animals where tier 2 was used and 50 per cent when tier 1 emission factors were used, in accordance with the Good Practice Guidebook (IPCC, 2000).

6.3.1.6 *Category-specific QA/QC and verification*

For this source category QA/QC procedures were focused in the livestock data obtained from INE. Two quality assessments of the livestock numbers were produced:

- Comparison between data from RGA 99 (INE) and data from Structure Survey (also from INE) concerning poultry and rabbits;
- Comparison between livestock data obtained from INE and FAO numbers.

The first analysis is described in the Activity Data chapter and the second in the Quality Assessment of Livestock Numbers chapter.

6.3.1.7 *Recalculations*

The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types (this revised series was given by INE).

For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009).

RGA 2009 AD revision also affected milk yield values (2000-2009).

Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values.

Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine.

Revision of the procedure for adding a time trend to the estimated quantities of the CH₄ emission factor for sheep and goats (1990-2009 except 1998). This new procedure is more in line with the one already in use for non-dairy cattle.

6.3.1.8 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

The tier 2 methodology in use today, although considering an enhanced and detailed characterization of livestock still needs the improvement of specific parameters. Efforts to improve the methodology are expected in the following years, although they will probably only affect the emission estimates in the second commitment period.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

6.3.2 CH₄ Emissions from Manure Management (CRF 4.B.)

6.3.2.1 *Overview*

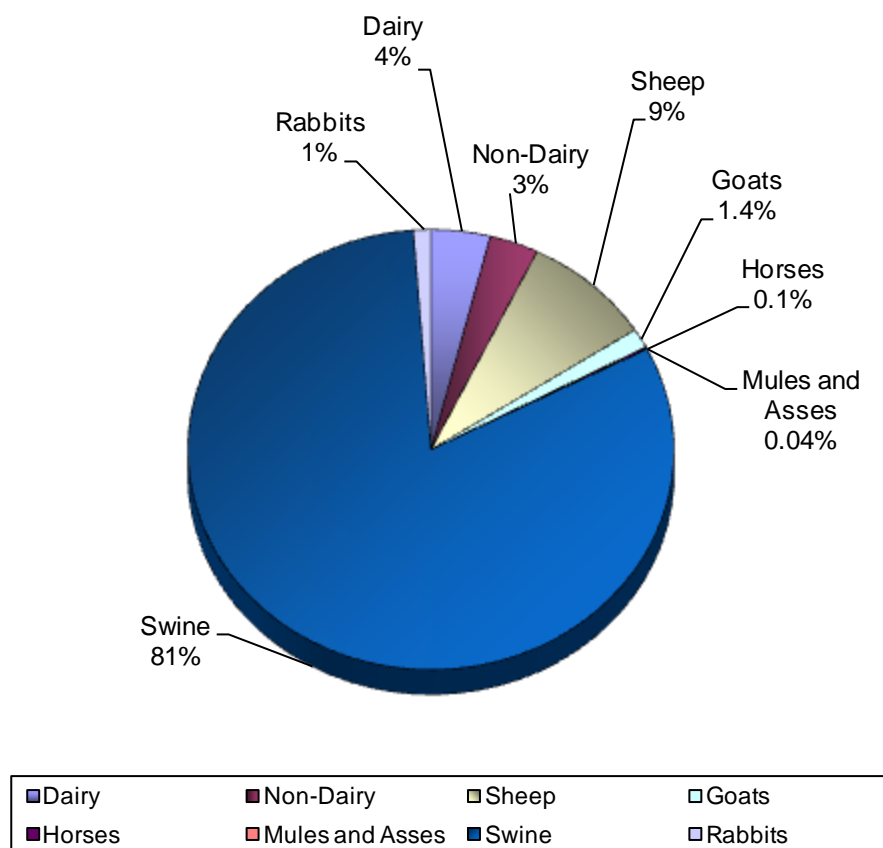
Methane emissions from manure occur when the organic material it contains, either solid or dung or liquid as urine, decomposes, during storage or treatment, in anaerobic environments by the action of methanogenic bacteria. The quantity that is emitted depends mostly of the existence of anaerobic conditions during storage of manure that promotes the activity of methanogenic microorganisms. Methane formation is therefore particularly important in highly anaerobic Manure Management Systems (MMS) such as anaerobic lagoons, anaerobic digesters, accumulation in tanks in liquid or slurry state or where manure remains for a long time residence on stall floor. Methane emissions resulting from manure deposited directly in soil during grazing and pasture, although in small quantities, are also included in this source category¹⁰¹.

In some systems, such as anaerobic lagoons and digesters, the emitted gas may be collected and burned for energy use or simply flared. In these cases, methane emissions to the atmosphere may be significantly reduced.

Methane emission from Manure Management in Portugal is a key source. According to origin of manure by specie, most emissions result from swine manure, with 81 per cent of emissions in 2010, as may be seen in Figure 6.17, and according to the Good Practice rule of thumb this specie is the only significant source.

¹⁰¹ Nitrous oxide emissions from manure deposited in soil during grazing and pasture are nevertheless included in source category N₂O from agricultural soil: Animal production, in accordance with UNFCCC reporting guidelines.

Figure 6.17 - Relative Importance of emissions of CH₄ from Manure Management per each animal species in 2010



6.3.2.2 Methodology

Following the 1996 IPCC Revised Guidelines and the Good Practice Handbook, emission estimates are calculated by the following simple equation (following equation 4.15 of GPG) applied for each animal type and considering emission factors dependent on animal type and climatic conditions. By this procedure both the quantity of manure produced per animal and the storage conditions are included in the determination of the emission factor, and will be discussed thereafter.

$$Emi_{CH_4} = \sum_i \sum_c [EF_{(i,k)} * N_{(i,k)}]$$

where, for each specie:

Emi_{CH_4} = methane emissions from manure management, kg CH₄/year;

$EF_{(i,k)}$ = emission factor for the specific population of animal type i, living in climate region k, kg/head/year;

$N_{(i,k)}$ = total number of animals of type i, living in climate region k, head.

6.3.2.3 Emission Factors

Emissions Factors for each animal type were established according to the tier 2 methodology proposed in GPG (equation 4.17), which considers the use of country specific information concerning the quantity of manure produce per animal and the share of each Manure

Management System that is used for each animal type. The equation used for the calculation of the EF for each animal species is therefore:

$$EF_{(i)} = VS_{(i)} * 365 * Bo_{(i)} * 0.67 * \sum_{jk} MCF_{(jk)} * MMS_{(jk)}$$

$EF_{(i)}$ - annual emission factor for a defined livestock animal specie i (kg/year);

$VS_{(i)}$ - Amount of excretion, expressed in Volatile Solids (VS) for an average animal i in the livestock population (kg VS /day);

$Bo_{(i)}$ - Maximum methane production capacity from manure (m^3/kg VS) for animal specie i. $0.67 kg/m^3$ is methane density;

$MCF_{(jk)}$ - methane conversion factor for each Manure Management System j and for each climate region k;

$MMS_{(jk)}$ - fraction of total manure from animal specie i handled with Manure Management System j and for each climate region k.

B_o values were set according to IPCC96 (IPCC,1997). The amount of volatile solids (VS) excretion per animal was estimated using the same data that was used to calculate Gross Energy (GE) intake for the determination of the emission factors of CH_4 from enteric fermentation, and using equation 4.16 of the Good Practice Guidebook:

$$VS = GE * ED_{feed} * (1-DE/100) * (1-Ash/100)$$

Where

GE – Daily average gross energy feed intake, MJ/day;

ED_{feed} – Energy Density of the feed, assumed constant and equal to $18.45 MJ/kg-dm$;

DE – Digestible energy of the feed, per cent;

Ash – mineral content of feed, per cent.

The next table presents the parameters that were used for each animal class: Digestibility of feed (DE; Ash content in manure (Ash) and the maximum methane production capacity from manure (B_o) for each animal type. VS values change along years as consequence of the change in Gross Energy estimates.

Table 6.21 – Parameters used in the estimate of Volatile Excretion per animal

Animal Class	sub-class	DE (MJ/kg)	Ash (%)	B ₀ (m ³ /kg VS)
Dairy-Cattle	Dairy Cows	60	8	0.24
non-dairy cattle	Calves (<1 yr)	65	8	0.17
	Other animals	60	8	0.17
Swine	Piglets (<20 kg)	79 [#]	2	0.45
	Fattening Pigs	73 [#]	2	0.45
	Sows and Boars	68 [#]	2	0.45
Ovines	All sub-classes	60	8	0.19
Caprines	All sub-classes	60	8	0.17
Equides	Horses	70	4	0.33
	Asses, Mules and hynies	70	4	0.33
Poultry	Hens Reproductive	63 [#]	5 [#]	0.32
	Hens eggs	63 [#]	5 [#]	0.32
	Broilers	68 ^{\$}	2 [#]	0.32
	Turkeys	68 [#]	3 [#]	0.32
	Ducks, Geese and Guinea Fowl	66 [#]	2 [#]	0.32
Other	Rabbits	57 [#]	3 [#]	0.33 (a)

Note: all values IPCC default, except:

- INRA (1984); \$ McDonald et al (2004); (a) Value assumed equal to horses

Expert guess¹⁰², based on survey data and field knowledge of technical personnel of the Ministry of Agriculture was used to establish the percent of each Management System in 1990. The same expertise was used to establish a prevailing trend in the period 1990-2010, considering the practices that are becoming more common and some results of legislation and institutional control. Although the exact year at which the situation changes is unknown, a linear evolution between year 1990 and the target year of 2010 was assumed.

The values for the fraction of manure handled in each MMS were revised for the 2010 submission by the Ministry of Agriculture technical personnel¹⁰³. This revision followed recommendation from the expert review team expressed in the 2009 review process. The MMS changes were only made to the 2010 values (1990 remained the same).

The final IEF of methane emissions from Manure Management, expressed in kg CH₄ per animal, that way derived for Portugal, results in considerable differences when in comparison to the default values in the 1996 Revised IPCC Guidelines (IPCC,1997). The different values are clearly justified by the use of a different share of Management Systems for Manure, which are presented in Table 6.22 and also in Figure 6.18. The country-specific used in Portugal differ from the one proposed in the IPCC default in the following aspects:

- swine manure in Portugal is usually treated in anaerobic lagoons, which have the highest MCF among MMS. A small number of explorations still have short retention pits (< 1 month), whoever due to new legislation constrains higher retention time pits are expected to be adopted in the near future;

¹⁰² Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005.

¹⁰³ Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 7, October 2009.

- the management of wastes from dairy cows kept in stall is split among solid storage and short retention time pits;
- dairy cows in pasture are more common in Portugal than the default assumption in IPCC;
- non dairy cows with milking calves are usually kept on pasture, but fattening animals are usually grown in confined areas. Solid storage was the prevalent method of treatment for wastes from other cattle in 1990, but has since been losing importance;
- daily spread and usage as fuel are practically unknown in Portugal;
- there is a small percentage of traditional swine kept outdoors and foraging in pasture range;
- some poultry is kept outside, either in small farms or industrial production of country poultry;
- there are no substantial seasonal variations in the share of management system.

Table 6.22 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990 and 2010.

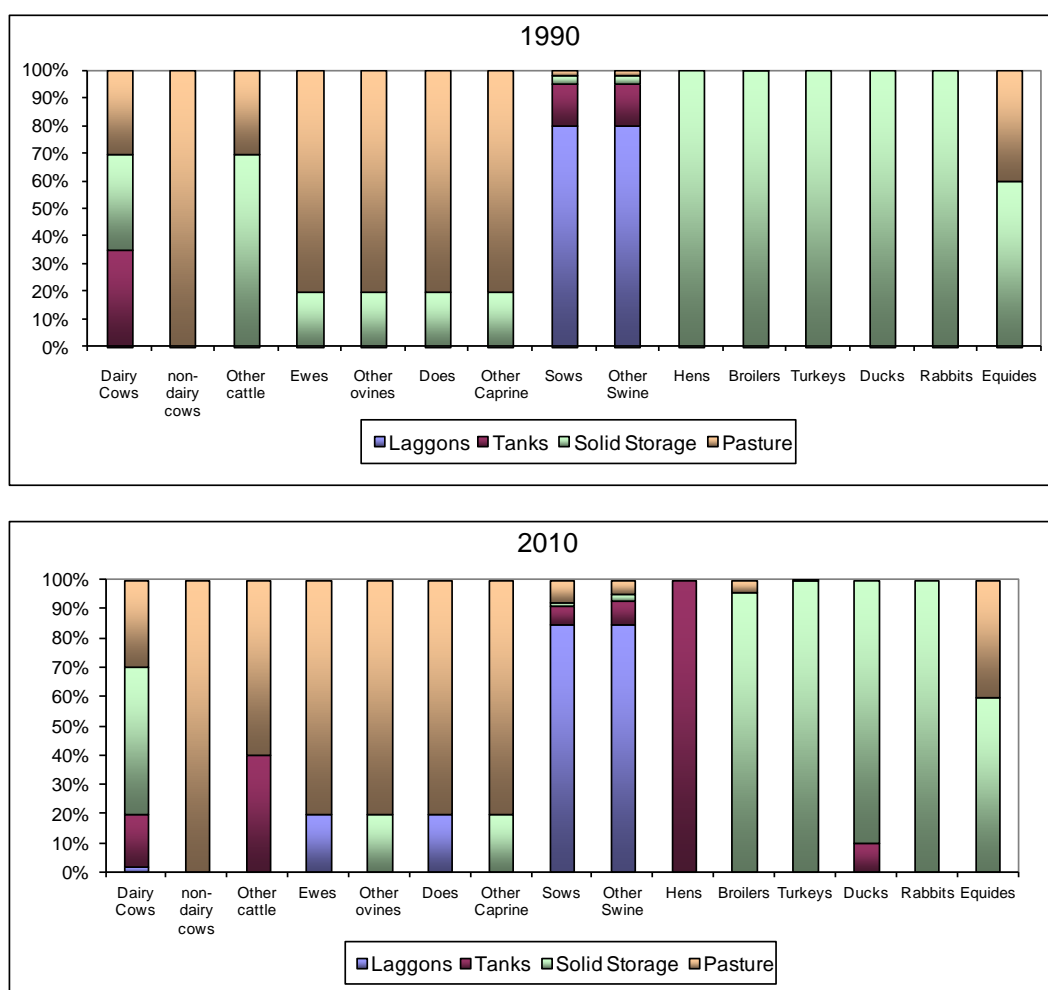
Animal Type	1990					2010				
	Laggons	Tanks	Solid Storage	Pasture	Total	Laggons	Tanks	Solid Storage	Pasture	Total
Dairy Cows	-	35	35	30	100	2	18	50	30	100
Non-dairy cows	-	-	-	100	100	-	-	-	100	100
Other cattle	-	-	70	30	100	-	40	-	60	100
Ewes	-	-	20	80	100	20	-	-	80	100
Other ovine	-	-	20	80	100	-	-	20	80	100
Does	-	-	20	80	100	20	-	-	80	100
Other caprine	-	-	20	80	100	-	-	20	80	100
Sows	80	15	3	2	100	85	6	1	8	100
Other Swine	80	15	3	2	100	85	8	2	5	100
Hens	-	-	100	-	100	-	100	-	-	100
Broilers	-	-	99.9	0.1	100	-	-	96	4	100
Turkeys	-	-	100	-	100	-	-	99.9	0.1	100
Ducks	-	-	100	-	100	-	10	90	-	100
Rabbits	-	-	100	-	100	-	-	100	-	100
Equides	-	-	60	40	100	-	-	60	40	100

Table 6.23 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type.

Animal Type	Laggons	Tanks	Solid Storage	Pasture
Dairy Cows	0.1	-0.85	0.75	-
non-dairy cows	-	-	-	-
Other cattle	-	2	-3.5	1.5
Ewes	1	-	-1	-
Other ovine	-	-	-	-
Does	1	-	-1	-
Other caprine	-	-	-	-
Sows	0.25	-0.45	-0.1	0.3
Other Swine	0.25	-0.35	-0.05	0.15
Hens	-	5	-5	-
Broilers	-	-	-0.195	0.195
Turkeys	-	-	-0.005	0.005
Ducks	-	0.5	-0.5	-
Rabbits	-	-	-	-
Equides	-	-	-	-

Note: values represent the annual increment in the per cent of MMS use. Positive values represent increment in the per cent of the MMS. Negative values represent decrease in use

Figure 6.18 - Percentage of manure handled by each Manure Management System, by animal type in 1990 and 2010



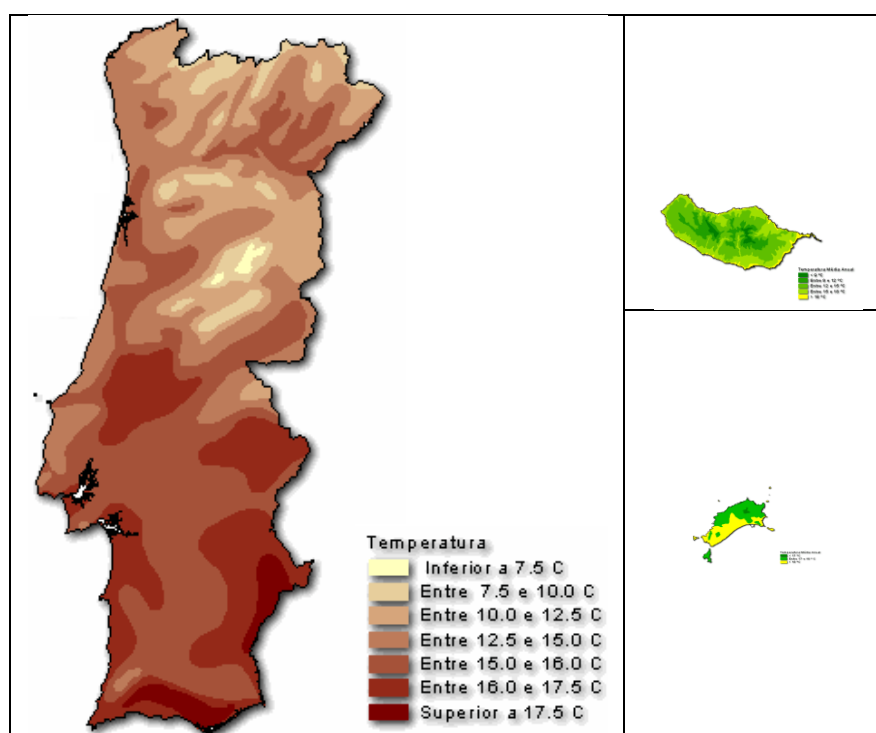
Two climate regions occur in Portugal, in accordance with IPCC definition (IPCC,1997): temperate (annual average temperature between 15°C and 25°C) and cool (annual average temperature below 15°C). Livestock populations living in each climate region were determined according to the following mode:

- the percentage of livestock numbers at each climate region was determined for each *concelho* territorial unit¹⁰⁴ and for each animal sub-type. Within each *concelho* territorial area a homogenous distribution of animals was assumed;
- for each *Concelho* territorial area in mainland Portugal and Madeira archipelago the percentage of land area above and below 15°C was determined using the annual average air temperature map, which is presented in Figure 6.19. All area in Azores islands were considered to be in temperate region;
- livestock numbers per animal type were available at *Concelho* level from two detailed agriculture surveys: RGA89 and RGA99¹⁰⁵. Data for 1999 was

¹⁰⁴ Concelho territorial unit in Portugal is the designation to land areas associated with one municipal administrative authority. There are 306 *concelhos* in Portugal with an average area of 289 km². A nut III level territorial unit is defined as a set of *Concelhos*.

- available for all animal types and for 1989 only for dairy cattle, other cattle, ewes, other sheep, female goats and other goats, sows and other swine;
- livestock numbers in each *Concelho* area were allocated to each climate region, for year 1999, according to the land area percentage, and always assuming an homogeneous distribution of animals in the *Concelho* territorial area. Animal numbers were summed at each Administrative Region (*Região*)¹⁰⁶ for all *Concelhos*, and a per cent of animals in each Region was established, and assumed constant in the period;
- Livestock population in each climate region and by Region was estimated annually from total livestock population in Region and considering the constant share and, finally, the total national livestock population for each region was calculated.

Figure 6.19 – Isothermal map for continental Portugal and Madeira archipelago (IA,1974) (Madeira island not to scale with mainland Portugal)



The percentage of livestock population living in cool climate regions for major animal types in 1990 and 2009, obtained in accordance with the above explained procedure, is presented in Table 6.24.

¹⁰⁵ Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

¹⁰⁶ *Região* in continental Portugal is equivalent to a NUT I level territorial unit. In Azores and Madeira, *Região* is equivalent to the whole autonomous region. There are 7 administrative regions in Portugal.

Table 6.24 – Percentage of livestock population living in climate cool regions in Portugal in years 1990 and 2010.

Animal Type	1990	2010
Dairy Cows	48	40
Other Cattle	43	25
Sheep	29	34
Goats	50	48
Horses	34	42
Mules and Asses	58	70
Swine	22	17
Poultry	41	43
Other	65	65

All the Methane Conversion Factors are the defaults for temperate regions of Western Europe and developed countries:

Table 6.25 - Methane Conversion Factors (MCF), per cent, for determination of CH₄ emissions from Manure Management

MMS	Temperate	Cool
Laggon	45	39
Tanks	0	0
Solid Storage	1.5	1
Pasture	1.5	1

In the 2010 review an issue concerning the CH₄ IEF for swine was identified by the UNFCCC review team: the IEF for 2008 was considered much higher than the IPCC default for Western Europe. In Portugal the majority of manure from swine is treated in anaerobic lagoons (84.5 per cent) contrary to what IPCC considers default (0 per cent). This MMS shows the highest CH₄ conversion factor among all management systems which explains the higher IEF for swine in Portugal.

6.3.2.4 *Activity Data*

In a consistent manner livestock numbers are the same that were used in previous sub-category: CH₄ from enteric fermentation. Although for this source category more species are considered in the emissions estimates, namely birds.

6.3.2.5 *Uncertainty Assessment*

Livestock numbers are considered to be the activity data of this source category and the uncertainty values were equal to uncertainty values discussed for CH₄ emissions from Enteric Fermentation, as explained in the previous chapter.

No recommendations exist in the Good Practice Handbook concerning the uncertainty levels associated with emission factors, and they were set in the following mode:

- total uncertainty in the emission factor was determined calculating the propagation of error in accordance with the equation that was used for the

determination of the Emission Factors and incorporating an additional factor for the consideration of errors in climate region determination;

- uncertainty for the quantity excreted, VS parameter, was set at 20 per cent, considering the use of an enhanced livestock characterization, similar to that used in the derivation of the emission factor of CH₄ from Enteric Fermentation;
- the uncertainty of the allocation of manure for each Manure Management System (MMS) was determined comparing the share patterns that were used in Seixas et al (1999) with the new revised patterns¹⁰⁷. This error was combined with the error associated with the MCF parameter: the uncertainty was assumed to be 100 per cent for Anaerobic Lagoons, given the possible range in the IPCC defaults (IPCC,2000), and Liquid Storage, in this case considering not only the range of IPCC defaults but also the uncertainty in the time period during which the manure is stored; for solid storage and pasture, the uncertainty values of 50 per cent reflect the variation of this parameter;
- the error associated with the parameters B₀ is specie dependent and was establish from the range of possible values in the IPCC, for developed and developing nations. Uncertainty values vary from 10 per cent for horses up to 22 per cent for dairy cows. The uncertainty of the biogas density was assumed not to be determinant of the overall uncertainty value;
- from observation of the climate maps it is evident that, from the particular conditions that affect Portuguese climate, small annual variations in average air temperatures and also mapping techniques could exert a profound modification in the percentage of livestock numbers that are classified as either cool or temperate. Territorial units under each climate class could easily change as much as 30 per cent in either direction, value that was assumed as representative of uncertainty for this factor.

The individual uncertainty values are presented in next table (using as base value 1990).

Table 6.26 – Uncertainty Values of the Emission Factors of CH₄ emissions from Manure Management

Specie	Σ MMS*MCF	VS	Bo	Region	EF
Dairy Cows	43	20	22.9	30	61
Mother cows	62	20	20.6	30	74
Other cattle	42	20	20.6	30	59
Sheep	44	20	15.8	30	59
Goats	44	20	11.8	30	58
Swine	82	20	17.8	30	91
Poultry	54	20	12.5	30	66
Rabbits	54	20	12.5	30	66
Equines	48	20	10.6	30	61

¹⁰⁷ Although these two patterns are not fully independent, they represent information from two different experts, and could be representative of the range of possible values.

6.3.2.6 *Recalculations*

The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types (this revised series was given by INE).

For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009).

Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values.

Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine.

6.3.2.7 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

6.3.3 **CH₄ Emissions from Rice Cultivation (CRF 4.C.)**

6.3.3.1 *Overview*

Methane production is enhanced in rice cultivation areas (rice paddies) due to the prevalence of anaerobic conditions which result from flooding and high levels of organic material in soil surface. The methane that is formed in soil underwater escapes to atmosphere as greenhouse gas emission, as visible bobbles or through transport inside plant stems.

6.3.3.2 *Methodology*

Methane emissions from rice production were estimated following the equation 4.41 of GPG, but simplified because there are no appreciable differentiation in Portugal in what concerns water management regimes or any other conditions that are known to affect emissions from this source sector. Original formula was therefore simplified to:

$$E_{\text{Rice}_{\text{CH}_4(y)}} = EF * \text{Rice}_{\text{Area}(y)} * 10^{-2}$$

where

$E_{\text{Rice}_{\text{CH}_4(y)}}$ - Emission from rice production estimated for year y (ton/yr);

EF - Final emission factor, seasonally integrated and adjusted for management practices ($\text{g/m}^2/\text{yr}$);

$\text{Rice}_{\text{Area}(y)}$ - Area under rice cultivation in year y (ha).

6.3.3.3 *Emission Factors*

According to GPG formulation, the final value for the emission factor results from the multiplication of several factors:

$$EF = E_{fc} * SF_w * SF_o * SF_s$$

where

EF - Final emission factor, seasonally integrated and adjusted for management practices (g/m²/yr);

E_{fc} - Seasonally integrated emission factor for continuously flooded fields without organic amendments (g/m²/yr);

SF_w - Scaling factor for water management regime and ecosystem hydrologic conditions;

SF_o - Scaling factor reflecting organic amendments (rice straw, manure, compost, wastes), because easily decomposable carbon increase methane formation;

SF_s - Scaling factor for soil type.

The default E_{fc} proposed in GPG (20 g/m²/yr) was not used, but replaced by a regional specific E_{fc} that was determined by reference to Schutz et al (1989)¹⁰⁸. Considering the information in tables in the original document¹⁰⁹, the E_{fc} more adjusted to the Portuguese conditions is 31.9 g/m²/yr. This value is slightly lower than the value that is proposed by IPCC96 in table 4-13 for Italy (36 g/m²/yr).

Rice culture in Portugal is almost homogeneous, in what concerns hydrologic management regime and characterized by cultivation being done under irrigated continuous flooded areas, where water regime is controlled by human activity (water diversion, irrigation and dikes). Rice fields are in standing water throughout all rice growing season and are only dried for harvest. All areas under rice cultivation are situated close to river banks almost at sea level. Accordingly the parameter SF_w was set as 1.0.

The time series of the quantity of residues that were burnt or plowed into soil before next crop season, was revised (SF_o was assumed to be 1 in the previous submissions) following the information received from the agriculture experts from the Portuguese Ministry of Agriculture:

- traditionally, stubbles and straw were burnt between crops;
- the use of rice straw as fodder or bedding is not significant, and is not removed from field;

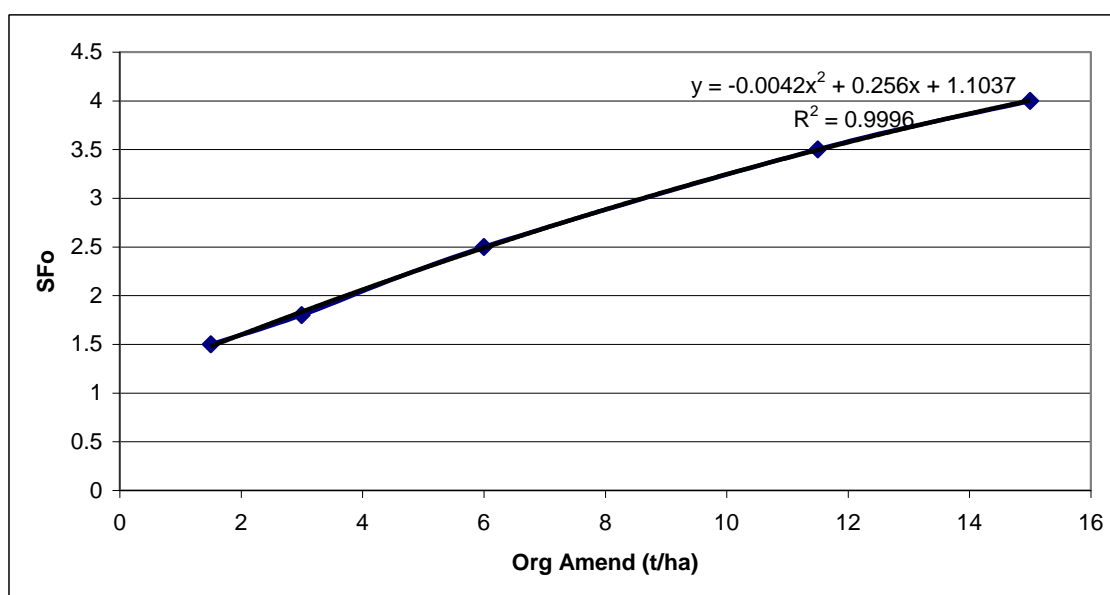
¹⁰⁸ This is one of the original references in IPCC (1997) with specific values for Italy, which conditions, in terms of climate and management, are similar to those in Portugal. Reference to: Schütz, H., A. Holzapfel-Pschorn, R. Conrad, H. Rennenberg and W. Seiler (1989a), "A 3-year continuous record on the influence of daytime, season and fertilizer treatment on methane emission rates from an Italian rice paddy." J. Geophys. Res. 94, 16,405-16,416.

¹⁰⁹ Table 1 - Average Seasonal CH₄ Emission Rates from Unfertilized Rice Paddies (pg 16 409); Table 2 - CH₄ Emission Rates Measured on fields which received Mineral or Organic Fertilizer Applications (pg 16 411); Table 3 - CH₄ Emission Rates in Rice Paddies Fertilized with both organic and Mineral Fertilizers (pg 16 414).

- more recently the agricultural practices have changed (2002 onwards). It became more common to leave the straw on ground and incorporate it into soil by plowing. This procedure is the only allowed if Techniques of Integrated Production and Protection¹¹⁰ are used;
- the area subjected to “Techniques of Integrated Production and Protection” occupied about 51 per cent of rice paddies in 2004. Today this represents about 54 per cent of total area;
- it may be assumed that, in 1990, 100 per cent of rice paddies were burnt and no organic amendments were added to soil. In 2010 the area subjected to burning was reduced to only about 45 per cent.

Total quantities of residues per hectare were estimated from rice production and assuming a residue/crop ratio (1.4) and a dry matter content (85 per cent) (table 4.16 IPCC's GP). Using this information SFO , the scaling factor for organic amendments, was determined using the data in table 4.21 of the GPG¹¹¹. The following regression was set from the original table.

Figure 6.20 – Relation between SFO and the quantity of organic amendments added to soil.



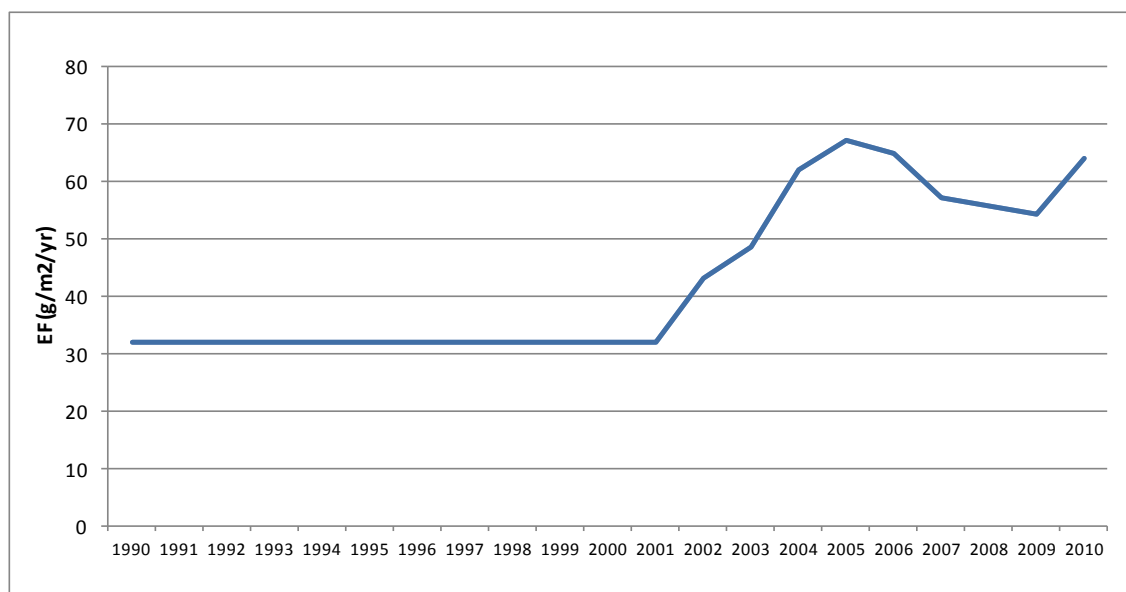
Finally, no information is available to establish influence of soil type and SFs was also set to one.

The overall EF changed over time according to the following graph.

¹¹⁰ “modos de protecção e produção integrada” in the original in Portuguese.

¹¹¹ The available data in Schutz et al (1989) could not be used to estimate this factor in accordance with EF_c .

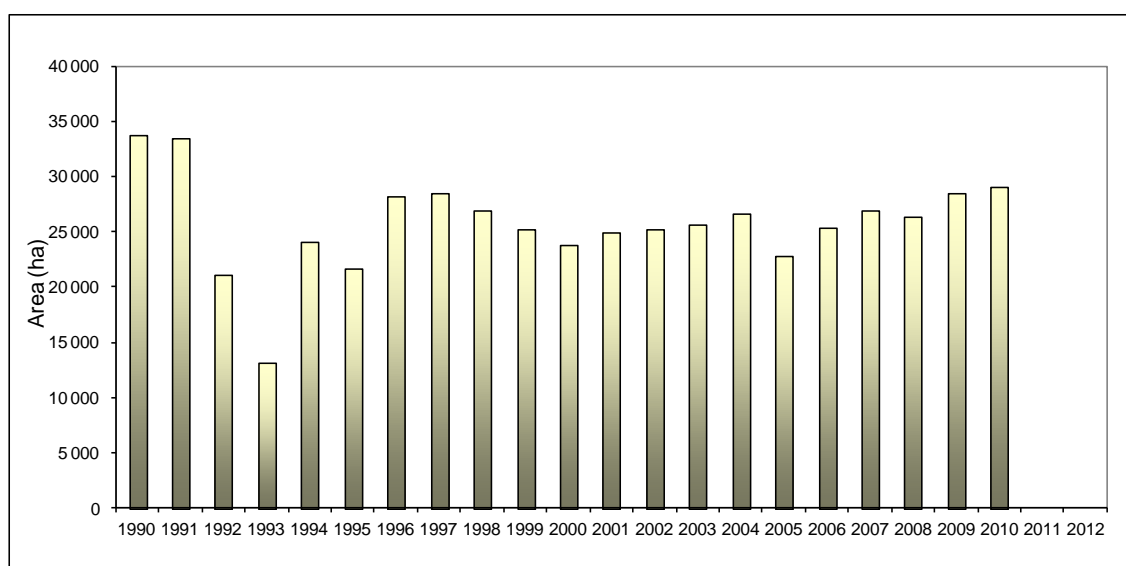
Figure 6.21 – Emission Factor EF used to estimate CH₄ emissions from rice paddies in Portugal (1990-2010)



6.3.3.4 Activity Data

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 6.22. It is noticeable the existence of huge variations in annual rice paddy areas, expressing annual variations in hydrological conditions. There is only one rice crop per year.

Figure 6.22 – Area under rice cultivation in Portugal



Relevant characteristics of rice cultivated areas, such as water management regime, organic amendments and soil type are included already in emission factor setting.

6.3.3.5 *Uncertainty Assessment*

The uncertainty in the adjusted seasonally integrated emission factor was considered to be 40 per cent, according to the range proposed in table 4.22 of the GPG. For activity data, the standard deviation of inter-annual area under rice cultivation was considered, also 40 per cent.

6.3.3.6 *Recalculations*

New data from GPP was obtained concerning areas in Techniques of Integrated Production and Protection. This new data revised the 1996-2009 time series.

6.3.3.7 *Further Improvements*

The establishing of a national integrated emission factor based on collection of data in Portugal would be welcomed but there are no current plans or studies to achieve that goal.

6.3.4 **N₂O Emissions from Manure Management (CRF 4.B.)**

6.3.4.1 *Overview*

Part of the Nitrogen that is in manure, either in faeces or urine is emitted as N₂O during management or during storage of manure, before application to soil, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen.

Emissions of N₂O that occur after manure is deposited in soil, either as a way for disposal or as a fertilizer process, are reported in the category N₂O from agricultural soils and are discussed later. Following the UNFCCC reporting guidelines, emissions of N₂O from dung and urine that are deposited directly into soil during grazing, pasture and in paddocks, are also included in category N₂O from agricultural soils.

In a short description, this is a biological based process where emission of N₂O from manure require the previous oxidation of organic nitrogen in ammonia form, which results from bacterial mineralization of organic nitrogen, into nitrites and nitrates (nitrification, a biological process mediated by bacteria such as *Nitrobacter* and *Nitrosomomas*) in an aerobic environment and thereafter the reduction of this compounds in an anaerobic environment (the denitrification process where nitrate is converted to N₂ and nitrous oxide). Although there is no extensive information concerning the factors that affect this process it is believed that N₂O emissions increase with aeration, at least to finalize the process, and hence increase under opposite conditions that determine methane emissions from solid storage or deposition during grazing and dry lot, which means that are lesser emissions in fully anaerobic systems like liquid systems and anaerobic lagoons.

In terms of the importance of each Manure Management System, observable in Figure 6.23, the great majority of emissions result from solid storage and dry-lot, totalizing on average in the 1990-2010 period 95.4 per cent of total N₂O emissions from Manure Management. The rest comprehends 2.4 per cent of emissions from anaerobic lagoons and 2.2 per cent of total emissions from liquid systems. In terms of origin by animal type¹¹², emissions are dominated by dairy cattle (49.8 per cent), poultry (31.7 per cent¹¹³) which together comprehend about 81.5 per cent of total emissions, as may be seen in Figure 6.24 for the year 2010.

¹¹² Division of emissions per animal type or specie is not required according to CRF reporting format, but it is nevertheless relevant to understand the origin of emissions and the relevance of each specie.

¹¹³ According to the IPCC rule of thumb in figure 4.4 of IPCC (2000), although in strict terms sub-categories for this source category are management systems and not animal species.

Figure 6.23 – Distribution of total N₂O emissions from Manure Management per System in year 2010

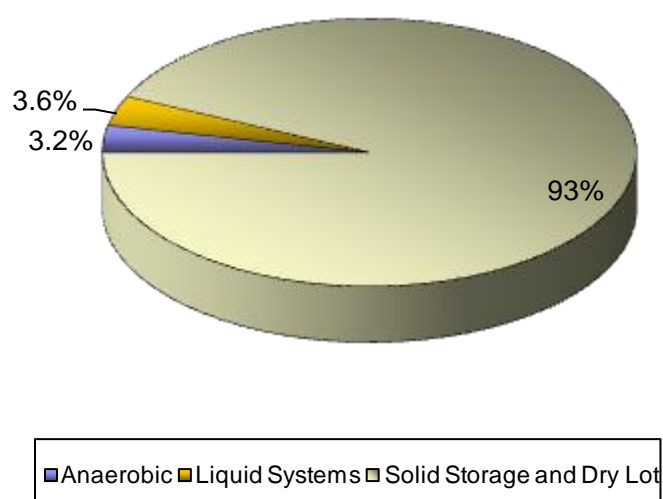
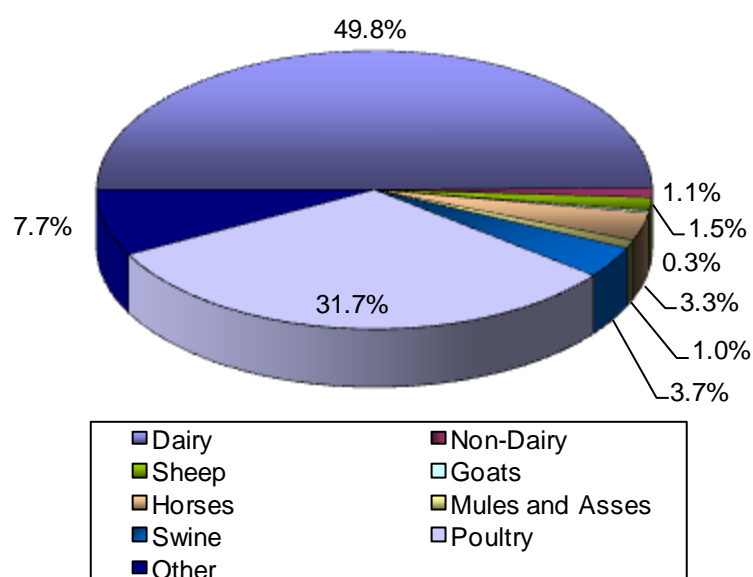


Figure 6.24 – Distribution of total N₂O emissions from Manure Management per animal species as origin of manure in year 2010



6.3.4.2 Methodology

Emissions of N₂O from manure for each Manure Management Systems were estimated from the following formula:

$$EN_2O_{(s)} = 44/28 * \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)}$$

where,

EN₂O_(s) - N₂O emissions from manure in Manure Management System S;

S - Manure Management System;

i - Animal/species category of livestock;

N_(i) - Number (head) of individuals from livestock category i in the country;

Nex_(i) - Annual country average N excretion per head of animal species/category i;

MS_(i,s) - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s;

EF3_(s) - N₂O emission factor for Manure Management System s (kg N₂O-N/kg N).

This formulation follows the one proposed in GPG (equation 4.18).

The following Manure Management Systems were considered for the calculation of total N₂O emissions from manure management, in accordance with the expert information received from the Ministry of Agriculture (MAMAOT). The following table presents the original classes from the MAMAOT and the correspondent classes in CRF table 4.D.

Table 6.27– Classification of Manure Management Systems in Portugal

MAMAOT	GPG Class (Table 4.12)	CRF classification
Water Treatment Plant: Anaerobic Lagoon	Anaerobic Lagoons	Anaerobic Lagoon
Tank	Liquid/slurry or Open pits below animal confinements	Liquid System
Solid Storage: Composting	Solid Storage	Solid Storage and Dry Lot

This same methodology was used to assess Direct N₂O soil emissions from manure deposited in soil during grazing (Pasture Range and Paddock). However, emissions from this activity are further discussed in the sub-chapter (6.2.5) “Direct Nitrous Oxide Emissions from agricultural soils”.

Parameters N_(i), Nex_(i) and MS_(i,s) will be discussed under “activity data” and EF3_(s) will be discussed as “emission factor”.

6.3.4.3 Emission Factors

N₂O emission factors are presented in next table for all MMS (although the uses of daily spread, use for fuel and other systems are not considered in the Portuguese inventory). These emission

factors are the default IPCC96 emission factors (table 4-22 which were maintained in GPG table 4.12) because there are no country-specific emission factors.

Table 6.28 – N₂O from Manure Management: Emission factors per Manure Management System

MMS	EF3 (kg N ₂ O-N/kg N)
Water Treatment Plant: Anaerobic Lagoon	0.001
Liquid Systems: Tank, Open Pit	0.001
Solid Storage and drylot	0.02
Pasture Range and Paddock	0.02

6.3.4.4 Activity Data

Livestock population numbers used to estimate total nitrogen excretion are the same that were also used to estimate emissions of CH₄ from Enteric Fermentation and CH₄ from Manure Management, and which were already presented in the chapter concerning CH₄ emissions from Enteric Fermentation.

The quantity of nitrogen excreted per head results from expert information provided by the Ministry of Agriculture¹¹⁴. The detailed pattern was chosen also to:

- allow the use of different excretion rates for animals according to age and sex, in accordance with the enhanced livestock characterization that was used in other source sectors (CH₄ emissions from Enteric Fermentation and Manure Management);
- be more consistent with the nitrogen balance, that is made by the National Statistical Institute (INE), with the technical help of the Ministry of Agriculture, and sent to the OECD/EUROSTAT.

Following recommendations from the 2009 centralized review process the nitrogen excretion rates from all animal types were revised. This revision process was conducted in close coordination with the Ministry of Agriculture expert team including LQARS technicians. The following procedures were taken in the revision of the nitrogen excretion rates:

- Analysis of the new nitrogen excretion rates proposed in the revision of the Agriculture Good Practice Code (CBPA – Código de Boas Práticas Agrícolas);
- Compliance of the nitrogen excretion rates from CBPA with livestock information used in the inventory;
- Resort to expert guesses when animal types are not covered in CBPA, by comparing with similar animal types reported in this document.

The nitrogen excretion rates determined in this update were considered to be more representative of the national conditions than those that were formerly submitted. Since this work had several expert guesses inputs, adjustments to the nitrogen excretion rates may be considered necessary in future inventory submission.

¹¹⁴ Dr^a Fátima Calouro, director of the Laboratório Químico Agrícola Rebelo da Silva in Lisbon. This laboratory was created in 1886. Performs research in the area of fertilizer use and improvement, soil and plant analysis and fertilizer recommendations.

The following section presents the detailed methodology used for establish the country/specific nitrogen ratios for dairy-cattle (which vary with milk production). For all other animal the nitrogen rates were determined following the methodology explained above.

6.3.4.4.1 Dairy-Cattle

CBPA defines the nitrogen excretion rate of dairy-cattle as a function of their milk production. The base nitrogen value for dairy-cattle is 115 kg N/hd/yr for 7000 kg milk produced/hd/year. For different milk production values the extrapolation procedures defined in CBPA are the following:

- The Nex decreases 10 per cent for every 1000 kg less of milk production;
- The Nex increases 2 per cent for every 1000 kg extra of milk production.

Milk production presented in Table 6.29, were provided by INE.

Table 6.29 – Milk production values

Year	Milk per Cow (kg/hd/yr)
1990	4 464
1991	4 440
1992	4 412
1993	4 111
1994	4 322
1995	4 556
1996	4 747
1997	4 813
1998	4 973
1999	5 718
2000	6 262
2001	6 647
2002	7 032
2003	6 768
2004	6 775
2005	7 233
2006	7 337
2007	7 311
2008	7 634
2009	7 826
2010	8 044
2011	-
2012	-

Nitrogen excretion values are presented in the following table:

Table 6.30 – Nitrogen excretion rate for dairy-cattle

Year	Nex (kg/hd/yr)
1990	85.8
1991	85.5
1992	85.2
1993	81.7
1994	84.2
1995	86.8
1996	89.0
1997	89.8
1998	91.6
1999	100.2
2000	106.4
2001	109.2
2002	115.1
2003	112.3
2004	112.3
2005	115.5
2006	115.8
2007	115.7
2008	116.4
2009	116.9
2010	117.4
2011	-
2012	-

6.3.4.4.2 Final Nexc and Nitrogen Excretion

The following table represents the nitrogen excretion rates applied in the estimation of N₂O from Manure Management. For consistency proposes all Nex used in previous submission were also included as were the IPCC default. There is an acceptable agreement between country-specific values and IPCC defaults for all species other than ovines and caprines. Albeit the nitrogen excretion rate for these two categories appearing too low, when in comparison to IPCC default, but it has similarities to those used by other parties.

Table 6.31 – N excretion rate per head and by animal species/category (Nex)

Animal Class	Animal type	Nex (kg N/hd/yr)				
		Sub 2012	Sub 08-09	Sub 06-07	Sub 2005	IPCC Default
Dairy-cattle	Dairy Cows	117.4	87.6	87.6	108.07	100
non dairy cattle	Beef calves (<1 yr)	25.0	26.3	26.3	54.03	70
	Calves, Males for Rep. (<1 yr)					
	Calves, Females for Rep. (<1 yr)					
	Males 1-2 yrs	40.0	52.6	52.6		
	Beef Fem. 1-2 yrs					
	Females for R. 1-2 yrs					
	Steers (>2 yrs)	41.0	61.3	61.3		
	Heifers for Beef (>2 yrs)	55.0	70.1	70.1		
	Heifers for Rep. (>2 yrs)					
	non-dairy cows	80.0	61.3	61.3		
Swine	Piglets (<20 kg)	0	2.0	2.0	14.89	20
	Fat. Pigs (20-50 kg)	7.0	7.0	7.0		
	Fat Pigs (50-80 kg)	13.0	10.0	10.0		
	Fat Pigs (80-110 kg)					
	Fat Pigs (> 110 kg)					
	Boars (>50 kg)	18.0	17.5	17.5	29.78	
	Sows, pregnant	20.0				
	Sows, non-pregnant	42.0				
Ovine	Ewes	9.17	9.2	7.0	6.9	
	Other Ovines	6.6				
	Lambs	0				2.8
Caprine	Does	7.0	7.0	7.0	4.93	25
	Other Caprines	6.6				
	kids	0				
Equides	Horses	44.0	60.0	60.0	54.03	
	Asses, Mules and hynies	22.0	22.0	22.0		
Poultry	Hens Reproductive	0.6	0.6	0.6	1.58	0.6
	Hens eggs	0.8				
	Broilers	0.45	0.8	0.8	0.74	
	Turkeys	0.48	1.8	1.8	3.29	
	Ducks, Geese and Guinea Fowl	0.48	0.9	0.9	1.58	
Other	Rabbits	9.0	7.4	7.4	1.5	25

Note: The Nex value for dairy-cattle associated with Sub 2011 represents the value for latest year reported in that submission (2009). The Nex values for the 2010 submission are equal to the 2011 submission.

Values for piglet (<20kg), lambs and caprine kids, are now 0 kg N/hd/yr because the new Nex include these animal types with their respective mothers:

- Piglet (<20kg) – included in sows, pregnant and sows, non-pregnant;
- Lambs – included in other ovines;
- Caprine kids – included in other caprines.

In previous UNFCCC Review processes questions were raised concerning the N₂O implied emission factors (IEF) obtained for Swine. Due to the large number of piglets in Portugal which have 0 kg N/hd/yr for excretion rate, the total IEF for swine tends to be smaller when comparing with the IPCC default and other European countries.

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to year 2010, is presented in the table below.

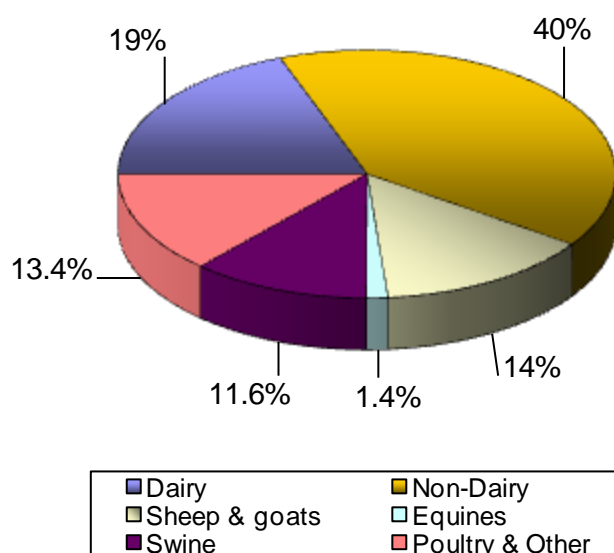
Table 6.32 – Total Nitrogen in Manure produced by livestock in Portugal (ton N/yr)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Dairy	33 830	33 177	32 457	31 305	32 147	33 262	33 803	34 031	34 364	36 929	37 566	36 101
Non-Dairy	43 438	44 308	43 599	43 602	43 888	45 511	47 217	48 392	49 477	50 316	51 394	52 693
Sheep	25 387	25 805	25 906	26 034	26 472	26 835	27 151	27 003	27 210	27 441	26 939	25 234
Goats	5 279	5 149	4 983	4 824	4 703	4 614	4 535	4 480	4 409	4 301	4 077	3 678
Horses	1 447	1 666	1 750	1 842	1 953	2 094	2 272	2 396	2 485	2 527	2 563	2 582
Mules and Asses	2 599	2 560	2 513	2 499	2 393	2 273	2 104	1 969	1 812	1 658	1 517	1 383
Swine	24 731	25 742	25 743	25 875	25 364	24 813	23 711	23 554	23 388	23 373	22 616	21 416
Poultry	17 095	17 286	17 569	17 864	17 821	17 407	17 071	17 157	18 218	19 757	20 805	20 874
Other	4 273	4 172	4 022	3 872	3 733	3 605	3 452	3 263	3 113	3 041	3 023	2 984
Total	158 079	159 866	158 544	157 716	158 473	160 415	161 317	162 247	164 475	169 342	170 500	166 945

Animal Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Dairy	35 821	33 341	33 064	33 462	32 914	31 817	31 284	30 779	29 933	-	-
Non-Dairy	53 869	55 201	56 592	58 318	59 523	60 536	61 211	61 741	62 388	-	-
Sheep	23 315	22 322	22 374	22 701	22 811	22 364	21 455	20 236	18 991	-	-
Goats	3 327	3 055	3 004	3 016	3 069	3 000	2 908	2 815	2 771	-	-
Horses	2 596	2 567	2 449	2 273	2 141	2 083	2 009	1 833	1 672	-	-
Mules and Asses	1 247	1 115	983	880	785	726	645	565	491	-	-
Swine	19 872	18 707	18 351	18 256	18 316	18 247	18 202	18 193	17 940	-	-
Poultry	20 013	19 113	18 149	17 112	16 203	15 445	15 740	16 938	18 340	-	-
Other	2 923	2 862	2 754	2 599	2 429	2 290	2 256	2 294	2 369	-	-
Total	162 983	158 283	157 720	158 618	158 191	156 507	155 712	155 394	154 894	-	-

The major contributors to total nitrogen from livestock in Portugal in 2010 were non-dairy cattle and dairy cattle, as may be seen in Figure 6.25.

Figure 6.25 – Origin of nitrogen in manure from livestock production in Portugal in 2010, per animal type



The percentage of manure that is attributed to each Manure Management System was established in a coherent mode with the share considered in CH₄ emissions from Manure Management¹¹⁵.

According to the national share of MMS, it is larger the percentage of cattle in pasture range than according to what it is recommended by the IPCC (IPCC,1997) in table B-3 (Appendix B in Reference Manual) , particularly for dairy cattle. Also, the percentage of dairy cows in solid storage is also higher than the per cent assumed by IPCC. Non dairy cattle not in pasture in Portugal is managed in dry storage manure systems, whereas IPCC assumes for western Europe a representative share of liquid systems. Therefore N₂O emissions from manure are larger than if the default MMS from IPCC was applied.

For pigs, the IPCC assumes most manure managed is in tanks while the national information considers Anaerobic Lagoons the most relevant MMS. However IPCC recommends a higher level of solid storage systems than the per cent that it was considered in the national inventory according to the experts of the Portuguese Ministry of Agriculture. There exist a small number of animals kept feeding by grazing in range.

For sheep and goats, there is a different percentage of animals in closed systems and in Pasture, but that does not affect significantly total N₂O estimates - because EF₃ has equal default value for both MMS - although emissions are allocated to different emission categories.

At national level it was preferred to classify MMS for poultry as solid storage rather than the ambiguous IPCC classification of other systems. Manure in poultry and small mammals

¹¹⁵ In the 1996 Revised IPCC Guidelines, however, there is no coherence between the default Manure Management System share proposed to estimate CH₄ from Manure Management and that for N₂O from Manure Management.

installations use mostly dry manure removal systems. Emissions are therefore higher than those that would result from estimates using IPCC default share of Manure Management Systems.

6.3.4.5 *Uncertainty Assessment*

Uncertainty in activity data is the result of the combined uncertainties in livestock number, nitrogen excretion rates and the distribution by each manure management system. The values for uncertainty in livestock numbers are the same that were for sector CH₄ emissions from enteric fermentation. The uncertainty in N-excretion rate was set at 37.5 per cent, considering an intermediate situation between the uncertainty values recommended by GPG for default N-excretion rates (50 per cent) and the lower uncertainty when country-specific values are based on accurate national statistics (25 per cent). Uncertainty in MMS share was determined as the maximum difference in total excretion for each MMS considering the allocation per MMS used in previous submissions (Seixas et al, 1999) and the new revised share of MMS by the Ministry of Agriculture, and the values vary from about 1 per cent for anaerobic lagoons and liquid systems to around 10 per cent for solid systems and pasture. The overall uncertainty values range from 37.5 per cent to 39 per cent.

The uncertainty in N₂O emission factors was set in accordance with the maximum values proposed in table 4.12 of the Good Practice Handbook (IPCC,2000), 100 per cent for all MMS.

6.3.4.6 *Category-specific QA/QC and verification*

Since this year no major changes were made for this source category QA/QC procedures consisted only on the comparison between inventory Nex values and the corresponding IPCC default (Table 6.31).

6.3.4.7 *Recalculations*

The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types (this revised series was given by INE).

For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009).

RGA 2009 AD revision also affected milk yield values (2000-2009).

Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values.

Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine.

6.3.4.8 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have

to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

6.3.5 Direct N₂O Emissions from Agricultural Soil (CRF 4.D.1.)

6.3.5.1 Overview

In agricultural soils, emission of N₂O is enhanced by an increase in available mineral nitrogen which promotes soil biogenic activities of nitrification and denitrification. Increase of available nitrogen in soil may be caused by anthropogenic activities such as the addition of nitrogen to soil as a fertilizer or in crop residues or as consequence of cultivation of organic soils where degradation of organic matter is enhanced liberating fixed nitrogen. N₂O emissions considered in this inventory include therefore only the increase in soil emissions that are due to human management of soils, and not comprehending the Nitrous Oxide emissions that would occur in the same area under unmanaged conditions (background emissions).

Although some scientific references indicate that soils may also be soil sinks of N₂O, there are no available sound estimate techniques and consequently these were not estimated in this inventory.

Direct emissions of N₂O resulting from the increase of nitrogen added to cultivated soils due to agricultural activities includes the following sub-categories:

- application of synthetic fertilizers;
- application of animal manure;
- animal manure (droppings) deposited directly by animals on pasture, range and paddock;
- nitrogen fixation by N-fixing crops (leguminous plants);
- nitrogen input from incorporation of crop residues into soils.

Most effort was placed to made estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources: N₂O, CH₄ and NH₃.

N₂O emission from the application of sewage sludge in agriculture soils occurs in Portugal but due to unavailability and poor data on this practice no emission were estimated separately for this source category. However these emissions are accounted in the 6.B: N₂O Emissions From Human Sewage sector, which assumes that all sewage nitrogen is discharged into aquatic environments (IPCC default method).

Considering climate conditions and the long period since when soils have been subjected to agriculture in Portugal, histosols represent at most a negligible emission quantity in Portugal, and they may be reported as not occurring for all practical purposes.

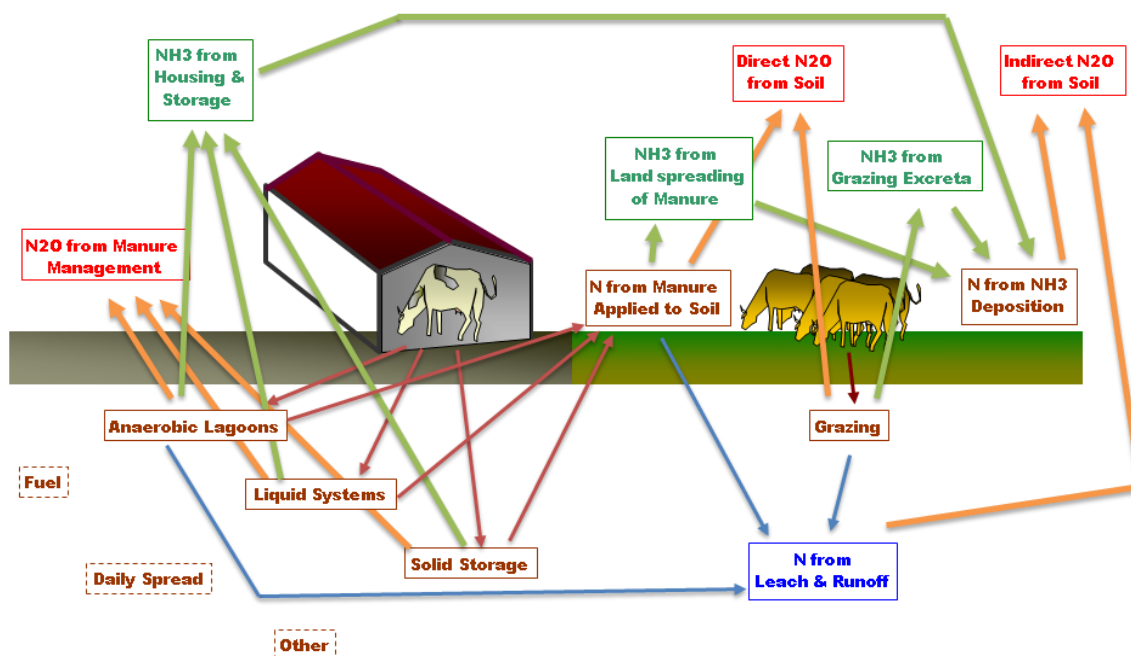
It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

The situation concerning N_2O emissions from manure is somehow complex because nitrogen originally in manure may give origin to N_2O emissions that are considered in different IPCC categories:

- emissions of N_2O , as well of ammonia, during the period that manure is stored in house or any Manure Managed System were already considered under source category N_2O emissions from Manure Management;
- emissions from nitrogen in manure added to soil as fertilizer is included in source category "direct N_2O from agricultural soils". In Portugal it was assumed that manure managed as liquid systems and solid storage is fully applied to agricultural soil as a fertilizer, irrespective of the animal species considered, whereas only a percentage of manure handled in anaerobic lagoons is placed in soil.

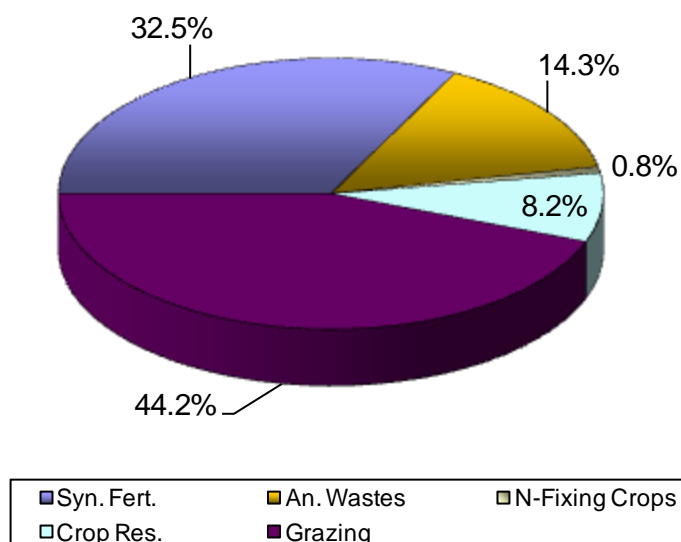
The following figure synthesizes the livestock system in what concerns nitrogen fluxes and direct and indirect N_2O emissions.

Figure 6.26 – Nitrogen fluxes from livestock system



The comparative importance of the several sub-source activities for 2010 is shown in Figure 6.27, from where it is evident the major contribution from direct deposition (Grazing 44.2 per cent) and synthetic fertilizers (Sin. Fert with 32.5 per cent) which may be considered significant sources in accordance with the IPCC rule of thumb. Manure used as fertilizer (An. Waste) is also an important source, responsible for 14.3 per cent of emissions.

Figure 6.27– Contribution of the various sub-sources to total N₂O emissions from Direct agricultural soil emissions in 2010



6.3.5.2 Methodology

6.3.5.2.1 N₂O emissions from agricultural soils other than animal production

The approach used to estimate N₂O emissions from agricultural soils other than animal production (emissions of N₂O in Pasture Range and Paddock) may be better classified as Tier 1a, because the same emission factor was used to all nitrogen sources to soil¹¹⁶.

Final N₂O emissions are estimated with a formulation derived from equation 4.20 of GPG:

$$EN_{2O_{Direct}} = 44/28 * (FSN + FAM + FBN + FCR) * EF_1$$

where:

EN_{2O_{Direct}} - Annual emission of N₂O

FSN - Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilizes as NH₃

FAM - Annual amount of animal manure nitrogen intentionally applied to soils adjusted to account for the amount that volatilizes as NH₃

FBN - Amount of nitrogen fixed by N-fixing crops cultivated annually

FCR - Amount of nitrogen in crop residues returned to soil annually

EF₁ - N₂O emission factor from N input to soil (kg N₂O-N/kg N input)

¹¹⁶ However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

FSN, the annual amount of synthetic fertilizer nitrogen applied to soil after adjusting to account for the amount that volatilizes, is estimated from:

$$FSN = N_{Fert} * (1 - Frac_{GASF})$$

where,

N_{Fert} - total amount of nitrogen in synthetic fertilizers consumed annually

$Frac_{GASF}$ - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH_3 or NO_x

The amount of nitrogen in animal manure that is used as fertilizer (FAM) was estimated from total nitrogen excreted from livestock that is applied to agricultural soils and after subtraction of nitrogen that was volatilized in housing, manure storage and after deposition in soil as fertilizer. The following equation applies:

$$FAM = \sum_i \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * (1 - EF_{NH3SD(i)}) \}$$

where

FAM - total amount of nitrogen in manure from Manure Management System that is applied to soil as fertilizer;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

$MSSD_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i,s)}$ - Fraction of nitrogen in Manure Management System s from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$ - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

This equation is equivalent to equation 4.23 of GPG if one considers that $Frac_{GASM}$ equals the sum of $EF_{NH3(i,s)}$ and EF_{NH3SD} and being aware that $Frac_{PRP}$ is partly represented by parameter MSSD. To maintain consistency to the Good Practice methodology, and although emissions of N_2O from manure handled in Anaerobic Lagoons, Liquid Storage and Solid Storage were already accounted in N_2O emissions from Manure Management, the subtraction of the nitrogen that is lost that way is not made here.

Estimates of nitrogen fixed by crops follows exactly the Tier1b approach of the GPG (Equation 4.26) which means that crop-specific residue to product ratio and dry matter content are used:

$$FBN = \sum_i \{ Crop_{BF(i)} * (1 + Res_{BF}/Crop_{BF(i)}) * Frac_{DM(i)} * Frac_{NCRBF(i)} \}$$

where

i - Crop type

Crop_{BF(i)} - Crop production of nitrogen fixing crops (ton/yr)

Res_{BF}/Crop_{BF(i)} - Residue to crop product mass ratio for nitrogen fixing crop i (ton/ton)

Frac_{DM(i)} - Fraction of dry matter in the aboveground biomass of crop type i

Frac_{NCRBF(i)} - nitrogen fraction in crop dry biomass (ton/ton)

Finally FCR, nitrogen input to soil in crop residues returned to soil, is estimated for all crops, whether they are nitrogen fixing crops or not, with the GPG tier 1b approach, which can be represented to the following equation, a similar simplification of equation 4.29 of the GPG:

$$FCR = \sum_i [(Crop_{(i)} * Res/Crop_{(i)} * Frac_{DM(i)} * Frac_{NCR(i)}) * [1 - Frac_{BURN(i)} - Frac_{FUEL(i)} - Frac_{CNST(i)} - Frac_{FOD(i)}]]$$

where

i - Crop type

Crop_(i) - Crop production (ton/yr)

Res/Crop_(i) - Residue to crop product mass ratio for crop i (ton/ton)

Frac_{DM(i)} - Fraction of dry matter in the aboveground biomass of crop type i (assumed to be equal to the fraction in the all plant)

Frac_{NCRBF(i)} - nitrogen fraction in crop dry biomass (ton/ton)

Frac_{BURN(i)} - fraction of crop residue burned in the field before and after harvest

Frac_{FUEL(i)} - fraction of crop residue burned as fuel outside field

Frac_{CNST(i)} - fraction of crop residue used for construction

Frac_{FOD(i)} - fraction of crop residue used as animal fodder.

6.3.5.2.2 Emissions of N₂O in Pasture Range and Paddock

Emissions of N₂O due to the input of nitrogen to soils from pasture, range and paddock were estimated with a methodology similar to that used to estimate emissions of N₂O from Manure Management. Emissions were therefore estimated with the following formula:

$$Emi_{N_2O} = 44/28 * FGR * EF_3$$

where,

Emi_{N₂O} - N₂O emissions from manure in Pasture, range and paddock;

EF₃ - N₂O emission factor (kg N₂O-N/kg N);

FGR - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture. This variable is determined from equation:

$$FGR = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)}]$$

where:

i - Animal/species category of livestock;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock.

In the determination of N_2O from Pasture Range and Paddock there is no need to account for the amount that volatilizes as NH_3 .

6.3.5.3 *Emission Factors*

EF_1 , the emission factor relating N input to soil with N_2O emissions, was set equal to the IPCC default value of 0.0125 kg N_2O -N/kg N input (table 4.17 of GPG and table 4.18 of IPCC96)¹¹⁷.

The emission factor of N_2O for Pasture, Range and Paddock (EF_3) was set at 0.02 kg N_2O -N/kg N which is the default IPCC96 emission factor (table 4-22) that is also maintained in GPG (table 4.12).

6.3.5.4 *Activity Data*

The estimated quantities of nitrogen added to agricultural soils from each specific source, and that are activity data for determining direct N_2O emissions, are shown in Table 6.33 below and the percent contribution of each one in year 2009 is also represented graphically in Figure 6.28.

For the last year in the inventory (2010) there are two categories that represent the majority of nitrogen added to soil: Synthetic Fertilizers (39 per cent) and direct droppings during grazing in Pasture (33.1 per cent). Also important to note the contributions of Animal Waste apply to the soil as fertilizer (17.1 per cent) and Crop Residue a apply to the soil (9.8 per cent). The contribution of N-Fixing Crops is marginal (0.9 per cent). Total nitrogen added to agricultural soils in Portugal increased slightly along years up to 2002, but after 2003/2004 successive years with severe droughts caused a sharp decline in the use of fertilizers (especially synthetic fertilizers). The nitrogen added to soil through the N-Fixing Crops also registered a decline since 1991. Therefore, total nitrogen added to soil was in 2010 about 17.2 per cent lower than what it was applied in 1990, although for the year 2002, application of nitrogen was 2.1 per cent higher than in base year.

¹¹⁷ Which is the same as stating that 1.25% of nitrogen input to soil is emitted as N_2O

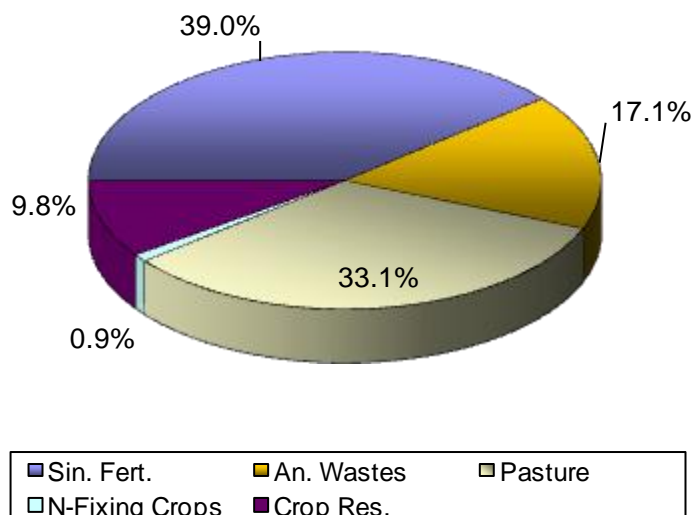
Table 6.33 - Total quantities of Nitrogen Added to Agricultural Soils that which is activity data for direct N₂O emissions¹¹⁸

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Synthetic Fertilizer	149 856	149 856	149 939	151 322	149 721	137 628	158 325	153 963	140 850	139 979	160 265	148 504
Animal Manure	55 010	55 378	54 845	54 281	54 004	53 793	53 043	52 586	52 896	54 726	55 000	53 305
Pasture Range	70 525	71 502	70 905	70 824	72 057	74 402	76 630	78 204	79 863	81 781	82 486	81 556
Fixed by Crops	5 032	4 701	4 272	3 906	3 740	3 780	3 667	3 411	3 043	2 838	2 668	2 640
Crop Residues	26 568	25 213	23 527	23 420	24 290	25 958	25 550	26 122	26 332	26 676	25 840	24 913
Total	306 992	306 650	303 487	303 754	303 812	295 561	317 215	314 286	302 984	306 001	326 260	310 919

ton N/yr	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Synthetic Fertilizer	154 529	103 834	118 648	96 793	82 393	106 543	94 485	99 118	99 118	-	-
Animal Manure	51 298	48 589	47 372	46 600	45 458	44 000	43 497	43 569	43 511	-	-
Pasture Range	80 826	80 390	81 711	83 776	85 049	85 552	85 408	84 784	84 226	-	-
Fixed by Crops	2 599	2 605	2 531	2 532	2 519	2 530	2 462	2 416	2 398	-	-
Crop Residues	24 095	25 022	24 090	24 077	23 398	24 352	24 931	24 977	24 988	-	-
Total	313 347	260 440	274 353	253 779	238 818	262 978	250 784	254 864	254 242	-	-

¹¹⁸ To be in accordance with CRF table 4.D nitrogen is expressed after subtraction of ammonia volatilization for synthetic fertilization and animal manure. In the case of Pasture Range/ Animal Production the values refer to nitrogen deposited in soil before NH₃ subtraction because, for determining N₂O from this category, there is no need to account for the amount that volatilizes as NH₃. For crop residues and N fixated in crops, no ammonia volatilization is considered.

Figure 6.28 – Sources of direct input of Nitrogen to agricultural soil in 2010



6.3.5.4.1 Synthetic Fertilizers

There are no available records of statistical information concerning the annual quantity of nitrogen used to agricultural soils or even available statistical information concerning sales of synthetic fertilizers. However, following the need to respond to other international requests, such as the calculation of the Nitrogen Balance for the OECD/EUROSTAT, the National Statistical Institute, in collaboration with the Laboratório Químico Agrícola Rebelo da Silva¹¹⁹ and ADP¹²⁰, having found the same lack of available data, produced a methodology (INE,2004) that estimates the Apparent Consumption of Fertilizers in the Agriculture activity (ACFA) by a simple mass balance, from sales and international market information data:

$$ACFA = Prod_{Sales} + Imports - Exports$$

Where $Prod_{Sales}$ is the annual quantity of nitrogen fertilizers produced and sold to market (excluding consumption in industry), and is based on the IAPI census¹²¹. Data of Imports and Exports is also from INE. The available time series is presented in Figure 6.29.

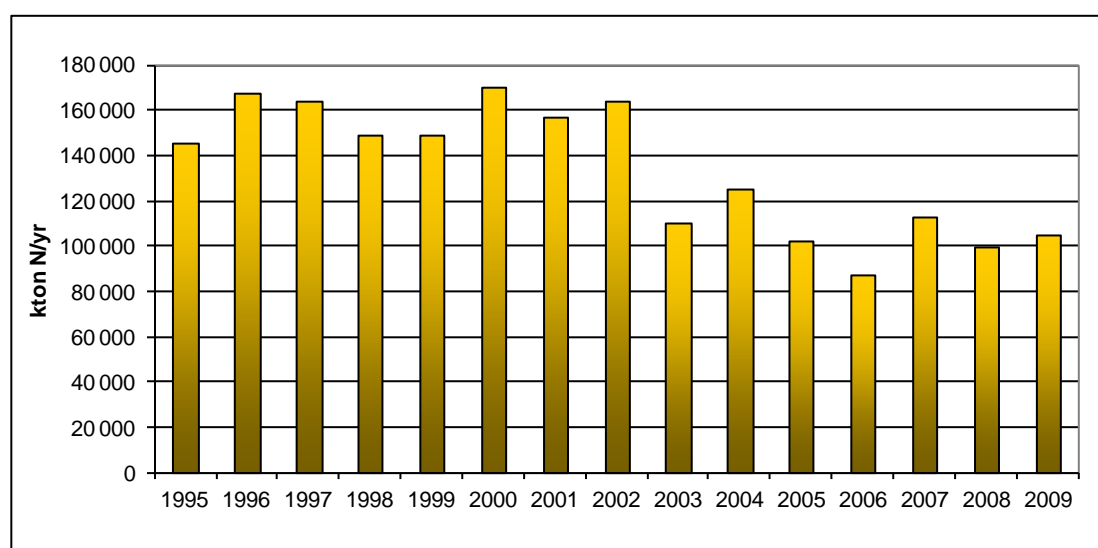
Two simplifications were made: (1) Only inorganic fertilizers were considered; (2) The effect of losses and stock variation was not accounted. According to INE (2004) these factors have no significant influence in the outcome.

¹¹⁹ Laboratório Químico Agrícola Rebelo da Silva is a public laboratory, under the Ministry of Agriculture, and proceeds to soil, plant and fertilizer analysis.

¹²⁰ ADP, Adubos de Portugal, S.A., is the main producer of fertilizers in Portugal, and responsible for about 75% of fertilizer sales (INE,2004)

¹²¹ Annual census made to the Manufacturing Industry, by INE.

Figure 6.29 - Use of Nitrogen Fertilizers in Portugal according to INE for the period 1995 to 2009 (ton N/yr)



Because of the limited time period requested by the OECD/EUROSTAT survey (1995-2003), and the unavailability of IAPI data prior to 1992 the time trend of this series is limited in time, and not covering the Inventory base year (1990).

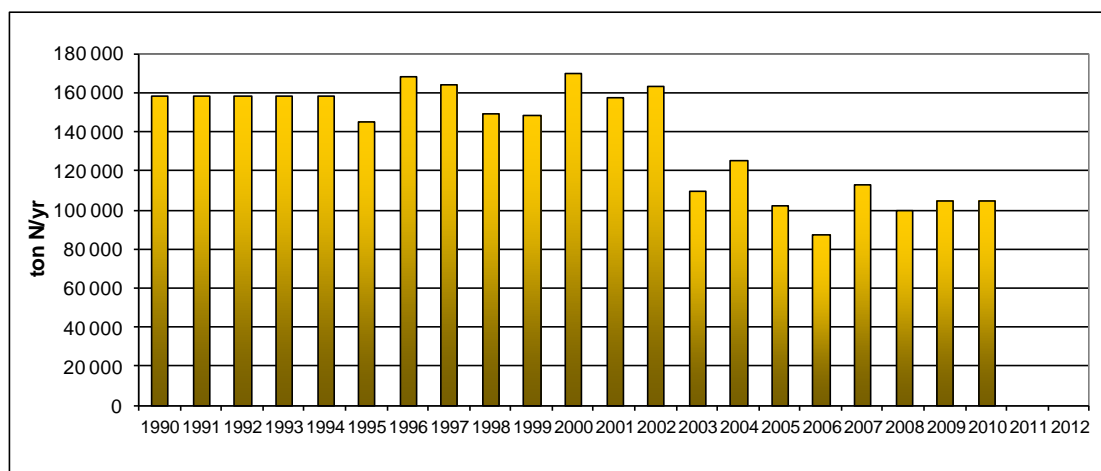
To overcome this limitation, and back-cast the time series to the base year, two regression curves between annual fertilizer use in 1995-2003 and estimated nitrogen fertilizer use considering annual crop production per crop and the rate of nitrogen application proposed by (MA,2000). One regression line considered the average application rate and the other assumed that the rate of application evolved in accordance with the average production per ha, also considering the variable rates from MA (2000). Neither regression curves show an adequate correlation, although the figures in the three series show a similar order of magnitude and a similar decreasing trend.

In the end, considering the difficulties in back-casting, considering the recommendations given by the ERT team that was responsible for the review of Submission 2006 under the UNFCCC and the IIR under the Kyoto Protocol, and given the fact that there is not a clear trend in the available time-series, the average quantity of synthetic fertilizers in the period 1995-2002, (158 945 t N/yr) was applied for all lacking years (1990-1994). The value for 2003 was maintained because it represents real, albeit transient, conditions values for the period. This results in a conservative approach causing underestimation emissions in the base year.

It is also important to explain that INE most up to date information on apparent consumption of fertilizers only goes to the year n-1 (for this inventory exercise - 2009). This is due to incompatibilities between the time IAPI data is made available (begin of n+2) and the need of information for estimating emissions in the inventory (late n+1). Because of this the 2010 apparent consumption of fertilizers was estimated from available data: due to fluctuations in the time series 2010 value was made equal to 2009.

The line that was obtained, Figure 6.30, shows an increasing trend until 2002, being the value of that year 3.1 per cent higher than the value reported for 1990, with a sharp decrease for the next year. In the period where the time series is available from INE, the annual application of nitrogen fertilizers decreased by 37.9 per cent, from 1995 till 2009.

Figure 6.30 - Use of Nitrogen Fertilizers in Portugal, estimated from INE data - Using a simple average value for 1990-1994 and 2010 equal to 2009 (ton N/yr)

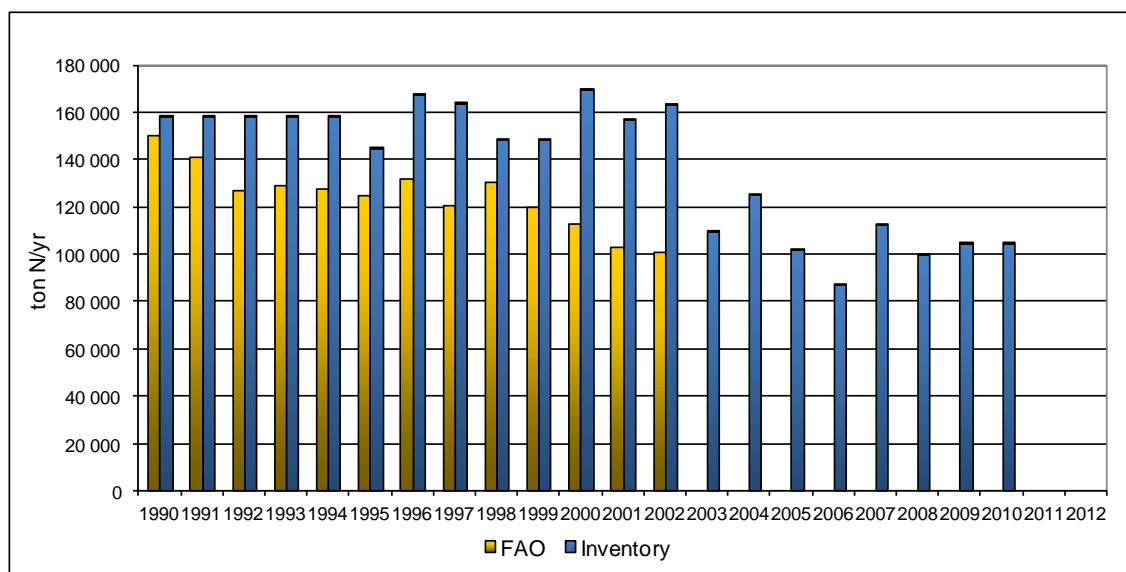


Losses of nitrogen from volatilisation of NH_3 and NO_x were estimated using a time variable and country-specific fraction $\text{Frac}_{\text{GASF}}$, which varies between 0.053 and 0.064 kg $\text{NH}_3\text{-N/kg N}$, and which are almost half the default value from table 4-19 of IPCC96 (0.1 kg $\text{NH}_3\text{-N/kg N}$). In what concerns acidification emissions it was assumed that these emissions are fully ammonia. A more detailed explanation of the methodology and assumptions used to derive these country-specific volatilization fractions is presented in chapter NH_3 Emissions from Volatilization in Agriculture Soils (Chapter 6.3.8).

6.3.5.4.1.1 Comparison to FAO database

The more complete time-series available is the FAO's statistical database (<http://faostat.fao.org>), with sales information for "Nitrogenous Fertilizers" from 1961 up to 2002. According to FAO, annual usage of nitrogenous fertilizers have decreased in Portugal from 150 200 ton N in 1990 to 101 000 ton N in 2004, i.e. an overall reduction of about 33 per cent. This series, presented in Figure 6.31, was used as activity data in the Inventory until the submission of 2005. However, and although its completeness, the Ministry of Agriculture and the National Statistical Institute, shown concerns about the origin of the information behind the final time series, and consider that it did not reflect clearly the situation that existed in Portugal in the period. Nevertheless, both series agree quite well near the base year, although the values in this series appear to be over-estimating the rate of decrease of synthetic fertilizers in Portugal.

Figure 6.31 - Use of Nitrogen Fertilizers in Portugal according to FAO, and comparison to time-series in the inventory (ton N/yr)



6.3.5.4.2 Animal Manure

The quantity of nitrogen in manure that is applied to soil as fertilizer resulting in N_2O emissions was estimated from the same data that was used to estimate nitrogen excreted in N_2O from Manure Management and assuming that all the manure that is treated under Solid Storage or Liquid Systems is used as soil fertilizer, i.e. $MSSD_{(i,s)}$ equals 1 only for Solid Storage and Liquid Systems. Concerning the other Manure Management System, Anaerobic Lagoons, 80 per cent of effluent is added to soil as fertilizer¹²², in accordance with a characterization study made in Portugal (Bicudo & Albuquerque, 1995; LNEC, 1996; GPPAA, 2001)¹²³. As explained before, under CH_4 and N_2O emissions from Manure Management, no other Manure Management Systems exist in Portugal. Quantities applied each year were also presented in Figure 6.28 above, where is shown that manure is the third major source of nitrogen applied to soil. Ammonia volatilisation factors, $EF_{NH_3(i,s)}$ and EF_{NH_3SD} , are presented and discussed in more detail in chapter NH_3 Emissions from Agriculture (Chapter 6.2.8) and they result from EMEP/UNECE Guidebook 3rd ed (table 3A in chapter B1050). These volatilization fractions depend only on animal class and not on the specific Manure Management System.

¹²² It is not clear if the nitrogen is disposed to soil as fertilizer or only as a final disposal site, and hence better classified as the last step of the treatment process rather than fertilization. For all purposes it was assumed that N_2O emissions would occur in soil according to similar processes, and included in this source category. The remaining 20% are rejected directly to the water system.

¹²³ According to the same studies the remaining 20% wastewater flow and nitrogen is rejected directly to water systems. This fraction is included in the determination of N_2O indirect emissions from agricultural soils.

Table 6.34 – Emission factors used for calculation of NH_3 volatilisation emissions from land spreading of manure as fertilizer

Animal Type	Losses after land spreading (kg $\text{NH}_3\text{-N/kg N}$)
Cattle	0.20
Sheep, goats	0.10
Swine	0.24
Equines	0.10
Poultry	0.24
Rabbits	0.24

In the same way, the factors for calculation of ammonia volatilisation from excreta and urine deposited into grasslands during grazing are from EMEP/CORINAIR (chapter B1010 version 4.0 (Sutton, 2003)) and are presented in Table 6.35 and in detail in chapter 6.2.8.

Table 6.35 – Emission factors used for calculation of NH_3 volatilisation from animal droppings during grazing (Pasture Range and Paddock)

Animal Type	Grazing in Pasture
Dairy Cows	0.08
Other Cattle	0.08
Sheep	0.04
Goats	0.04
Swine	0.08
Equines	0.08

The use of emission factors of ammonia volatilisation from EMEP/UNECE results, therefore, in obtaining a value for $\text{Frac}_{\text{GASM}}$ that is different and slightly higher than the default value for $\text{Frac}_{\text{GASM}}$ (0.2 kg $\text{N-NH}_3 + \text{N-NO}_x$ / kg of N excreted, in table 4-19 of IPCC96). The resultant implied $\text{Frac}_{\text{GASM}}$ oscillates between 0.22 to 0.23 kg $\text{N-NH}_3 + \text{N-NO}_x$ / kg of N excreted¹²⁴.

6.3.5.4.3 Nitrogen Fixed by Crops and Crop Residues returned to soil

Quantities of nitrogen added to soil as result of crop fixation (FBN) and in crop residues returned to soil (FCR) were estimated from crop production. The National Institute of Statistics (INE - Instituto Nacional de Estatística) records crop production each year at Regional Area level (RA - Região Agrária) for the most important species. INE also records the area under cultivation of each species allowing the estimate of productivity. For the year 1989 data gathered by the Statistical Institute was collected at a lower level of territorial desagregation: Agricultural Zone (ZA - Zona Agrária) and for 1999 the data was collected at an even thinner desagregation: Concelho. For some crops however the only available information refers to FAO Statistical Database (<http://www.apps.fao.org>) which information was used to complete the dataset.

The data series for crops that was considered in the inventory, at National level, is presented in Table 6.36 for leguminous crops and in Table 6.37 for non leguminous crops. For each year a

¹²⁴ The rates presented in previous tables are expressed in kg $\text{N-NH}_3 + \text{N-NO}_x$ / kg of N deposited in soil.

three year average centred in the reporting year was used¹²⁵. It must be stressed that not only pulses and beans were included in nitrogen fixing crops but all leguminous crops, and also included is a perennial: carob tree (*Ceratonia siliqua*). In a similar way when estimating crop residues not only annual crops were considered but also permanent crops, such as orchards and pastures, were included.

¹²⁵ For year n the value reported as production crop is the average of n-1, n and n+1, except for last year of the inventory where only n-1 and n are used.

Table 6.36 – Annual (three year average) production of Leguminous Crops (metric tons)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Peanut ^{(1) after 1995}	29	32	29	26	20	17	20	23	27	25	25	25
Broad Beans ^{(1) 95-96}	15 486	15 402	15 285	15 182	14 766	15 050	12 776	10 417	7 390	7 533	6 902	7 108
Broad Beans, green	32 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000
Beans	31 243	27 426	21 926	17 071	13 553	12 679	11 722	10 756	8 926	7 426	6 106	5 802
Chick-Peas	3 563	3 081	2 583	2 101	1 937	1 899	1 815	1 810	1 478	1 196	965	1 009
Lupins	48	43	35	37	34	34	34	34	34	34	34	34
Peas Green ⁽¹⁾	5 867	5 867	5 433	5 533	5 867	6 533	7 210	7 417	7 390	6 947	6 974	7 000
Carobs ⁽¹⁾	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green ⁽¹⁾	25 000	25 000	25 000	25 000	32 200	37 433	40 308	33 461	26 844	21 002	18 107	16 679
Total	133 236	126 850	120 292	114 950	118 377	123 646	123 886	113 917	102 088	94 164	89 113	87 657

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Peanut ^{(1) after 1995}	25	25	25	25	27	28	30	30	30	-	-
Broad Beans ^{(1) 95-96}	6 703	7 540	7 540	7 540	7 540	7 540	7 540	7 540	7 540	-	-
Broad Beans, green	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	-	-
Beans	5 310	4 788	3 881	3 655	3 483	3 501	2 882	2 322	2 074	-	-
Chick-Peas	1 166	1 317	1 132	899	749	788	752	622	607	-	-
Lupins	34	34	34	34	34	34	34	34	34	-	-
Peas Green ⁽¹⁾	7 000	7 000	7 000	7 000	7 233	7 467	7 700	7 700	7 700	-	-
Carobs ⁽¹⁾	20 000	20 000	20 000	20 667	20 667	20 667	20 000	20 000	20 000	-	-
Beans Green ⁽¹⁾	16 833	16 563	16 563	16 563	16 563	16 563	16 563	16 563	16 563	-	-
Total	87 071	87 268	86 175	86 382	86 295	86 588	85 501	84 811	84 547	-	-

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.37 – Annual Production of non-leguminous Crops (metric tons)

Crop	1990	1995	2000	2005	2010
Wheat	510 519	409 404	286 821	207 992	103 362
Triticale	61 983	63 141	29 849	21 716	30 581
Maize	666 832	738 450	909 279	617 285	630 146
Barley	95 691	73 074	26 085	52 690	51 710
Rye	98 612	51 326	42 088	23 605	18 499
Oats	91 718	65 778	83 605	57 859	68 431
Rice Paddy	156 939	142 842	146 731	143 473	165 989
Sunflower	46 954	34 806	23 242	6 809	9 534
Hops	194	129	51	29	29
Tomatoes	714 563	877 383	937 512	1 089 729	1 376 084
Tobacco	5 072	5 283	5 895	4 135	1 523
Tea ⁽¹⁾ until 2002	170	62	120	121	141
Chicory ⁽¹⁾	2 203	2 644	2 633	2 517	2 600
Potatoes	1 374 093	1 329 140	833 837	628 439	425 821
Sugar Beet	12 225	46 492	415 982	517 160	7 284
Yams ⁽¹⁾ after 1994	1 294	1 176	2 100	2 233	2 700
Sugar Cane ⁽¹⁾ after 1991	3 760	4 000	4 000	4 333	5 100
Sweet Potatoes ⁽¹⁾	27 000	23 667	22 000	23 000	27 000
Maize for Forage ⁽¹⁾	3 398 333	4 633 333	5 000 000	5 020 000	5 010 000
Sorghum for Forage ⁽¹⁾	331 667	346 667	360 000	364 000	362 000
Roots Fodder ⁽¹⁾	378 333	395 000	420 000	424 000	422 000
Forage ⁽¹⁾	6 300 000	6 866 667	7 200 000	7 220 000	7 210 000
Pumpkins ⁽¹⁾	4 200	9 700	12 000	12 000	13 500
Lettuce ⁽¹⁾ until 1996	32 000	56 367	66 190	59 192	59 192
Garlic ⁽¹⁾	1 667	1 467	1 400	1 433	1 800
Eggplants ⁽¹⁾	6 667	5 833	5 500	5 667	6 500
Onions ⁽¹⁾ until 1996	57 200	107 900	62 362	37 079	37 079
Carrots ⁽¹⁾ until 1996	82 667	128 133	90 898	50 170	50 170
Cauliflower ⁽¹⁾ until 1996	19 667	26 700	20 378	17 161	17 161
Cabbages ⁽¹⁾ until 1996	166 667	150 000	209 110	179 489	179 489
Spinach ⁽¹⁾	16 667	14 667	14 000	14 333	16 500
Watermelons ⁽²⁾ until 1996	64 385	26 355	32 427	26 355	26 355
Melons ⁽²⁾ until 1996	127 281	85 122	91 754	85 122	85 122
Cucumbers ⁽¹⁾	8 333	7 333	7 000	7 333	0
Chillies ⁽²⁾ until 1996	51 662	52 461	45 088	52 461	52 461
Mushrooms ⁽¹⁾	1 000	1 000	1 000	1 000	1 050
Quinces	4 567	2 647	2 200	2 561	5 202
Loquat	1 528	1 666	829	737	973
Pomegranate	1 803	1 636	411	424	468
Pineapples ⁽¹⁾ after 1992	1 476	2 091	1 798	1 700	1 539
Bananas ⁽¹⁾ after 1993	43 648	34 910	29 580	23 005	20 458
Peach	90 123	85 731	52 787	43 067	36 520
Apples	270 551	234 541	261 052	260 761	238 038

Crop	1990	1995	2000	2005	2010
Kiwi	3 406	9 554	9 417	16 551	25 415
Pears	93 580	108 363	139 368	163 757	188 402
Sour Cherries	642	606	91	57	90
Fig	15 100	6 656	3 761	2 675	2 980
Kaki	4 650	2 785	2 606	2 773	3 074
Apricots	4 543	4 956	4 757	3 684	3 557
Cherry	11 795	10 891	12 406	15 754	10 906
Plum	16 332	17 757	15 043	15 304	17 101
Avocados ⁽¹⁾	20 967	13 000	13 000	13 667	16 000
Strawberries ⁽¹⁾	2 500	2 500	2 500	2 550	2 600
Raspberries ⁽¹⁾	100	100	100	233	700
Berries nes ⁽¹⁾	100	100	100	100	100
Tangerine	25 125	34 769	45 246	53 453	33 206
Lemon	10 117	10 402	11 466	11 264	12 880
Orange	169 155	191 883	230 441	220 614	188 678
Pomelo	4 950	6 769	3 749	3 249	1 248
Grapefruit	832	996	306	244	171
Walnut	5 610	3 053	4 146	3 852	3 558
Chestnuts	19 052	23 316	30 855	29 781	23 328
Hazelnuts	1 993	976	636	398	340
Almonds	50 377	26 406	17 859	11 411	8 079
Olives (Oil)	302 638	269 537	235 516	288 970	424 848
Olives (fruit)	21 400	9 156	10 895	9 167	9 292
Wine grapes ⁽¹⁾	1 285 581	1 036 179	960 977	973 150	466 903
Grapes	52 752	55 401	52 543	33 540	20 897

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>); (2) FAO data used as trend for previous years

The Nitrogen fixed by crops was estimated from the ratio of residue to crop product mass ($\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$), the fraction of dry matter in product (Frac_{DM}) and the fraction of dry biomass in the whole plant that is nitrogen ($\text{Frac}_{\text{NCRBF}}$). These parameters were established for each leguminous plant using the default IPCC values (table 4.17 of IPCC 1996 Revised Guidelines which was latter replaced by table 4.16 of Good Practice Handbook) when available, and from other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in Table 6.38

Table 6.38 – Parameters considered for determination of N fixed by nitrogen fixing plants

Crop	$\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$	Frac_{DM} (%)	$\text{Frac}_{\text{NCRBF}}$ (%)
Peanut	1.0	86.0	1.06
Broad Beans	1.5	86.5	2.02
Broad Beans, green	1.5	35.0	2.02
Beans	2.1	85.5	2.62
Chick-Peas	1.5	85.0	2.62
Lupins	1.5	85.0	2.96
Peas Green	1.5	87.0	1.42
Carobs	1.0	85.0	2.62
Beans Green	1.5	20.0	2.62

Nitrogen added to soil in crop residue was also estimated from Res/Crop , Frac_{DM} and Frac_{NCR} . Values for estimation of nitrogen in residues from nitrogen fixing plants are the same that were used in the estimate of nitrogen fixed by crops (Table 6.38). The values for other non-leguminous crops were determined from IPCC defaults (IPCC96 and GP) and other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in next table.

Table 6.39 - Parameters for determination of N added to soil in crop residue from non-leguminous plants

Crop	Res _{BF} /Crop _{BF}	Frac _{DM} (%)	Frac _{NCRO} (%)
Wheat	1.30	85.0	0.28
Triticale	1.45	87.5	0.38
Maize	1.00	78.0	0.81
Barley	1.20	85.0	0.43
Rye	1.60	90.0	0.48
Oats	1.30	92.0	0.70
Rice	1.40	85.0	0.67
Sunflower	1.00	93.3	1.94
Hops	0.10	0.0	0.00
Tomatoes	2.00	27.0	1.50
Tobacco	2.00	15.0	0.67
Tea	2.00	15.0	0.67
Chicory	2.00	15.0	0.67
Potatoes	0.40	22.0	1.10
Sugar Beet	0.20	15.0	1.50
Yams	1.00	15.0	1.50
Sugar Cane	1.00	83.0	0.40
Sugar Potato	0.40	22.0	1.10
Maize for Forage	0.09	17.8	1.58
Sorghum for Forage	0.09	27.6	1.08
Roots Fodder	0.30	10.0	2.28
Forage	0.09	20.0	1.08
Pumpkins	1.00	15.0	1.50
Lettuce	0.10	10.0	1.36
Garlic	0.10	10.0	1.36
Eggplants	1.00	15.0	1.50
Onions	0.10	10.0	1.36
Carrots	0.10	12.5	1.36
Cauliflower	0.10	13.5	2.70
Cabbages	0.10	13.5	2.70
Spinach	0.10	10.0	1.36
Fresh Fruit ^(a)	1.00	15.0	1.50
Dry Fruits ^(b)	1.00	85.0	1.50
Olives	1.00	15.0	1.50
Wine/ Grapes	1.00	15.0	1.50

(a) Fresh fruit: Watermelon, Melons, Cucumbers, Chillies, Mushrooms and fruits from orchards (Apples, pears, etc); (b) dry fruit: Walnut, Chestnuts, Hazelnuts, Almonds and other dry fruits

In estimating the parameter FCR the following assumption was also made: - Frac_{FUEL}, Frac_{CNST} and Frac_{FOD} were set to zero for all crops. Use of crop residues as combustible has negligible expression in Portugal and also there is no tradition of its use as a building material. Although some residues are used as animal feeding, particularly, as result of grazing in after harvesting

cereal areas, it is not possible to estimate that fraction quantitatively. Using a conservative approach it was decided not to remove this part of nitrogen added to soil: this approach may result however in some doubling counting of nitrogen added to soil in this sub-category and in nitrogen added to soil from animal production (Pasture Range and Paddock). In a consistent way, $Frac_{BURN}$ is the same value used in estimate of GHG emissions from field burning of agriculture residues.

6.3.5.5 *Uncertainty Assessment*

The Good Practice Guidebook presents no information concerning the uncertainty in activity data, and therefore, the values were set in the following mode:

- Synthetic Fertilizers: Apart from the time series of the total quantity of nitrogen applied in synthetic fertilizers from INE, that was considered as activity data for the period 1995-2000, other estimates are available or were made for the inventory for the same time period: PNAC studies (Seixas et al, 1999), FAO statistical database and the estimates of nitrogen necessity using the Good Practice Use of Fertilizers (MA,2000). Comparing the values of nitrogen in synthetic fertilizers from these independent data sources between 1995 and 2000 a maximum uncertainty value of 17 per cent was obtained;
- For nitrogen in animal manure applied to soil and animal production the same uncertainty value that was used for activity data in N_2O from Manure Management was used and increased, in the case of animal manure applied to soil, by 100 per cent due to the uncertainty in the percentage of manure that ends up in soil;
- An uncertainty error of 25 per cent in crop production was considered in accordance with GPG considerations about overall error for the all source sector;
- Errors due to determination of nitrogen volatilization are difficult to access because of the interconnections with indirect emissions, and were quantified only in source category Indirect N_2O emissions from Agricultural Soils.

GPG presents a possible variation from one-fifth to 5 times the default emission factor of 1.25 per cent. From that range an uncertainty of 500 per cent was assumed in uncertainty analysis for nitrogen applied as synthetic fertilizers, manure, crop residues and nitrogen fixed by n-fixing crops. Considering that in the cases of nitrogen added to soil from n-fixing crops and crop residues, an additional 100 per cent uncertainty was added to take into account errors in the determination of nitrogen content of crops and residues from production. In the case of animal production a lower uncertainty of 100 per cent was used, following table 4.12 of the GPG.

6.3.5.6 *Category-specific QA/QC and verification*

The QA/QC procedures applied in this source category comprehend a comparison between FAO data and INE values concerning the use of nitrogen fertilizers in Portugal. This procedure and the corresponding results are explained in the chapter Comparison to FAO database.

6.3.5.7 *Recalculations*

The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types and crops (this revised series was given by INE).

For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009).

RGA 2009 AD revision also affected milk yield values (2000-2009).

Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values.

Following the times series revision provided by the RGA 2009 (2000-2009), values on crop area and production for the 1990-1999, for some crop types, were also updated. This revision was also supported by INE values.

Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine.

Also important to note the revision of the 2009 value for apparent consumption of synthetic fertilizers.

6.3.5.8 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

The share of each nitrogen fertilizer, particularly the importance of urea use, is still under consideration by INE and will be used to improve the preliminary estimate that was made by APA and that is temporarily being used in this year report.

Efforts are going to be made concerning the collection of data for the application of sewage sludge in agriculture soils. New developments are expected in future submission.

6.3.6 *Indirect N₂O Emissions from Agriculture (CRF 4.D.2.)*

6.3.6.1 *Overview*

Emissions of N₂O from agriculture are considered indirect emissions from agriculture when they result from nitrogen that was not emitted when was applied the first time into soil but that has first suffered a path through one of two environmental systems:

- the atmospheric system - after volatilisation as ammonia or nitrogen oxides and intermediate transformation in nitric acid and ammonium salts in particulate or aerosol form
- the soil-water system - after leaching and/or runoff as ammonia, nitrite, nitrate or light organic compounds.

Actually N_2O indirect emissions result from the same microbial process associated to nitrification and denitrification that causes direct emissions. The only difference results from the fact that direct emissions occur solely in agricultural soils whether indirect emissions will occur in whenever conditions are adequate: in agricultural soils, non agricultural soils and even aquatic, Benthic and wetland systems.

Also, all NO_x and NH_3 emissions from other emissions sources may settle in soil and water and result in similar N_2O emissions. However, estimates of indirect emissions from these sources are not included in the Portuguese inventory.

Indirect emissions of N_2O from ammonia and NO_x volatilisation were estimated from ammonia volatilised whether actual indirect N_2O emissions occurred in the Portuguese territory or not. In the case of N_2O indirect emissions from leaching and runoff the geographical characteristics of the territory - where there are no water basins discharging to other countries - cause that all indirect emissions will occur still on the national territory or nearby ocean waters¹²⁶.

Even though this nitrogen flow is evident in Figure 6.26, it's important to stress the fact that indirect emissions of N_2O from volatilization result from 2 volatilization processes: the first as direct NH_3/NO_x emission and the second as N_2O indirect emission. Between these two processes occurs deposition of nitrogen from NH_3/NO_x direct emissions.

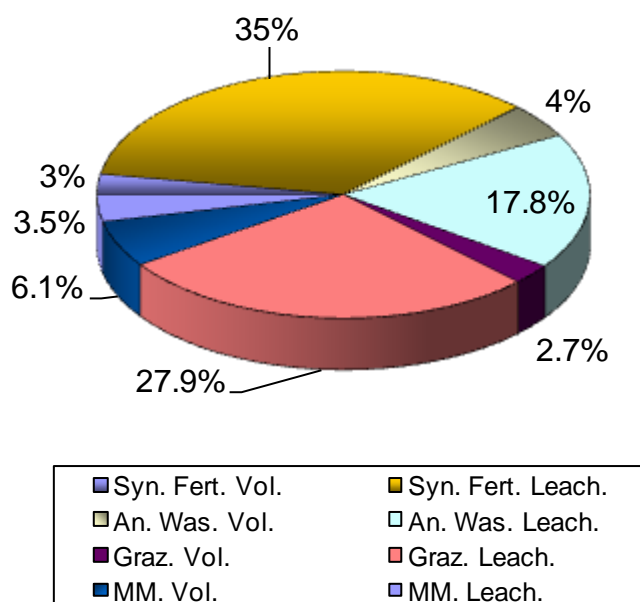
Figure 6.37 shows the percent importance of each sub-source for year 2010, where:

- Syn. Fert. Vol. – Synthetic Fertilizers N volatilization;
- Syn. Fert. Leach - Synthetic Fertilizers N resulting from leaching and runoff;
- An. Was. Vol. – Volatilization of N from Animal Waste (manure) applied to soil as fertilizer;
- An. Was. Leach. - Leaching and runoff of N from Animal Waste (manure) applied to soil as fertilizer
- Graz. Vol. – N volatilization from droppings during Grazing;
- Graz. Leach. – N leached from droppings during Grazing;
- MM. Vol. – Volatilizations of N from Manure Management Systems;
- MM. Leach. – Leaching and runoff of N from Manure Management Systems;

Indirect emissions from runoff and leaching from synthetic fertilizers, animal manure applied to soil and direct droppings during grazing are significant sources of N_2O indirect emission in this source category.

¹²⁶ In fact, part of indirect N_2O emissions from leaching and runoff from agriculture activities in Spain will occur most probably in Portuguese territory. These emissions are not included however in the Portuguese inventory.

Figure 6.32 – Relative importance of Indirect emissions of N₂O from agriculture in year 2010



6.3.6.2 Methodology

Different methodologies were used to estimate Indirect emissions from Agriculture. These methodologies are explained in the following chapters.

6.3.6.2.1 Volatilization

N₂O_(G), Indirect N₂O emissions from atmospheric deposition of nitrogen that has volatilised as NO_x and ammonia from nitrogen used in agriculture as an external input¹²⁷, either synthetic or in animal manure. The following equation, that is similar to GPG Tier1a equation, was utilized for N₂O emissions from volatilisation:

$$N_2O_{(G)} = 44/28 * (SF_NVol + MMS_NVol + AM_NVol + GR_NVol) * EF_4$$

where

SF_NVol - Total volatilisation, as ammonia or nitrogen oxides, of the nitrogen from synthetic fertilizers applied to soil (ton NH₃-N+NO_x-N/yr);

MMS_NVol - Volatilisation of nitrogen from manure in Manure Management Systems (emissions in housing and outside storage) (ton NH₃-N+NO_x-N/yr);

AM_NVol - Volatilisation of nitrogen from manure applied to soil as fertilizer (ton NH₃-N+NO_x-N/yr);

GR_NVol - Volatilisation of nitrogen from animal excreta deposited in soil during grazing in pasture range and paddock (ton NH₃-N+NO_x-N/yr);

¹²⁷ No indirect N₂O emissions are estimated from nitrogen leached or removed in runoff from nitrogen fixation by leguminous plants or from nitrogen in crop residues.

EF₄ - Emission factor for N₂O emissions from atmospheric deposition of nitrogen on soil and water surfaces (kg N₂O-N/kg NH₃-N+kg NO_x-N).

Methodologies for the estimation of ammonia from synthetic fertilizers, manure and animal excreta are explained in chapter NH₃ Emissions from agriculture (6.2.8). It was assumed that volatilisation emissions occur predominantly in ammonia form.

6.3.6.2.2 Leaching and Run-off

Indirect N₂O emissions from nitrogen that was removed from agricultural soils after being applied as fertilizer in soil - either as synthetic fertilizer or as manure - and from there removed as consequence of infiltration/percolation and runoff was estimated from next equation, that is proposed in GPG (equation 4.35 or 4.37):

$$N_2O_{(L)} = 44/28 * (N_{Fert} + N_{AM} + N_{GR}) * Frac_{LEACH} * EF_5$$

where,

N_{Fert} - Annual amount of synthetic fertilizer nitrogen applied to soils (ton N/yr);

N_{AM} - Annual amount of animal manure nitrogen intentionally applied to soils (ton N/yr), calculated from:

$$N_{AM} = \sum_i \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] \}$$

N_(i) - Number (head) of individuals from livestock category i in the country;

Nex_(i) - Annual country average N excretion per head of animal species/category i;

MS_(i,s) - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

MSSD_(i,s) - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

EF_{NH3(i,s)} - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

N_{GR} - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture;

Frac_{LEACH} - Fraction of N input that is lost through leaching and runoff

EF₅ - Emission factor for leaching/runoff (Kg N₂O / kg NH₃-N + NO_x-N)

Until submission 2007, 80 per cent of the effluent from anaerobic lagoons is used as soil fertilizer whereas the remaining 20 per cent is discharged to the water system. However, during the 2006 inventory review under the UNFCCC and the IIR under the Kyoto Protocol, one of the findings was concerned with the utilization of the remaining fraction of animal manure from anaerobic lagoons and the inclusion of this fraction in the calculations of N₂O emissions in agriculture, in order to achieve consistency with the GP.

In the 1996 Revised IPCC Guidelines and the Good Practice, there is no clear recommendation preventing the removal of direct discharge to water. However, the GP recommends that all

Nitrogen excreted should be added to soil, while only the following fractions should be subtracted: Fuel, Grazing Livestock, Feeding and Construction (Equation 4.23). In a similar manner the AD to estimate indirect N₂O emissions from Leaching and run-off should be estimated from total nitrogen production after removal of fuel, feed and construction, and then the application of the leaching factor.

The 2006 guidelines, used here only as an indicative reference, refer the possibility of subtraction of the fraction of nitrogen in manure that goes directly to the water system, although these guidelines are referring to the specific case of dry lots, where run-off and leaching could contribute directly to the water system without passage by soil. In chapter 10 (N₂O from Manure Management) emissions from Leaching and Runoff from Manure Management could be estimated according to Equations 10.28 and 10.29, and using the default EF from Leaching and Run-off from agricultural soils.

$$\begin{aligned} &\text{EQUATION 10.28} \\ &\text{N LOSSES DUE TO LEACHING FROM MANURE MANAGEMENT SYSTEMS} \\ &N_{\text{leaching-MMS}} = \sum_S \left[\sum_T \left[(N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)}) \cdot \left(\frac{\text{Frac}_{\text{leachMS}}}{100} \right)_{(T,S)} \right] \right] \end{aligned}$$

$$\begin{aligned} &\text{EQUATION 10.29} \\ &\text{INDIRECT N}_2\text{O EMISSIONS DUE TO LEACHING FROM MANURE MANAGEMENT} \\ &N_{2O_{L(mm)}} = (N_{\text{leaching-MMS}} \cdot EF_5) \cdot \frac{44}{28} \end{aligned}$$

In a similar mode, Chapter 11 (pg 11.13) also refers that Nitrogen to soil should be estimated according to equation 10.34 (pg 10.64 in chapter 10.5.4) from where it could be inferred that nitrogen to soil should be estimated considering total production and thereafter removing losses (including leaching, volatilization and N₂O emissions).

$$\begin{aligned} &\text{EQUATION 10.34} \\ &\text{MANAGED MANURE N AVAILABLE FOR APPLICATION TO MANAGED SOILS, FEED, FUEL OR} \\ &\text{CONSTRUCTION USES} \\ &N_{\text{MMS_Avb}} = \sum_S \left\{ \sum_T \left[\frac{(N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)}) \cdot \left(1 - \frac{\text{Frac}_{\text{LeachMS}}}{100} \right)}{[N_{(T)} \cdot MS_{(T,S)} \cdot N_{\text{beddingMS}}]} \right] \right\} \end{aligned}$$

The procedure that could be more akin to what is happening in reality is the estimate of emissions of N₂O in the water system resulting from the 20 per cent fraction of nitrogen fertilizer. This procedure reflects in the best way what is happening in the environment. Nevertheless, the final value will not be consistent with the activity data reported as F_{SN} (Nitrogen added to soil as synthetic fertilizer), F_{aw} (Nitrogen added to soil as animal manure) and Nitrogen deposited into soil during grazing and pasture. Also the reported Frac_{LEACH} in table 4Ds2 will no longer reflect the actual leaching and run-off rate that is applied to the nitrogen added on soil. With the agreement of ERT, the methodology that was chosen is simply to estimate emissions using the default emission factor for Indirect emissions from Leaching and Run-off (EF5), 0.025 kg N-N₂O/kg N-leached, applied to the quantity of nitrogen discharged¹²⁸. In general terms the

¹²⁸ Total contribution, not assuming volatilization or leaching rates.

emissions of N₂O from nitrogen discharged directly from Manure Management Systems N₂O_MM_(L) are estimated from:

$$N_2O_MM_{(L)} = 44/28 * \sum_i \{N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSW_{(i,s)}]\} * EF_5$$

where,

N_(i) - Number (head) of individuals from livestock category i in the country;

Nex_(i) - Annual country average N excretion per head of animal species/category i;

MS_(i,s) - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

MSSW_(i,s) - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is discharged directly to the water system¹²⁹;

EF₅ – Emission factor for leaching/runoff (kg N₂O / kg NH₃-N + NO_x-N)

6.3.6.3 *Emission Factors*

Default IPCC emission factors were used for EF₄ and EF₅ (table 4-23 of the 1996 IPCC and table 4.18 of the GPG):

Table 6.40 – Emission factors for N₂O indirect emissions from agricultural soil

Emission Factor	kg N ₂ O / kg NH ₃ -N + NO _x -N
EF4 (Deposited nitrogen from volatilization)	0.010
EF5 (Leaching and Runoff)	0.025

GPG recommends strongly the use of the default IPCC emission factor for deposited nitrogen after volatilisation (EF₄). According to GPG the default value for EF₅ will be probably revised in the near future.

¹²⁹ MSSW in the case of Anaerobic Lagoons is equal to 1-MSSD.

6.3.6.4 *Activity Data*

Emissions of N₂O from atmospheric deposition of nitrogen compounds that were volatilised consider 4 components: SF_NVol (Synthetic Fertilizers); MMS_NVol (Manure Management Systems); AM_NVol (Animal Manure applied as fertilizers) and GR_NVol (Grazing), that are presented in Table 6.41 and which contribution of sub-sources in year 2010 is presented in Figure 6.33.

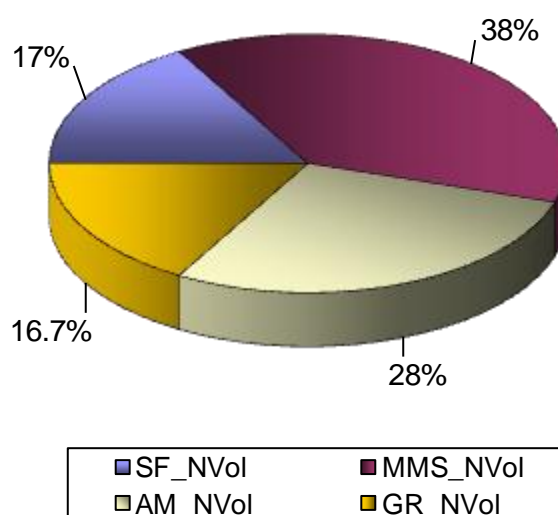
Nitrogen from NH₃ volatilisation and subsequent deposition from Manure Management Systems was the major contributor to indirect emissions with about 38 per cent of total deposition in 2010. The following most important components are nitrogen in manure applied to soil as fertilizer (28 per cent) and nitrogen in synthetic fertilizers (17 per cent). Nitrogen volatilised from droppings during grazing is a less important source with 16.7 per cent of total contribution in 2010. Total ammonia emissions and deposition have decreased about 16.7 per cent from base year to last year in the inventory.

Table 6.41 – Nitrogen added to soil from Ammonia volatilisation, by emission source/component, which is activity data for Indirect N₂O emission

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SF_NVol	9 089	9 089	9 006	7 623	9 224	8 187	9 904	10 325	8 453	8 965	9 744	9 007
MMS_NVol	16 852	17 030	16 909	16 788	16 665	16 534	16 221	16 097	16 232	16 817	16 926	16 452
AM_NVol	12 604	12 681	12 553	12 413	12 342	12 287	12 100	11 998	12 084	12 554	12 658	12 306
GR_NVol	4 660	4 728	4 681	4 674	4 761	4 939	5 108	5 239	5 365	5 511	5 588	5 580
Total	43 205	43 528	43 148	41 499	42 992	41 946	43 334	43 659	42 134	43 848	44 917	43 345

ton N/yr	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SF_NVol	9 372	6 298	7 196	5 871	4 997	6 462	5 731	6 012	6 012	-	-
MMS_NVol	15 812	14 994	14 601	14 332	13 984	13 564	13 482	13 627	13 730	-	-
AM_NVol	11 879	11 254	10 975	10 802	10 536	10 199	10 114	10 188	10 227	-	-
GR_NVol	5 594	5 599	5 705	5 859	5 955	6 012	6 031	6 021	6 014	-	-
Total	42 657	38 145	38 477	36 863	35 471	36 236	35 358	35 848	35 982	-	-

Figure 6.33 – Percent importance of nitrogen added to soil from volatilization of ammonia, by emission source/component in 2010



The fraction of nitrogen input to soil that is lost through leaching and runoff ($\text{Frac}_{\text{LEACH}}$) of nitrogen added to soil was determined as 0.3 kg N/kg N, the default value in IPCC96. However, as explained before, the quantity the total nitrogen rejected directly into the water system from anaerobic lagoons is also resulting in emissions of nitrous oxide¹³⁰.

The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in Table 6.42 and in, for each component that is considered in lixiviation/runoff estimate: FSN (Synthetic Fertilizers), FAM (Animal Manure), FGR (Grazing) and direct discharge to the water system. Nitrogen added to soil in synthetic fertilizers is the major lixiviation/runoff source. From 1990 to 2010 nitrogen deposited into soil has decreased by 17.4 per cent.

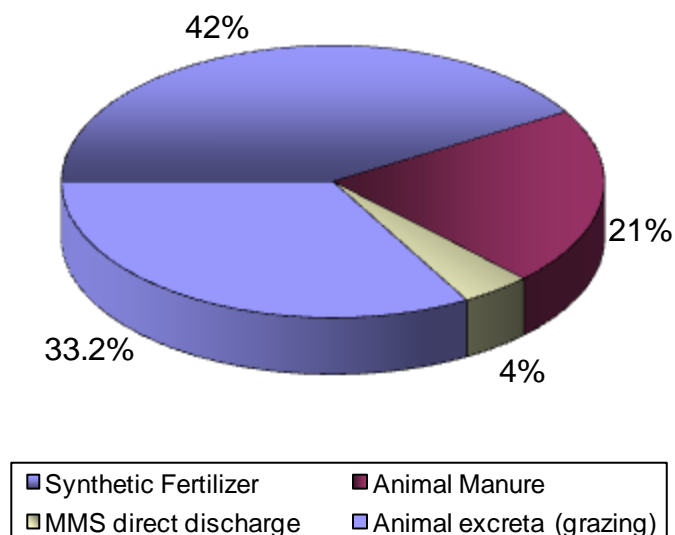
¹³⁰ Which explains the fact that in CRF table 4Ds2, the “implicit” $\text{Frac}_{\text{LEACH}}$ is a little higher than the default.

Table 6.42 – Nitrogen lost from soil from lixiviation and runoff (ton N/yr)

Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Synthetic Fertilizer	47 684	47 684	47 684	47 684	47 684	43 745	50 469	49 286	44 791	44 683	51 003	47 253
Animal Manure	20 284	20 418	20 219	20 008	19 904	19 824	19 543	19 375	19 494	20 184	20 297	19 683
MMS direct discharge	3 087	3 274	3 333	3 408	3 406	3 399	3 323	3 361	3 399	3 463	3 429	3 326
Animal excreta (grazing)	21 158	21 451	21 271	21 247	21 617	22 321	22 989	23 461	23 959	24 534	24 746	24 467
Total	92 213	92 826	92 507	92 348	92 610	89 288	96 323	95 484	91 643	92 865	99 476	94 729

Description	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Synthetic Fertilizer	49 170	33 040	37 753	30 799	26 217	33 902	30 065	31 539	31 539	-	-
Animal Manure	18 953	17 953	17 504	17 221	16 798	16 260	16 083	16 127	16 121	-	-
MMS direct discharge	3 169	3 056	3 060	3 108	3 165	3 193	3 211	3 225	3 201	-	-
Animal excreta (grazing)	24 248	24 117	24 513	25 133	25 515	25 666	25 622	25 435	25 268	-	-
Total	95 540	78 165	82 831	76 261	71 695	79 020	74 981	76 326	76 129	-	-

Figure 6.34 – percent importance of sub-sources of Nitrogen Lost from soil from lixiviation and runoff in 2010



6.3.6.5 *Uncertainty Assessment*

The uncertainty in emission factors was set at an order of magnitude, in accordance with the considerations in GPG (IPCC,2000). In what concerns the uncertainty associated with activity data an additional 50 per cent error was applied to the uncertainty in activity data reported in N₂O Direct emissions, in order to incorporate the error of the volatilization and leaching fractions, also in accordance with GPG (IPCC,2000), and the final resultant uncertainty value is 63 per cent.

6.3.6.6 *Recalculations*

The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types and crops (this revised series was given by INE).

For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009).

RGA 2009 AD revision also affected milk yield values (2000-2009).

Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values.

Following the times series revision provided by the RGA 2009 (2000-2009), values on crop area and production for the 1990-1999, for some crop types, were also updated. This revision was also supported by INE values.

Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine.

Also important to note the revision of the 2009 value for apparent consumption of synthetic fertilizers.

6.3.6.7 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

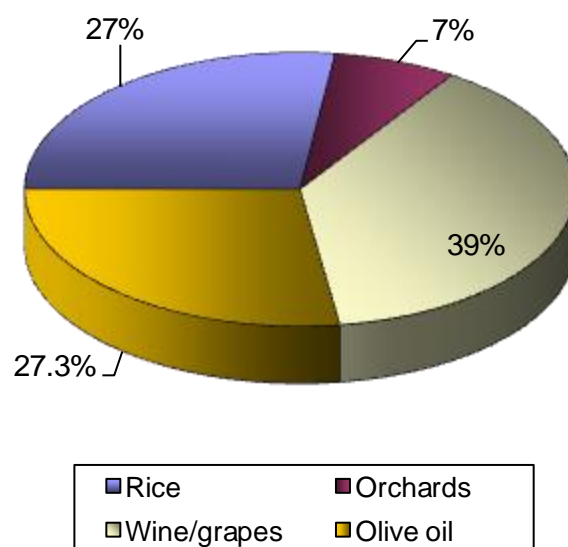
6.3.7 **Field Burning of Agriculture Residues (CRF 4.F.)**

6.3.7.1 *Overview*

In-site burning of agricultural residues is still practiced nowadays in Portugal, being however forbidden by law-decree during the Forest Fire Season from May to September. These burning, results in emissions of trace gases as in other combustion processes, including methane, nitrous oxide, carbon monoxide, nitrous oxides and volatile organic compounds. Carbon dioxide is of course also emitted in this process but because it has biomass origin and it is in principle re-absorbed during next growing season, it is not considered in GHG emission inventory.

Considering equivalent carbon dioxide emissions (Figure 6.35), burning of residues from vineyards and olive oil are the most significant sources of this non-key source.

Figure 6.35 – Importance of GHG emissions from field burning of agriculture residues by crop in 2010



6.3.7.2 Methodology

Emissions of in-site burning of agriculture residues were estimated from the following equation:

$$\text{Emission}_{(p,crop,y)} = \text{EF}_{(p,crop)} * \text{Crop}_{\text{BURN}(crop,y)} * 10^{-3}$$

where

$\text{Emission}_{(p,crop,y)}$ - Emission estimate of pollutant p from field burning of residues from a specific crop in year y (ton/year);

$\text{Crop}_{\text{BURN}(crop,y)}$ - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{EF}_{(p,crop)}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm).

Other methodology formulations could be used that would result in equal results. However activity data definition in dry matter terms was chosen in order that emission factors would be expressed in the same units that are presented in Implied Emission Factors (IEF) of table 4.F of CRF format. Consequently part of methodology that is in fact used to determine emissions, is included in emission factor determination and part also in activity data determination and they are subsequently described in the appropriate chapters. But for all relevant aspects, the methodology that it is used, follow the same methodology proposed in IPCC96 except for the fact that residue biomass is not estimated from crop production but from residue production quantities by cultivated area.

6.3.7.3 Emission Factors

Except for NMVOC and SO_x , emission factors for each specific pollutant are estimated from different equations whether they are carbon containing pollutants (CO_2 , CH_4 and CO) or nitrogen containing pollutants (NO_x and N_2O). This methodology - after IPCC96 - assumes that some fixed part of carbon and nitrogen that are submitted to burning are emitted as specific compounds.

For carbon containing pollutants the equation is:

$$\text{EF}_{(pol,crop)} = \text{C}_{\text{Fraction}(Crop)} * \text{Frac}_{\text{RESOXI}(crop)} * \text{ER}_{(crop,pol)} * \text{MWC}_{(Pol)}$$

For nitrogen containing compounds the equation is:

$$\text{EF}_{(pol,crop)} = \text{C}_{\text{Fraction}(Crop)} * \text{Frac}_{\text{RESOXI}(crop)} * \text{NC}_{\text{Ratio}(crop)} * \text{ER}_{(crop,pol)} * \text{MWC}_{(Pol)}$$

where

$\text{EF}_{(pol,crop)}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$\text{C}_{\text{Fraction}(Crop)}$ - Ratio of carbon content in dry biomass matter (kg C/kg dm);

$\text{Frac}_{\text{RESOXI}(crop)}$ - Fraction or ratio of carbon that it is oxidized during the active burning period (kg C/kg C);

$\text{NC}_{\text{Ratio}(crop)}$ - Ratio of nitrogen to carbon in crop residue (kg N/kg C);

$ER_{(crop,pol)}$ - Emission ratio, the fraction of total carbon/nitrogen content that it is emitted as pollutant pol (kg C/kg C or kg N/kg N);

$MWC_{(Pol)}$ - Stechiometric correction fraction to convert emissions in carbon/nitrogen units to total molecular weight emissions (kg/kg C or kg/kg N respectively for carbon compounds or nitrogen compounds).

The parameters used to establish emission factors for each crop are presented in next table.

Table 6.43 – Parameters used for determination of emission factors for field burning of agricultural residues

Crop	C _{fraction}	Frac _{RESOXI}	NC _{Ratio}
Rice	0.6	0.9	0.04
Orchards	0.6	0.9	0.05
Wine/Grapes	0.6	0.9	0.04
Olive oil	0.6	0.9	0.04

The pollutant specific emission ratios that were used follow the IPCC default emission ratios proposed in table 4-17 of IPCC96 and which were still not updated in GPG (Annex 4.A.2).

Table 6.44 – Pollutant specific emission ratios for determination of emissions from field burning of agricultural residues

Pollutant	Emission Ratio (ER)	Units	MWC Ratio
CH ₄	0.5	% Carbon Released from fuel	16/12
N ₂ O	0.7		44/28
CO	6.0		28/12
NO _x	12.1		46/14

Final emission factors for these four pollutants are reproduced in the following table.

Table 6.45 – Final emission factors for field burning of agricultural residues by pollutant and crop (kg/ha) – CH₄, N₂O, NO_x and CO

Crop	CH ₄	N ₂ O	NO _x	CO
Rice	9.5 - 25.6	0.3 – 0.7	9.2 - 24.7	199.5 - 538.5
Fresh Fruits	0.4	0.04	1.3	9.1
Citrines	0.4	0.04	1.3	9.1
Dry fruits	0.4	0.04	1.3	9.1
Wine/grapes	1.8	0.12	4.3	37.8
Olive oil	0.7	0.04	1.6	14.2

The emission factors for NMVOC are those proposed by AP-42 (USEPA,1992), which are reproduced in Table 6.46.

Table 6.46 – Emission factors for field burning of agricultural residues by pollutant and crop (kg/ha) - NMVOC

Crop	NMVOC
Rice	26.1 - 33.5
Fresh Fruits	2.0
Citrines	4.0
Dry fruits	2.4
Wine/grapes	7.5
Olive oil	2.6

Emission of SO_x were estimated with EMEP/CORINAIR (2009) emissions factors. These can be seen in the following table:

Table 6.47 – Emission factors for field burning of agricultural residues by pollutant and crop (kg/ton dm) – SO_x

Crop	SO _x
Rice	0.3
Fresh Fruits	0.3
Citrines	0.3
Dry fruits	0.3
Wine/grapes	0.3
Olive oil	0.3

6.3.7.4 *Activity data*

According to expert information from the Ministry of Agriculture (Seixas et al, 2000) only vegetal residues from wine, olive oil cultivation and orchards¹³¹ are subjected to significant on-site burning.

The basic activity data available from the National Statistical Institute that was used is area cultivated for each relevant crop. Expert opinion from the Agriculture Ministry (Seixas et al, 2000) was used to establish the quantity of residues that is generated annually by each crop and what percentage is actually burnt in site. Rice is the only crop for which a detailed and time-series could be developed following the information received from the agriculture experts from the Portuguese Ministry of Agriculture:

- Traditionally, stubbles and straw were burnt between crops;
- The use of rice straw as fodder or bedding is not significant, and is not removed from field;
- More recently the agricultural practices have changed (2002 onwards). It became more common to leave the straw on ground and incorporate it into soil by

¹³¹ Comprehending fresh fruit, citrines and dry fruits (nuts)

plowing. This procedure is the only allowed if Techniques of Integrated Production and Protection¹³² are used;

- The area subjected to “Techniques of Integrated Production and Protection” occupied about 51 per cent of rice paddies in 2004. Today this are represents about 54 per cent of total area;
- It may be assumed that, in 1990, 100 per cent of rice paddies were burnt and no organic amendments were added to soil. In 2010 the area subjected to burning was reduced to only about 45 per cent.

Activity data in suitable units is estimated from:

$$\text{Crop}_{\text{BURN (crop,y)}} = \text{Crop}_{\text{AREA(crop,y)}} * \text{Resid}_{\text{PROD (crop)}} * \text{Dm}_{\text{Content(crop)}} * \text{Frac}_{\text{RESBURN (crop)}} * 10^{-7}$$

where

$\text{Crop}_{\text{BURN (crop,y)}}$ - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{Crop}_{\text{AREA (crop,y)}}$ - Cultivated area for each specific crop in year y (ha/yr);

$\text{Resid}_{\text{PROD (crop)}}$ - Quantity of residue generated from each unit cultivation area of crop y expressed in live weight (kg/ha);

$\text{Dm}_{\text{Content(crop)}}$ - Dry matter content of crop residues (% dm/live weight);

$\text{Frac}_{\text{RESBURN (crop)}}$ - Fraction of total residues from a specific crop that are burnt in site (%).

Parameters $\text{Resid}_{\text{PROD}}$, $\text{Dm}_{\text{Content}}$ and $\text{Frac}_{\text{RESBURN}}$ are the same considered in (Seixas et al, 2000) and are presented in Table 6.48. Final activity data expressed in crop area dry matter content may be seen in Table 6.48 and Table 6.49.

Table 6.48 – Parameters used for the estimation of the quantity of burnt crop residues

Crop	Resid _{PROD}	Frac _{RESBURN}	DMContent
	kg live weight/ha	%	%
Rice	3 900	30-100	85
Orchards	800	30	50
Wine/Grapes	2 500	40	50
Olive oil	375	100	50

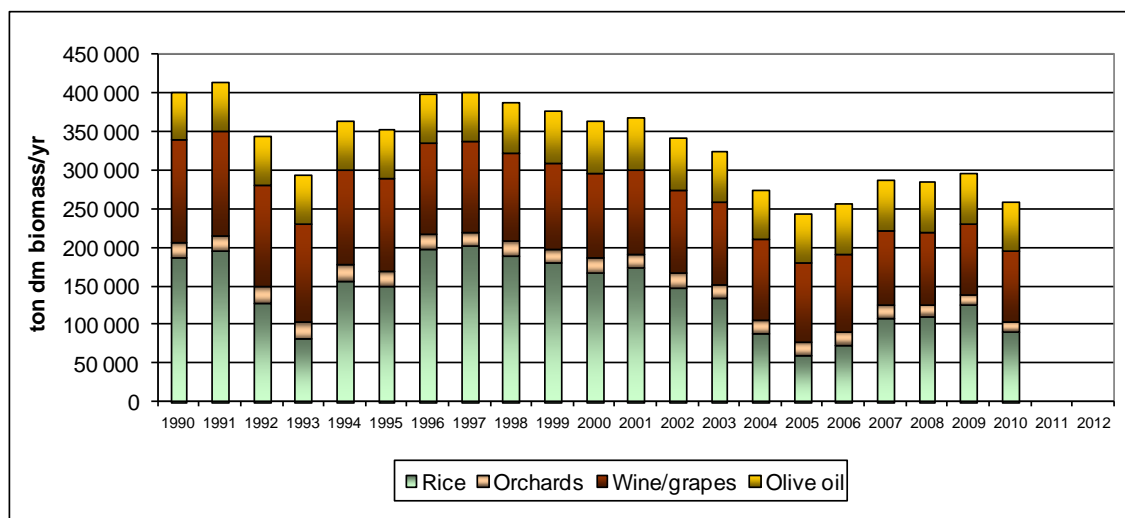
¹³² “modos de protecção e produção integrada” in the original in Portuguese.

Table 6.49 – Crop area per crop (ha)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Rice	33 824	33 466	21 118	13 200	24 051	21 726	28 278	28 540	27 020	25 307	23 859	24 936
Orchards	164 147	166 122	168 103	166 840	165 690	164 748	163 844	162 337	161 383	158 792	158 301	156 014
Wine/grapes	264 359	271 160	264 062	254 528	247 615	241 964	236 654	232 226	226 497	219 442	217 899	217 691
Olive oil	337 189	333 757	338 948	340 579	340 672	333 144	336 621	338 414	347 271	369 032	367 351	361 606
Total	799 519	804 505	792 231	775 147	778 028	761 582	765 397	761 517	762 171	772 573	767 410	760 247

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rice	25 216	25 657	26 620	22 881	25 392	26 903	26 334	28 470	29 120	-	-
Orchards	153 581	150 956	147 743	144 383	140 623	134 469	131 214	126 750	126 787	-	-
Wine/grapes	216 642	213 385	208 956	204 494	199 313	193 988	187 800	181 920	180 791	-	-
Olive oil	354 040	350 064	347 276	348 426	347 901	347 369	347 140	344 199	343 219	-	-
Total	749 479	740 062	730 595	720 184	713 229	702 729	692 488	681 339	679 917	-	-

Figure 6.36 – Estimated total quantities of burnt crop residues per crop



6.3.7.5 *Uncertainty Assessment*

The uncertainty in activity data is higher than the error associated with crop area determination, because there is a higher uncertainty in the percentage of crop areas that are subjected to burning and in which crops field burning is practiced. An uncertainty value of 100 per cent was therefore considered.

The uncertainty range in emission factors was set at 20 per cent in accordance with recommendations from GPG (IPCC,2000).

6.3.7.6 *Recalculations*

Recalculations for this sector result from the following actions:

- The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all crops (this revised series was given by INE);
- New data from GPP was obtained concerning rice areas in Techniques of Integrated Production and Protection. This new data revised the 1996-2009 time series.

6.3.7.7 *Further improvements*

Associated with agriculture activities, the burning of hedge rows and some weeds is still practice in Portugal. There is still no data concerning this activity and a better insight on this subject will have to be developed in next inventories.

The adoption of three year average for crop area and emissions will be discussed under Methodology Development Plan, which is not use yet for consistent with determination of emissions from forest fires.

6.3.8 *NH3 Emissions from Volatilization in Agriculture Soils*

6.3.8.1 *Methodology*

Although emissions of ammonia from nitrogen were already discussed in several chapters, it is explained again here to allow a clearer understanding of this emission source.

Ammonia volatilisation from the application of synthetic fertilizers (SN_NH₃) is calculated using the following formula:

$$SN_{NH_3} = N_{Fert} * Frac_{GASF}$$

where,

N_{Fert} - total amount of nitrogen in synthetic fertilizers consumed annually

$Frac_{GASF}$ - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH₃ or NO_x

Ammonia emission from manure may occur in 4 different places in the life cycle of manure, with differentiated emission factors according to EMEP/CORINAIR Emission Factor Handbook:

- Emission in housing;
- Emission in outside storage;
- Emissions from land spreading of manure collected in each Manure Management Systems;
- Emissions of ammonia volatilised from droppings deposited directly in soil during grazing.

Emissions from manure during housing and storage (MMS_NH₃) are not differentiated and are estimated according to equation:

$$MMS_{NH_3} = \sum_i [N_{(i)} * Nex_{(i)} * (1 - MS_{GRAZ(i)}) * EF_{NH3(i)}]$$

where

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$EF_{NH3(i)}$ - Fraction of nitrogen from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock;

For the time being the emission factors are only dependent on animal type and not on the manure management system, except in what concerns the differentiation of ammonia volatilisation in grazing.

Emissions from manure collected in Manure Management Systems and that is later deposited in agricultural soil as fertilizer (AM_NH₃) is calculated from:

$$AM_{NH_3} = \sum_i \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

where

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category T that is managed in Manure Management System s, except grazing;

$MSSD_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i)}$ - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(t)}$ - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

Emissions from volatilisation of nitrogen added to soil during grazing (GZ_NH_3) was estimated by:

$$GZ_NH_3 = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * EF_{NH3(i)}]$$

where:

i - Animal/species category of livestock;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock;

$EF_{NH3(i)}$ - Fraction of nitrogen excreted from livestock category i during grazing that is lost to atmosphere as ammonia.

Ammonia emissions from agriculture also result from field burning of residues as it was already presented in chapter 6.3.7.

6.3.8.2 *Emission Factors*

6.3.8.2.1 Ammonia Volatilization from Synthetic Fertilizers

The volatilization ratio from synthetic fertilizers, $Frac_{GASF}$, was determined from an estimate of the share of nitrogen synthetic fertilizers used in Portugal based on statistical information from INE on import, export and national production of each individual nitrogen fertilizer. Albeit some deficiencies still found in the basic information data, it was considered this volatilization ratio to be more suitable to represent the national conditions than to use the default IPCC approach that is recognized to be too high and not representative of the national conditions of fertilization, particularly when the results of the inventory are being used to discuss capes under the European Emissions Ceiling (NEC). The following approach was used:

- Data information concerning national production of nitrogen synthetic fertilizers was available from INE from 1992 till 2000, from the IAPI industrial survey and using PRODCOM product classification. This statistical information has confidential constraints and may not be published in the present report;

- Statistical information about foreign trade is available also from INE concerning importation and exportation of nitrogen fertilizers. Products are classified according to NC codes. The same confidential constraints apply to this data;
- Annual consumption of nitrogen fertilizers per fertilizer type was hence estimated by APA for the years from 1992 to 2000, using the following equation¹³³. In Figure 6.37 the share of consumption of each nitrogen fertilizer, as estimated by APA, is presented as an average situation in the 1992-2000 period, where it may be seen that Calcium Ammonium Nitrate is the main fertilizer in use and urea, the fertilizer more prone to nitrogen volatilization, represented about 17 per cent of nitrogen added as fertilizer to soils.

$$\text{Consumption}_{(f)} = \text{Production}_{(f)} + \text{Import}_{(f)} - \text{Export}_{(f)}$$

where,

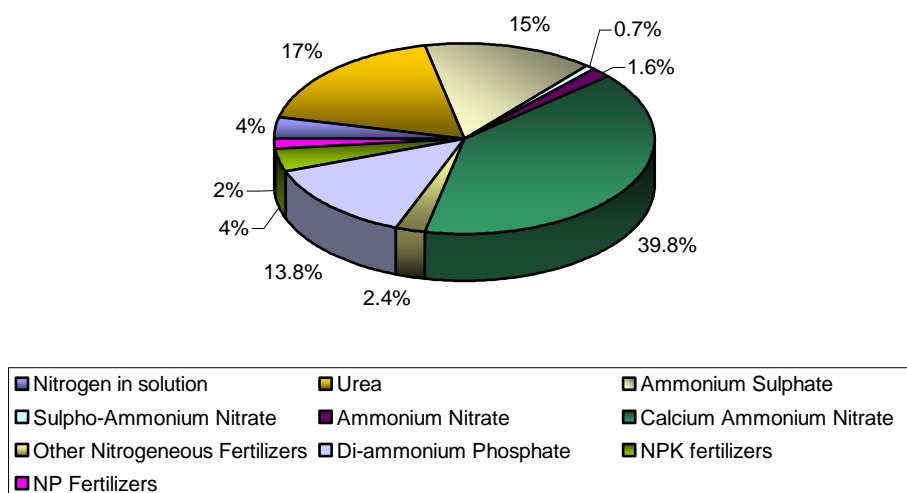
Consumption_(f) – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

Production_(f) – Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

Import_(f) – Annual importation in Portugal of nitrogen fertilizer f (ton N/yr);

Export_(f) – Annual exportation in Portugal of nitrogen fertilizer f (ton N/yr);

Figure 6.37 – Relative Importance of the use of various nitrogen fertilizers in Portugal, as estimated by APA from production and foreign trade



- product specific volatilization rates from EMEP/CORINAIR (EEA,2003) were used for each nitrogen fertilizer type according to Table 6.50.

¹³³ This estimates are only preliminary guesses and are being revised together with INE and the Ministry of Agriculture.

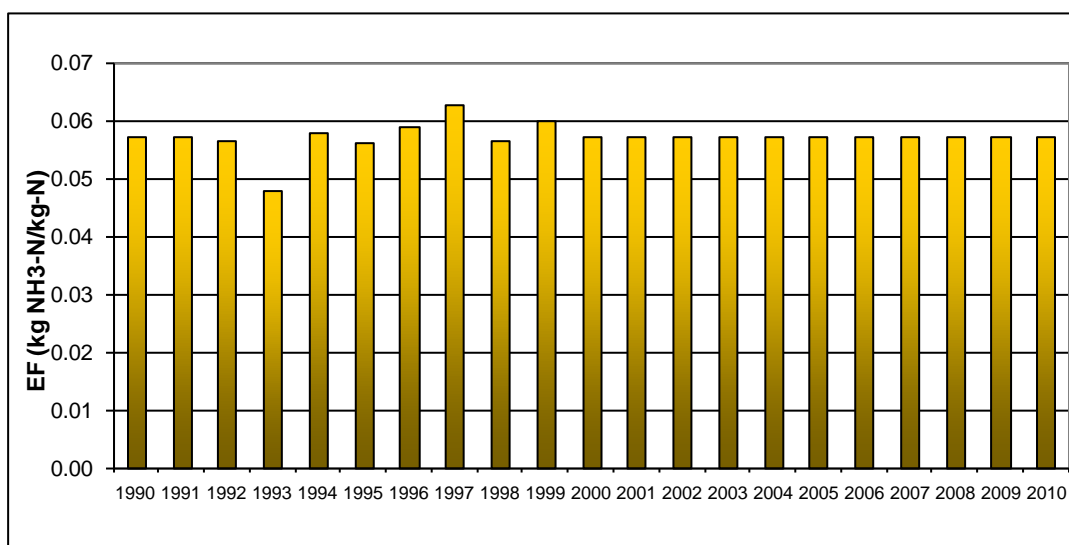
Table 6.50 – Volatilization rates for each nitrogen fertilizer

Acronym	Product	EF (kg NH ₃ /kg N)
UAN	Nitrogen in solution	0.08
UREA	Urea	0.15
AS	Ammonium Sulphate	0.08
SAN	Sulpho-Ammonium Nitrate	0.05
AN	Ammonium Nitrate	0.02
CAN	Calcium Ammonium Nitrate	0.02
N	Other Nitr.Fertilizers	0.053
DAP	Di-ammonium Phosphate	0.05
NPK	NPK fertilizers	0.02
NP	NP Fertilizers	0.02

Source: EMEP/CORINAIR file B1010vs4 - Revision of 3rd ed in Jan2003

- finally, the weighted average ammonia volatilization rate was estimated for each year from 1992 to 2000 and the average value in that period applied to 1990, 1991 and extrapolated to 2001-2010. The final volatilization rates appear in Figure 6.38.

Figure 6.38 – Final volatilization rate of ammonia from the application of synthetic fertilizer in agricultural soils



6.3.8.2.2 Ammonia Volatilization from Animal Excreta

The emission factors that were used to estimate ammonia emissions from manure from domestic livestock were already presented in source categories N₂O emissions from manure management and direct N₂O emissions from Agricultural Soils and are present again in Table 6.51. These emission factors result from EMEP/UNECE 3rd edition in annex A of chapter B1050 and version 4.0 of chapter B1010 and are not dependent on the Manure Management System that is used. Final emission factors per animal class are presented in next table.

Table 6.51 - Emission factors used for calculation of NH_3 volatilisation from animal housing, land spreading and grazing in pasture (kg N-NH_3 /kg N excreted)

Classe	Housing & Outside Storage	Land spreading of Manure	Grazing in Pasture
Dairy Cows	0.17	0.17	0.08
Other Cattle	0.17	0.17	0.08
Sheep	0.10	0.07	0.04
Goats	0.10	0.07	0.04
Swine	0.22	0.16	0.08
Equines	0.12	0.07	0.08
Poultry	0.22	0.16	-
Hens	0.23	0.15	-
Rabbits	0.22	0.16	-

The use of emission factors from EMEP/UNECE results therefore in values for $\text{Frac}_{\text{GASM}}$ that are different and higher than the default value for $\text{Frac}_{\text{GASM}}$ (0.2 kg N-NH_3 + N-NO_x / kg of N excreted, in table 4-19 of IPCC96).

6.3.8.3 *Activity Data*

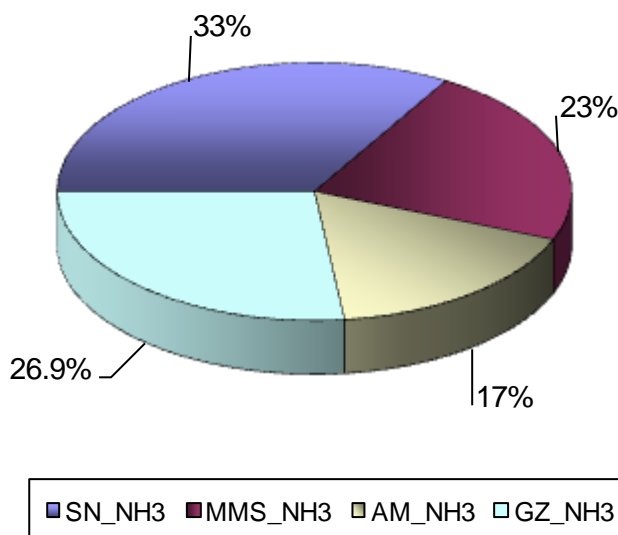
The quantity of nitrogen that is subjected to volatilisation through direct emission is presented in Table 6.52 and in Figure 6.39.

Table 6.52 – Nitrogen subjected to volatilization from each emission source/component, which is activity data for NH₃ emissions

Source	ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Synthetic Fertilizers	SN_NH ₃	158 945	158 945	158 945	158 945	158 945	145 815	168 229	164 288	149 303	148 944	170 009	157 511
M.M.S.	MMS_NH ₃	87 553	88 364	87 639	86 891	86 417	86 013	84 687	84 042	84 612	87 561	88 014	85 389
Animal Manure	AM_NH ₃	67 054	67 432	66 740	66 050	65 741	65 474	64 523	63 957	64 347	66 642	67 024	65 138
Grazing/ Pasture	GZ_NH ₃	70 525	71 502	70 905	70 824	72 057	74 402	76 630	78 204	79 863	81 781	82 486	81 556
Total	-	384 078	386 243	384 229	382 711	383 159	371 703	394 069	390 492	378 125	384 928	407 534	389 594

Source	ton N/yr	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Synthetic Fertilizers	SN_NH ₃	163 902	110 132	125 844	102 663	87 391	113 005	100 216	105 130	105 130	-	-
M.M.S.	MMS_NH ₃	82 158	77 892	76 008	74 842	73 142	70 955	70 304	70 610	70 668	-	-
Animal Manure	AM_NH ₃	62 816	59 599	58 034	57 058	55 591	53 798	53 234	53 431	53 451	-	-
Grazing/ Pasture	GZ_NH ₃	80 826	80 390	81 711	83 776	85 049	85 552	85 408	84 784	84 226	-	-
Total	-	389 701	328 013	341 597	318 340	301 172	323 311	309 162	313 954	313 476	-	-

Figure 6.39 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation in 2010



For the last inventory year the majority of nitrogen added to soil, that contribute to NH_3 emissions, resulted from the application of Synthetic Fertilizers (33 per cent). Direct droppings during grazing in Pasture (26.9 per cent) and Manure Management System (23 per cent) are also two important sources of nitrogen add to soil that is activity data in the determinations of NH_3 emission.

6.3.8.4 Recalculations

The major recalculation for this source category was the introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types (this revised series was given by INE).

For some animal types like swine and ovine the AD revision affects all the 1990-2009 time series. This results from the fact that for some animal subcategories livestock values for the first years of the time series were corrected with data from later years (now revised with RGA 2009).

RGA 2009 AD revision also affected milk yield values (2000-2009).

Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series (1990-2009 when coupled with the RGA revision). This revision was also supported by INE values.

Revised livestock and slaughter data for Lambs (ovine) and Kids (caprine) due to inconsistencies found in the AD used (1990-2009). This procedure also revised livestock numbers for Other Ovine and Other Caprine.

Also important to note the revision of the 2009 value for apparent consumption of synthetic fertilizers.

6.3.8.5 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

The importance of the Manure Management System in ammonia emissions needs to be included in the methodology, but that depends on the existence of appropriate emission factors.

It is expected that efforts will continue to ameliorate the volatilisation rates from the application of synthetic fertilizers, following a future better knowledge of the nitrogen fertilizer types used in Portuguese agricultural soils.

7 LAND USE, LAND USE CHANGE AND FORESTRY (CRF 5.)

7.1 Overview of LULUCF

7.1.1 Quantitative overview and description

This chapter refers to the estimation of emissions and removals of CO₂ and non-CO₂ for the Land-Use, Land-Use Change and Forestry (LULUCF) sector.

The sector has been deeply revised in order to respond to UNFCCC reviews and to apply to a greater extent the 2003 IPCC Good Practice Guidance for LULUCF (GPG LULUCF), and to include the estimates from the Autonomous Regions of Azores and Madeira.

Land area has been classified according to the six GPG LULUCF categories: Forest Land (5A), Cropland (5B), Grassland (5C), Wetlands (5D), Settlements (5E) and Other Land (5F). All these classes have been divided into “lands remaining in the same land use category” and “lands converted into another land use category”, on the basis of a 20 years transition period.

Carbon stock changes have been estimated for all pools as presented in Table 7.1. The gases estimated by source are summarised in Table 7.2. Above and belowground biomass considers both gains and losses.

Table 7.1 - Carbon Pools considered

Above ground biomass	Below ground biomass	Litter	Dead wood	Mineral Soils	Organic soils
Yes	Yes	Yes	Included Elsewhere ¹³⁴	Yes	Not Occurring ¹³⁵

Table 7.2 - Greenhouse Gas Sources considered

Fertilization	Soil drainage	Liming	Biomass burning		
N ₂ O	N ₂ O	CO ₂	CO ₂	CH ₄	N ₂ O
Included Elsewhere ¹³⁶	Not reported	Yes	Yes	Yes	Yes

N₂O emissions from nitrogen fertilisation of forest soils have not been estimated separately as they are already included in the chapter on Agriculture. This is mostly due to the fact that statistical information does not distinguish between fertilizer use in forest and agricultural areas.

¹³⁴ Emissions from dead wood resulting from harvesting were included as harvesting emissions, which consider the instant oxidation of the entire tree. Emissions from dead wood from forest fires were included as indirect CO₂ emissions from biomass burning. Other emissions and removals from the dead wood pool were not estimated.

¹³⁵ Area of organic soils in Portugal is negligible.

¹³⁶ Included in Chapter 4 – Agriculture. The level of aggregation of the activity data of the use of fertilizers does not allow distinguishing among the quantities used in agriculture and forestry. Since the amounts used in agriculture are substantially higher than those used in forestry, all of it was included in sector 4 estimations.

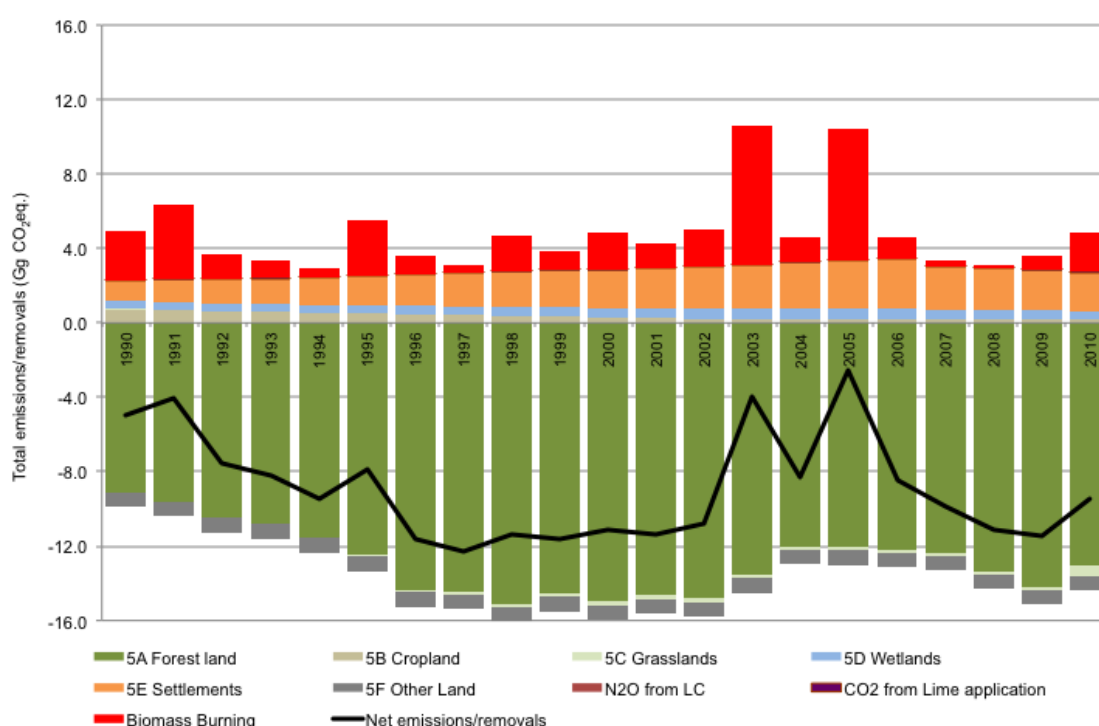
N₂O emissions from enhanced mineralization of soil organic matter associated with land-use conversion to cropland are estimated. N₂O emissions from soil drainage have not been estimated, since they are not common practices in croplands, grasslands or forest lands.

CO₂ emissions from liming in croplands and grasslands are also now considered in the inventory despite not being a common practice in forest lands or other land uses.

This report presents the estimates for carbon stock changes of Harvested Wood Products (CRF 5.G). The method applied is based on a first decay function as described in IPCC 2006 guidelines, chapter 4 AFOLU, chapter 12 HWP.

According to the current estimates, the sector was a net sink for the whole period and was responsible for the sequestration of 9.9 Mt of CO₂ e. in 2010. This tendency was influenced mostly by category 5A – Forest Land. The inventory considers the whole national forest, as all forests are considered to be affected by human intervention, and consequently considered as non-natural/managed.

Figure 7.1 – Net Annual CO₂e Change from LULUCF (Gg CO₂e)



7.1.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

In this submission, the map used to derive dynamics in Land Use and Land Use Change areas in Portugal's mainland and Madeira was the Corine Land Cover (CLC). The CLC products were generated in the framework of the Global Monitoring for Environment and Security Land Fast Track Service Precursor (GMES Land FTSP) for Mainland Portugal. GMES Land FTSP is an initiative created by the European Environment Agency (EEA) and European Commission (EC), namely with the goal of updating previous CLC mapping initiatives. At present, CLC is the only

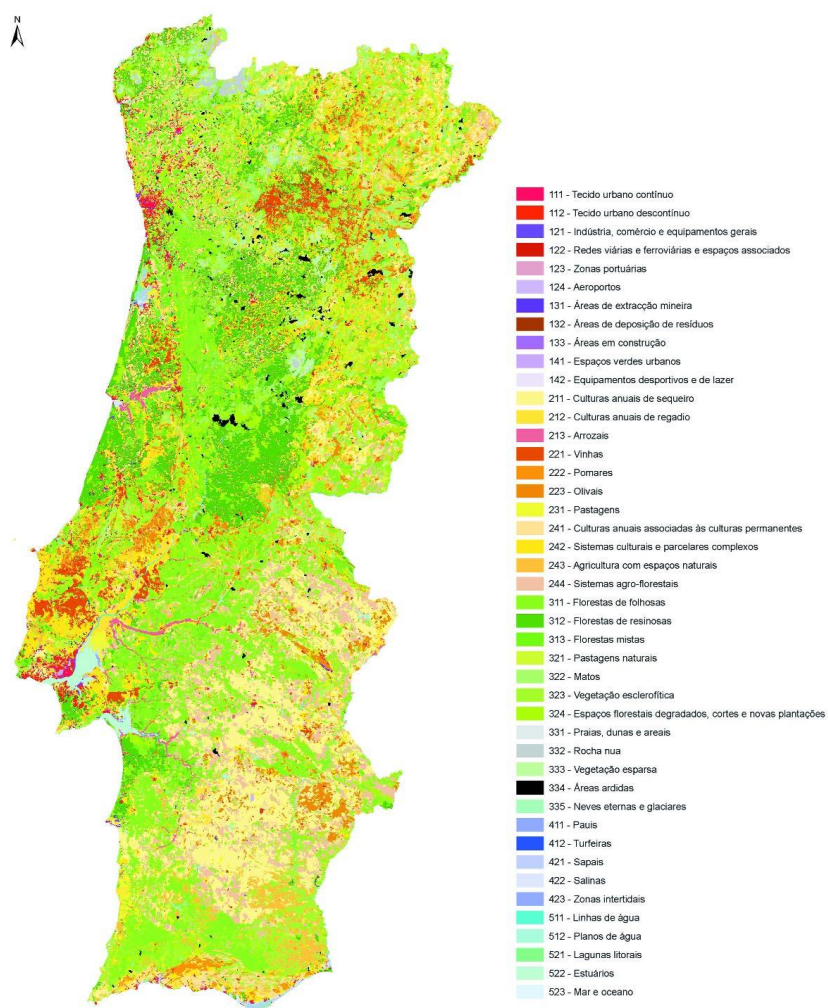
information source available in Portugal with two methodologically consistent wall-to-wall land use maps with two time references that includes all the mandatory reporting categories.

In Mainland and Madeira both CORINE products (CLC90-R and CLC06_PT) rely on Landsat satellite¹³⁷ data. It follows the Heyford-Gauss system with Lisbon Datum, Heyford Ellipsoid, complemented with data from several other sources (Painho & Caetano, 2005), have a scale of 1: 100 000, minimum areas of 25 ha and inter-line space of 100 m in the military Cartesian coordinate system. The nomenclature is a 3-level hierarchy and has 44 classes at its third and most detailed level. As a result of a validation procedure the map's estimated overall accuracy was 90,2%, with an absolute precision of 1,3 at the 95% confidence level. Land use data for the CLC90-R reflects the land use in the years 1985-1987, while CLC06_PT refers only to the year 2006 (Figure 7.3).

IGP is the Portuguese authority for the production and analysis of geographical information. The role of IGP in the reporting process is related essentially with the production of land use cartography in order to determine land use at different points in time and land use changes areas to be used in further calculations.

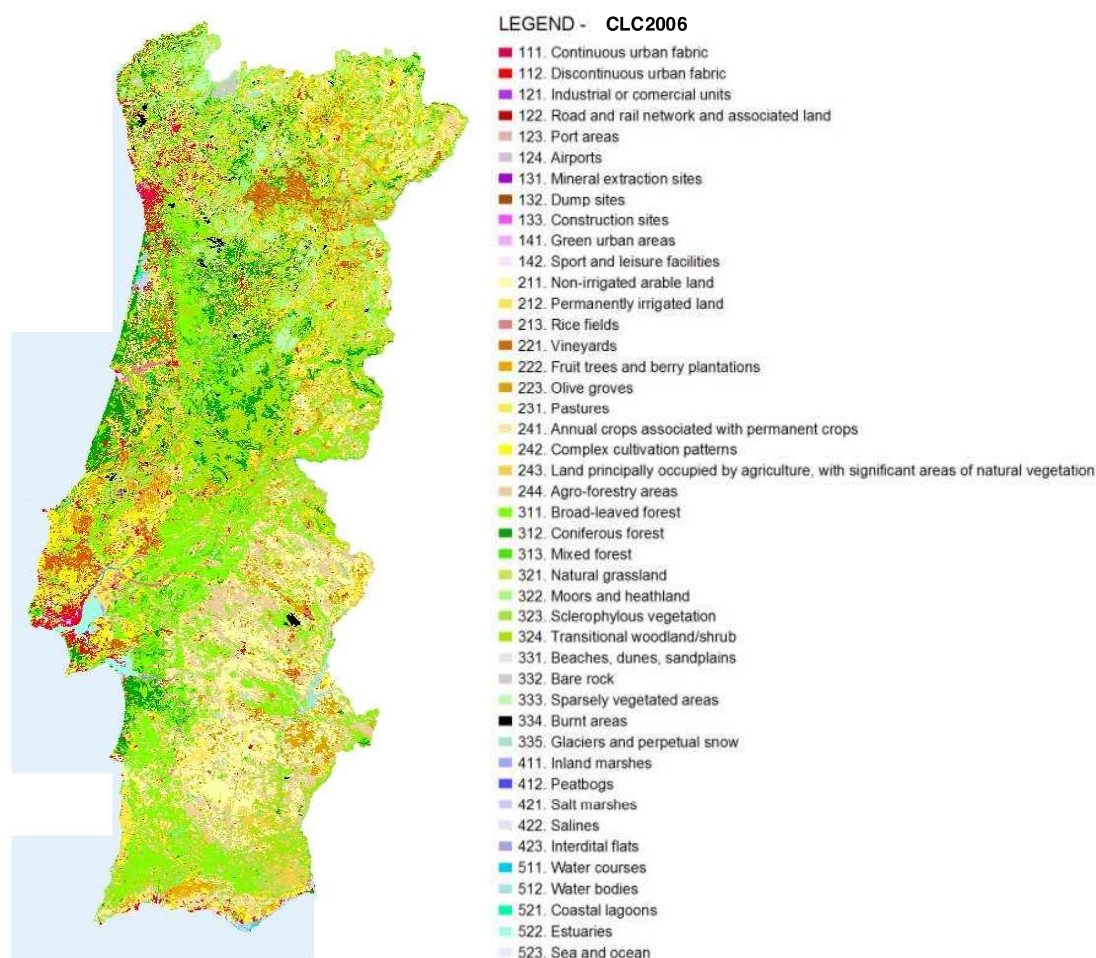
¹³⁷ Thematic Mapper (TM) and Multispectral Scanner (MSS) from Landsat-5 (1985-87) and Enhanced Thematic Mapper (ETM+) from Landsat-7 (2000)

Figure 7.2 – CLC90-R map.



Source: IA, 2006.

Figure 7.3 – CLC06_PT map.



Source: Caetano *et al.*, 2009¹³⁸

The total areas of forest (forest land), agriculture (cropland and grassland) and other land (wetlands, settlements and other land) were derived from CLC for 1990 and 2006. For obtaining total areas in the intermediate years (1990-2006) a direct interpolation was made, which resulted in a constant variation rate of the area among the years of the time series. The trend derived for 1990-2006 was considered constant for the periods 1970-1989 and 2007-2009. Figure 7.4 – below shows the areas of the above-mentioned categories.

For the Autonomous Region of Azores, CLC is not yet available and COS2007 was the only map available which could be used to determine the six classes' areas. Therefore, forest areas in 2007 were obtained from COS 2007 and the remaining time series was obtained from the Forestry Inventory of the Autonomous Region of Azores (IFRAA)¹³⁹ trends using 1987 compared with 2007 areas.

¹³⁸ [Caetano, M., V. Nunes and A. Nunes, 2009. CORINE Land Cover 2006 for Continental Portugal, Technical report, Instituto Geográfico Português.](#)

¹³⁹ Secretaria Regional da Agricultura e das Florestas (2007): *Inventário Florestal da Região Autónoma dos Açores*.

The same applies for cropland and grassland areas in 2007. The remaining time series is obtained from Agriculture statistics (RGA) compiled by National Statistics Institute (INE) defining trends by using 1985 compared with 1999 and 1999 with 2009 areas.

For the remaining categories – wetlands, settlements and other land, areas were available only for 2007 and no other data source was available. Therefore, the areas were considered constant and equal to 2007.

Figure 7.4 – Areas of Forest land, Cropland, Grassland, Wetlands, Settlements and Other land in Portugal.

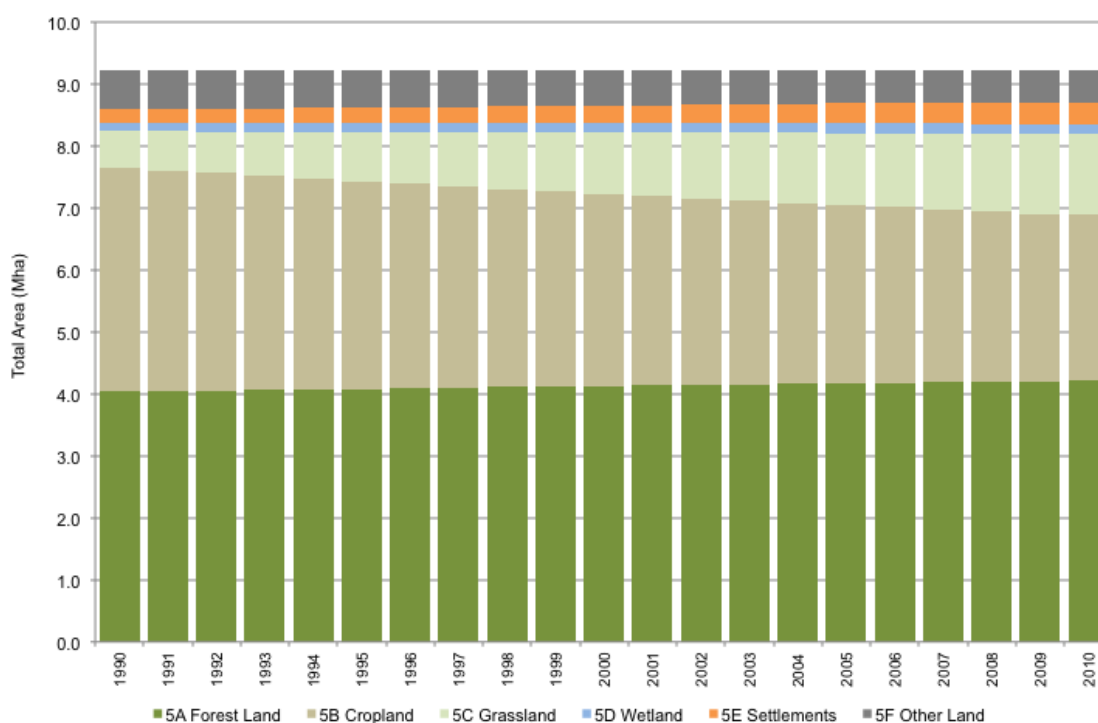


Table 7.3 - and Table 7.4 - summarize total Land Use and Land Use Changes, including its annual variation, derived from CLC90-R and CLC06_PT and its comparison in Mainland.

Table 7.3 - Total Land Use in 1990 and 2006 and Land Use Changes in Mainland (1.000ha).

	Land Use	2006			Total area 1990
		Forest land	Cropland + Grassland	Other land	
1986	Forest land	3799.000	64.000	60.000	3923.000
	Cropland + Grassland	183.000	3784.000	112.000	4079.000
	Other land	105.000	21.000	790.000	917.000
	Total area 2006	4087.000	3869.000	962.000	8919.000

Table 7.4 - Annual Land Use Changes between 1986 and 2006 in Mainland (1.000ha).

Land Use	Forest land	Cropland + Grassland	Other land	Loss of area
Forest land	-	3.200	3.000	6.200
Cropland + Grassland	9.150	-	5.600	14.750
Other land	5.250	1.050	-	6.300
Gain of area	14.400	4.250	8.600	

Table 7.5 - and Table 7.6 - summarize total Land Use and Land Use Changes, including its annual variation, derived from CLC90-R and CLC06_PT and its comparison in Azores.

Table 7.5 - Total Land Use in 1990 and 2006 and Land Use Changes in Azores (1.000ha).

		2006			Total area 1990
Land Use		Forest land	Cropland + Grassland	Other land	
1986	Forest land	43.960	0.000	0.000	43.960
	Cropland + Grassland	14.212	124.334	0.000	138.546
	Other land	0.592	13.680	34.898	49.170
	Total area 2006	58.764	138.014	34.898	231.676

Table 7.6 - Annual Land Use Changes between 1986 and 2006 in Azores (1.000ha).

Land Use	Forest land	Cropland + Grassland	Other land	Loss of area
Forest land	-	-	-	-
Cropland + Grassland	0.836	-	-	0.836
Other land	0.035	0.805	-	0.840
Gain of area	0.871	0.805	-	

Table 7.7 - and Table 7.8 - summarize total Land Use and Land Use Changes, including its annual variation, derived from CLC90-R and CLC06_PT and its comparison in Madeira.

Table 7.7 - Total Land Use in 1990 and 2006 and Land Use Changes in Madeira (1.000ha).

		2006			Total area 1990
Land Use		Forest land	Cropland + Grassland	Other land	
1986	Forest land	36.417	0.231	0.584	37.232
	Cropland + Grassland	0.146	20.735	3.567	24.447
	Other land	0.000	0.006	18.417	18.423
	Total area 2006	36.562	20.972	22.568	80.102

Table 7.8 - Annual Land Use Changes between 1986 and 2006 in Madeira (1.000ha).

Land Use	Forest land	Cropland + Grassland	Other land	Loss of area
Forest land	-	0.014	0.037	0.051
Cropland + Grassland	0.009	-	0.223	0.232
Other land	-	0.000	-	0.000
Gain of area	0.009	0.015	0.259	

The areas with specific management activities – no tillage in Cropland and Sown Biodiverse Permanent Pastures in Grassland were obtained through IFAP¹⁴⁰ and are included in the total areas, avoiding double counting.

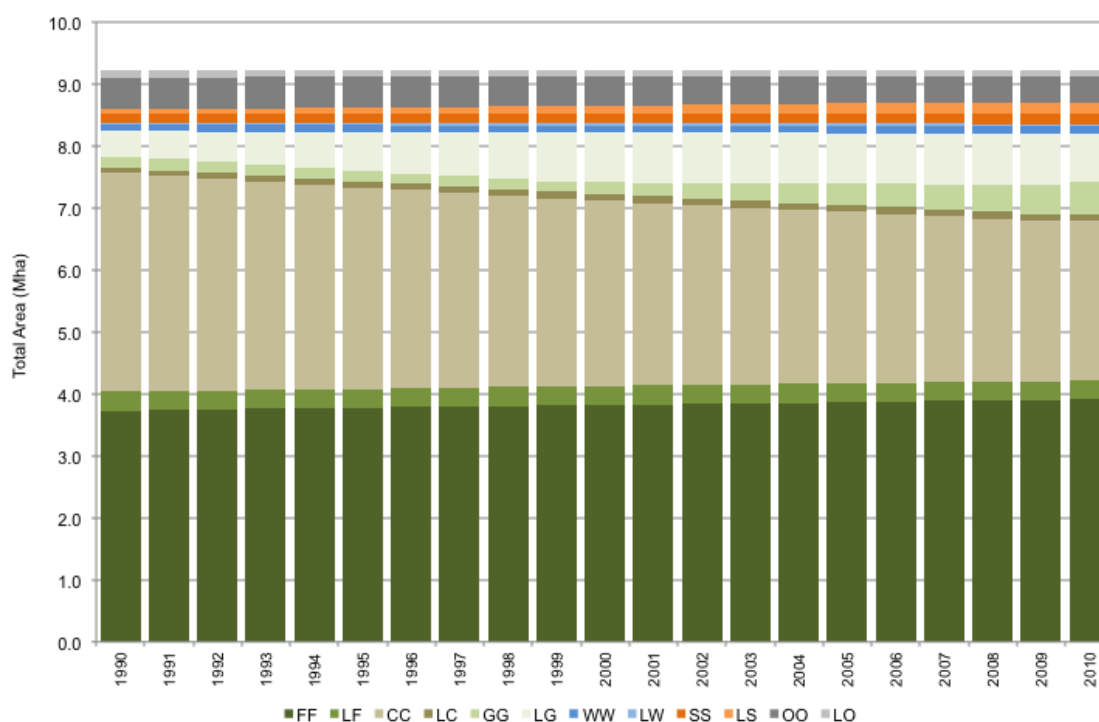
In order to follow the IPCC 2003 LULUCF GPG, the areas and changes, for the six major categories, between 1970 and 2009 were divided between:

- Land remaining Land
- Land converted to Other land

Figure 7.5 – shows the total LU and LUC dynamics between 1990 and 2010 in Portugal (including Mainland, Azores and Madeira).

¹⁴⁰ Paying Agency for EU subsidies to agriculture and forest (EAGF and ERDF)

Figure 7.5 – Land Use And Land Use Change 1990-2010 in Portugal¹⁴¹.



In addition to the land use cartography used, the Corine Land Cover (CLC) CLC90-R and CLC06_PT, CLC90 and CLC06 Madeira and COS2007 Azores from the Portuguese Geographic Institute (IGP), the information on land areas was combined with:

- The National Forestry Inventory (NFI) from the Portuguese National Authority for Forest (AFN)
- The Forestry Inventory of the Autonomous Region of Azores (IFRAA) from the Regional Directorate for the Environment from Azores (DRFA)
- The Forestry Inventory of Madeira (IFRAM) from the Regional Secretariat for the Environment (SRA)
- The annual cartography of burnt areas (AFN)
- The National Agriculture Statistics (RAC, RGA and IEA) from the National Statistics Institute (INE), which include all agriculture crops' and grasslands' areas
- The areas of specific activities for agriculture and grasslands from the Institute of Agriculture and Fisheries Financing (IFAP).

¹⁴¹ FF – Forest land remaining Forest land, LF – Land converted to Forest land; CC – Croplands remaining Croplands, LC – Land converted to Cropland; GG – Grasslands remaining Grasslands, LG – Land converted to Grasslands; WW – Wetlands remaining Wetlands, LW – Land converted to Wetlands; SS – Settlements remaining Settlements, LS – Land converted to Settlements; OO – Other land remaining Other land, LO – Land converted to Other land.

7.1.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories (e.g. land use and land-use change matrix)

Land use areas in CLC Changes are classified according to a hierarchic nomenclature, with 3 levels and 44 classes¹⁴² at the lowest (3rd) level. A correspondence was established between the CLC classes and the 6 IPCC categories as presented in Table 7.9.

The land-use areas used in the reporting are consistent with the land-use categories of the IPCC 2003 LULUCF GPG:

- Forest land: agro-forestry areas (annual crops or grazing land under the wooded cover of forestry species) and forests (areas occupied by forests and woodlands which can be used for the production of timber or other forest products. The forest trees are under normal climatic conditions higher than 5 m with a canopy closure of 30 % at least).
- Cropland: arable land, permanent crops, heterogeneous agricultural areas.
- Grassland: pastures.
- Wetlands: inland wetlands, coastal wetlands, salt marshes, salines and intertidal flats.
- Settlements: includes artificial areas such as urban fabric, industrial, commerce and transport units, mines, dump and construction sites and artificial non-agricultural vegetated areas.
- Other Land: beaches, dunes, sand plains and bare rocks. Includes also shrubland.

The description of all CLC categories can be consulted in: http://www.igeo.pt/gdr/pdf/CLC2006_nomenclature_addendum.pdf.

For the cases of burnt areas and shrubland, which may result from a transitional state in forest, cropland or grassland areas due to disturbances, the following criteria were applied:

- Burnt areas reclassified as Forest/Agriculture/Grassland if
 - Burnt 1990 = F/C/G in 2006
 - Burnt 2006 = F/C/G in 1990
 - Burnt = Other in all other cases
- Shrubs reclassified as Forest/Agriculture/Grassland if
 - Shrubs 1990 = F/C/G in 2006
 - Shrubs 2006 = F/C/G in 1990
 - Shrubs = Other in all other cases.

¹⁴² 42 classes were used in the Portuguese cartography (Painho & Caetano, 2005).

Table 7.9 – Land Use Nomenclature in CLC products and its correspondence to IPCC LU categories.

CODE	Level 3	Sector	IPCC LU category
111	Continuous Urban fabric	5E	Settlements
112	Discontinuous urban fabric	5E	Settlements
121	Industrial or commercial units	5E	Settlements
122	Road and rail networks and associated land	5E	Settlements
123	Port areas	5E	Settlements
124	Airports	5E	Settlements
131	Mineral extraction sites	5E	Settlements
132	Dump sites	5E	Settlements
133	Construction sites	5E	Settlements
141	Green urban areas	5E	Settlements
142	Sport and leisure facilities	5E	Settlements
211	Non-irrigated arable land	5B	Cropland
212	Permanently irrigated land	5B	Cropland
213	Rice fields	5B	Cropland
221	Vineyards	5B	Cropland
222	Fruit trees and berry plantations	5B	Cropland
223	Olive groves	5B	Cropland
231	Pastures	5C	Grassland
241	Annual crops associated with permanent crops	5B	Cropland
242	Complex cultivation patterns	5B	Cropland
243	Land principally occupied by agriculture, with significant areas of natural vegetation	5B	Cropland
244	Agro-forestry areas	5A	Forest land
311	Broad-leaved forest	5A	Forest land
312	Coniferous forest	5A	Forest land
313	Mixed forest	5A	Forest land
321	Natural grasslands	5C	Grassland
322	Moors and heathland (Shrubland)	5A 5B 5C 5F	Forest land Cropland Grassland Other
323	Sclerophyllous vegetation	5A 5B 5C 5F	Forest land Cropland Grassland Other
324	Transitional woodland-shrub	5A	Forest land
331	Beaches, dunes, sands	5F	Other
332	Bare rocks	5F	Other
333	Sparsely vegetated areas	5C	Grassland
334	Burnt areas	5A 5B 5C 5F	Forest land Cropland Grassland Other
411	Inland marshes	5D	Wetland
421	Salt marshes	5D	Wetland
422	Salines	5D	Wetland
423	Intertidal flats	5D	Wetland
511	Water courses	5D	Wetland
512	Water bodies	5D	Wetland
521	Coastal lagoons	5D	Wetland
522	Estuaries	5D	Wetland
523	Sea and ocean	5D	Wetland

Shrub areas were reclassified as forest land/cropland/grassland if: Shrubs 1990 = FL/CL/GL in 2006; Shrubs 2006 = FL/CL/GL in 1990; Shrubs = Other in all other cases

Burnt areas were reclassified as forest/cropland/grassland if: Burnt 1990 = FL/CL/GL in 2006; Burnt 2006 = FL/CL/GL in 1990; Burnt = Other in all other cases

The estimates of GHG emissions/removals were done at a more desagregated level in order to reflect the most significant Portuguese land uses. The full legend of the areas used comprehends 19 LU subcategories (Table 7.10 –).

Table 7.10 – Land Use classes considered in the GHG emissions/removals estimates

Sector	IPCC LU category	Subcategory
5A	Forest	<i>Pinus pinaster</i>
		<i>Quercus suber</i>
		<i>Eucalyptus spp.</i>
		<i>Quercus rotundifolia</i>
		<i>Quercus spp.</i>
		Other broadleaves
		<i>Pinus pinea</i>
		Other coniferous
5B	Cropland	Non-irrigated annual crops
		Irrigated annual crops (excluding rice)
		Rice paddies
		Vineyards
		Olive groves
		Other permanent crops
5C	Grassland	Grassland
5D	Wetlands	Wetlands
5E	Settlements	Settlements
5F	Other land	Shrubland
		Other land

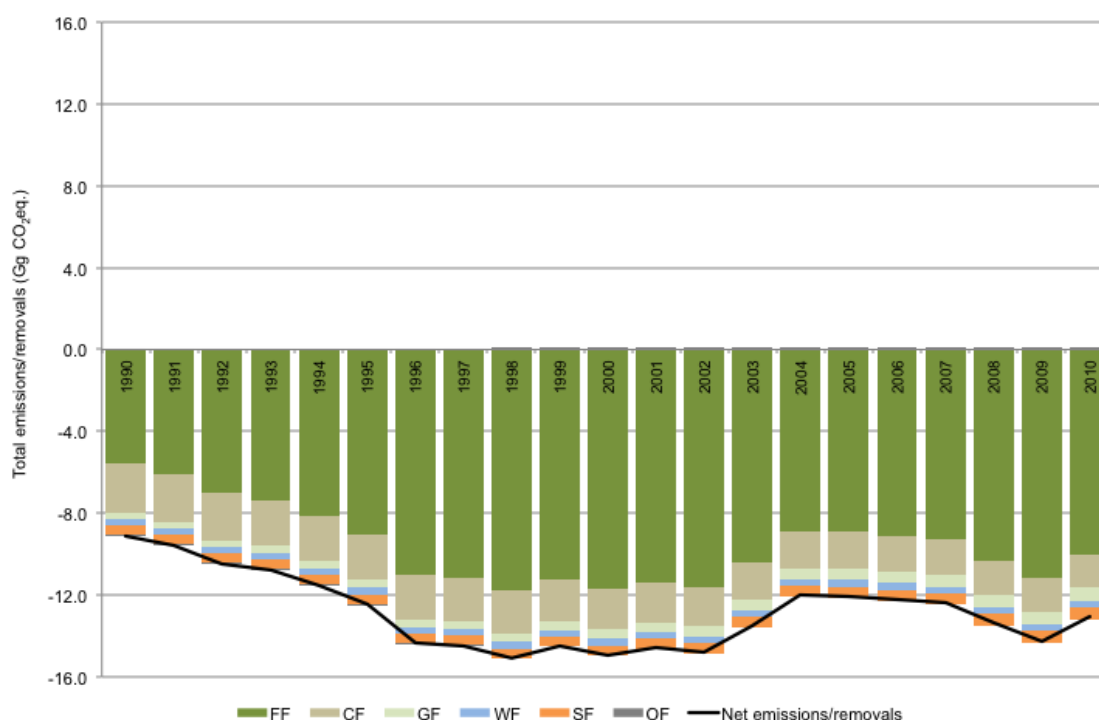
Besides the LU subcategories identified above, the areas with activities such as no tillage and biodiverse pastures were identified through IFAP database and a specific additional emission factor was used to reflect the related carbon sequestration.

7.2 Forest Land (CRF 5.A.)

7.2.1 Description

Forest Land is a net sink, totalizing -6.5 Mt CO₂e in 1990 and -10.9 Mt CO₂e in 2010. The pool mostly contributing to that is living biomass.

Figure 7.6 – Net emissions/removals associated with Forest Land.¹⁴³



7.2.2 Definitions

The inventory considers the total national area under the forest definition, as all forests are considered to be affected by human intervention, and consequently considered as non-natural/managed.

Data for deriving forest area per species were based on data from national forest inventories NFI, which refer to Mainland Portugal, conducted by the AFN.

Forest definition used by AFN is based on the UNECE/FAO definition: forest is defined as vegetation formations constituted by woody trees with a crown cover of at least 10%, a minimum area of 0.5 ha and a minimum 20 meters width, where trees have the potential to reach a minimum height of 5 meters at maturity. The same definition was used for Convention reporting purposes.

The NFI, IFRAA and IFRAM classify forests according to the ensemble of tree species present in each sampling plot. Areas are allocated to a particular forest species whenever that species

¹⁴³ FF – Forest remaining Forest; CF – Croplands converted to Forest; GF – Grasslands converted to Forest; WF – Wetlands converted to Forest; SF – Settlements converted to Forest; OF – Other lands converted to Forest.

is either the only species present in the area (pure stands) or is the dominant species (mixed stands of two or more tree species).

Available national forest inventories for the period 1970-2009 are the NFI 2nd revision (1982), the NFI 3rd revision (1995) and the NFI 2005/06, the IFRA 1987 and 2007 and IFRAM 2004. The calculation and reporting of emissions and removals is subdivided into the eight main tree species/groups of species.

Table 7.11 – Aggregation of forest areas by tree species.

Forest Category used in the NIR	Scientific name	English common name	Portuguese common name
<i>Pinus pinaster</i>		Maritime Pine	Pinheiro Bravo
<i>Quercus suber</i>		Cork Oak	Sobreiro
<i>Eucalyptus</i> spp.	<i>E. globulus</i>	Tasmanian Blue Gum	Eucalipto Glóbulo
	<i>E. camaldulensis</i>	Red Gum	Eucalipto Vermelho
	<i>Eucalyptus</i> spp.	Other gums	Outros Eucaliptos
<i>Quercus rotundifolia</i>		Holm Oak	Azinheira
<i>Quercus</i> spp.	<i>Quercus faginea</i>	Portuguese Oak	Carvalho Português
	<i>Quercus pyrenaica</i>	Pyrenean Oak	Carvalho Negral
	<i>Quercus robur</i>	Pedunculate Oak	Carvalho Alvarinho
	<i>Quercus</i> spp.	Other oaks	Outros Carvalhos
Other broadleaves	<i>Acacia</i> spp.	Acacias	Acácias
	<i>Arbutus unedo</i>	Strawberry Tree	Medronheiro
	<i>Betula</i> spp.	All Birches	Bétulas
	<i>Castanea sativa</i>	Chestnut Tree	Castanheiro
	<i>Ceratonia siliqua</i>	Carob Tree	Alfarrobeira
	<i>Salix</i> spp.	Willows	Salgueiros
	<i>Ulmus</i> spp.	Elms	Ulmeiros
	<i>Pittosporum undulatum</i>	Australian cheesewood	Árvore do Incenso
	<i>Myrica faia</i>	Fire tree	Faia das Ilhas
	<i>Persea indica</i>		Vinhático das Ilhas
	Other broadleaves	Other broadleaves / Laurel forests	Outras folhosas / Floresta laurissilva
<i>Pinus pinea</i>		Umbrella Pine	Pinheiro Manso
Other coniferous	<i>Cupressus</i> spp.	Cypresses	Ciprestes
	<i>Pinus halepensis</i>	Aleppo Pine	Pinheiro de Alepo
	<i>Pinus sylvestris</i>	Scots Pine	Pinheiro de Casquinha
	<i>Pinus</i> spp.	Other Pines	Outros Pinheiros
	<i>Pseudotsuga menziesii</i>	Douglas Fir	Pseudotsuga
	<i>Cryptomeria japonica</i>	Japanese Cedar	Criptoméria / Cedro japonês
	<i>Chamaecyparis</i> spp.	Lawson's Cypress	Cipreste de Lawson
	Other coniferous	Other coniferous	Outras Resinosas

The following table was derived from NFI data for the Portugal Mainland. The share of area per forest type was calculated for two periods: 1982-1995 and 1995-2005 based on NFI data of forest area for 1982, 1995 and 2005. The same share of areas was applied also to 1970-1982 and 2005-2009, respectively (following table).

Table 7.12 – Distribution of total forest area by forest type in Mainland.

Species/Group	1970-1981	1982	1983-1994	1995	1996-2004	2005	2006-2009
<i>Pinus pinaster</i>	Same trend as 1982-1995	41%	Interpolation of 1982-1995	31%	Interpolation of 1995-2005	28%	Same trend as 1995-2005
<i>Quercus suber</i>		22%		22%		22%	
<i>Eucalyptus spp.</i>		13%		21%		24%	
<i>Quercus rotundifolia</i>		15%		14%		13%	
<i>Quercus spp.</i>		3%		4%		5%	
Other broadleaves		4%		4%		4%	
<i>Pinus pinea</i>		2%		2%		4%	
Other coniferous		1%		1%		1%	

Note: Other woody biomass and other wooded land were not considered in the estimates.

Sources: AFN, 1982; AFN, 1995; AFN, 2005.

The following table was derived from IFRAA data for the Azores Autonomous Region. The share of area per forest type was calculated for one period: 1987-2007. The same share of areas was applied also to 1970-1987 and 2007-2010, respectively (following table).

Table 7.13 – Distribution of total forest area by forest type in Azores.

Species/Group	1970-1987	1987	1988-2007	2007	2007-2010
<i>Pinus pinaster</i>	Same trend as 1987-2007	1.1%	Interpolation of 1987-2007	1.5%	Same trend as 1987-2007
<i>Quercus suber</i>		0.0%		0.0%	
<i>Eucalyptus spp.</i>		1.1%		6.0%	
<i>Quercus rotundifolia</i>		0.0%		0.0%	
<i>Quercus spp.</i>		0.0%		0.0%	
Other broadleaves		21.4%		71.5%	
<i>Pinus pinea</i>		0.0%		0.0%	
Other coniferous		76.4%		21.1%	

Note: Other woody biomass and other wooded land were not considered in the estimates.

Sources: DRFA, 1987 and DRFA, 2007.

The following table was derived from IFRAM data for the Madeira Autonomous Region. The share of area per forest type was only available for 2007 and was applied to the whole time series (following table).

Table 7.14 – Distribution of total forest area by forest type in Madeira.

Species/Group	1970-2004	2004	2005-2010
<i>Pinus pinaster</i>	Same share as 2004	19.1%	Same share as 2004
<i>Quercus suber</i>		0.0%	
<i>Eucalyptus spp.</i>		19.3%	
<i>Quercus rotundifolia</i>		0.0%	
<i>Quercus spp.</i>		0.0%	
Other broadleaves		58.5%	
<i>Pinus pinea</i>		0.0%	
Other coniferous		3.1%	

Note: Other woody biomass and other wooded land were not considered in the estimates.

Sources: SRA *et al.*, 2004.

For the purpose of calculating the percentages above, a reclassification of NFI, IFRAA and IFRAM areas was done as follows:

- Diverse & Burnt areas (allocated to all species, according to species area)

- Final felling areas (allocated to pine and eucalypts, according to species area).

These percentages were then applied to the total Forest land area, as estimated, to determine the area per forest type per year.

7.2.3 Methodological issues

7.2.3.1 Activity data

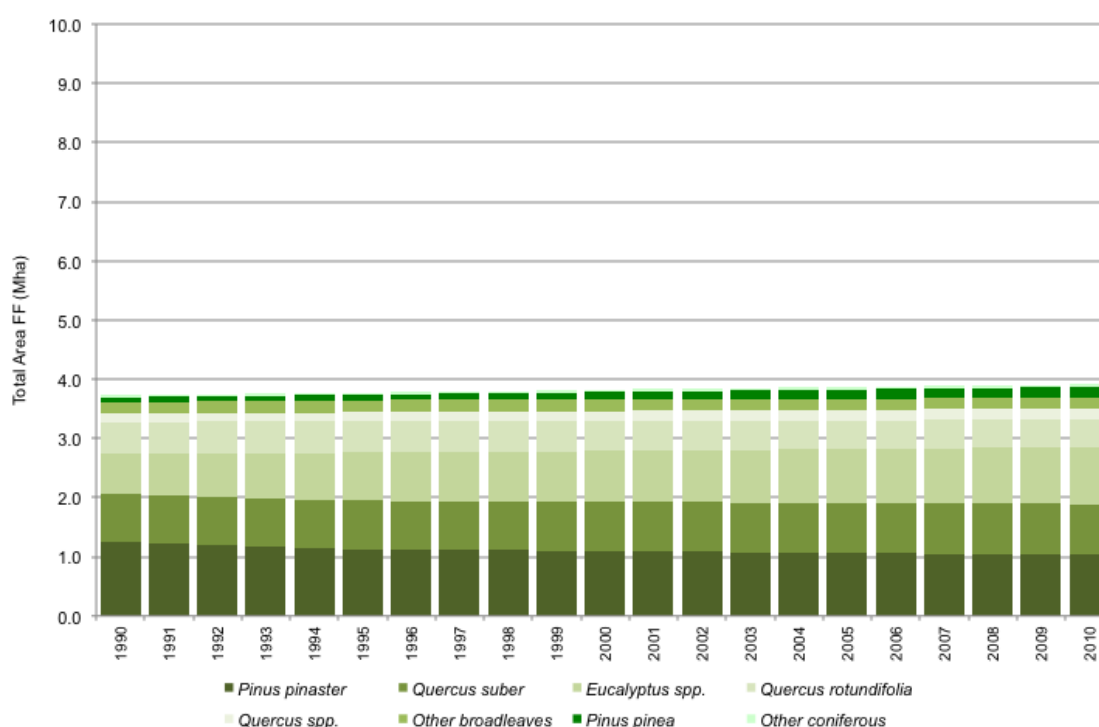
7.2.3.1.1 Forest Land remaining Forest Land (FF)

The total areas of FF consist on the total area of forest land in a particular year minus the sum of areas converted to forest over the previous 20 years (which are reported as land converted to forest).

The total areas of each forest type were calculated in a similar fashion and included also areas of other forest types converted to that forest type, over the previous 20 years.

Figure 7.7 – and Table 7.31 (Annex) show the total area of FF per specie.

Figure 7.7 – FF per forest type (1990-2010).



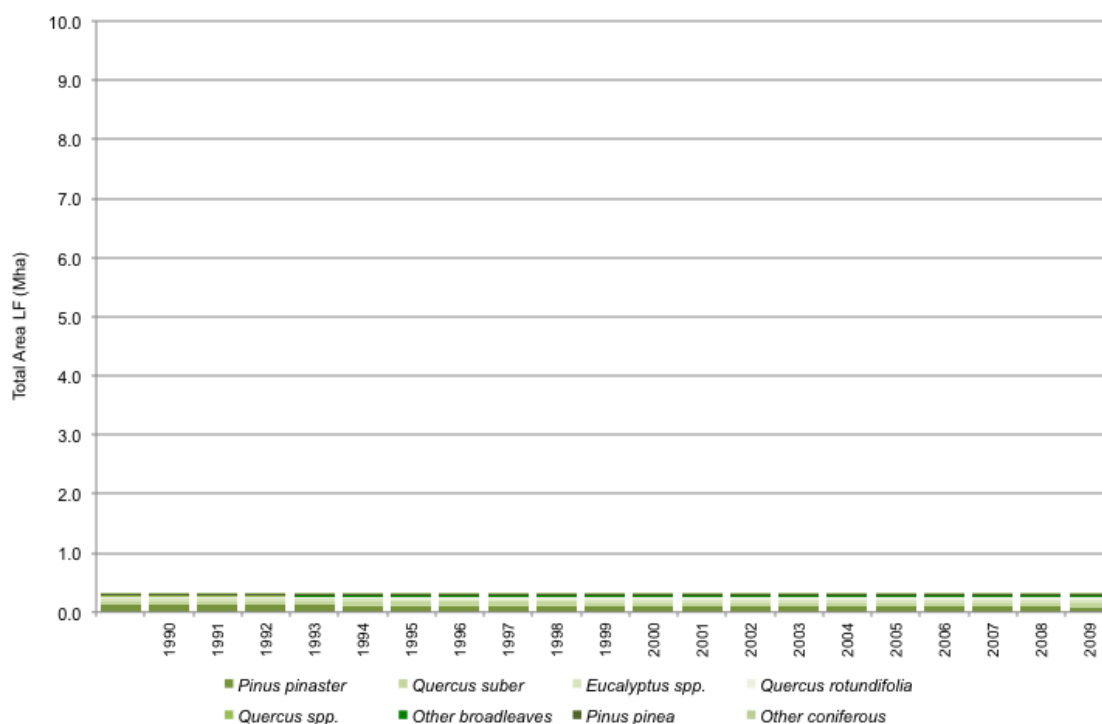
7.2.3.1.2 Land converted to Forest Land (LF)

The areas of LF were determined by the sum of all areas of non-forest Land Use classes (Cropland, Grassland and Other land) converted to Forest land in the previous 20 years.

The allocation of areas to each forest type was made considering the same share of areas of each forest type in total forest area in that particular year.

Figure 7.8 and Table 7.32 (Annex) show the area of Land converted to Forest Land per forest type (1990-2010).

Figure 7.8 – Land converted to Forest Land per forest type (1990-2010).



7.2.3.2 Methods

Carbon stock changes were calculated for all pools (Living Biomass – LB, Dead Organic Matter – DOM and Mineral Soils – MSO) and all the classes of LU and LUC. The area of Organic Soils (OS) is negligible, and therefore, considered “not occurring” and was not reported.

The methodology for calculating Carbon stock change was the correspondent to the Gains/Losses methodology, as in the IPCC GPG2003, equation 3.1.1.

$$\Delta C = \sum_i A_i \times (C_i - C_L)_i$$

Where:

ΔC = carbon stock change in the pool, t C.yr⁻¹

A = area of land, ha

i = corresponds to land-use types

C_i = rate of gain of carbon, t C.ha-1.yr⁻¹

C_L = rate of loss of carbon, t C.ha-1.yr⁻¹.

Portugal uses a Tier 2 approach applying country specific emission factors and activity data for the most important land uses/activities.

7.2.3.2.1 Carbon stock change in Living Biomass

For all the land uses, carbon stock changes in living biomass were calculated for LU and LUC, including gains and losses.

For FF, gains are associated with the biomass increment and losses are due to harvest and forest fires. Emissions from harvesting consider the instant oxidation of the entire tree (including dead wood).

For calculating C gains, the following method was adopted:

$$C_I = \sum_j A_j \times AIR_j \times BEF_j \times (1 + RTS)_j \times C_{dm_j}$$

Where:

C_I = rate of gain of Carbon, t C.ha⁻¹.yr⁻¹

j = corresponds to forest type j

A_j = Area of FF per forest type, ha (Table 7.31)

AIR = annual Average Increment Rate per forest type, m³.ha⁻¹.y⁻¹ (Table 7.15)

BEF = Biomass Expansion Factor per forest type, t dm.m⁻³ (Table 7.16)

$1+RTS$ = Root To Shoot ratio per forest type (Table 7.16)

C_{dm} = Carbon fraction of dry matter per forest type (Table 7.16)

The parameters used are summarized in the following tables.

Annual increments by forest species in pure stands have been reported as constant throughout the period 1990-2009. Growth rates in mixed stands have been estimated using the data on area and wood volume of mixed stands from the National Forest Inventories of 1995 and 2005. Increment rates for the period 1990-1995 were considered equal to those of 1995. Increment rates for the period 1996-2004 were interpolated from those of 1995 and 2005. Increment rates for the period 2005-2020 were considered equal to those of 2005. Given the high proportion of mixed forests in Portugal, growth rates for dominated species are also considered (Table 7.15).

Table 7.15 – Annual Average Increment Rate in pure and mixed forests (m³.ha⁻¹.y⁻¹).

		Dominant Species							
		<i>Pinus pinaster</i>	<i>Quercus suber</i>	<i>Eucalyptus spp.</i>	<i>Quercus rotundifolia</i>	<i>Quercus spp.</i>	Other broadleaves	<i>Pinus pinea</i>	Other coniferous
Dominated species	<i>Pinus pinaster</i>	5.6	0.1	0.4	0.0	0.5	1.0	0.4	0.1
	<i>Quercus suber</i>	0.0	0.5	0.0	0.1	0.0	0.0	0.1	0.0
	<i>Eucalyptus spp.</i>	1.0	0.0	9.5	0.0	0.2	0.5	0.0	0.0
	<i>Quercus rotundifolia</i>	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
	<i>Quercus spp.</i>	0.1	0.0	0.0	0.0	2.9	0.3	0.0	0.1
	Other broadleaves	0.1	0.0	0.0	0.0	0.5	2.9	0.0	0.2
	<i>Pinus pinea</i>	0.2	0.4	0.0	0.0	0.0	0.1	5.6	0.0
	Other coniferous	0.0	0.1	0.0	0.2	0.0	0.2	0.0	5.0

Source: IFN4, 1995.

The BEFs were obtained also from data from the last IFN, and corresponds to the relation between the total biomass and total volume. RTS ratio and C_{dm} were obtained from the same information source (following table).

Table 7.16 – BEF (t dm.m⁻³), 1+RTS and C_{dm}.

	BEF	1 + RTS	C _{dm}
<i>Pinus pinaster</i>	0.528	1.098	0.51
<i>Quercus suber</i>	1.100	1.430	0.48
<i>Eucalyptus spp.</i>	0.630	1.249	0.48
<i>Quercus rotundifolia</i>	1.100	1.430	0.48
<i>Quercus spp.</i>	0.570	1.430	0.48
Other broadleaves	0.570	1.430	0.48
<i>Pinus pinea</i>	1.166	1.054	0.51
Other coniferous	0.532	1.102	0.51

Source: IFN5, 2006.

For LF, the approach was the same, considering the area of other land (Cropland, Grassland or Other Land) converted to Forest (Table 7.32/ Annex).

The estimation of C losses considered in this category refers to harvest activities. The following method was applied.

$$C_L = \sum_j Harv_j \times BEF_j \times (1 + RTS)_j \times C_{dm_j}$$

Where:

C_L = rate of loss of carbon, t C.ha⁻¹.yr⁻¹

j = corresponds to forest type j

Harv_j = Annual harvested volume in FF per forest type, m³ub.y⁻¹ (Table 7.31)

AIR = annual Average Increment Rate, $\text{m}^3 \cdot \text{ha}^{-1} \cdot \text{y}^{-1}$

BEF = Biomass Expansion Factor, $\text{t dm} \cdot \text{m}^{-3}$

1+RTS = Root To Shoot ratio

C_{dm} = Carbon fraction of dry matter (Table 7.16)

The annual harvested volume in FF was obtained from the total annual harvest (FAO) minus the harvested volume in LF. Volumes of harvest in LF refer exclusively to *Eucalyptus*, due to its rotation length (12 years). All other species are not considered as harvested in the LF category. The FAO harvest data is mostly derived from industrial wood acquisition statistics from domestic markets. All FAO harvest was allocated to *Pinus pinaster* (conifers) and *Eucalyptus spp.* (broadleaves), as these are the most important species for industrial roundwood production in Portugal.

- *Eucalypts* are harvested mostly for the production of wood pulp and wood panels, although it can also be used for other industrial and energy uses. The rotation length depends on productivity of the site and forest owner decisions, varying from 11 to 15 years, with 12 years being the most representative value. Given this rotation length, eucalypt plantations are the only forest type for which harvest values were considered in Land Converted to Forest, since harvesting takes place before the conversion period of 20 years (considered for all land converted to forests) is concluded.
- Maritime pine is more plastic in terms of industrial use, ranging from wood for poles, wood pulp, wood panels, wood packaging and sawnwood. The rotation length depends on productivity of the site, forest owner decisions and intended wood use, varying from 20 to 80 years, with 40 years being the most representative value. Smaller diameters usually result from thinning activities rather than final felling.

Carbon losses considered also firewood depletion. Firewood collection data is relatively scarce. To include this, an additional harvesting rate of 25% of the total increment was assumed for all other forest types. This approach is considered conservative, as for many tree species occurring in Portugal, wood production is not the main driver of forest management:

- Some forest types are managed mostly for non-wood purposes. That is the case for species used for seed production for human and/or animal consumption; Holm Oak (*Quercus rotundifolia*); Umbrella Pine (*Pinus pinea*); Carob Tree (*Ceratonia siliqua*); Strawberry Tree (*Arbutus unedo*); and partially Chestnut Tree (*Castanea sativa*); Walnut Tree (*Juglans regia*)
- Cork Oaks (*Quercus suber*) are managed mostly for cork (=bark) production, and harvestable surface, rather than volume is the correct production unit. There is no incentive for harvest, as wood has a very low value compared to cork, and cork production increases with tree size;
- Some species, namely Cork Oaks (*Quercus suber*) and Holm Oaks (*Quercus rotundifolia*), are protected by law and it is illegal to harvest or deforest those areas without a special permit.
- Some areas, e.g. protected areas or riparian corridors, are protected by law and it is illegal to harvest or deforest those areas without a special permit.

In the period 1990 to 2010 total harvesting levels in Portugal have ranged between 9.4 and 11.9 million cubic meters underbark, with an average of about 10.8 million cubic meters underbark, with Eucalypts and Maritime pine being the main wood producing species, responsible for about 94% of total harvest.

7.2.3.2.2 Net carbon stock change in DOM

Net carbon stock changes in DOM comprise the areas of Land remaining Land with intern transitions (Forest, Cropland and Other Land) and the alterations associated with LUC, which influence litter.

For every category and LU the methodology to calculate the net variations in this pool is similar and, therefore, its description is agglutinated. For LL, the formula used was:

$$C_{DOM} = \sum_{LL} A_{LL} \times C_{Lit,L}/20$$

Where:

C_{DOM} = net carbon stock change in DOM, Gg C

LL = corresponds to LU

A = Area of LL, ha (Table 7.31, Table 7.38 and Table 7.40)

C_{lit} = Carbon content in Litter, Gg C.kha⁻¹.y⁻¹

Table 7.17 – Average C stocks in litter per land use type (Gg C.kha-1.y-1)¹⁴⁴

		1990-2009
Forest land	<i>Pinus pinaster</i>	2,9
	<i>Quercus suber</i>	1,7
	<i>Eucalyptus spp.</i>	1,5
	<i>Quercus rotundifolia</i>	1,7
	<i>Quercus spp.</i>	1,7
	Other broadleaves	1,7
	<i>Pinus pinea</i>	2,4
	Other coniferous	3,8
Cropland	Non-irrigated annual crops	0,0
	Irrigated annual crops (except rice)	0,0
	Rice paddies	0,0
	Vineyards	0,0
	Olive groves	0,0
	Other permanent crops	0,0
Grassland	All grasslands	0,0
Wetland	Wetland	0,0
Settlements	Settlements	0,0
Other	Shrubland	1,0
	Other	0,0

Source: Rosas, 2009

For the cases of LUC, the formula used was:

$$C_{DOM} = \sum_{LUC,fi} A_{LUC} \times (C_{Lit,f} - C_{Lit,i})/20$$

Where:

C_{DOM} = net carbon stock change in DOM, Gg

LUC_{fi} = corresponds to LUC pairs, referring to the final and initial land use

A = Area converted, ha (Table 7.32, Table 7.39 and Table 7.41)

$C_{Lit,f}$ = Carbon content in litter of the final land use, Gg C.kha⁻¹.y⁻¹

$C_{Lit,i}$ = Carbon content in litter of the initial land use, Gg C.kha⁻¹.y⁻¹

¹⁴⁴ C stock in Wetlands and Settlements was assumed as 0

Table 7.18 – Average C stocks changes in litter per land use type (Gg C.kha-1.y-1).

Changes		To																		
		Forest								Croplands						G	W	S	OL	
From		Pp	Qs	E spp	Qr	Q spp	Ob	P pinea	OC	Ni	I	R	V	O	Op	G	W	S	Sh	O
Forest land	Pinus pinaster	0.00	0,00	-0,07	-0,06	-0,06	-0,06	-0,02	0,04	-0,14	-0,14	-0,14	-0,14	-0,14	-0,14	-0,14	-0,14	-0,14	-0,09	-0,14
	Quercus suber	0,06	0,01	-0,01	0,00	0,00	0,00	0,04	0,10	-0,08	-0,08	-0,08	-0,08	-0,08	-0,08	-0,08	-0,08	-0,08	-0,03	-0,08
	Eucalyptus spp.	0,07	0,00	0,00	0,01	0,01	0,01	0,05	0,12	-0,07	-0,07	-0,07	-0,07	-0,07	-0,07	-0,07	-0,07	-0,07	-0,02	-0,07
	Quercus rotundifolia	0,06	0,00	-0,01	0,00	0,00	0,00	0,03	0,10	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,04	-0,09
	Quercus spp.	0,06	0,00	-0,01	0,00	0,00	0,00	0,03	0,10	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,04	-0,09
	Other broadleaves	0,06	-0,04	-0,01	0,00	0,00	0,00	0,03	0,10	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,09	-0,04	-0,09
	Pinus pinea	0,02	-0,10	-0,05	-0,03	-0,03	-0,03	0,00	0,07	-0,12	-0,12	-0,12	-0,12	-0,12	-0,12	-0,12	-0,12	-0,12	-0,07	-0,12
	Other coniferous	-0,04	0,08	-0,12	-0,10	-0,10	-0,10	-0,07	0,00	-0,19	-0,19	-0,19	-0,19	-0,19	-0,19	-0,19	-0,19	-0,19	-0,14	-0,19
Cropland	Non-irrigated annual crops	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
	Irrigated annual crops (except rice)	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
	Rice paddies	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
	Vineyards	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
	Olive groves	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
	Other permanent crops	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
Grassland	All grasslands	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
Wetland	Wetland	0,14	0,08	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
Settlements	Settlements	0,14	0,03	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00
Other	Shrubland	0,09	0,08	0,02	0,04	0,04	0,04	0,07	0,14	-0,05	-0,05	-0,05	-0,05	-0,05	-0,05	-0,05	-0,05	-0,05	0,00	-0,05
	Other	0,14	0,00	0,07	0,09	0,09	0,09	0,12	0,19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00

7.2.3.2.3 Net carbon stock change in Mineral Soils (MS)

Net carbon stock changes comprise the areas of Land remaining Land with intern transitions (Forest, Cropland and Other Land) and the alterations associated with LUC, which influence the carbon content in MS. The transition period assumed is 20 years. For LL that maintains the same forest type or culture it is assumed that the soil is already in equilibrium and no net changes occur.

Liming in Portuguese Forest soils is not a common practice and, therefore, it is considered negligible. Also the area of Organic soils is considered negligible.

Every categories and LU the methodology to calculate the net variations in this pool are similar and, therefore, its description is agglutinated.

For transitions inside LL, the formula used was:

$$C_{DOM} = \sum_{LL} A_{LL} \times C_{MS,L}/20$$

Where:

- C_{MS} = net carbon stock change in DOM, Gg
- LL = corresponds to LU
- A = Area of LL, ha (Table 7.31, Table 7.38 and Table 7.40)
- C_{lit} = Carbon content in MS, Gg C.kha⁻¹.y⁻¹ (Table 7.19)

For the cases of LUC, the formula used was:

$$C_{DOM} = \sum_{LUC,fi} A_{LUC} \times (C_{MS,f} - C_{MS,i})/20$$

Where:

- C_{MS} = net carbon stock change in MS, Gg
- LUC_{fi} = corresponds to LUC pairs, referring to the final and initial land use
- A = Area converted, ha (Table 7.32, Table 7.39 and Table 7.41)
- $C_{Lit,f}$ = Carbon content in MS of the final land use, Gg C.kha⁻¹.y⁻¹ (Table 7.19)
- $C_{Lit,i}$ = Carbon content in MS of the initial land use, Gg C.kha⁻¹.y⁻¹ (Table 7.19)

The average carbon stock in soil is based on the Level I grid of the International Co-operative Programme (ICP) on Assessment and Monitoring of Air Pollution Effects on Forests operating under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution.

ICP Forests was launched in 1985 and monitors the forest condition in Europe, in cooperation with the European Union using two different monitoring intensity levels. The first grid (called Level I) is based on around 6000 observation plots on a systematic transnational grid of 16 x 16 km throughout Europe. The intensive monitoring level comprises around 800 Level II plots in selected forest ecosystems in Europe. Currently 41 countries participate in the ICP Forests.

In Portugal measurements were made in 1995 (under ICP Forest project), 1999 (LQARS data for agricultural soils) and 2005 (Biosoil project), and the average of the soil content for the measurements at 0-40 cm was used. These values were kept constant and used in all the time series (Table 7.19).

Table 7.19 – Average C stocks in soils 0-40 cm (Gg C.kha-1.y-1)¹⁴⁵.

	1990-2010
<i>Pinus pinaster</i>	116
<i>Quercus suber</i>	54
<i>Eucalyptus spp.</i>	68
<i>Quercus rotundifolia</i>	58
<i>Quercus spp.</i>	98
Other broadleaves	88
<i>Pinus pinea</i>	38
Other coniferous	77
Non-irrigated annual crops	38
Irrigated annual crops (except rice)	54
Rice paddies	54
Vineyards	40
Olive groves	55
Other permanent crops	42
All grasslands	49
Wetland	0
Settlements	0
Shrubland	91
Other	38

Source: LQARS, AFN, Biosoil project

¹⁴⁵ C stock in Wetlands and Settlements was assumed as 0. For Other (Other land) the value is assumed as the minimum of the measurements (non-irrigated annual crops). Rice is assumed to have the same value as annual irrigated crops

Table 7.20 – Average C stocks changes in soils per land use type (Gg C.kha-1.y-1).

Changes		To																		
		Forest								Croplands						G	W	S	OL	
From		Pp	Qs	E spp	Qr	Q spp	Ob	P pinea	OC	Ni	I	R	V	O	Op	G	W	S	Sh	O
Forest land	Pinus pinaster	0,0	-3,1	-2,4	-2,9	-0,9	-1,4	-3,9	-1,9	-3,9	-3,1	-3,1	-3,8	-3,0	-3,7	-3,3	-5,8	-5,8	-1,2	-3,9
	Quercus suber	3,1	0,0	0,7	0,2	2,2	1,7	-0,8	1,1	-0,8	0,0	0,0	-0,7	0,0	-0,6	-0,3	-2,7	-2,7	1,8	-0,8
	Eucalyptus spp.	2,4	-0,7	0,0	-0,5	1,5	1,0	-1,5	0,4	-1,5	-0,7	-0,7	-1,4	-0,7	-1,3	-1,0	-3,4	-3,4	1,1	-1,5
	Quercus rotundifolia	2,9	-0,2	0,5	0,0	2,0	1,5	-1,0	0,9	-1,0	-0,2	-0,2	-0,9	-0,1	-0,8	-0,4	-2,9	-2,9	1,7	-1,0
	Quercus spp.	0,9	-2,2	-1,5	-2,0	0,0	-0,5	-3,0	-1,1	-3,0	-2,2	-2,2	-2,9	-2,2	-2,8	-2,5	-4,9	-4,9	-0,4	-3,0
	Other broadleaves	1,4	-1,7	-1,0	-1,5	0,5	0,0	-2,5	-0,6	-2,5	-1,7	-1,7	-2,4	-1,7	-2,3	-2,0	-4,4	-4,4	0,1	-2,5
	Pinus pinea	3,9	0,8	1,5	1,0	3,0	2,5	0,0	2,0	0,0	0,8	0,8	0,1	0,9	0,2	0,6	-1,9	-1,9	2,7	0,0
	Other coniferous	1,9	-1,1	-0,4	-0,9	1,1	0,6	-2,0	0,0	-1,9	-1,1	-1,1	-1,8	-1,1	-1,7	-1,4	-3,8	-3,8	0,7	-1,9
Cropland	Non-irrigated annual crops	3,9	0,8	1,5	1,0	3,0	2,5	0,0	1,9	0,0	0,8	0,8	0,1	0,9	0,2	0,6	-1,9	-1,9	2,7	0,0
	Irrigated annual crops (except rice)	3,1	0,0	0,7	0,2	2,2	1,7	-0,8	1,1	-0,8	0,0	0,0	-0,7	0,1	-0,6	-0,3	-2,7	-2,7	1,9	-0,8
	Rice paddies	3,1	0,0	0,7	0,2	2,2	1,7	-0,8	1,1	-0,8	0,0	0,0	-0,7	0,1	-0,6	-0,3	-2,7	-2,7	1,9	-0,8
	Vineyards	3,8	0,7	1,4	0,9	2,9	2,4	-0,1	1,8	-0,1	0,7	0,7	0,0	0,8	0,1	0,5	-2,0	-2,0	2,6	-0,1
	Olive groves	3,0	0,0	0,7	0,1	2,2	1,7	-0,9	1,1	-0,9	-0,1	-0,1	-0,8	0,0	-0,7	-0,3	-2,8	-2,8	1,8	-0,9
	Other permanent crops	3,7	0,6	1,3	0,8	2,8	2,3	-0,2	1,7	-0,2	0,6	0,6	-0,1	0,7	0,0	0,4	-2,1	-2,1	2,5	-0,2
Grassland	All grasslands	3,3	0,3	1,0	0,4	2,5	2,0	-0,6	1,4	-0,6	0,3	0,3	-0,5	0,3	-0,4	0,0	-2,5	-2,5	2,1	-0,6
Wetland	Wetland	5,8	2,7	3,4	2,9	4,9	4,4	1,9	3,8	1,9	2,7	2,7	2,0	2,8	2,1	2,5	0,0	0,0	4,6	1,9
Settlements	Settlements	5,8	2,7	3,4	2,9	4,9	4,4	1,9	3,8	1,9	2,7	2,7	2,0	2,8	2,1	2,5	0,0	0,0	4,6	1,9
Other	Shrubland	1,2	-1,8	-1,1	-1,7	0,4	-0,1	-2,7	-0,7	-2,7	-1,9	-1,9	-2,6	-1,8	-2,5	-2,1	-4,6	-4,6	0,0	-2,7
	Other	3,9	0,8	1,5	1,0	3,0	2,5	0,0	1,9	0,0	0,8	0,8	0,1	0,9	0,2	0,6	-1,9	-1,9	2,7	0,0

7.2.3.3 *Uncertainties and time-series consistency*

Under revision.

7.2.3.4 *Category-specific QA/QC and verification, if applicable*

QA/QC procedures applied include a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report. These procedures were applied by the inventory team who performed the calculations and also by the members of the GT SNIERPA 3.3/3.4.

7.2.3.5 *Category-specific recalculations, if applicable, including changes made in response to the review process*

Main changes made in this submission refer to the accounting of the whole national territory to consider the two Autonomous Regions of Azores and Madeira. Previous submissions referred exclusively to Portugal Mainland.

The annual change of area in the Mainland is estimated on the basis of the CLC cartography for 1990 (based on 1985-1987 images) and 2006. The 16 year period previously used for interpolation of annual area changes considered total changes from 1990-2006. This value was changed to a 20 year period, to better reflect the actual year of the underlying CLC data (1985-1987).

7.2.3.6 *Category-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process*

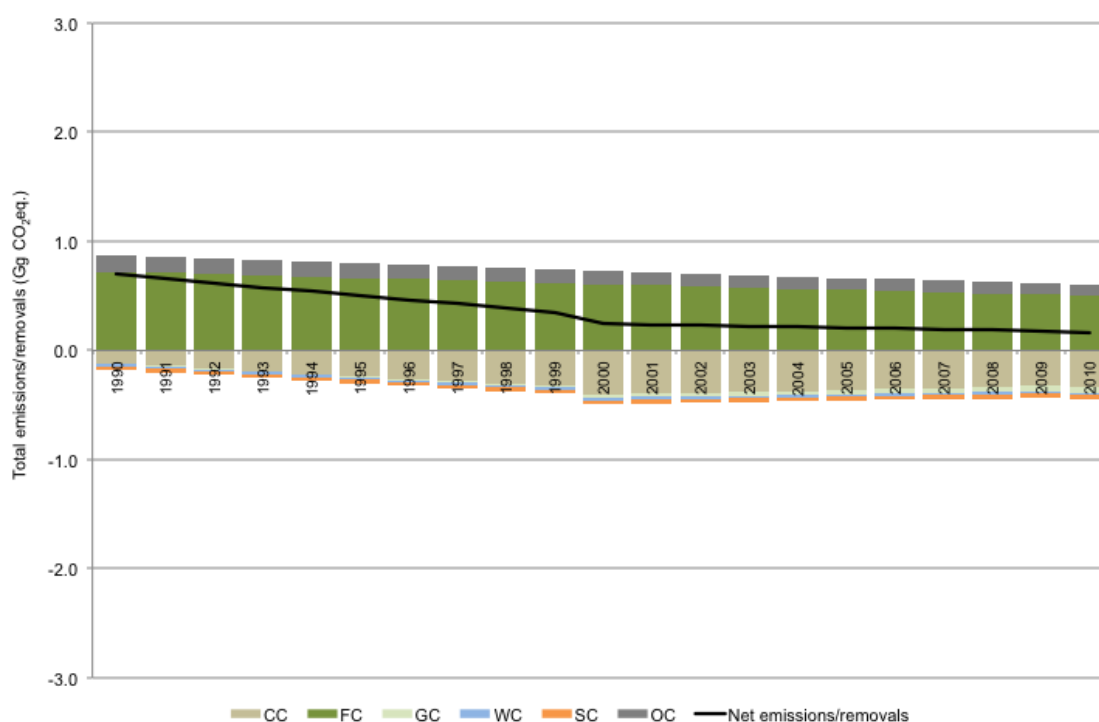
Under development

7.3 Cropland (CRF 5.B.) and Grassland (CRF 5.C.)

7.3.1 Description (e.g., characteristics of category)

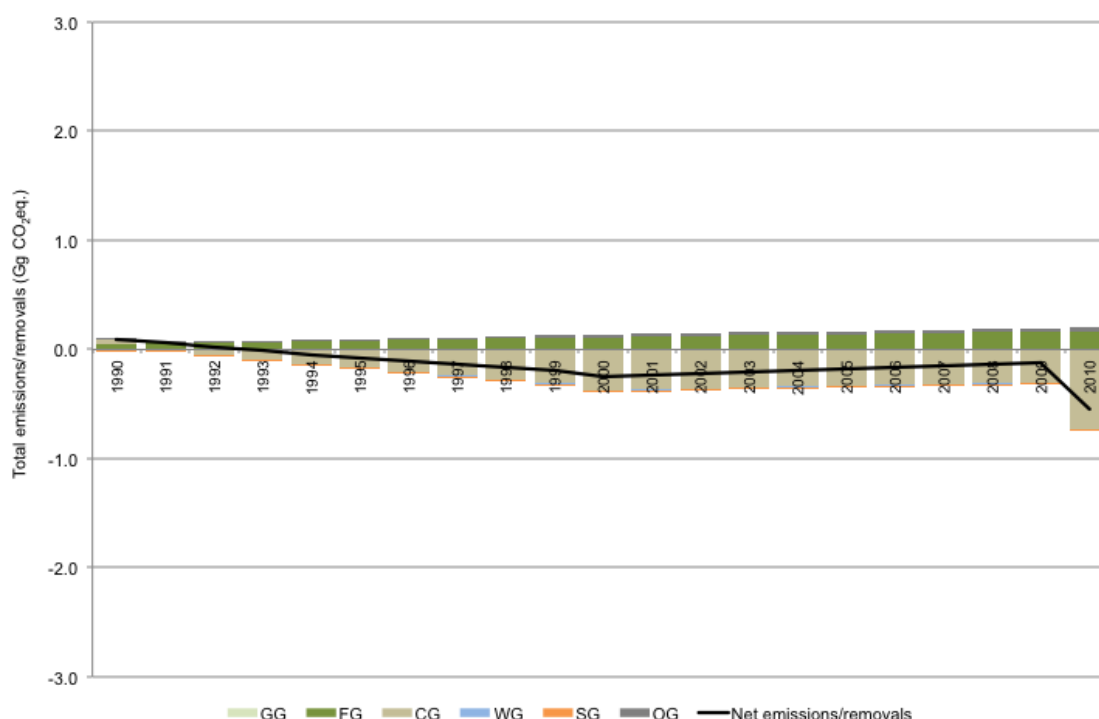
Cropland is a net source of emissions: in 1990 it emitted 0.7 Mt CO₂e and in 2010 0.2 Mt CO₂e. Most of the emissions are related to the conversion from Forest Land (Figure 7.9).

Figure 7.9 – Net emissions/removals associated with Cropland.



Grassland changed its behaviour from being a net emitter to a net sink: in 1990 it emitted 0.095 Mt CO₂e and in 2010 it removed -0.545 Mt CO₂e (Figure 7.10).

Figure 7.10 – Net emissions/removals associated with Grassland.



The estimated increase in removals in 2010 results from the change in the 1990-2009 growing tendency of the grassland area, and is associated in particular with the fact that from 2010 onwards there are no losses from the conversion of cropland into grassland as in the previous years.

7.3.2 Definitions

Complementary information sources were used to estimate areas per cropland type. These include Agriculture statistics compiled by INE in 1979 (RAC, INE), 1989 and 1999 (RGA, INE) and 2007 (IEA, MADRP). Table 7.22 summarizes the share of each crop type used in each reporting year.

Table 7.21 – Aggregation of cropland classes by main crop types

Cropland category used in NIR	Scientific name	English common name	Portuguese common name
Non-irrigated annual crops	<i>Avena sativa L.</i>	oats	Aveia
	<i>Secale cereale L.</i>	rye	Centeio
	<i>Hordeum vulgare L.</i>	barley	Cevada
	<i>Triticum aestivum L.</i>	wheat	Trigo
	<i>Helianthus annuus L.</i>	sunflower	Girassol
Irrigated annual crops(except rice)	<i>Zea mays L.</i>	maize	Milho
	<i>Sorghum bicolor L.</i>	sorghum	Sorgo
	<i>Lycopersicon esculentum Mill.</i>	tomatoes	Tomate
	-	other vegetables	Outras hortícolas
Rice paddies	<i>Oryza sativa L.</i>	rice	Arroz
Vineyards	<i>Vitis vinifera L.</i>	vineyards	Vinha
Olive groves	<i>Olea europaea L.</i>	olive groves	Olival
Other permanent crops	-	orchards	Pomares

Table 7.22 – Distribution of Cropland (including Grassland).

Crop type	1979	1989	1999	2009
Mainland				
Total Cropland	98%	90%	79%	69%
Non-irrigated annual crops	57%	51%	38%	34%
Irrigated annual crops (except rice)	15%	12%	15%	9%
Rice paddies	1%	1%	1%	1%
Vineyards	9%	8%	8%	7%
Olive groves	11%	12%	12%	13%
Other permanent crops	4%	4%	5%	5%
Total grasslands	2%	10%	21%	31%
Azores				
Total Cropland	n.a.	n.a.	13%	12%
Non-irrigated annual crops	n.a.	n.a.	10%	10%
Irrigated annual crops (except rice)	n.a.	n.a.	0%	0%
Rice paddies	n.a.	n.a.	0%	0%
Vineyards	n.a.	n.a.	1%	1%
Olive groves	n.a.	n.a.	0%	0%
Other permanent crops	n.a.	n.a.	2%	1%
Total grasslands	n.a.	n.a.	87%	88%
Madeira				
Total Cropland	n.a.	n.a.	91%	90%
Non-irrigated annual crops	n.a.	n.a.	15%	8%
Irrigated annual crops (except rice)	n.a.	n.a.	28%	37%
Rice paddies	n.a.	n.a.	0%	0%
Vineyards	n.a.	n.a.	27%	21%
Olive groves	n.a.	n.a.	0%	0%
Other permanent crops	n.a.	n.a.	22%	25%
Total grasslands	n.a.	n.a.	9%	10%

Source: INE and MADRP.

These percentages were then applied to the total Croplands' and Grasslands' areas to determine the area per cropland and grassland type per year.

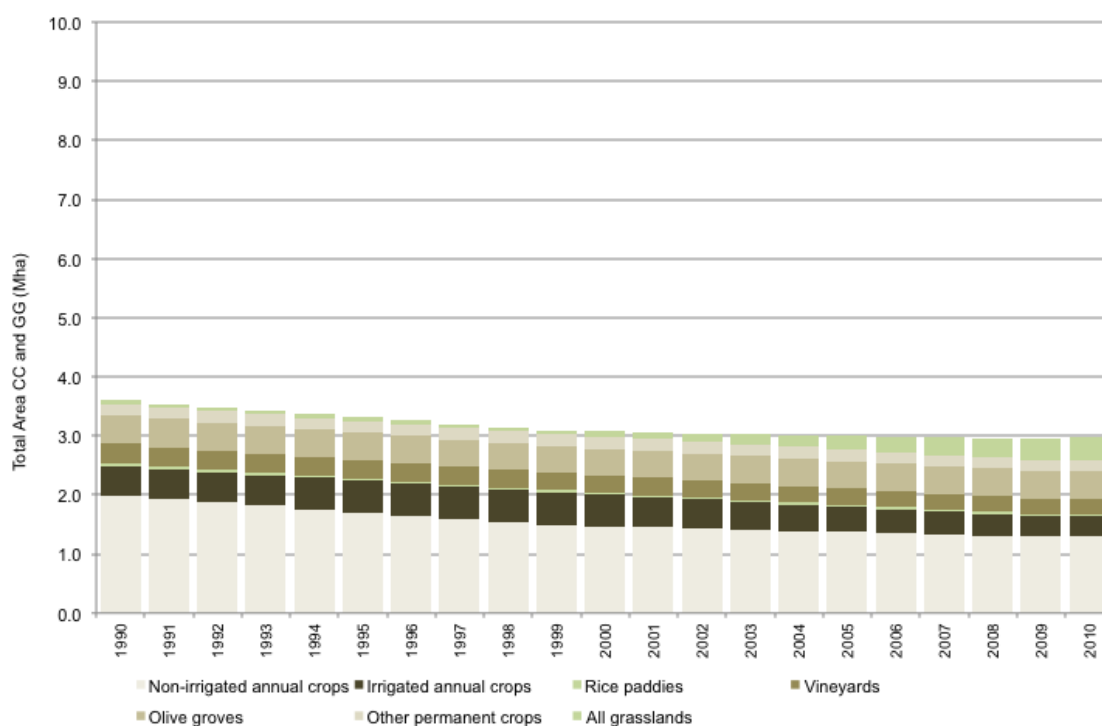
7.3.3 Methodological issues

7.3.3.1 Activity data

7.3.3.1.1 Cropland remaining Cropland (CC) and Grassland remaining Grassland (GG)

As is shown in Figure 7.11 the total area of CC has been decreasing while the area of GG has been increasing. Non-irrigated annual crops are the most significant culture. Table 7.38 shows these data in detail.

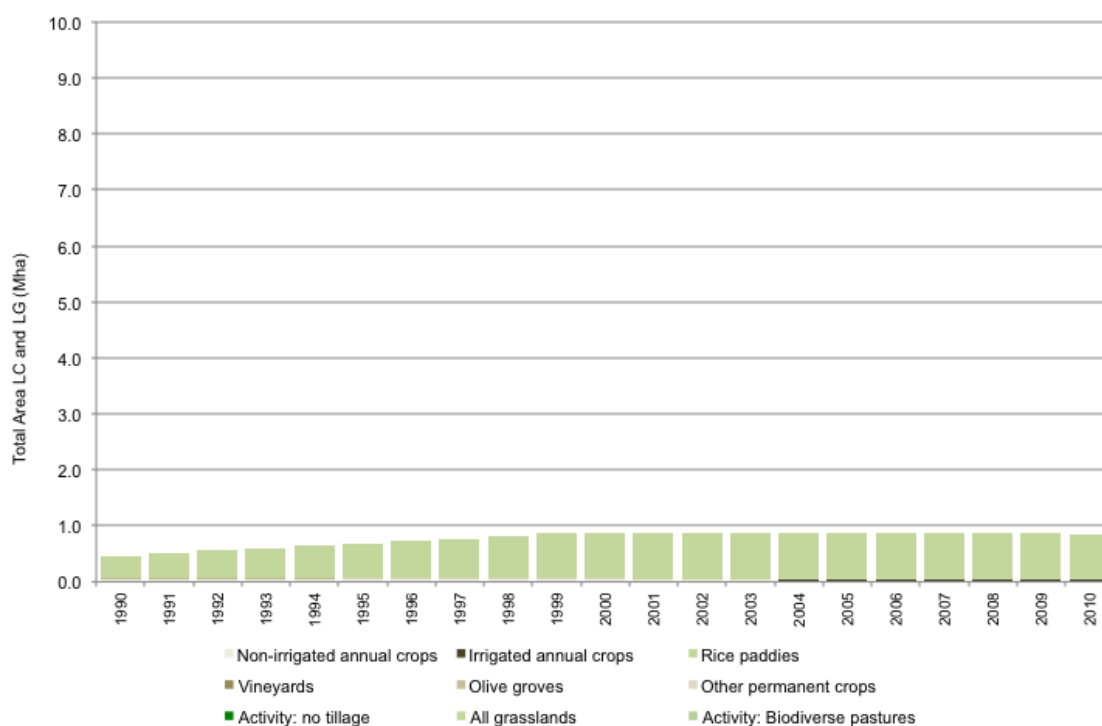
Figure 7.11 – CC and GG per culture (1990-2010).



7.3.3.1.2 Land converted to Cropland (LC) and Land converted to Grassland (LG)

Figure 7.12 and Table 7.39 show the area of Land converted to Cropland and Grassland per crop type (1990-2010). As said before, Grassland has been seeing its area increase. However, this trend has been slowing since 1999 and in 2010 there was an inversion of this growing trend.

Figure 7.12 – LC and LG per crop type (1990-2010).



7.3.3.2 Methods

7.3.3.2.1 Carbon stock change in Living Biomass

Cultures with meaningful living biomass (above and belowground) are vineyards, olive groves and other permanent crops.

For CC, Carbon gains were calculated as follows:

$$C_{Ij} = A_j \times AIR_j \times (1 + RTS)_j$$

Where:

C_I = rate of gain of Carbon, t C.ha⁻¹.yr⁻¹

j = corresponds to culture j

A = Area of CC per culture, ha (Table 7.38/ Annex)

AIR = annual Average Increment Rate, Gg C.ha⁻¹.y⁻¹ (Table 7.23)

RTS = Root To Shoot ratio (Table 7.23).

The parameters used are shown in Table 7.23.

Table 7.23 – AIR (Gg C.1000 ha⁻¹.y⁻¹) and 1+RTS associated with cropland cultures.

	AIR	1 + RTS
Non-irrigated annual crops a)	0.04	-
Irrigated annual crops a)	0.04	-
Rice paddies a)	0.04	-
Vineyards b)	0.16	1.857
Olive groves b)	0.41	1.146
Other permanent crops b)	0.45	1.176

Source: a) EEA Guidebook 2009; b) Spanish GHG Inventory, 2011.

Gains of C associated to living biomass include all the areas converted from other land uses (forest, grassland and other land) to permanent crops (vineyards, olive groves or other permanent crops) and were calculated using the same methodology. No gains were considered for annual crops as there is no associated C accumulation.

Losses of C in living biomass from Cropland include the passage to other land use from areas previously occupied by non-irrigated and irrigated annual crops, rice paddies, vineyards, olive groves or other permanent crops. Therefore, the same formula and parameters were used.

7.3.3.2.2 Net carbon stock change in DOM

This pool is considered negligible and no estimates have been calculated.

7.3.3.2.3 Net carbon stock change in Mineral Soils (MS)

The approach and parameters considered in the accounting of this pool are presented in section 7.2.3.2.3.

7.3.3.3 *Uncertainties and time-series consistency*

Under revision.

7.3.3.4 *Category-specific QA/QC and verification, if applicable*

QA/QC procedures applied include a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report. These procedures were applied by the inventory team who performed the calculations and also by the members of the GT SNIERPA 3.3/3.4.

7.3.3.5 *Category-specific recalculations, if applicable, including changes made in response to the review process*

The specific recalculations made for this category refer to the:

- consideration of biomass losses for non-irrigated and irrigated annual crops, and rice paddies. Previously only vineyards, olive groves or other permanent crops biomass was accounted.
- assumption that average the biomass is reached in 20 years, which is consistent with the approach that considers areas converted over the last 20 years (LC or LG). Previous submission considered a 10 years period.

7.3.3.6 *Category-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process*

No specific improvements are foreseen for this category.

7.4 Other Land (Wetlands (CRF 5.D.) + Settlements (CRF 5.E.) + Other Land (CRF 5.F.))

7.4.1 Description (e.g., characteristics of category)

As can be seen in the following figures, Wetlands and Settlements are always a net source of emissions. The sharp decrease of the net emissions for Settlements from 2006 to 2007 (Figure 7.14) results from the estimated discontinuity of the conversion of schrubland (Other land) into settlements in 2007 with the resulting reduction of C losses.

Figure 7.15 shows that Other land is a net sink for whole the period, which results mostly from the conversion of cropland and in a minor extent from the conversion of grassland into shrubland (other land).

Figure 7.13 – Net emissions/removals associated with Wetland.

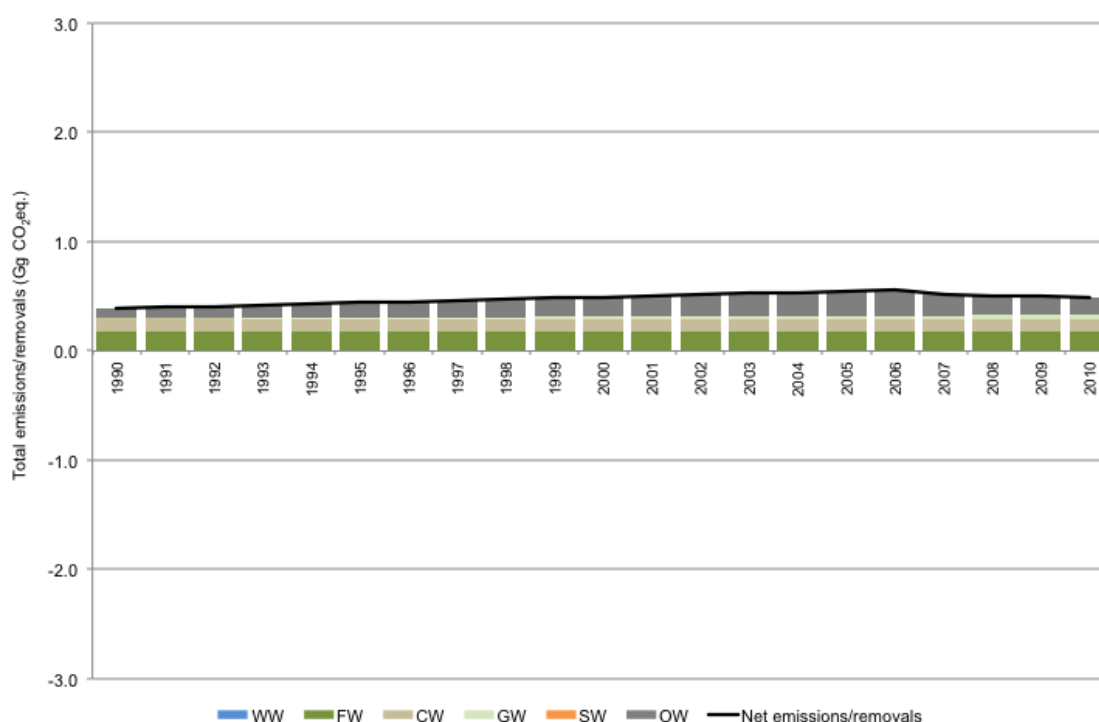


Figure 7.14 – Net emissions/removals associated with Settlements.

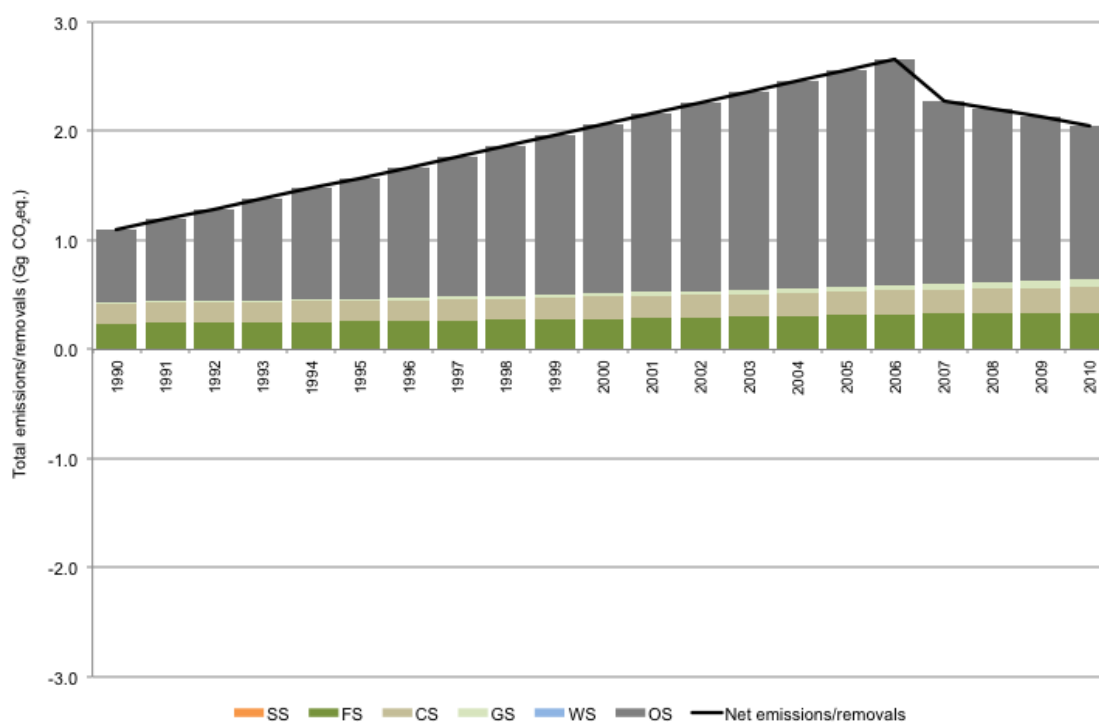
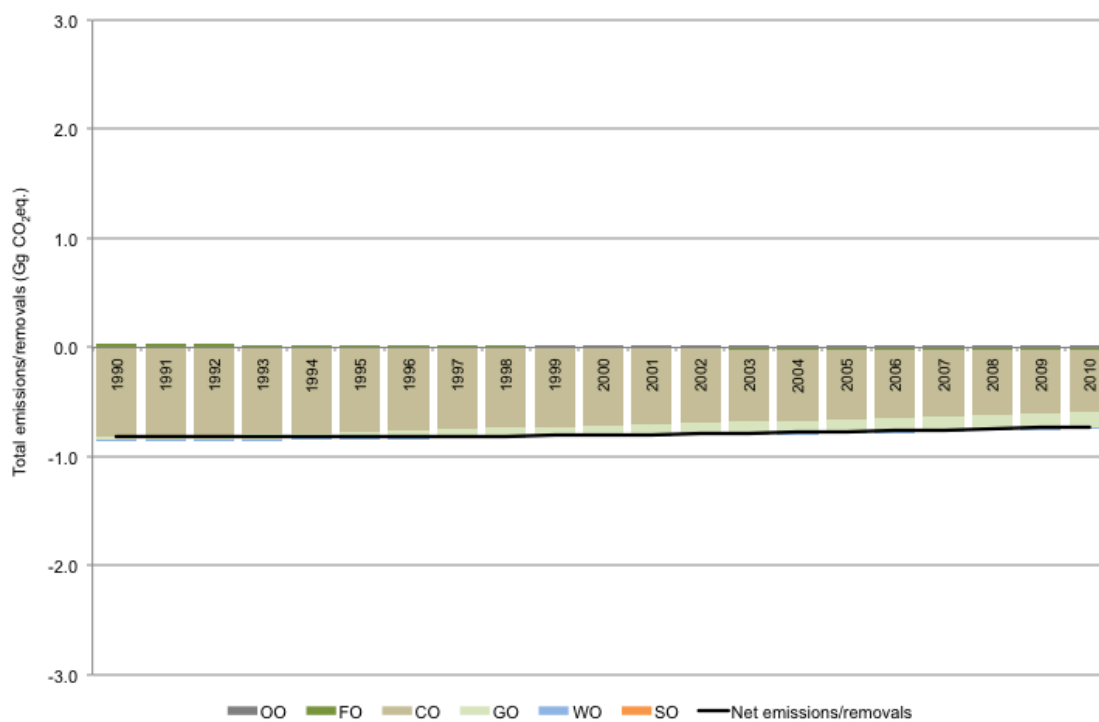


Figure 7.15 – Net emissions/removals associated with Other Land.



7.4.2 Definitions

Other land as used in the calculations of GHG emissions and removals in this submission refers to Wetlands, Settlements and Other Land (Other land – rocks, sand dunes, among others and Shrubland).

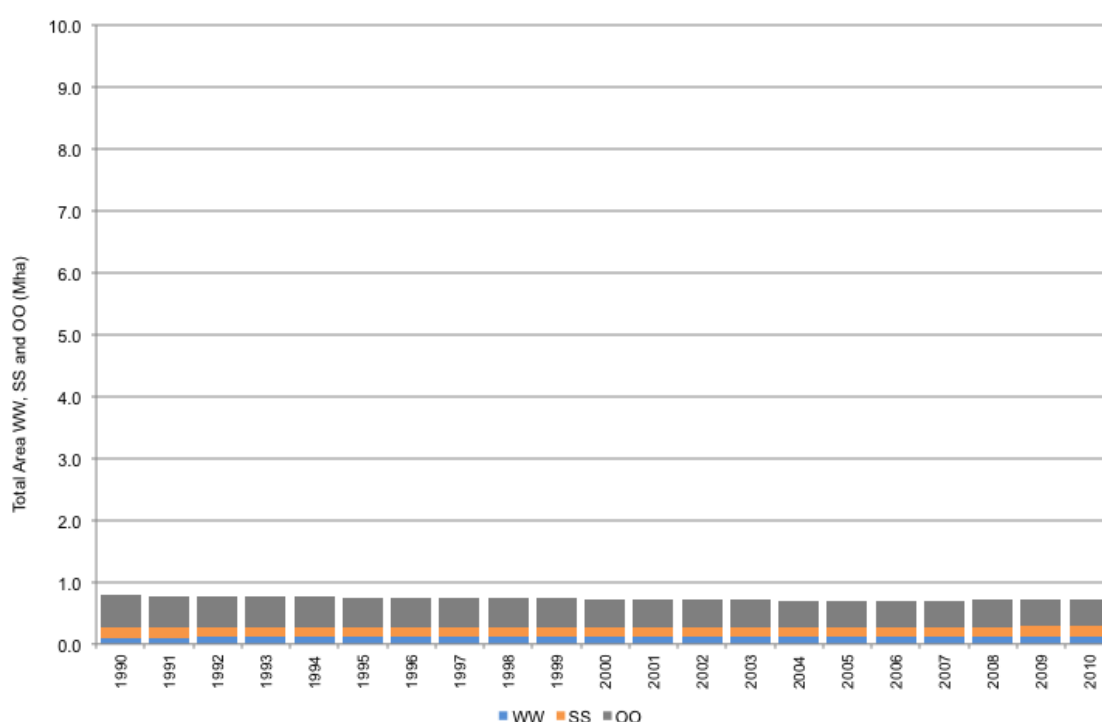
7.4.3 Methodological issues

7.4.3.1 Activity data

7.4.3.1.1 Other Land (Wetlands + Settlements + Other Land) remaining Other Land (OO)

Other land as used in the calculations of GHG emissions and removal in this submission refers to Wetlands, Settlements and Other Land (Other land – rocks, sand dunes, among others and Shrubland). This aggregate shows a constant total area in the period analyzed. Wetlands' and Settlements' area have been increasing, while Shrubland have been decreasing. Table 7.40 and Figure 7.16 show the area of WW, SS and OO.

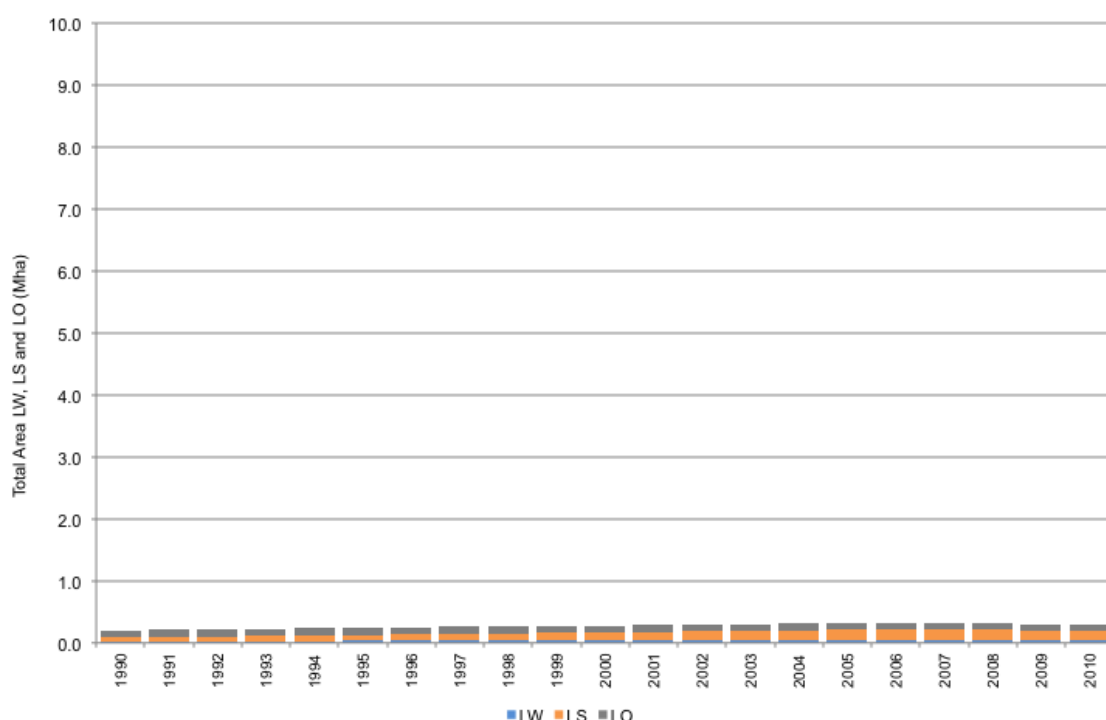
Figure 7.16 – Areas of Wetlands remaining Wetlands, Settlements remaining Settlements and Other Land remaining Other Land (1990-2010).



7.4.3.1.2 Land converted to Other Land (Wetlands + Settlements + Other Land) (LO)

Table 7.41 and Figure 7.17 show the areas for these transitions.

Figure 7.17 – Areas of Land converted to Wetlands, Land converted to Settlements and Land converted to Other Land (1990-2010).



7.4.3.2 Methods

The categories: Wetlands, Settlements and Other Land (Other land – rocks, sand dunes, among others) are considered to have no C stock in living biomass.

Shrublands is the only category considered to have significant carbon pools. Gains and losses of C in living biomass associated with OO, were calculated as in the case of cropland. The parameters used were those shown in Table 7.24.

Table 7.24 – AIR (Gg C.ha⁻¹.y⁻¹) and 1+RTS associated with shrublands.

	AIR	1 + RTS
Shrubland	0.41	1

Source: Rosas, 2009.

7.4.3.3 Uncertainties and time-series consistency

Under revision.

7.4.3.4 Category-specific QA/QC and verification, if applicable

QA/QC procedures applied include a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report. These procedures were applied by the inventory team who performed the calculations and also by the members of the GT SNIERPA 3.3/3.4.

7.4.3.5 Category-specific recalculations, if applicable, including changes made in response to the review process

The main changes made refer to the:

- change of the root-to-shoot ratio which is assumed to be equal to the areal biomass (previously the double was considered)
- assumption that the average biomass is reached in 20 years, which is considered to be consistent with the 20 years period used for the areas under conversion (LC or LG). Previous submission considered a 10 years period.

7.4.3.6 *Category-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process*

No specific improvements are foreseen for this category.

7.5 Harvested Wood Products (CRF 5G.)

Portugal reported in its Submission for Forest Management Reference Level the emissions associated with Harvested Wood Products (HWP) and also includes it in this submission.

Changes in the Carbon stock in HWP pool were estimated using IPCC methodologies, as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4: Agriculture, Forestry and Other Land-Use; Chapter 12 Harvested Wood Products.

Data for production, imports and exports was derived from UNECE for the period 1964-2009 (last updated July 2010)¹⁴⁶. Production estimates from 1900-1963 were produced using IPCC equation 12.6. The production of HWP that came from domestic harvest was estimated using equation 12.4.

Product grades considered were wood pulp (UNECE product code 7, half-live of 2 years); wood panels (UNECE product code 6, half-live of 25 years) and sawnwood (UNECE product code 5, half-live 35 years).

The results of the exercise are presented in Figure 7.19.

¹⁴⁶ <http://timber.unece.org/fileadmin/DAM/statsdata/flatfile-2010-07.zip>

Figure 7.18 – Estimated and Reported Annual Production of Harvested Wood Products.

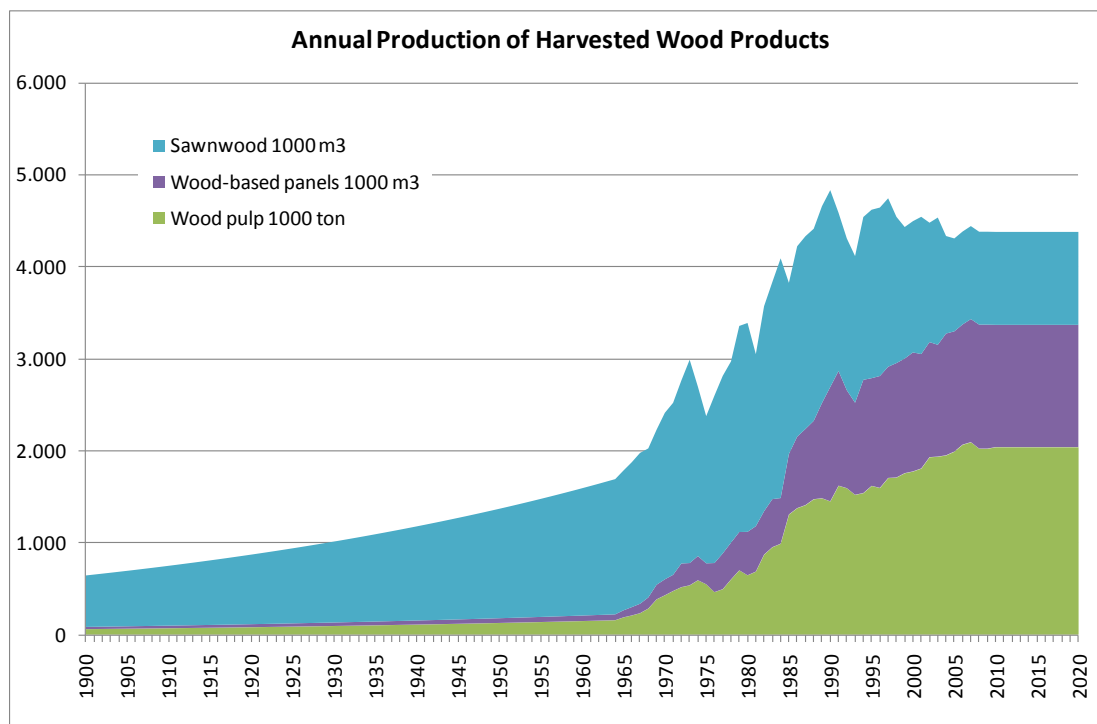
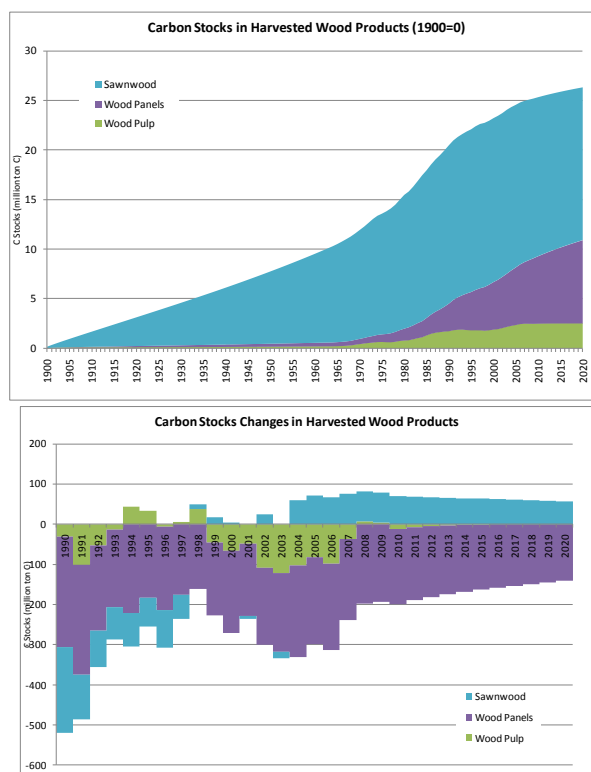


Figure 7.19 – Evolution of Carbon Stocks and Carbon Stock Changes in Harvested Wood Products



7.5.1.1 *Uncertainties and time-series consistency*

To be developed in the future.

7.5.1.2 *Category-specific QA/QC and verification, if applicable*

To be developed in the future.

7.5.1.3 *Category-specific recalculations, if applicable, including changes made in response to the review process*

No recalculations have been made since previous submission.

7.5.1.4 *Category-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process*

Not foreseen for the immediate future.

7.6 Direct N₂O emissions from N fertilization of Forest Land (CRF 5(I))

Emissions are quantified together with N fertilization of cropland and grassland and are reported in the Agriculture sector, since it is not possible to distinguish among the fertilizers used in agriculture and in forestry.

7.7 Non-CO₂ emissions from drainage of soils (CRF 5(II))

The source is considered negligible and is reported as Not Occurring.

7.8 N₂O emissions from disturbance associated with land-use conversion to cropland (CRF 5(III))

7.8.1 Source description

According to IPCC 2003 GPG, it is good practice to estimate emissions/removals from 'land converted to cropland' for a period sufficient for the carbon stock changes to occur following land-use conversion. Since the default inventory period for changes in soil carbon is 20 years, this period of time should be used in area accounting for conversions to cropland.

7.8.2 Methodological issues

7.8.2.1 *Methods*

The equation used was

$$N_2O - N_{conv} = EF_1 \times \Delta C_{LCMineral} \times \frac{1}{C:N \text{ ratio}} \times 10^{-6}$$

Where:

$N_2O - N_{conv}$ = N₂O emissions as a result of the disturbance associated with land-use conversion of forest land, grassland, or other land to cropland, Gg N₂O-N.yr⁻¹

EF_1 = IPCC default emission factor used to calculate emissions from agricultural land caused by added N, whether in the form of mineral fertilizers, manures, or crop residues, kg N₂O-N.kg⁻¹ N. (The default value used is 0.0125 kg N₂O-N.kg⁻¹ N)

$\Delta C_{LCMineral}$ = C emissions from land LC

C:N ratio = the ratio by mass of C to N in the MS, kg C.kg⁻¹ N

7.8.2.2 *Emission factor*

For this case, IPCC default values were used for EF₁ (0.0125 kg N₂O-N.kg⁻¹ N) and for C:N ratio (15).

7.8.2.3 *Uncertainties and time-series consistency*

Under revision.

7.8.2.4 *Category-specific QA/QC and verification, if applicable*

QA/QC procedures applied include a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report.

7.8.2.5 *Category-specific recalculations, if applicable, including changes made in response to the review process*

The changes in this category refer mainly to the different base used for the identification of areas and LUC which was based on the overlay of Corine 1990 and 2006 cartographies, and the separation of the areas under conversion on the basis of the IPCC default (20 years period).

7.8.2.6 *Category-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process*

No specific improvements are foreseen for this category.

7.9 CO₂ emissions from agricultural lime application (CRF 5(IV))

The source is estimated for the first time in this submission on the basis of the information collected directly by APA from the plants producing lime agricultural correctives.

7.9.1 Source description

Liming of soils in forest and agriculture land is considered a minor practice in Portugal and information on the application of lime in soils is scarce.

7.9.2 Methodological issues

7.9.2.1 *Methods*

The estimation of this source followed the Tier 1 IPCC guidance and was based on the equation:

$$\text{CO}_2\text{-C Emission} = (M_{\text{Limestone}} \cdot \text{EF}_{\text{Limestone}}) + (M_{\text{Dolomite}} \cdot \text{EF}_{\text{Dolomite}})$$

Where:

CO₂-C Emission = annual C emissions from lime application, tonnes C.yr⁻¹

M = annual amount of calcic limestone (CaCO₃) or dolomite (CaMg(CO₃)₂), tonnes.yr⁻¹

EF = emission factor, tonne of C.(tonne of limestone or dolomite)⁻¹

7.9.2.2 *Activity data*

The amount of carbonate containing lime applied annually to soils in the country was estimated on the basis of the information collected directly from the national producing limestone and dolomite for agricultural use. Due to the inherent characteristics of these products (low economic value and weight) it was assumed that no imports exist of these materials. The same

was considered for exportation, information which was corroborated from the enquiries to the plants.

7.9.2.3 *Emission factor*

The IPCC default emission factors of 0.12 for limestone and 0.13 for dolomite were applied, which are equivalent to carbonate carbon contents of the materials (12% for CaCO_3 , 13% for $\text{CaMg}(\text{CO}_3)_2$).

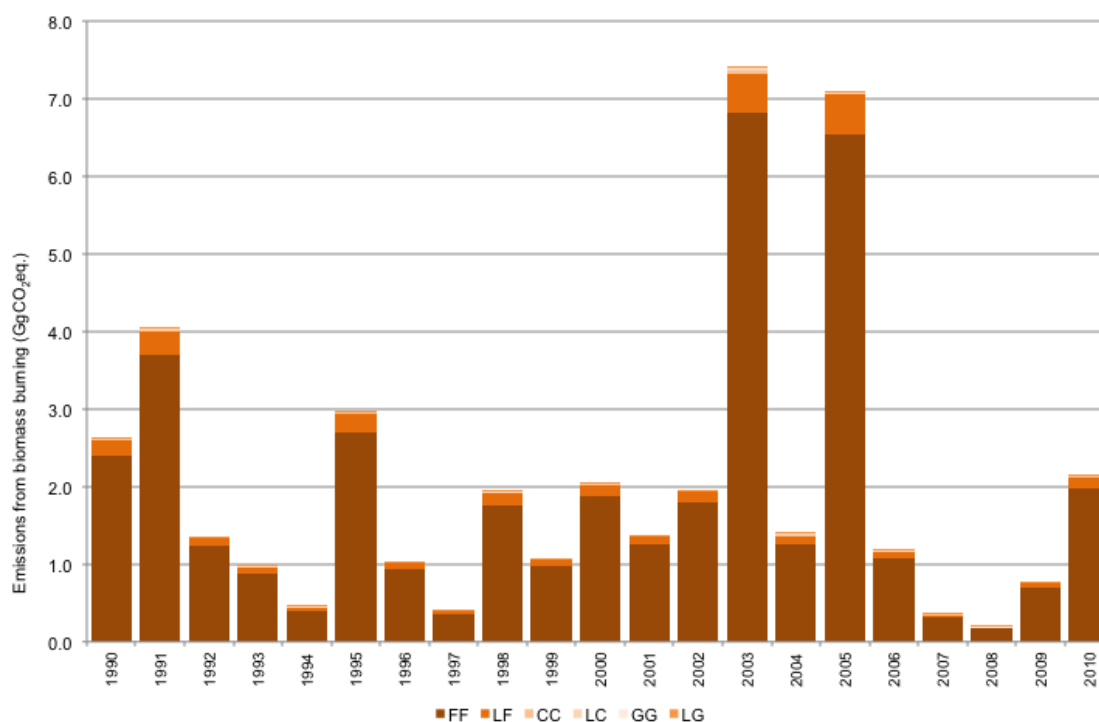
7.10 Emissions from biomass burning (CRF 5(V))

7.10.1 Source description

Forest fires are the main disturbance to forests in Portugal. They are highly correlated to weather conditions, both within each year (about 90% of the fires take place during period June-September, usually the hotter and drier months of the year), and between years (years with hot and dry summers have much higher burnt areas than years with mild and wet summers).

As a consequence, annual burnt rates are highly variable, as illustrated in Figure 7.21 and Figure 7.22. This originates emissions from CO_2 and CH_4 and N_2O in Forest land, Croplands and Grasslands, which have a great variability in the time-series (Figure 7.20 –), having a minimum in 2008 and a maximum in 2003, corresponding to emissions of 186 $\text{GgCO}_2\text{eq.}$ and 7415 $\text{GgCO}_2\text{eq.}$, respectively.

Figure 7.20 – Annual emissions associated with Biomass Burning Burnt Area in Portugal (1990-2010).



7.10.2 Methodological issues

7.10.2.1 Activity data

AFN reports annually the annual burnt area per forest type. AFN obtains the total areas of burnt forest by species comparing annual forest fire cartography with the plots of NFI. This submission also considers the biomass burning in croplands and grasslands.

Species were grouped as shown in Table 7.33Table 7.12 – and shares of forest burnt area per forest type calculated. These shares were then applied to forest areas per forest type in forest land remaining forest land and land converted to forest as shown in Table 7.36 and Table 7.37 and the following figures.

Figure 7.21 – Annual Forest Land remaining Forest Land Burnt Area per specie in Portugal (1990-2010).

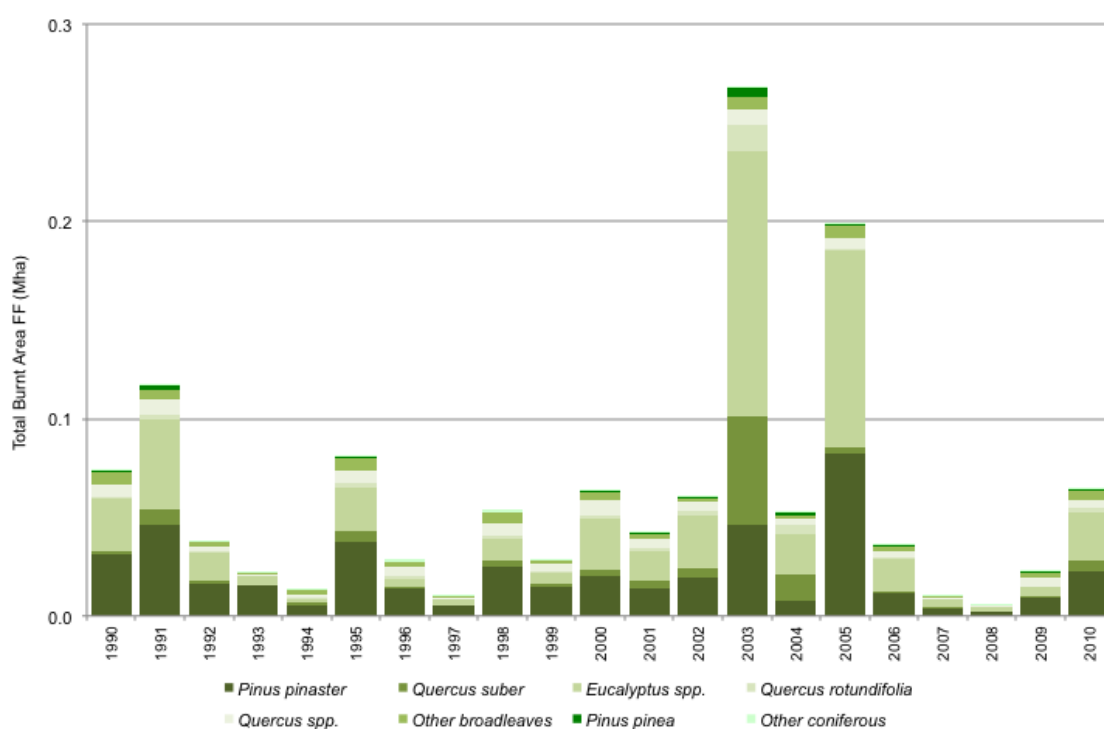


Figure 7.22 – Annual Land converted to Forest Land Burnt Area in Portugal (1990-2010).

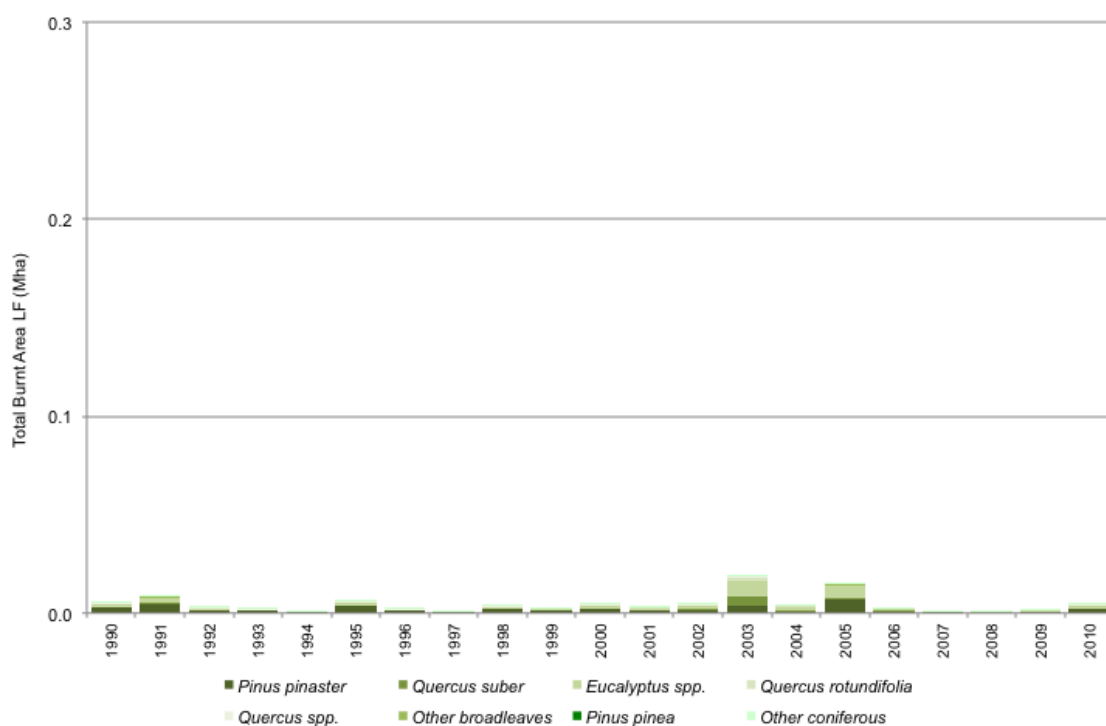


Figure 7.23 – Annual CC and GG Burnt Area in Portugal (1990-2010).

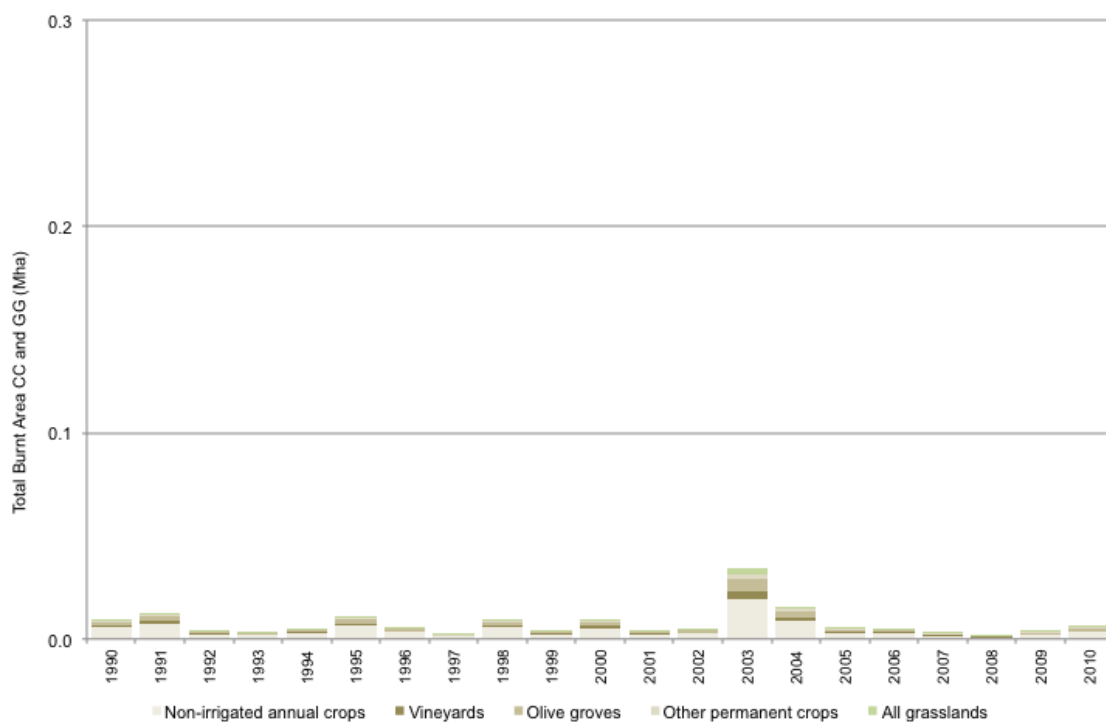
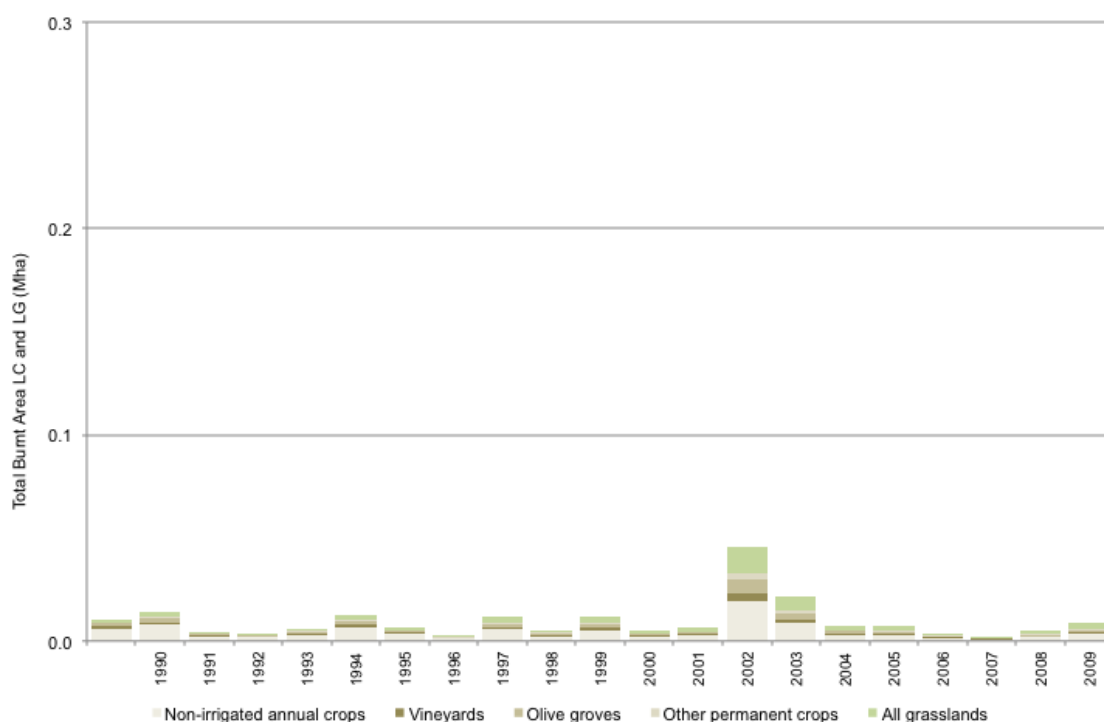


Figure 7.24 – Annual LC and LG Burnt Area in Portugal (1990-2010).



7.10.2.2 Methods

Emissions from biomass burning include both direct and indirect emissions from wildfires in FF and LF of CO₂, CH₄ and N₂O. For CC, LC, GG and LG emissions of CH₄ and N₂O were considered for non-irrigated annual crops, vineyards, olive groves and other permanent crops and all grasslands.

Direct CO₂ emissions from wildfires were calculated as follows:

$$CO_{2\text{fires},dir} = A_{burnt,j} \times B_{ABG,j} \times (B_{leaves,j} \times BCF_{leaves,j} + B_{branches,j} \times BCF_{branches,j}) \times \frac{44}{12}$$

Where:

CO_{2fires,dir} = direct CO₂ emissions from wildfires, Gg CO₂eq

j = corresponds to forest type *j*

A_{burnt,j} = Area burnt per, kha (Table 7.36 – and Table 7.37 –)

B_{ABG} = Average C stock in above ground biomass, Gg C.kha⁻¹ (Table 7.26 and Table 7.26)

B_{leaves} = Percentage of leaf's biomass in above ground biomass, % (Table 7.26)

BCF_{leaves} = Combustion factor of leaves, % (Table 7.26)

$B_{branches}$ = Percentage of small branches' biomass in above ground biomass, % (Table 7.26)

$BCF_{branches}$ = Combustion factor of small branches, % (Table 7.26)

44/12 = Conversion factor from C to CO₂

Table 7.25 – B_{ABG} (Gg C.kha⁻¹) in trees

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<i>Pinus pinaster</i>	27.9	27.9	27.9	27.9	27.9	27.9	27.8	27.6	27.5	27.3	27.2
<i>Quercus suber</i>	18.8	18.8	18.8	18.8	18.8	18.8	18.7	18.6	18.6	18.5	18.5
<i>Eucalyptus spp.</i>	16.6	16.6	16.6	16.6	16.6	16.6	16.7	16.9	17.0	17.1	17.3
<i>Quercus rotundifolia</i>	11.5	11.5	11.5	11.5	11.5	11.5	11.4	11.3	11.1	11.0	10.9
<i>Quercus spp.</i>	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.1	11.1	11.2	11.2
<i>Other broadleaves</i>	15.9	15.9	15.9	15.9	15.9	15.9	16.6	17.3	17.9	18.6	19.3
<i>Pinus pinea</i>	24.8	24.8	24.8	24.8	24.8	24.8	24.1	23.5	22.8	22.2	21.5
<i>Other coniferous</i>	8.4	8.4	8.4	8.4	8.4	8.4	9.0	9.6	10.1	10.7	11.3
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
<i>Pinus pinaster</i>	27.0	26.9	26.8	26.6	26.5	26.5	26.5	26.5	26.5	26.5	
<i>Quercus suber</i>	18.4	18.3	18.3	18.2	18.1	18.1	18.1	18.1	18.1	18.1	
<i>Eucalyptus spp.</i>	17.4	17.5	17.6	17.8	17.9	17.9	17.9	17.9	17.9	17.9	
<i>Quercus rotundifolia</i>	10.8	10.7	10.6	10.5	10.4	10.4	10.4	10.4	10.4	10.4	
<i>Quercus spp.</i>	11.3	11.3	11.4	11.4	11.5	11.5	11.5	11.5	11.5	11.5	
<i>Other broadleaves</i>	20.0	20.6	21.3	22.0	22.6	22.6	22.6	22.6	22.6	22.6	
<i>Pinus pinea</i>	20.9	20.3	19.6	19.0	18.3	18.3	18.3	18.3	18.3	18.3	
<i>Other coniferous</i>	11.9	12.5	13.1	13.6	14.2	14.2	14.2	14.2	14.2	14.2	

Table 7.26 – B_{leaves} (%), BCF_{leaves} (%), $B_{branches}$ (%) and $BCF_{branches}$ (%)

	B_{leaves}	BCF_{leaves}	$B_{branches}$	$BCF_{branches}$
<i>Pinus pinaster</i>	7%	88%	11%	58%
<i>Quercus suber</i>	10%		18%	
<i>Eucalyptus spp.</i>	9%		7%	
<i>Quercus rotundifolia</i>	6%		11%	
<i>Quercus spp.</i>	22%		56%	
<i>Other broadleaves</i>	22%		56%	
<i>Pinus pinea</i>	5%		8%	
<i>Other coniferous</i>	8%		12%	

Sources: AFN, 2005 and Rosa, 2009 (*Quercus suber*, *Quercus rotundifolia* and *Quercus spp.*)

Indirect CO₂ emissions from wildfires were calculated as follows:

$$CO_{2\text{fires},ind} = A_{burnt,j} \times B_{ABG,j} \times M_{fire,j} \times 1 - SW_j \times (1 + RTS_j \times \frac{44}{12} - CO_{2\text{fires},dir}$$

Where:

$CO_{2\text{fires},ind}$	= indirect CO ₂ emissions from wildfires, Gg CO ₂ eq
j	= corresponds to forest type j
$A_{burnt,j}$	= Area burnt per, kha (Table 7.36 – and Table 7.37 –)
B_{ABG}	= Average C stock in above ground biomass, Gg C.kha ⁻¹ (Table 7.26)
RTS	= Root To Shoot ratio (Table 7.16)
M_{fire}	= Mortality due to fire, %
SW	= Percentage of salvaged wood in total wood, %
$CO_{2\text{fires},dir}$	= Direct CO ₂ emissions from wildfires, Gg CO ₂ eq
$44/12$	= Conversion factor from C to CO ₂

Table 7.27 – M_{fire} (%) and SW (%)

	M_{fire}	SW
<i>Pinus pinaster</i>	70	40
<i>Quercus suber</i>	30	40
<i>Eucalyptus spp.</i>	50	50
<i>Quercus rotundifolia</i>	10	40
<i>Quercus spp.</i>	30	40
Other broadleaves	30	40
<i>Pinus pinea</i>	30	40
Other coniferous	70	40

Sources: AFN, 2005 and Rosa, 2009 (*Quercus suber*, *Quercus rotundifolia* and *Quercus spp.*)

Direct CH₄ and N₂O emissions from wildfires were calculated as follows:

$$CH_{4\text{fires},dir} \text{ or } N_{2O\text{fires},dir} = A_{burnt,j} \times B_{ABG,j} \times B_{leafs,j} \times BCF_{leafs,j} + B_{branches,j} \times BCF_{branches,j} \times EF \times CFC \times GWP$$

Where:

$CH_{4\text{fires},dir}$ or $N_{2O\text{fires},dir}$	= direct CH ₄ or N ₂ O emissions from wildfires, Gg CO ₂ eq
j	= corresponds to forest type j or cropland culture or grassland
$A_{burnt,j}$	= Area burnt, kha (Table 7.36 – and Table 7.37 –)

B_{ABG} = Average C stock in above ground biomass, Gg C.kha⁻¹ (Table 7.25, Table 7.28 and The estimates consider also the above ground biomass of croplands and grasslands.

Table 7.29 –)

B_{leafs} (Table 7.26)	= Percentage of leaf's biomass in above ground biomass, % (Table 7.26)
BCF_{leafs}	= Combustion factor of leafs, % (Table 7.26)
B_{branches} (Table 7.26)	= Percentage of small branches' biomass in above ground biomass, % (Table 7.26)
BCF_{branches}	= Combustion factor of small branches, % (Table 7.26)
EF (Table 7.30)	= Percentage of lost Carbon or Nitrogen emission factor by gas, % (Table 7.30)
CFC	= Conversion factor from C to the gas, % (Table 7.30)
GWP	= Global Warming Potential (Table 7.30)

Further to the accounting of above ground biomass of forest trees, the estimates of non-CO₂ emissions consider also the undergrowth cover and the biomass from litter in forest land.

Despite the fact that LULUCF GPG considers good practice to estimate both CO₂ and non-CO₂ emissions resulting from carbon losses due to disturbances as wildfires, it is also accepted that, if the method applied in the quantification of the carbon sequestration does not consider the removals by re-growth after the disturbances (which is not considered), it is not mandatory to report the CO₂ emissions associated with the disturbances events.

Table 7.28 – B_{ABG} (Gg C.kha-1) in scrubs understorey and litter in forest land

	B_{ABG} shrubs in forest areas	B_{ABG} in litter
<i>Pinus pinaster</i>	4.1	2.9
<i>Quercus suber</i>	1.5	1.7
<i>Eucalyptus spp.</i>	2.5	1.5
<i>Quercus rotundifolia</i>	0.9	1.7
<i>Quercus spp.</i>	3.1	1.7
<i>Other broadleaves</i>	3.1	1.7
<i>Pinus pinea</i>	1.8	2.4
<i>Other coniferous</i>	3.5	3.8

Source: Rosa (2009).

The estimates consider also the above ground biomass of croplands and grasslands.

Table 7.29 – B_{ABG} (Gg C.kha⁻¹ for cropland and all grasslands.

	B_{ABG}
Non-irrigated annual crops	0.8
Vineyards	3.2
Olive groves	8.3
Other permanent crops	9.0
All grasslands	1.1

Sources: non-irrigated annual crops and all grasslands EEA Guidebook 2009 and for vineyards, olive groves and other permanent crops Spain NIR 2009.

In the case of cropland and grassland, the combustion factor for above ground biomass is considered to be 100%, assuming that all the biomass is burnt. The combustion factor considered for litter is 75% and for scrubs understorey is 72%.

Table 7.30 – EF (%), CFC and GWP

GHG	EF	CFC	GWP
CH ₄	1.2%	1.3	21
N ₂ O	0,7%	3.1	310

Sources: AFN, 2005 and Rosa, 2009 (*Quercus suber*, *Quercus rotundifolia* and *Quercus spp.*) and IPCC, 2003 for GWP

7.10.3 Uncertainties and time-series consistency

Under revision.

7.10.4 Category-specific QA/QC and verification, if applicable

QA/QC procedures applied include a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report. These procedures were applied by the inventory team who performed the calculations and also by the members of the GT SNIERPA 3.3/3.4.

7.10.5 Category-specific recalculations, if applicable, including changes made in response to the review process

Recalculations in this category result mainly from the consideration for the first time in this submission of the emissions from wildfires in cropland and grassland, for the Mainland and Madeira. In Azores wildfires do not occur. In previous submissions this category accounted only with emissions from forest fires.

7.10.6 Category-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process.

No improvements are foreseen for the near future.

7.11 Annex

Table 7.31 – Areas of FF (kha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
FF	3.734	3.743	3.752	3.761	3.769	3.778	3.787	3.796	3.805	3.814	3.823	3.832	3.840	3.849	3.858	3.867	3.876	3.885	3.894	3.903	3.912
<i>Pinus pinaster</i>	1.257	1.231	1.205	1.179	1.152	1.126	1.120	1.115	1.109	1.103	1.096	1.090	1.084	1.077	1.071	1.064	1.057	1.050	1.043	1.036	1.029
<i>Quercus suber</i>	805	808	811	814	817	820	823	825	828	831	833	836	839	841	844	847	849	852	855	858	860
<i>Eucalyptus spp.</i>	682	708	734	760	785	811	821	830	840	850	860	869	880	890	900	910	921	931	942	953	963
<i>Quercus rotundifolia</i>	535	534	533	531	530	529	524	520	515	511	507	502	498	493	489	484	480	475	471	466	462
<i>Quercus spp.</i>	134	138	141	145	149	153	156	158	161	163	166	169	171	174	177	179	182	185	187	190	193
Other broadleaves	196	198	201	203	206	209	206	204	202	199	197	195	193	191	189	187	184	182	180	178	176
<i>Pinus pinea</i>	85	86	87	88	89	90	96	103	110	117	124	130	137	144	151	158	164	171	178	185	192
Other coniferous	39	40	40	40	41	41	41	41	40	40	40	40	39	39	39	39	38	38	38	37	37

Table 7.32 – Areas of LF (kha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LF	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305	305
<i>Pinus pinaster</i>	122	119	117	115	113	110	108	106	104	102	100	98	97	95	93	92	90	89	88	87	85
<i>Quercus suber</i>	62	62	62	62	62	63	63	63	63	63	63	63	63	63	63	63	64	64	64	64	64
<i>Eucalyptus spp.</i>	34	36	38	40	42	44	45	47	49	51	52	54	55	57	58	59	61	62	63	64	65
<i>Quercus rotundifolia</i>	44	44	44	43	43	43	43	43	42	42	42	42	41	41	41	40	40	40	39	39	39
<i>Quercus spp.</i>	8	8	8	8	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12	12	13
Other broadleaves	21	21	21	21	22	22	22	22	23	23	23	23	23	23	23	23	23	23	23	23	23
<i>Pinus pinea</i>	6	6	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8	9	9	9	10
Other coniferous	9	9	9	8	8	8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	7

Table 7.33 – Annual percentage of burnt area per specie for Mainland according to IFN.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<i>Pinus pinaster</i>	43%	40%	45%	70%	41%	47%	49%	49%	47%	51%	32%	34%	33%	17%	15%	42%	33%	41%	40%	41%	n.a.
<i>Quercus suber</i>	2%	7%	4%	2%	13%	6%	5%	1%	6%	5%	5%	10%	8%	21%	26%	1%	4%	6%	4%	3%	n.a.
<i>Eucalyptus spp.</i>	35%	38%	38%	19%	8%	27%	12%	27%	20%	19%	41%	35%	43%	50%	38%	50%	46%	39%	37%	21%	n.a.
<i>Quercus rotundifolia</i>	1%	2%	1%	1%	11%	3%	5%	2%	3%	4%	2%	4%	3%	5%	10%	0%	2%	4%	4%	3%	n.a.
<i>Quercus spp.</i>	9%	6%	7%	3%	11%	7%	16%	10%	12%	14%	12%	10%	8%	3%	5%	3%	10%	4%	9%	21%	n.a.
Other broadleaves	8%	4%	5%	5%	10%	7%	8%	8%	9%	4%	6%	6%	3%	2%	3%	3%	4%	4%	4%	11%	n.a.
<i>Pinus pinea</i>	1%	1%	0%	0%	1%	1%	0%	0%	0%	0%	1%	2%	1%	2%	3%	0%	1%	2%	0%	0%	n.a.
Other coniferous	1%	1%	1%	0%	4%	1%	5%	4%	2%	3%	1%	1%	0%	0%	1%	1%	1%	0%	1%	1%	n.a.

Table 7.34 – Total burnt areas according to AFN fire statistics (Mainland)¹⁴⁷ and Regional-Directorate of Forestry (Madeira) (ha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Mainland																					
Forest land	79.549	125.488	39.701	23.839	13.487	87.554	30.542	11.466	57.393	31.052	68.646	45.617	65.164	286.055	56.271	213.921	36.320	9.829	5.461	24.097	46.079
Shrubland	57.703	56.998	17.311	26.124	63.836	82.058	58.325	19.068	100.975	39.561	90.958	66.695	59.455	139.784	73.836	125.168	39.738	39.535	12.103	63.323	87.011
Croplands and Grasslands	10.466	13.915	4.347	3.810	5.896	12.933	6.776	2.328	12.076	5.384	12.170	5.172	6.371	45.974	21.334	7.642	7.098	3.922	2.444	5.327	8.749
Madeira																					
Forest land	123	681	727	56	1.230	411	342	104	657	128	60	37	64	1.968	650	489	2.265	1.022	327	62	4.241
Shrubland	5	26	39	1	210	43	20	12	629	17	79	33	29	1.750	272	143	1.067	461	149	227	4.391
Croplands and Grasslands	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

¹⁴⁷ No data no data on agriculture in AFN's fire database 1990-2000. Estimated based on % of agriculture/(forest + shrub) in 2001-2010

Table 7.35 – Total reported burnt areas per forest specie, agricultural crop or grassland (ha)¹⁴⁸.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<i>Pinus pinaster</i>	34.511	50.508	17.900	16.671	5.797	41.489	15.119	5.589	27.122	15.828	21.753	15.433	21.488	50.247	8.447	89.659	12.321	4.252	2.240	9.775	24.010
<i>Quercus suber</i>	1.585	8.936	1.640	370	1.698	5.318	1.435	135	3.330	1.550	3.321	4.343	4.999	59.158	14.352	2.927	1.298	591	243	664	5.895
<i>Eucalyptus spp.</i>	27.898	47.765	15.224	4.651	1.259	23.678	3.690	3.123	11.807	6.022	28.248	15.781	28.234	142.914	21.590	106.644	17.281	4.052	2.109	5.113	26.562
<i>Quercus rotundifolia</i>	1.082	2.563	302	128	1.524	2.531	1.620	207	1.894	1.232	1.672	1.669	2.203	14.608	5.471	831	833	392	201	660	2.081
<i>Quercus spp.</i>	6.821	7.676	2.653	646	1.531	6.472	4.871	1.098	6.860	4.232	8.045	4.663	5.085	8.213	2.801	5.801	3.514	409	513	5.076	4.349
Other broadleaves	6.355	5.808	2.467	1.272	2.116	6.718	2.501	951	5.508	1.400	4.332	2.657	2.301	6.432	2.040	6.915	2.721	960	429	2.580	5.472
<i>Pinus pinea</i>	424	1.820	14	67	149	547	17	11	86	122	547	796	772	5.272	1.626	396	259	158	10	52	657
Other coniferous	996	1.093	230	90	642	1.212	1.631	456	1.444	793	788	312	146	1.181	595	1.237	359	37	44	239	788
Non-irrigated annual crops	6.052	7.859	2.397	2.048	3.090	6.600	3.365	1.124	5.661	2.449	5.443	2.275	2.756	19.555	8.922	3.142	2.869	1.558	954	2.044	3.357
Irrigated annual crops (except rice) ¹⁴⁹	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice paddies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vineyards	1.005	1.326	411	358	549	1.195	621	212	1.089	482	1.070	447	541	3.835	1.749	615	561	305	186	399	655
Olive groves	1.469	1.951	609	533	825	1.808	946	325	1.684	750	1.701	725	895	6.477	3.014	1.082	1.008	558	349	762	1.252
Other permanent crops	550	749	240	215	341	765	410	144	763	348	775	325	395	2.817	1.290	456	418	228	140	302	496
All grasslands	1.391	2.030	691	655	1.092	2.566	1.434	524	2.879	1.357	3.181	1.400	1.784	13.290	6.359	2.346	2.241	1.273	814	1.820	2.989
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Settlements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other land (Shrubland)	57.708	57.024	17.350	26.125	64.046	82.101	58.345	19.080	101.604	39.578	91.037	66.729	59.483	141.533	74.108	125.311	40.805	39.995	12.252	63.550	91.402

¹⁴⁸ Data for 2010 was obtained as the average of the 1990-2009 time series.

¹⁴⁹ For irrigated annual crops, rice paddies, wetlands and settlements fires are reported as not occurring.

Table 7.36 – Annual FF, CC and GG burnt areas per specie, culture or grasslands (ha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<i>Pinus pinaster</i>	31.464	46.049	16.324	15.190	5.300	37.787	13.791	5.104	24.802	14.487	19.930	14.154	19.727	46.199	7.778	82.527	11.380	3.933	2.071	9.021	22.223
<i>Quercus suber</i>	1.472	8.297	1.523	343	1.578	4.942	1.333	125	3.096	1.441	3.088	4.038	4.649	55.019	13.349	2.723	1.208	550	226	618	5.487
<i>Eucalyptus spp.</i>	26.576	45.466	14.485	4.420	1.207	22.479	3.501	2.956	11.165	5.686	26.636	14.866	26.572	134.407	20.294	100.147	16.243	3.812	1.981	4.793	24.939
<i>Quercus rotundifolia</i>	1.000	2.369	279	118	1.409	2.340	1.498	192	1.750	1.138	1.544	1.542	2.035	13.486	5.050	767	769	362	185	609	1.920
<i>Quercus spp.</i>	6.451	7.257	2.507	610	1.446	6.111	4.596	1.036	6.464	3.986	7.573	4.387	4.783	7.721	2.632	5.450	3.300	384	481	4.766	4.082
Other broadleaves	5.944	5.452	2.331	1.191	2.021	6.295	2.346	890	5.147	1.305	4.018	2.461	2.129	6.019	1.908	6.386	2.601	928	408	2.367	5.206
<i>Pinus pinea</i>	396	1.698	13	63	139	510	16	10	81	116	517	754	733	5.008	1.546	377	246	151	9	50	626
Other coniferous	929	1.021	216	85	602	1.131	1.521	425	1.345	738	733	290	135	1.099	553	1.147	337	37	41	221	738
Non-irrigated annual crops	5910	7671	2338	1998	3012	6430	3276	1094	5507	2381	5294	2213	2681	19029	8684	3059	2793	1517	929	1991	3272
Irrigated annual crops (except rice)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice paddies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vineyards	982	1295	402	349	536	1167	606	207	1063	470	1044	436	528	3742	1706	600	548	297	182	389	639
Olive groves	1428	1896	592	518	801	1755	919	315	1633	728	1646	700	864	6238	2898	1039	966	534	333	727	1194
Other permanent crops	536	728	232	208	328	734	392	137	725	329	733	307	373	2659	1217	430	394	215	132	284	468
All grasslands	215	280	86	73	110	233	117	39	191	81	297	174	273	2389	1300	533	557	342	234	554	1015

Table 7.37 – Annual LF, LC and LG burnt areas per specie, culture or grasslands (ha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<i>Pinus pinaster</i>	3046	4459	1576	1481	497	3702	1328	485	2320	1341	1823	1279	1761	4048	669	7131	941	319	170	755	1787
<i>Quercus suber</i>	113	638	117	26	121	377	102	10	235	109	234	305	350	4139	1002	204	90	41	17	46	407
<i>Eucalyptus spp.</i>	1323	2298	739	230	53	1200	190	167	642	336	1612	915	1662	8507	1296	6497	1038	240	128	320	1623
<i>Quercus rotundifolia</i>	82	194	23	10	115	191	122	16	144	94	128	128	169	1122	421	64	64	30	16	51	161
<i>Quercus spp.</i>	369	419	146	36	85	361	275	63	396	246	472	276	303	492	169	351	213	25	31	311	267
Other broadleaves	411	356	135	81	95	423	155	61	361	95	314	196	172	413	132	529	119	33	21	213	265
<i>Pinus pinea</i>	29	122	1	5	10	37	1	1	5	7	29	42	39	265	80	19	13	8	0	3	32
Other coniferous	67	72	14	6	41	80	110	31	99	55	56	22	10	82	42	90	22	1	3	18	50
Non-irrigated annual crops	6052	7859	2397	2048	3090	6600	3365	1124	5661	2449	5443	2275	2756	19555	8922	3142	2869	1558	954	2044	3357
Irrigated annual crops (except rice)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice paddies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vineyards	1005	1326	411	358	549	1195	621	212	1089	482	1070	447	541	3835	1749	615	561	305	186	399	655
Olive groves	1469	1951	609	533	825	1808	946	325	1684	750	1701	725	895	6477	3014	1082	1008	558	349	762	1252
Other permanent crops	550	749	240	215	341	765	410	144	763	348	775	325	395	2817	1290	456	418	228	140	302	496
All grasslands	1391	2030	691	655	1092	2566	1434	524	2879	1357	3181	1400	1784	13290	6359	2346	2241	1273	814	1820	2989

Table 7.38 – Areas of CC and GG (kha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC	3.524	3.470	3.415	3.361	3.306	3.252	3.198	3.144	3.090	3.036
Non-irrigated annual crops	1.984	1.927	1.871	1.815	1.760	1.704	1.650	1.595	1.541	1.487
Irrigated annual crops	503	510	516	523	529	535	541	547	552	558
Rice paddies	42	41	40	39	38	38	37	36	35	34
Vineyards	335	331	327	323	318	314	310	306	302	298
Olive groves	475	472	470	467	464	461	458	455	452	450
Other permanent crops	185	188	191	194	197	200	202	205	208	210
GG	180	178	176	174	172	169	167	164	161	158
Activity: no tillage	0	0	0	0	0	0	0	0	0	0
Activity: biodiverse pastures	0	0	0	0	0	0	0	0	0	0

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CC	2.991	2.945	2.900	2.856	2.811	2.767	2.722	2.678	2.635	2.591	2.586
Non-irrigated annual crops	1.468	1.448	1.429	1.410	1.391	1.372	1.353	1.334	1.316	1.297	1.294
Irrigated annual crops	535	513	491	470	448	426	405	383	362	341	341
Rice paddies	34	35	36	36	37	37	38	38	39	39	39
Vineyards	294	290	285	281	277	273	268	264	260	256	255
Olive groves	451	453	455	457	459	461	463	465	467	469	467
Other permanent crops	208	206	204	201	199	197	195	193	191	189	189
GG	180	178	176	174	172	169	167	164	161	158	180
Activity: no tillage	0	0	0	0	0	0	0	0	4	10	22
Activity: biodiverse pastures	0	0	0	0	0	0	0	0	15	21	29

Table 7.39 – Areas of LC and LG (kha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LC	90	91	93	94	96	98	100	102	105	107	107	108	108	108	108	108	109	109	109	109	106
Non-irrigated annual crops	37	37	36	36	36	35	35	34	34	33	32	32	31	31	30	29	29	28	28	27	27
Irrigated annual crops	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Rice paddies	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vineyards	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5
Olive groves	7	7	7	7	7	7	7	7	7	7	8	8	8	8	8	8	8	8	8	8	8
Other permanent crops	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
LG	406	450	495	539	583	627	671	715	759	803	806	808	811	814	817	820	822	825	828	831	787

Table 7.40 – Areas of WW, SS and OO (kha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WW - Wetlands	90	91	93	94	96	98	100	102	105	107	107	108	108	108	108	108	109	109	109	109	106
SS - Settlements	154	154	154	154	155	155	155	155	155	155	155	155	154	154	154	154	153	159	165	172	178
OO - Shrubland	498	493	487	482	477	471	466	461	456	450	445	440	435	430	425	420	415	416	418	420	421
OO - Other	26	25	24	23	23	22	21	21	20	19	19	18	17	16	16	15	14	15	15	15	15

Table 7.41 – Areas of LW, LS and LO (kha).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LW - Wetlands	28	29	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	43	42	41	40
LS - Settlements	60	67	74	81	88	95	102	110	117	125	132	140	148	155	163	171	179	174	169	163	158
LO - Shrubland	114	113	113	112	112	111	111	110	109	109	108	107	106	105	104	103	101	100	99	98	97
LO - Other	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3

Table 7.42 – Annual harvested volumes (1000 m³ub.y⁻¹)

Total Annual Harvest	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<i>Pinus pinaster</i>	6.684	5.726	5.311	5.283	5.107	5.117	4.760	4.760	4.384	4.380	3.974	3.958	3.285	3.532	4.177	3.468	3.701	3.837	3.316	3.620	3.589
<i>Quercus suber</i>	108	109	109	110	110	110	111	111	111	112	112	112	113	113	113	114	114	114	115	115	116
<i>Eucalyptus spp.</i>	4.521	5.083	4.967	4.924	4.712	4.233	4.218	4.218	4.164	4.598	4.709	4.988	5.457	6.141	6.692	7.278	7.104	6.986	6.853	5.992	6.837
<i>Quercus rotundifolia</i>	72	72	72	72	72	71	71	70	70	69	69	68	67	67	66	66	65	64	64	63	63
<i>Quercus spp.</i>	103	106	109	111	114	118	120	122	124	126	128	130	132	134	136	138	140	143	145	147	149
Other broadleaves	120	122	123	125	126	128	126	124	122	120	118	116	114	112	109	107	105	103	101	106	100
<i>Pinus pinea</i>	128	130	131	132	133	135	144	154	163	173	183	193	202	212	222	232	242	252	262	272	282
Other coniferous	40	41	41	42	42	42	42	42	42	41	41	41	41	40	40	40	40	39	39	257	319
1. Forest Land remaining Forest Land																					
<i>Pinus pinaster</i>	6.684	5.726	5.311	5.283	5.107	5.117	4.760	4.760	4.384	4.380	3.974	3.958	3.285	3.532	4.177	3.468	3.701	3.837	3.316	3.620	3.589
<i>Quercus suber</i>	108	109	109	110	110	110	111	111	111	112	112	112	113	113	113	114	114	114	115	115	116
<i>Eucalyptus spp.</i>	4.375	4.927	4.802	4.749	4.528	4.039	4.015	4.005	3.942	4.366	4.467	4.737	5.196	5.871	6.412	6.989	6.805	6.678	6.541	5.676	6.518
<i>Quercus rotundifolia</i>	72	72	72	72	72	71	71	70	70	69	69	68	67	67	66	66	65	64	64	63	63
<i>Quercus spp.</i>	103	106	109	111	114	118	120	122	124	126	128	130	132	134	136	138	140	143	145	147	149
Other broadleaves	120	122	123	125	126	128	126	124	122	120	118	116	114	112	109	107	105	103	101	106	100
<i>Pinus pinea</i>	128	130	131	132	133	135	144	154	163	173	183	193	202	212	222	232	242	252	262	272	282
Other coniferous	40	41	41	42	42	42	42	42	42	41	41	41	41	40	40	40	40	39	39	257	319
2. Land converted to Forest Land																					
<i>Pinus pinaster</i>																					
<i>Quercus suber</i>																					
<i>Eucalyptus spp.</i>	146	156	165	175	184	194	203	213	222	232	242	251	261	270	280	289	299	308	312	315	319
<i>Quercus rotundifolia</i>																					
<i>Quercus spp.</i>																					
Other broadleaves																					
<i>Pinus pinea</i>																					
Other coniferous																					

7.12 Further developments

Portugal has been doing significant efforts to achieve a higher methodological level, identifying opportunities for improvements towards Tier 2 type of information, in order to guarantee a more complete, transparent and accurate reporting of the activities associated with LULUCF sector, namely the coherence with also the estimations associated with the activities reported under Articles 3.3 and 3.4 of the Kyoto Protocol.

7.12.1 Development of KP land-use cartography 1995, 2007, 2010

In April 2012 a contract between the Portuguese Carbon Fund and the IGP (the National Cartography Authority) has been signed aiming at improving the basis for area estimations used in UNFCCC reporting and KP accounting.

The project will develop full land-use maps for the years 1995 and 2010 (using the existing COS 2007 as a basis for comparison).

These reference years have been selected to benefit from existing work (2007) and because these are years (1995, 2010) for which a complete aerial photography of the country is available; and these set of years close enough to KP's base year and 1st commitment period reporting years. This set of 3 maps will be used to derive land-use change maps for those periods and, by interpolation, annual trends in land-use change to be used in UNFCCC and KP reporting.

An image with comparable quality for 1990 is not available and, therefore, reporting data for 1990 will have to be extrapolated using the land-use change trends 1995-2007.

This project is expected to produce preliminary data in December 2012, based on 4km² sampling of around 6% of the territory and full wall-to-wall data in December 2013..

7.12.2 National Forest Inventory (NFI-6)

In April 2011 a contract between the Portuguese Carbon Fund and the AFN (the National Forest Authority) has been signed aiming at updating and improving several aspects of Forest and Land-use reporting and accounting.

The NFI-6 foresees the following tasks:

- 1. Applying the systematic sampling (500x500m grid) used in NFI-5 (2005) to the images of 1995 and 2010 to derive data on land-use (expanded from forest classes to full land-use classification) and land-use changes
- 2. Full forest inventory (volumes, etc) based on sampling in 2012 (2x2km grid) of forest plots, to update the information of C stocks in forests already sampled in NFI-5.
- 3. Soil C inventory in forest land, cropland and grassland, to improve the quality data used in reporting Soil C stocks and stock-changes.

Data on task 1 is expected in the Fall 2012, while the results for tasks 2 and 3 will become available only end 2013.

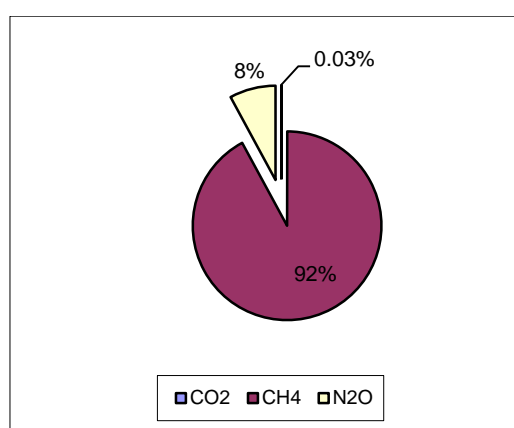
8 WASTE (CRF 6.)

8.1 Overview

Waste management and treatment of industrial and municipal wastes are sources of GHG emissions. The inventory covers emissions resulting from solid waste disposal on land, treatment of liquid wastes and waste incineration.

The most important gas produced is CH₄, resulting from the anaerobic decomposition of organic waste disposed on land and from handling of wastewater treatment under anaerobic conditions.

Figure 8.1 – Emissions of GHG from waste by gas (2010)



Decomposition of organic waste does not occur instantaneously after disposition on land, but rather over a long period of time, and CH₄ is emitted at a diminishing rate. Different factors affect the generation of CH₄: Waste disposal practices (degree of control of disposal sites – in general, controlled placement of waste favors anaerobic activity and consequently landfill gas formation, but the gas can be recovered and be either flared or used for energy purposes); Waste composition (quantities of degradable materials is one major element influencing biogas production); and Physical factors (e.g. moisture content and temperature).

Solid waste disposal sites (SWDS), which include both managed landfills and open dump sites, can also produce directly significant amounts of CO₂. In fact, the decomposition of organic materials originates landfill gas or biogas consisting of approximately 50 per cent CH₄ and 50 per cent CO₂ by volume. However, this carbon dioxide results in its major part from oxidation of biomass materials and does not contribute hence to ultimate CO₂. Additionally, a much smaller percentage of landfill gas is composed of NMVOC and NH₃.

The biodegradation of soluble organic matter in wastewater can occur under aerobic or anaerobic conditions. CH₄ emissions result from handling of wastewater and the biomass (sludge) produced under anaerobic conditions. The amount of CH₄ produced depends on the extent of biodegradation occurring under anaerobic versus aerobic conditions. CH₄ produced during deliberate anaerobic wastewater treatment processes can be collected and flared or combusted for energy. Untreated wastewater may originate CH₄ if held under anaerobic circumstances.

CH₄ emissions are affected by:

- Wastewater characteristics. Determines how much organic compounds are degraded. Also the degradable organic content of wastewater determines the CH₄ producing potential of wastewater, because it affects the extent to which oxygen is removed from the system. Under anaerobic conditions and all the same conditions, such as temperature, wastewater with higher BOD (Biochemical Oxygen Demand) or COD (Chemical Oxygen Demand) concentrations will produce more CH₄ than wastewater with lower BOD or COD concentrations);
- Handling Systems – anaerobic versus aerobic conditions in system design and operation (the management conditions of collection and wastewater treatment systems determine the potential of CH₄ generation; systems providing anaerobic conditions will generally produce higher CH₄ emissions than systems having aerobic conditions);
- Temperature (CH₄ generation increases with temperature; CH₄ production occurs with temperatures higher than 15°; this factor is especially important in uncontrolled systems and warm climates);
- Systems characteristics (other factors affecting CH₄ production are retention time, degree of wastewater treatment, and other site specific conditions).

Wastewater treatment is also potentially a source of NMVOC and N₂O. Although the available methodologies to estimate these pollutants are far from suitable, N₂O emissions from human sewage were estimated using a basic approach.

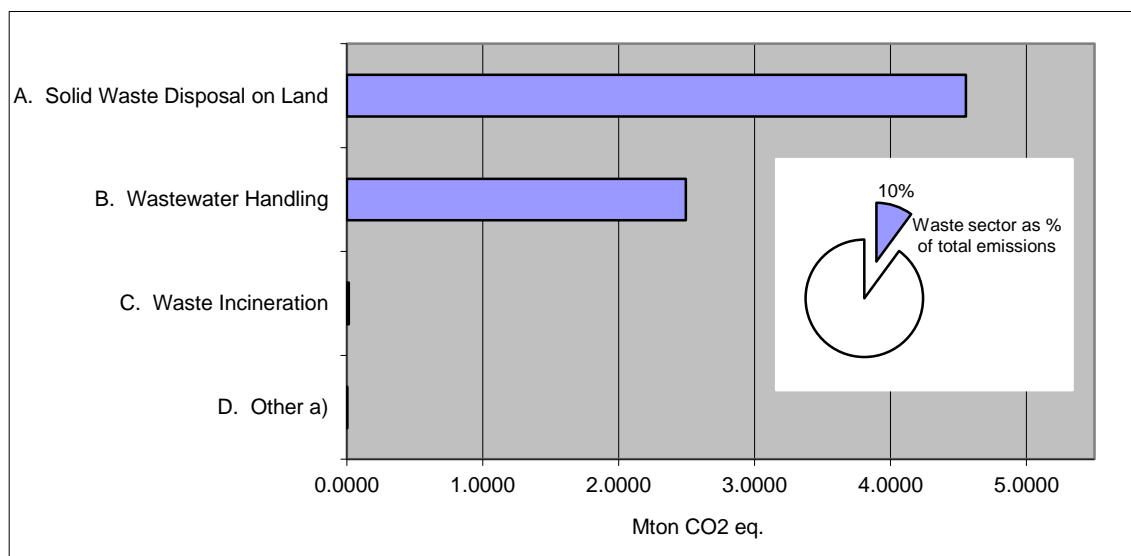
Incineration of solid wastes originates emissions of CO₂, CH₄, N₂O, CO, NO_x and NMVOC. Out of the direct GHG, CH₄ emissions are considered to be the less significant due to combustion conditions in incinerators. According to the IPCC Guidelines (IPCC,1997), only CO₂ emissions resulting from the incineration of carbon in waste of fossil origin (e.g. plastics, certain textiles, rubber, liquid solvents, and waste oil) are to be included in emissions estimates, while the carbon fraction that is derived from biomass materials (e.g. paper, food waste, and wooden material) should not be included. Thus, CO₂ emissions from waste combustion depends, on the quantities of waste incinerated, the carbon content of the waste, and the fraction of the carbon that is of fossil origin.

Combustion of municipal solid wastes (MSW) in Portugal is done with energy recovery, and thus, according to the IPCC Guidelines, they are accounted for in the energy sector (sub-category 1A(a) Public electricity and heat production). The incineration of hospital waste occurs without energy recovery and is therefore allocated to the waste sector. Nevertheless, as the methodology applies for both situations (with and without energy recover), in order to avoid a double description, it is presented only once in this sub-section.

This sector includes also the incineration of industrial waste without energy recovery that occurs in industrial units. Due to a classification error, this source was previously accounted as “open burning of industrial solid waste on land”. These estimates will be revised in future submissions.

Emissions generated from waste activities represented in 2010 10.5 per cent of total GHG emissions (excluding LULUCF). The biggest sub-category within the sector refers to solid waste disposed on land – 4.6 Mt CO₂e. - corresponding to approx. 62 per cent of the sector’s emissions.

Figure 8.2 – Sources of GHG in waste sector (2010)



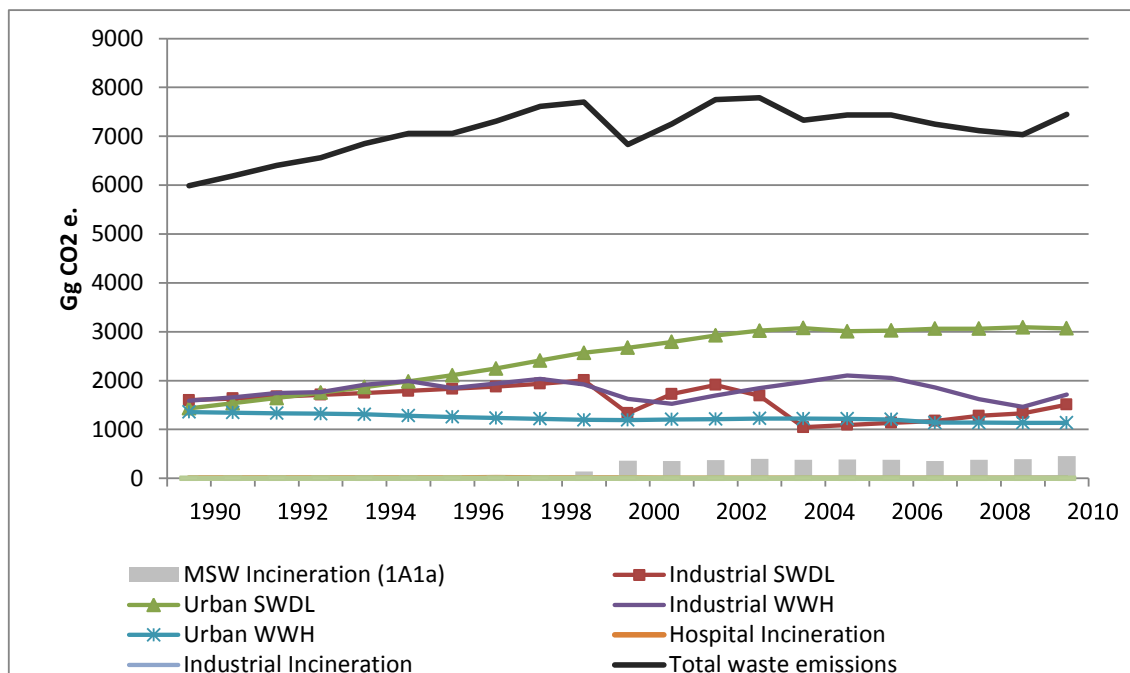
Note: a) Emissions from biogas combustion without energy recovery (flaring in SWDS).

In the period 1990-2010 GHG emissions from waste activities are estimated to have increased 24 per cent. The increase in the sector is strongly related to the change of consumption patterns registered in Portugal in the last decades, associated with new commercial structures. The opening of the first supermarket occurred in 1961. By the end of that decade/ beginning of the next one, several distribution companies appeared. The late 70s/ beginning of the 80s registered another increase of these commercial units, with the number of supermarkets rising from 196 in 1974 to 375 in 1985. The following years, which recorded a steady economic growth in particular since the Portuguese accession to the EU in 1986, have led to the reduction of customs barriers and the revival of domestic demand, and have definitively changed the consumption habits of the Portuguese population. Since 1985, year of the opening of the first hypermarket in Portugal, until 1997, they were settled 40 hypermarkets and 943 supermarkets in the country (APED)¹⁵⁰.

Another factor related to the emissions growth of this sector refers to the geographical distribution change of the Portuguese population. Since 1960, there was a significant increase of the population living in urban centres. This trend was accompanied by the development of solid waste collection systems: the population served by solid waste collection systems is estimated to have increased from 40% in 1960 to 100% in 2000.

¹⁵⁰ APED, Anuário da Distribuição Portuguesa 1999.

Figure 8.3 – Emission trends of GHG from waste by sub-category



The aggregated emission trend presented in the previous figure is related to a large extent by the growth of emissions from SWDS, and particularly the emissions from the disposal on land of urban waste which represents approx. 62 per cent of the sector's total. The fluctuations observed are also highly influenced by the level of emissions from industrial waste disposed on land, as can be observed in the previous figure. These variations are related to the change in the quantities of waste disposed in landfills in the different years and the composition of waste (Degradable Organic Carbon).

In the most recent years the sector registers a stagnation in emissions, which is in part related to the start of operation of two incineration units dedicated to MSW incineration in Portugal Mainland (1999), and another incineration unit the Autonomous Region of Madeira in 2001/02. These emissions occur with energy recovery and are therefore accounted in the energy sector (category 1A1a).

Furthermore, the relative declining of the emissions in the more recent years are also related to biogas flaring in landfills that can occur with and without energy recovery. Landfill gas with energy recovery is burned in several units which produce and sell electricity to the grid. Also, the quantities of selectively collected waste, which have more than doubled since 1999, have deviate waste flows from SWDS and incineration units, and contributed to this trend.

Emissions from biogas combustion are also accounted and are reported in the energy sector when there is energy recovery or in the waste sector when biogas is flared (without energy recovery).

8.2 Source categories

8.2.1 Solid Waste Disposal on Land (CRF 6.A.)

8.2.1.1 CH₄ emissions from Solid Waste Disposal Sites (SWDS)

8.2.1.1.1 Methodology

To better take into account the fact that CH₄ emissions from SWDS occur over a long period of time and not immediately after disposal of waste on land, the methodological approach considered was the First Order Decay Method (Tier 2).

This method can be represented by equations (1) and (2):

$$Q_{T,x} = k R_x L_0 e^{-k(T-x)} \quad (1)$$

where:

$Q_{T,x}$ - methane generated in current year (T) by the waste R_x (Mg CH₄/yr);

k - methane generation rate constant (1/yr);

R_x - quantity of waste disposed in year x (Mg/yr);

L_0 - methane generation potential (Mg CH₄/Mg waste);

x – year of waste input;

T – current year.

$$\text{CH}_4 \text{ emitted in year } T \text{ (Gg/yr)} = [\text{CH}_4 \text{ generated in year } T - R(T)] * (1 - \text{OX}) \quad (2)$$

where:

$R(T)$ - CH₄ recovered in year T (Gg/yr);

OX - oxidation factor (fraction).

CH₄ recovery ($R(T)$) is the amount of CH₄ generated at SWDS that is recovered and combusted (e.g. flared or used for energy) and not emitted as CH₄ but as CO₂¹⁵¹. On the other hand, the CH₄ that is recovered but subsequently vented to atmosphere is not subtracted from emissions.

The Oxidation factor (OX) reflects the portion of CH₄ from SWDS that is oxidised to CO₂ in the soil or other material covering the waste. If the OX is zero, no oxidation takes place, and if OX is 1 then 100% of CH₄ is oxidised. Well-managed disposal sites tend to have higher oxidation results than unmanaged dump sites with no cover or where large amounts of CH₄ can escape through cracks in the cover.

The methane generation potential (L_0) depends upon the composition of waste, waste disposal practices and of the physical characteristics of the SWDS. It is estimated by the formula:

¹⁵¹ Although not ultimate CO₂.

$$L_o = MCF * DOC * DOC_F * F * 16/12$$

where:

MCF - CH₄ correction factor (fraction);

DOC - degradable organic carbon (fraction) (Mg C/Mg waste);

DOCF - fraction DOC dissimilated;

F - fraction (volume) of CH₄ in landfill gas.

Methane correction factor (MCF) accounts for the effect of management practices on CH₄ generation. Unmanaged disposal sites present lower methane-generating potential, because a larger fraction of waste decomposes aerobically in the top layers.

Degradable organic carbon (DOC) is the organic carbon that is accessible to biochemical decomposition. It is a function of the composition of waste and can be calculated from a weighted average of carbon content of various components of waste.

$$DOC = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)$$

where:

A = fraction of waste that is paper and textiles;

B = fraction of waste that is garden waste, park waste or other non-food organic putrescibles;

C = fraction of waste that is food waste;

D = fraction of waste that is wood or straw.

Fraction of degradable organic carbon dissimilated (DOCF) is an estimate of the fraction of carbon that is ultimately degraded and converted into landfill gas, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS.

Fraction of CH₄ in landfill gas (F) landfill gas is usually considered to be composed dominantly by half of CO₂ and half of CH₄¹⁵².

8.2.1.1.2 Activity data and parameters

SWDS include solid municipal or urban waste (household, garden, commercial-services wastes) and industrial wastes.

8.2.1.1.2.1 Urban waste

8.2.1.1.2.1.1 Quantities of waste landfilled

In 2010, the management of municipal solid waste (MSW) in Portuguese mainland was under the responsibility of 25 management systems (13 multi-municipal and 12 inter-municipal systems). In the Autonomous Region of Azores, municipality authorities are the responsible

¹⁵² Other gases exist in lesser quantities however.

entities for the management of MSW, and in the Autonomous Region of Madeira, this responsibility is shared between municipalities and the Regional Government.

Since 1999, data on MSW is available for the majority of these systems, including production amounts, final disposal and, to a less extent, waste composition.

For previous years, information on urban waste was not collected on a regular basis, and most information was available from:

- PERSU - “Plano Estratégico dos Resíduos Sólidos Urbanos” (Strategic Plan on Municipal Solid Waste), which was approved by the Government in 1997. This plan includes data from annual municipal registries;
- a study performed by Quercus (1995) – “Caracterização dos Resíduos Sólidos Urbanos e Inventariação dos Locais de Deposição em Portugal” (Characterization of Municipal Solid Waste and Survey of Disposal Sites in Portugal). The study of Quercus (1995) considered open dump sites, managed landfills, composting and incineration units, covering aspects as the quantities of waste treated or landfilled and other characteristics (opening and closure year of operation, waste composition, existence of flaring equipment, etc). Data was based on a survey performed in 1994, which enabled the calculation of per capita generation rates for 1994, based on the amounts of waste collected and the population served by waste collection.

The use of the FOD method requires building a data time series for several decades in the past concerning waste quantities, composition and disposal practices. According to IPCC (2000), it is good practice to estimate historical data if such data are not available, when this is a key source category (Annex A). In what concerns the extent of the time series, it was adopted the criteria from USA, based on the emissions model from EPA(1993), and it was considered that landfill waste produces CH₄ for 30 years after disposal.

Before 1994, data on landfill wastes had to be estimated based on expert judgment for waste generation growth rates. For the period 1960-1980 it was considered a per capita waste generation growth rate of 2.5% per year; for the following years (1980-1994) 3% per year. Therefore municipal solid wastes production was estimated for each municipality as follows:

[Population (inhabitants) * Annual per capita generation rate (ton/inhabitants/year)]

Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991 and 2001. Data for intermediate years were estimated, by interpolation, for each municipality. Figures for 2001 onwards are forecasts.

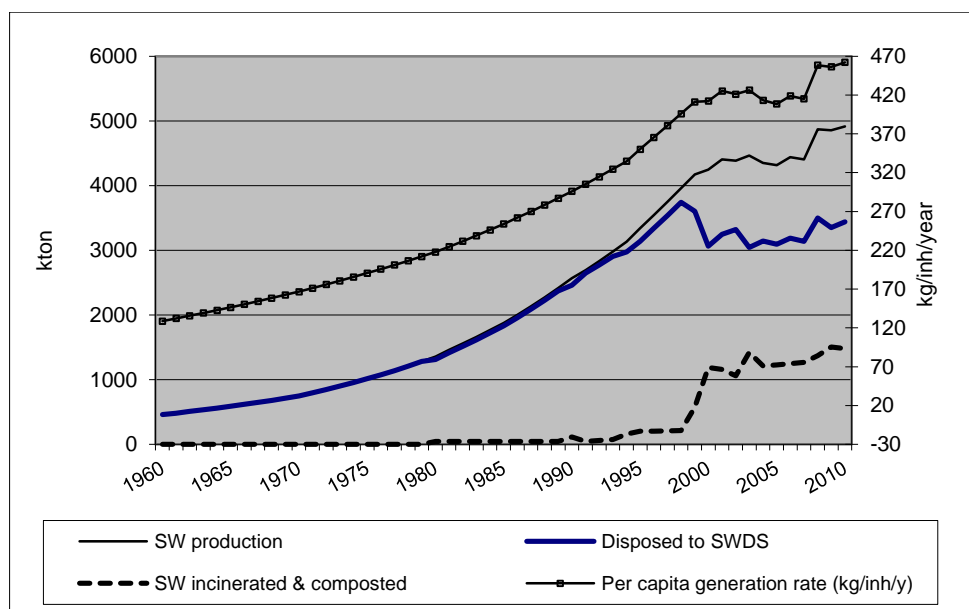
To take into account the fact that part of the population (rural areas) was not served by an organised waste collection and waste disposal system, values of annual production were multiplied by the percentage of population served by waste collection in each municipality. After 2000, it was assumed that all the population of the country is served by waste collecting systems (100%). The total amount of waste disposed to SWDS was then calculated based on this estimated value minus the amounts of waste incinerated and composted:

$$\begin{aligned}
 \text{Waste disposed to SWDS} = & [\text{Population} * \text{Annual per capita generation rate} * \\
 & \text{Percentage of Population served by waste collection}] \\
 & - \text{Quantity of incinerated waste} - \text{Quantity of composted waste}
 \end{aligned}$$

Next figure presents the trends of the per capita generation rates, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series.

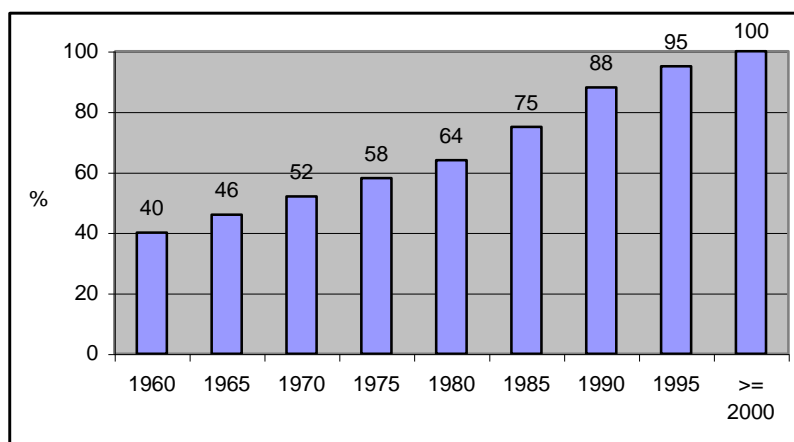
For the more recent years (for 1994, and since 1999) the information refers to data effectively collected and reported by the waste management systems. As presented in the graph, waste disposed to SWDS start reducing in 1999 which corresponds to the beginning of operation of two MSW incineration units.

Figure 8.4 – Urban waste (excluding selective collection)



Source: APA; Quercus study

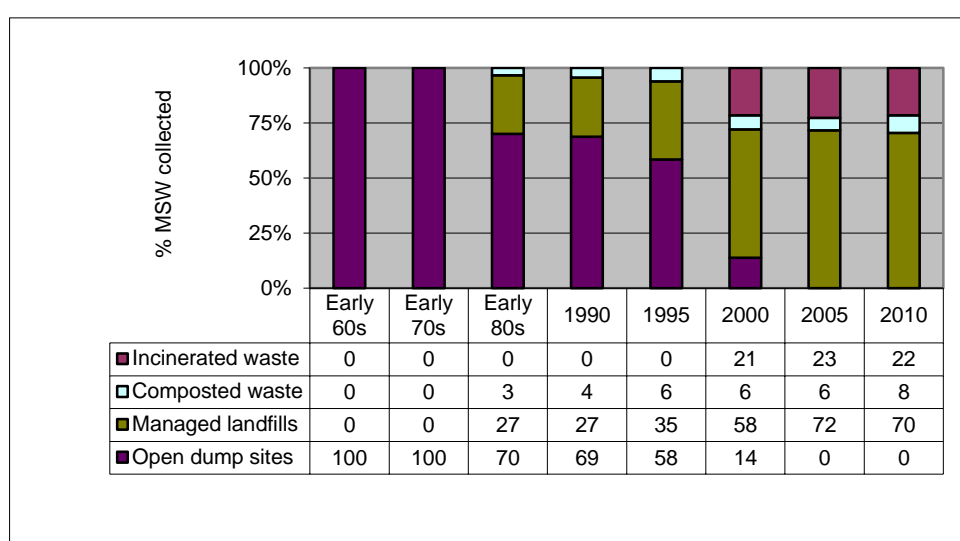
Figure 8.5 - Population served by solid waste collection systems



Source: APA estimates.

The share of final disposal destiny for the first years of the time series was calculated having as a basis the Quercus survey. Data for recent years (mainly since 1999) refer to data collected from management systems. As shown in the next figure there was a significant effort at national level to deactivate and closure all uncontrolled dumping sites. This effort was concluded in 2002 when all uncontrolled dumping sites had been closed. Another fact refers to the relatively reduction of final waste disposal on land in favour of incineration. As previously mentioned, in 1999 two MSW incineration units start operating, which was accompanied by a drop of waste disposal in SWDS (in 1998 disposal in SWDS represented 95% of total waste disposal; in 2010 this figure fall to 70 per cent, and the percentage of waste incinerated represents 22 per cent).

Figure 8.6 – Final disposal of waste (% of municipal solid waste without selective collection)



Source: APA estimates; Quercus

8.2.1.1.2.1.2 CH₄ generation potential (Lo)

The parameters used in the calculation are mainly IPCC default values.

Table 8.1 – Parameters used in Lo calculation

Parameter	Explanation	Value considered
MCF	IPCC defaults	Managed landfills = 1.0 Open dump sites = 0.6
DOC	National estimate	Variable on waste composition
DOCF	IPCC default (including lignin C)	0.6
F	IPCC default	0.5

The estimation of Degradable Organic Carbon (DOC), presented in the following table, was based on information on the waste composition from several sources.

Table 8.2 - Composition of waste disposed to SWDS (fermentable fractions)

Fermentable fractions	Early 60s	Early 70s	Early 80s	Early 90s	Mid-90s	2000	2010
	Percentage of weight						
Paper and textiles (fraction A)	22.5	22.5	22.5	24.9	25.8	29.0	22.5
Non-food fermentable materials (fraction B)	0.0	0.0	0.0	13.4	18.7	17.4	8.1
Food waste (fraction C)	59.9	59.9	59.9	42.0	34.8	26.5	42.8
Wood or straw (fraction D)	0.0	0.0	0.0	0.2	0.3	0.5	1.5
DOC	18.0	18.0	18.0	18.6	18.8	18.7	17.2

Notes: Early 60s, 70s and 80s data refer to Fernandes, A Pastor (1982), "RSU do Continente - um Guia para Orientação e Inform. Das Autarquias", LNETI. Early 90s: estimates from interpolation. Mid 90s: data refer to 1994; DGA. 2000 and 2010: APA

8.2.1.1.2.1.3 Other parameters

The value of CH₄ generation rate constant (k) depends on several factors as the composition of the waste and the conditions of the SWDS. In the absence of national studies to determine this parameter, and following the recommendations of the in-depth review, the values used in previous submissions were revised in order to apply the guidance from IPCC 2000.

This parameter is related to the time taken for the DOC in waste to decay to half its initial mass ('half life' or $t_{1/2}$) as follows: $k = \ln 2 / t_{1/2}$. The k value considered was 0.07 (half life of about 10 years), which represents a higher decay rate compared to the k default value proposed by the IPCC 2000 (0.05 - half life of about 14 years).

GPG 2000 proposes to consider an historical time series 3 to 5 half lives in order to achieve an acceptably accurate result. The data series considered are 3 half life periods back in time, i.e. a time trend of 30 years, which is in accordance with the emissions model from EPA(1993) that considers landfilled waste to produce CH₄ for 30 years after disposal.

Data on landfill gas recovered and combusted is flared or used for energy purposes. Until the present submission, data on recovered landfill gas referred only to the amounts of biogas consumed in electrical production in landfill systems, and was based on the information collected annually by DGEG in an annual inquiry. This year, an extra questionnaire was launched by APA aiming at collecting the total amount of landfill gas combusted either in flaring (without energy recovery) or used for energy purposes. This inquiry was focused on the more recent years (since 2005) and included additional variables on the characterization of the biogas (e.g. percentage of CH₄ in biogas).

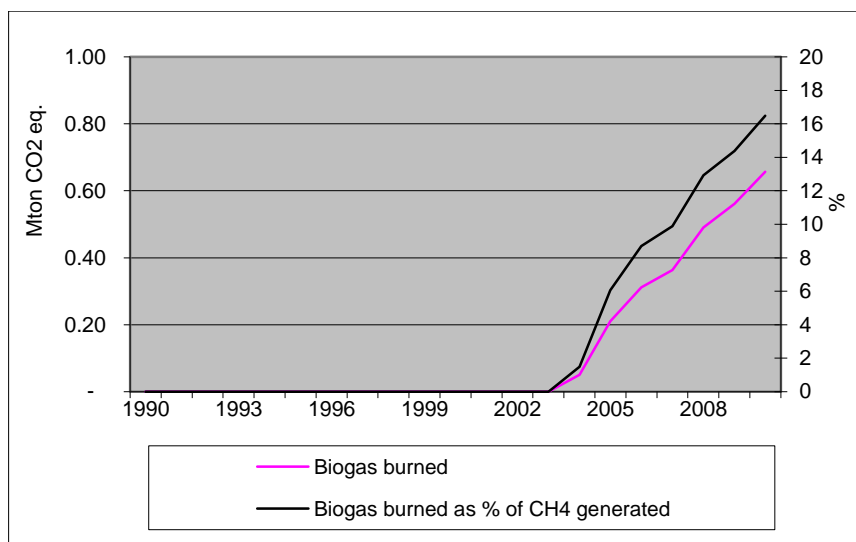
The annual quantities of biogas burnt (in flares and energy recovering units) reported by each landfill (in cubic meters) were converted into CH₄ amounts considering the CH₄ percentages in biogas (based on measurements) reported by management systems. In previous submissions the percentage of CH₄ considered in biogas was a theoretical of 60%. The conversion into mass was done considering a density of 0.72 kg/m³.

Table 8.3 –CH₄ in landfill gas

		2005	2006	2007	2008	2009	2010
Average share of CH ₄	%	51	54	53	52	53	54

Source: 2012 APA's questionnaire

Figure 8.7 – Quantities of CH₄ combusted (SWDS)



Source: APA questionnaire data (flared and energy recovered quantities); 2004: DGEG data (energy recovery only).

In what concerns the oxidation factor (OX), the IPCC default value – zero - was used for unmanaged SWDS. For landfill sites, which are considered as well-managed SWDS, it was used 0.1 for OX, as recommended in GPG (IPCC, 2000). The OX factor was applied after subtraction of CH₄ recovered.

8.2.1.1.2.1.4 Industrial waste

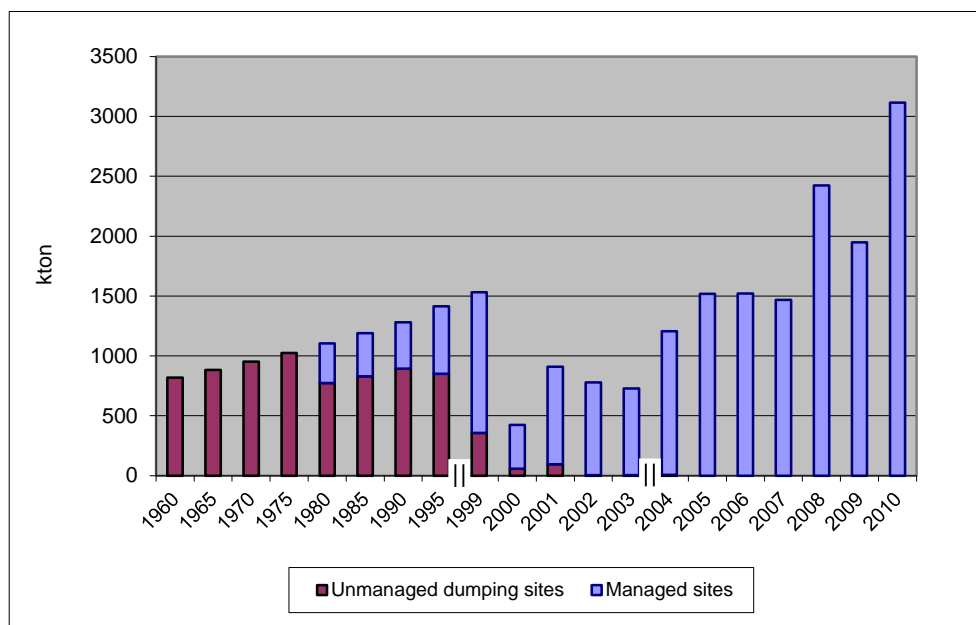
8.2.1.1.2.2 Quantities of waste landfilled

Industrial wastes considered refer only to the fermentable part of industrial waste. Historical time series are based on 1999 data which refer to annual registries relating to industrial units declarations sent to the regional environment directorates (CCDR), and have been estimated based on expert judgment.

For the period 1960-1990 it was considered a growth rate of 1.5% per year; for the following years (1990-1998) 2% per year. Data for the years 2000, 2002 and 2003 refer to annual registries. The year 2001 refer to estimates based on the average of 1999 and 2000 data. Data from 2004 onwards refer to data collected under the Waste Registry (Mapa Integrado de Registo de Resíduos (MIRR)) on the framework of SIRAPA (APA website for the communication between APA and environmental stakeholders). Data provided by the different waste operators and industrials on the amounts of non-urban waste generated are statistical treated by the INE (Statistical Institute) in order to extrapolate the information for the universe of enterprises of each economic branch. Therefore, data from 2004 onwards represent a break from previous years, as data in earlier years were not extrapolated to consider the non-responses.

All industrial waste was considered to be disposed in SWDS together with urban waste. However, as there is no available information concerning final industrial waste disposal for the earlier years, it was assumed that all estimated waste produced have followed the urban disposal pattern between uncontrolled and controlled SWDS.

Figure 8.8 – Quantities of fermentable industrial waste disposed to SWDS



Source: APA

8.2.1.1.2.2.1 CH₄ generation potential (Lo)

The parameters used in the calculations are basically the same as the ones presented for urban waste, excepted for DOC. Data for this parameter varies according to the available information on industrial waste composition: 0.28 (1960 – 1999), 0.20 for 2000, 0.26 (average of available data) for 2001, 0.29 for 2002, 0.26 for 2003, 0.16 for 2004-2007, and 0.15 since 2008.

Available data on industrial waste production come from INR (Waste Institute), now APA, and refer to annual registries from industrial units declarations. This information is classified according to the European Waste Catalogue list (EWC) and is disaggregated by disposal type. From this database the APA selected (by expert judgment) the EWC categories referring to organic origin. Each one of these categories was classified according to a group and was assigned with a DOC value, also defined by expert guess.

The referred DOC values resulted from weighted averages based on the quantities reported for each EWC category considered and the respective assigned DOC, and refer to disposal on land.

Table 8.4– Base table for industrial waste C content estimation

Groups	C Total (0..1)	DOC (0..1)	% C Biogenic
Paper and textiles	0.40	0.40	100
Garden waste, park waste or other non-food organic putrescibles	0.17	0.17	100
Food waste	0.15	0.15	100
Wood or straw	0.30	0.30	100
Fuels	0.85	0	0
Plastics	0.85	0	0
Sludge from natural origin	0.14	0.14	100
Sludge from non-natural origin or hydrocarbons	0.43	0	0
Synthetic fibres	0.85	0	0
Non-natural organic substances	0.85	0	0

8.2.1.1.2.2.2 Other parameters

Data on quantities of CH₄ recovered and combusted were considered jointly with urban waste, as all industrial waste was considered to be disposed together with urban waste in SWDS.

8.2.2 Wastewater Handling (CRF 6.B.)

8.2.2.1 Domestic Wastewater

The accounting of this category is based on data trends for the public urban wastewater treatment systems which were compiled by INAG (Water Institute, the National Focal Point of the National System for this sector).

8.2.2.1.1 CH₄ emissions from Wastewater Handling (WWH)

8.2.2.1.1.1 Methodology

CH₄ emissions from urban wastewater handling were estimated using a methodology adapted from IPCC 1996 Revised Guidelines (IPCC, 1997) and GPG (IPCC, 2000), which follows three basic steps:

8.2.2.1.1.1.1 1 – Determination of the total amount of organic material originated in each wastewater handling system

The main factor determining the CH₄ generation potential of waste is the amount of degradable organic component (DC) of the wastewater stream, which is expressed in terms of either BOD (recommended for domestic wastewater and sludge), or COD (more appropriate for industrial waste streams). Total organic waste (TOW) is a function of human population and the amount of waste generated per person.

$$TOW_{dom} = P * D_{dom}$$

where:

TOW_{dom} - total domestic/commercial organic waste in kg BOD/yr;

P - population in 1000 persons;

D_{dom} - domestic/commercial degradable organic component in kg BOD/1000 persons/yr.

8.2.2.1.1.1.2 2 – Estimation of emission factors

The emission factor for each wastewater and sludge type depends on the maximum CH₄ producing potential of each waste type (B_{oi}) and a weighted average of CH₄ conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_{oi} \times \sum_x (WS_{ix} \times MCF_x)$$

where:

EF_i - emission factor (kg CH₄ /kg DC) for waste type i (e.g., domestic wastewater or sludge, etc);

B_{oi} - maximum methane producing capacity (kg CH₄/kg DC) for waste type i;

WS_{ix} - fraction of waste type i treated using wastewater handling system x;

MCF_x - methane conversion factors of each wastewater system x.

Maximum CH₄ producing capacity (B_o) is the maximum amount of CH₄ that can be generated from a given quantity of wastewater or sludge.

Methane Conversion Factor (MCF) is an estimate of the fraction of DC that will ultimately degrade anaerobically. The MCF varies between 0 for a completely aerobic system to 1.0 for a completely anaerobic system.

8.2.2.1.1.1.3 3 – Calculation of emissions

Emissions are a function of total organic waste generated and an emission factor characterising the extent of CH₄ generation for each wastewater handling system. CH₄ that is recovered and flared or used for energy should be subtracted from total emissions, as it is not emitted into the atmosphere.

$$M = \sum_i (TOW_i * EF_i - MR_i)$$

where:

M - Total CH₄ emissions from wastewater and sludge handling in kg CH₄

TOW_i - total organic waste for waste type i in kg DC/yr. (Step 1)

EF_i - emission factor for waste type i in kg CH₄/kg DC (Step 2)

MR_i - total amount of methane recovered or flared from wastewater type i in kg CH₄.

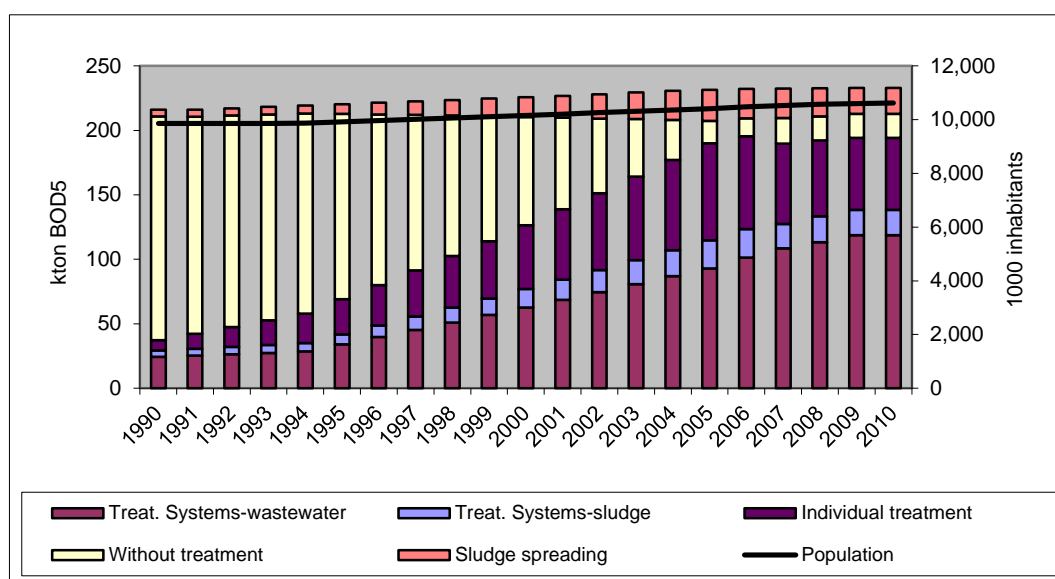
8.2.2.1.1.2 Activity data and parameters

Total organic content of domestic sewage (TOW_{dom}) was determined multiplying the total population for each year by a per capita wastewater BOD₅ production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation. The BOD₅ factor considered was 60 g BOD₅/cap/day, which is the figure considered in the Council Directive 91/271/CEE, 21st Mai, referring to urban waste water treatment.

Background data for wastewater handling systems and types of treatment are based on a compilation study performed by INAG (Water Institute, the National Focal Point of the National System for this sector) of all surveys and inventories done in the past concerning sanitation and wastewater treatment infrastructures. Data from this study refer to 1990, 1994 and 1999. More recent data (from 2005 onwards) is based on the new database (INSAAR – Inventário Nacional de Sistemas de Abastecimento e de Águas Residuais/ National survey on public water supply and wastewater systems) which is has already been implemented and is managed by INAG. From 2000 to 2004, data used in the calculations are interpolations based on the 1999 and 2005 figures.

Total organic waste (TOW in terms of BOD₅ produced) was divided into different fractions (please see next figure), according to the information on wastewater handling types and on assumptions (expert judgment from INAG) concerning the fraction of the organic load treated as a liquid phase (wastewater) and as sludge according to types of wastewater handling systems, and for the % of the organic load retained as non mineralised sludge that is spread in the environment (please see next table).

Figure 8.9 – Wastewater BOD produced according to handling systems (ton BOD₅) and national population trends



Source: APA (estimates).

Notes: Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with and without anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Lagoons without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Preliminary treatment, Treatment not specified, Lagoon, with anaerobic pond and Imhoff Tanks (100% of organic load). Treatment systems – sludge: refer to Biodisks with anaerobic sludge digestion, Activated sludge with anaerobic sludge digestion, Percolation beds with anaerobic sludge digestion, Oxidation ponds, Other treatment (37% of organic load) and unspecified treatment.

Individual treatment: refer to wastewater not collected by a public system. It's assumed that the population has a private handling system (private septic tanks).

Without treatment: refer to wastewater collected but not treated, referring to discharges into the ocean, inland waters, soil, and unknown disposal type.

Sludge spreading: refer to the % of the organic load retained as non mineralised sludge in primary treatment (30% of primary organic load generated), and 37% in activated sludge without anaerobic sludge digestion, lagoons without anaerobic pond, Percolation beds without anaerobic sludge digestion, oxidation ponds and other treatment.

Table 8.5 - Percentage of population by wastewater handling system

Wastewater handling systems	1990	1994	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	% population													
Population without sewerage														
1.1- % Pop: without sewerage (latrines)	37.0	23.4	6.4	5.3	4.3	3.2	2.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0
1.2- % Pop: individual treatment (private septic tanks)	1.5	8.2	14.8	16.9	19.0	21.2	23.3	25.4	27.5	24.0	22.5	22.0	21.0	21.0
Population with sewerage														
2.1- % de Pop: with discharge into the ocean, without treatment	6.5	6.5	6.5	5.6	4.7	3.8	2.8	1.9	1.0	1.0	1.9	1.5	1.2	1.2
2.2- % de Pop: with discharge into inland waters, without treatment	36.8	40.8	30.3	25.9	21.5	17.1	12.8	8.4	4.0	3.0	3.1	1.9	1.2	1.2
2.3- % de Pop: with discharge into soil, without treatment	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2.4- % de Pop: unknown disposal	0.0	0.0	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.0	3.5	4.6	5.6	5.6
3- % Pop: with treatment	18.2	21.1	42.0	45.8	49.7	53.5	57.3	61.2	65.0	70.0	69.0	70.0	71.0	71.0
3.1- % Pop: collective septic tanks	2.2	2.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	7.0	4.3	3.3	3.0	3.0
3.2- % Pop: with preliminary treatment	0.0	0.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	7.0	7.8	8.0	7.6	7.6
3.3- % Pop: with primary treatment	5.2	5.2	9.0	8.5	8.0	7.5	7.0	6.5	6.0	3.0	5.6	5.9	1.9	1.9
3.4- % Pop: with secondary and tertiary treatment	10.8	13.6	28.0	31.8	35.7	39.5	43.3	47.2	51.0	53.0	51.3	52.9	58.5	58.5
3.4.1- Biodisks with anaerobic sludge digestion	1.1	1.4	2.0	1.7	1.4	1.1	0.8	0.5	0.2	0.2	0.1	0.1	0.1	0.1
3.4.2- Biodisks without anaerobic sludge digestion	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.7	0.8	0.8	0.7	0.3	0.2	0.2
3.4.3- Activated sludge with anaerobic sludge digestion	1.4	2.0	4.6	6.9	9.2	11.5	13.9	16.2	18.5	18.9	16.2	17.5	16.7	16.7
3.4.4- Activated sludge without anaerobic sludge digestion	1.4	2.0	4.6	5.8	7.0	8.1	9.3	10.5	11.7	11.9	10.2	11.3	14.0	14.0
3.4.5- Laguning, with anaerobic pond	1.7	1.9	3.6	3.0	2.4	1.9	1.3	0.8	0.2	0.2	0.2	0.2	0.3	0.3
3.4.6- Laguning, without anaerobic pond	0.6	0.6	1.2	1.9	2.6	3.2	3.9	4.6	5.3	5.5	4.6	5.1	4.4	4.4
3.4.7- Percolation beds with anaerobic sludge digestion	3.6	4.6	8.8	8.0	7.1	6.3	5.4	4.6	3.7	3.7	3.2	3.1	2.9	2.9
3.4.8- Percolation beds without anaerobic sludge digestion	0.0	0.0	0.0	0.7	1.3	2.0	2.6	3.3	3.9	4.0	3.4	2.4	1.8	1.8
3.4.9- Imhoff Tank	0.6	0.3	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.3	1.1	1.0	0.8	0.8
3.4.10- Oxidation ponds with anaerobic sludge digestion	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.6	0.6	0.6	0.6
3.4.11- Oxidation ponds without anaerobic sludge digestion	0.3	0.4	1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.6	1.3	1.4	1.4	1.4
3.4.12- Other treatment with anaerobic sludge digestion	0.0	0.0	0.0	0.4	0.8	1.2	1.5	1.9	2.3	2.3	1.9	2.0	2.5	2.5
3.4.13- Other treatment without anaerobic sludge digestion	0.0	0.3	1.6	1.4	1.1	0.9	0.7	0.4	0.2	0.2	2.0	0.2	0.2	0.2
3.4.14- With unspecified treatment	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.7	0.8	1.7	5.9	7.7	12.8	12.8

Source: INAG

Parameters: Bo and MCF - The default IPCC (2000) value for Bo 0.6 kg CH₄/kg BOD was used for wastewater and sludge. Table 8.6 presents MCF factors used for each wastewater treatment system considered.

Table 8.6 - Wastewater handling systems and associated Methane Conversion Factors (MCF), and fraction of organic load treated as liquid and solid phase

Wastewater handling systems			MCF		Share between liquid phase and solid treatment		Sludge spread in the environment (e)
			Wastewater	Sludge	Wastewater	Sludge	
(% of organic load)							
Population without sewerage							
1.1-	% Pop: without sewerage (latrines)	a)	0.61	-	-	-	
1.2-	% Pop: individual treatment (private septic tanks)		0.50	-	-	-	
Population with sewerage							
2.1-	% de Pop: with discharge into the ocean, without treatment		0.00	-	-	-	
2.2-	% de Pop: with discharge into inland waters, without treatment	b)	0.30	-	-	-	
2.3-	% de Pop: with discharge into soil, without treatment	b)	0.30	-	-	-	
2.4-	% de Pop: with unknown disposal		0.20	-	-	-	
3-	% Pop: with treatment						
3.1-	% Pop: colective septic tanks		0.50	-	-	-	
3.2-	% Pop: with preliminary treatment		0.00	0.00	-	-	
3.3-	% Pop: with primary treatment		0.00	0.00	70%	-	30%
3.4-	% Pop: with secondary and tertiary treatment		-	-	-	-	
3.4.1-	Biodisks w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.2-	Biodisks w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.3-	Activated sludge w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.4-	Activated sludge w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.5-	Laguning, w ith anaerobic pond	d)	0.20	0.00	100%	-	
3.4.6-	Laguning, w ithout anaerobic pond		0.00	0.00	63%	-	37%
3.4.7-	Percolation beds w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.8-	Percolation beds w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.9-	Imhoff Tank		0.80	0.00	100%	-	
3.4.10-	Oxidation ponds w ith anaerobic sludge digestion		0.00	0.00	63%	-	37%
3.4.11-	Oxidation ponds w ithout anaerobic sludge digestion	d)	0.20	0.00	63%	37%	
3.4.12-	Other treatment w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.13-	Other treatment w ithout anaerobic sludge digestion		0.00	0.00	63%	-	37%
3.4.14-	With unspecified treatment		0.20	0.00	100%	-	

Notes:

a) Expert judgment, assuming that half of the situations refer to bad conditions (stagnant sewer MCF=0.5), due to the Summer reduced flow in many sewerage, the high temperatures, and the stagnant conditions and eutrophication of inland waters in many places during that season. The other half of the situations was considered in good drainage and flow conditions of the sewer network (MCF=0.1).

b) Expert judgment, considering 85% of the cases (in majority in the North of the country) as humid conditions (MCF=0.7), and 15% in the better conditions (MCF=0.1).

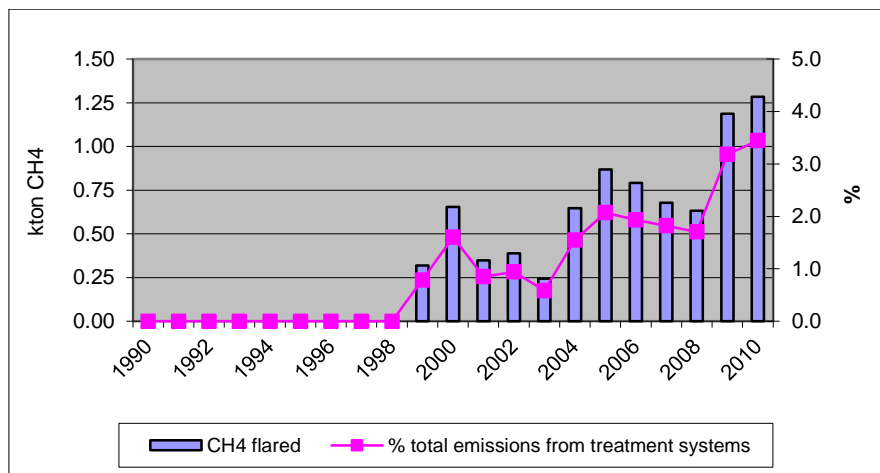
c) Wastewater: expert judgement, assuming a value between "well management" and "aerobic treatment plant, not well managed".

d) Value corresponding to shallow lagoons (majority of systems).

e) Unknown disposal.

Recovery of CH₄: data on landfill gas flared refer to the amounts of biogas consumed in electrical production in municipal wastewater treatment systems. This information is collected annually by DGEG (annual inquiry), together with data on electric energy produced and sold, typology of equipments, etc. The quantities of biogas that are reported in Nm³ were converted into CH₄ amounts, considering a density of 0.72 kg/m³ and a percentage of 60% of CH₄ in biogas.

Figure 8.10 - Quantities of CH₄ flared



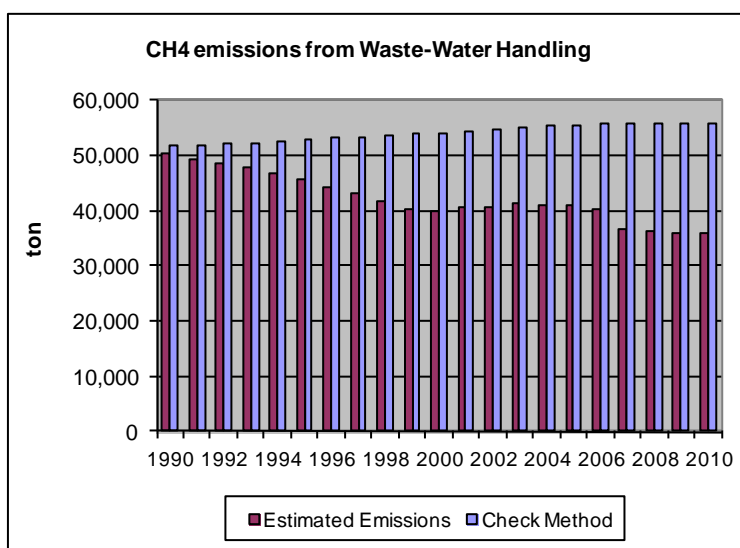
Source: Quantities based on data DGEG data.

8.2.2.1.2 Comparison between estimates for ch₄ emissions from waste-water handling and ipcc “check method”

Domestic CH₄ estimated emissions were compared with the “check method” proposed in the IPCC GPG. The comparison shows a small discrepancy (3%) between the reported emissions and this method, for the base year. The check method estimate for 2010 (~ 56 kton) was around 36% higher than estimated emissions (~ 36 kton) (see table W-8 in the attachment).

The differences between the two approaches for the most recent years reflect the fact that the application of the check method did not considered an evolution of treatment and disposal types. In fact, the reported emission estimates take account of the country development and amelioration of sewerage systems since the 1990s, and the significant decrease of poor drainage conditions since then. Some disposal systems types, such as latrines and discharge into inland waters without treatment, registered a reduction trend since the early 90s.

Figure 8.11– Comparison between estimated CH₄ domestic emissions and “check method”



8.2.2.1.2.1 Methodology

IPCC check method is presented in the following to check national estimates. Default parameter values used refer to IPCC GPG.

$$WM = P \times D \times SBF \times EF \times FTA \times 365 \times 10^{-6}$$

where:

WM = Annual CH₄ emission per country, from domestic wastewater (ton)

P = Population of country or urban population for some developing countries (inhab.)

D = Organic load in biochemical oxygen demand per person (g BOD/inhab./day), overall default = 60 g BOD/inhab./day

SBF = Fraction of BOD that readily settles, default = 0.5

EF = Emission factor (g CH₄/g BOD), default = 0.6

FTA = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

8.2.2.1.2.2 Discussion of the results

As previously mentioned, the results of the application of the “check method” are well above the reported emissions for the most recent years. Also the trend variation during the 1990-2010 is contradictory. The “check method” accounts for a 8% increase in the 1990-2010 period, as a result of the population growth, while the national reported emissions are estimated to decrease around 28%.

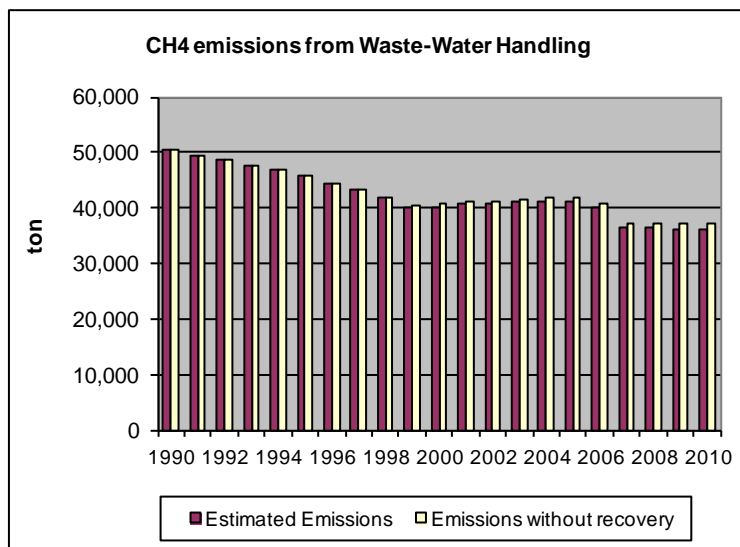
The variables Population (P), Organic load in biochemical oxygen demand per person (D), and the EF (g CH₄/g BOD, default = 0.6) are the same in both approaches. Consequently the differences result from other parameters, i.e., the fraction of BOD that degrades anaerobically, and the consideration of CH₄ recovery in the case of the reported emissions.

The differences between the two approaches reflect the consideration of the evolution of treatment and disposal types in the national emissions calculation. As previously said, these estimates take account of the country amelioration of sewerage systems in the period considered, with the significant decrease of poor drainage conditions since the early 90s.

Although the MCF values considered are based on expert judgment (Table 8.5), they are considered to represent a better approximation of the real national circumstances than the defaults suggested by the “check method”.

The influence of the CH₄ recovery is becoming more significant as the percentage of the estimated recovery amounts represent approx. 10 per cent of emissions generated in municipal wastewater systems.

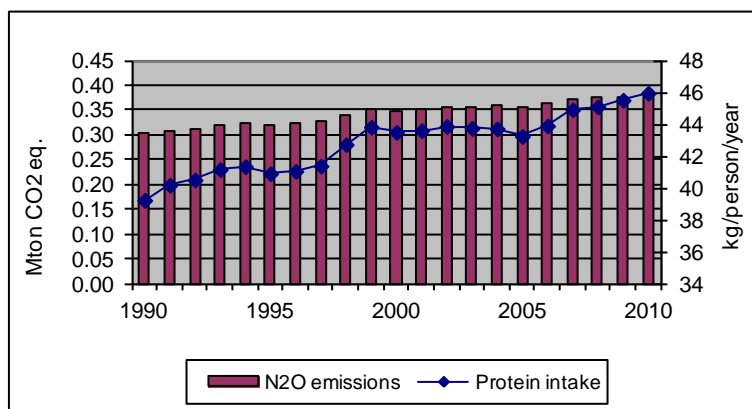
Figure 8.12– Comparison between CH₄ domestic emissions with and without recovery



8.2.2.1.3 N₂O emissions from wastewater (Human Sewage)

Human sewage can be disposed on land or discharged into aquatic environments (e.g. rivers and estuaries), either directly without treatment or after treatment in septic systems or wastewater treatment facilities. N₂O can be generated during all these stages through nitrification/denitrification of the nitrogen in faeces, urine and other liquid wastes, which are typically in the form of urea and proteins. In general, temperature, pH, BOD, and nitrogen concentration influence N₂O production from human sewage.

Figure 8.13 – N₂O emissions from human sewage and per capita protein intake



Source: Protein intake: INE data; 2008-2010 data refer estimates. .

8.2.2.1.3.1 Methodology

Emissions of N₂O from domestic wastewater were estimated following the proposal of IPCC 1996 Revised Guidelines (IPCC,1997), that considers that the amount of protein consumed by humans determines the quantity of nitrogen contained in sewage.

$$N_2O_{(s)} = \text{Protein} * \text{Frac}_{NPR} * \text{Pop} * \text{EF} \times 44/28$$

where:

$N_2O_{(s)}$ - N_2O emissions from human sewage (kg N_2O -N/yr);

Protein - annual per capita protein intake (kg/person/yr);

Frac_{NPR} - fraction of nitrogen in protein (kg N/kg protein);

Pop - number of inhabitants in country;

EF - emissions factor (kg N_2O -N/kg sewage-N produced);

44/28 is the molecular weight ratio of N_2O to N_2 .

This approach assumes that N disposal, and thus N_2O emissions associated with land disposal and domestic wastewater treatment are negligible and all N is discharged directly into aquatic environments. No amount of N is considered to be removed with the sludge and applied in agriculture land or disposed in other forms.

Final disposal of sludge in Portugal comprehends landfill, incineration and agricultural recycling. However, the information available on sludge quantities produced and disposed on land is still scarce and disperse and the existing data refer in majority to estimates. This is the rationale for not accounting separately emissions from land sludge application.

8.2.2.1.3.2 Activity data and parameters

Activity data results of protein intake, according to national data from National Statistical Office (INE) (please see next table), multiplied by total population, from the INE Census for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation. Previous time series of protein intake from FAO has been replaced with country data from INE, in order to follow the UNFCCC review recommendations.

Other parameters considered for the estimations are based on IPCC (1997) defaults.

Table 8.7 - Data and parameters used calculation of N₂O emissions from wastewater

Parameter	Year	INE data (kg/person/year)	FAO data (kg/person/year)
Annual per capita protein intake	1990	39.2	37.2
	1991	40.2	37.7
	1992	40.5	38.5
	1993	41.2	39.3
	1994	41.4	40.1
	1995	40.9	39.5
	1996	41.1	40.2
	1997	41.4	39.2
	1998	42.7	41.4
	1999	43.8	42.0
	2000	43.5	41.6
	2001	43.6	42.1
	2002	43.9	41.4
	2003	43.8	40.7
	2004	43.7	41.8
	2005	43.3	41.9
	2006	43.9	43.5
	2007	44.9	43.5
	2008	45.1	43.5
	2009	45.5	43.4
	2010	46.0	43.4
Fraction of nitrogen in protein 1)	16%	(constant)	(constant)
Emission factor	0.01 kg N ₂ O-N/kg N	(constant)	(constant)

Note:

1) IPCC default

2) INE data; 2008-2010 data refer to estimates.

3) FAO data from 2005 onwards: refer to estimates.

8.2.2.2 Industrial Wastewater

8.2.2.2.1 CH₄ Emissions from Industrial Wastewater Handling

8.2.2.2.1.1 Methodology

The method to estimate methane emissions from industrial wastewater handling also follows the default methodology proposed in the 1996 IPCC Guidelines (IPCC, 1997) and the Good Practice Guidebook. The following formula is used, combining equations 5.5 and 5.7 in the GP:

$$Emi_{CH_4} = \sum_i \{TOW_{(j)} * \sum_h [WHS_{(j,h)} * MCF_{(h)}] - Rec_{CH_4(j,h)}\}$$

Where,

Emi_{CH_4} – Total methane emissions from industrial wastewater handling, t CH₄/yr;

$TOW_{(j)}$ – Total Organic wastewater generated from industrial sector j, expressed in COD, t O₂/yr;

$WHS_{(j,h)}$ – Part of the total organic wastewater generated in industrial sector j that is handled by system h, fraction;

$MCF_{(h)}$ – Methane Conversion Factor, fraction;

$Rec_{CH_4(j,h)}$ – Quantity of methane generated from Industrial Wastewater Handling system h and industrial sector j, that is recovered and not released directly or indirectly to atmosphere, t CH₄/yr.

In accordance with the IPCC (2000) methodology, TOW and Rec_{CH_4} will be discussed as activity data and Bo, WHS and MCF are discussed as emission factors.

8.2.2.2.1.2 Activity data

The use of data from specific industrial plants concerning COD concentrations in discharge and its flow could in principle be used to estimate organic wastewater load. Although efforts are being done presently, by the Water Institute in Portugal (INAG) to obtain a reliable survey of industrial discharges, the collected data in the INSAAR system¹⁵³ is still not suitable to be used in the inventory of air emissions. Data on sources is scarce, available with difficulty and its representativeness as estimator of load from all units in the sector is undetermined.

After consultation with the experts from INAG, under the works for the Inventory Methodological Development Plan, an alternative approach had to be developed. This approach, which is in line with the recommendations of the IPCC Good Practices, estimates organic wastewater load (TOW) using statistical production data on industries (Ind_{PROD} , ton product/yr) multiplied by pollution coefficients (Pol_{COEF} , kg O₂/ton product).

$$TOW = Ind_{PROD} * Pol_{COEF}$$

The pollution coefficients that were used are different from those proposed in table 5.4 of the GP, but result from a study specifically done for the estimate of the loads from the Portuguese Industry (Cartaxo et al, 1985). Although these coefficients have the drawback of being relatively

¹⁵³ The INSAAR systems is a data collected data implemented by INAG

old, the fact that they had been developed from field monitoring data at installations in Portugal, make them more representative of the country specific conditions.

To ascertain the validity of our pollution coefficients consultation was made to the lead author of the study (Leonor Cartaxo), with a special focus was made to the top 6 industrial sectors¹⁵⁴. The main conclusions from the meeting were:

- The COD in the Cotton fibres processing industries is mainly generated in textile printing an ink application, and should not be applied twice to production of thread production and final textile production;
- Taking into account the scope of the COD coefficients it was necessary to revised some of the industrial activity data;
- It is important to find other data sources to validate/update some of the coefficients.

In 2007 and following the consultation with Leonor Cartaxo and after careful revision of the industrial initial data, some changes were made to the activity data of specific industrial sectors.

The following table shows the pollution coefficients that were used in organic load estimates, based on the coefficients available in Cartaxo et al (1985).The set of available coefficients determined the list of industrial sectors that were considered in the estimation of water pollution discharges. For the estimation of emissions of methane TOW equals COD load.

¹⁵⁴ -Cork Granulation; Aliphatic hydrocarbons; Cyclic hydrocarbons; Kraft pulping; Synthetic fertilizers; Acid sulphite pulping.

Table 8.8 – Pollution Coefficients to estimate Industrial organic wastewater production

Industry	Unit prod (PU)	Discharge (m3/PU)	CBO5 (kg/PU)	CQO (kg/PU)	in.eq. (kg yr/PU)
Slaughter House	ton	6	18	27	0.881
Slaughter House, swine	ton	6	18	42	0.900
Slaughter House, Poultry	ton	9	6	13	0.269
Meat Packing	ton	10	20	30	0.978
Milk processing	m3	1	1	2	0.044
Cheese	m3 milk	8	13	20	0.651
Other dairy products	m3 milk	5	7	10	0.347
Fruit and vegetables conservation	ton	15	15	27	0.734
Tomato juice	ton	100	19	32	0.930
Fruit Juices	ton	9	45	77	2.216
Fish processing and canning	ton	35	18	35	0.856
Olive oil production	ton olives	1	15	45	0.734
Olive oil processing	ton	6	1	1	0.044
Edible oils	ton	3	13	19	0.612
Margarine	ton	25	3	8	0.161
Grains milling and processing	ton	3	5	9	0.220
Sugar processing	ton	8	2	4	0.093
Yeast	ton	120	600	1 080	29.354
Ethanol	m3	17	328	1 192	16.068
Spirits Distillation	m3	8	95	218	4.628
Wine Cellars	ton grapes	2	5	8	0.220
Beer	m3	5	4	9	0.215
Mineral water and similars	ton	8	6	10	0.294
Wool production	ton	44	89	366	4.354
Wool processing	ton	537	87	347	4.256
Synthetic fibres processing	ton	155	155	268	7.583
Artificial fibres processing	ton	42	30	52	1.468
Cotton fibres processing	ton	317	155	268	7.583
Leather industry	ton	85	85	213	4.159
Cork processing	ton	1	2	8	0.073
Cork granulation	m3	1	83	1 104	4.061
Kraft pulping	ton	140	28	158	1.345
Acid sulphite pulping	ton	270	283	1 050	13.845
Kraft paper	ton	14	1	3	0.034
Wafer board and Strand board	ton	1	14	43	0.695
Chorine and alkalis	ton ClNa	28	0	39	1.336
Inorganic acids	ton	100	0	50	1.712
Cyclic Hydrocarbons	ton	190	285	570	13.943
Aliphatic Hydrocarbons	ton	190	285	570	13.943
Synthetic fertilizers	ton	15	15	38	0.734
Pesticides	ton	4	23	30	1.111
Polymers	ton	15	15	45	0.734
Synthetic rubber	ton	15	15	45	0.734
Artificial fibres production	ton	300	150	450	7.339
Polyester fibres production	ton	348	6	16	0.313
Acrylic fibres production	ton	65	50	121	2.422
Paints, varnishes and lacquers	ton	0	1	9	0.029
Pharmaceutical products	employee	0	0	14	0.462
Soaps	ton	4	6	12	0.294
detergents	ton	3	1	2	0.029
Petroleum refining	ton	2	1	2	0.029

For each industrial sector identified, several statistical information sources - although obtained from the same institution - had to be used to establish the full time series from 1990 to 2009. Nevertheless, efforts were made to guarantee that the consistency in time series was not impaired by the use of different origins of information, as will be later explained. Detailed information on industrial production for each sector can not be delivered in this report, because of confidential restraints existing in certain sectors.

For the construction of the time series the following methodology was used:

- Identification of the industrial sectors which represented 95% of the total wastewater CH₄ emissions in the Initial Report. From a total of 51 industrial sectors 15 represent 95% of the total CH₄ emissions (time period 1990-2004);
- In-depth analysis of the activity data time series for each industrial sector that represented 95% of the total wastewater CH₄ emissions. This analysis was conducted for every good produced by the 15 main industrial sectors. Extrapolations of activity data were made when required and feasible;

- General analysis of the time series for the remaining industrial sectors. For each of the 36 remaining industrial sectors a sector by sector analysis of the total goods produced was done. Again extrapolations of activity data were made when required and feasible.

Concerning the sources of information:

- Preference was given to statistical information publicly available from the webpage of the National Statistical Institute (INE) - <http://www.ine.pt/prodserv>. The use of these data guarantees the absence of confidential issues and usually comprehends the full time-series. It was not possible to use this data for all sectors because the level of disaggregation was seldom compatible with the needs of the inventory;
- The National Statistical Institute (INE) makes periodical annual surveys on industrial production. Unfortunately the survey that was executed until 1991, the IAIT survey, uses a different methodology, than the one that was used in the IAPI survey, that is being used since 1992.
- The IAIT survey was based on an inquiry to each industrial facility, used the Economic Activity Class code rev.1 (CAE rev 1) and a set of specific codes for products and materials. The IAPI survey uses the new revision of the CAE system (CAE rev2), and products and materials use a common code system (PRODCOM) in connection with CAE code. In opposition to the IAIT survey, the IAPI collected data for each company (headquarters). These two surveys were delivered to the Institute of Environment for inventory purposes, but with the compromise that confidential data could not be published;
- Refining of crude oil and petroleum products was established from the DGEG's Energy Balance, which data is available annually from 1990 till 2009;
- Production of paper pulp was available directly from the individual industrial plants, for the all period.

Tables Table 8.9 and Table 8.10 present the building blocks of the activity data time series from the available information. Gaps in mid years were estimated by linear interpolation. In a similar mode, linear extrapolation was used to estimate data for years 1990-1991 and 2001 till 2009, whenever they were not available. All constructed time series were checked against the occurrence of inconsistencies that could appear due to the use of different sources of information¹⁵⁵. The checking of the time series was based on graph plotting of the data, and basically the aim was to detect unexpected sudden changes in the magnitude of the time series from 1991 till 1992, when IAIT was changed to IAPI. In some situations the beginning years when IAPI was started had to be discarded, because a sudden and temporary drop from IAIT values was observable and after some years they rise again and continue with a trend compatible with that that existed in IAIT. It was assumed that an adaptation period to the new industrial survey lead to a temporary underestimation of industrial production statistics.

¹⁵⁵ It must be stressed though, that all information sources were produced by the National Statistical Institute (INE). Only methodological procedures for data collection change according to years.

Table 8.9 - Sources of Information used to define the time-series of industrial production (1/2)

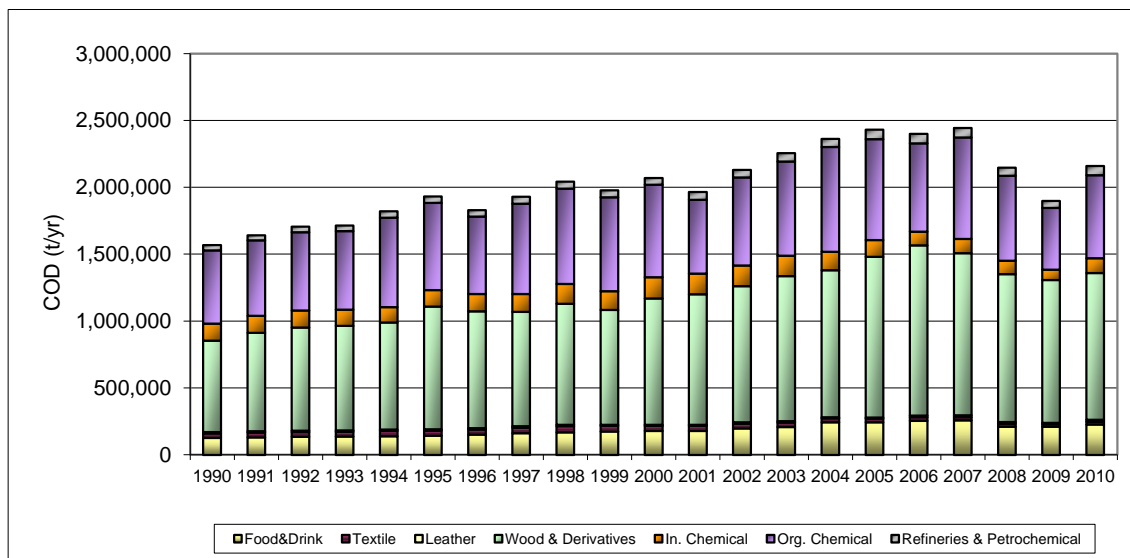
Industry	IAIT CAE rev1	IAP PRODCOM	Infoline	Note
Slaughter House			1990-2010	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2010	
Slaughter House, Poultry			1990-2010	Broilers, Turkeys, ducks, quails, ostrich, guinea-fowl, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200	-	
Milk processing	3112		1994-2010	
Cheese	3112	15510	-	
Other dairy products	3112		1994-2010	Cream, yogurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2010	
Tomato juice			1994-2010	
Fruit Juices	3131+3132		1994-2010	
Fish processing and canning	3114	15200	-	
Olive oil production		15412	-	
Olive oil processing	31152	15420113	-	
Edible oils	31152	1541; 1542	-	Only Olive oil
Margarine	31154	1543	-	
Grains milling and processing	3116	156; 15860	-	
Sugar processing	3118	15830	-	
Yeast			1993-2010	
Ethanol	313110	159101070; 1592011	-	
Spirits Distillation	3131+3132	1591010-159101070+1592012	-	
Wine Cellars	3131+3132	15930; 15950	2001-2010	
Beer	3133	1596010	-	
Mineral water and similars			1993-2010	

Table 8.10 - Sources of Information used to define the time-series of industrial production (2/2)

Industry	IAIT CAE rev1	IAP PRODCOM	Infoline	Note
Wool production		171002021	-	
Wool processing		171002027; 1710042; 1710053	-	
Synthetic fibres processing	321130	171003031; 171003039; 1710052 31/32/33/39/91/92/93 /99; 1710055	171003039+17 1005231/32/33/ 39/91/92/93/99 +1710055	
Artificial fibres processing	321130	171003050; 1710054/ 55	-	
Cotton fibres processing	321130	1710043; 171004553; 171004555; 171004557; 1720020; 173001023	-	
Leather industry		19101; 19102	-	
Cork processing		2010	-	AD is cork consumption in all industrial activities
Cork granulation		2052213; 2052214	-	
Kraft pulping			-	LPS Data
Acid sulphite pulping			-	LPS Data
Kraft paper	3412	2112022; 2112023	-	
Wafer board and Strand board	33 (code 15460)	20202	-	
Chlorine and alkalis		241301111; 2413015; 2413022	-	
Inorganic acids		2413014-241301453- 241301475- 241301477	-	
Cyclic Hydrocarbons		2414312; 2414314	-	
Aliphatic Hydrocarbons		2414311	-	
Synthetic fertilizers		2415	-	Original units is kg N, kg P2O5 and K2O and were converted to ton of fertilizer
Pesticides	3512	242	-	
Polymers	351312	24160-2416058	-	
Synthetic rubber		2417	-	
Artificial fibres production		2470023; 247003070	-	
Polyester fibres production		247001130; 247001315; 247001350	-	
Acrylic fibres production		247001150	-	
Paints, varnishes and lacquers	3521	24301	-	
Pharmaceutical products			1998-2010	
Soaps		2451131	-	
detergents		2451120/32	-	
Petroleum refining			-	Energy Balance (DGGE): 1990-2010

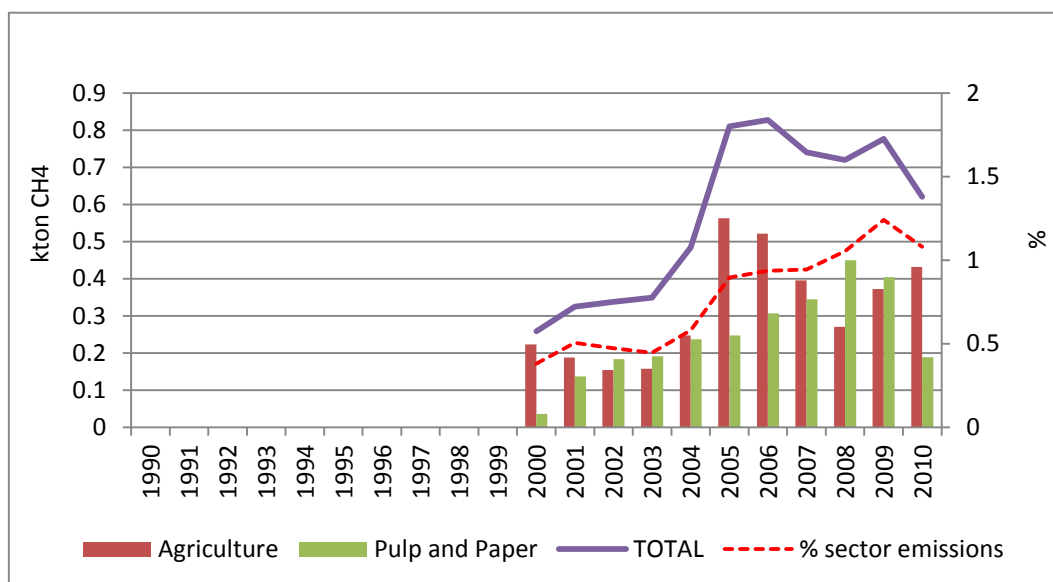
Total wastewater load aggregated per industrial group is presented in Figure 8.14 below, from where it is evident the continuous growth of discharge from 1990 to 2007, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry. The most recent years, 2008 and 2009, registered an inversion of the previous trend, with a reduction of wastewater loads what can be related to the economic crises and the closure of several industrial facilities.

Figure 8.14 - Industrial Wastewater load, expressed in COD, from major groups of industrial activity



Biogas generated in sludge treatment systems is flared for electrical production in cogeneration units. DGEG collects information on the amounts of biogas consumed in an annual inquiry. The quantities of biogas that are reported in Nm3 were converted into CH₄, considering a density of 0.72 kg/m³ and a percentage of 60% of CH₄ in biogas.

Figure 8.15 – Methane recovery



Source: Quantities based on DGEG data.

8.2.2.2.1.3 Emission Factors

8.2.2.2.1.3.1 Wastewater handling systems

As consequence of the fact that there was no available comprehensive information about the existence of each treatment system, the necessary information to determine the per cents for each sector had to be guessed specifically for the inventory using information collected from:

- EPER data. At the time that the inventory was compiled the EPER data was available for 2000 and partially for 2004. Information for the following sectors was available: paper pulp production; crude oil refining; slaughterhouses and meat processing; pig farms; olive oil extraction; fish canning and processing and chemical industry;
- Covenants of Environmental Adaptation. These were voluntary agreements between the Environmental Ministry, other ministries responsible for the permits of specific industrial sectors (Ministry of Economy or the Ministry of Agriculture, Rural Development and Fisheries) and several industrial associations in representation of the industrial units. The agreements were established between March 1997 and February 1998 with the objective to define a time schedule to reach the complete respect of legal constraints concerning the water, air, wastes and noise. The contract involved the elaboration of an *Assessment of the Environmental State*¹⁵⁶ and a *Specific Plan of Elaboration*¹⁵⁷. Eighteen sectors were involved: textile; dairy; stone quarrying and processing; vegetable oils; chemical industry; graphics and paper transformation; shoe making; rubber; ceramics; cork; wood and wood products; paper and card; electric and electronic equipment production; naval industry; crop protection industry; paint and varnishes, glues and adhesives and tomato processing. There was a specific agreement with the sector of extraction of olive oil.
- Information for individual plants or industrial associations, such as the paper pulp production industry and the oil refineries

For each specific industrial sector the share of use of each specific treatment system was aggregated according to the following classes:

- There is no treatment of wastewater and the effluent is discharged in the water system or in soil;
- Use of individual Septic Tank;
- Primary treatment only;
- Secondary treatment, with deficient management;
- Secondary treatment, well managed;
- Discharge into the sewer system common to the treatment of domestic wastewater system;
- Unknown destiny of effluent, determined as difference to total.

There was also shortage of information concerning the evolution for each sector, that is, the trend in time of the use of each specific wastewater treatment system. The following considerations apply:

¹⁵⁶ Caracterização da Situação Ambiental, in the original Portuguese nomenclature.

¹⁵⁷ Plano Específico de Adaptação, in the original Portuguese nomenclature.

- if data from the Covenants of Environmental Adaptation was used, the situation detected in the *Assessment of the Environmental State* was assumed to characterize well the situation before 1997, with no time trend. The plans were assumed to be effective in year 2000 and the situation was considered constant thereafter;
- if only one year was available, for example if data was obtained from EPER, a constant situation was assumed;
- the situation in the activity of refining of crude oil was known annually from 1990 to 2010.

The profiles obtained by this approach albeit suffering from substantial lacks of information, considerable error and inclusion of expert assumptions, represent, nevertheless, the best estimate that can be obtained for the time being. The per cent of total industrial load, expressed in COD, for which the treatment system and final destination of effluents was unknown, varied between 44 and 49%.

8.2.2.2.1.3.2 Methane Production Potential

The parameter B_0 , representing the maximum Methane Production Potential, was assumed constant and common to all sectors and treatment systems, and set to 0.25 kg CH₄/kg COD, the default value in the Good Practice Guidance from IPCC (2000).

8.2.2.2.1.3.3 Methane Conversion Factor

The GPG (IPCC,2000) is not very comprehensive in what concerns the choice of default MCF values. The new guidelines from IPCC that were recently published (IPCC,2006) present more detailed values, now specific of treatment systems and management conditions, and they were used to establish the new MCF values, as may be seen in the next table.

Table 8.11 - Methane Conversion Factors (MCF) and assumptions

Treatment System	MCF (%)	Explanatory Note
No treatment	10	IPCC (2006). Table 6.8 Sea, river and lake discharge
Primary	0	Assuming that retention time is insufficient to create anaerobic conditions
Secondary, well managed	0	IPCC (2006) Table 6.8: Aerobic Treatment Plant. Well managed
Secondary, not well managed	30	IPCC (2006) Table 6.8: Aerobic Treatment Plant. Not well managed
Septic Tank	50	IPCC (2006) Table 6.3: Septic system

In the case where the industrial effluent was discharged into the unitary municipal treatment system, the MCF was determined from the average situation in Portugal for the domestic wastewater system when there is any form of treatment, either primary, secondary or tertiary. The values follow the evolution in the urban sector that was explained in previous chapters, have decreased from 18% in 1990 to 16% in 2010. In a similar mode, for the unknown situations the average weighted MCF for all situations of treatment of domestic wastewater was used as a best guess. Values also change over time, from 24% in 1990 to 16% in 2010.

8.2.2.2.1.4 Comparison of the Country Specific Methodology and the IPCC defaults

In order to evaluate if Portugal was over-estimating or under-estimating emissions in the base year, the CS Pollutant Coefficients (PC) used in submission 2006 were compared with the Pollutant Coefficients proposed by the IPCC GP (table 5.4 of the Good Practice). For the

industrial sectors identified in Portugal, and whenever possible¹⁵⁸, the comparison of the PC of Cartaxo et al (1985) (named CS) were compared with the equivalent IPCC in the next table¹⁵⁹.

Table 8.12 – Comparison of Pollutant Coefficients from Cartaxo et al (1985) and IPCC defaults.

Industry	Unit prod (PU)	CS (kg/PU)	IPCC default (kg/PU)	IPCC/CS
Slaughter House	ton	27.0	53.3	1.97
Slaughter House, swine	ton	41.9	53.3	1.27
Slaughter House, Poultry	ton	12.7	53.3	4.20
Meat Packing	ton	30.0	53.3	1.78
Milk processing	m3	1.8	18.9	10.50
Cheese	m3 milk	20.1	18.9	0.94
Other dairy products	m3 milk	10.1	18.9	1.87
Fruit and vegetables conservation	ton	27.0	100.0	3.70
Tomato juice	ton	32.0	100.0	3.13
Fruit Juices	ton	77.3	100.0	1.29
Fish processing and canning	ton	35.0	32.5	0.93
Olive oil production	ton olives	45.0	NA	-
Olive oil processing	ton	1.2	NA	-
Edible oils	ton	18.8	2.6	0.14
Margarine	ton	7.5	18.9	2.52
Grains milling and processing	ton	9.0	90.0	10.00
Sugar processing	ton	4.2	35.2	8.38
Yeast	ton	1 080.0	NA	-
Ethanol	m3	1 192.3	264.0	0.22
Spirits Distillation	m3	217.9	34.5	0.16
Wine Cellars	ton grapes	7.5	34.5	4.60
Beer	m3	9.3	18.3	1.96
Mineral water and similars	ton	9.6	100.0	10.42
Wool production	ton	366.0	154.8	0.42
Wool processing	ton	347.0	154.8	0.45
Synthetic fibres processing	ton	268.0	154.8	0.58
Artificial fibres processing	ton	52.0	154.8	2.98
Cotton fibres processing	ton	268.0	154.8	0.58
Leather industry	ton	212.5	NA	-
Cork processing	ton	8.0	NA	-
Cork granulation	m3	1 104.0	NA	-
Kraft pulping	ton	158.4	1 458.0	9.20
Acid sulphite pulping	ton	1 050.0	1 458.0	1.39
Kraft paper	ton	2.8	1 458.0	520.71
Wafer board and Strand board	ton	43.4	NA	-
Chlorine and alkalis	ton ClNa	39.0	NA	-
Inorganic acids	ton	50.0	NA	-
Cyclic Hydrocarbons	ton	570.0	201.0	0.35
Aliphatic Hydrocarbons	ton	570.0	201.0	0.35
Synthetic fertilizers	ton	37.5	NA	-
Pesticides	ton	30.0	NA	-
Polymers	ton	45.0	2.2	0.05
Synthetic rubber	ton	45.0	2.2	0.05
Artificial fibres production	ton	450.0	2.2	0.00
Polyester fibres production	ton	16.3	2.2	0.14
Acrylic fibres production	ton	121.1	2.2	0.02
Paints, varnishes and lacquers	ton	9.2	30.3	3.29
Pharmaceutical products	employee	13.5	NA	-
Soaps	ton	12.0	2.6	0.21
detergents	ton	1.7	2.6	1.50
Petroleum refining	ton	1.5	0.6	0.40

Departing from the revised COD estimates, new estimates of COD were made using the Pollution Coefficients that are IPCC default (whenever available) and emission estimates rebuilt. The results are presented in the next two figures.

¹⁵⁸ The level of detail of the IPCC Pollutant Coefficients is not so detailed as the CS data set.

¹⁵⁹ The original IPCC table refers only to wastewater generation rate and COD concentration. The Pollutant Coefficients presented in the table were obtained multiplying the wastewater by the COD concentration. If no recommend value was available in the original table the average value in the range was used.

Figure 8.16 - Comparison between COD estimates using CS PC and IPCC defaults.

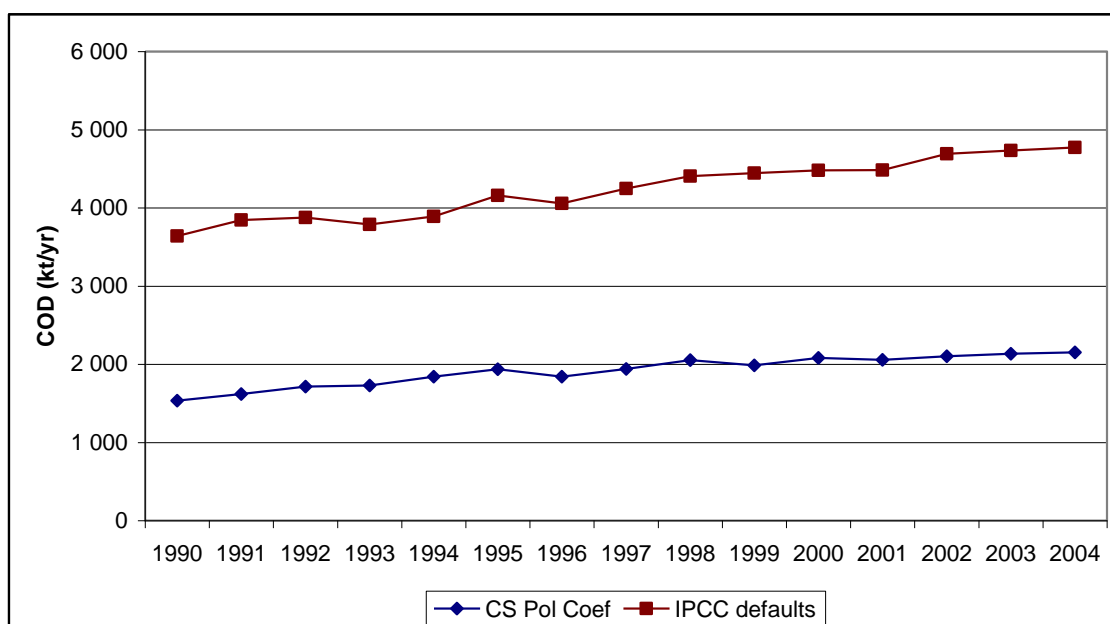
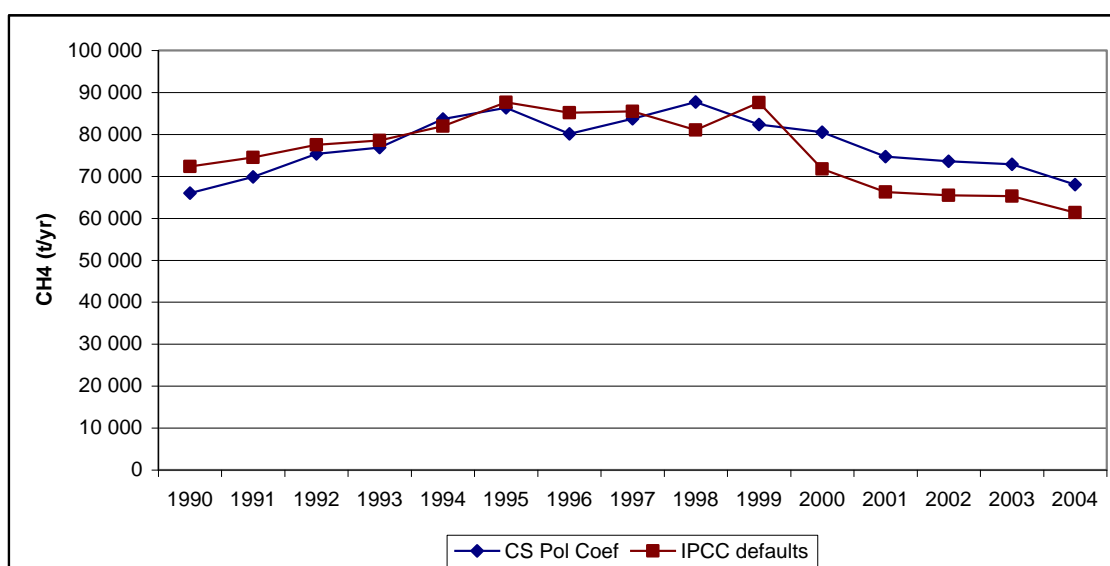


Figure 8.17 - Comparison between CH₄ emission estimates using CS PC and IPCC defaults.



The comparison to IPCC defaults indicates that estimates made by INERPA are probably under-estimating AD and emissions in the base year, and potentially over-estimating emissions in the most recent years. However, total methane emissions are less affected by the choice of Pollutant Coefficients.

8.2.2.2.1.5 Recalculations

Recalculations refer to the revision of activity data on industrial production time series and the revision of treatment types.

8.2.2.2.1.6 Further Improvements

Considering the limitations in the time trend in load and the share of each treatment system, efforts will continue in order to improve the knowledge of the situation of industrial wastewater. It is expected that the situation will improve soon, after the implementation of a new survey system and data base by the National Water Institute.

Namely, only for some industrial sectors, specific characterization of the share of Wastewater treatment schemes was available. Although efforts were made to characterize better the situation for the remaining sectors, in particular for the six major emission contributors, in the end it was not possible to improve the methodology on this issue, mainly because there are no reliable records of the situation existing in 1990 concerning the treatment systems. The situation after 2000 can be better known for some plants, mainly from Environmental Licensing (European Union's IPPC directive). Nevertheless, the implementation of this directive, and other previous environmental programs (Covenants of Environmental Adaptation) caused the improvement in the situation of wastewater treatment and the situation in 2000 should not be considered representative of the situation in 1990. More efforts are expected in this area.

8.2.2.2.2 N₂O Emissions from Industrial Wastewater Handling

8.2.2.2.2.1 Methodology

The IPCC does not propose any methodology to estimate N₂O emissions from industrial handling. The CORINAIR/EMEP Handbook (EEA,2000) proposes a simple methodology based on the knowledge of total production of wastewater, expressed in equivalent-inhabitants, and the use of a very simple and unspecific emission factor. Although it is recognized that this emission factor does not express the conditions that characterize industrial wastewater – namely, it considers that the nitrogen content of industrial wastewater is similar to that of urban wastewater – it was assumed to be better to have that crude estimate than to under-estimate emissions, in accordance of UNFCCC guidelines. Therefore, emissions are estimated from:

$$Emi_{N_2O} = TLH_{(j)} * EF_{N_2O}$$

Where,

Emi_{N_2O} – Total nitrous oxide emissions from industrial wastewater handling, t N₂O/yr;

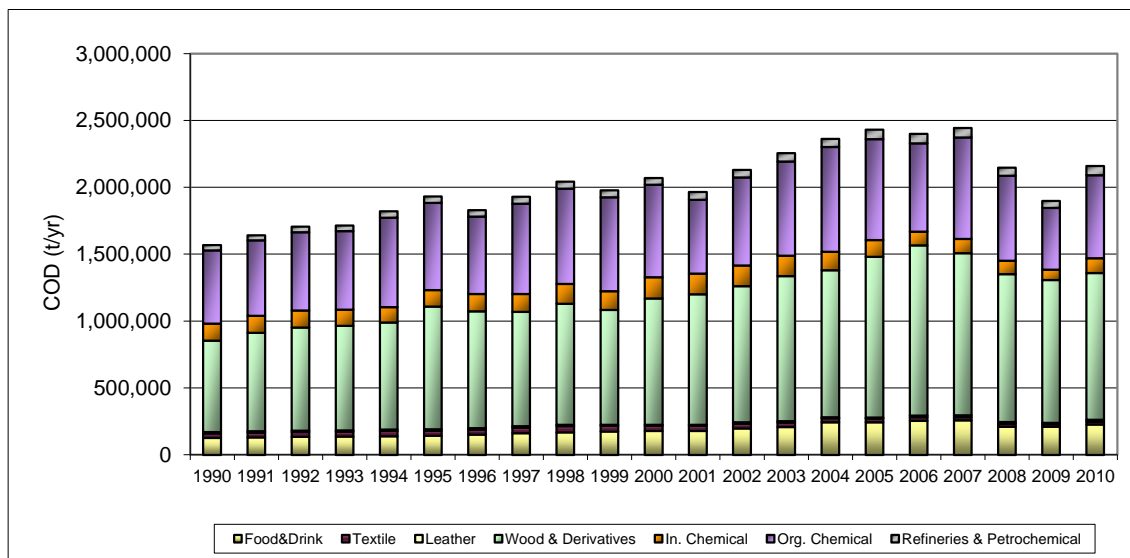
$TLH_{(j)}$ – Total Wastewater Load generated from industrial sector j, expressed in inhabitants-equivalent;

EF_{N_2O} - Emission factor, kg N₂O/inhab-eq/yr.

8.2.2.2.2.2 Activity Data

The total industrial load, in this case expressed in inhabitants-equivalent was also estimated from data on industrial production and multiplication by pollution coefficients. The methodology was already explained under CH₄ emissions from industrial wastewater management. The evolution of total load, and the contribution from major sectors, are presented in Figure 8.18.

Figure 8.18 - Industrial Wastewater load from major groups of industrial activity



8.2.2.2.3 Emission Factors

The emission factor, 0.02 kg N₂O/kg inhab-eq, is from chapter B9101 from EMEP/CORINAIR (EEA, 2002). As stated before this emission factor is not specific for industrial wastewaters.

8.2.2.2.4 Recalculations

No change in methodology was made for this sector and emissions estimates were only changed since last submission as result of the revision of activity data.

8.2.2.2.5 Further Improvements

The emission estimates for this sector needs to be improved by the calculation of the total load of nitrogen in industrial effluents, which would allow the use of the methodology proposed by IPCC for domestic wastewater (IPCC, 2000; IPCC, 2006). Nevertheless, the lack of pollution coefficients of comprehensive data on wastewater characteristics may postpone improvements in this sector for the near future.

8.2.3 Waste Incineration (CRF 6.C.)

The IPCC GPG determines that emissions from incineration with energy recovery should be reported in the energy sector (sub-category 1A(a) Public electricity and heat production).

Combustion of municipal solid wastes (MSW) in Portugal is done in three modern units where energy is recovered, and thus these emissions are accounted for in the energy sector. The incineration of hospital waste occurs without energy recovery and is therefore allocated to the waste sector.

Nevertheless, as the methodology applies for both situations (with and without energy recover), in order to avoid a double description, it is presented only once in this sub-section.

Emissions have been estimated for the non-biogenic and biogenic component of the waste. Emissions from the non-biogenic component have been reported under public electricity and heat production – other fuels. Non-CO₂ emissions from the biogenic part are accounted under public electricity and heat production – biomass, and the CO₂ emissions are reported as a memo item from solid biomass use.

This category includes also emissions from the incineration of industrial solid waste in industrial units.

8.2.3.1 CO₂ emissions

8.2.3.1.1 Methodology

IPCC Guidelines (IPCC,1997) proposes the following method for ultimate CO₂ emissions estimation from waste incineration, for each waste type (e.g. MSW, hazardous waste, clinical waste, and sewage sludge):

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * CCW_i * FCF_i * EF_i * 44 / 12)$$

where:

i - waste type;

IW_i - Amount of incinerated waste of type i (Gg/yr);

CCW_i - Fraction of carbon content in waste of type i;

FCF_i - Fraction of fossil carbon in waste of type i;

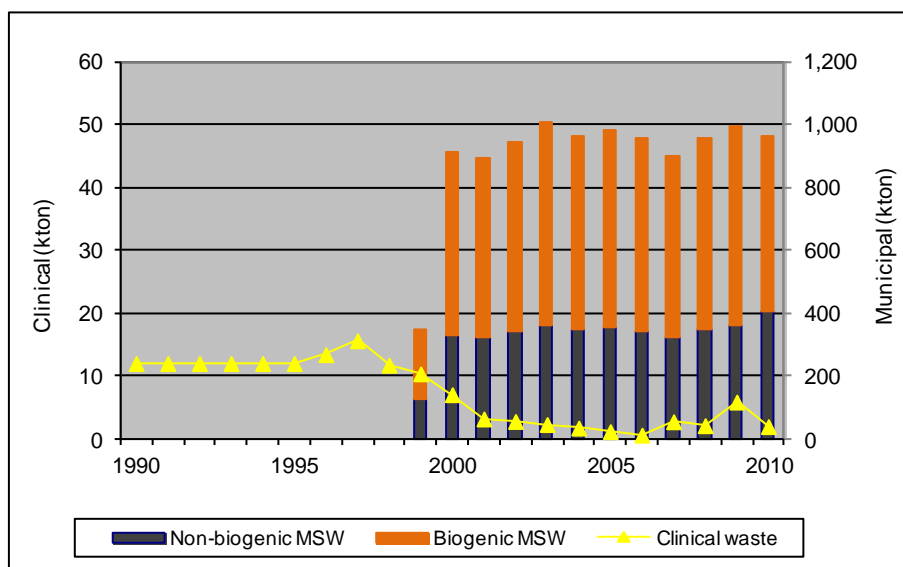
EF_i - Burn out efficiency of combustion of incinerators for waste of type i (fraction).

8.2.3.1.2 Activity data and parameters

8.2.3.1.2.1 Municipal waste

Until 1999, incineration of solid wastes refers exclusively to the incineration of hospital hazardous wastes. The figure for 1995 was used as an estimate for the former years.

Figure 8.19 – Quantities of municipal and clinical wastes incinerated (kton)



Sources: APA (include estimates); DGS.

In 1999, two new incineration units, Valorsul and Lipor started to operate in an experimental regime, respectively in April and August 1999. Their industrial exploration started at the end of the same year or early January 2000. More recently another unit started operating in one of the Autonomous regions (Madeira Island). These units are dedicated to the combustion of MSW which is composed of domestic/commercial waste.

Emissions associated with the components of fossil origin – plastics, synthetic fibers, and synthetic rubber – are accounted for in the net emissions, which include also the non-CO₂ emissions from the combustion of organic materials (e.g. food waste, paper). CO₂ emissions from the biogenic component are only reported as a memo item.

All the incineration units considered are modern units using best available technologies, either concerning the abatement technologies or the incineration techniques used, which aim at the optimization of the combustion process, and consequently the minimisation of atmospheric pollutants.

The incineration process used refers to mass burning with heat recovery for steam and electricity production. The waste is burnt in a combustion grate at approximately 1000°C. During the waste incineration process, high temperature gases are released. These gases remain at least 2 seconds in the combustion chambers at a minimum temperature of 850°C. After the passage in the recovery boiler, the produced steam is used for electric power generation; the cooled gases suffer several treatment processes to remove NO_x, acid gases, dioxins, furans, heavy metals and particulates.

Abatement technologies used include:

- NO_x reduction system based on the ammonia or urea injection in the combustion chamber;
- semi-dry treatment process, consisting of a reactor, where spray fine droplets of an alkaline reagent (calcium hydroxide) are introduced to neutralise the acid gases;
- activated carbon injection to remove dioxins, furans and heavy metals;
- fabric filter for particulate removal.

Data on clinical waste incinerated refers only to Mainland Portugal and correspond to data declared in registry maps of public hospital units (there is no incineration in private units). The quantities of clinical waste incinerated decreased strongly in recent years as shown in the previous figure. Twenty-five incinerators were closed in recent years in Mainland Portugal, and only 1 remaining hospital incinerator is operating since 2004. Other clinical wastes receive alternative treatment or are sent abroad.

The existing hospital incinerator suffered two main requalification processes, the most significant occurred in 2004.

The incineration unit includes 2 combustion chambers. At a first stage, the waste is burnt in oxygen deficit conditions at temperatures from 850°C to 950°C. The resulting gases get into a second combustion chamber or thermal reactor where the gases suffer a new combustion reaching higher temperatures (1100°C – 1200°C) during 2 seconds. These gases are then conducted into a boiler where they are cooled. After that, the gases suffer a dry treatment chemical process, in a contact reactor, through the direct injection of sodium bicarbonate and

activated carbon in the gas flux. At the end, the gas is conducted into a ceramic filter where the particulate matter is trapped.

The non-biogenic components fractions are considered to be different for clinical waste and MSW. Data are presented in the two following tables.

Table 8.13 - Parameters considered: clinical waste

	Unit	Clinical waste
C content of waste	%	60 a)
Fraction of fossil carbon in waste	% total C	40 a)

Note:

a) IPCC default.

GPG refers that it is good practice to assume that the composition of incinerated MSW is the same as the composition of MSW. The fossil C content in MSW was calculated from the weighted average of the C content in plastics and textiles (fossil carbon) and the respective fractions of waste weight. The total C content of MSW, which includes the biogenic and non-biogenic (fossil) components, results from the weighted average of the different waste fractions and the respective total C content. The % of fossil carbon in waste was then obtained dividing the fossil C component by the total C content in MSW.

Information used for the calculation is presented in the next table.

Table 8.14– Base table for MSW C content estimation

	C content		Waste composition (% of weight)				
	Non-biogenic	Total C	1990	1994	1999	2000	2010
Paper/ Card	0	40	21.1	22.7	25.8	26.4	13.7
Glass	0	0	4.4	5.1	7.0	7.4	3.7
Plastics	85	85	9.2	11.7	11.2	11.1	10.8
Metals	0	0	2.8	2.7	2.7	2.75	2.0
Food waste	0	15	42.0	34.8	27.9	26.5	42.8
Textiles	40	80	3.8	3.1	2.7	2.6	8.8
Non-food fermentable materials	0	17	13.4	18.7	17.6	17.4	8.1
Wood	0	30	0.2	0.3	0.5	0.5	1.5
Other	0	0	3.2	0.8	4.6	5.35	8.7
C content in Plastics and Textiles (1)			9.3	11.2	10.6	10.5	12.7
Total C of waste (2)			27.9	30.0	29.3	29.2	29.9
% non-biogenic C in waste (1)/(2) * 100			33.5	37.3	36.2	35.9	42.4

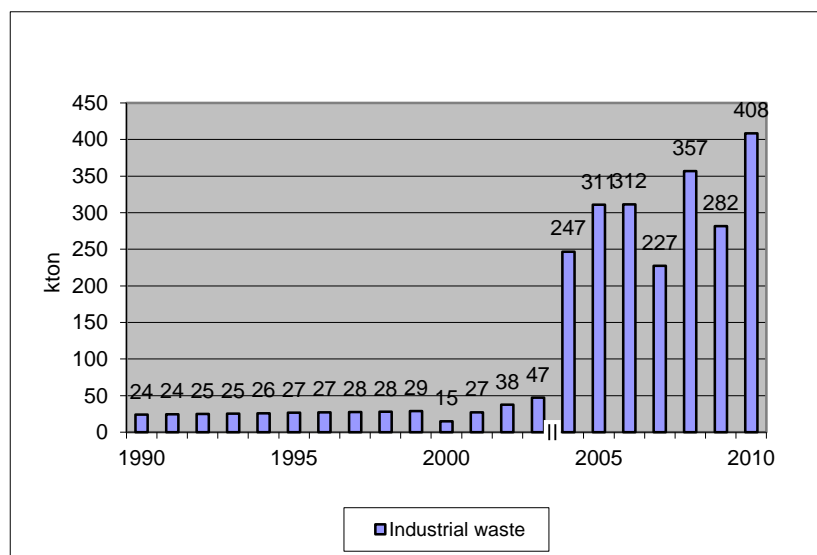
The efficiency of combustion is considered in both situations as 95% (IPCC default).

8.2.3.1.2.2 Industrial waste

Data refer to combustion of industrial solid waste in industrial units which were collected from INR. Data for the years 1999, 2000, 2002 and 2003 refer to industrial units declarations. Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%. The figure for 2001 is interpolated. Data from 2004 onwards refer to data collected under the Waste Registry (Mapa Integrado de Registo de Resíduos (MIRR)) on the framework of SIRAPA (APA website for the communication between APA and environmental stakeholders). Data provided by the different waste operators and industrials on the amounts of non-urban waste generated are statistical treated by the INE (Statistical Institute) in order to extrapolate the information for the universe of each economic

branch. Therefore, data from 2004 onwards represent a break from previous years, as data in earlier years were not extrapolated to consider the non-responses.

Figure 8.20– Quantities of combusted industrial waste



Source: APA (include estimates).

Table 8.15- Parameters considered

	Unit	Industrial Solid Waste
C content of waste	%	14-20 a)
Fraction of fossil carbon in waste	% total C	0.3-24 a)
Efficiency of combustion	%	95 b)

Notes:

- a) Range of values considered according to the years.
- b) IPCC default.

The parameters presented in the previous table (C content and % total C) are national estimates based on the background data on industrial waste production. This information is classified according to the European Waste Catalogue list (EWC) and is disaggregated by disposal type. Each one of the EWC categories were classified according to a group and were assigned with an estimated fraction of C content and a fraction of fossil carbon in waste, which has been defined by expert judgment (please see Table 8.4). The values considered resulted from weighted averages based on quantities reported for each of the EWC categories and the respective assigned C content and fraction of fossil C, and refer to disposal type “incineration”.

8.2.3.2 *Non-CO2 emissions*

8.2.3.2.1 Methodology

Emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * EF_i) * 10^{-6}$$

where:

IW_i = Amount of incinerated waste of type i (Gg/yr);

EF_i = Aggregate pollutant emission factor for waste type i (kg pollutant/Gg)

8.2.3.2.2 Activity data and parameters

8.2.3.2.2.1 Urban waste

Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR (EEA,2002).

Table 8.16 - Emissions factors of GHG and precursors gases from incineration of MSW

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH ₄	g/GJ	6.500	CORINAIR 94
N ₂ O	kg/ton MSW	0.100	Corinair 3rd version. Activity 090201. No NO _x abatement
SO _x	kg/ton MSW	0.022	Country measured data
NO _x	kg/ton MSW	0.724	Country measured data
COVNM	kg/ton MSW	0.020	Corinair 3rd version. Activity 090201. Uncontrolled
CO	kg/ton MSW	0.036	Country measured data

Table 8.17 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: until 2004

Pollutants	Unit	EF	Source
LHV	MJ/kg W	7.82	PROET study
CH ₄	g/GJ	6.5	CORINAIR 94
N ₂ O	kg/ton W	0.1	Corinair 3rd version. Activity 090201. No NO _x abatement
SO _x	kg/ton W	1.09	AP-42 Uncontrolled
NO _x	kg/ton W	1.40	2009 guidebook
COVNM	kg/ton W	0.70	2009 guidebook
CO	kg/ton W	1.48	AP-42 Uncontrolled

Table 8.18 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: after 2005

Pollutants	Unit	EF	Source
LHV	MJ/kg W	7.82	PROET study
CH ₄	g/GJ	6.5	CORINAIR 94
N ₂ O	kg/ton W	0.1	Corinair 3rd version. Activity 090201. No NO _x abatement
SO _x	kg/ton W	0.357	AP-42 Control level: Dry Sorbent Injection/C injection/Fabric Filter
NO _x	kg/ton W	1.4	2009 guidebook
COVNM	kg/ton W	0.7	2009 guidebook
CO	kg/ton W	1.48	AP-42 Uncontrolled

8.2.3.2.2 Industrial waste

Emission factors applied at present refer to “open burning of municipal waste” and were obtained from the international sources US/AP42 or EMEP/CORINAIR (EEA,2002). The figures used in the estimates of this category should be revised in the near future to better reflect the conditions and technologies used by industrial units where incineration occurs.

Table 8.19 - Emissions factors of GHG and precursors gases for Industrial Solid Wastes incineration

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.8	PROET study
CH ₄	kg/ton MSW	6.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
N ₂ O	kg/ton MSW	0.1	Corinair 3rd version. Activity 090201. No NOx abatement
SO _x	kg/ton MSW	0.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
NO _x	kg/ton MSW	3.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
COV	kg/ton MSW	15.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
CO	kg/ton MSW	42.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)

8.2.4 CH₄ and N₂O emissions from landfill gas and other biogas burning (CRF 6.D.)

The capture and burning of landfill gas and biogas (e.g. from sewage sludge) is used for energy purposes or flaring (without energy recovery). The resulting CO₂ from the combustion of landfill gas and biogas of biogenic origin, only needs to be reported as a memo item when there is energy recovery. CH₄ and N₂O emissions from the combustion of landfill gas and biogas captured need to be estimated and should be included in the energy sector when there is energy recovery, or in the waste sector when is flared.

For practical reasons all information related to the estimates of emissions from biogas combustion (with and without energy recovery) is presented here. However, the emissions related to energy recovery situations are accounted in sector 1A1a, and the emissions resulting from flaring are considered in category 6D.

8.2.4.1 Methodology

Emissions from the combustion of landfill gas and biogas with and without energy recovery have been estimated using emission factors based on the energy of the biogas consumed (combusted).

8.2.4.2 Activity data and parameters

The quantities of landfill gas and biogas combusted refer to DGEG data (biogas consumed in electrical production) and to the 2012 APA's direct questionnaires sent to the landfill management systems, which were focused on the more recent years (since 2005), and covered both situations with and without energy recovery.

Table 8.20 – Activity data and emission factors for landfill gas and biogas combusted

Quantities of landfill gas and biogas combusted			2005	2006	2007	2008	2009	2010
	Electrical production a)	GJ	331,622	313,590	536,868	787,149	962,456	1,205,189
	Flaring b)	GJ	266,085	416,332	388,578	382,593	332,984	257,181
Emission factors								
	CO ₂	kg/GJ						
	CH ₄	g/GJ						
	N ₂ O	g/GJ						
	NO _x	g/GJ						
	NM VOC	g/GJ						
	CO	g/GJ						
	SO _x	%						

Notes:

- a) Includes landfill biogas and other (e.g. sludge treatment plants) with energy recovery. Data refer mostly to DGEG data.
- b) Data refer to landfill gas flared without energy recovery. Data refer to 2012 APA's questionnaires.
- c) Memorandum item.
- d) According to the guidelines, CO₂ emissions from source categories "Solid waste disposal on land and Waste incineration" should only be included if they derive from non-biological or inorganic waste sources.

8.3 Uncertainty Assessment

8.3.1 Solid Waste Disposal on Land

8.3.1.1 *Municipal Solid Wastes*

The uncertainty of activity data for Municipal Solid Wastes is considered high for past years as data was estimated for each year from population and per capita waste production ratio and mostly because of the low accuracy in the backcast establishment of past solid wastes disposal since 1960. The situation changed in more recent years, where data refer to data collected by waste management systems. An uncertainty of 15% was considered as representative of the accuracy of the present time series for production of Municipal Solid Wastes.

8.3.1.2 *Industrial Wastes*

The activity data for the calculation of emissions from Industrial Waste Production has a lower accuracy than Municipal Solid Wastes, because the time trend since 1960 was established with poor information only collected after 1999. The uncertainty considered for the annual production of industrial solid wastes was about 68%, value determined by the comparison of the production of industrial solid wastes from 1999 till 2002 which showed expressive annual variations. An uncertainty the double of this value was considered (136%), to incorporate the error in backward forecasts till 1960, which is of the order that IPCC (2000) recommends for countries with low quality data was considered: 100%.

Uncertainty in the determination of the emission factor follows the rules of error propagation and were set from the default values proposed in the GPG for DOC (50%), DOC_F (50%), MCF (10% for Managed systems and 60% for unmanaged) and F (20%) and 300% for k, the methane generation rate constant¹⁶⁰. An overall error of 62 %, for managed systems and 86 % for unmanaged systems, was therefore obtained and used for both urban and industrial wastes.

8.3.2 Wastewater Handling

For urban waste water treatment the activity data, expressed in organic load to wastewater systems, was estimated from population and per capita production and the error associated with both variables needs to be incorporated in the determination of the final uncertainty value. Assuming the default uncertainties proposed in GPG, 5% for human population and 30% for BOD per capita, a final 30.4% error was set for this activity.

Concerning the methane emission factor, the uncertainty of this parameter includes an error in the Maximum Methane Producing Capacity (Bo), for which the GPG default of 30% was used, and the error determination in the fraction of water treated anaerobically. For urban water the uncertainty in this last fraction was estimated as 22%, considering the percentage of individual septic tanks and the lack of knowledge of in which conditions they operate.

¹⁶⁰ The uncertainty for this variable affects nevertheless when emissions occur and not how much and affects emission estimates exponentially.

In the case of industrial waste-water systems the available information is much scarcer. The uncertainty value was estimated for each industrial sector separately for the COD load and the uncertainty in the production activity data:

- the uncertainty in load was estimated for each available coefficient of pollution from the range of COD concentration values presented in the original documentation document (Cartaxo et al, 1985). Uncertainty values range from 11%, for the dairy industry, up to 100%;
- the uncertainty of production data is 20% if data was obtained from National Statistics and 50% if was interpolated.

The uncertainty considering all industrial activities, according to their production, varied between 22 and 24%, according to years.

For industrial wastewater treatment, also the uncertainty in the methane emission factor also changes with time and considers:

- the uncertainty in B_0 , the maximum methane generation potential, is 30% according to the GP;
- the error of the allocation of each specific treatment system, established from the per cent of unknown situations, adds 20% to the error for the known cases;
- the uncertainty in MCF for each specific treatment system, set from the GP, and varying from 10% for Secondary Treatment, well managed, to 50% for the no treatment situation.

Finally the error was determined for each industry and propagated accordingly. The final uncertainty varies in time from 29% to 35%.

8.3.3 Waste Incineration and Other

The uncertainty of the quantity of urban wastes was assumed to be 5%, considering that they are obtained directly from the incineration plants. For hospital wastes an uncertainty of 48% was calculated from comparison of annual variation in the quantities reported as incinerated, and also considering the fact that there is a fair lack of information of the production time series, particularly before 1995. In a way similar to what was done for determination of the uncertainty of production of industrial solid wastes, the comparison of the incineration of industrial solid wastes from 1999 till 2002 and its annual variations, allowed the estimation of an annual uncertainty of about 45%.

The uncertainty of CO_2 emission factors was set as 25% for urban and industrial wastes and 50% for hospital wastes, which expresses the uncertainty in carbon content and the additional uncertainty in the fraction of the incinerated carbon that has fossil origin. For N_2O and CH_4 emission factors a 100% uncertainty was considered.

8.3.4 Landfill gas and other biogas burning

CH_4 and N_2O emissions from biogas flaring reported in category 6D refer to data collected from a direct enquiry to landfill management systems and refer to measured data. The uncertainty value for quantities of biogas flared was set at 1 per cent, which is in accordance to the values considered for LPS data in category 1A1a (biogas burning with energy recovery).

The uncertainty associated with CH₄ and N₂O emission factors was set to 150 per cent and 1000 per cent, respectively.

8.4 QA/QC and verification

8.4.1 Solid Waste Disposal on Land

8.4.1.1 *General QC 1*

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and data field relationships;
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

8.4.1.2 *QC2 procedures*

Activity level parameters were compared with Revised 1996 IPCC Guidelines default values. Data used for the early 90s concerning the MSW generation and disposal rates are consistent with data presented for southern countries. In the most recent years the rates are closer to most industrialized countries, which is in line with the strong economic growth registered in the country since 1990.

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2010/ FCCC/WEB/SAI/2010), in particular those with similar natural, demographic and economic conditions.

An analysis of emission trends and of IEF were performed to detect unusual trends in order to identify potential underlying problems.

8.4.2 Wastewater Handling

8.4.2.1 *General QC 1*

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and data field relationships
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

8.4.2.2 *QC2 procedures*

Country-specific emission factors, in particular for industrial wastewater sector, were compared with IPCC default values. Domestic wastewater emissions were also estimated using the IPCC default method.

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2010/ FCCC/WEB/SAI/2010), in particular those with similar natural, demographic and economic conditions. Significant deviations were observed for category 6B. These differences should be analysed more deeply for the next inventory submission.

An analysis of emission trends and of IEF were performed to detect unusual trends in order to identify potential underlying problems.

8.4.3 **Waste Incineration and Other**

8.4.3.1 *General QC 1*

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and data field relationships
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

8.4.3.2 *QC2 procedures*

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2010/ FCCC/WEB/SAI/2010), in particular those with similar natural, demographic and economic conditions.

An analysis of emission trends and of IEF were performed to detect unusual trends in order to identify potential underlying problems.

8.5 **Recalculations**

The changes for this sector refer in majority to CH₄ emissions and result basically from:

- Solid Waste Disposal on Land
 - Quantities of SW disposed into land: error of compilation (link) in the 2011 submission
 - Industrial waste: revision of the waste categories containing organic/fermentable fractions based in the categories of the REGULATION (EC) No 2150/2002 on waste statistics (substance approach). This revision which resulted in a decrease of the quantities of the waste disposed in land (since 2004) is considered to be more accurate, as the previous selection

was based in aggregated classes which included many non fermentable categories.

- Landfill gas recovered and combusted: until the present submission, data on recovered landfill gas referred only to the amounts of biogas consumed in electrical production in landfill systems, and was based on the information collected annually by DGEG. This year, an extra questionnaire was launched by APA aiming at collecting the total amount of landfill gas combusted either in flaring (without energy recovery) or used for energy purposes. This inquiry was focused on the more recent years (since 2005) and included additional variables on the characterization of the biogas (e.g. percentage of CH₄ in biogas).
- Domestic wastewater: AD updates of % population served by handling systems and type of treatment
- Industrial wastewater: revision of activity data on industrial production time series and the revision of treatment types.
- Waste incineration
 - Quantities of SW disposed into land: error of compilation (link) in the 2011 submission
 - Industrial waste: revision of quantities of waste incinerated (without energy recovery).
 - Industrial waste/ CO₂ emissions: revision/update of the C content of waste based on the annual composition of waste.
- Other/Landfill gas and other biogas burning
 - CH₄ and N₂O emissions from biogas burning refer to a new accounting.

Synthesis of changes may be observed in figure and table below.

Figure 8.21 – Differences between 2011 and 2012 submissions (CO₂eq)

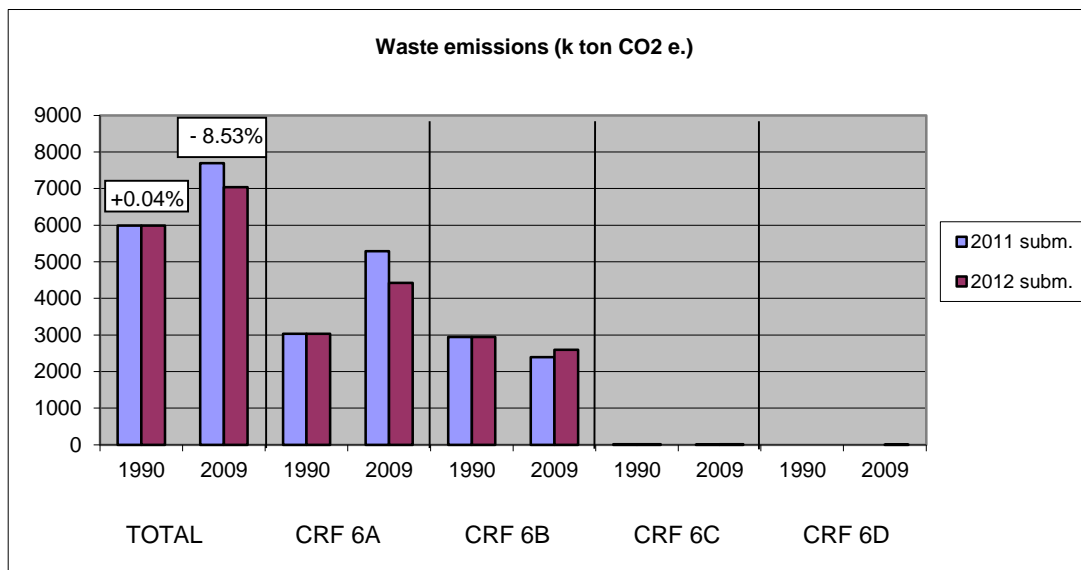


Table 8.21 – Recalculations (differences between 2011 to 2012 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2011 subm.	2012 subm.	Diff. (1)	2011 subm.	2012 subm.	Difference (1)	2011 subm.	2012 subm.	Diff. (1)
	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)
1990									
6. Waste	10.10	10.10	0.00	5,514.11	5,513.95	0.00	461.51	464.01	0.54
6.A. Solid Waste Disposal on Land	NA	NA		3,032.57	3,032.57	0.00			
6.B. Wastewater Handling				2,481.50	2,481.34	-0.01	460.39	462.89	0.54
6.C. Waste Incineration	10.10	10.10	0.00	0.04	0.04	0.00	1.12	1.12	0.00
6.D. Other	NO	NO		NO	NO		NO	NO	
2009									
6. Waste	0.60	5.06	739.98	7,167.73	6,475.62	-9.66	524.11	555.26	5.94
6.A. Solid Waste Disposal on Land	NA	NA		5,293.54	4,422.46	-16.46			
6.B. Wastewater Handling				1,874.14	2,052.84	9.54	522.62	546.21	4.51
6.C. Waste Incineration	0.60	5.06	739.98	0.05	0.31	498.44	1.49	8.91	498.44
6.D. Other	NO	NO		NO	0.01		NO	0.14	

Notes:(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

8.6 Further Improvements

Considering the limitations in the time trend in load and the share of each treatment system concerning industrial wastewater handling, efforts will continue in order to improve the assessment of the situation concerning industrial wastewater. These should include the development of a database aggregating information collected under different schemes: IPPC, PRTR, SEVESO and information from the discharge permits.

N₂O emissions from human sewage have been estimated according to the IPCC default methodology (IPCC,1997), assuming that all sewage nitrogen is discharged into aquatic environments, and not counting separately with N₂O emissions related with land disposal and sewage treatment.

Despite the fact that the present approach that accounts the N₂O emissions from wastewater treatment altogether (not separating the N input according to the final disposal) is a fairly good approximation of the N₂O emissions related to domestic wastewater systems and associated

sludge production, it is envisaged to implement the necessary methodological developments to report separately the N₂O emissions from agriculture sludge application in the near future, as soon as the collection of real data starts to be available.

8.7 Background Data Tables

Table 8.22 – National population, per capita generation rates, and urban waste production

Year	Population	Annual per capita generation rate	Pop. served by waste collection syst.	Urban waste production				
				Total	Open dump sites	Managed landfills	Composted waste	Incinerated waste
	inhabitants	kg/inh/year	% pop.	kton				
1960	8,889,197	128.8	40	457.8	457.8	0.0	0.0	0.0
1961	8,861,388	132.1	41	482.4	482.4	0.0	0.0	0.0
1962	8,833,580	135.6	42	507.8	507.8	0.0	0.0	0.0
1963	8,805,771	139.1	44	534.1	534.1	0.0	0.0	0.0
1964	8,777,962	142.8	45	561.4	561.4	0.0	0.0	0.0
1965	8,750,154	146.5	46	589.6	589.6	0.0	0.0	0.0
1966	8,722,345	150.3	47	618.8	618.8	0.0	0.0	0.0
1967	8,694,536	154.2	48	649.1	649.1	0.0	0.0	0.0
1968	8,666,727	158.3	50	680.4	680.4	0.0	0.0	0.0
1969	8,638,919	162.4	51	712.8	712.8	0.0	0.0	0.0
1970	8,611,110	166.7	52	746.3	746.3	0.0	0.0	0.0
1971	8,722,192	171.2	53	794.5	794.5	0.0	0.0	0.0
1972	8,833,274	175.9	54	845.2	845.2	0.0	0.0	0.0
1973	8,944,357	180.7	56	898.5	898.5	0.0	0.0	0.0
1974	9,055,439	185.6	57	954.5	954.5	0.0	0.0	0.0
1975	9,166,521	190.6	58	1,013.4	1,013.4	0.0	0.0	0.0
1976	9,277,603	195.8	59	1,075.1	1,075.1	0.0	0.0	0.0
1977	9,388,685	201.0	60	1,140.0	1,140.0	0.0	0.0	0.0
1978	9,499,767	206.4	62	1,208.1	1,208.1	0.0	0.0	0.0
1979	9,610,850	212.0	63	1,279.5	1,279.5	0.0	0.0	0.0
1980	9,721,932	217.7	64	1,354.4	949.2	360.5	44.7	0.0
1981	9,833,014	224.6	66	1,462.0	1,021.1	396.2	44.7	0.0
1982	9,836,427	231.6	68	1,558.2	1,088.1	425.4	44.7	0.0
1983	9,839,841	238.8	71	1,658.9	1,158.2	456.0	44.7	0.0
1984	9,843,254	246.2	73	1,764.5	1,231.7	488.1	44.7	0.0
1985	9,846,667	253.9	75	1,875.0	1,308.6	521.7	44.7	0.0
1986	9,850,081	261.8	78	2,001.1	1,396.3	560.1	44.7	0.0
1987	9,853,494	269.9	80	2,133.2	1,488.2	600.3	44.7	0.0
1988	9,856,907	278.3	83	2,271.7	1,584.5	642.5	44.7	0.0
1989	9,860,320	287.0	85	2,416.8	1,685.4	686.7	44.7	0.0
1990	9,863,734	295.9	88	2,568.7	1,764.9	692.1	111.7	0.0
1991	9,867,147	305.1	89	2,690.9	1,731.9	913.5	45.5	0.0
1992	9,916,044	314.7	91	2,831.4	1,821.8	951.7	57.8	0.0
1993	9,964,941	324.5	92	2,978.4	1,915.3	989.4	73.7	0.0
1994	10,013,838	334.6	93	3,132.3	1,839.0	1,137.2	156.2	0.0
1995	10,062,735	350.0	95	3,341.2	1,951.7	1,184.4	205.1	0.0
1996	10,111,632	365.4	96	3,542.8	2,027.8	1,310.3	204.7	0.0
1997	10,160,529	380.7	97	3,748.6	2,007.1	1,531.4	210.1	0.0
1998	10,209,426	395.9	98	3,958.7	1,507.5	2,236.0	215.2	0.0
1999	10,258,323	411.0	99	4,173.3	974.1	2,626.6	226.2	346.4
2000	10,307,220	412.1	100	4,247.9	588.3	2,473.6	274.8	911.1
2001	10,356,117	425.2	100	4,403.1	460.2	2,784.6	266.6	891.7
2002	10,407,463	421.1	100	4,382.7	27.8	3,294.7	116.2	943.9
2003	10,474,685	426.2	100	4,464.6	25.9	3,019.2	416.1	1,003.4
2004	10,529,255	413.3	100	4,351.6	22.3	3,118.9	250.6	959.7
2005	10,569,592	408.4	100	4,316.2	0.0	3,091.0	246.9	978.4
2006	10,599,095	418.7	100	4,437.8	0.0	3,189.1	294.1	954.6
2007	10,617,575	415.0	100	4,406.3	0.0	3,139.5	318.9	947.9
2008	10,627,250	458.3	100	4,871.0	0.0	3,498.0	380.0	993.0
2009	10,637,713	456.4	100	4,854.9	0.0	3,351.1	421.2	1,082.6
2010	10,636,979	462.2	100	4,915.9	0.0	3,462.9	394.6	1,058.4

Notes:

Selectively collected wastes (deviated to recycling) excluded.

Sources:INE; APA; Quercus Study

Table 8.23 – Fermentable industrial waste disposal

Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills
	kton			kton			ton	
1960	819	0	1977	1,055	0	1994	835	551
1961	832	0	1978	1,071	0	1995	850	565
1962	844	0	1979	1,087	0	1996	848	594
1963	857	0	1980	773	330	1997	810	661
1964	870	0	1981	782	338	1998	594	907
1965	883	0	1982	794	343	1999	358	1,173
1966	896	0	1983	806	348	2000	59	365
1967	909	0	1984	818	354	2001	95	815
1968	923	0	1985	830	359	2002	5	773
1969	937	0	1986	842	365	2003	4	723
1970	951	0	1987	854	370	2004	6	1199
1971	965	0	1988	867	376	2005	0	1518
1972	980	0	1989	880	382	2006	0	1521
1973	994	0	1990	893	388	2007	0	1467
1974	1,009	0	1991	843	463	2008	0	2422
1975	1,024	0	1992	860	473	2009	0	1947
1976	1,040	0	1993	876	483	2010	0	3116

Notes:

Share between open dump and managed landfills based on disposal of municipal solid wastes.

2002 to 2004: disposal on open dump sites refer to disposal on controlled dump sites.

Source: APA (include estimates)

Table 8.24 – Quantities of CH₄ recovered and combusted (SWDS)

	Biogas burned	Biogas burned	Biogas burned as % of CH ₄ generated
	kton CH ₄	Mton CO ₂ eq.	%
1990	0.00	-	0
1991	0.00	-	0
1992	0.00	-	0
1993	0.00	-	0
1994	0.00	-	0
1995	0.00	-	0
1996	0.00	-	0
1997	0.00	-	0
1998	0.00	-	0
1999	0.00	-	0
2000	0.00	-	0
2001	0.00	-	0
2002	0.00	-	0
2003	0.00	-	0
2004	2.39	0.05	1
2005	10.47	0.22	6
2006	14.38	0.30	9
2007	16.62	0.35	10
2008	22.42	0.47	13
2009	25.51	0.54	14
2010	30.09	0.63	16

Source: APA's questionnaires.

Table 8.25 – National population and wastewater BOD produced by handling systems

	Population (1000 inhabitants)	BOD5 produced (kton/year)					
		Total	Treatment systems		Individual treatment	Without treatment	Sludge spreading
			wastewater	sludge			
1990	9,853	216	24	5	8	173	5
1991	9,857	216	25	5	12	168	5
1992	9,860	216	26	6	15	164	6
1993	9,864	216	27	6	19	160	6
1994	9,867	216	29	6	23	155	6
1995	9,916	217	34	8	27	144	8
1996	9,965	218	40	9	31	132	9
1997	10,014	219	45	10	36	121	11
1998	10,063	220	51	12	40	109	12
1999	10,112	221	57	13	44	97	14
2000	10,161	223	63	14	49	84	15
2001	10,209	224	69	16	55	71	17
2002	10,258	225	75	17	60	58	19
2003	10,307	226	81	19	65	45	21
2004	10,356	227	87	20	70	31	22
2005	10,407	228	93	22	75	17	24
2006	10,475	229	101	22	72	14	23
2007	10,529	231	109	19	62	20	23
2008	10,570	231	113	20	59	19	22
2009	10,599	232	119	20	56	19	20
2010	10,618	233	119	20	56	19	20

Source: APA (estimates).

Notes: Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with and without anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Lagoons without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Preliminary treatment, Treatment not specified, Lagoon, with anaerobic pond and Imhoff Tanks (100% of organic load). Treatment systems – sludge: refer to Biodisks with anaerobic sludge digestion, Activated sludge with anaerobic sludge digestion, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (37% of organic load).

Individual treatment: refer to private and collective septic tanks.

Without treatment: refer to discharge into the ocean and inland waters and without sewerage (latrines).

Sludge spreading: refer to the % of the organic load retained as non mineralised sludge in primary treatment (30% of primary organic load generated), and 37% in activated sludge without anaerobic sludge digestion, lagoons without anaerobic pond, Percolation beds without anaerobic sludge digestion, oxidation ponds and other treatment.

Table 8.26 – Quantities of CH₄ combusted from municipal wastewater handling systems

Year	Sludge treatment systems	
	kton/year	% emissions of total emissions
1990	0.00	0.0
1991	0.00	0.0
1992	0.00	0.0
1993	0.00	0.0
1994	0.00	0.0
1995	0.00	0.0
1996	0.00	0.0
1997	0.00	0.0
1998	0.00	0.0
1999	0.32	0.8
2000	0.65	1.6
2001	0.35	0.9
2002	0.39	0.9
2003	0.24	0.6
2004	0.65	1.5
2005	0.87	2.1
2006	0.79	1.9
2007	0.68	1.8
2008	0.63	1.7
2009	1.19	3.2
2010	1.28	3.4

Source: Quantities based on data DGEG data

Table 8.27 – Quantities of waste incinerated (accounted CRF 6)

Year	Clinical waste quantities	Industrial solid waste incinerated
	kton	
1990	12	24
1991	12	24
1992	12	25
1993	12	25
1994	12	26
1995	12	27
1996	13	27
1997	16	28
1998	12	28
1999	10	29
2000	7	15
2001	3	27
2002	3	38
2003	2	47
2004	2	247
2005	1	311
2006	1	312
2007	3	227
2008	2	357
2009	6	282
2010	2	408

Note: Estimates in italics

Sources: APA (include estimates); DGS

Table 8.28 – MSW waste incinerated (accounted CRF 1A1a)

Year	Quantities incinerated		Emissions	
	Biogenic	Non-biogenic	Biogenic	Non-biogenic
	kton		kton CO2 e.	
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	221	125	226	128
2000	584	327	593	332
2001	571	320	580	325
2002	605	339	614	344
2003	643	360	653	366
2004	615	345	625	350
2005	627	351	637	357
2006	612	343	621	348
2007	575	322	584	327
2008	613	344	623	349
2009	638	358	648	363
2010	553	406	576	423

Table 8.29 – Comparison between estimates for CH₄ emissions from waste-water handling and IPCC check-method

Year	CH ₄ emissions			National CH ₄ emissions	
	Check method ton	National estimates ton	% difference %	w ithout recovery ton	recovered ton
1990	51,844	50,305	3.0	50,305	0
1991	51,862	49,312	4.9	49,312	0
1992	52,119	48,540	6.9	48,540	0
1993	52,376	47,759	8.8	47,759	0
1994	52,633	46,968	10.8	46,968	0
1995	52,890	45,714	13.6	45,714	0
1996	53,147	44,445	16.4	44,445	0
1997	53,404	43,163	19.2	43,163	0
1998	53,661	41,865	22.0	41,865	0
1999	53,918	40,235	25.4	40,554	319
2000	54,175	40,117	25.9	40,771	654
2001	54,432	40,639	25.3	40,988	349
2002	54,702	40,827	25.4	41,215	388
2003	55,055	41,262	25.1	41,505	243
2004	55,342	41,100	25.7	41,746	646
2005	55,554	41,061	26.1	41,930	869
2006	55,709	40,159	27.9	40,950	791
2007	55,806	36,555	34.5	37,232	678
2008	55,857	36,416	34.8	37,048	632
2009	55,912	36,115	35.4	37,302	1,187
2010	55,908	36,015	35.6	37,300	1,285
% variation 1990-2010	7.8	-28.4	-	-25.9	-

9 RECALCULATIONS AND IMPROVEMENTS

This section presents an overview of the recalculations made in the 2012 submission. The recalculations made result mostly from the recommendations issued during the UNFCCC reviews and updates of activity data.

9.1 Overview of the UNFCCC Review Process

The listing below concerns mostly the review from 2010.

The ERT Review Report from 2011 was not available to the inventory team. Therefore there could be additional ERT comments which are yet not included in the list below. The issues which will raise from the review report of 2011 will be covered in future NIR submissions.

Table 9.1 Overview of the responses to the UNFCCC review

CRF Sector	Status of Implementation	Comments
Energy (CRF 1.)		
The ERT encourages Portugal to continue its efforts to incorporate plant-specific data into its inventory	Under Development	More plant specific data has been added to the inventory. This work will be continued.
The ERT recommends that Portugal improve the consistency and transparency of its NIR in its next annual submission by improving the description of the energy sector categories, particularly by including municipal solid waste incineration facilities for electricity production in the energy chapter	Implemented	
CO ₂ emissions from agriculture/forestry/fisheries increased 37.4 per cent between 2007 and 2008. The ERT encourages Portugal to investigate this issue and, if necessary, make the appropriate changes to ensure consistency throughout the time series in its next annual submission.	Under Development	We will further investigate this issue in future submissions.
Reiterating question from S&A report about CRF 1B2a: The inter-annual changes of CO ₂ emissions from Refining/storage for 1991-1992, 1993-1997, 1999-2001 and 2002-2003 (ranging from -12.8% to 400.2%) have been identified as outliers. The 2007 value is 1180.2% higher than the 1990 value. The trend is unstable after 1993 and fluctuates. Your response to this was that cracking units data should be discussed with refineries. Could you please tell us, did you receive any answers yet?	Under Development	
Emissions have been estimated and reported for practically all categories, except for N ₂ O from flaring.	Under Development	
The ERT identified significant fluctuations in the trends of CH ₄ emissions from natural gas transmission between 1997 and 2008, ranging from -69.6 per cent to 207.6 per cent. The ERT recommends that Portugal investigate this issue further, ensuring time-series consistency, and document its findings in its next annual submission.	Implemented	No new information for this issue could be gathered from DGEG. The NIR explains the rationale behind the observed fluctuations (information given by DGEG).
The ERT reiterates the recommendation made in previous review reports that Portugal continue to make efforts to improve its estimates of emissions from the use of feedstocks and include estimates of combustion emissions from feedstock and non-energy use of fuels in the sectoral approach in its next annual submission.	Under Development	We foresee improvement in this source category in the near future.

CRF Sector	Status of Implementation	Comments
Industrial Processes (CRF 2.)		
Data on clinker production for the period 1990–2008 were received by the Party directly from each industrial plant. Portugal used the tier 2 methodology to estimate emissions from this key category. However, the Party used the default EF (0.507 t CO ₂ /t clinker) based on the default CaO fraction in clinker (64.6 per cent). During the review, the ERT was informed that Portugal will implement new estimates based on the EU ETS methodology (kiln input-based methodology) in its 2011 submission. The ERT welcomes this planned improvement and recommends that Portugal report its emission estimates accordingly in its next annual submission.	Implemented	
Portugal has made considerable efforts to improve the AD used for emission estimates for lime production for the years 2001–2007, based on surveys by INE. However, AD for 2008 were estimated again using a simple linear forecast. The ERT recommends that Portugal make efforts to continue using the statistical data for the most recent year or obtain plant-specific data and report its emission estimates accordingly in its next annual submission.	Implemented	
There is only one industrial plant for ammonia production in Portugal. Therefore, the AD and EFs are reported as confidential for this category. CO ₂ emissions were estimated from feedstock consumption (vacuum residual fuel oil) for the period 1990–1994 and an average feedstock/ammonia production ratio for the period 1994–2007. However, AD for 2008 were estimated using a simple linear forecast. During the review, the ERT was informed that Portugal plans to obtain AD directly from the plant. The ERT welcomes this planned improvement and recommends that Portugal report its emission estimates accordingly in its next annual submission.	Implemented	AD has been revised based on IAPI data for 2008. In 2009, this plant has stopped activity and the ammonia production has been relocated to India.
Nitric acid is produced in three industrial plants in Portugal. For all years, the AD and EFs are reported as confidential for this category. During the review, the ERT was informed that the country-specific EF used in emission estimates is based on monitored data from one of the three existing production units for 2001 and that the EF was assumed to be similar for the other units. The ERT recommends that Portugal derive country-specific EFs that are appropriate for all production units, and report on them in its next annual submission.	Implemented	We start obtaining AD directly from the facilities and derived plant specific EFs based on monitoring data.
The ERT welcomes Portugal's efforts to update the AD (Nitric Acid) from INE for the period 2001–2007. However, AD for 2008 were estimated using a simple linear forecast. During the review, the ERT was informed that Portugal plans to obtain AD directly from the production units. The ERT welcomes this planned improvement and recommends that Portugal report its emission estimates accordingly in its next annual submission.	Implemented	We start obtaining AD directly from the facilities and derived plant specific EFs based on monitoring data.
<u>Iron and Steel:</u> The ERT noted that AD for estimating emissions from iron and steel	Under Development	

CRF Sector	Status of Implementation	Comments
production is mainly based on interpolated or proxy data. The ERT encourages Portugal to make efforts to find appropriate statistical data for the whole time series or to use plant-specific data and report its emission estimates accordingly in its next annual submission.		
CRF table summary 3 does not include information on methods and emission factors(EFs) used for the estimation of HFC, PFC and SF6 emissions from the consumption of halocarbons and SF6. The ERT recommends that Portugal provide this information in its next annual submissions.	Under Development	
Time-series consistency analysis for fugitive emissions from oil refining activities.	Under Development	
Agriculture (CRF 4.)		
The CH4 implied emission factor (IEF) for non-dairy cattle in 2008 (57.47 kg/head/year) is 2.4 per cent higher than the 2007 value, higher than the IPCC default value for Western Europe (48 kg/head/year) and higher than the upper range of IPCC default values (56 kg/head/year). The ERT recommends that Portugal include these detailed background data for its EF calculation for the whole time series in the next NIR to improve transparency. Furthermore, the ERT recommends that the Party include similar information for the sheep EF estimation in its next NIR.	Implemented	
Revise digestibility values for dairy-cows	Under Development	This issue is still under development. We expect to have additional information future submissions.
Revise EF for anaerobic lagoons	Under Development	This issue is still under development. We expect to have additional information in future submissions.
The CH4 IEF for swine reported by Portugal for 2008 (21.42 kg/head/year) is much higher than the IPCC default value for Western Europe, temperate climate (10 kg/head/year) and higher than the IPCC default value for Western Europe, warm climate (19 kg/head/year). The ERT recommends that Portugal provide this information in its next annual submission to improve transparency.	Implemented	
However, the ERT reiterates the recommendation from the previous review report that Portugal verify and justify the N excretion rate for swine, which is lower than the IPCC default value and that Portugal provides information on this verification and justification in its next submission.	Implemented	
Nevertheless, the ERT further recommends that Portugal investigate the possibility of obtaining preliminary consumption data (fertilizers) from INE at an earlier date and implement measures to avoid the need for frequent recalculations in the future.	Under Development	Data on synthetic fertilizer production cannot be obtained from INE earlier (explanation provided in the respective chapter. We are still investigating alternative data sources. Expect developments in future submissions.

CRF Sector	Status of Implementation	Comments
<p>The ERT noted that N₂O emissions from the liberation of carbon from organic matter when soil is converted to cropland are reported in the agriculture sector in CRF table 4.D, but the description is included in the LULUCF sector in the NIR (pages 7–19). The ERT recommends that Portugal reallocate these emissions to the LULUCF sector, in line with the IPCC good practice guidance for LULUCF and document this in the NIR.</p> <p>FracR is in the CRF tables given to 0.71. This should be 0 as no crop residues are removed from the field according to the estimation methodology in the NIR (made by definition). Despite this is it recommended Portugal to include relevant data on removed crop residues as this takes place in future submissions</p>	Implemented	No new developments were made concerning this issue
LULUCF (CRF 5.)		
LULUCF emission and removal estimates are not complete in terms of geographical coverage as the Azores and Madeira territories are not included	Implemented	
Significant inconsistencies in the representation of land use should be address in the next annual submission Recommendation to provide a description in its next annual inventory submission of the methods and assumptions used for estimating carbon stock changes associated with all land-use changes, particularly for those that are key categories.	Implemented	Descriptions have been included in the NIRRepresentation of land use and related emission estimates have been implemented on the basis of CLC cartography
Present estimates and complete tables for cropland management and grazing land management for its base year (1990) Recommendation to provide detailed explanations about methods used, assumptions made and emission and carbon stock factors selected, as well as QA/QC measures for reducing uncertainties of the settlements categories	Implemented	Descriptions have been included in the NIR
Further develop and improve the methodologies used for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol;Recommendation to disaggregate the area of cropland remaining cropland into several strata corresponding with several combinations of soil types, climate regions, land management and level of carbon inputs, in order to improve the accuracy of estimates of carbon stock changes	Under Development/ Implemented	
Enhance the transparency of reporting by improving the description of methods and assumptions made for estimates in the LULUCF sector	Implemented/ Under Development	
Emissions from application of lime are reported as Not Estimated: Could Portugal indicate the reasons for not having reported this category?	Implemented	First estimates reported in the 2012 submission
Waste (CRF 6.)		
Recommendation to make efforts to use country-specific parameters in the FOD model for its next annual inventory submission.	No new developments were made concerning this issue	There are no national studies that enable the use of country-specific parameters. The development of these can represent significant economic resources still not

CRF Sector	Status of Implementation	Comments
<p>Wastewater handling – CH₄ and N₂O</p> <p>The ERT recommends that Portugal make efforts to update the country-specific data used in its calculations and verify its assumptions on CH₄ recovery in its next annual inventory submission.</p>	Implemented/ Under Development	<p>available</p> <p>An inquiry has been implemented in order to quantify biogas flared (without energy purposes) in landfills; CH₄ recovery is based on measured data, but efforts should be further implemented in order to increase the completeness of this activity concerning wastewater treatment systems.</p>
<p>Human sewage – N₂O</p> <p>Emissions of N₂O from human sewage were estimated following the methodology from the Revised 1996 IPCC Guidelines. AD on protein intake were taken from the FAO database. The ERT recommends that Portugal make efforts to obtain country-specific data on protein intake and use these data in its calculations for this category in its next annual inventory submission</p>	Implemented	
<p>Include in the NIR a description of the sector-specific QA/QC procedures implemented for the waste sector Human sewage – N₂O</p> <p>Emissions of N₂O from human sewage were estimated following the methodology from the Revised 1996 IPCC Guidelines. AD on protein intake were taken from the FAO database. The ERT recommends that Portugal make efforts to obtain country-specific data on protein intake and use these data in its calculations for this category in its next annual inventory submission</p>	Implemented	
<p>Improve the information on industrial wastewater, based on the implementation of a new survey system and database by the National Water Institute.</p>	No new developments	
<p>Cross-cutting issues</p> <p>The ERT encourages Portugal to develop and include country specific uncertainty values for AD and EFs for key categories and document this in the NIR in its next annual submission.</p>	Implemented/ Under development	
<p>The ERT encourages Portugal to report category-specific QC and verification activities for all categories in accordance with the UNFCCC reporting guidelines in its next annual submission.</p>	Implemented	
<p>The ERT recommends that Portugal improve the consistency of the information reported in the CRF and in the NIR in its next submission.</p>	Continuous development	
Supplementary information required under Art. 7.1 of KP		
<p>Demonstration that carbon pools not accounted for are not sources of GHG emissions; information on factoring out removals from elevated concentrations of CO₂, from nitrogen</p>	Implemented	<p>Several improvements have been done in order to tackle most of the recommended issues.</p>

Recalculations and Improvements

CRF Sector	Status of Implementation	Comments
deposition and from the dynamics of age–class structure; demonstration that the starting date for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol is after 1 January 1990 and that they are human-induced; information on how reforestation is distinguished from deforestation; and demonstration that activities under Article 3, paragraph 4, are not included under Article 3, paragraph 3.		
Information on the minimization of adverse impacts in accordance with Article 3, paragraph 14, of the Kyoto Protocol, need to be further improved	Implemented/Under Development	To be further improved

9.2 Implications in emissions levels

The implications of recalculations for emission levels by category and for the national totals by gas are presented in the following tables.

Recalculations and Improvements

Table 9.2 – Synthesis of recalculations made for the 2010 inventory submission and their implications to the emission level in 1990 and 2009

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO ₂ eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2009	in 1990	in 2009
Total			652.94	-288.70	1.09	-0.39
1. Energy			623.75	386.48	1.04	0.52
1.A.	Fuel Combustion Activities		636.36	384.02	1.06	0.52
1.A.1.	Energy Industries	Fuel consumption and emission factor revision.	355.22	-123.65	0.59	-0.17
		1) Revised CO ₂ emission factors and oxidation factors for several power plants; 2) Revised data for Caniçal power plant was obtained from Madeira Regional Environmental entities; 3) Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series for auto-producers. These new values were accompanied by revised LHV.				
1.A.2.	Manufacturing Industries and Construction	Fuel consumption and emission factor revision.	1.12	188.69	0.00	0.25
		1) Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series for auto-producers. These new values were accompanied by revised LHV; 2) In depth revision of the Pulp and Paper industrial sector resulted in revised fuel consumption and pulp production data, and more extensive use of plant specific emissions factors; 3) Updated fuel consumption values for the Chemical industrial sector were obtained from LCP directive; 4) For the Cement industrial sector several small revisions/updates were made to the emission estimation, resulting from data				

Recalculations and Improvements

CRF Category		Recalculation	Reason for the Recalculation	Emission Impact (Gg CO ₂ eq.)		Impact on Total Emissions without LULUCF (%)	
				in 1990	in 2009	in 1990	in 2009
			received from EU-ETS				
1.A.3.	Transport	Fuel and other activity data and road transport emission factors	1) New version of COPERT IV (version 9.0 - October 2011) available; 2) New data on km/vehicles for passenger cars and light duty vehicles from a model based on data from the vehicle inspection centers; 3) Information available from national statistics on activity data from HDV and Buses; 4) Update of sulphur content in gasoline and diesel according to DL 235/2004 (Directive 2003/17/CE) with implications on N ₂ O emissions 5) Adoption of CO ₂ default emission factor to calculate emissions from the combustion of gasoline since country-specific EF was not available. 6) Revision of the toe/ton conversion factors used to convert railways fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series for auto-producers. These new values were accompanied by revised LHV; 2) Revision of railways coal consumption;	234.22	294.58	0.39	0.40
1.A.4.	Other Sectors	Fuel consumption revision	1) Revision of the toe/ton conversion factors used to convert fuel consumption from energy balance toe to INERPA ton. The newer values were obtained from DGEG and updated for all times series for auto-producers. These new values were accompanied by revised LHV; 2) Update of fuel consumption in fishing bunkers.	45.37	24.41	0.08	0.03
1.A.5.	Other			0.43	0.00	0.00	0.00

Recalculations and Improvements

CRF Category		Recalculation	Reason for the Recalculation	Emission Impact (Gg CO ₂ eq.)		Impact on Total Emissions without LULUCF (%)	
				in 1990	in 2009	in 1990	in 2009
1.B.	Fugitive Emissions from Fuels			-12.61	2.46	-0.02	0.00
1.B.1.	Solid fuel			74.66	0.00	0.12	0.00
1.B.2.	Oil and Natural Gas	Pipeline extension revision.	1) Revised values for pipeline extension were given by DGEG.	-12.61	2.46	-0.02	0.00
2. Industrial Processes				-35.41	257.49	-0.06	0.35
2.A.	Mineral Products	1) Revision of Lime Production (2A2) activity data for the period 1990-2010. 2) Revision of Limestone and Dolomite Use (2A3) activity data for the period 1990-2010.	1) Minor double counting. 2) Analysis of time series consistency.	13.35	91.29	0.02	0.12
2.B.	Chemical Industry	Nitric Acid Production (2B2) new estimates.	Data available at facility level	-48.76	166.15	-0.08	0.22
2.C.	Metal Production			0.00	0.10	0.00	0.00
2.D.	Other Production	Wood Chipboard production AD revision based on INE (IAPI) survey. 2008-2010.	Updated time series for the period 2008-2010.	0.00	-0.05	0.00	0.00
2.G.	Other			0.00	0.00	0.00	0.00
3. Solvent and Other Product Use		Method and EF for 3 D 2 Domestic Solvent Use including Fungicides	Methodology update according to EMEP/CORINAIR guidelines (EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009)	-14.59	-26.06	-0.02	-0.04
4. Agriculture				76.84	-288.39	0.13	-0.39

Recalculations and Improvements

CRF Category		Recalculation	Reason for the Recalculation	Emission Impact (Gg CO ₂ eq.)		Impact on Total Emissions without LULUCF (%)	
				in 1990	in 2009	in 1990	in 2009
4.A.	Enteric Fermentation	Revised AD due to RGA 2009	1) Introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types. For some animal types (like swine) this affects the 1990-2009 time series; 2) Revised milk yield also due to RGA 2009; 3) Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series.	26.59	-62.51	0.04	-0.08
4.B.	Manure Management	Revised activity data	1) Introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types. For some animal types (like swine) this affects the 1990-2009 time series; 2) Revised milk yield also due to RGA 2009; 3) Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series.	8.36	-203.57	0.01	-0.27
4.C.	Rice Cultivation	Revised activity data	1) New data from GPP was obtained concerning areas in Techniques of Integrated Production and Protection.	0.00	-85.60	0.00	-0.12
4.D.	Agricultural Soils (4)	Revised activity data	1) Introduction of RGA 2009 data which revised the 2000-2009 time series for all animal types and crops. For some animal types (like swine) this affects the 1990-2009 time series; 2) Revised milk yield also due to RGA 2009; 3) Due to the in-depth AD revision provided by the RGA 2009 efforts were also made to revise the slaughtering values for the 1990-1999 time series;	41.89	61.57	0.07	0.08

Recalculations and Improvements

CRF Category		Recalculation	Reason for the Recalculation	Emission Impact (Gg CO ₂ eq.)		Impact on Total Emissions without LULUCF (%)	
				in 1990	in 2009	in 1990	in 2009
4.E.	Prescribed Burning of Savannas	-	4) Revision of the 2009 value for apparent consumption of synthetic fertilizers.	0.00	0.00	0.00	0.00
4.F.	Field Burning of Agricultural Residues	Revised activity data	1) Introduction of RGA 2009 data which revised the 2000-2009 time series for all crops; 2) Revision of the 2009 value for apparent consumption of synthetic fertilizers.	0.00	1.73	0.00	0.00
4.G.	Other			0.00	0.00	0.00	0.00
6 Waste				2.35	-656.50	0.00	-0.88
6.A.	Solid Waste Disposal on Land	Quantities of SW disposed into Land	1) Quantities of MWDL: error of compilation in the 2011 subm. 2) Industrial waste: revision of the waste categories/amounts containing organic/fermentable fractions. 3) Landfill gas recovered and combusted: new data collected for biogas flaring (without energy recovery).	0.00	-871.08	0.00	-1.17
6.B.	Waste-water Handling	1) Domestic treatment 2) Industrial organic load and treatment	1) AD updates/revision of % population served by handling systems and type of treatment 2) Revision of activity data on industrial production (which influenced early years due to AD backcast estimates); and revision of treatment types	2.35	202.29	0.00	0.27
6.C.	Waste Incineration		Industrial waste: revision/updates of quantities of waste incinerated (without energy recovery) and C content of waste	0.00	12.14	0.00	0.02
6.D.	Other	Emissions from biogas combustion without energy	Source not accounted previously	0.00	0.00	0.00	0.00

Recalculations and Improvements

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO ₂ eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2009	in 1990	in 2009
	recovery					
7 Other			0.00	0.00	0.00	0.00

Figure 9.1 Recalculation of total CO₂, CH₄ and N₂O emission (LULUCF excl.)

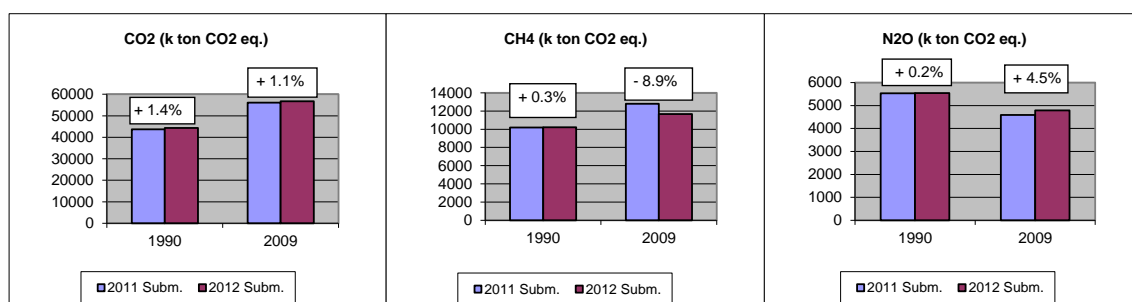


Table 9.3 – Recalculation of total CO₂, CH₄ and N₂O emission (LULUCF excl.)

Year	CO ₂			CH ₄			N ₂ O		
	2011 Subm.	2012 Subm.	Difference (%)	2011 Subm.	2012 Subm.	Difference (%)	2011 Subm.	2012 Subm.	Difference (%)
1990	43,702	44,317	1.4	10,188	10,217	0.3	5,534	5,543	0.2
2009	56,155	56,766	1.1	12,804	11,660	-8.9	4,586	4,792	4.5

9.3 Implications in emissions trends

A slighter difference upwards in the base year (1990: +1.1%) as compared with the reduction in 2009: -0.39%, resulted in a decrease of the growing trend from 25.6% % (2011 submission without LULUCF) to 23.8% (2012 submission without LULUCF).

Figure 9.2 – Recalculation of total emission levels (LULUCF excl.)

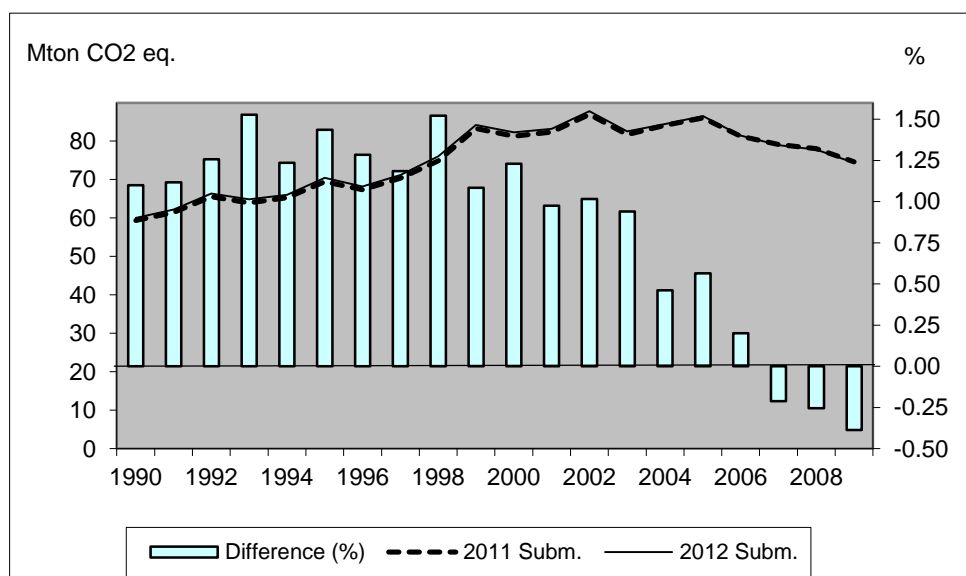


Table 9.4 – Recalculation of total emissions trends (LULUCFs excl.)

Year	2011 Submission (kton CO2 eq.)	2012 Submission (kton CO2 eq.)	Difference (%)
1990	59424	60077	1.10
1991	61518	62205	1.12
1992	65542	66367	1.26
1993	63955	64932	1.53
1994	65275	66082	1.24
1995	69498	70496	1.44
1996	67364	68230	1.28
1997	70430	71264	1.18
1998	74935	76075	1.52
1999	83294	84196	1.08
2000	81293	82293	1.23
2001	82407	83212	0.98
2002	86963	87846	1.02
2003	81761	82530	0.94
2004	84134	84522	0.46
2005	86054	86540	0.56
2006	81346	81509	0.20
2007	79188	79020	-0.21
2008	78023	77825	-0.25
2009	74660	74372	-0.39

9.4 Changes in methodological descriptions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	RECALCULATIONS Please tick where this is also reflected in recalculations compared to the previous year CRF	REFERENCE If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)			
1. Energy			
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries			
2. Manufacturing Industries and Construction	✓	✓	In depth revision of the fuel consumption data and EF used for estimating emissions in the Pulp and Paper Sector. To maintain reporting consistency with other industrial sectors, the methodological description for this source category in the NIR hasn't changed much apart from a revision of AD values and LHV in chapter "Paper and Paper Pulp Industry" in "Tables of consumption per activity", and EF in the "Emission Factors" chapter. Also pulp production has changed (chapter "Production Data").
3. Transport	✓	✓	1 A 3 b, Road transports, all gases, page 2-109, distance travelled
4. Other Sectors			
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
2. Oil and Natural Gas			
2. Industrial Processes			
A. Mineral Products	✓	✓	Revision of Lime Production (2A2) activity data for the period 1990-2010. Revision of Limestone and Dolomite Use (2A3) activity data for the period 1990-2010.
B. Chemical Industry	✓	✓	Nitric Acid Production (2B2) new estimates.
C. Metal Production	✓	✓	There is no ferroalloys production (2C2) in Portugal in the period 1990-2010.
D. Other Production	✓	✓	Revised AD for the period 2008-2010 based on IAPI time series.
E. Production of Halocarbons and SF ₆			
F. Consumption of Halocarbons and SF ₆	✓	✓	Revised AD for Commercial Refrigeration (Number of Hypermarkets). Revised AD for Electric Equipment for the period 2007-2010. Revised AD for Industrial Air Conditioning based on APCC time series.
G. Other			
3. Solvent and Other Product Use	✓	✓	3 D 5, Domestic use of solvents, page 3-35
4. Agriculture			
A. Enteric Fermentation			
B. Manure Management			
C. Rice Cultivation			
D. Agricultural Soils			
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues			
G. Other			
5. Land Use, Land-Use Change and Forest	✓	✓	Several revisions done in particular referring to the accounting of the two Autonomous Regions of Madeira and Açores.
A. Forest Land			
B. Cropland			
C. Grassland			
D. Wetlands			
E. Settlements			
F. Other Land			
G. Other			
6. Waste			
A. Solid Waste Disposal on Land	✓	✓	Quantities of industrial waste revised (CRF 6A); Biogas recovery in CRF 6A Urban waste (Other parameters)
B. Waste-water Handling			
C. Waste Incineration		✓	Quantities of industrial waste revised (CRF 6C)
D. Other	✓	✓	New accounting: CH ₄ and N ₂ O emissions from landfill gas and other biogas burning (CRF 6D)
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			
Aviation			
Marine			
Multilateral Operations			
CO ₂ Emissions from Biomass			
NIR Chapter	DESCRIPTION Please tick where the latest NIR includes major changes in descriptions compared to the previous year NIR		REFERENCE If ticked please provide some more detailed information for example reference to pages in the NIR
Chapter 1.2 Institutional arrangements			
Chapter 1.6 QA/QC plan			

9.5 Future improvements

Future improvements are defined annually under the MDP which is settled each year in the context of the SNIERPA and which is developed under the responsibility of the APA, in cooperation with the sectoral Focal Points. The MDP pretends to reflect the results of the various review processes, in particular the UNFCCC reviews, the annual inventory compilation process (all experts and entities involved can make proposals for methodological development), and generally the results of the application procedures of Quality Control and Quality Assurance which have been defined under the Control and Quality Assurance System.

10 KP-LULUCF

10.1 General information

In this submission, the cartography used to derive Land Use and Land Use Change area dynamics in Portugal's mainland and Madeira is the Corine Land Cover (CLC) products: CLC90-R and CLC06_PT, which rely, respectively, on Landsat satellite¹⁶¹ data for the years 1985-1987 and the year 2006. For the Autonomous Region of Azores the only map available at present is the COS2007 (the CLC map is not yet available). The forest areas and other categories in 2007 were obtained from COS 2007. The land use evolution in time was obtained from the Forestry Inventory of the Autonomous Region of Azores (IFRAA)¹⁶² for 1987 and 2007. Data from the Azores Agricultural Census for 1999 and 2009 were also used to derive land use change for the remaining categories.

10.1.1 Definition of forest and any other criteria

In its Initial Report, Portugal adopted a forest definition according to the following parameters:

- Minimum tree cover: 10%
- Minimum land area: 1 ha
- Minimum tree height: 5 m
- Minimum width: 20 m.

The parameters chosen in the Initial Report for the definition of forest are within the agreed values in decision 16/CMP.1. Portugal stated in the Initial Report that the threshold value selected for minimum area (1 ha) is higher than the value used for reporting to the FAO, which is 0.5 ha. The value selected corresponds to the most detailed information available from the national mapping of land-use and forest areas for 1990 and the commitment period, which will be available when the Land Use Cartographic Map – COS is available.

For this submission the minimum area for forest area is 25 ha since the Corine Land Cover (CLC) was used as the basis for the identification of the areas. The CLC is, at present, the only information source with two methodologically consistent wall-to-wall land use maps with two time references. Despite this fact, the use of the CLC cartography represents a considerable amelioration relating to previous submissions, since the whole Portuguese mainland is now covered, allowing the harmonization among UNFCCC's and KP's activity data on the areas of the activities and correspondent Land Uses.

In Portugal all forests are considered managed, as all have anthropogenic activities. Forest management is guided by the rules defined in 2006 in the National Forest Strategy¹⁶³ and the Regional Forest Plans.

¹⁶¹ Thematic Mapper (TM) and Multispectral Scanner (MSS) from Landsat-5 (1985-87) and Enhanced Thematic Mapper (ETM+) from Landsat-7 (2000)

¹⁶² Secretaria Regional da Agricultura e das Florestas (2007): *Inventário Florestal da Região Autónoma dos Açores*.

¹⁶³ National Forest Strategy / Estratégia Florestal Nacional (2006)
<http://www.afn.min-agricultura.pt/portal/gestao-florestal/ppf/enf>

The Regional forest Plans provide silvicultural models for different ecological situations and for different management objectives; they provide goals for the forest area and the species composition at that level. Minimum silvicultural measures are included in the regional plans and are to be applied by all forest owners. Pending on the size of the forest holding, management plans at local level are mandatory (and approved by the National Forest Authority). Those instruments are designed to increase stands productivity, as in average, and mainly due to the effects of forest fires, the standing volume is considered to be very low and below possibility. The quantification of the expected increase is, however, very difficult and can/will only be assessed by subsequent national forest inventories. In order to improve forest management practices, particularly in areas of fragmented forest holdings, there is also support for a special type of collective management, in forest intervention zones.

Concerning fire prevention, the national plan for forest fire prevention¹⁶⁴ was approved also in 2006 and it aims at increasing resilience of forests towards fires, reduce the consequences of forest fires, improve fire management and suppression, rehabilitate and recover forest ecosystems and adapt the organization structure. It established a plan of action, measures and goals, and identifies the entities responsible for implementing them.

The existing public support programs followed the objectives and goals defined on the policy instruments mentioned above. They support measures to prevent forest fires, for instance by establishing fuel breaks and by assuring first intervention teams to forest owners association and local authorities.

10.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

Portugal accounts for Article 3.3 activities (mandatory) – Afforestation (A), Reforestation (R) and Deforestation (D), and has elected the following Article 3.4 activities – Forest Management (FM), Cropland Management (CM) and Grassland Management (GM) (FCCC/IRR/2007/PRT).

10.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

The areas time series for ARD, FM, CM and GM activities were derived from Corine Land Cover (CLC) for 1990 (based on 1985-1987 data) and 2006, using the same approach of sector CRF 5. The trend for the period 2007-2010 was derived from the changes of the 1986-2006 period, assuming a constant pattern of LUC. All the activities were established consistently over time using the same principles and definitions

The following strata were considered as “Forest”:

- Agro-Forestry Systems
- Broadleaves forests
- Coniferous forests
- Mixed forests
- Degraded forest, clear cuts and new plantations
- Burnt areas (if forest in 1990 or 2006)

¹⁶⁴ National (2006) and local Plans (2007-2008) for Protection against Forest Fires
<http://www.afn.min-agricultura.pt/portal/dudf/Resource/pdf/dgrf-2006-pndfci-rcm65.pdf>

- Shrubs (if forest in 1990 or 2006).

The correspondence among the nomenclature of CLC and IPCC LU categories can be seen in Table 7.9. These same categories were used for KP reporting.

The areas were further classified as follows:

- AR – areas that were not forest in 1990 and are classified in one of the above discriminated categories
- D – areas that were forest in 1990 and are classified as any other use in 2006.

All the areas that were classified as Forest before 1 January 1990 and remained as Forest were classified as FM.

Further, for the allocation of burnt areas to other uses, the following criteria were used:

- Burnt areas – if the classification as burnt area remains from 1990 to 2006
- Other use – if the area had any other use in 1990
- FM – if burnt areas in 2006 and forest in 1990.

For shrub land, a similar set of criteria was applied:

- Shrub land – if the classification as shrub land remains from 1990 to 2006
- Other use – if the area had any other use in 1990.

On the other hand, general GM and CM areas were identified also recurring to CLC and the areas related to sown biodiverse permanent pastures rich in legumes (SBPPRL) and those under no-tillage (with or without mulching) were included based on IFAP's database, since both are declared in farmers' annual applications to EU agriculture subsidies.

These approaches were applied during all the time series – 1990-2009. Therefore:

- Article 3.3 Afforestation
 - Sum of land converted to forests since 1990
- Article 3.3 Deforestation
 - Sum of forests converted to other uses since 1990
- Article 3.4 Forest Management
 - Total area of forests in 1990 – 3.3 deforestation
- Article 3.4 Cropland Management and Article 3.4 Grassland Management

- Total area of cropland (grassland) in year – forests converted to cropland (grassland) since 1990 + croplands (grasslands) converted to other land-uses since 2008.

10.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified.

Since the 2011 submission, Agro-Forestry Systems have been classified as Forest and, therefore, included in activities such as ARD, D or FM. This classification is in accordance with the CLC definition of Forest and the NFI which include the agro-forestry areas.

This classification represents however a change to the hierarchical rules originally established (classification of agro-forestry areas as GM or CM).

10.2 Land-related information

10.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit for determining the area of the units of land under Article 3.3 is the used in CLC products (see 7.1.3 and 7.2.3.1).

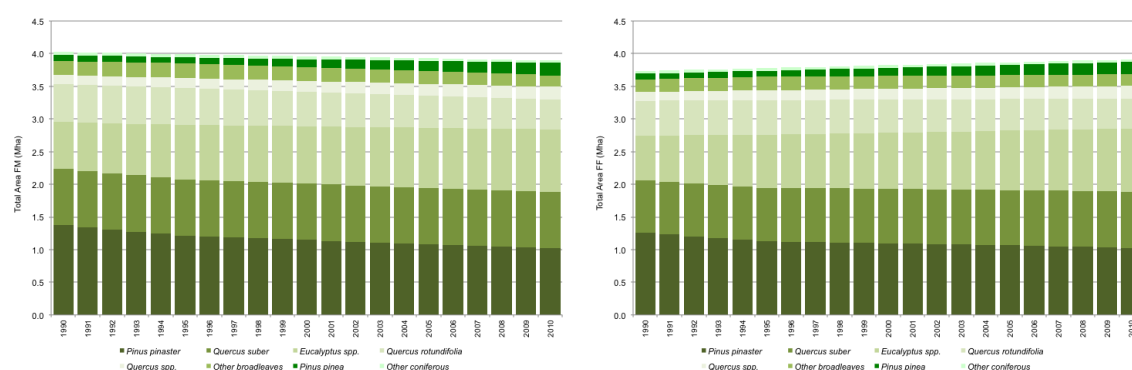
10.2.2 Methodology used to develop the land transition matrix

The basis to develop the land transition matrix is fully described in 7.1.2. The methodology to calculate the KP areas present however some differences to those reported for the UNFCCC due to its definition.

- Article 3.3 AR: Sum of land converted to forests since 1990
- Article 3.3 D: Sum of forests converted to other uses since 1990
- Article 3.4 FM: Total area of forests in 1990 – 3.3 D.

Forest management” refers to areas that have been forest since 1990, while “Forest land remaining forest land” refers to areas that have been forest for more than 20 years. Thus, the areas being reported under each category (see following figure) are different.

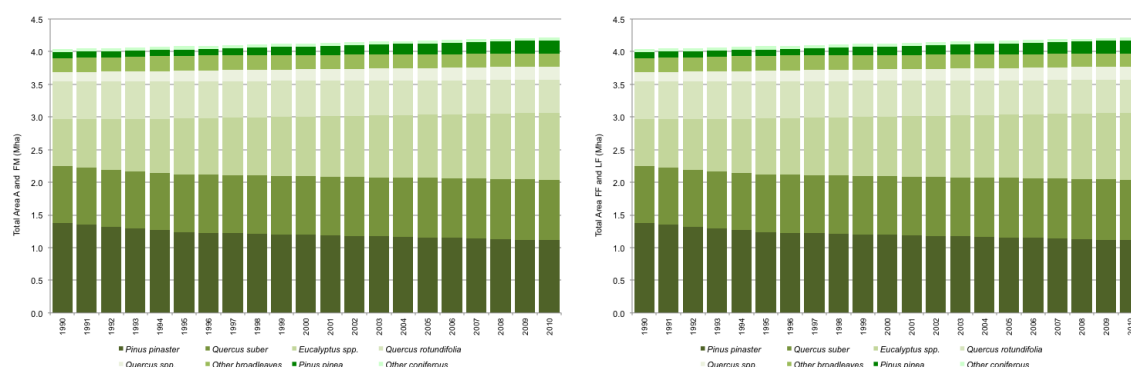
Figure 10.1 – Areas under Kyoto Protocol 3.4 Forest Management and UNFCCC Forest Land Remaining Forest Land



However, as Figure 10.2 shows, the total forest areas reported under Kyoto tables 5(KP-I)A.1.1 and 5(KP-I)A.1.2 (3.3 afforestation and reforestation) and table 5(KP-I)B1 (3.4 forest

management) are equal to the total forest areas reported under the convention tables 5A.1 (Forest land remaining forest land) and 5A.2 (Land converted to forest land).

Figure 10.2 – Total Forest Areas reported under Kyoto Protocol and UNFCCC.



10.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The maps and databases used to identify the geographical locations and the system of identification codes for the geographical locations are fully described in 7.1.2.

10.3 Activity-specific information

10.3.1 Methods for carbon stock change and GHG emission and removal estimates

10.3.2 Description of the methodologies and the underlying assumptions used

The areas of the activities for 1990, and 2008 to 2010 were calculated based on CLC90_R and CLC_06 as explained in 7.1.2 and 0. For CM and GM (net-net) the areas of the 20 precedent years were also considered.

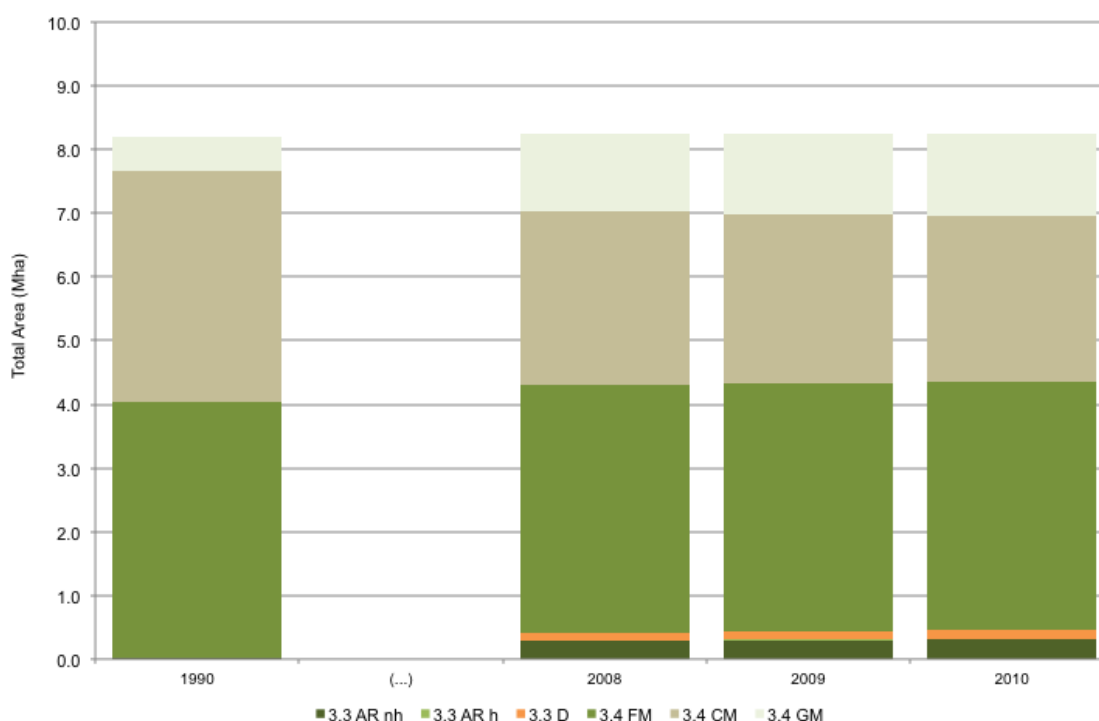
For AR, the areas had to be desegregated among harvested (ARh) and not harvested (ARnh). Similarly in what was reported under the UNFCCC, only Eucalypts are harvested in time intervals that should be reported. Table 10.1 and Figure 10.3 show the area per activity per year.

Table 10.1 – Areas of KP activities (kha).

Activity	Year			
	1990	2008	2009	2010
3.3 AR nh	15,3	286,8	298,8	310,9
<i>Pinus pinaster</i>	5,0	82,6	86,5	90,4
<i>Quercus suber</i>	3,1	60,6	63,8	67,0
<i>Eucalyptus spp.</i>	2,6	57,2	57,6	57,9
<i>Quercus rotundifolia</i>	2,1	37,3	39,1	40,9
<i>Quercus spp.</i>	0,5	11,7	12,4	13,1
Other broadleaves	1,1	22,1	23,2	24,3
<i>Pinus pinea</i>	0,3	8,7	9,4	10,1
Other coniferous	0,4	6,5	6,8	7,1
3.3 AR h	0,0	3,2	6,3	9,6
<i>Pinus pinaster</i>	0,0	0,0	0,0	0,0
<i>Quercus suber</i>	0,0	0,0	0,0	0,0
<i>Eucalyptus spp.</i>	0,0	3,2	6,3	9,6
<i>Quercus rotundifolia</i>	0,0	0,0	0,0	0,0
<i>Quercus spp.</i>	0,0	0,0	0,0	0,0
Other broadleaves	0,0	0,0	0,0	0,0
<i>Pinus pinea</i>	0,0	0,0	0,0	0,0
Other coniferous	0,0	0,0	0,0	0,0
3.3 D	6,2	118,2	124,5	130,7
<i>Pinus pinaster</i>	2,1	35,5	37,2	38,8
<i>Quercus suber</i>	1,4	26,0	27,4	28,8
<i>Eucalyptus spp.</i>	1,1	25,7	27,2	28,8
<i>Quercus rotundifolia</i>	0,9	16,0	16,8	17,5
<i>Quercus spp.</i>	0,2	5,0	5,3	5,6
Other broadleaves	0,3	5,3	5,5	5,7
<i>Pinus pinea</i>	0,1	3,7	4,0	4,3
Other coniferous	0,1	1,0	1,0	1,1
3.4 FM	3.999,9	3.909,4	3.903,2	3.896,9
<i>Pinus pinaster</i>	1.396,9	1.048,2	1.035,9	1.023,5
<i>Quercus suber</i>	857,0	857,9	857,5	857,1
<i>Eucalyptus spp.</i>	684,0	944,4	952,6	960,8
<i>Quercus rotundifolia</i>	576,9	473,1	466,5	459,8
<i>Quercus spp.</i>	136,4	187,8	190,1	192,3
Other broadleaves	211,5	181,5	178,3	175,2
<i>Pinus pinea</i>	90,1	178,5	185,0	191,5
Other coniferous	47,1	38,1	37,4	36,7
3.4 CM	3.662,0	2.695,5	2.654,0	2.648,4
Non-irrigated annual crops	2.086,3	1.327,8	1.307,3	1.302,6
Irrigated annual crops	507,2	383,6	362,1	360,8
Rice paddies	44,1	41,3	42,1	41,9
Vineyards	346,7	262,0	257,5	256,6
Olive groves	491,0	481,1	483,4	481,6

Activity	Year			
	1990	2008	2009	2010
Other permanent crops	186,7	199,6	197,4	196,6
<i>Areas classified as 3.4 grassland 3.4 Cropland converted to other land uses</i>		0,0	4,1	8,2
Activity: no tillage	0,0	3,5	9,9	22,4
3.4 GM	542,3	1.250,3	1.283,7	1.281,2
All grasslands	542,3	1.250,3	1.282,0	1.277,7
<i>Areas classified as 3.4 grassland converted to other land uses</i>	0	0,0	1,7	3,5
Activity: Biodiverse pastures	0	14,6	20,8	29,0

Figure 10.3 – Areas of KP's activities.



The methodology for calculating Carbon stock change was the correspondent to the Gains/Losses methodology, as in the IPCC GPG2003, equation 3.1.1.

$$\Delta C = A \times (C_I - C_L)_{ijk}$$

Where:

ΔC = carbon stock change in the pool, t C.yr⁻¹

A = area of land, ha

C_I = rate of gain of carbon, t C.ha⁻¹.yr⁻¹

C_L = rate of loss of carbon, t C.ha⁻¹.yr⁻¹.

As referred before Portugal uses a Tier 2 approach applying emission factors and activity data, which are defined by the country for the most important land uses/activities. Country-defined emission factors/activity data are more appropriate for the land use systems in that country. Higher resolution activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use categories.

The gases and mentioned subcategories were calculated as summarized in next table.

Table 10.2 – Gases and subcategories in a given Activity.

Gas	Subcategory	Notation Keys
CO ₂	Living biomass	Included
	DOM	Included
	Soils	Included

The methodology, namely formulas, emission or removal factors and parameters are fully consistent with the UNFCCC submission. Carbon gains and losses were calculated to AR_{nh}, AR_h, D, FM, CM and GM including gains and losses in aboveground and belowground biomass, DOM (litter) and Mineral Soils (Table 10.2) considering the annual activity areas (Table 10.1).

Emissions from biomass burning occurring in AR or FM areas (Table 10.3) were also calculated using the same methodological approach as in the UNFCCC reporting and considering CO₂, CH₄ and N₂O emissions. These last, CH₄ and N₂O also include CM and GM.

Table 10.3 – Burnt areas on KP activities (ha).

Activity	Year			
	1990	2008	2009	2010
3.3 AR nh	289,2	367,3	1.715,8	4.842,2
Pinus pinaster	125,4	160,1	754,8	1.896,2
Quercus suber	5,8	16,0	46,0	427,4
Eucalyptus spp.	101,3	123,0	319,7	1.692,5
Quercus rotundifolia	3,9	14,7	51,1	169,8
Quercus spp.	24,8	30,0	310,7	277,5
Other broadleaves	22,9	20,5	213,4	292,5
Pinus pinea	1,5	0,5	2,5	32,9
Other coniferous	3,6	2,5	17,7	53,3
3.3 AR h	0	0,0	0,0	0,0
Pinus pinaster	0	0,0	0,0	0,0
Quercus suber	0	0,0	0,0	0,0
Eucalyptus spp.	0	0,0	0,0	0,0
Quercus rotundifolia	0	0,0	0,0	0,0
Quercus spp.	0	0,0	0,0	0,0
Other broadleaves	0	0,0	0,0	0,0
Pinus pinea	0	0,0	0,0	0,0
Other coniferous	0	0,0	0,0	0,0
3.4 FM	79.382,9	5.422,6	22.443,8	64.993,8
Pinus pinaster	34.385,2	2.080,6	9.020,7	22.118,0
Quercus suber	1.579,3	226,7	618,2	5.467,2
Eucalyptus spp.	27.797,0	1.986,4	4.793,3	24.873,4
Quercus rotundifolia	1.077,9	186,2	608,8	1.911,3
Quercus spp.	6.796,0	482,7	4.765,7	4.071,4
Other broadleaves	6.332,5	409,4	2.366,6	5.192,3
Pinus pinea	422,6	9,4	49,6	624,4
Other coniferous	992,5	41,3	221,0	735,8
3.4 CM	9.067,7	1.601,6	3.699,3	6.421,8
Non-irrigated annual crops	6.046,9	936,8	2.004,6	3.289,4
Irrigated annual crops (except rice)	0,0	0,0	0,0	0,0
Rice paddies	0,0	0,0	0,0	0,0
Vineyards	1.003,9	183,2	391,6	642,6
Olive groves	1.467,5	343,6	750,2	1.231,0
Other permanent crops	549,4	138,0	296,7	486,8
3.4 cropland converted to other land since 2008		0,0	256,2	772,0
Activity: no tillage	0,0	0,0	0,0	0,0
3.4 GM	1.389,8	805,1	1.910,8	3.266,3
All grasslands	1.389,8	805,1	1.798,7	2.951,6
3.4 grassland converted to other land since 2008		0,0	112,1	314,6
Activity: Biodiverse pastures	0,0	0,0	0,0	0,0

10.3.2.1 *Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4*

As referred before the organic soils' area in Portugal is negligible and therefore the pool is not considered.

10.3.2.2 *Information on whether or not indirect and natural GHG emissions and removals have been factored out*

Portugal did not factor out indirect effects of climate change in expected emissions and removals from forest management. This was mostly due to technical difficulties associated with that calculation. However, and in qualitative terms, science on the impacts of climate change impacts in Portugal suggests that the net-effect will most likely result in a reduction of forest productivity. In this sense, ignoring factoring out in the Reference Level results in a conservative estimate, as emissions in the commitment period are likely to be higher than those included in the Reference Level.

"The present capacity of Portuguese forests to store carbon is high. In the future, however, it may not be as high as it could be under present climatic condition due to: (1) decreases or only modest increases in NPP, (2) lower standing biomass due to changes in vegetation and increase in fire frequency and (3) enhanced soil respiration due to warmer winters, thus decreasing the importance of the below ground carbon store"¹⁶⁵.

10.3.2.3 *Changes in data and methods since the previous submission (recalculations)*

This submission includes several improvements as regards the previous one.

It considers for the first time the whole national territory including the two Autonomous Regions of Azores and Madeira. Previous submissions referred exclusively to Portugal Mainland.

CH₄ and N₂O emissions from wildfires in cropland and grassland gave been estimated for the first time, as well as CO₂ emissions from agricultural lime application.

Furthermore, the annual area change in Portugal Mainland that is estimated on the basis of the CLC cartography for 1990 (based on 1985-1987 images) and 2006, has been change from a 16 year period to a 20 years period (to consider the medium year of the underlying CLC data (1985-1987)).

10.3.2.4 *Uncertainty estimates*

To be developped.

10.3.2.5 *Information on other methodological issues*

The Party may explore providing information on measurement intervals, inter-annual variability, etc. (see, inter alia, section 4.2.3 of the IPCC good practice guidance for LULUCF

10.3.2.6 *The year of the onset of an activity, if after 2008*

None of the activities have started after 2008.

¹⁶⁵ <http://www.siam.fc.ul.pt/SIAMExecutiveSummary.pdf>

10.4 Article 3.3

10.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Areas under afforestation and deforestation were derived from the land use change obtained by comparing CLC06_PT and CLC90-R (referring to 1990). All forest in Portugal is considered to be affected by human intervention, and consequently considered as non-natural/managed. Bush lands are basically non-managed areas and are not considered in the estimates – they were included in the category Other Land. Deforestation is also man induced, by definition.

10.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

In Portugal all forests are considered managed, as all have anthropogenic activities. Forest management is guided by the rules defined in 2006 in the National Forest Strategy¹⁶⁶ and the Regional Forest Plans.

The Regional forest Plans provide silvicultural models for different ecological situations and for different management objectives; they provide goals for the forest area and the species composition at that level. Minimum silvicultural measures are included in the regional plans and are to be applied by all forest owners. Pending on the size of the forest holding, management plans at local level are mandatory (and approved by the National Forest Authority). Those instruments are designed to increase stands productivity, as in average, and mainly due to the effects of forest fires, the standing volume is considered to be very low and below possibility. The quantification of the expected increase is, however, very difficult and can/will only be assessed by subsequent national forest inventories. In order to improve forest management practices, particularly in areas of fragmented forest holdings, there is also support for a special type of collective management, in forest intervention zones.

Concerning fire prevention, the national plan for forest fire prevention¹⁶⁷ was approved also in 2006 and it aims at increasing resilience of forests towards fires, reduce the consequences of forest fires, improve fire management and suppression, rehabilitate and recover forest ecosystems and adapt the organization structure. It established a plan of action, measures and goals, and identifies the entities responsible for implementing them.

The existing public support programs followed the objectives and goals defined on the policy instruments mentioned above. They support measures to prevent forest fires, for instance by establishing fuel breaks and by assuring first intervention teams to forest owners association and local authorities.

Supported by these programmes and under current practices harvesting is usually followed by reforestation.

Adding to this, Mediterranean forests usually recover after fire and there are subsidies to speed-up fire recovery. Therefore, only transitions to non-burnt and non-shrub are considered deforestation (and Afforestation) (see 10.1.3 and 10.4.3).

¹⁶⁶ National Forest Strategy / Estratégia Florestal Nacional (2006)
<http://www.afn.min-agricultura.pt/portal/gestao-florestal/ppf/enf>

¹⁶⁷ National (2006) and local Plans (2007-2008) for Protection against Forest Fires
<http://www.afn.min-agricultura.pt/portal/dudf/Resource/pdf/dgrf-2006-pndfci-rcm65.pdf>

10.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

For the cases of burnt areas and shrubland, which may result from a transitional state in forest, cropland or grassland areas due to disturbances, the following criteria were applied:

- Burnt areas reclassified as Forest/Agriculture/Grassland if
 - Burnt 1990 = F/C/G in 2006
 - Burnt 2006 = F/C/G in 1990
 - Burnt = Other in all other cases
- Shrubs reclassified as Forest/Agriculture/Grassland if
 - Shrubs 1990 = F/C/G in 2006
 - Shrubs 2006 = F/C/G in 1990
 - Shrubs = Other in all other cases.

10.5 Article 3.4

10.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

The basis for the identification of all the areas, including those with FM, CM or GM, is CLC90-R and, therefore, all the above considered refer to after 1 January 1990. On the other hand, GM and CM included the areas related to sown biodiverse permanent pastures and no tillage obtained from IFAP (only available in years 2008 to 2010).

As referred above (10.4.2) all forests are considered managed and, by definition, all FM activities are human induced.

In what concerns CM and GM all the areas are managed, having a productive end, and all specific activities (sown biodiverse pastures and no tillage) are declared on farmers' annual applications to EU subsidies at IFAP.

10.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

CLC90-R is the base for the identification of the areas for the base year (see 10.2.3).

No specific CM and GM activities occurred in base year.

10.5.3 Information relating to Forest Management

10.5.3.1 *That the definition of forest for this category conforms with the definition in item 11.1 above*

The identification of the areas of ARD and FM was done using the same data sources, namely CLC and IFN and, therefore, the definition of forest is consistent.

10.5.3.2 *That forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner (paragraph 1 (f) of the annex to decision 16/CMP.1 (Land use, land-use change and forestry*

See section 0.

10.6 Other information

10.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Following the guidance of GPG LULUCF (IPCC 2003), the assessment of key categories under Articles 3.3 and 3.4 of the Kyoto Protocol was based on the assessment made for the UNFCCC inventory. Accordingly, whenever a category is identified as key in the UNFCCC inventory, the associated activity under the Kyoto Protocol was considered as key in reporting under the Kyoto Protocol, following the guidance from table 5.4.4 GPG LULUCF.

The 3.3 activities and all elected 3.4 activities were identified as key categories.

10.6.2 Information relating to Article 6

Portugal has no activities of the Article 6 of the KP in its territory.

10.7 Further Developments

See section 1.12

11 INFORMATION ON ACCOUNTING KYOTO UNITS

11.1 Background Information

This section includes supplementary information required under Article 7, paragraph 1, following the reporting requirements of the Annex of Decision 15/CMP.1.

The standard electronic format (SEF) tables for providing information on ERUs, CERs, tCERs, ICERs, AAUs and RMUs for the year 2011 has been submitted to the electronically (SEF_PT_2012_1_9-55-24 3-1-2012.xls), and constitutes Annex D.

11.2 Summary of Information Reported in the SEF Tables

The total number of AAU units in the Portuguese registry at the end of the year 2011 was 365,518,266 AAUs, of which 255,539,763 units were in the Party holding account, 32,710,074 units in the entity holding accounts, and 77,268,429 units in the retirement account.

There was 9,415,186 CERs in the registry at the end of 2011: 4,623,936 CERs were held in the entity holding accounts and 4,791,250 CERs were held in the retirement account.

The number of ERUs was 412,799. The registry did not contain any RMUs, t-CERs or I-CERs. There were no units in the Article 6 issuance and conversion accounts; no units in the Article 3.3 and Article 3.4 issuance or cancellation accounts and no units in the Article 12 afforestation and reforestation accounts.

The total amount of the units in the registry corresponded to 375,346,251 tonnes CO₂e.

11.3 Discrepancies and notifications

There were no discrepant transactions.

No CDM notifications were received, no non replacements occurred and no invalid units were identified during the 2011, as presented in the annexed RRITL worksheet (SIAR_Reports_PT_2011_R2_R5.xls).

11.4 Publicly Accessible Information

The public information was made available in the Registry site in the middle of 2009. The information is accessible in the RPLE site (<https://rple.pt>). It includes non-confidential information stated in Annex XVI of the Commission Regulation (EC) No 2216/2004 amended by Commission Regulation (EC) No 916/2007 and Commission Regulation (EC) No 994/2008, specifically account list, account holdings, project list, annex I & II projects, transaction info and user fees. Information on representatives names and contact information is classified as confidential, except when account representatives themselves requested its disclosure.

Previous recommendations from SIAR 2010 Assessment Report to improve the Publicly Accessible Information have been implemented.

11.5 Calculation of the Commitment Period Reserve (CPR)

The CPR has not been changed. Portuguese assigned amount was fixed in 381 937 527 tonnes CO₂ eq. The calculation of the CPR was based on the assigned amount (90% of the assign amount) and is estimated to be 343 743 774 tonnes of CO₂e.

11.6 KP-LULUCF accounting

Portugal selected accounting of the KP-LULUCF activities at the end of the commitment period. No information on the accounting of these activities is therefore included in the SEF tables.

12 CHANGES IN NATIONAL SYSTEM

Several changes occurred during the reported year.

After the 2011 elections the Ministries of Environment and the Ministry of Agriculture have been merged into the new Ministry for Agriculture, Sea, Environment and Land Use Planning. However, the restructuring process of several departments as the APA is still not finished and accordingly the SNIERPA was not yet reformulated.

Other changes refer to:

- InventAr, Estudos e Projectos Unip Lda, has ceased the contract with APA;
- Ecoprogresso, Consultores em Ambiente e Desenvolvimento has terminated the contact with APA;
- CAOS Sustentabilidade has been contracted to support the inventory unit in the development of the methodological approach to quantify KP-LULUCF activities.

Information on the NS is included in the Introduction section of the NIR.

13 CHANGES IN NATIONAL REGISTRY

13.1 Contact names and Internet address

The contact names and the internet address of the national registry have not changed.

13.2 Cooperation arrangement

The Portuguese registry is operated independently. i.e. in a non-consolidated way.

There have been no changes during the reported year to the cooperation arrangement.

13.3 Changes to the National Registry

No changes in the database infrastructure have been performed. The current database capacity has proved to be sufficient so far and in the near future.

The Portuguese registry is in full operation with CR software since 8th October 2007 (at that date linked with CITL). In 2011, the only major change made in the Portuguese registry occurred on the 21st January, when the 2nd factor authentication was implemented in CR version 5.0. Since then, all proposed operations require the introduction of a PIN sent by SMS before being sent to the ITL. This change has been preceded with internal testing, whose results are presented in section 1.7.

In addition to this major software update, minor bugs have been detected and corrected, namely regarding the availability of public information and security issues, and some functionality has been added to the registry software. All changes have been preceded with intense testing and have passed to the production environment in the following dates:

- 7th September;
- 23rd September.

No changes occurred in the communication infra-structure and in the way the registry conforms to the technical standards for data exchange.

13.4 Procedures to minimize discrepancies

No changes have occurred in the way the registry minimizes discrepancies. It should be stressed that during the six and a half years period of operation of the registry no major discrepancies have been found between the registry, the ITL and the CITL. Only minor reconciliation issues have occurred due to terminated transfer operations, which were quickly sorted out. No complaint has also been reported by the registry users regarding a hypothetical discrepancy in their accounts.

13.5 Security measures

Although no security breaches have occurred in the Portuguese registry, following the security threats of the beginning of 2011 in other registries, thorough checks have been performed, which included:

- Penetration tests;
- Correction of non-compliances expressed in the penetration tests;
- Implementation of the recommendations expressed in the penetration tests;

- Software review according to the recommendations from the European Commission;
- Adoption of the 2-factor authentication for transfers;
- Strengthening of security recommendations to users;

The penetration tests were performed by an external party and concluded that the site presented a suitable security protection level against external attacks. Three non-compliant control points were identified and five recommendations were expressed. Although they didn't represent high security concerns for the global level of security, they were corrected and implemented.

13.6 Disaster management

No changes have occurred in the way the registry ensures the integrity of data storage and possibility of recovering from data losses. No incidents have occurred which may have put in danger the integrity of data storage. The Party prepared a disaster recovery plan which was successfully tested in March 2010.

A disaster management exercise was planned but postponed given the planned migration of the registry to the European Union Consolidated Registry.

13.7 Test results on registry software upgrade to CR v5

13.7.1 Internal testing

Testing CR v5

Tester: Joana Simões

Date: 13-15 July 2010

Environment: DEV (cyclic testing)

Step #	Instruction	Expected result	Actual result	Comments
1	Government account creation (100 CP0, 230 CP1, 300 CP1)	Successfully account creation	Pass	Problems in CITL with account creation
2	Send CSV file to ITL for upload in DEVELOPER	File uploaded in ITL	Pass	If file not uploaded in ITL, we cannot retire
3	Installation account creation (120 CP0, Inst ID 1, Permit ID 1; 120 CP0, Inst ID 2, Permit ID 2)	Successfully account creation	Pass	
4	Person holding account creation (121 CP0)	Successfully account creation	Pass	
5	Set authorization limits (assigned amount, RMU, %limit CER & ERU surrendering)	Autorization limits set	Pass	
6	NAP upload (APA_RPLE_Gestão200911\Scripts\application_pars Folder NAPtestes2010\FromCirca; file NAPLOAD_3_1.xml)	Successful NAP upload	Pass	This needs to be done to issue units
7	Send NAP to CITL for upload in DEVELOPER			If file not uploaded in CITL, we cannot issue EUA
8	AAU issuance	AAUs transferred to Party account	Pass	
9	EUA issuance	EUA transferred to Party account	Pass	
10	RMU issuance	RMU transferred to Party account	Pass	Not all LULUCF are successfully transferred
11	Allowance allocation	EUA transferred to OHA	Pass	
12	Receive CER from CDM	CER transferred to party account	Pass	Cyclic testing specific
13	Create operator account with Ins ID 3; permit ID 3	Account created	Pass	
14	Upload NAP update with account 3 (file NAPLOAD_4_1.xml)	Success	Pass	
15	Upload NAP update with 2009 allocation correction (file NapUpdate_4_2.xml)	Success	Pass	
16	Internal transfer from Party to Operator (AAU, RMU, EUA) and vice-versa	Successful transfer	Pass	
17	Internal transfer from Party to Person and vice-versa	Successful transfer	Pass	
18	Internal transfer from Operator to Person and vice-versa	Successful transfer	Pass	
19	Internal transfer from Operator to Operator	Successful transfer	Pass	
20	Internal transfer from Person to Person	Successful transfer	Pass	
21	Account blocking	Account blocked	Failed	System failure
22	Verified emission	Introduced	Pass	Grant right to

				submit VE
23	Surrender of EUA and CER	Successful transfer	Pass	
24	Conversion of retired EUA	Successful transfer	Pass	
25	Retirement of retired AAU and CER	Successful transfer	Pass	
26	Kyoto retirement	Successful transfer	Pass	
27	Project creation (13390, ERU, track1; 13461, ERU from RMU, track1, 13532, ERU, track2; 13603, ERU from RMU, track2)	Success	Pass	
28	Project conversion	Successful transfer	Pass	
29	External transfer	Successful transfer	Pass	
30	Permit revocation	Success	Pass	
31	Installation closure	Success	Fail	Check 7117
32	Voluntary cancellation	Success	Pass	
33	Account update	Success	Pass	
34	Add 2 AAR	AAR added	Pass	
35	Remove 1 AAR	AAR removed	Pass	
36	Visibility criteria	Success	Pass	
37	Reconciliation	ITL completed	Pass	
38	Replace people	Success	Pass	
39	Create government accounts for notifications (210, 250, 422, 423)	Success	Pass	
40	Send accounts to ITL	Accounts uploaded in ITL	Pass	
41	Notification type 1			
42	Notification type 4			
43	Notification type 5			
44	Notification type 9		Pass	Automatically done

PAR and SAR

Step #	Instruction	Expected result	Actual result	Comments
1	Access account		Pass	
2	Change password		Pass	
3	Check functionalities		Pass	
4	Transfer		Pass	

AAR

Step #	Instruction	Expected result	Actual result	Comments
1	Access account		Pass	
2	Change password		Pass	
3	Check functionalities		Pass	Can see transactions; cannot see transfer

Tester: Joana Simões

Date: 30 May 2011

Environment: DEV (ad-hoc testing)

Step #	Instruction	Expected result	Actual result	Comments
1	Government account creation (100 CP0, 230 CP1, 300 CP1)	Accounts created	Pass	
2	Send CSV file to ITL for upload in DEVELOPER	File uploaded	Pass	
3	Installation account creation (120 CP0, Inst ID 1, Permit ID 1; 120 CP0, Inst ID 2, Permit ID 2)	Accounts created	Pass	
4	Person holding account creation (121 CP0)	Account created	Pass	
5	Set authorization limits (assigned amount, RMU, %limit CER & ERU surrendering)	Limits set	Pass	
6	NAP upload (APA_RPLE_Gestão200911\Scripts\application_pars Folder NAPtestes2010\FromCirca; file NAPLOAD_3_1.xml)	NAP successfully uploaded	Pass	
7	Send NAP to CITL for upload in DEVELOPER	File sent	Pass	
8	AAU issuance	Transaction completed	Pass	
9	EUA issuance			
10	RMU issuance	Transaction completed	Pass	
11	Allowance allocation			
12	Receive CER from CDM			
13	Create operator account with Ins ID 3; permit ID 3			
14	Upload NAP update with account 3 (file NAPLOAD_4_1.xml)			
15	Upload NAP update with 2009 allocation correction (file NapUpdate_4_2.xml)			
16	Internal transfer from Party to Operator (AAU, RMU, EUA) and vice-versa	Transactions completed	Pass	
17	Internal transfer from Party to Person and vice-versa			
18	Internal transfer from Operator to Person and vice-versa			
19	Internal transfer from Operator to Operator			
20	Internal transfer from Person to Person			
21	Account blocking			
22	Verified emission			
23	Surrender of EUA and CER			
24	Conversion of retired EUA			
25	Retirement of retired AAU and CER			
26	Kyoto retirement			
27	Project creation (13390, ERU, track1; 13461, ERU from RMU, track1, 13532, ERU, track2; 13603, ERU from RMU, track2)	Projects created	Pass	
28	Project conversion	Transaction completed	Pass	
29	External transfer			
30	Permit revocation			
31	Installation closure			
32	Voluntary cancellation			
33	Account update			
34	Add 2 AAR			
35	Remove 1 AAR			
36	Visibility criteria			
37	Reconciliation			
38	Replace people			
39	Create government accounts for notifications (210, 250, 422, 423)			
40	Send accounts to ITL			
41	Notification type 1			
42	Notification type 4			
43	Notification type 5			
44	Notification type 9			

Tester: Joana Simões

Date: 19 September 2011

Environment: DEV (cyclic testing)

Goal: test public information, retirement and surrendering

Step #	Instruction	Expected result	Actual result	Comments
1	Government account creation (100 CP0, 230 CP1, 300 CP1, 210 CP1, 220 CP2)	Accounts created	Ok	
2	Send CSV file to ITL for upload in DEVELOPER	File uploaded	Ok	
3	Installation account creation (120 CP0, Inst ID 1, Permit ID 1; 120 CP0, Inst ID 2, Permit ID 2)	Accounts created	Ok	
4	Person holding account creation (121 CP0)	Account created	Ok	
5	Set authorization limits (assigned amount, RMU, %limit CER & ERU surrendering)	Limits set	Ok	
6	NAP upload (APA_RPLE_Gestão200911\Scripts\application_pars Folder NAPtestes2010\FromCirca; file NAPLOAD_3_1.xml)	NAP successfully uploaded	Ok	
7	Send NAP to CITL for upload in DEVELOPER	File sent	Ok	
8	AAU issuance	Transaction completed	Ok	
9	EUA issuance			
10	RMU issuance	Transaction completed	Ok	
11	Allowance allocation			
12	Receive CER from CDM			
16	Internal transfer from Party to Operator (AAU, RMU, EUA) and vice-versa	Transactions completed	Pass	
17	Internal transfer from Party to Person and vice-versa			
18	Internal transfer from Operator to Person and vice-versa			
19	Internal transfer from Operator to Operator			
20	Internal transfer from Person to Person			
23	Surrender of EUA and CER (above % limit)			
24	Conversion of retired EUA			
25	Retirement of retired AAU and CER			
26	Kyoto retirement			
27	Project creation (13390, ERU, track1; 13461, ERU from RMU, track1, 13532, ERU, track2; 13603, ERU from RMU, track2)	Projects created	Ok	
28	Project conversion	Transaction completed	Ok	
29	External transfer			
32	Voluntary cancellation			
41	Notification type 1			
42	Notification type 4			
43	Notification type 5			
44	Notification type 9			

13.8 Response to Review Recommendations on the National Registry

Recommendation to enhance the public information in the registry website (P2.4.2.1 of IAR/2010/PRT/2/1)

Public information has been enhanced according to the Recommendations of the Expert Review Team. Transactions of types issuance, cancellation or carry-over that did not take place are now displayed with 0.

Recommendation to correct the public information in the registry website regarding external transfers (P2.4.2.2 of IAR/2010/PRT/2/1)

Public information has been corrected. External transfers are only displayed after 5 years of the concerned year.

Recommendation to report changes to support a user authentication mechanism (P2.4.2.3 of IAR/2010/PRT/2/1)

The user authentication mechanism was implemented in the beginning of 2011. The Competent Authority requested the update of the contract with the cell phone numbers of the representatives of the account holders. These data was updated in the database. A new table was created: operation_SMS. This table stores the PIN and the cell phone number to which it was sent. The interface was changed to accommodate this functionality: after proposing a transaction, the representative has to introduce the PIN so the transaction is sent to ITL.

14 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

This chapter provides information on how Portugal is implementing its commitment under Article 3, paragraph 14 of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing countries.

Portugal's contribution to the minimization of the adverse effects of climate change in other Parties, particularly developing countries, is carried out first of all through a strong commitment to implementing the Convention and the Kyoto Protocol.

By working on the implementation of the Protocol, Portugal is struggling to minimize not only the adverse effects of climate change in specific sectors, industries or other Parties, but also any adverse effects due to the reduction of greenhouse gases. This is due to the development of different actions and implementation of different instruments conceived to promote sustainable development and the commitment to support developing countries.

The policies and measures implemented, adopted or foreseen in the National Plan for Climate Change (PNAC), targeting the six GHG of the Kyoto Protocol through its broad portfolio of instruments and wide-ranging coverage of all sectors of the economy, make up a significant effort by the Portuguese Government to address climate change, including the minimization of adverse effects of such policies.

The transition to a lower carbon Portuguese economy relies on the contribution of all sectors. Particularly, the Portuguese Energy Strategy relies to a great extent in the diversification of energy sources (including those referring to fossil fuels) and to the increase of endogenous resources (renewable). In some cases, the measures pertaining to the diversification of primary energy sources (namely shifting to natural gas), can simultaneously have positive effects on Portugal's emissions reduction and in the economy of some fossil fuel exporting countries.

As a member of the EU, Portugal also pursues the minimization of adverse effects of the policies and measures in this context through the implementation of activities such as the:

- EU Emissions Trading System (EU ETS): the EU's main policy mechanism for reducing CO₂ emissions from energy intensive sectors;
- Inclusion of aviation in the EU emission trading scheme which addresses the challenge of reducing emissions from this sector, and enables the creation of additional financial resources for climate change mitigation and adaptation in developing countries through the auction of emission allowances by member states;
- EU Renewables Directive (Directive 2009/28/EC): sets ambitious targets for each member state for the share of renewable energy generation by 2020 and the proportion of renewable energy in the transport sector (includes biofuels, biogas, hydrogen and electricity from renewables);
- Greenhouse Gas Effort Sharing Decision which sets targets for emissions reductions or growth limits in those sectors of Member States' economies not covered by the EU ETS (excluding Land Use, Land Use Change and Forestry);

- Roadmap for moving to a competitive low carbon economy in 2050, which outlines a strategy to meet the long-term target of reducing domestic emissions by 80 to 95% by 2050. Portugal is developing a national strategy to define the guidelines for the various sectors of activity and to serve as a supporting element for the preparation of future national plans for reducing emissions.
- (<http://www.apambiente.pt/index.php?ref=16&subref=81&sub2ref=117&sub3ref=303>)

Furthermore, the cooperation of Portugal with third countries looks to the integration of the adaptation dimension of climatic change in the several sectoral policies and instruments of planning, vulnerabilities and risks associates to climate change. The action of the Portuguese cooperation is developed on the basis of geographical priorities which are centered in the countries of Portuguese official language, in particular the PALOP and Timor East. All these countries are within the group of more vulnerable countries to the variations caused by climate changed either, because they are situated in its majority in Africa, or belong to the set of least developed countries and/or are small insular States.

At a multilateral level, Portugal supports the implementation of adaptation measures in the most vulnerable countries, in particular within the CPLP (Comunidade dos Países de Língua Portuguesa), and contributes to the adaptation fund, in the framework of the EU responsibilities. It also supports institutional capacity building within RELAC/CPLP (Rede Lusófona para as Alterações Climáticas).

At a bilateral level, assists ONGD (non-governmental organizations for development) projects in Angola, Cabo Verde, Guiné-Bissau, Moçambique e São Tomé e Príncipe; and promotes the sectoral integration the adaptation component in the Cooperation Programs, in particular in the scope of Superior education and of Research in the field of Environmental Engineering, Agriculture and Rural Development, and Health.

Table 14.1 - Climate Change related Official Development Assistance (ODA)

	2008	2009	2010
ODA (M €)	17.7	8.9	42.7

Source: IPAD

15 List of Acronyms

ABS	Acrylonitrile Butadiene Styrene	Acrilo Nitrilo Butadieno Estireno
AC	Air Conditioning	Ar condicionado
ACAP	Portuguese Association of Automobile Business	Associação do Comércio Automóvel de Portugal
AG	Aviation Gasoline	Gasolina de Aviação
AN	Ammonium Nitrate	Nitrato de Amónio
ANA	Airports and Air Navigation	Aeroportos e Navegação Aérea
ANAM	Madeira Island Airports and Air Navigation	Aeroportos e Navegação Aérea da Madeira
ANECRA	National Association of Companies of Automobile Business and Reparation	Associação Nacional das Empresas do Comércio e da Reparação Automóvel
APED	Portuguese Association of Distribution Companies	Associação Portuguesa de Empresas de Distribuição
APIRAC	National Association of Industry of Refrigeration and Air Conditioning	Associação Portuguesa dos Industriais da Refrigeração e Ar Condicionado
APORBET	Portuguese Association of Bituminous Mixes Producers	Associação Portuguesa de Fabricantes de Misturas Betuminosas
AS	Ammonium Sulphate	Sulfato de Amónia
ASN	Ammonium Sulphate Nitrate	Sulfonitrato de Amónia
BAT	Best Available Technologies	-
BOD	Biochemical Oxygen Demand	Carência Bioquímica de Oxigénio
BOF	Basic Oxygen Furnace	-
CAFE	Clean Air For Europe	-
CAN	Calcium Ammonium Nitrate	Nitrato de Cálcio-amónio
CCDR-LVT	Lisbon and Tagus Valley Coordination and Regional Development Commission	Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
CELPA	Portuguese Paper Industry Association	Associação da Indústria Papeleira
CFC	Chlorofluorocarbons	Clorofluorcarbonetos
CH ₄	Methane	Metano
CITEPA	Interprofessional Technical Center of Studies of Atmospheric Pollution	Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique
CKD	Cement Kiln Dust	-
CMN	Calcium Magnesium Nitrate	-
CN	Calcium Nitrate	Nitrato de Cálcio
CO	Carbon Monoxide	Monóxido de Carbono
CO ₂	Carbon Dioxide	Dióxido de Carbono ou anidrido carbónico
CO ₂ e	Carbon dioxide equivalente	Dióxido de carbono equivalente
COD	Chemical Oxygen Demand	Carência Química de Oxigénio
CONCAWE	-	-
Concelho	Portuguese territorial unit under the responsibility of a municipal authority	-
CORINAIR	Core Inventory Air Emissions	Inventário de Emissões Atmosféricas
CRF	Common Reporting Format	-
CTCV	Technological Centre for Ceramics and Glass	Centro Tecnológico da Cerâmica e do Vidro
DAP	Di-ammonium phosphate	-

DBH	Diameter at Breast Height	Diâmetro à Altura do Peito (DAP)
DC	Degradable Organic Component	Fracção Orgânica Degradável
DGA	General Directorate of Environment	Direcção Geral do Ambiente
DGF	General Directorate of Forests	Direcção-Geral das Florestas
DGEG (ex DGGE)	General Directorate for Energy and Geology	Direcção Geral de Energia e Geologia
DGAE (ex DGE)	Economic Activities General Directorate	Direcção Geral das Actividades Económicas
DGRF	General Directorate for Forestry Resources	Direcção Geral dos Recursos Florestais
DGTT	General Directorate of Terrestrial Transportation	Direcção Geral dos Transportes Terrestres
Distrito	Portuguese territorial unit comprehending several concelhos but not coincident with a region which is NUT II.	-
DOC	Degradable Organic Carbon	Carbono Orgânico Degradável
DOCF	Degradable Organic Carbon Dissimilated	-
DRAOT	Regional Directorate of Environment and Land Use Planning	Direcção Regional do Ambiente e Ordenamento do Território
EAF	Electric Arc Furnace	Forno Arco Eléctrico
EAPA	European Asphalt Pavement Association	-
EF	Emission Factors	Factores de Emissão
EMEP	Cooperative Programme for Monitoring and Evaluation of the Longrange Transmission of Air Pollutants in Europe	-
EPER	European Pollutant Emission Register	Registo Europeu de Emissões Poluentes
E-PRTR	European Pollutant Release and Transfer Register	-
FAEED	Federal Aviation Administration Aircraft Engine Emission Database	-
FAM	Animal Manure Nitrogen Applied to Soils	-
FAO	Food and Agriculture Organization of the United Nations	-
FCC	Fluidized-bed Catalytic Cracking	Cracking catalítico de leito fluidizado
FCR	Fixation in Crop Residues	-
FCT-UNL	Faculty of Science and Technology of New University of Lisbon	Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
FGR	Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that volatilises as NH ₃	-
FOD	First Order Decay	Decaimento de Primeira Ordem
FSN	Nitrogen in Synthetic Fertilizers	-
GASA	Analysis Group of Ambiental Systems	Grupo de Análises de Sistemas Ambientais
GCV	Gross Calorific Value	-
GHG	Green House Gases	Gases Com Efeito de Estufa
GHV	Gross Heating Value	Poder Calorífico Superior
GIC	Large Combustion Plants (LCP)	Grandes Instalações de Combustão
GPG	Good Practice Guidance	-
GWP	Global Warming Potential	-
H ₂ S	Hydrogen Sulfide	Sulfureto de Hidrogénio

HCFC	Hydrochlorofluorocarbons	-
HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias
HFC	Hydrofluorocarbons	-
APA	Portuguese Environmental Agency	Agência Portuguesa do Ambiente
IAIT	Annual Survey to Manufacturing Industry	Inquérito Anual à Indústria Transformadora
IAPI	Annual Survey to Industrial Production	Inquérito Anual à Produção Industrial
ICAO	International Civil Aviation Organization	
IEF	Implied Emission Factors	Factores de Emissão Implícitos
IEP	Portuguese Road Institute	Instituto de Estradas de Portugal
IFADAP	Institute for Financing and Support of Development of Agriculture and Fisheries	Instituto de Financiamento e Apoio ao Desenvolvimento da Agricultura e das Pescas
IFRAA	Forestry Inventory of the Autonomous Region of Azores	Inventário Florestal da Região Autónoma dos Açores
IFRAM	Forestry Inventory of the Autonomous Region of Madeira	Inventário Florestal da Região Autónoma da Madeira
IMTT (ex. DGV)	Institute for Mobility and Terrestrial Transportation	Instituto da Mobilidade e dos Transportes Terrestres
INAG	National Water Institute	Instituto da Água
INE	National Statistics Institute	Instituto Nacional de Estatística
INR	National Wastes Institute	Instituto Nacional de Resíduos
INRA	National Institute for Agronomic Investigation (France)	Institut National de la Recherche Agronomique (França)
IPCC	Intergovernmental Panel on Climate Change	-
ISP	Portuguese Insurance Institute	Instituto de Seguros de Portugal
IST-UTL	Technical Superior Institute - Lisbon Technical University	Instituto Superior Técnico - Universidade Técnica de Lisboa
JP	Jet Fuel	-
LCP	Large Combustion Plants (the same as GIC)	o mesmo que GIC
LDPE	Low Density Poly Ethylene	Polietileno de Baixa Densidade (PEBD)
LDV	Light Duty Vehicles	Veículos Ligeiros de Mercadorias
LNG	Liquified Natural Gas	Gás Natural Liquefeito
LOSP	Light Organic Solvent-based Preservatives	-
LPS	Large Point Sources (Corinair definition)	Grandes Fontes Poluidoras
LRTAP	Long-range Transboundary Air Pollution	Poluição Atmosférica Transfronteiras a Longa Distância
LTO	Landing and Take-off	Aterragens e Descolagens
LUCF	Land-use Change and Forestry	Alteração do Uso do Solo e Florestas
LULUCF	Land Use, Land-use Change and Forestry	Uso do Solo, Alteração do Uso do Solo e Florestas
MAC	Mobile Air-conditioning systems	-
MADRP	Ministry of Agriculture, Rural Development and Fisheries (changed to MAMAOT)	Ministério da Agricultura, Desenvolvimento Rural e Pescas (changed to MAMAOT)
MAMAOT	Ministry for Agriculture, Sea, Environment and Land Use Planning	Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território
MAOT	Ministry of Environment and Land Use Planning (changed to MAMAOT)	Ministério do Ambiente e Ordenamento do Território (changed to MAMAOT)
MCF	Methane Conversion Factor	Factor de Conversão de Metano

MCOTA	Ministry of Urban Affairs, Land Use Planning and Environment (older name of Ministry of Environment)	Ministério das Cidades, Ordenamento do Território e Ambiente (older name of Ministry of Environment)
MDI	Metered Dose Inhalers	-
MEET	Methodologies For Estimating Air Pollutant Emissions From Transport	-
MMS	Manure Management Systems	Sistema de Gestão de Estrumes
MSW	Municipal Solid Wastes	Resíduos Sólidos Municipais
MTBE	Methyl Tertiary Butyl Ether	Metil-Ter-Butil-Éter
Na ₂ S	Sodium Sulphide	Sulfureto de Sódio
NaOH	Sodium Hydroxide	Hidróxido de Sódio
NATO	North Atlantic Treaty Organisation	Organização do Tratado do Atlântico Norte
NAV	National Entity responsible for air traffic	Navegação Aérea
NCV	Net Calorific Value	-
NFI	National Forestry Inventories	Inventário Florestal Nacional
NFR	New Format Reporting	-
NH ₃	Ammoniac	Amoníaco
NMVOC	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NO _x	Nitrogen Oxides (NO + NO ₂)	Óxidos de Azoto (NO+NO ₂)
NPK	Nitrogen, Phosphorus and Potassium	Nitrogénio, Fósforo e Potássio
NSS	Normal Super Phosphates	Superfosfatos simples
NUTS (0..III)	Nomenclature of Territorial Units for Statistics	Nomenclatura de Unidades Territoriais para fins estatísticos
OD	Origin - Destiny	Origem - Destino
ODS	Ozone Depleting Substances	-
OECD	Organization for Economic Co-operation and Development	Organização para a Cooperação e Desenvolvimento Económico (OCDE)
OX	Oxidation Factor	Factor de Oxidação
PAF	Florestal Action Program	Programa de Acção Florestal
PAH	Polycyclic Aromatic Hydrocarbons	Hidrocarbonetos Aromáticos Policíclicos
PCI	Low Heating Value (LHV)	Poder Calorífico Inferior
PEN	National Energetic Program	Plano Energético Nacional
PER	Perchloro-ethylene	Percloroetileno
PERSU	Strategic Plan on Municipal Solid Wastes	Plano Estratégico dos Resíduos Sólidos Urbanos
PETROGAL	Portuguese Petroleum Company	Empresa de Petróleos de Portugal
PFC	Perfluorinated Hidrocarbons	-
PM ₁	Particles with Aerodynamic Diameter smaller than 1 micrometer	Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro
PM ₁₀	Particles with Aerodynamic Diameter smaller than 10 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros
PM _{2.5}	Particles with Aerodynamic Diameter smaller than 2.5 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 2.5 micrómetros
PNAC	National Climate Change Program	Programa Nacional para as Alterações Climáticas
PNPA	National Plan for Environmental Policy	Plano Nacional da Política de Ambiente
PP	Poly Propylene	Polipropileno

PS	Poly Styrene	Poliestireno
PTEN	National Emission Ceilings Program	Programa para os Tectos de Emissão Nacional
PVC	Poly Vinyl Chloride	Cloreto de Polivinil
RA	Agricultural Region	Região Agrária
REN	National Electric System	Rede Eléctrica Nacional
RVP	Reid Vapour Pressure	Pressão de Vapor de Reid
SF6	Sulphur Hexafluoride	Hexafluoreto de Enxofre
SNIERPA	National System of Inventories of Emissions and Remotions of Atmospheric Pollutants	Sistema Nacional de Inventários de Emissões e Remoções de Poluentes Atmosféricos
SOx	Sulphur Oxides	Óxidos de Enxofre
SW	Solid Wastes	Resíduos Sólidos
SWDS	Solid Waste Disposal Sites	Locais para Deposição de Resíduos Sólidos
TANKS	Software designed to estimate air emissions from organic liquids in storage tanks (USEPA, September 27, 2001)	Software criado para a estimativa de emissões atmosféricas a partir de líquidos orgânicos em tanques de armazenamento (USEPA, 27 de Setembro de 2001)
TNT	Trinitrotoluene	Trinitrotolueno
TOE	Tons of oil equivalent	Toneladas Equivalentes de Petróleo (TEP)
TOW	Total Organic Waste	Resíduo Orgânico Total
TRANSGÁS	Portuguese Company of Natural Gas	Sociedade Portuguesa de Gás Natural (Empresa)
TSP	Total Suspended Particles	Partículas Totais em Suspensão
TSS	Triple Super Phosphates	Superfosfatos Triplos
UNECE	United Nations Economic Commission for Europe	-
UNFCCC	United Nations Framework Convention on Climate Change	Convenção Quadro das Nações Unidas para as Alterações Climáticas
USEPA	United States Environmental Protection Agency	Agência de Protecção Ambiental dos Estados Unidos da América
VCM	Vinyl Chloride Monomer	Monómero de Cloreto de Vinilo
VOC	Volatile Organic Compounds	Compostos Orgânicos Voláteis
VRF	Vacuum Residual Fuel Oil	Resíduo de Alto Vácuo
WWH	Wastewater Handling	Tratamento de Águas Residuais
ZA	Agricultural Zone	Zona Agrária

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ANNEX A: Key Category Analysis

A.1 Introduction

This chapter provides an analysis of key categories following recommendations of the IPCC Good Practice Guidance (IPCC 2000) and IPCC Good Practice Guidance for LULUCF (IPCC 2003). A key category (source or sink) “is one that is prioritised within the national inventory system because its estimate has a significant influence on a country’s total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.” The aim of defining key categories is the improvement of the inventory’s accuracy. As key categories are the most important sources or removals in terms of their contribution to the absolute level of national emissions, the identification of these categories enables the prioritisation of national efforts and a more efficient use of available resources in order to reach an improvement of national estimates. Information on key categories is also important for the development of policies and measures for emissions reduction.

IPCC Good Practice Guidance (IPCC 2000) purposes several methods for performing key source analysis, which are:

- Tier 1 approach (level and trend assessments);
- Tier 2 approach (level and trend assessments with uncertainty analysis);
- Qualitative approach.

A.2 Methodology for key source identification: Portuguese inventory

Having as a basis the 2012 Portuguese inventory estimates (1990-2010), the determination of key categories was conducted using the Tier 2 including LULUCF.

Tier 2 - Level assessment

The level assessment is based on the quantified uncertainties presented in the introduction, according to the equation:

Level Assessment with Uncertainty= Tier 1 Level Assessment • Relative category Uncertainty

$$LU_{x,t} = L_{x,t} \bullet U_{x,t}$$

Where,

$LU_{x,t}$ = Level Assessment with Uncertainty

$L_{x,t}$ = calculated as in Tier 1 equation

$U_{x,t}$ = relative category uncertainty in the year t

Tier 2 - Trend assessment

The trend assessment is based according to the equation:

Trend Assessment with Uncertainty= Tier 1 Trend Assessment • Relative category Uncertainty

$$TU_{x,t} = T_{x,t} \bullet U_{x,t}$$

Where,

$TU_{x,t}$ = Trend Assessment with Uncertainty

$T_{x,t}$ = calculated as in Tier 1 equation

$U_{x,t}$ = relative category uncertainty in the year t

The key categories are those that add up to 90% of the total value of either $LU_{x,t}$ and $TU_{x,t}$.

A.3 Presentation of results

Key category analysis can be very influenced by the definitions of source categories (extent of the split). If a large category is broken into many subcategories, then these subcategories may not have a significant contribution to the total inventory to be considered as a key source. On the opposite, several non-key sources categories may become key source categories if aggregated into a unique source category.

In a general way, the source and removal categories have been split into (sub) categories that have been estimated using the same methodology and emission factors.

Following the recommendations from the ERT report, LULUCF and Agricultural sectors have been disaggregated according to the IPCC GPG (IPCC 2000 and 2003).

The analysis was based on the application of Tier 2 method with the LULUCF sector and resulted in the identification of 55 key categories.

Table A-1 presents a summary of identified key categories for 1990-2010 using Tier 2 analysis including LULUCF, and the criteria used (level, trend) in the identification.

Three other tables are presented, Tables A-2.1 to A-2.3 for 1990 and 2010 inventory year's level assessment and trend assessment for 1990-2010.

Table A. 1 – Portuguese key categories (1990-2010) based on Tier 2 with LULUCF

KEY SOURCE CATEGORY ANALYSIS (Tier 2 Approach)

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identificat	Comments on level assessment	2010 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	8,046.5
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level Trend	All years	6,002.4
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	2004, 2005, 2006, 2007, 2008, 2009, 2010	4,703.8
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level	All years	3,376.3
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level	All years	3,361.2
6 A Municipal SWDL	SW Disposal on Land	CH ₄	✓	Level Trend	All years	3,070.0
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level	All years	2,766.5
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	✓	Level Trend	All years	2,052.2
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Level Trend	2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	1,907.5
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1,855.9
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level	1990, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	1,841.3
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level	All years	1,512.7
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	All years	1,507.4
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	1,171.5
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1,102.4
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1,064.8
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	1990	1,057.7
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2005	1,037.7
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007	767.3
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	756.3
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2009, 2010	544.0
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	✓	Level Trend	All years	492.6
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	✓	Level	All years	487.5
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2010	474.3
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	All years	431.5
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level	1990, 1995, 1996, 1997, 1998	398.2
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level	2010	391.9
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend	2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	214.5
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	✓	Level Trend	All years	203.1
1A 4 b Residential	Biomass	CH ₄	✓	Level Trend	All years	187.6
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	158.0
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	✓	Level	1991, 2003, 2005	157.1
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	128.7
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend	All years	90.1
1B 2 b Natural gas	Gaseous Fuels	CO ₂	✓	Trend		71.3
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO ₂	✓	Level	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	62.4
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend	1991, 1992, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2006	56.9
5 B 2 Land converted to Cropland	Emissions/Removals	N ₂ O	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	49.3
2 F 2 Foam Blowing	Consumption	HFC	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008, 2009	47.7
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend	All years	39.7
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	36.3
1A 2 f Other	Biomass	N ₂ O	✓	Level	1990, 1991, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	27.6
1A 1a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level Trend	All years	27.2
1A 1a Public Electricity and Heat Production	Biomass	N ₂ O	✓	Level Trend	2000, 2003, 2005, 2006, 2007, 2008, 2009, 2010	26.7
2 C 1 Iron and Steel Production	Production Quantities	CO ₂	✓	Trend		17.7
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		14.5
1A 1a Public Electricity and Heat Production	Other Fuels	N ₂ O	✓	Trend		12.6
2 F 8 Electrical Equipment	Consumption	SF ₆	✓	Trend		7.1
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level	All years	3.5
1A 1a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1992	2.5
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	1990, 1999, 2000, 2001, 2003, 2004, 2005, 2007, 2008	0.0
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	✓	Level	2010	-546.3
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-729.8
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-2,951.4
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-8,199.5
Sub-total with LULUCF		All gases				51,396.4
% of total with LULUCF		All gases				84.6
TOTAL EMISSIONS WITH LULUCF		All gases				60,719.0

Table A. 2 – Tier 2 Level assessment with LULUCF: 1990

Tier 2 Level Assessment (1990)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO ₂ eq.) 1990	Current year Estimate (kton CO ₂ eq.) 1990	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 Da AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	2127	2127	0.03	500.28	15.12	0.30	0.30
6 A 3 Industrial SWDL	Industrial Waste Disposal	CH ₄	1599	1599	0.02	149.82	3.41	0.07	0.36
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-3328	-3328	0.05	64.09	3.03	0.06	0.42
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	161	161	0.00	1000.33	2.29	0.04	0.47
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	-3409	-3409	0.05	47.24	2.29	0.04	0.51
1 A 4 c Agriculture/ Forestry / Fishing	Liquid Fuels	CO ₂	153	153	0.00	1000.05	2.18	0.04	0.56
4 Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	1333	1333	0.02	113.05	2.14	0.04	0.60
6 A Municipal SWDL	SW Disposal on Land	CH ₄	1433	1433	0.02	67.27	1.37	0.03	0.62
1 A 4 b Residential	Biomass	N ₂ O	73	73	0.00	1001.80	1.03	0.02	0.64
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1184	1184	0.02	60.90	1.02	0.02	0.66
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	1094	1094	0.02	64.09	1.00	0.02	0.68
1 A 3 b Road Transportation	All Fuels	CO ₂	9476	9476	0.13	7.07	0.95	0.02	0.70
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1425	1425	0.02	44.16	0.89	0.02	0.72
4 A ENTERIC FERMENTATION	Population size	CH ₄	2664	2664	0.04	20.90	0.79	0.02	0.74
1 A 4 b Residential	Biomass	CH ₄	343	343	0.00	161.55	0.79	0.02	0.75
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	1056	0.02	48.28	0.72	0.01	0.77
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	-813	-813	0.01	64.09	0.74	0.01	0.78
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	813	813	0.01	59.36	0.69	0.01	0.79
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7913	7913	0.11	5.10	0.57	0.01	0.80
1 A 2 f Other	Liquid Fuels	CO ₂	3361	3361	0.05	11.18	0.53	0.01	0.82
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	36	0.00	1000.00	0.51	0.01	0.83
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6405	6405	0.09	5.10	0.46	0.01	0.83
2 A 1 Cement Production	Production Quantities	CO ₂	3176	3176	0.05	10.10	0.46	0.01	0.84
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	3	0.00	10000.05	0.37	0.01	0.85
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	388	388	0.01	64.09	0.35	0.01	0.86
1 A 2 f Other	Solid Fuels	CO ₂	2126	2126	0.03	11.18	0.34	0.01	0.86
1 A 3 a ii Domestic	Liquid Fuels	CO ₂	228	228	0.00	100.11	0.32	0.01	0.87
1 A 2 f Other	Biomass	N ₂ O	21	21	0.00	1001.80	0.30	0.01	0.88
2 A 2 Lime Production	Production Quantities	CO ₂	194	194	0.00	105.34	0.29	0.01	0.88
1 A 4 c Agriculture/ Forestry / Fishing	Liquid Fuels	CO ₂	1661	1661	0.02	11.18	0.26	0.01	0.89
1 A 4 b Residential	Liquid Fuels	CO ₂	1660	1660	0.02	11.18	0.26	0.01	0.89
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	569	0.01	31.57	0.26	0.01	0.90
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	15	0.00	1000.00	0.22	0.00	0.90
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	182	182	0.00	76.16	0.20	0.00	0.91
1 A 3 d ii National navigation	Liquid Fuels	CO ₂	260	260	0.00	50.64	0.19	0.00	0.91
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	227	0.00	53.62	0.17	0.00	0.91
1 A 2 d Pulp, Paper and Print	Biomass	N ₂ O	12	12	0.00	1000.00	0.16	0.00	0.92
1 A 4 b Residential	Liquid Fuels	N ₂ O	11	11	0.00	1000.05	0.16	0.00	0.92
1 A 2 f Other	Liquid Fuels	N ₂ O	11	11	0.00	1000.05	0.16	0.00	0.92
1 A 1 b Petroleum refining	Liquid Fuels	CO ₂	1910	1910	0.03	5.10	0.14	0.00	0.92
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	821	821	0.01	11.18	0.13	0.00	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	302	302	0.00	30.41	0.13	0.00	0.93
1 A 1 b Petroleum refining	Liquid Fuels	N ₂ O	9	9	0.00	1000.00	0.13	0.00	0.93
5 B 2 Land converted to Cropland	Emissions/Removals	N ₂ O	17	17	0.00	502.49	0.12	0.00	0.93
1 A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	746	746	0.01	11.18	0.12	0.00	0.94
1 A 2 c Chemicals	Liquid Fuels	CO ₂	1373	1373	0.02	5.83	0.11	0.00	0.94
1 B 1 a Coal Mining	Solid Fuels	CH ₄	66	66	0.00	100.12	0.09	0.00	0.94
1 A 2 c Chemicals	Liquid Fuels	N ₂ O	6	6	0.00	1000.00	0.09	0.00	0.94
2 B 5 Other	Production Quantities	CO ₂	63	63	0.00	100.50	0.09	0.00	0.94
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	95	95	0.00	64.09	0.09	0.00	0.95
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO ₂	56	56	0.00	1000.05	0.79	0.02	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N ₂ O	5	5	0.00	1001.80	0.08	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	518	518	0.01	10.05	0.07	0.00	0.96
1 B 2 a Oil	Liquid Fuels	CH ₄	51	51	0.00	100.08	0.07	0.00	0.97
1 A 2 f Other	Solid Fuels	N ₂ O	5	5	0.00	1000.05	0.07	0.00	0.97
1 B 2 a Oil	Liquid Fuels	CO ₂	92	92	0.00	50.16	0.07	0.00	0.97
2 A 7 Other	Production Quantities	CO ₂	81	81	0.00	113.66	0.13	0.00	0.97
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	746	746	0.01	5.83	0.06	0.00	0.97
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-104	-104	0.00	40.61	0.06	0.00	0.97
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	33	0.00	105.02	0.05	0.00	0.97
1 A 3 b Road Transportation	All Fuels	CH ₄	85	85	0.00	40.31	0.05	0.00	0.98
1 A 3 b Road Transportation	All Fuels	N ₂ O	67	67	0.00	50.25	0.05	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO ₂	96	96	0.00	262.39	0.36	0.01	0.98
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	526	526	0.01	6.05	0.05	0.00	0.98
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH ₄	30	30	0.00	101.98	0.04	0.00	0.99
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	N ₂ O	37	37	0.00	76.16	0.04	0.00	0.99
1 A 2 a Iron and Steel	Solid Fuels	CO ₂	466	466	0.01	5.83	0.04	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO ₂	49	49	0.00	50.09	0.03	0.00	0.99
1 A 4 a Commercial / Institutional	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.03	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.03	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N ₂ O	22	22	0.00	101.98	0.03	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N ₂ O	2	2	0.00	1001.27	0.03	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	N ₂ O	2	2	0.00	1004.99	0.03	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO ₂	2	2	0.00	1000.05	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N ₂ O	2	2	0.00	1000.00	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH ₄	10	10	0.00	150.03	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N ₂ O	1	1	0.00	1000.00	0.02	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO ₂	176	176	0.00	7.07	0.02	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH ₄	8	8	0.00	150.33	0.02	0.00	0.99
1 A 5 Other	Liquid Fuels	CO ₂	95	95	0.00	11.18	0.02	0.00	0.99
3 D OTHER	Other Use of Chemicals	N ₂ O	99	99	0.00	25.00	0.04	0.00	0.99
1 A 2 a Iron and Steel	Liquid Fuels	CO ₂	155	155	0.00	5.83	0.01	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CO ₂	9	9	0.00	100.12	0.01	0.00	0.99
2 B 5 Other	Production Quantities	CH ₄	8	8	0.00	100.50	0.01	0.00	0.99
1 A 5 Other	Liquid Fuels	N ₂ O	1	1	0.00	1000.05	0.01	0.00	1.00

Table A. 3 – Tier 2 Level assessment with LULUCF: 2010

Tier 2 Level Assessment (2010)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.)	Current year Estimate (kton CO2 eq.)	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 Da AGRICULTURAL SOILS, Direct Emissions	Inout to soils	N2O	2127	1856	0.02	500.28	10.72	0.22	0.22
5 A1 Forest Land remaining Forest Land	Emissions/Removals	CO2	-3409	-8200	0.09	47.24	4.47	0.09	0.31
6 A3 Industrial SWDL	Industrial Waste Disposal	CH4	1599	1507	0.02	149.82	2.61	0.05	0.36
6 A Municipal SWDL	SW Disposal on Land	CH4	1433	3070	0.04	67.27	2.38	0.05	0.41
6 B1 Industrial Wastewater	Wastewater	N2O	161	203	0.00	1000.30	2.35	0.05	0.45
5 A2 Land converted to Forest Land	Emissions/Removals	CO2	-3328	-2951	0.03	64.09	2.18	0.04	0.50
5 E2 Land converted to Settlements	Emissions/Removals	CO2	1094	2052	0.02	64.09	1.52	0.03	0.53
1 B2 d Other (Geothermal)	Energy Production	CO2	2	129	0.00	1000.05	1.49	0.03	0.56
1 A3 b Road Transportation	All Fuels	CO2	9476	18046	0.21	7.07	1.47	0.03	0.59
4 Db AGRICULTURAL SOILS, Indirect Emissions	Inout to soils	N2O	1333	1102	0.01	113.05	1.44	0.03	0.62
2 F1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	1171	0.01	99.29	1.34	0.03	0.65
1 A4 c Agriculture/ Forestry / Fishing	Liquid Fuels	N2O	153	90	0.00	1000.05	1.04	0.02	0.67
1 B2 b Natural gas	Gaseous Fuels	CH4	0	544	0.01	150.33	0.94	0.02	0.69
6 B1 Industrial Wastewater	Wastewater	CH4	1425	1513	0.02	43.88	0.77	0.02	0.70
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1184	1065	0.01	60.90	0.75	0.02	0.72
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO2	56	62	0.00	1000.05	0.72	0.01	0.73
4 A ENTERIC FERMENTATION	Population size	CH4	2664	2766	0.03	20.90	0.67	0.01	0.74
5 F2 Land converted to Other Land	Emissions/Removals	CO2	-813	-730	0.01	64.09	0.54	0.01	0.75
2 A2 Lime Production	Production Quantities	CO2	194	431	0.00	105.34	0.52	0.01	0.77
1 A4 b Residential	Biomass	N2O	73	40	0.00	1001.80	0.46	0.01	0.77
1 A2 f Other	Liquid Fuels	CO2	3361	3361	0.04	11.18	0.43	0.01	0.78
6 B2 Domestic and Commercial wastewater	Wastewater	CH4	1056	756	0.01	48.28	0.42	0.01	0.79
1 A1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	36	0.00	1000.00	0.42	0.01	0.80
2 A6 Road Paving with Asphalt	Production Quantities	CO2	3	4	0.00	10000.05	0.41	0.01	0.81
5 C2 Land converted to Grassland	Emissions/Removals	CO2	95	-546	0.01	64.09	0.40	0.01	0.82
2 A1 Cement Production	Production Quantities	CO2	3176	3376	0.04	10.10	0.39	0.01	0.82
5 D2 Land converted to Wetlands	Emissions/Removals	CO2	388	487	0.01	64.09	0.36	0.01	0.83
1 A1 a Public Electricity and Heat Production	Solid Fuels	CO2	7913	6002	0.07	5.10	0.35	0.01	0.84
1 A4 b Residential	Biomass	CH4	343	188	0.00	161.55	0.35	0.01	0.85
5 B2 Land converted to Cropland	Emissions/Removals	CO2	813	493	0.01	59.36	0.34	0.01	0.85
1 A2 f Other	Biomass	N2O	21	28	0.00	1001.80	0.32	0.01	0.86
1 A1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	27	0.00	1000.00	0.31	0.01	0.87
1 A1 a Public Electricity and Heat Production	Biomass	N2O	0	27	0.00	1000.00	0.31	0.01	0.87
5 B2 Land converted to Cropland	Emissions/Removals	N2O	17	49	0.00	502.49	0.29	0.01	0.88
2 A7 Other	Production Quantities	CO2	81	214	0.00	113.66	0.28	0.01	0.88
1 A1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	4704	0.05	5.10	0.28	0.01	0.89
1 B2 a Oil	Liquid Fuels	CO2	92	474	0.01	50.16	0.27	0.01	0.89
1 A2 f Other	Gaseous Fuels	CO2	0	1908	0.02	11.18	0.25	0.00	0.90
4 C RICE CULTIVATION	Culture Surface	CH4	227	392	0.00	53.62	0.24	0.00	0.90
2 F2 Foam Blowing	Consumption	HFC	0	48	0.00	435.48	0.24	0.00	0.91
1 A4 b Residential	Liquid Fuels	CO2	1660	1841	0.02	11.18	0.24	0.00	0.91
1 A2 d Pulp, Paper and Print	Biomass	N2O	12	15	0.00	1000.00	0.17	0.00	0.92
3 A PAINT APPLICATION	Paint application	CO2	96	57	0.00	262.39	0.17	0.00	0.92
1 A2 f Other	Gaseous Fuels	N2O	0	14	0.00	1000.05	0.17	0.00	0.92
5 B1 Cropland remaining Cropland	Emissions/Removals	CO2	-104	-323	0.00	40.61	0.15	0.00	0.93
1 A4 b Residential	Liquid Fuels	N2O	11	13	0.00	1000.05	0.15	0.00	0.93
1 A1 a Public Electricity and Heat Production	Other Fuels	N2O	0	13	0.00	1000.00	0.15	0.00	0.93
5 A1 Forest Land remaining Forest Land	Emissions/Removals	CH4	182	157	0.00	76.16	0.14	0.00	0.94
1 A4 c Agriculture/ Forestry / Fishing	Liquid Fuels	CO2	1661	1058	0.01	11.18	0.14	0.00	0.94
6 B2 Domestic and Commercial wastewater	Wastewater	N2O	302	381	0.00	30.41	0.13	0.00	0.94
1 A3 d ii National navigation	Liquid Fuels	CO2	260	227	0.00	50.64	0.13	0.00	0.94
2 B5 Other	Production Quantities	CO2	63	109	0.00	100.50	0.13	0.00	0.95
1 B2 b Natural gas	Gaseous Fuels	CO2	0	71	0.00	150.33	0.12	0.00	0.95
1 A3 b Road Transportation	All Fuels	N2O	67	175	0.00	50.25	0.10	0.00	0.95
1 A1 b Petroleum refining	Liquid Fuels	CO2	1910	1724	0.02	5.10	0.10	0.00	0.95
1 A1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1000.00	0.10	0.00	0.96
1 A4 c Agriculture/ Forestry / Fishing	Biomass	N2O	0	9	0.00	1001.80	0.10	0.00	0.96
1 A2 f Other	Liquid Fuels	N2O	11	9	0.00	1000.05	0.10	0.00	0.96
1 A4 a Commercial / Institutional	Liquid Fuels	CO2	746	767	0.01	11.18	0.10	0.00	0.96
3 D OTHER	Other Use of Chemicals	CO2	70	78	0.00	103.08	0.09	0.00	0.96
1 A2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	821	669	0.01	11.18	0.09	0.00	0.97
1 A4 b Residential	Gaseous Fuels	CO2	0	639	0.01	11.18	0.08	0.00	0.97
1 A4 a Commercial / Institutional	Gaseous Fuels	CO2	0	559	0.01	11.18	0.07	0.00	0.97
2 A3 Limestone and Dolomite Use	Production Quantities	CO2	33	57	0.00	105.02	0.07	0.00	0.97
1 B2 a Oil	Liquid Fuels	CH4	51	56	0.00	100.08	0.06	0.00	0.97
1 A2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	6	0.00	1000.00	0.06	0.00	0.97
1 A1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6405	1038	0.01	5.10	0.06	0.00	0.97
1 A2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.06	0.00	0.97
1 A4 b Residential	Gaseous Fuels	N2O	0	5	0.00	1000.05	0.06	0.00	0.98
1 A2 c Chemicals	Liquid Fuels	CO2	1373	774	0.01	5.83	0.05	0.00	0.98
1 A2 f Other	Other Fuels	N2O	0	4	0.00	1000.05	0.05	0.00	0.98
1 A1 b Petroleum refining	Gaseous Fuels	N2O	0	4	0.00	1000.00	0.05	0.00	0.98
1 A2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	393	0.00	11.18	0.05	0.00	0.98
1 A4 a Commercial / Institutional	Gaseous Fuels	N2O	0	4	0.00	1000.05	0.05	0.00	0.98
1 A2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	708	0.01	5.83	0.05	0.00	0.98
1 A2 c Chemicals	Liquid Fuels	N2O	6	4	0.00	1000.00	0.05	0.00	0.98
1 A2 c Chemicals	Gaseous Fuels	N2O	0	4	0.00	1000.00	0.04	0.00	0.98
1 A3 a ii Domestic	Liquid Fuels	N2O	2	3	0.00	1000.00	0.04	0.00	0.98
1 A2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	3	0.00	1000.05	0.04	0.00	0.99
2 B2 Nitric Acid Production	Production Quantities	N2O	518	296	0.00	10.05	0.03	0.00	0.99
1 A1 b Petroleum refining	Gaseous Fuels	CO2	0	568	0.01	5.10	0.03	0.00	0.99
1 A2 c Chemicals	Gaseous Fuels	CO2	0	492	0.01	5.83	0.03	0.00	0.99
1 A1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	3	0.00	1000.00	0.03	0.00	0.99
1 A4 a Commercial / Institutional	Liquid Fuels	N2O	2	3	0.00	1000.05	0.03	0.00	0.99
5 A1 Forest Land remaining Forest Land	Emissions/Removals	N2O	37	32	0.00	76.16	0.03	0.00	0.99
1 A2 f Other	Gaseous Fuels	CH4	0	16	0.00	150.33	0.03	0.00	0.99
1 A2 d Pulp, Paper and Print	Liquid Fuels	CO2	746	378	0.00	5.83	0.03	0.00	0.99
1 A2 f Other	Other Fuels	CO2	12	196	0.00	11.18	0.03	0.00	0.99
1 A1 a Public Electricity and Heat Production	Other Fuels	CO2	0	423	0.00	5.10	0.02	0.00	0.99
1 A2 c Chemicals	Biomass	N2O	1	2	0.00	1000.00	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	30	20	0.00	101.98	0.02	0.00	0.99
1 A3 a ii Domestic	Liquid Fuels	CO2	228	398	0.00	5.00	0.02	0.00	0.99
1 B2 c Venting and flaring	Liquid Fuels	CO2	49	39	0.00	50.09	0.02	0.00	0.99
1 A2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.02	0.00	0.99
1 A3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1001.27	0.02	0.00	0.99

Table A. 4 – Tier 2 Trend assessment with LULUCF: 1990-2010

Tier 2 Trend Assessment (1990-2010)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO ₂ eq.) 1990	Current year Estimate (kton CO ₂ eq.) 2010	Trend Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N ₂ O	2127	1856	0.01	500.28	4.13	0.13	0.13
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-3328	-2951	0.05	64.09	3.51	0.11	0.24
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	-3409	-8200	0.06	47.24	2.65	0.08	0.32
1 B 2 d Other (Geothermal)	Energy Production	CO ₂	2	129	0.00	1000.05	1.82	0.06	0.38
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	1171	0.02	99.29	1.68	0.05	0.43
6 A Municipal SWDL	SW Disposal on Land	CH ₄	1433	3070	0.02	67.27	1.39	0.04	0.47
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	153	90	0.00	1000.05	1.22	0.04	0.51
1 B 2 b Natural gas	Gaseous Fuels	CH ₄	0	544	0.01	150.33	1.18	0.04	0.54
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	-813	-730	0.01	64.09	0.86	0.03	0.57
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	1094	2052	0.01	64.09	0.74	0.02	0.59
1 A 3 b Road Transportation	All Fuels	CO ₂	9476	18046	0.10	7.07	0.74	0.02	0.62
6 A 3 Industrial SWDL	Industrial Waste Disposal on	CH ₄	1599	1507	0.00	149.82	0.69	0.02	0.64
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N ₂ O	1333	1102	0.01	113.05	0.68	0.02	0.66
1 A 4 b Residential	Biomass	N ₂ O	73	40	0.00	1001.80	0.63	0.02	0.68
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	0	36	0.00	1000.00	0.52	0.02	0.70
1 A 4 b Residential	Biomass	CH ₄	343	188	0.00	16.55	0.48	0.01	0.71
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6405	1038	0.09	5.10	0.46	0.01	0.72
1 A 1 a Public Electricity and Heat Production	Biomass	N ₂ O	0	27	0.00	1000.00	0.38	0.01	0.74
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	813	493	0.01	59.36	0.37	0.01	0.75
1 A 2 f Other	Solid Fuels	CO ₂	2126	158	0.03	11.18	0.37	0.01	0.76
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	0	4704	0.07	5.10	0.35	0.01	0.77
2 A 2 Lime Production	Production Quantities	CO ₂	194	431	0.00	105.34	0.32	0.01	0.78
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	756	0.01	48.28	0.31	0.01	0.79
1 A 2 f Other	Gaseous Fuels	CO ₂	0	1908	0.03	11.18	0.31	0.01	0.80
2 F 2 Foam Blowing	Consumption	HFC	0	48	0.00	435.48	0.30	0.01	0.81
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	0	0.01	3157	0.30	0.01	0.82
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	161	203	0.00	1000.30	0.28	0.01	0.83
1 B 2 a Oil	Liquid Fuels	CO ₂	92	474	0.01	50.16	0.27	0.01	0.83
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1184	1065	0.00	60.90	0.25	0.01	0.84
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7913	6002	0.04	5.10	0.22	0.01	0.85
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	3	0.00	1000.00	0.22	0.01	0.86
5 B 2 Land converted to Cropland	Emissions/Removals	N ₂ O	17	49	0.00	502.49	0.21	0.01	0.86
1 A 2 f Other	Gaseous Fuels	N ₂ O	0	14	0.00	1000.05	0.21	0.01	0.87
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	27	0.00	1000.00	0.20	0.01	0.88
2 A 7 Other	Production Quantities	CO ₂	81	214	0.00	113.66	0.20	0.01	0.88
3 A PAINT APPLICATION	Paint application	CO ₂	96	57	0.00	262.39	0.20	0.01	0.89
1 A 1 a Public Electricity and Heat Production	Other Fuels	N ₂ O	0	13	0.00	1000.00	0.18	0.01	0.89
1 B 2 b Natural gas	Gaseous Fuels	CO ₂	0	71	0.00	150.33	0.15	0.00	0.90
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	1661	1058	0.01	11.18	0.14	0.00	0.90
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N ₂ O	0	9	0.00	1001.80	0.13	0.00	0.91
1 B 1 a Coal Mining	Solid Fuels	CH ₄	66	0	0.00	100.12	0.11	0.00	0.91
1 A 4 b Residential	Gaseous Fuels	CO ₂	0	639	0.01	11.18	0.10	0.00	0.91
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	392	0.00	53.62	0.10	0.00	0.92
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	95	-546	0.00	64.09	0.10	0.00	0.92
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	0	559	0.01	11.18	0.09	0.00	0.92
4 A ENTERIC FERMENTATION	Population size	CH ₄	2664	2766	0.00	20.90	0.08	0.00	0.92
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N ₂ O	0	6	0.00	1000.00	0.08	0.00	0.93
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	4	0.00	10000.05	0.08	0.00	0.93
1 A 2 f Other	Liquid Fuels	CO ₂	3361	3361	0.01	11.18	0.08	0.00	0.93
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1425	1513	0.00	43.88	0.07	0.00	0.93
1 A 3 b Road Transportation	All Fuels	N ₂ O	67	175	0.00	50.25	0.07	0.00	0.94
1 A 4 b Residential	Gaseous Fuels	N ₂ O	0	5	0.00	1000.05	0.07	0.00	0.94
1 A 2 f Other	Solid Fuels	N ₂ O	5	0	0.00	1000.05	0.07	0.00	0.94
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-104	-323	0.00	40.61	0.07	0.00	0.94
1 A 2 c Chemicals	Liquid Fuels	CO ₂	1373	774	0.01	5.83	0.07	0.00	0.94
1 A 2 f Other	Other Fuels	N ₂ O	0	4	0.00	1000.05	0.06	0.00	0.95
1 A 1 b Petroleum refining	Gaseous Fuels	N ₂ O	0	4	0.00	1000.00	0.06	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	0	393	0.01	11.18	0.06	0.00	0.95
1 A 4 a Commercial / Institutional	Gaseous Fuels	N ₂ O	0	4	0.00	1000.05	0.06	0.00	0.95
1 A 2 f Other	Liquid Fuels	N ₂ O	11	9	0.00	1000.05	0.06	0.00	0.95
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	0	708	0.01	5.83	0.06	0.00	0.96
1 A 2 c Chemicals	Gaseous Fuels	N ₂ O	0	4	0.00	1000.00	0.06	0.00	0.96
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	182	157	0.00	76.16	0.06	0.00	0.96
1 A 2 f Other	Biomass	N ₂ O	21	28	0.00	1001.80	0.05	0.00	0.96
2 B 5 Other	Production Quantities	CO ₂	63	109	0.00	100.50	0.05	0.00	0.96
1 A 3 d i National navigation	Liquid Fuels	CO ₂	260	227	0.00	50.64	0.05	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	N ₂ O	6	4	0.00	1000.00	0.05	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N ₂ O	0	3	0.00	1000.05	0.04	0.00	0.97
1 A 2 a Iron and Steel	Solid Fuels	CO ₂	466	16	0.01	5.83	0.04	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	821	669	0.00	11.18	0.04	0.00	0.97
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	518	296	0.00	10.05	0.04	0.00	0.97
1 A 1 b Petroleum refining	Gaseous Fuels	CO ₂	0	568	0.01	5.10	0.04	0.00	0.97
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	388	487	0.00	64.09	0.04	0.00	0.97
1 A 2 c Chemicals	Gaseous Fuels	CO ₂	0	492	0.01	5.83	0.04	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	746	378	0.01	5.83	0.04	0.00	0.98
1 A 3 b Road Transportation	All Fuels	CH ₄	85	33	0.00	40.31	0.04	0.00	0.98
2 A 1 Cement Production	Production Quantities	CO ₂	3176	3376	0.00	10.10	0.04	0.00	0.98
1 A 2 f Other	Gaseous Fuels	CH ₄	0	16	0.00	150.33	0.03	0.00	0.98
1 A 1 b Petroleum refining	Liquid Fuels	CO ₂	1910	1724	0.01	5.10	0.03	0.00	0.98
3 D OTHER	Other Use of Chemicals	N ₂ O	99	23	0.00	25.00	0.03	0.00	0.98
1 A 1 a Public Electricity and Heat Production	Other Fuels	CO ₂	0	423	0.01	5.10	0.03	0.00	0.98
1 A 2 f Other	Other Fuels	CO ₂	12	196	0.00	11.18	0.03	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	57	0.00	105.02	0.03	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	N ₂ O	12	15	0.00	1000.00	0.03	0.00	0.99
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	526	299	0.00	6.05	0.03	0.00	0.99
1 A 1 b Petroleum refining	Liquid Fuels	N ₂ O	9	9	0.00	1000.00	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH ₄	30	20	0.00	10.198	0.02	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	N ₂ O	2	3	0.00	1000.00	0.02	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N ₂ O	2	1	0.00	1000.00	0.02	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N ₂ O	1	13	0.00	100.12	0.02	0.00	0.99
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	302	381	0.00	30.41	0.02	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO ₂	176	47	0.00	7.07	0.02	0.00	0.99
3 C CHEMICAL PRODUCTS. MANUFACTURE AND	Chemical manufacture and	CO ₂	56	62	0.00	1000.05	0.02	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CO ₂	9	0	0.00	100.12	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N ₂ O	22	15	0.00	10.198	0.01	0.00	0.99
1 A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	746	767	0.00	11.18	0.01	0.00	0.99
1 A 2 a Iron and Steel	Solid Fuels	N ₂ O	1	0	0.00	1000.00	0.01	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N ₂ O	5	5	0.00	1001.80	0.01	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO ₂	49	39	0.00	50.09	0.01	0.00	0.99
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	N ₂ O	37	32	0.00	76.16	0.01	0.00	0.99
1 A 2 a Iron and Steel	Liquid Fuels	CO ₂	155	44	0.00	5.83	0.01	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	N ₂ O	0	1	0.00	1000.00	0.01	0.00	0.99

ANNEX B: Uncertainty Analysis Methodology

B1 Introduction

Uncertainty in the inventory of emissions and removals of GHG result from the natural variability of emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameter due to errors in original monitoring data, reference studies and expert judgment.

Uncertainty values were defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

The uncertainty analysis was performed only for the direct GHG: CO₂, CH₄, N₂O, HFC and SF₆, considering all emissions in CO₂e. The uncertainty of all source activities was considered to overall uncertainty including the uncertainty of LULUCF category.

A tier 1 methodology was used to estimate total uncertainty for the inventory, for one individual year and also the uncertainty in trend. Basically this method of classical analysis, which is explained in more detail in IPCC(2000), attributes uncertainty values to activity data and emission factors, for each of the pollutants, and uses error propagation rules to combine uncertainty estimates for each individual source into total uncertainty. In accordance with IPCC (2000) considerations the uncertainty in Global Warming Potentials (GWP) is not included in uncertainty quantification. The uncertainty values, both for activity data and emission factors, are discussed in the detailed analysis of emission estimates for each individual source sector.

The uncertainty is estimated for individual years, from emission estimates in specific years and uncertainty values for both activity data and implied emission factors, but also for the trend of emissions for each individual category. In the last case, the sensitivity factor of the emissions is also calculated.

B2 Methodology Issues

Level of Analysis

The level at which uncertainties were estimated was determined at the level at which different uncertainty values must be attributed. Therefore the following factors were considered:

- Origin of activity data. A different level was defined whenever activity data resulted from a different origin, including different classes in Energy Balance. In the case when Large Point Source (LPS) was used to estimate part of emissions from a given source sector the uncertainty analysis had to be done independently for that fraction, because the resultant error is different, and uncertainty level was independently made for emissions from LPS and from the remaining Area sources. This separation is also very important in agriculture where different animal types have very different levels of error in activity data;
- Emission Factor. A different class is used for sub-sources whenever different emission factors were used. For example, that has caused the detailed consideration of emissions for each product from organic chemical industry

(PVC, Polypropylene, etc) because emission factors have different origins. In the same way fuels (e.g. biomass) were analyzed independently in situations where uncertainty values are different.

- For certain processes, if the emission estimate depends of different parts of the product life-time, uncertainty analysis was done at the lowest level also. That is the case of aviation, where separation is done for LTO and cruise emissions, and fluorine gas emissions from refrigeration equipment, where uncertainty analysis was performed independently for assembly, operation and disposal.

Uncertainty Values

The uncertainty values that were used were set from:

- Good Practice Guidebook (IPCC,2000);
- references to emission factors, such as AP42¹⁶⁸;
- comparison of several sources of information. For example, comparison to international sources such as FAO, IEA;
- inter-annual un expected variations of activity data;
- statistical variation in the determination of country-specific emission factors, for different units or different years.

The actual uncertainty values that were used for each activity source is reported in following chapters for each source.

Error propagation

Two different rules were used in error propagation (IPCC,2000):

Rule A: For the case when the quantities are to be combined by addition, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms;

$$U_{Total} = \left\{ \sum_i [U_i * x_i]^2 \right\}^{0.5} / \sum_i [x_i]$$

Where:

U_{total} is the percentage uncertainty in the sum of the quantities expressed as a percentage;

¹⁶⁸ In this reference source quality codes are usually reported from A (good quality) to E (poor quality). The following conversion rules was used in uncertainty assessment:

A	5 %
B	10 %
C	50 %
D	100 %
E	1 000 %

x_i and U_i are the uncertain quantities and the percentage uncertainties associated with them, respectively;

Rule B: quantities are to be combined by multiplication, a simpler rule applies:

$$U_{\text{Total}} = [\sum_i U_i^2]^{0.5}$$

Where:

U_{total} is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

U_i are the percentage uncertainties associated with each of the quantities.

Explanation of table¹⁶⁹

The uncertainty was estimated in a consistent way for all years from 1990 to 2009. However, the table presents information only for 2009 and include the following columns:

- Sector;
- Category: second level of source category according to the IPCC;
- Individual category: the more detailed level at which uncertainties are determined;
- Fuel: type of fuel used in the category, when relevant;
- Source type: uncertainties are estimated with different uncertainty values when emissions are estimated using data from Large Point Sources (LPS) or from national statistics (AREA) ;
- IPCC code: the IPCC code defined for the individual category under calculus (Column A of table 6.1 in GP (IPCC,2000));
- Gas: GHG under consideration: CO₂ ; CH₄ ; N₂O and F G (F gases). Emissions are reported for F gases (HFC, PFC and SF₆) after conversion to CO₂eq using the appropriate GWP factor. Removals and emissions of the LULUCF sector, except fires, are reported as CO₂, by conversion of all carbon fluxes (Column B of table 6.1 in GP (IPCC,2000));
- Base Year emissions: Emissions and removals per category in 1990. Emissions are reported as positive values and removals as negative values¹⁷⁰. All emissions, irrespective of the gas, are reported as CO₂e (Column C of table 6.1 in GP (IPCC,2000));
- Current Year emissions : Emissions and removals per category in the last year of the inventory. (Column D of table 6.1 in GP (IPCC,2000));

¹⁶⁹ Tables provided in excel annex

¹⁷⁰ Note: all calculation is done with absolute values.

- AD Uncertainty: uncertainty value attributed to the activity data, half the 95% net confidence interval divided by the mean and expressed as percentage. Detailed presentation of the assumptions and determination of individual values are discussed in main text (Column E of table 6.1 in GP (IPCC,2000));
- EF Uncertainty: the uncertainty value attributed to the implied emission factor, per cent. The determination of this value from basic parameters is discussed in main text. (Column F of table 6.1 in GP (IPCC,2000));
- Combined Uncertainty: derived from the uncertainties of AD and EF and using propagation rule B. (Column G of table 6.1 in GP (IPCC,2000));
- Combined uncertainty as per cent of total national emissions in current year: represents the importance of the uncertainty of each specific individual category to the overall uncertainty in the current year. The addition of the squares of all the entries in column H and after taking the square root (Rule A) is an estimate of the percentage uncertainty in total national emissions in the current year. (Column H of table 6.1 in GP (IPCC,2000));
- type A sensitivity: The per cent difference in emissions for this individual category following a 1% increase in both the base year and current year, expressing the sensitivity in trend to a uncertainty systematic in nature (Column I of table 6.1 in GP (IPCC,2000));
- type B sensitivity: The per cent difference in emissions for this individual category following a 1% increase in the current year only, expressing the sensitivity in trend to a uncertainty due to random error in emission estimate (i.e. error not correlated between years). (Column J of table 6.1 in GP (IPCC,2000));
- Uncertainty in trend from the uncertainty in EF: In all cases type A sensitivity (correlation) was used to estimate uncertainty in EF. (Column K of table 6.1 in GP (IPCC,2000));
- Uncertainty in trend from the uncertainty in AD: In all cases type B sensitivity (no correlation) was used to estimate uncertainty in AD. (Column L of table 6.1 in GP (IPCC,2000));
- Uncertainty into the trend in total national emissions. is an estimate of the uncertainty introduced into the trend in national emissions by the source category in question, derived from the data in columns K and L using Rule B. Total uncertainty in trend is calculated from the entries above using the error propagation equation, summing the squares of all the entries in column M and taking the square root.(Column M of table 6.1 in GP (IPCC,2000)).

B3 Tier 1 Uncertainty Estimates: 2010

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	CO2	6,405	1,038	1	5	5	0.09	-0.12	0.02	-0.59	0.03	0.59
	Public Electricity and Heat Production	S	1A1a	CO2	7,913	6,002	1	5	5	0.50	-0.06	0.11	-0.28	0.16	0.33
	Public Electricity and Heat Production	G	1A1a	CO2	0	4,704	1	5	5	0.40	0.09	0.09	0.44	0.13	0.46
	Public Electricity and Heat Production	O	1A1a	CO2	0	423	1	5	5	0.04	0.01	0.01	0.04	0.01	0.04
	Petroleum refining	L	1A1b	CO2	1,910	1,724	1	5	5	0.14	-0.01	0.03	-0.04	0.05	0.06
	Petroleum refining	G	1A1b	CO2	0	568	1	5	5	0.05	0.01	0.01	0.05	0.02	0.06
	Iron and Steel	L	1A2a	CO2	155	44	3	5	5	0.00	0.00	0.00	-0.01	0.00	0.01
	Iron and Steel	S	1A2a	CO2	466	16	5	5	7	0.00	-0.01	0.00	-0.05	0.00	0.05
	Iron and Steel	G	1A2a	CO2	0	96	5	5	7	0.01	0.00	0.00	0.01	0.01	0.02
	Iron and Steel	O	1A2a	CO2	3	1	3	5	6	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	CO2	1,373	774	3	4	5	0.06	-0.01	0.01	-0.06	0.05	0.08
	Chemicals	S	1A2c	CO2	44	49	5	5	7	0.01	0.00	0.00	0.00	0.01	0.01
	Chemicals	G	1A2c	CO2	0	492	5	5	7	0.06	0.01	0.01	0.05	0.07	0.08
	Chemicals	O	1A2c	CO2	63	97	5	5	7	0.01	0.00	0.00	0.00	0.01	0.01
	Pulp, Paper and Print	L	1A2d	CO2	746	378	3	4	5	0.03	-0.01	0.01	-0.03	0.03	0.04
	Pulp, Paper and Print	G	1A2d	CO2	0	708	3	4	5	0.05	0.01	0.01	0.05	0.06	0.07
	Food Processing, Beverages and Tobacco	L	1A2e	CO2	821	669	10	5	11	0.12	-0.01	0.01	-0.03	0.18	0.18
	Food Processing, Beverages and	G	1A2e	CO2	0	393	10	5	11	0.07	0.01	0.01	0.04	0.10	0.11

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Tobacco														
	Other	L	1A2f	CO ₂	3,361	3,361	3	3	4	0.21	-0.01	0.06	-0.03	0.23	0.23
	Other	S	1A2f	CO ₂	2,126	158	3	4	5	0.01	-0.04	0.00	-0.19	0.01	0.19
	Other	G	1A2f	CO ₂	0	1,908	3	2	4	0.12	0.04	0.04	0.08	0.16	0.18
	Other	O	1A2f	CO ₂	12	196	3	5	5	0.02	0.00	0.00	0.02	0.01	0.02
	Civil Aviation. Domestic	L	1A3aii	CO ₂	228	398	48	5	48	0.32	0.00	0.01	0.01	0.51	0.51
	..International	L	1A3ai	CO ₂	1,461	2,608	48	5	48	2.07	0.02	0.05	0.09	3.33	3.33
	Road Transportation		1A3b	CO ₂	9,476	18,046	5	5	7	2.10	0.14	0.34	0.68	2.40	2.49
	Railways	L	1A3c	CO ₂	176	47	5	5	7	0.01	0.00	0.00	-0.01	0.01	0.02
	Navigation. Domestic	L	1A3dii	CO ₂	260	227	50	5	51	0.19	0.00	0.00	-0.01	0.30	0.30
	..International	L	1A3di	CO ₂	1,386	1,618	50	5	51	1.35	0.00	0.03	0.00	2.17	2.17
	Commercial / Institutional	L	1A4a	CO ₂	746	767	10	5	11	0.14	0.00	0.01	-0.01	0.20	0.20
	Commercial / Institutional	G	1A4a	CO ₂	0	559	10	5	11	0.10	0.01	0.01	0.05	0.15	0.16
	Residential	L	1A4b	CO ₂	1,660	1,841	10	5	11	0.34	0.00	0.03	-0.01	0.49	0.49
	Residential	G	1A4b	CO ₂	0	639	10	5	11	0.12	0.01	0.01	0.06	0.17	0.18
	Agriculture / Forestry / Fishing	L	1A4c	CO ₂	1,661	1,058	53	3	53	0.92	-0.02	0.02	-0.05	1.48	1.49
	Agriculture / Forestry / Fishing	G	1A4c	CO ₂	0	22	10	5	11	0.00	0.00	0.00	0.00	0.01	0.01
	Agriculture / Forestry / Fishing	B	1A4c	CO ₂	0	1	60	5	60	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	L	1A5	CO ₂	95	86	5	5	7	0.01	0.00	0.00	0.00	0.01	0.01
	Oil and natural gas		1B2	CO ₂	143	713	2	183	183	2.16	0.01	0.01	1.90	0.04	1.90
Industrial	Mineral Products		2A	CO ₂	3,488	4,083	11	12	17	1.12	0.00	0.08	0.02	1.23	1.23

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
Processes	Chemical Industry		2B	CO ₂	633	109	9	88	89	0.16	-0.01	0.00	-1.02	0.03	1.02
	Metal Production		2C	CO ₂	16	18	10	30	32	0.01	0.00	0.00	0.00	0.00	0.00
	Other Production		2D	CO ₂	0	0	100	0	100	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Paint Application		3A	CO ₂	96	57	6	21	22	0.02	0.00	0.00	-0.02	0.01	0.02
	Degreasing And Dry Cleaning		3B	CO ₂	12	8	7	0	7	0.00	0.00	0.00	0.00	0.00	0.00
	Chemical Products, Manufacture And Processing		3C	CO ₂	56	62	5	26	27	0.03	0.00	0.00	0.00	0.01	0.01
	Other		3D	CO ₂	70	78	6	81	81	0.10	0.00	0.00	0.00	0.01	0.01
Waste	Waste Incineration		6C	CO ₂	10	2	5	50	50	0.00	0.00	0.00	-0.01	0.00	0.01
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	CH ₄	1	1	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	S	1A1a	CH ₄	1	1	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	G	1A1a	CH ₄	0	2	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	B	1A1a	CH ₄	0	3	1	148	148	0.01	0.00	0.00	0.01	0.00	0.01
	Public Electricity and Heat Production	O	1A1a	CH ₄	0	0	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Petroleum refining	L	1A1b	CH ₄	2	1	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Petroleum refining	G	1A1b	CH ₄	0	0	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	L	1A2a	CH ₄	0	0	3	138	138	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	S	1A2a	CH ₄	0	0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	G	1A2a	CH ₄	0	0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	B	1A2a	CH ₄	0	0	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	O	1A2a	CH ₄	0	0	3	150	150	0.00	0.00	0.00	0.00	0.00	0.00

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Chemicals	L	1A2c	CH ₄	1	1	3	125	125	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	S	1A2c	CH ₄	0	0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	G	1A2c	CH ₄	0	0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	B	1A2c	CH ₄	0	0	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	O	1A2c	CH ₄	0	0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	L	1A2d	CH ₄	3	4	3	144	144	0.01	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	G	1A2d	CH ₄	0	1	3	131	132	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	B	1A2d	CH ₄	10	11	4	145	145	0.03	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	L	1A2e	CH ₄	1	1	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	G	1A2e	CH ₄	0	0	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	B	1A2e	CH ₄	1	1	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Other	L	1A2f	CH ₄	8	8	3	98	98	0.01	0.00	0.00	0.00	0.00	0.00
	Other	S	1A2f	CH ₄	4	0	3	127	127	0.00	0.00	0.00	-0.01	0.00	0.01
	Other	G	1A2f	CH ₄	0	16	5	141	141	0.04	0.00	0.00	0.04	0.00	0.04
	Other	B	1A2f	CH ₄	3	3	35	87	93	0.01	0.00	0.00	0.00	0.00	0.00
	Other	O	1A2f	CH ₄	0	0	3	149	149	0.00	0.00	0.00	0.00	0.00	0.00
	Civil Aviation. Domestic	L	1A3aii	CH ₄	1	0	48	100	111	0.00	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3ai	CH ₄	3	2	48	100	111	0.00	0.00	0.00	0.00	0.00	0.00
	Road Transportation		1A3b	CH ₄	85	33	5	40	40	0.02	0.00	0.00	-0.05	0.00	0.05
	Railways	L	1A3c	CH ₄	0	0	5	40	40	0.00	0.00	0.00	0.00	0.00	0.00

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Navigation. Domestic	L	1A3dii	CH ₄	0	0	50	100	112	0.00	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3di	CH ₄	0	1	50	100	112	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	L	1A4a	CH ₄	1	1	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	G	1A4a	CH ₄	0	0	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	B	1A4a	CH ₄	0	0	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	L	1A4b	CH ₄	1	1	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	G	1A4b	CH ₄	0	1	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	B	1A4b	CH ₄	343	188	60	150	162	0.50	0.00	0.00	-0.58	0.30	0.65
	Agriculture / Forestry / Fishing	L	1A4c	CH ₄	3	2	60	36	70	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	G	1A4c	CH ₄	0	0	10	148	149	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	B	1A4c	CH ₄	0	0	70	41	81	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	L	1A5	CH ₄	0	0	5	40	40	0.00	0.00	0.00	0.00	0.00	0.00
	Oil and natural gas		1B2	CH ₄	52	600	9	136	136	1.35	0.01	0.01	1.38	0.14	1.39
Industrial Processes	Mineral Products		2A	CH ₄	1	1	31	0	31	0.00	0.00	0.00	0.00	0.00	0.00
	Chemical Industry		2B	CH ₄	8	10	7	72	73	0.01	0.00	0.00	0.00	0.00	0.00
Agriculture	Enteric Fermentation		4A	CH ₄	2,664	2,766	7	12	14	0.63	-0.01	0.05	-0.06	0.53	0.54
	Manure Management		4B	CH ₄	1,184	1,065	9	74	75	1.31	-0.01	0.02	-0.40	0.26	0.48
	Rice Cultivation		4C	CH ₄	227	392	36	40	54	0.35	0.00	0.01	0.10	0.37	0.39
	Field Burning Of Agricultural Wastes		4F	CH ₄	30	20	100	20	102	0.03	0.00	0.00	-0.01	0.05	0.05
Waste	Urban Solid Waste Disposal On Land		6A	CH ₄	1,433	3,070	13	53	55	2.77	0.03	0.06	1.44	1.02	1.76

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Industrial Solid Waste Disposal On Land		6A	CH ₄	1,599	1,507	118	55	130	3.22	-0.01	0.03	-0.33	4.72	4.73
	Industrial Wastewater		6B	CH ₄	1,425	1,513	25	36	44	1.09	0.00	0.03	-0.08	0.99	1.00
	Domestic and Commercial wastewater		6B	CH ₄	1,056	756	30	38	48	0.60	-0.01	0.01	-0.32	0.61	0.69
	Waste Incineration		6C	CH ₄	0	0	5	100	100	0.00	0.00	0.00	0.00	0.00	0.00
	Other Waste		6D	CH ₄	0	0	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	N ₂ O	15	3	1	996	996	0.04	0.00	0.00	-0.28	0.00	0.28
	Public Electricity and Heat Production	S	1A1a	N ₂ O	36	27	1	1,000	1,000	0.45	0.00	0.00	-0.26	0.00	0.26
	Public Electricity and Heat Production	G	1A1a	N ₂ O	0	36	1	1,000	1,000	0.60	0.00	0.00	0.68	0.00	0.68
	Public Electricity and Heat Production	B	1A1a	N ₂ O	0	27	1	982	982	0.43	0.00	0.00	0.49	0.00	0.49
	Public Electricity and Heat Production	O	1A1a	N ₂ O	0	13	1	1,000	1,000	0.21	0.00	0.00	0.24	0.00	0.24
	Petroleum refining	L	1A1b	N ₂ O	9	9	1	1,000	1,000	0.14	0.00	0.00	-0.03	0.00	0.03
	Petroleum refining	G	1A1b	N ₂ O	0	4	1	1,000	1,000	0.07	0.00	0.00	0.08	0.00	0.08
	Iron and Steel	L	1A2a	N ₂ O	1	0	3	957	957	0.00	0.00	0.00	-0.01	0.00	0.01
	Iron and Steel	S	1A2a	N ₂ O	1	0	5	1,000	1,000	0.00	0.00	0.00	-0.02	0.00	0.02
	Iron and Steel	G	1A2a	N ₂ O	0	1	5	1,000	1,000	0.01	0.00	0.00	0.01	0.00	0.01
	Iron and Steel	B	1A2a	N ₂ O	0	0	60	1,000	1,002	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	O	1A2a	N ₂ O	0	0	3	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	N ₂ O	6	4	3	857	857	0.06	0.00	0.00	-0.05	0.00	0.05
	Chemicals	S	1A2c	N ₂ O	0	0	5	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	G	1A2c	N ₂ O	0	4	5	1,000	1,000	0.06	0.00	0.00	0.07	0.00	0.07

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Chemicals	B	1A2c	N ₂ O	1	2	60	1,000	1,002	0.03	0.00	0.00	0.01	0.00	0.01
	Chemicals	O	1A2c	N ₂ O	0	1	5	1,000	1,000	0.01	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	L	1A2d	N ₂ O	2	1	3	710	710	0.01	0.00	0.00	-0.02	0.00	0.02
	Pulp, Paper and Print	G	1A2d	N ₂ O	0	6	3	709	709	0.06	0.00	0.00	0.07	0.00	0.07
	Pulp, Paper and Print	B	1A2d	N ₂ O	12	15	7	898	898	0.22	0.00	0.00	0.03	0.00	0.03
	Food Processing, Beverages and Tobacco	L	1A2e	N ₂ O	2	2	10	1,000	1,000	0.03	0.00	0.00	-0.01	0.00	0.01
	Food Processing, Beverages and Tobacco	G	1A2e	N ₂ O	0	3	10	1,000	1,000	0.05	0.00	0.00	0.06	0.00	0.06
	Food Processing, Beverages and Tobacco	B	1A2e	N ₂ O	5	5	60	1,000	1,002	0.09	0.00	0.00	-0.02	0.01	0.02
	Other	L	1A2f	N ₂ O	11	9	3	507	507	0.07	0.00	0.00	-0.04	0.00	0.04
	Other	S	1A2f	N ₂ O	5	0	3	842	842	0.01	0.00	0.00	-0.08	0.00	0.08
	Other	G	1A2f	N ₂ O	0	14	3	478	478	0.11	0.00	0.00	0.13	0.00	0.13
	Other	B	1A2f	N ₂ O	21	28	44	731	732	0.33	0.00	0.00	0.05	0.03	0.06
	Other	O	1A2f	N ₂ O	0	4	3	980	980	0.07	0.00	0.00	0.08	0.00	0.08
	Civil Aviation. Domestic	L	1A3aii	N ₂ O	2	3	48	1,000	1,001	0.06	0.00	0.00	0.02	0.00	0.02
	..International	L	1A3ai	N ₂ O	13	23	48	1,000	1,001	0.38	0.00	0.00	0.16	0.03	0.16
	Road Transportation		1A3b	N ₂ O	67	175	5	50	50	0.15	0.00	0.00	0.09	0.02	0.10
	Railways	L	1A3c	N ₂ O	11	3	5	50	50	0.00	0.00	0.00	-0.01	0.00	0.01
	Navigation. Domestic	L	1A3dii	N ₂ O	2	2	50	1,000	1,001	0.03	0.00	0.00	-0.01	0.00	0.01
	..International	L	1A3di	N ₂ O	11	13	50	1,000	1,001	0.22	0.00	0.00	0.01	0.02	0.02
	Commercial /	L	1A4a	N ₂ O	2	3	10	1,000	1,000	0.04	0.00	0.00	0.00	0.00	0.00

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Institutional														
	Commercial / Institutional	G	1A4a	N ₂ O	0	4	10	1,000	1,000	0.07	0.00	0.00	0.08	0.00	0.08
	Commercial / Institutional	B	1A4a	N ₂ O	0	0	60	1,000	1,002	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	L	1A4b	N ₂ O	11	13	10	1,000	1,000	0.21	0.00	0.00	-0.01	0.00	0.01
	Residential	G	1A4b	N ₂ O	0	5	10	1,000	1,000	0.08	0.00	0.00	0.09	0.00	0.09
	Residential	B	1A4b	N ₂ O	73	40	60	1,000	1,002	0.65	0.00	0.00	-0.81	0.06	0.82
	Agriculture / Forestry / Fishing	L	1A4c	N ₂ O	153	90	79	53	96	0.14	0.00	0.00	-0.09	0.19	0.21
	Agriculture / Forestry / Fishing	G	1A4c	N ₂ O	0	0	10	970	970	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	B	1A4c	N ₂ O	0	9	80	51	95	0.01	0.00	0.00	0.01	0.02	0.02
	Other Combustion	L	1A5	N ₂ O	1	1	5	50	50	0.00	0.00	0.00	0.00	0.00	0.00
	Oil and natural gas		1B2	N ₂ O	2	3	3	0	3	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry		2B	N ₂ O	518	296	1	10	10	0.05	-0.01	0.01	-0.06	0.01	0.06
Solvent And Other Product Use	Other		3D	N ₂ O	99	23	10	0	10	0.00	0.00	0.00	0.00	0.01	0.01
Agriculture	Manure Management		4B	N ₂ O	526.0	299	36	93	100	0.49	-0.01	0.01	-0.53	0.29	0.60
	Agricultural Soils		4D	N ₂ O	3,460.5	2,958.3	20	181	182	8.86	-0.02	0.06	-3.37	1.54	3.70
	Field Burning Of Agricultural Wastes		4F	N ₂ O	22	15	100	20	102	0.03	0.00	0.00	0.00	0.04	0.04
Waste	Industrial Wastewater		6B	N ₂ O	161	203	25	1,000	1,000	3.35	0.00	0.00	0.36	0.13	0.38
	Domestic and Commercial wastewater		6B	N ₂ O	302	381	30	0	30	0.19	0.00	0.01	0.00	0.31	0.31
	Waste Incineration		6C	N ₂ O	1	13	5	100	100	0.02	0.00	0.00	0.02	0.00	0.02

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Other Waste		6D	N ₂ O	0	0	1	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land		5A	CO ₂	-6,736	-11,151	27	40	49	8.91	-0.07	-0.21	-2.62	-8.04	8.45
	Cropland		5B	CO ₂	696	157	135	129	187	0.48	-0.01	0.00	-1.55	0.56	1.65
	Grassland		5C	CO ₂	95	-546	68	111	130	1.17	-0.01	-0.01	-1.37	-0.99	1.69
	Wetlands		5D	CO ₂	388	487	37	19	42	0.33	0.00	0.01	0.02	0.48	0.48
	Other Land		5E	CO ₂	1,094	2,052	69	32	76	2.56	0.02	0.04	0.48	3.74	3.77
	Forest Land		5A	CH ₄	0	0	133	120	179	0.00	0.00	0.00	0.00	0.00	0.00
	Forest Land		5A	N ₂ O	0	0	4	6	7	0.00	0.00	0.00	0.00	0.00	0.00
	Cropland		5B	N ₂ O	0	0	27	18	32	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons and Sulphur Hexafluoride		2F	F Gases	70	1,239	12	70	71	1.45	0.02	0.02	1.53	0.40	1.58

ANNEX C: Energy Balance Sheet for 2010

Draft version from 30-11-2011

Annexes

BALANÇO ENERGÉTICO tep	Hulha e Antracite Estrangeira	Antracite Nacional	Coque	Total de Carvão	Petróleo Bruto	Refugos e Produtos Intermediários	GPL	Gasolinas	Petróleos	Jets	Gasóleo	Fuelóleo	Nafte	Coque de Petróleo	Total de Petróleo Energético	Lubrificantes	Asfaltos	Parafinas	Solventes	Propileno	Total de Petróleo Não Energético	Total de Petróleo
2010 (provisório)	1	2	3	4 = 1+3	5	6	7	8	9	10	11	12	13	14	15 = 5+14	16	17	18	19	20	21 = 16+20	22 = 15+21
IMPORTAÇÕES	1.	1 698 322	2 148	1 700 470	11 389 215	360 619	474 658	190 240	842	134 296	1 205 310	251 761	459 099	444 323	14 910 363	53 991	205 969	2 080			262 040	15 172 403
PRODUÇÃO DOMÉSTICA	2.																					
VARIACÃO DE "STOCKS"	3.	- 26 674	- 29	- 26 703	- 133 822	- 37 247	14 729	- 31 480	1 373	11 968	- 117 445	8 825	- 16 242	3 245	- 296 096	5 732	- 4 921	- 1 401	765	403	578	- 295 518
SAÍDAS	4.	70 416		70 416			71 196	1 087 977		961 971	86 763	1 261 853	379 856		3 869 856	103 563	120 851	4 519	25 314	98 694	352 941	4 222 597
Exportações	4.1	70 416		70 416			71 196	1 087 977		961 971	86 763	1 261 853	379 856		3 869 856	103 563	120 851	4 519	25 314	98 694	352 941	4 222 597
Transportes Marítimos Internacionais	4.2										51 084	406 699			457 783	8					457 791	458 732
Aviação Internacional	4.3									888 672					888 672						888 680	888 680
CONSUMO DE ENERGIA PRIMÁRIA	5.	1 654 580	2 177	1 656 757	11 523 037	397 866	388 733	- 866 257	- 531	- 839 643	1 235 992	- 1 038 957	95 485	441 078	11 336 803	- 55 304	90 039	- 1 038	- 26 079	- 99 097	- 91 479	11 245 324
PARA NOVAS FORMAS DE ENERGIA	6.	1 597 427		1 597 427	11 521 431	143 157	- 417 263	- 2 331 277	- 2 241	- 992 967	- 4 331 573	- 1 508 414	- 1 099 181		981 750	- 123 930	- 245 486	- 11 361	- 29 540	- 101 102	- 511 419	470 331
Briquetes	6.1																					
Coque	6.2																					
Produtos de Petróleo	6.3				11 521 431	28 291	- 417 263	- 2 331 277	- 2 241	- 992 967	- 4 356 978	- 2 211 762	- 1 136 161		101 073	- 123 930	- 245 486	- 11 361	- 29 540	- 101 102	- 511 419	- 410 346
Gás de Cidade	6.4																					
Petroquímica	6.5													36 980	36 980							36 980
Electricidade	6.6	1597 427		1 597 427							24 529	258 562			283 091							283 091
Cogeração	6.7					114 866					676	444 786			560 606							560 606
Produção de Electricidade	6.7.1											43	39 375		39 418							39 418
(Central do Barreiro)	6.7.1.1																					
Refinação de Petróleo	6.7.2					77 886						91 072			69 058							69 058
Gás de Cidade	6.7.3																					
Agricultura	6.7.4																					
Alimentação, bebidas e tabaco	6.7.5										66	56 224			56 290							56 290
Têxteis	6.7.6										441	79 947			79 388							79 388
Papel e Artigos de Papel	6.7.7											7	43 308		43 308							43 308
Químicas e Plásticos	6.7.8										28	60 761			97 769							97 769
Cerâmicas	6.7.9										7	7 844			7 851							7 851
Vidro e Artigos de Vidro	6.7.10											2 270			2 270							2 270
Cimento	6.7.11																					
Metallúrgicas	6.7.12																					
Siderurgia	6.7.13																					
Vestuário, Calçado e Curtumes	6.7.14										35	7 791			7 826							7 826
Madeira e Artigos de Madeira	6.7.15										152	39 262			39 414							39 414
Borracha	6.7.16																					
Metal-electro-mecánicas	6.7.17											2 424			2 494							2 494
Outras Industrias Transformadoras	6.7.18																					
Indústrias Extractivas	6.7.19											4 312			4 312							4 312
Serviços	6.7.20						78				27	11 096			11 201							11 201
CONSUMO DO SECTOR ENERGÉTICO	7.				1 605	254 709	10 946	584	124	547	3 037	20 148	286		291 986	3 130	2 909	182	579	32	6 832	298 818
Consumo Próprio da Refinação	7.1					203 876	10 807	7	1		640	19 432			234 763	13	2 701				2 714	237 477
Perdas da Refinação	7.2				1 605	50 833	80	577	123	547	2 397	716	286		57 164	750	208	182	579	32	1 751	58 915
Coquerias e outras não especificadas	7.3																					
Centrais Eléctricas	7.4						59								59	2 367					2 367	2 426
Bombagem Hidroeléctrica	7.5																					
Gás de Cidade	7.6																					
Extracção de Carvão, Petróleo e GN	7.7																					
Perdas de Transporte e Distribuição	7.8																					
CONSUMO COMO MATÉRIA PRIMA							61 294					34 043	1 194 530		1 289 867							1 289 867
DISPONÍVEL PARA CONSUMO FINAL	8.	57 153	2 177	59 330	1		733 756	1 464 436	1 586	152 777	5 564 528	415 266	- 150	441 078	8 773 200	65 496	332 616	10 141	2 882	1 973	413 108	9 186 308
ACERTOS	9.	9 134	- 4	9 130	1		- 3 598	1 344	- 71	900	- 16 042	890	- 150	- 173	- 16 977	665	339	328	- 1 378	- 436	- 482	- 17 459
CONSUMO FINAL	10.	48 019	2 181	50 200			737 354	1 463 092	1 657	151 877	5 580 570	414 376		441 251	8 790 177	64 831	332 277	9 813	4 260	2 409	413 590	9 203 767
AGRICULTURA E PISCAS	10.1						7 334	1 044	933		343 589	15 239			368 139	447					447	368 586
Agricultura	10.1.1						7 294	567	933		242 187	3 908			254 889	90					90	254 979
Piscas	10.1.2						40	477			101 402	11 331			113 250	357					357	113 607
INDÚSTRIAS EXTRACTIVAS	10.2						1 830	8			41 884	1 002			44 724	1 455	13 214				14 669	59 393
INDÚSTRIAS TRANSFORMADORAS	10.3	48 019	2 181	50 200			77 408	2 950	50		92 640	221 656		441 251	835 955	18 422	1 153	9 813	4 221	2 409	36 018	871 973
Alimentação, bebidas e tabaco	10.3.1						21 817	568	5		24 704	111 767			158 861	210					210	159 071
Têxteis	10.3.2						3 053		1		525	17 390			20 969	865					865	21 834
Papel e Artigos de Papel	10.3.3						2 234	8	3		3 794	68 669			74 708	494					494	75 202
Químicas e Plásticos	10.3.4	10 111	2 181	12 292			8 483	9	9		1 864	11 877			22 233	5 025	823	6 119	4 007	2 409	18 383	40 616
Cerâmicas	10.3.5						6 042	9	6		2 938	491		11 048	20 534	144					144	20 678
Vidro e Artigos de Vidro	10.3.6						317				1 367	520			2 204	94					94	2 298
Cimento	10.3.7	33 965		33 965			1 619	207			24 197	5 045		430 203	461 261	322	24				346	461 607
Metallúrgicas	10.3.8						3 699				774	519			4 992	80					80	5 072
Siderurgia	10.3.9	3 943		3 943			57		3		907				967	452					452	1 419
Vestuário, Calçado e Curtumes	10.3.10						3 702				337	1 810			5 849	13					13	5 862
Madeira e Artigos de Madeira	10.3.11						1 417				6 146	383			7 946	770	3 093			3 863	11 809	
Borracha	10.3.12						99		1			767			867	6 638		529		7 167	8 034	
Metal-electro-mecánicas	10.3.13						22 137	2 158	22		5 429	137			29 883	2 881	94			2 975	32 858	
Outras Industrias Transformadoras	10.3.14						2 732				19 668	2 281			24 681	434	212	72	214	932	25 613	
CONSTRUÇÃO E OBRAS PÚBLICAS	10.4						12 082	2 847	3		148 783	22 667			186 382	2 384	313 710		39		316 133	502 515
TRANSPORTES	10.5						31 839	1 455 525	6	123 022	4 715 045	77 039			6 402 476	41 298	3				41 301	6 443 777
Aviação Nacional	10.5.1						16	5 388		123 022					128 426	8					8	128 434
Transportes Marítimos Nacionais	10.5.2						22	3			44 626	77 039			121 690	606				606	122 296	
Caminho de Ferro	10.5.3																					

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ANNEX D: Standard Electronic Format Tables

The SEF tables are included in the Excel file submitted with this report