



**PORTUGUESE NATIONAL INVENTORY REPORT
ON GREENHOUSE GASES, 1990 - 2008**

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

Amadora

April, 15th 2010

Technical Reference

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Preface

The National Environmental Agency (Agência Portuguesa do Ambiente)/ Ministry for the Environment and Land Use Planning (Ministério do Ambiente e do Ordenamento do Território), 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 sectorial 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 2010 NIR objective is to present a general overview of the inventory, overall results for 2008 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 2010 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.

Ministry for Environment and Land Use Planning

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EXECUTIVE SUMMARY

Background information

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC), 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, taking into account the adopted Reporting Guidelines on Annual Inventories (FCCC/SBSTA/2004/8).

The UNFCCC Guidelines require that Parties prepare a National Inventory Report (NIR) as one part of their annual submissions. The NIR should contain detailed and complete information related to methodologies, emission factors, activity data, and should give explanations concerning any recalculations of historical inventories, in order to ensure transparency and enable the inventory review.

This report was prepared in order to comply with the international commitments under the UNFCCC and the European Commission (EC). It presents a description of the methods, assumptions and background data used in the preparation of the 2010 national inventory submission of GHG. 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 possible.

The report presents estimates for the 6 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 1990-2008.

The report is structured generally in accordance with the adopted UNFCCC Reporting Guidelines on Annual Inventories (FCCC/SBSTA/2004/8).

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 bunkers 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 2008, i.e., the inventory is internally consistent.

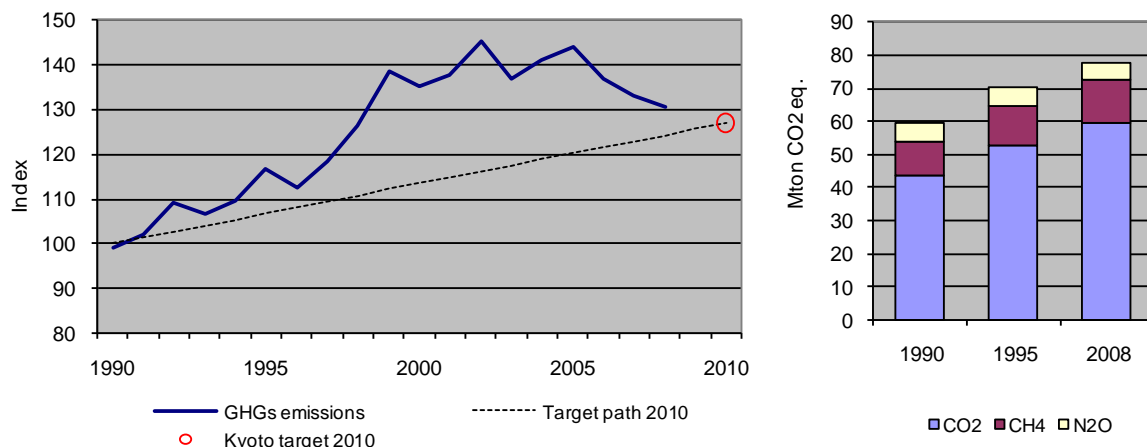
The report is structured according to the following source sectors: energy production and transformation, combustion in industry, domestic, agriculture, fisheries, institutional and commerce sectors, transportation (road, rail, maritime and air), industrial production and use of solvents, waste production (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.

Summary of national emissions and removal related trends

In 2008, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated at about 78.4 Mt CO₂e, representing an increase of 30% compared to 1990 levels (Assigned Amount level). 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. Comparing the 1990 -

2008 growth with the linear target path from 1990 to 2008, Portuguese GHG emissions were, in 2008, 6% above this target path. (Figure ES. 1).

Figure ES. 1 – GHG emissions (without LULUCF)

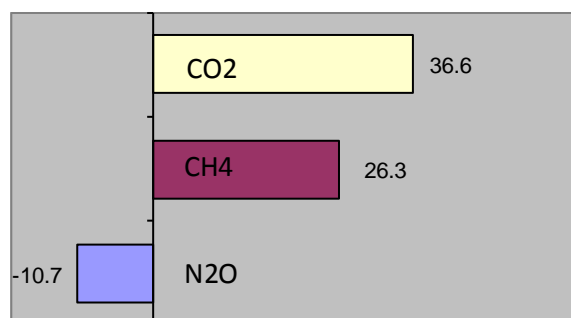


After a steady increase of the Portuguese emissions during the 90s, the growth of emissions thereafter has been more moderate and even appears to be a sort of stagnation in the more recent years. This situation is in part consequence of the implementation of some measures, such as the introduction of 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 installed capacity of renewable electrical generation has grown from 8.28 MW in 1995 to 8151 MW in 2008. The eolian installed capacity in 2008 was about 2800 MW, distributed by 175 parcs and 1526 aerogenerators. The windmill production is increasing importance in electrical production. In the last 5 years (2004-2008) the eolian production rose 86%. In 2006 eolian production increase 67%, in 2007, 38%, and in 2008 42%. Within electric production from renewable sources, windmill production represented 38% of the 2008 production.

The principal source of GHGs in Portugal in 2008 is the energy sector. The largest gas emitted is CO₂ representing 76.0% 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 90.5% of total CO₂ emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2008, 84% 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. 16% 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 ES. 2 illustrates the GHG trend in the period 1990-2008. CO₂ is the gas having registered the biggest increase, 37%¹.

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 2008: 1.3%)

Figure ES. 2– Increase of emissions by gas over the 1990-2008 period (percent)



The overall trend for direct GHG emissions in the 1990-2008 period is presented in Table ES. 1.

Table ES. 1 – GHG emissions and removals in Portugal by gas: 1990-2008

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO₂ equivalent (Gg)										
CO2 emissions including net CO2 from LULUCF	47,784	49,784	49,476	47,270	47,005	53,219	47,453	49,823	55,810	61,959
CO2 emissions excluding net CO2 from LULUCF	43,590	45,311	49,412	47,999	49,102	52,998	50,159	53,390	58,063	64,870
CH4 emissions including CH4 from LULUCF	10,396	10,771	10,675	10,638	11,075	11,525	11,481	11,629	12,217	12,371
CH4 emissions excluding CH4 from LULUCF	10,168	10,445	10,572	10,571	11,042	11,282	11,393	11,596	12,054	12,288
N2O emissions including N2O from LULUCF	5,583	5,575	5,541	5,372	5,622	5,688	5,960	5,930	5,555	5,974
N2O emissions excluding N2O from LULUCF	5,534	5,516	5,504	5,338	5,593	5,637	5,925	5,900	5,512	5,939
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	55	77	110	152	209
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	1	6	12
SF6	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	5	5	6	6	6
Total (including LULUCF)	63,763	66,130	65,691	63,280	63,703	70,493	64,976	67,499	73,746	80,530
Total (excluding LULUCF)	59,292	61,272	65,489	63,908	65,737	69,977	67,559	71,004	75,793	83,324
CO₂ equivalent (Gg)										
CO2 emissions including net CO2 from LULUCF	62,049	61,510	65,546	69,814	65,096	72,918	61,905	58,832	56,546	
CO2 emissions excluding net CO2 from LULUCF	63,691	64,402	68,396	63,718	65,901	68,285	63,798	61,524	59,544	
CH4 emissions including CH4 from LULUCF	11,626	12,365	12,861	13,538	12,821	12,955	12,674	12,439	12,855	
CH4 emissions excluding CH4 from LULUCF	11,430	12,248	12,688	12,818	12,694	12,411	12,588	12,415	12,843	
N2O emissions including N2O from LULUCF	5,911	5,748	5,763	5,218	5,400	5,204	4,891	5,010	4,972	
N2O emissions excluding N2O from LULUCF	5,865	5,710	5,719	5,118	5,361	5,123	4,856	4,981	4,944	
HFCs	303	391	498	610.48	687.29	785.68	873.07	937.79	1,033.42	
PFCs	6	13	10	9.53	9.31	9.97	6.55	5.72	9.02	
SF6	6	6	6	6.81	7.51	7.12	8.10	7.73	7.85	
Total (including LULUCF)	79,901	80,033	84,686	89,197	84,022	91,881	80,358	77,232	75,424	
Total (excluding LULUCF)	81,301	82,769	87,318	82,281	84,660	86,622	82,129	79,872	78,381	

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

Overview of source and sink category's emission estimates and trends

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. Figure ES. 3 and Figure ES. 4 represent direct GHG emissions by sector for 1990 and 2008, respectively.

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: 1990

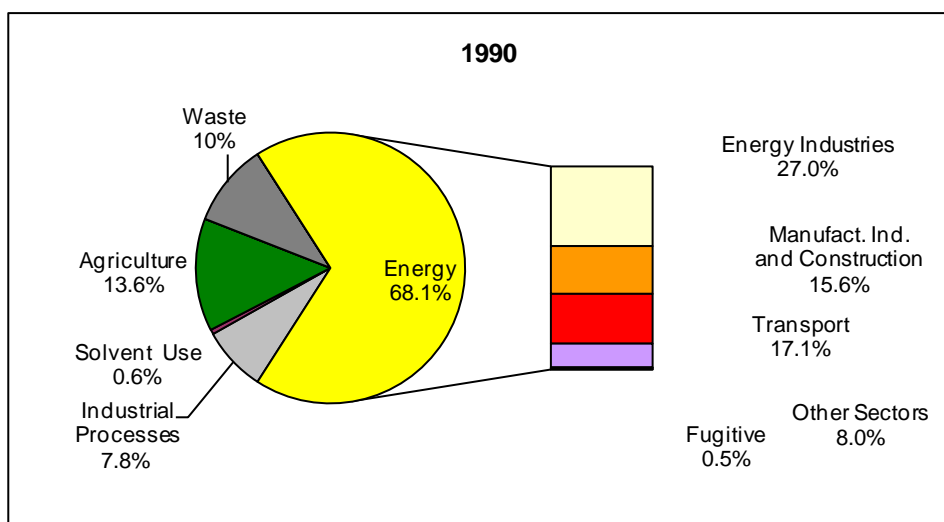
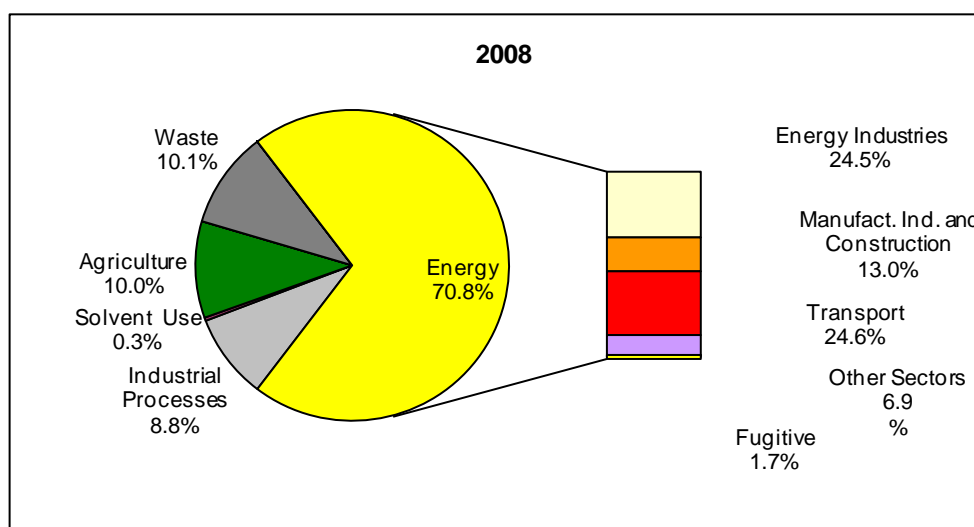


Figure ES. 4 – GHG emissions in Portugal by sector: 2008

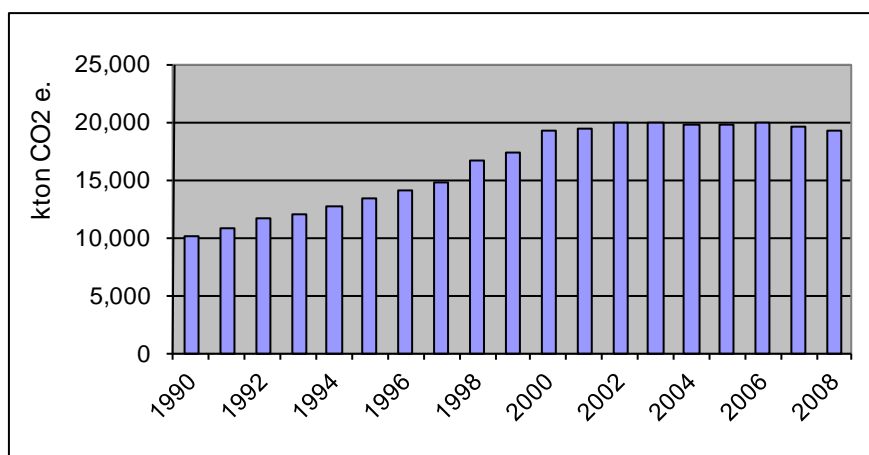


Energy is by far the most important sector, accounting for 70.8% of total emissions in 2008, and presenting an increase of 37.4% over the 1990-2008 period. Energy industries and transport are the two most important sources representing approximately 24.5% of total emissions. This reflects the country 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 1990-2008 these emissions increased 91%, 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 may be seen in Figure ES. 5, as the growth of transport emission has first stabilised and even started to decline in most recent years.

Figure ES. 5 – Transport emissions (1990-2008)



Agriculture was, in the period analysed, the second most significant source of GHGs emissions, with 10.0% of the Portuguese emissions in 2008, registering a decrease of 2.5% since 1990.

The waste and industrial processes sectors represented, respectively, 10.1% and 8.8% of Portuguese emissions in 2008, recording an increase of approximately 33% and 50% since 1990. Solvent use represents less than 1% of total emissions, and is mainly related to NMVOC emissions².

Estimates of emissions and sinks from land use change and forestry category, show that this category has changed from being a net emitter in 1990 (4.5 Mt CO₂e) to becoming a carbon sink in 1993 and the following years until 2002. The situation was again reverted in 2003 and 2005, when this category was again estimated as a net emitter. This pattern of variation is explained by the exceptional occurrences and extension of forest fires in specific years, and the use of the burnt materials as inputs to the industry.

Table ES. 2 presents the overall sectoral trend for direct GHG emissions in the 1990-2008 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: 1990-2008

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO ₂ equivalent (Gg)										
1. Energy	40,383	42,098	46,427	45,028	45,586	48,919	46,335	48,999	53,347	60,736
2. Industrial Processes	4,611	4,584	4,352	4,202	4,926	5,654	5,459	6,082	6,291	6,184
3. Solvent and Other Product Use	332	319	339	298	328	323	344	367	299	299
4. Agriculture	8,038	8,132	7,973	7,812	8,028	8,028	8,357	8,248	8,242	8,410
5. Land-Use Change and Forestry ⁽⁷⁾	4,472	4,858	203	-628	-2,034	516	-2,584	-3,505	-2,047	-2,794
6. Waste	5,928	6,139	6,397	6,567	6,868	7,054	7,064	7,308	7,613	7,695
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

GHGs SOURCE AND SINK	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂ equivalent (Gg)									
1. Energy	59,442	60,747	64,646	60,127	61,647	63,817	59,552	56,981	55,476
2. Industrial Processes	6,079	5,879	6,162	6,208	6,750	6,771	6,600	6,989	6,925
3. Solvent and Other Product Use	306	307	297	278	303	306	270	269	265
4. Agriculture	8,676	8,540	8,586	7,959	8,214	7,985	7,851	7,945	7,836
5. Land-Use Change and Forestry ⁽⁷⁾	-1,400	-2,736	-2,632	6,917	-637	5,258	-1,772	-2,639	-2,958
6. Waste	6,798	7,296	7,626	7,709	7,745	7,744	7,856	7,687	7,879
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA

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

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: 1990-2008

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
(Gg)										
CO	849	865	897	845	820	804	795	763	752	728
NO _x	259	274	294	282	283	293	292	295	306	321
NMVOC	321	324	332	307	300	292	289	285	285	279
SO ₂	320	311	373	317	297	333	273	293	342	345

Gas emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	% change
(Gg)										1990-08
CO	695	624	611	588	581	562	538	522	502	-40.9
NO _x	321	320	331	309	313	315	293	281	268	3.4
NMVOC	267	254	252	243	236	230	226	221	218	-32.3
SO ₂	306	287	285	191	193	198	174	168	113	-64.6

In 2008, SO_x, CO and NMVOC emissions have decreased from 1990 levels: -64.6%, -40.9% and -32.3%. NO_x emissions registered a positive trend: +3.4%, (Table ES.3).

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, and CO emissions, respectively 44% and 28% of 2008 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 even 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 1990-2008 period, respectively, -72% and -82%.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 51% of the 2008 totals.

SO_x emissions are mainly generated in the energy industry sector (approximately 53% of total emissions in 2008) and combustion in manufacturing industries (approximately 26% of total emissions in 2008), 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 some 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 1990-2008 shows in fact a decrease in SO_x emissions in both sub-categories: manufacturing industries and energy industries -61% and -70%. From 2007 to 2008, SO_x emissions from the energy industries registered a significant reduction (approximately -46%) 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 was the annual precipitation 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% 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% 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, CH₄, CO, CO₂, N₂O and NH₃) 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)

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 of Ministry for the 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.

InventAr, Estudos e Projectos Unip Lda, was contracted by APA to work in close collaboration with the inventory team on the calculation of emission estimates and the elaboration of the NIR and the compilation of the CRF tables.

Ecoprogresso, Consultores em Ambiente e Desenvolvimento, was contracted by APA to apply QC procedures and to work and 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

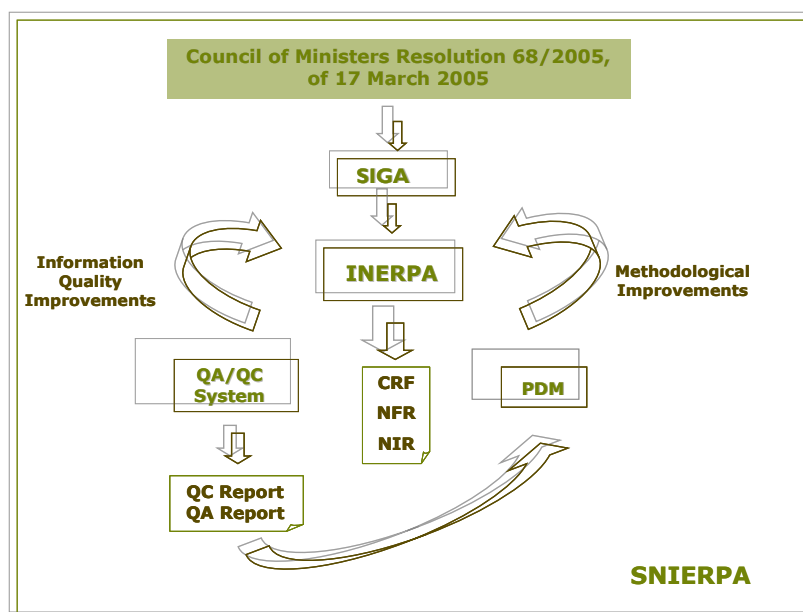


Table 1.2 lists the main focal points and involved entities, by sector of activity.

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 12.

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 fulfilment 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

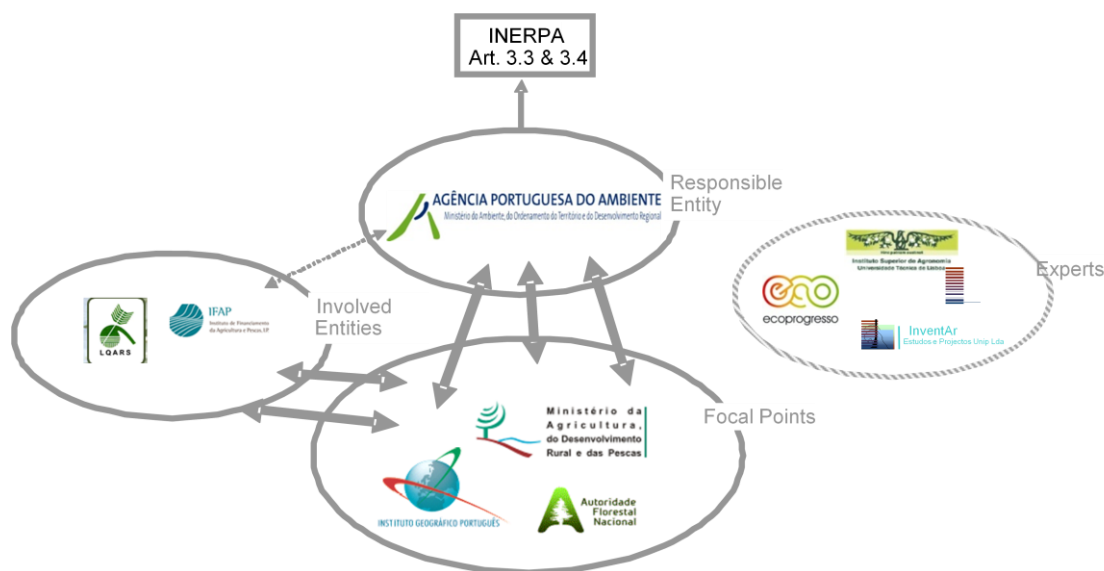
Additional provisions to deal with the supplementary information under Kyoto Protocol refer mainly to arrangements to account for further requirements concerning Art. 3.3 and 3.4.

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:

- APA – Portuguese Agency for the Environment (www.apambiente.pt)
- MADRP – Ministry of Agriculture/ Ministério da Agricultura, do Desenvolvimento Rural e das Pescas

- GPP – Gabinete de Planeamento e Políticas (<http://www.gpp.pt>)
- AFN – Forestry National Authority/ Autoridade Florestal Nacional estais/MADRP (<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
- Ecoprogresso (<http://www.ecoprogresso.pt/>)
- InventAr

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.



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 and INVENTAR³, which also provides technical advice concerning all aspects of inventory development: methodologies, sources of information and emission factors, and participates in the annual definition of priorities concerning the MDP. However many other institutions and agencies contributed to the inventory process, providing activity data, sectoral expert judgement, 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.

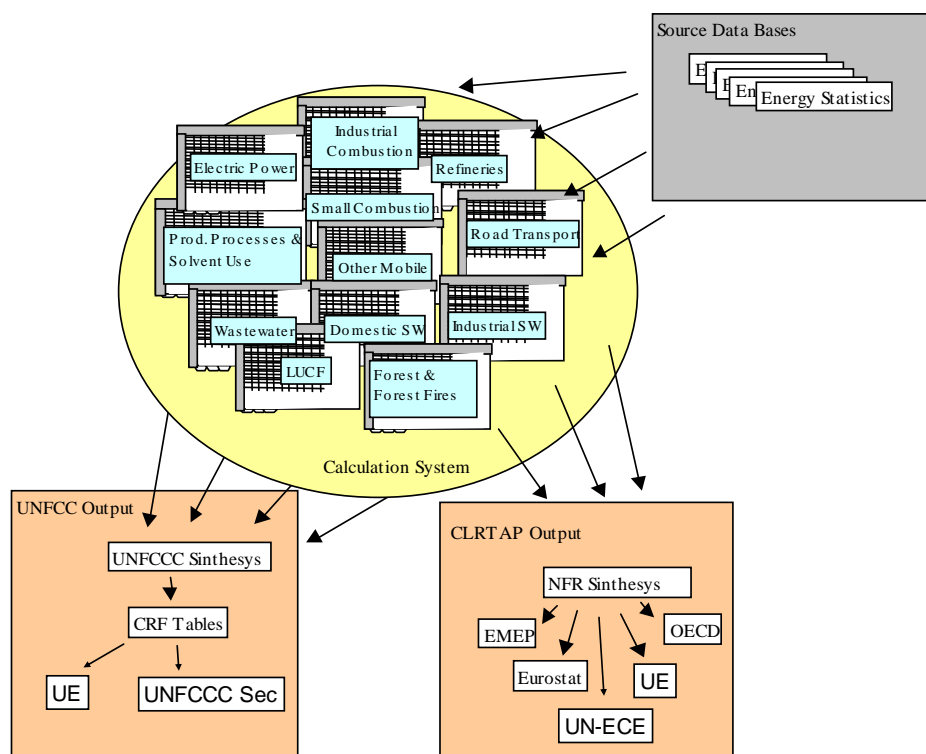
The information received from the several data suppliers is stored in its original format (paper or magnetic). A copy of this information is converted into the working workbooks, where data is further processed, linkage made and calculations performed, maintaining hence the integrity of the original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

³ InventAr, Estudos e Projectos Unip Lda

Figure 1.2 – 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 plans to rebuild this informatic system, having found some limitations for its expansion, namely in what concerns the storage of large amounts of data. This problem will be aggravated in the future with the implementation of inventory improvements: spacialization of emission data, connection to plant-specific monitoring programs and uncertainty analysis. The restructuring of all the inventory system is under study and discussion.

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 1.4 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	CS,D,T2	CS,D	D	D	D,T2	CS,D						
A. Forest Land	CS,T2	CS,D	D	D	D	D						
B. Cropland	T2	CS,D	NA	NA								
C. Grassland	T2	CS,D	NA	NA	NA	NA						
D. Wetlands	D,T2	CS,D	NA	NA	NA	NA						
E. Settlements	D,T2	CS,D	NA	NA	NA	NA						
F. Other Land	D,T2	CS,D	NA	NA	NA	NA						
G. Other	NA	NA	NA	NA	T2	CS,D						
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			D	CS,D	D	CR,D						
C. Waste Incineration	D	CS,D	D	CR	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 1.5 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 (DGTT) • 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
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
Portuguese National Inventory Report 2010		MAOT

1.5 Brief description of key source categories

Key category analysis to the 2009 Portuguese inventory estimates (1990-2008) was conducted using Tier 2 approach with the LULUCF sector. Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2008 period. A qualitative assessment has also been used.

The Tier 2 analysis with LULUCF resulted in the identification of 56 key categories, listed in the following table.

Table 1.6 – Summary overview of Portuguese key categories (1990-2008) based on Tier 2 approach

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identificat	Comments on level assessment	2008 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend All years		1346
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level All years		8978
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend 1999, 2004, 2005, 2006, 2007, 2008		563
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level All years		3928
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level All years		3864
6 A Municipal SWDL	SW Disposal on Land	CH ₄	✓	Level Trend All years		349
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level All years		2958
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Level Trend 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		2186
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		1944
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N ₂ O	✓	Level Trend All years		1793
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend All years		1768
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level All years		1655
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006		1412
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007		1392
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend All years		1265
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	✓	Level All years		1108
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N ₂ O	✓	Level Trend All years		1070
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend 1990, 1991, 1993		1051
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		990
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend All years		754
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		652
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		629
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2007, 2008		408
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level 2003, 2004, 2006, 2007, 2008		386
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend All years		378
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level 1990, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 2005, 2006, 2007		360
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	✓	Level 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2006, 2007, 2008		354
1A 4 b Residential	Biomass	CH ₄	✓	Level Trend All years		310
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	✓	Level Trend All years		226
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		181
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	✓	Trend 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005,		135
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Level Trend 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005,		126
3 D OTHER	Other Use of Chemicals	CO ₂	✓	Level All years		102
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend All years		102
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend All years		65
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2006		63
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO ₂	✓	Level All years		56
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend 1990, 1991, 1992, 1993, 1994, 1995, 1996		54
1B 2 b Natural gas	Gaseous Fuels	CO ₂	✓	Trend		53
2 F 2 Foam Blowing	Consumption	HFC	✓	Level Trend 2003, 2004, 2005, 2006, 2007, 2008		45
1A 1a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level All years		42
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		40
3 D OTHER	Other Use of Chemicals	N ₂ O	✓	Level Trend 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2004, 2005		34
1A 2 f Other	Biomass	N ₂ O	✓	Level All years		27
1A 1a Public Electricity and Heat Production	Biomass	N ₂ O	✓	Level Trend 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008		20
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	✓	Level 2006, 2007, 2008		18
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		17
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	✓	Level Trend 2003, 2005		13
1A 1a Public Electricity and Heat Production	Other Fuels	N ₂ O	✓	Trend		11
2 F 8 Electrical Equipment	Consumption	SF ₆	✓	Qualitative		8
1A 1a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend 1992		5
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level Trend All years		4
2 F 4 Aerosols	Consumption	HFC	✓	Qualitative		1
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	✓	Trend		-164
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	✓	Level Trend All years		-577
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	✓	Level Trend All years		-3837
Sub-total with LULUCF		All gases				65114
% of total with LULUCF		All gases				86.3
TOTAL EMISSIONS WITH LULUCF		All gases				75424

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 judgement, 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.

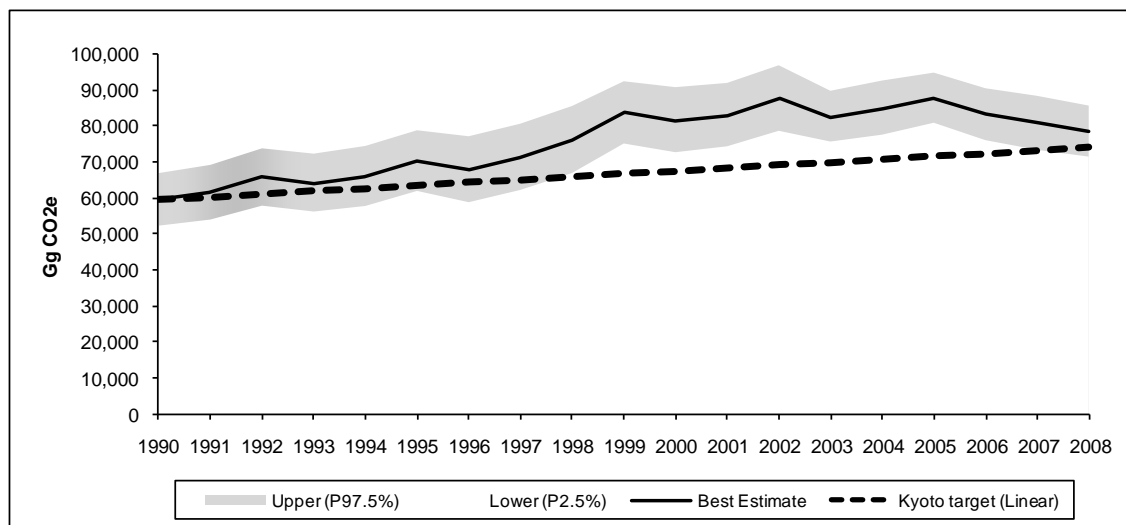
The uncertainty assessment was performed using inventory data for all years from 1990 to 2008. The results are presented in Table 1.7. The full range of emission possibilities, considering the confidence limit may be observable in Figure 1.3.

Total uncertainty varies along years from a minimum value of 7.8% up to 13.5%, from 1990 to 2008. The uncertainty in trend from 1990 to 2008 is 12.7%. 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	6.5	28.5	115.0	60.8	-	12.3
1991	6.5	28.2	115.4	287.0	-	12.3
1992	6.4	28.4	115.9	77.6	-	12.1
1993	6.3	28.9	119.1	62.7	-	12.5
1994	6.3	28.2	114.5	53.5	-	12.6
1995	6.1	27.8	109.9	62.0	77.5	12.0
1996	6.6	27.6	112.2	49.6	73.5	13.5
1997	6.4	27.7	112.5	47.6	71.1	12.9
1998	6.1	27.3	115.0	50.3	76.1	12.2
1999	3.8	27.3	108.1	49.1	78.5	10.3
2000	3.8	23.3	117.2	51.5	64.5	11.1
2001	3.9	25.9	116.9	50.2	72.0	10.6
2002	3.7	27.1	117.6	51.1	70.8	10.4
2003	4.0	27.2	112.0	34.2	68.2	8.5
2004	3.9	26.4	113.2	109.2	66.1	8.8
2005	3.7	26.5	113.0	34.1	67.5	7.8
2006	4.0	26.5	113.3	82.8	66.2	8.6
2007	4.6	26.9	114.9	67.9	66.2	9.2
2008	3.3	26.7	113.0	62.4	66.8	9.1

Figure 1.3 - Trend of total GHG emissions without 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 2010 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.

Despite the efforts done, it was still not possible to collect the necessary background information to quantify three categories that are missing from the inventory: N₂O from fire extinguishers, N₂O from aerosol cans and CO₂ emissions from agricultural lime application.

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 under an external consultancy with Ecoprogresso and InventAr, 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.

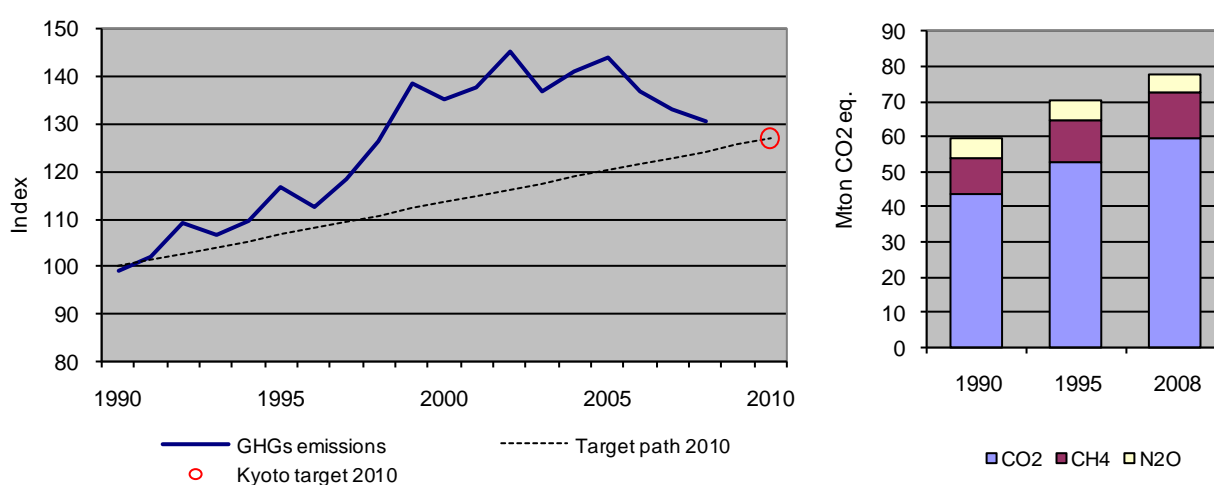
A detailed explanation of the sectoral future improvements are presented in each source specific sub-chapter.

2 TRENDS IN PORTUGUESE GHG EMISSIONS

2.1 Trends of Total Emissions

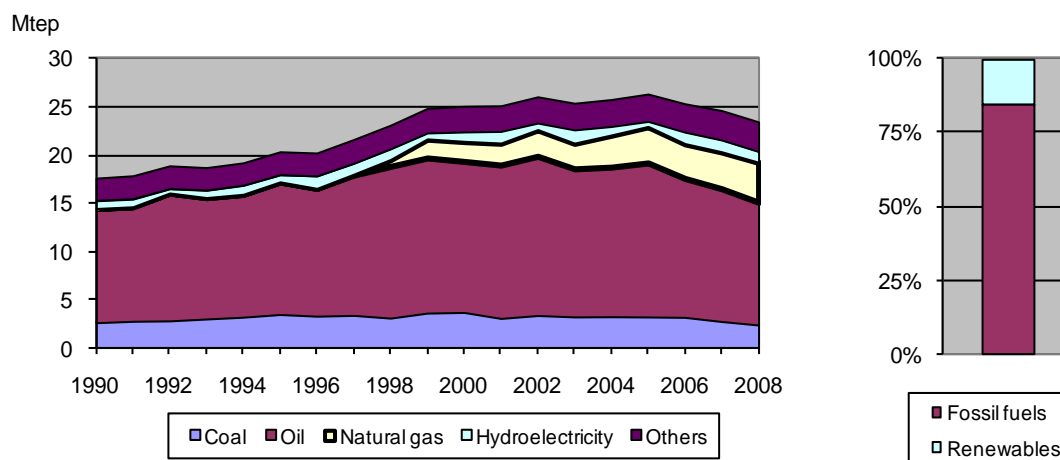
In 2008, total Portuguese GHG emissions without LULUCF were estimated at about 78.4Mt CO₂e, representing an increase of 30% compared to 1990 levels (Assigned Amount level). Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27% compared to the 1990 level. Comparing the 1990-2008 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2008, 6% above this target path.

Figure 2.1– GHG emissions (without LULUCF)



The principal source of GHGs in Portugal in 2008 is the energy sector. The largest gas emitted is CO₂ representing 76.0% 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 90.5% of total CO₂ emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2008, 84% 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. 16% 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



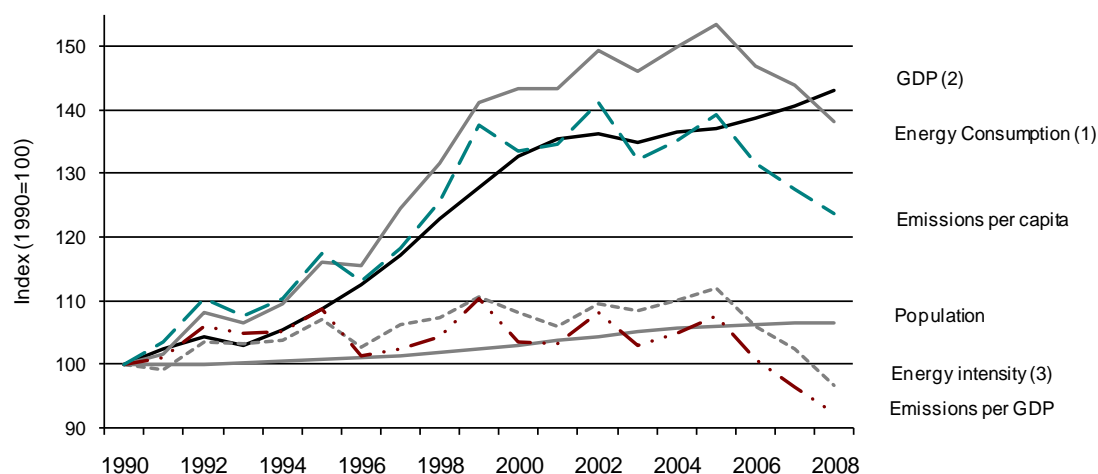
Notes: Hydroelectricity: domestic production. Others: includes fuelwood, wastes, and biogas. Fossil fuels: includes coal, oil and natural gas. Renewables: includes domestic hydroelectricity and others.
Source: DGGE.

The average annual emissions growth rate for the overall period 1990-2008 is about 2%. 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%; from 1995 to 1999 4.7%, and since 2000 a more moderate increase and even a decreasing tendency recently 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 rapid economic growth with an increase in GDP of about 43.0% in the period 1990-2008, corresponding to an average annual increase of 2.4%. The most rapid growth occurred from the years 1993 to 2000, where the average annual growth rate reached the 4.1%. 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

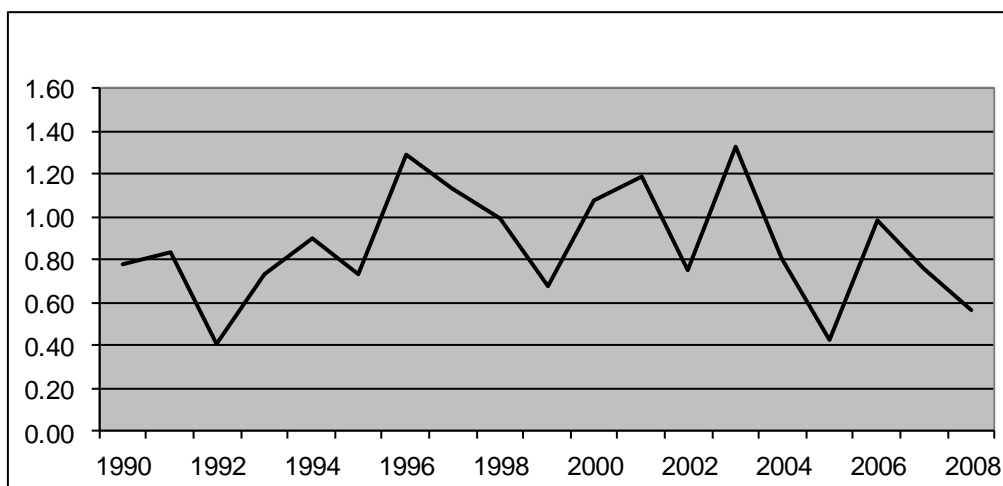


Notes:
Primary Energy Consumption.
GDP at 2000 prices.
Energy Consumption per GDP.
Sources: INE, DGEG.

During the period analysed, the country has achieved a slight 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.

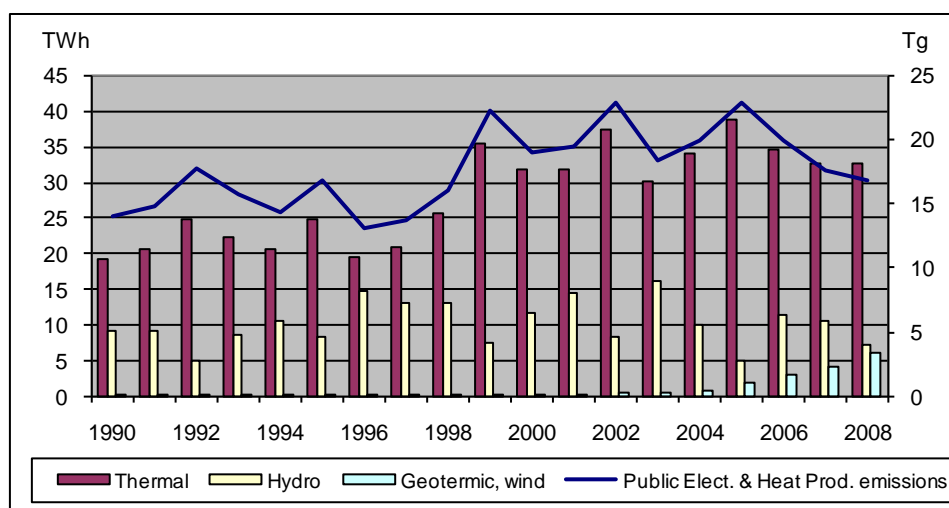
The level of emissions in the period analysed show significant inter-annual variations, which are related to the pronounced fluctuations of hydroelectric power generation, that is highly affected by annual variations in precipitation. Concerning recent years, year 2003 had a higher value of total annual 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 and 2008 present nevertheless a change in this relation, since the precipitation was lower (respectively, HI of 0.76 and 0.56) than the previous year (2006 HI of 0.98) and the emissions from the energy sector were lower in both 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.

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 1990-2008 period, CO₂ is the gas having registered the biggest increase (36.6%) and N₂O decreased by about 11%. F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2008: 1.3%).

Figure 2.6 – Increase of GHG emissions by gas over the 1990-2008 period

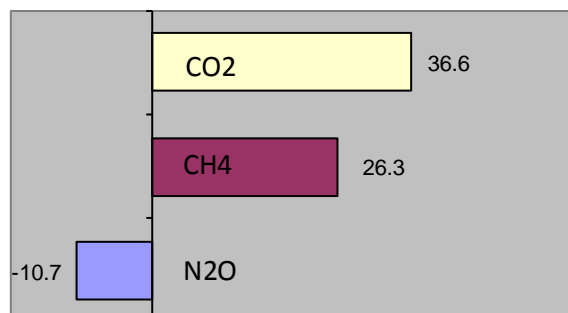


Figure 2.7 illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2008, being evident CO₂ as the primary GHG, accounting for about 76% of Portuguese emissions on a carbon equivalent basis in 2008 (LULUCF excluded). The second most important gas is CH₄, followed by N₂O, representing, respectively, 16% and 6% of total emissions in 2008. Portugal has chosen 1995 as the base year for fluorinated gases. In 2008 these gases represented about 1% 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: 1990 and 2008

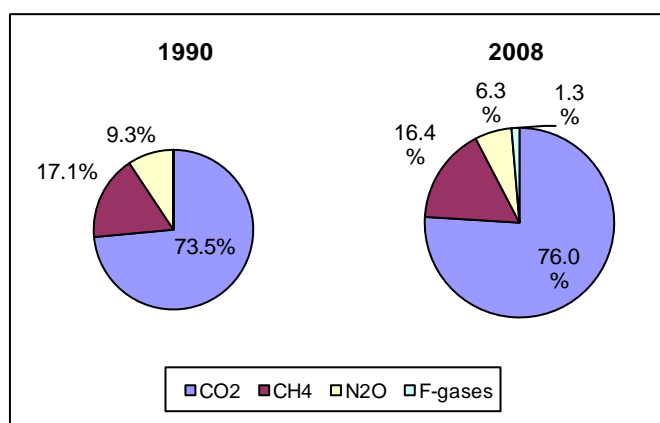


Table 2.1 – GHG emissions and removals in Portugal by gas: 1990-2008

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO ₂ equivalent (Gg)										
CO ₂ emissions including net CO ₂ from LULUCF	47,784	49,784	49,476	47,270	47,005	53,219	47,453	49,823	55,810	61,959
CO ₂ emissions excluding net CO ₂ from LULUCF	43,590	45,311	49,412	47,999	49,102	52,998	50,159	53,390	58,063	64,870
CH ₄ emissions including CH ₄ from LULUCF	10,396	10,771	10,675	10,638	11,075	11,525	11,481	11,629	12,217	12,371
CH ₄ emissions excluding CH ₄ from LULUCF	10,168	10,445	10,572	10,571	11,042	11,282	11,393	11,596	12,054	12,288
N ₂ O emissions including N ₂ O from LULUCF	5,583	5,575	5,541	5,372	5,622	5,688	5,960	5,930	5,555	5,974
N ₂ O emissions excluding N ₂ O from LULUCF	5,534	5,516	5,504	5,338	5,593	5,637	5,925	5,900	5,512	5,939
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	55	77	110	152	209
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	1	6	12
SF ₆	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	5	5	6	6	6
Total (including LULUCF)	63,763	66,130	65,691	63,280	63,703	70,493	64,976	67,499	73,746	80,530
Total (excluding LULUCF)	59,292	61,272	65,489	63,908	65,737	69,977	67,559	71,004	75,793	83,324

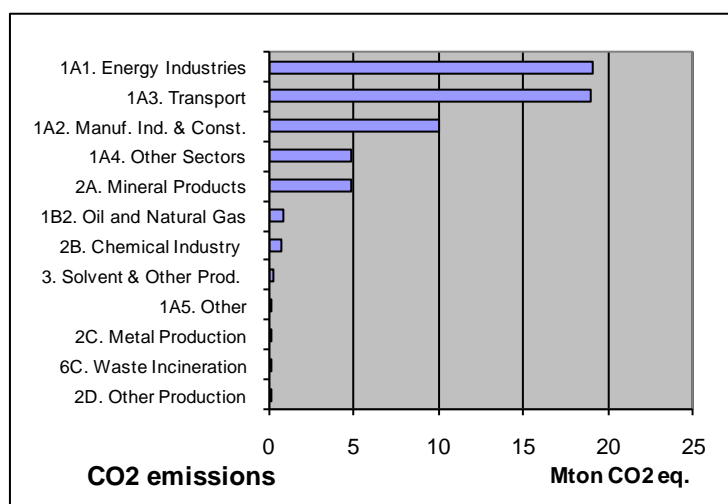
	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂ equivalent (Gg)									
CO ₂ emissions including net CO ₂ from LULUCF	62,049	61,510	65,546	69,814	65,096	72,918	61,905	58,832	56,546
CO ₂ emissions excluding net CO ₂ from LULUCF	63,691	64,402	68,396	63,718	65,901	68,285	63,798	61,524	59,544
CH ₄ emissions including CH ₄ from LULUCF	11,626	12,365	12,861	13,538	12,821	12,955	12,674	12,439	12,855
CH ₄ emissions excluding CH ₄ from LULUCF	11,430	12,248	12,688	12,818	12,694	12,411	12,588	12,415	12,843
N ₂ O emissions including N ₂ O from LULUCF	5,911	5,748	5,763	5,218	5,400	5,204	4,891	5,010	4,972
N ₂ O emissions excluding N ₂ O from LULUCF	5,865	5,710	5,719	5,118	5,361	5,123	4,856	4,981	4,944
HFCs	303	391	498	610.48	687.29	785.68	873.07	937.79	1,033.42
PFCs	6	13	10	9.53	9.31	9.97	6.55	5.72	9.02
SF ₆	6	6	6	6.81	7.51	7.12	8.10	7.73	7.85
Total (including LULUCF)	79,901	80,033	84,686	89,197	84,022	91,881	80,358	77,232	75,424
Total (excluding LULUCF)	81,301	82,769	87,318	82,281	84,660	86,622	82,129	79,872	78,381

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

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

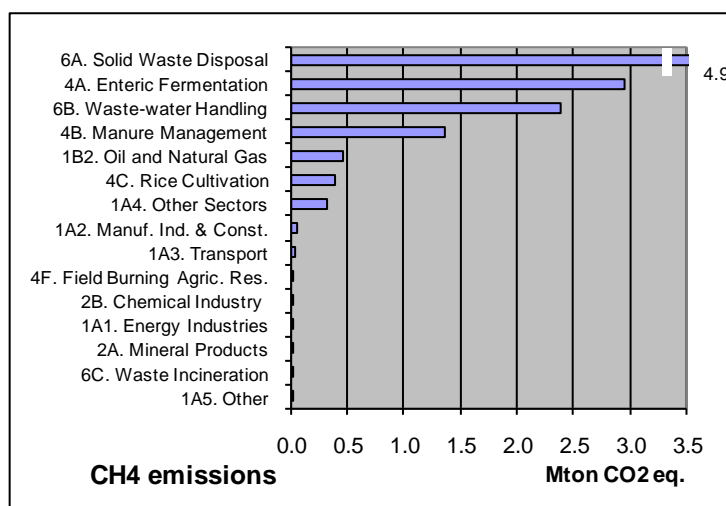
The largest GHG gas emitted is CO₂ which is mainly generated from fossil fuel combustion in energy-related activities (IPCC categories 1). Some other non-energy production processes such as cement production (included in category 2A), are also responsible for considerable quantities of CO₂ emissions.

Figure 2.8 – 2008 sources categories of CO₂



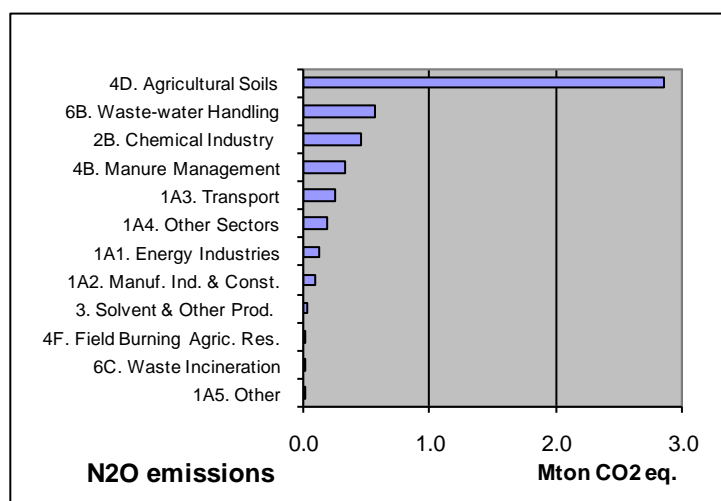
CH₄ is primarily generated through anaerobic decomposition of organic matter in biological systems, like decomposition of municipal and animal wastes, waste-water handling systems, or enteric fermentation in animals. Other sources are also responsible for these emissions, such as biomass burning, the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

Figure 2.9 – 2008 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 – 2008 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 these sectors with the exception of Agriculture. The interpretation of the LULUCF sector is somehow different, with positive figures representing that the sector is a net emitter, and negative values meaning that the source is estimated as a sink.

Figure 2.11 – GHG emissions and removals by sector: 1990-2008

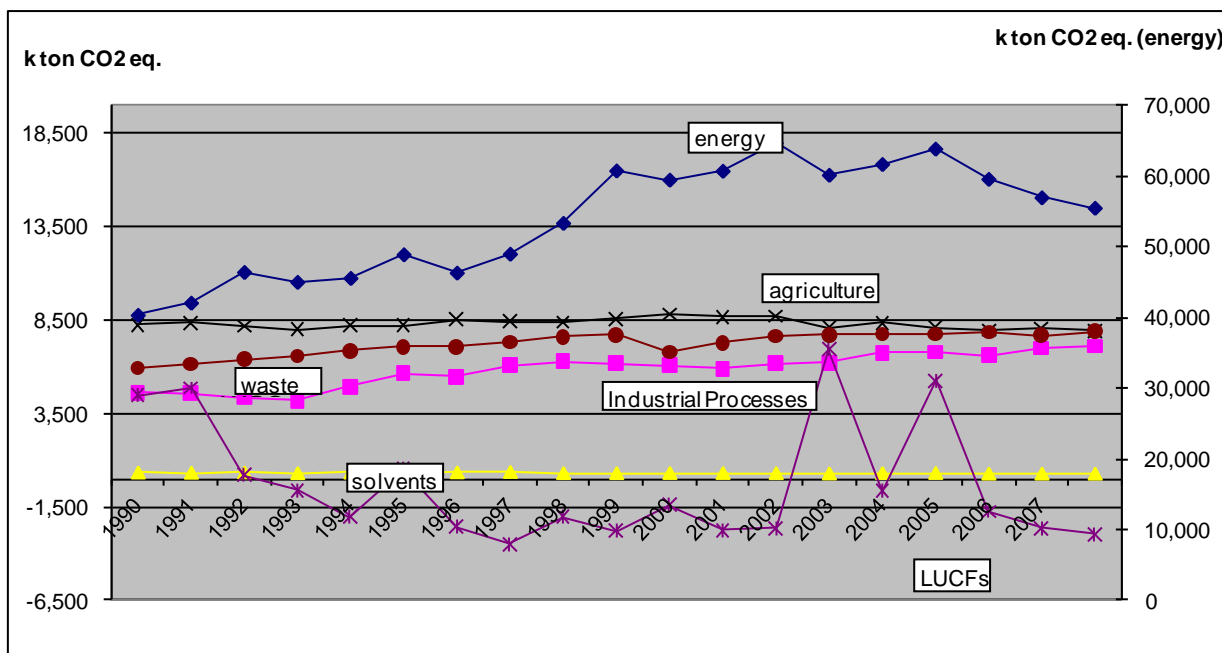


Figure 2.12 – GHGs emissions percentage change (1990-2008) by IPCC category (LULUCF excluded)

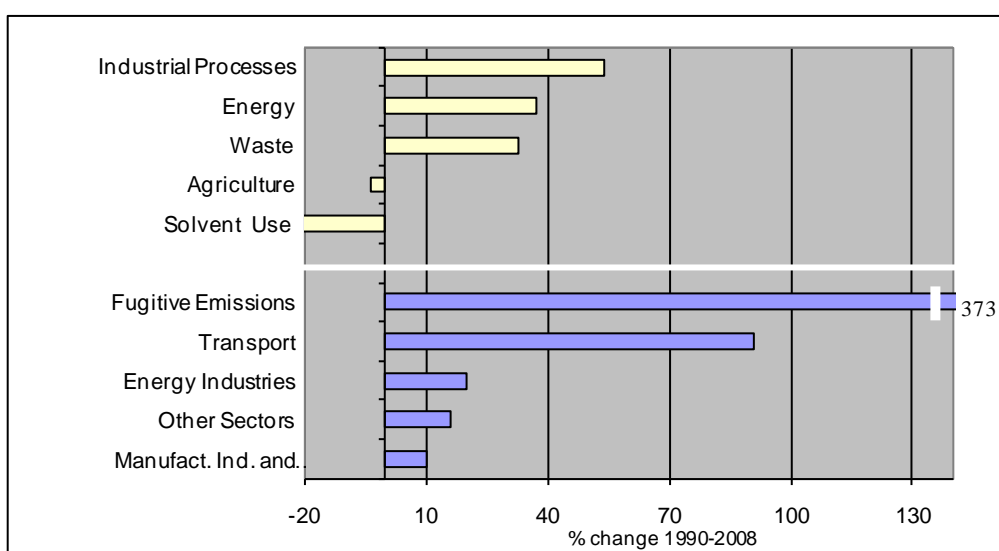


Table 2.2 – GHG emissions and removals by sector: 1990-2008

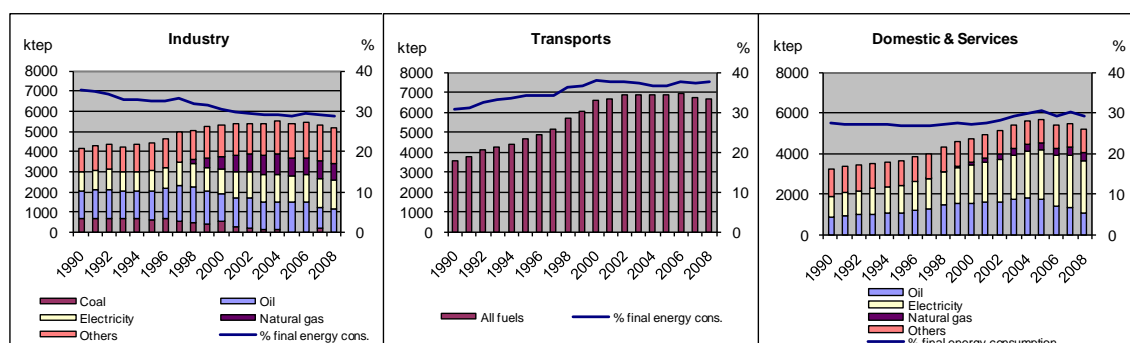
GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO ₂ equivalent (Gg)										
1. Energy	40,383	42,098	46,427	45,028	45,586	48,919	46,335	48,999	53,347	60,736
2. Industrial Processes	4,611	4,584	4,352	4,202	4,926	5,654	5,459	6,082	6,291	6,184
3. Solvent and Other Product Use	332	319	339	298	328	323	344	367	299	299
4. Agriculture	8,038	8,132	7,973	7,812	8,028	8,028	8,357	8,248	8,242	8,410
5. Land-Use Change and Forestry ⁽⁷⁾	4,472	4,858	203	-628	-2,034	516	-2,584	-3,505	-2,047	-2,794
6. Waste	5,928	6,139	6,397	6,567	6,868	7,054	7,064	7,308	7,613	7,695
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

GHGs SOURCE AND SINK	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂ equivalent (Gg)									
1. Energy	59,442	60,747	64,646	60,127	61,647	63,817	59,552	56,981	55,476
2. Industrial Processes	6,079	5,879	6,162	6,208	6,750	6,771	6,600	6,989	6,925
3. Solvent and Other Product Use	306	307	297	278	303	306	270	269	265
4. Agriculture	8,676	8,540	8,586	7,959	8,214	7,985	7,851	7,945	7,836
5. Land-Use Change and Forestry ⁽⁷⁾	-1,400	-2,736	-2,632	6,917	-637	5,258	-1,772	-2,639	-2,958
6. Waste	6,798	7,296	7,626	7,709	7,745	7,744	7,856	7,687	7,879
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA

Energy is by far the most important sector, accounting for 70.8% of total emissions in 2008, and presenting an increase of 37.4% over the 1990-2008 period. Energy industries and transport are the two most important sources representing each one approximately 24.5% of total emissions. Within the energy industries, public electricity and heat production represents alone 21% 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 or even 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% of the final energy demand, decreased to 29% since 2003. On the other hand, as previously mentioned, transports have been increasing importance, having raised from 31% in 1990 to 38% of the final energy consumption in the early 2000s. The increase of energy consumption of this sector was 91% from 1990 to 2005, but the variation dropped to 87 in the 1990-2008 period. Also, the services is one of the sectors that have increased the most, having registered a 218% rise of energy consumption from 1990 to 2005, and having slowing its increase to 170% from 1990 to 2008. In 2008, this sector together with the domestic sector, represented 29% 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% in 2004). This fuel has been losing relatively importance since 1990, when the share was 40% of the sectoral energy consumption. In the period 1990-2008 the emissions of transportation sources increased 91%, 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 stabilised in the mid 2000s.

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% rise), but this tendency has decelerated (around 15% increase in the 1990-2008 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 analysed, the second most significant source of GHG emissions, with 10.0% of the Portuguese emissions in 2008, and presents a decrease of 2.5% 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% of Portuguese emissions in 2008, recording an increase of approximately 33% 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 urbanisation growth registered in the country during the last decade) and the deposition of waste in landfills.

Industrial processes represented 8.8% of the Portuguese emissions in 2008, and have grown 50% 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% of total emissions, and is mainly related to NMVOC emissions⁴.

Estimates of emissions and sinks from LULUCF category, show that this category has changed from being a net emitter in 1990 (4.5 Mt CO₂e) to becoming a carbon sink in 1993 and the following years until 2002. The situation was again reverted in 2003 and 2005, when this category was again estimated as a net emitter. This pattern of variation is explained by the exceptional occurrences and extension of forest fires in specific years, and the use of the burnt materials as inputs to the industry.

2.4 Indirect GHG and SOx 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.

⁴ These are converted into ultimate carbon dioxide after being emitted to atmosphere.

Figure 2.14 – Indirect GHG and SO_x emissions: 1990-2008 variation

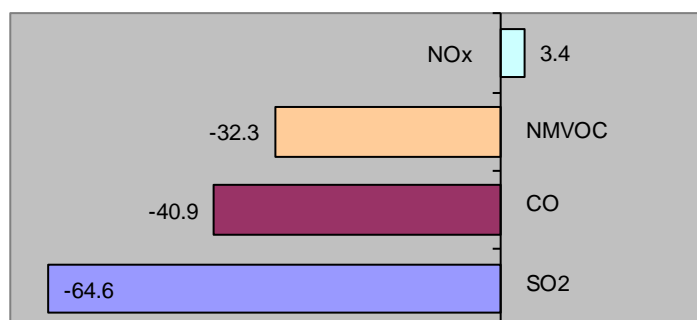


Table 2.3 – Indirect GHG and SO_x emissions: 1990-2008

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	(Gg)									
CO	849	865	897	845	820	804	795	763	752	728
NOx	259	274	294	282	283	293	292	295	306	321
NMVOC	321	324	332	307	300	292	289	285	285	279
SO2	320	311	373	317	297	333	273	293	342	345

Gas emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	% change
	(Gg)									1990-08
CO	695	624	611	588	581	562	538	522	502	-40.9
NOx	321	320	331	309	313	315	293	281	268	3.4
NMVOC	267	254	252	243	236	230	226	221	218	-32.3
SO2	306	287	285	191	193	198	174	168	113	-64.6

In 2008, SO_x, CO and NMVOC emissions have decreased from 1990 levels: -64.6%, -40.9% and -32.3%. NO_x emissions registered a positive trend: +3.4% (Table 2.3 Table ES.3).

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 and CO emissions, respectively 44% and 28% of 2008 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 even 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 1990-2008 period, respectively, -72% and -82%.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 51% of the 2008 totals.

SO_x emissions are mainly generated in the energy industry sector (approximately 53% of total emissions in 2008) and combustion in manufacturing industries (26% of total emissions in 2008), 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 some energy efficiency measures, among other factors as reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 of 10th November). 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 1990-2008 shows in fact a decrease in SO_x emissions in both sub-categories: manufacturing industries and energy industries -61% and -70%. From 2007 to 2008, SO_x emissions from the energy industries registered a significant reduction (approximately -46%) which is explained by the implementation of two new abatement systems (desulfurization in two Large Point Source Energy Plants in Mainland Portugal).

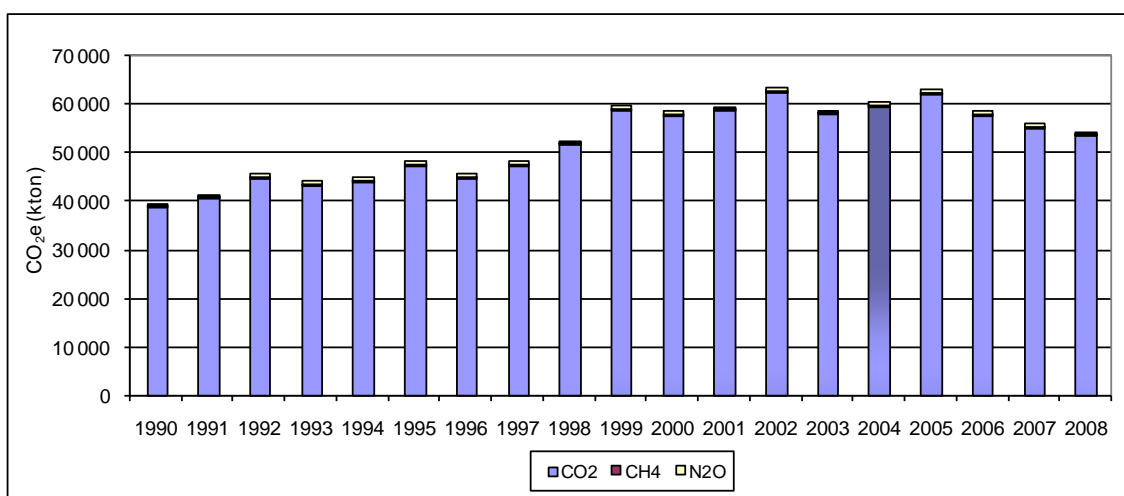
3 ENERGY (CRF 1.)

3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting in 2008 for 70.8% of total emissions of CO₂e excluding LULUCF. Total emissions from this sector have increased 37.4% 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. Also, after a continuous increase from 1990 to 1999, emissions since then have suffered only annual oscillations, which reflect the inter-annual variation in availability of hydropower, without the appearance of a clear pattern or trend. Hence, from 1999 till 2008 emissions have even decreased by 8.7%. This stagnation in emissions is concurrent not only with the existence of a period of economic stagnation in Portugal, which partially explain the situation, 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 equipments to use renewable sources.

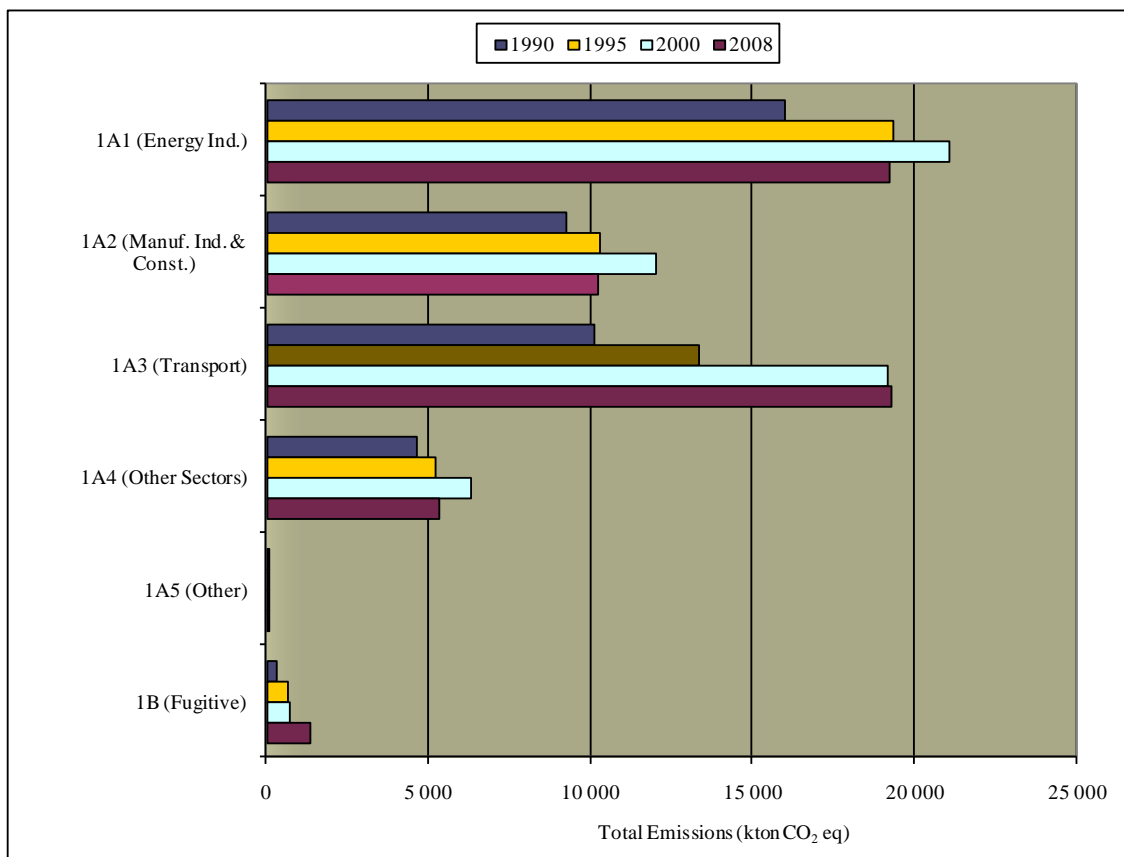
The relative importance of total CO₂e emissions from the Energy sector has increased, from 66.3% in 1990 to 68.8% in 2008. By far the most important gas emitted by this sector is CO₂, with 97.2% of sector emissions expressed in CO₂e.

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, the stagnation of the increase for sectors 1A1 and 1A3 in recent years, and even the decrease in emissions occurred in 1A2 and 1A1. These two categories are the main contributors for the decrease in emission from 2007 to 2008.

Figure 3.2 – Importance of CO₂e emissions from sub-sectors in Energy sector in selected years – 1990, 1995, 2000 e 2008.



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, 24.1% and 20.7% of total GHG emissions excluding LULUCF in year 2008. 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 12.8% of total emissions in 2008. GHG emissions from Refining of Petroleum Products is another relevant source with 3.3% of total emissions for this sector. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 6.7% 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.

Figure 3.3 – Total GHG emissions in source 1A, expressed as CO₂e, in 1990, 1995, 2000 and 2008

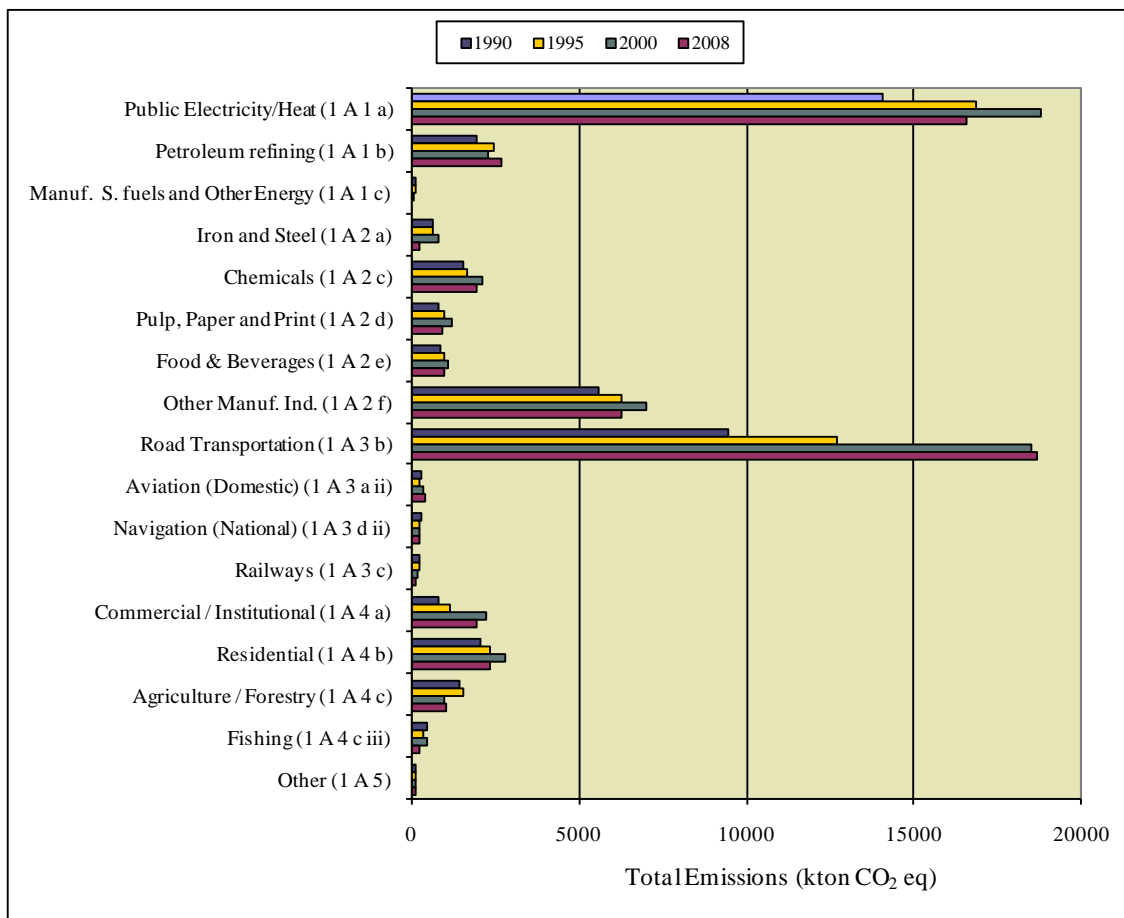
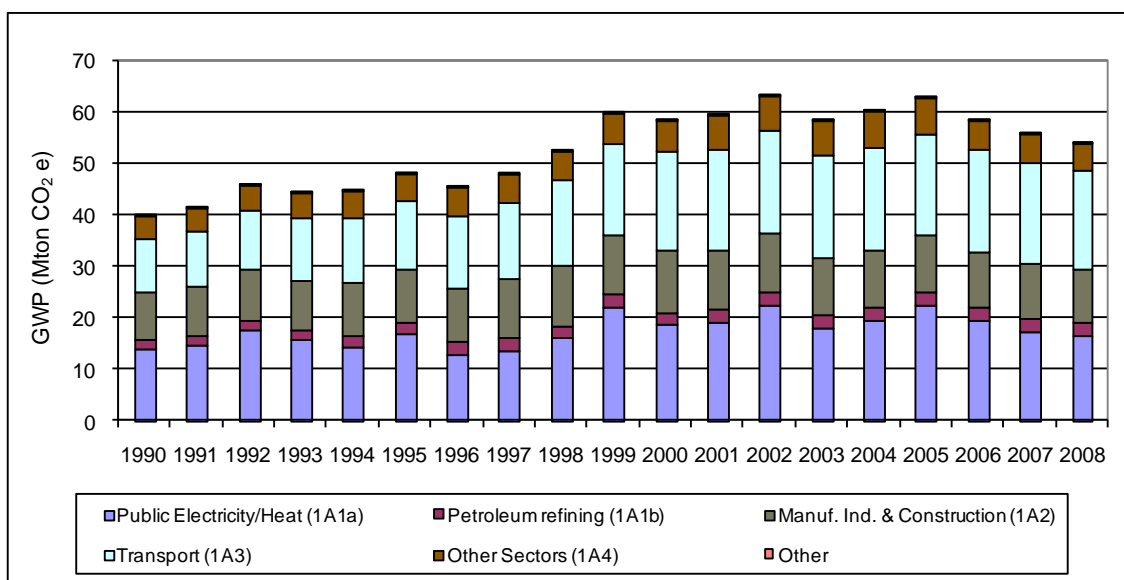


Figure 3.4 – Trend of total GHG emissions in source 1A, expressed as CO₂e, by sub-sector



GHG emissions from this activity sector are almost fully dominated by direct CO₂ emissions, which represent about 98.0% of GHG emissions in 2008. CH₄ and N₂O are minor sources, respectively 0.8% and 1.2% of total GHG emissions from the 1A sector in 2008.

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 include in carbon dioxide estimates (ultimate CO₂)⁵.

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 toward 2008.

GHG emissions occurring as CO₂ are responsible for 64.7% of 1B total emissions in 2008, being the remaining 35.3% emissions of CH₄. Emissions by gas are represented in Figure 3.6.

⁵ 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 latter 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 (1990-2008)

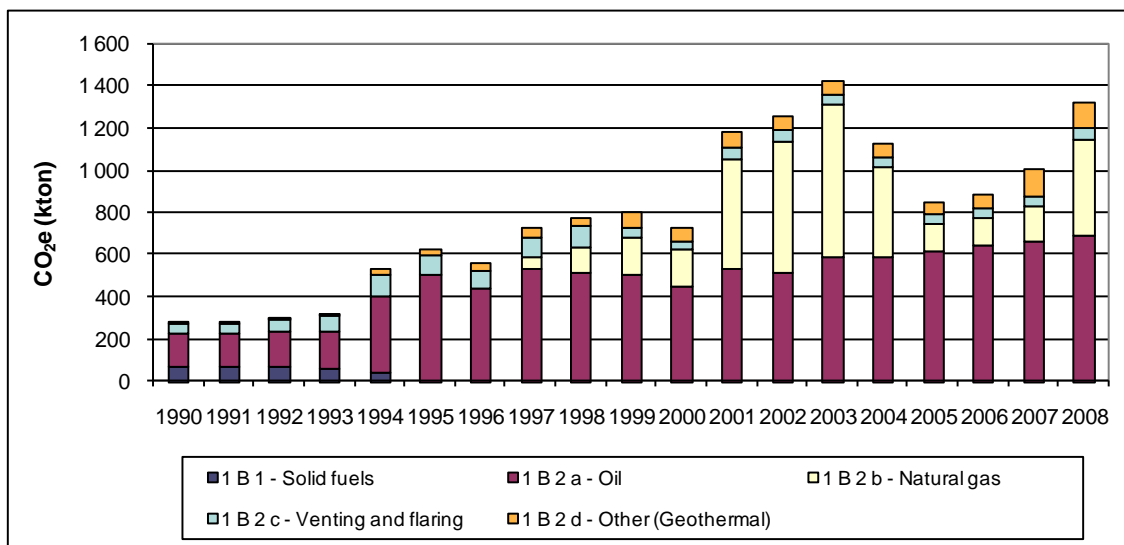
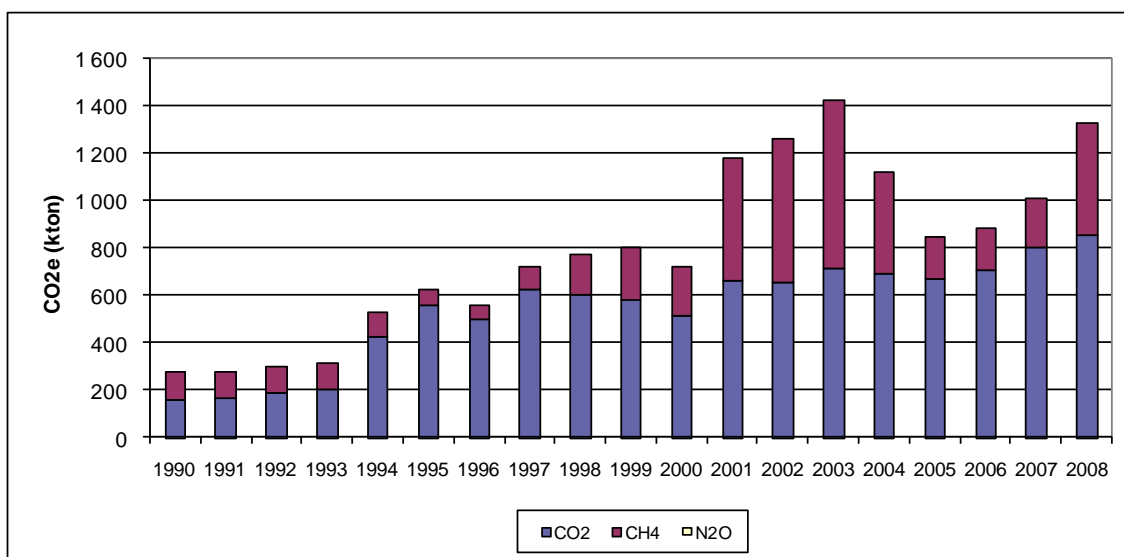


Figure 3.6 – Trend of total GHG emissions in source 1B, expressed as CO₂e, by GHG (1990-2008)



3.2 Category Sources

3.2.1 Energy Industries

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

3.2.1.1.1 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 TER⁶ 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 producers⁷.

Several components of the electricity and heat producing sector where 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.

3.2.1.1.1.1 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 12 units at present. Power plants and installed power are listed in table below together with their main relevant characteristics.

⁶ TER – Termoelétrica do Carregado

⁷ 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.

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

Power Plant	Location	Start	Situation	Fuel***	Power MWe	Treatment of Gas Effluents	Stack Height (m)	Comments
Tapada do Outeiro	Gondomar	1959	De-activated (2003)	LIG + FO	150/100/47**	ESP	60 (3)	Lignite use stopped in 1997
Portgen (new Tapada do Outeiro)	Gondomar	1998	Working	NG + GO	990 (2x330)	-	-	Combined Cycle
Soporgen	Lavos	2001	Working	NG	67	-	-	Co-generation. Combined Cycle
Energim	Alhambra	2002	Working	NG	43.7	-	-	Co-generation. Combined Cycle
Mortágua	Mortágua	1999	Working	Wood wastes + NG	9	ESP	-	-
Pêgo	Abrantes	1993	Working	HC + FO	615.2	ESP + Low NOx Burner + WFGD (after 2008) ****	225 (1)	-
Carregado	Alenquer	1968	Working	FO + NG	710 (2x250*)	ESP	100 (3)	Natural gas introduced in 1997
TER	Alenquer	2004	Working	NG	1 176	-	-	Combined Cycle
Carriço	Sines	2006	Working	NG	487	-	-	Co-generation
Alto do Mira	Amadora	1975	De-activated (2003)	GO	132	-	10-11	Gas turbine
Barreiro	Lavradio	1978	Working	FO	56	-	104 (1)	Co-generation
Setúbal	Setúbal	1979	Working	FO	946	ESP	200 (2)	-
Sines	Sines	1985	Working	HC + FO	1 192	ESP & Low NOx burners (after 2000) + WFGD(after 2008) ****	225 (2)	-
Tunes	Silves	1973	Working	GO	197	-	9-17	Gas 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

**** WFGD – Wet Flue Gas Desulfurization

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 touristy seasonal peak demands. The unit near Lisbon (Alto do Mira) has interrupted its activity in 2003.

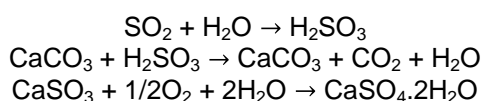
There has also been a change in the production structure along the 1990-2005 period, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase in the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was 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 build 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;
- Finally other new units, Soporgen and Energin, in central Portugal and Carriço, in the south, start production recently (Soporgen 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.

3.2.1.1.1.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

This represents a new emission source estimated for first time in this inventory submission. 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.

3.2.1.1.1.3 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 diesel oil.

Table 3.2 - Electricity Power Plants in the Azores and Madeira

Power Station
Porto Santo
Vitória
Santa Bárbara
Belo Jardim
Caldeirão
Pico
Caniçal

3.2.1.1.1.4 Non public co-generation Energy Producers

Apart from Barreiro, Soporgen, Energin and Carriço power plant units, already discussed as Large Point Sources, production of electricity by co-generation process in smaller private owned units started after 1993. Some of these units, 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.

3.2.1.1.2 Methodology

3.2.1.1.2.1 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:

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

$$Fossil_{CO2(y)} = \sum_u \sum_f [U_{CO2(u,f,y)} * C_{Fossil(f)} * 10^{-2}]$$

$U_{CO2(y)}$ – Total carbon liberated to atmosphere from consumption of fuel f in unit plant u, expressed in 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 (%);

$Fac_{OX(f)}$ – 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 CO_2 in the atmosphere or after deposition on soil. Emissions of CO_2 at stack exhaust (End-of-pipe emissions) may be estimated from final CO_2 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);

CH_4 - Methane emissions (ton);

TPM - Total Particulate Matter emissions (ton);

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

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

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:

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

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).

3.2.1.1.2.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

In the desulfurization processes it's important to determine the emission of CO_2 and the reduction of SO_2 . For both determinations the lime consumption was used as activity data:

$$CO_2 \text{ Emission}_{(u,y)} = CaCO_3_{Cons(u,y)} * CO_2Ratio * 10^{-3}$$

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

$\text{CO}_2 \text{ Emission}_{(u,y)}$ – Emission of CO_2 estimated from CaCO_3 consumption in power plant u in year y(ton);

$\text{SO}_2 \text{ Removal}_{(u,y)}$ – Quantity of SO_2 not emitted estimated from CaCO_3 consumption in power plant u in year y(ton);

$\text{CaCO}_3\text{Cons}_{(u,y)}$ – Consumption of CaCO_3 in power plant u in year y(ton);

CO_2Ratio – Stequiometric ratio between CO_2 emitted and CaCO_3 consumption;

SO_2Ratio – Stequiometric ratio between the SO_2 and CaCO_3 consumption;

The CO_2 and SO_2 ratios were determined using the stequiometric relations presented in the overview chapter.

Since the methodology for determining combustion SO_2 does not consider the use of abatement systems, the quantity of SO_2 removed in the desulfurization equipment will be subtracted to the total SO_2 emissions.

3.2.1.1.3 Emission Factors

3.2.1.1.3.1 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);
- AP-42 (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

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

Fuel	$\text{UCO}_2^{(i)}$ kg/GJ	$\text{FaCO}_x^{(i)}$ 0..1	FossilC %	$\text{CH}_4^{(i)}$ g/GJ	$\text{N}_2\text{O}^{(i)}$ 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
Biomass	109.6	1.000	0	15	4.3 ⁽ⁱⁱ⁾
Diesel (GT) ⁸	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

⁸ Mainly used in Gas Turbine plants.

3.2.1.1.3.2 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 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 3.4 for the power plants belonging to the public system in Azores and Madeira, and in Table 3.5 for the non public co-generation self producers⁹.

Table 3.4 – 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

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

Table 3.5 – 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

3.2.1.1.4 Activity Data

Activity data has different origins according to specific energy plants:

3.2.1.1.4.1 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. This is the main source of information for LPS fuel date;

⁹ Power producers as main activity only.

- Self-control program (*Programa Autocontrolo*)¹⁰;
- Plant activity reports (EDP 2000-2008) - mainly for Mortágua and Tunes power plant;
- EU-ETS – This source has been gaining relevance since the last inventory. As of now only Tunes fuel consumption is compiled using EU-ETS, but more fuel data is expected to be collected from this source in the future.

Nevertheless, 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 ¹¹ 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 3.6 – Low Heating Value per fuel type

Fuel	LHV/NCV	
Lignite	16.42 (15.57 - 17.02)	MJ/kg
Hard Coal	25.78 (24.51 - 27.23)	MJ/kg
Fuel-oil	40.22 (39.42 - 41.15)	MJ/kg
Orimulsion	28.00	MJ/kg
Diesel oil	43.30	MJ/kg
Natural Gas	38.27 (36.02 - 39.16)	MJ/kg
Biomass	7.8	MJ/kg

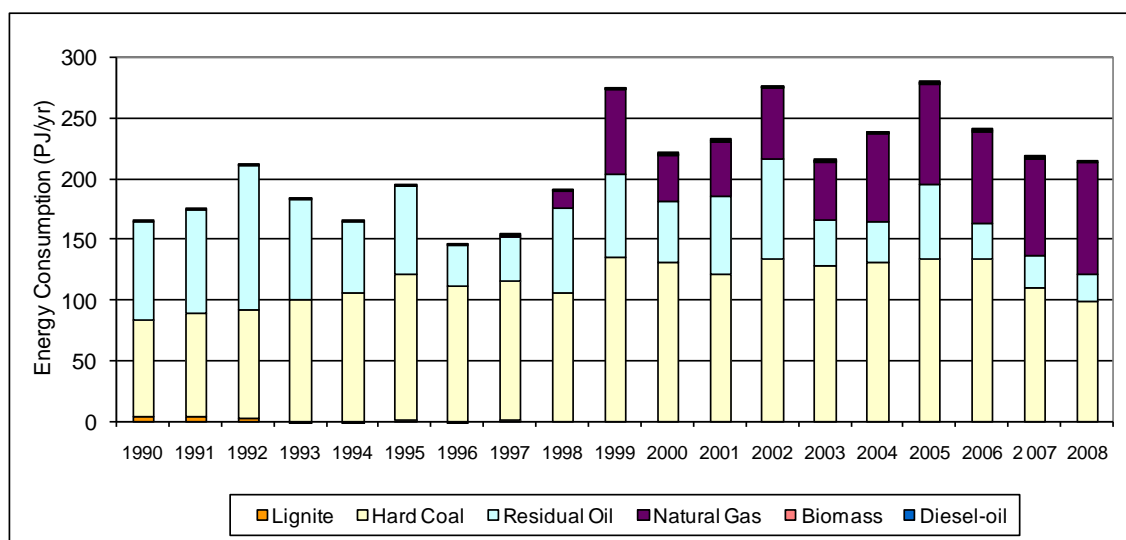
Source: The same as for the fuel consumption

Total consumption per fuel type in comparable energy units (GJ) may be verified in Figure 3.7.

¹⁰ The *Auto-controlo* program is a legal obligation for major emitters.

¹¹ 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 3.7 – Trends of fuel consumption per fuel type (1990-2008) ¹²



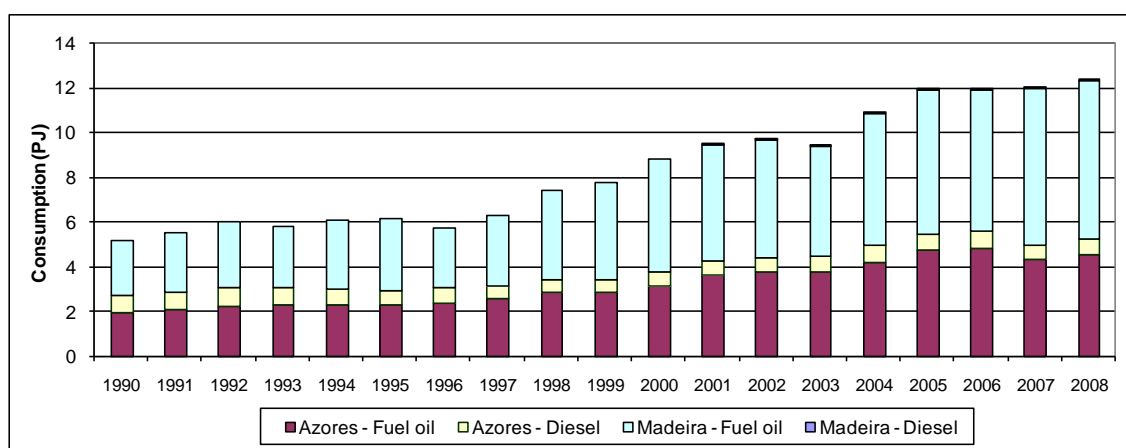
3.2.1.1.4.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

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.

3.2.1.1.4.3 Energy Plants in Azores and Madeira Autonomous Regions

The quantity of residual fuel-oil and diesel oil used in Madeira and Azores in electricity production is available from 1990 to 2000 from General-Directorate of Energy (DGE, 2003). Figures from 2001 to 2002 were obtained from the reports made to the European Union's Emission Trading Scheme (EU-ETS). The values for 2003 to 2008 were obtained through the Regional Environmental entities. Full fuel consumption time series can be observed in the figure below:

Figure 3.8 – Trends of fuel consumption in Azores and Madeira Archipelagos (1990-2008)



Note: Consumption of diesel oil in Madeira represents a very small quantity after 2001 and it is not visible in figure

¹² Time series not visible in the graph: Consumption of diesel oil in gas turbines increased from 29 TJ in 1990 to a peak value of 784 TJ in 2001 and thereafter decreased again until 510 TJ in 2003. Biomass (wood wastes) consumption was only 86 TJ in 1999, 147 TJ in 2000, 316 TJ in 2001, 555 TJ in 2002 and 700 TJ in 2003. Orimulsion and fuel-oil are represented together as Petroleum products.

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 3.7 - LHV per fuel type

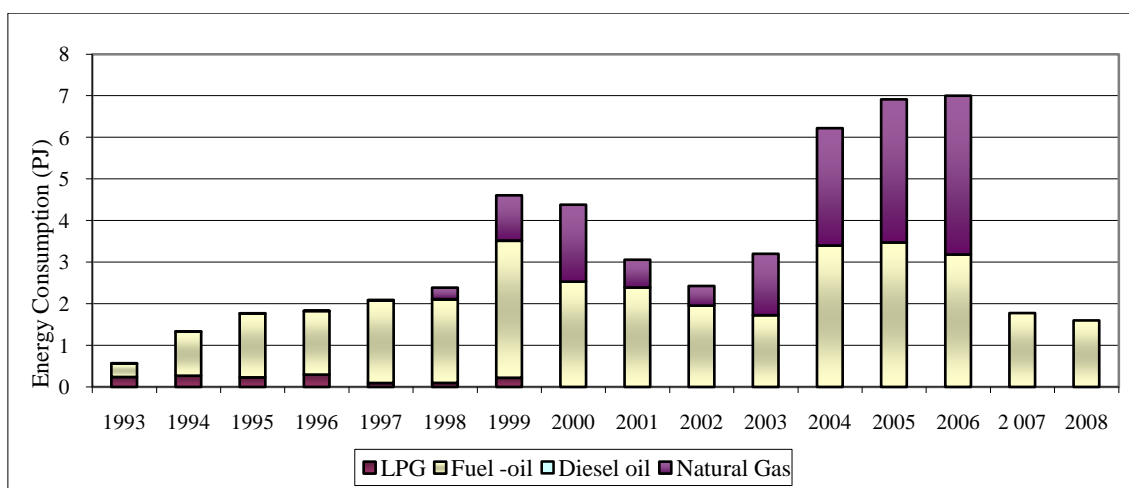
Region	Fuel type	LHV/NCV (MJ/kg)
Azores	Residual fuel oil	40.17
	Diesel oil	43.30
Madeira	Residual fuel oil	40.17
	Diesel oil	43.30

Source: The same as for the fuel consumption

3.2.1.1.4.4 Non-public co-generation Energy Producers

Consumption of fuels in co-generation units, except *Barreiro*, *Soporgem* and *Energim* power plants is available in toe units from the revised energy balances from DGEG and is presented in Figure 3.9.

Figure 3.9 – Trends in consumption of fuels in non-public co-generation plants (1990-2008)



Since 2007 the Energy Balance ceased to report Natural Gas consumption in this category.

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

Table 3.8 - LHV per fuel type used for non-public co-generation plants estimates

Fuel	LHV (MJ/kg)
LPG	49.76
Fuel -oil	40.17
Diesel oil	43.30
Natural Gas	38.74 (MJ/Nm ³)

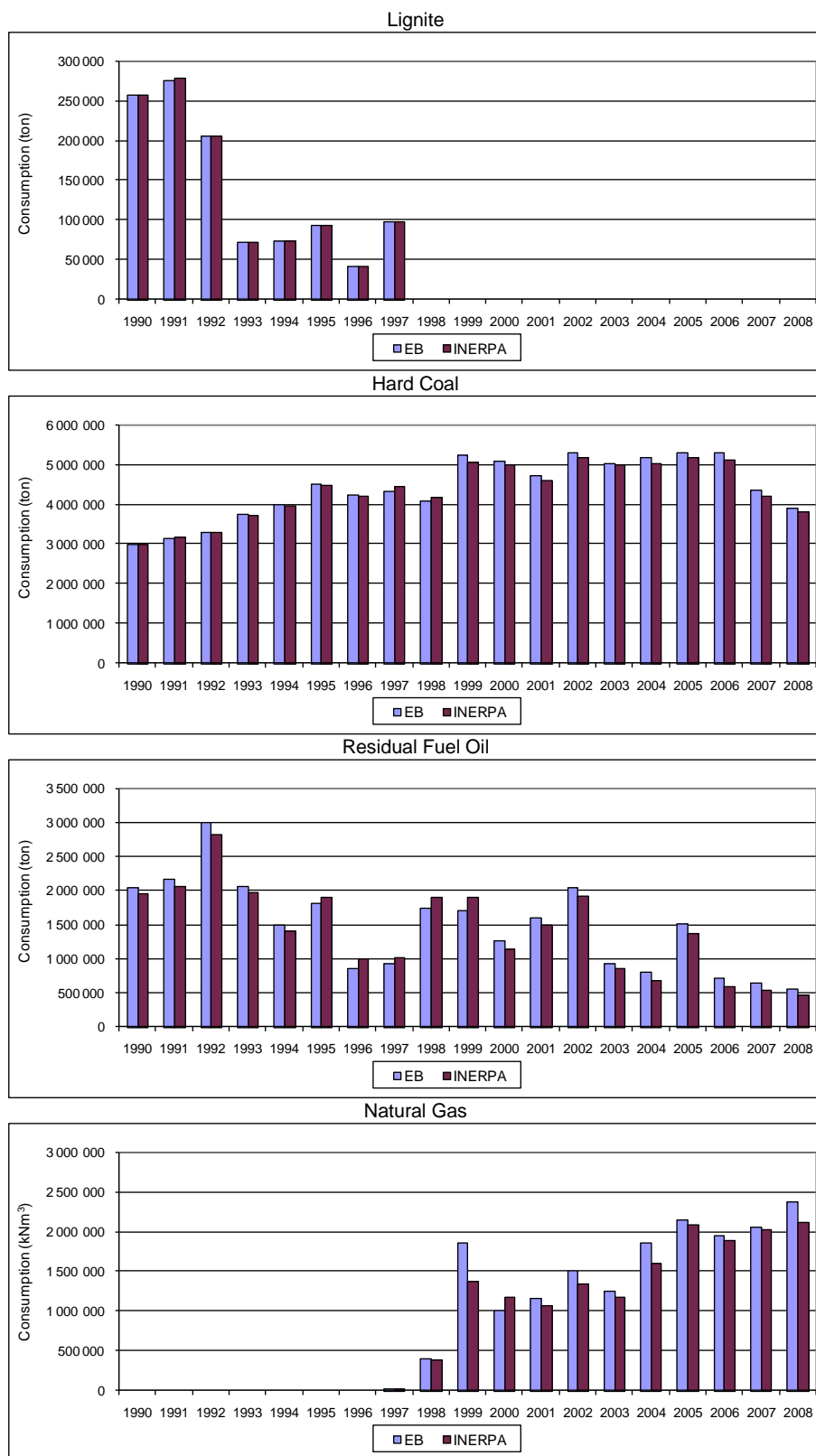
Source: The same as for the fuel consumption

3.2.1.1.4.5 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. 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 3.10 – Comparison of total fuel consumption in large power plants, between values used in the inventory (INERPA) and in the Energy Balance (1990-2008)



3.2.1.1.5 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%, 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% 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%, 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% for CH₄ and 1000% for N₂O.

The EU-ETS defines a maximum uncertainty value of 7.5% 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.

3.2.1.1.6 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. Also 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).

General checks were made to the emission compilation spreadsheets. An error was identified and corrected in the emission compilation for non-public co-generation energy producers. This does not affect total emissions from 1.A.1.a - the correction only reallocated emissions between fuel types (within the same sub-source).

3.2.1.1.7 Recalculations

Recalculations for this sector comprise:

- Revision of DGEGs energy balance for 2007;
- Update on fuel consumption for Tunes power plant using EU-ETS data (2006 and 2007);
- Update on fuel consumption for Autonomous Regions power plants using data provided by the regional environmental entities (2001-2007);
- Correction of a compilation error for non-public co-generation energy producers. This does not affect the emissions that were estimated for this source category.

3.2.1.1.8 Further Improvements

The main improvement programmed for the next submission concerns the implementation of more accurate emission factors, through the use of plant specific emission data from Self-Control Program (*Programa Autocontrolo*). Data from this source is already used for estimating emission factors but its application is still limited. Further incorporation of time evolution of these emission factors is also necessary. Efforts to increase the percentage of units treated as LPS is also considered a desirable objective. These efforts are in accordance with the goals that the EC¹³ has set to streamline data collection for the inventories and for the EU-ETS¹⁴.

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. As an indication of this compliance between DGEG and APA, this year Energy Balance already contained some information compiled through EU-ETS.

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

3.2.1.2.1 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 (dessulphurization). 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, alquilation 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 does also result from sulphur that is removed from intermediate or final products, mostly to respect environmental regulations, and conveyed in final flux gases. 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.

3.2.1.2.2 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.

¹³ European Commission.

¹⁴ European CO2 trading scheme.

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 (%);

$Fac_{OX(f)}$ – 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).

3.2.1.2.3 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 3.9 – Emission Factors for combustion sources in Refining of Petroleum Products. Greenhouse Gases.

Fuel	Equipment	$U_{CO_2}^{(i)}$ kg/GJ	$Fac_{Ox}^{(i)}$ 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)

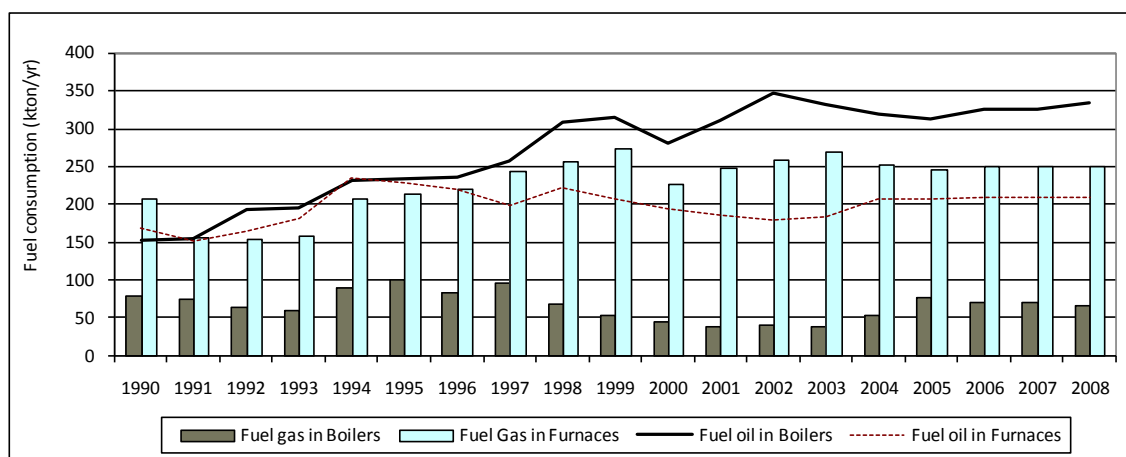
3.2.1.2.4 Activity Data

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

The three refinery units consume self produced residual fuel-oil¹⁵, fuel-gas, liquefied petroleum gases (LPG) and diesel oil.

The quantities of fuel consumption from 1990 to 2008 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. 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.

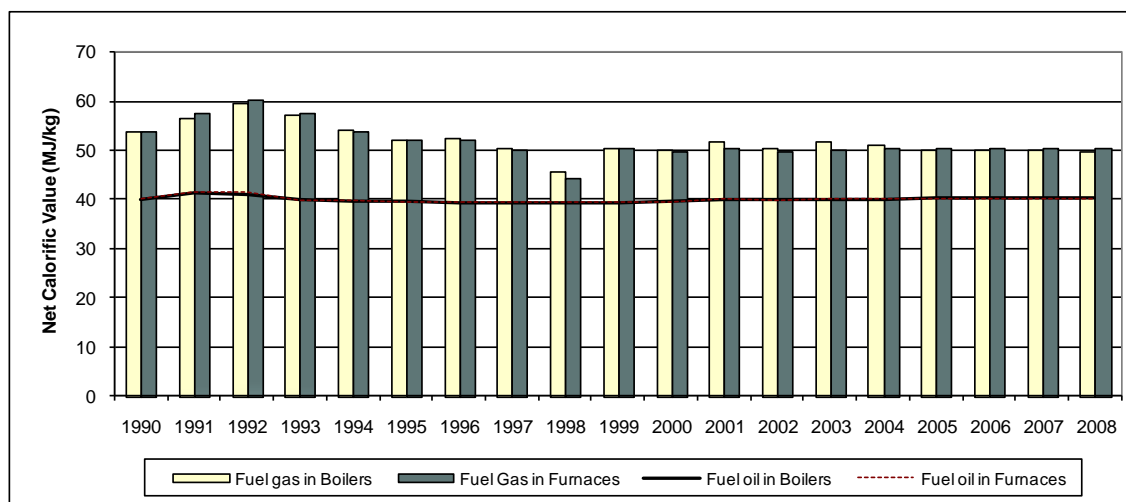
Figure 3.11 – Fuel consumption per year by type of equipment



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 and are weighted averages for all three plants.

¹⁵ In strict terms this fuel is not traded and must not be named fuel-oil, to avoid confusion to traded fuel oil.

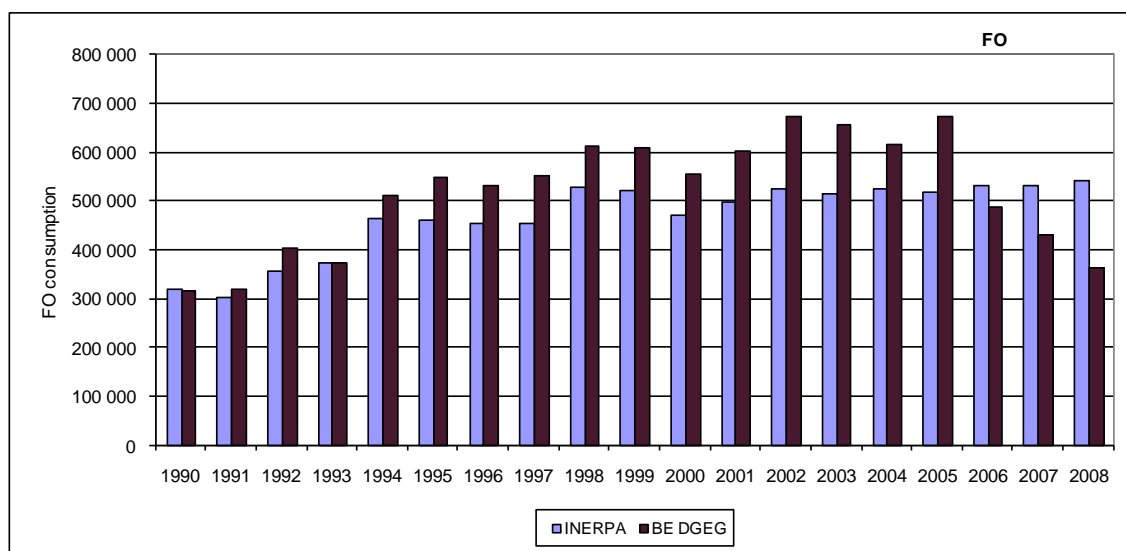
Figure 3.12 – Net Calorific Value (NCV) or Low Heating Value (LHV) expressed in MJ/ kg by type of equipment

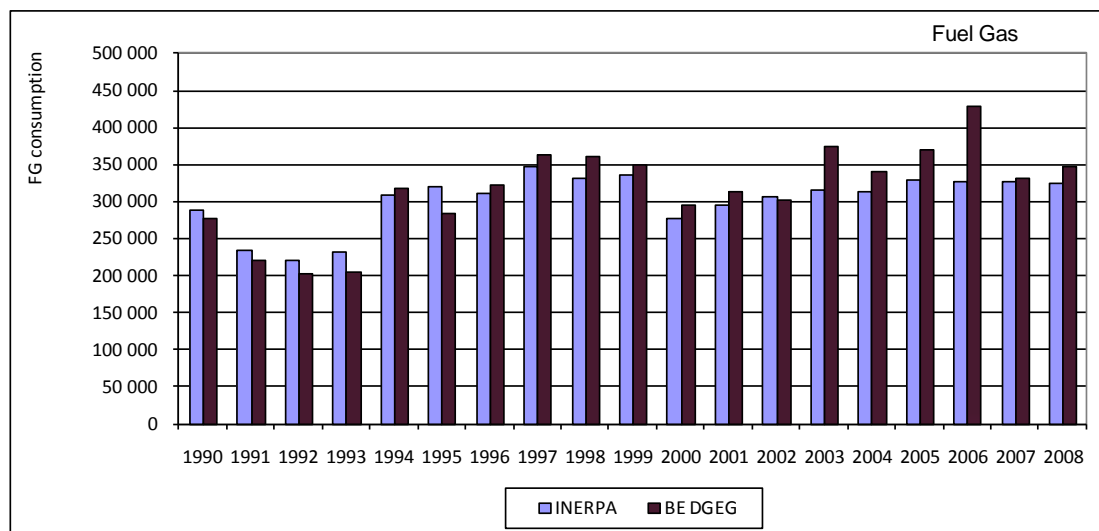


3.2.1.2.4.1 Comparison of LPS data vs. National Statistics

In a similar mode that 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 and the Energy Balance and graphs for residual fuel oil (FO) and fuel gas are presented in the next figure. Generally, there is an agreement between the two sources of information, in particular for the initial years in the period, although not so good as that that was obtained for the electric energy sector.

Figure 3.13 – Comparison of total fuel consumption in crude oil refineries, between values used in the inventory (INERPA) and in the Energy Balance.





3.2.1.2.5 Uncertainty Assessment

The uncertainty value was established at 1%, 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%, 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% for CH₄ and 1000% for N₂O.

3.2.1.2.6 Recalculations

No changes in methodology and emission factors were made for this source sector since last year's submission.

3.2.1.3 Other Energy Industries (CRF 1.A.1.c.)

3.2.1.3.1 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.

3.2.1.3.2 Methodology

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

$$U_{CO_2(y)} = 44/12 * EF_C * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3}$$

$$Fossil_{CO_2(y)} = U_{CO_2(y)} * C_{Fossil(f)} * 10^{-2}$$

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_C – Carbon content of fuel 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);

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

For CH_4 and N_2O 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 CO_2 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 CO_2 in kg/GJ).

3.2.1.3.3 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 3.10.

Table 3.10 – 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
$Fossil_C$	100	100	100	100	%
CH_4	2.5	⁽ⁱⁱ⁾ 2.9	⁽ⁱⁱ⁾ 2.9	⁽ⁱ⁾ 1.4	g/GJ
$N_2O^{(i)}$	1.40	0.60	0.60	1.40	

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

3.2.1.3.4 Activity Data

3.2.1.3.4.1 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:

$$\text{Coquerie}_{\text{CONS}}(y) = \text{Coquerie}_{\text{CONS}}(91 - 94) / \text{Total}_{\text{CONS}}(91 - 94) * \text{Total}_{\text{CONS}}(y)$$

where

$\text{Coquerie}_{\text{CONS}}(y)$ - consumption of coke gas in the coquerie in year y;

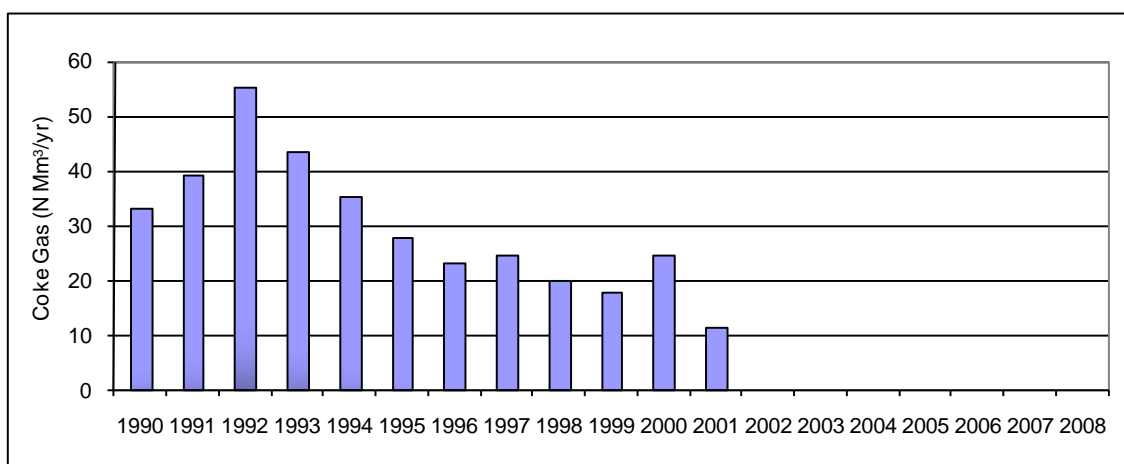
$\text{Coquerie}_{\text{CONS}}(91-94)$ - consumption of coke gas in the coquerie from 1990 till 1994;

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

$\text{Total}_{\text{CONS}}(y)$ - 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 3.14. Conversion in energy units was calculated using a LHV of 18.78 MJ/Nm³, the value that is reported under LCP directive.

Figure 3.14 – Coke gas consumption in the coquerie: (1990-2008)

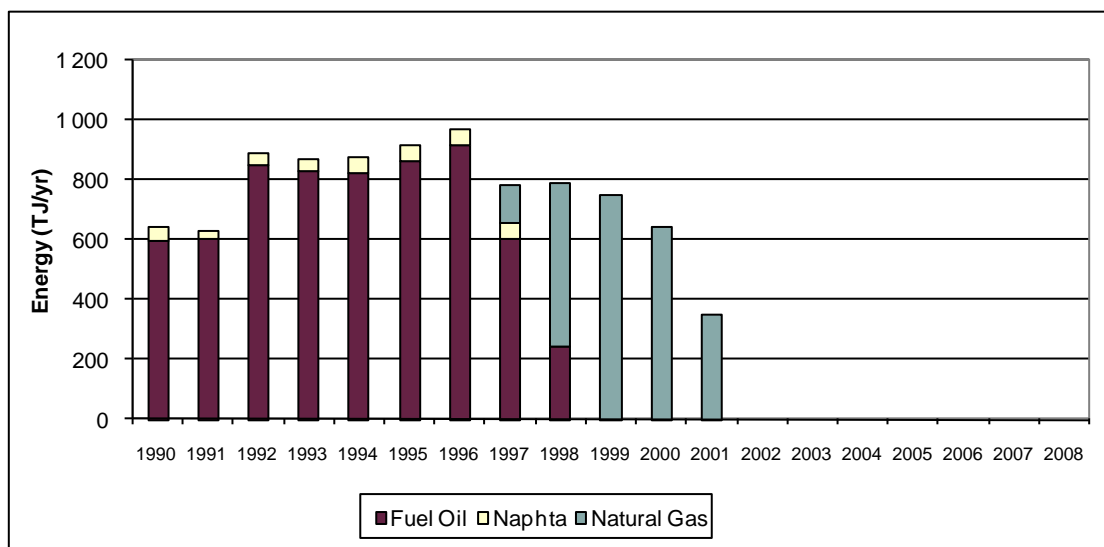


3.2.1.3.4.2 City Gas Production

According to the energy balances from DGEG, this activity has used fuel oil, naphta and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001¹⁶. The available time series is presented in Figure 3.15.

¹⁶ 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

Figure 3.15 – Consumption of fuels in co-generation in city gas production (1990-2008)



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

Table 3.11 – NCV/LHV per fuel type for city gas production

Fuel	NCV (MJ/kg)
Fuel-oil	40.17
Naphta	43.3
Natural Gas	46.0

3.2.1.3.5 Uncertainty Assessment

Coke production is based extensively in extrapolations from a reduced time-series. Therefore 10% 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% 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%, 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% for CH₄ and 1000% for N₂O.

3.2.1.3.6 Recalculations

No recalculations were done for this source sub-sector since last year's submission.

3.2.2 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 reported 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 units¹⁷.

3.2.2.1 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:

$$U_{CO_2(y)} = 44/12 * EF_C * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3}$$

$$Fossil_{CO_2(y)} = U_{CO_2(y)} * C_{Fossil(f)} * 10^{-2}$$

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_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 (%);

$Fac_{OX(f)}$ – 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).

¹⁷ 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).

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 steps¹⁸:

- 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 2006-2008.

Table 3.12 – Incorporation rate of biodiesel. (1990-2008)

	1990-2005	2006	2007	2008
Incorporation rate (%)	0	1.33	2.57	2.50

¹⁸ 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.

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. For the following industrial sectors specific estimation procedures were taken.

3.2.2.1.1 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).

3.2.2.1.2 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.

3.2.2.1.3 Ceramic Industry

Emissions of SO_x, NO_x, NMVOC and CH₄ 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

3.2.2.1.4 Glass Production

Similarly to ceramic industry, emission 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.

3.2.2.1.5 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.

3.2.2.2 Activity data

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

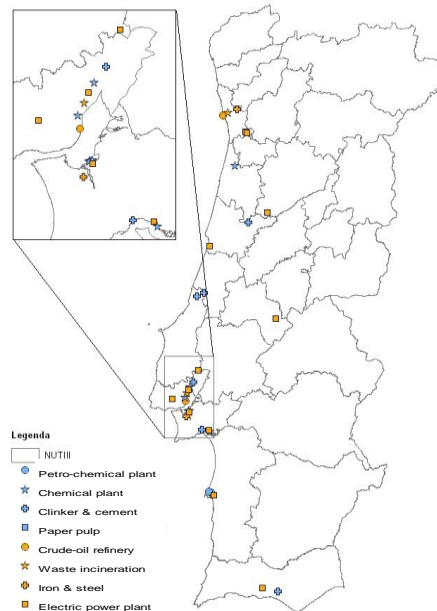
3.2.2.2.1 Combustion Data

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 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 (all) paper pulp plants and six cement plants (covering all clinker producing units).

Figure 3.16 – Distribution of Large Point Sources in continental Portugal¹⁹



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 3.17 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,

¹⁹ 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) (tep/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);

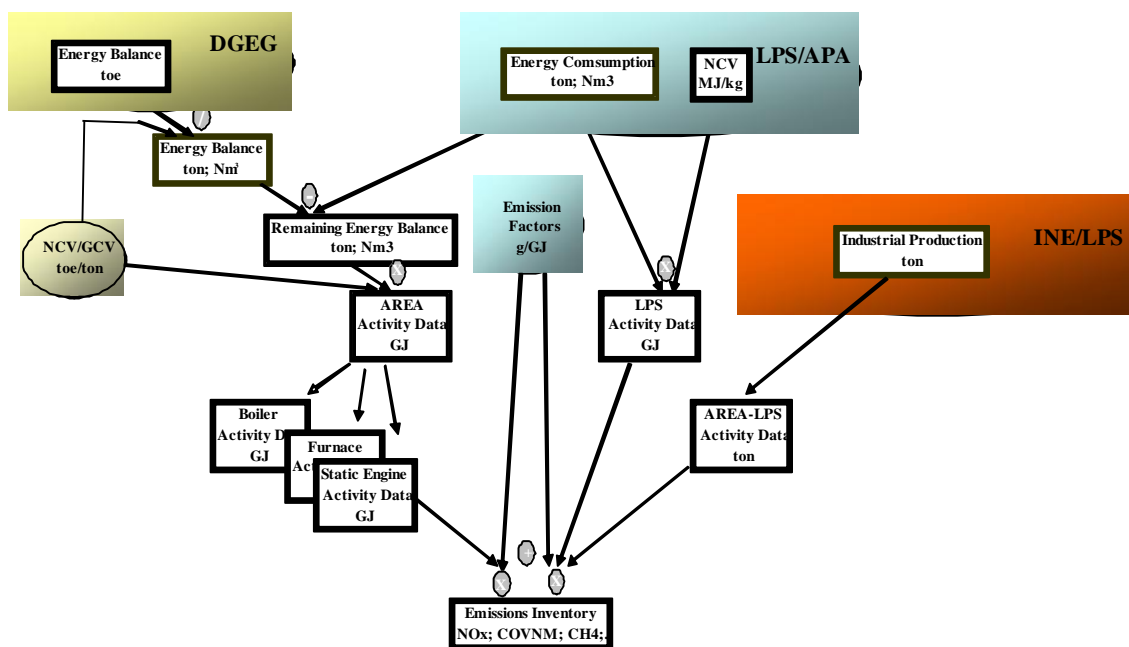
$Frac_{Equi(s,f)}$ – Fraction of consumption of fuel f in sector s that is used in equipment e (0..1);

$LHV_{LPS(u,f,e)}$ – 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 (tep/ton or tep/ 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)²⁰.

Figure 3.17 – General procedure for emissions estimate



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

²⁰ In most cases similar values to Energy Balance are used

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 DGEG's energy balances make a separation between quantities used in co-generation and quantities used without co-generation.

3.2.2.2.1.1 The Energy Balance

The Portuguese Energy Balance (EB) is published annually by DGEG 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 2008 is presented in annex to the NIR.

Table 3.13 – 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	Brigettes		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		Construction and Public Works
			Other Manufacturing Industries		Transport
			Extractive		National airplanes
			Services		National ships
					Railways
					road
					Domestic
					Services

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

Coal	Imported coal	Non Energ Products	Lubricants
	National coal		Asphalts
	coal coke		Parafin
Oil	Intermediate refinery products		Solvents
	LPG		Propylene
	Gasoline	Electr city	Hydro-electricity
Gases	Kerosene		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 3.15 – 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

3.2.2.2.1.2 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 six LCP units summed together.

3.2.2.2.1.2.1 Iron and Steel Industry

Table 3.16 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Iron and Steel Industry (MJ/kg)

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Coke oven gas (MJ/Nm3)	Blast furnace gas (MJ/Nm3)	Tar	Waste Oil	Gasoline	Biodiesel
46.1-47.3	43.7	43.3	40.2-40.4	38.7	18.8	2.87	34.1	40.4	40.4	37.0

Table 3.17 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (1/2)
(1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
1990	461 183	1 342	22 985	1 231 825	0
1991	452 052	1 630	14 950	323 588	0
1992	520 339	1 349	16 393	338 976	0
1993	598 721	1 787	18 807	1 370 162	0
1994	594 734	2 890	16 258	1 136 114	0
1995	602 784	2 915	15 671	941 816	0
1996	558 584	2 809	17 333	984 083	0
1997	408 806	3 293	5 663	941 594	205 705
1998	280 599	3 156	6 792	623 019	673 357
1999	326 145	2 925	6 898	712 034	723 011
2000	410 522	586	7 796	821 247	937 138
2001	395 179	0	7 999	748 872	992 909
2002	351 303	0	9 581	737 769	986 044
2003	239 687	0	13 896	640 649	1 338 709
2004	241 659	0	16 344	646 026	1 218 182
2005	240 810	0	17 354	682 374	1 486 586
2006	241 783	0	19 383	1 027 992	1 584 163
2007	241 365	0	23 501	665 941	1 961 930
2008	237 976	0	17 747	40 586	1 796 377

Table 3.18 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (2/2)
(1990-2008)

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	621
2008	0	0	333 420	10 255	454

Table 3.19 – Fuel consumption in the Iron and Steel industry in Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	1 673	22 985	0
1991	1 099	14 950	0
1992	1 727	16 393	0
1993	1 049	18 807	0
1994	1 805	16 258	0
1995	1 462	15 671	0
1996	2 251	17 333	0
1997	235	5 663	0
1998	141	6 792	0
1999	177	6 898	0
2000	151	7 796	0
2001	3 401	7 999	0
2002	164	9 581	0
2003	46	13 896	0
2004	0	16 344	0
2005	0	17 354	0
2006	0	19 383	262
2007	0	23 501	621
2008	0	17 747	454

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 3.18 – Total Energy Consumption in the Iron and Steel Industry between 1990 and 2008

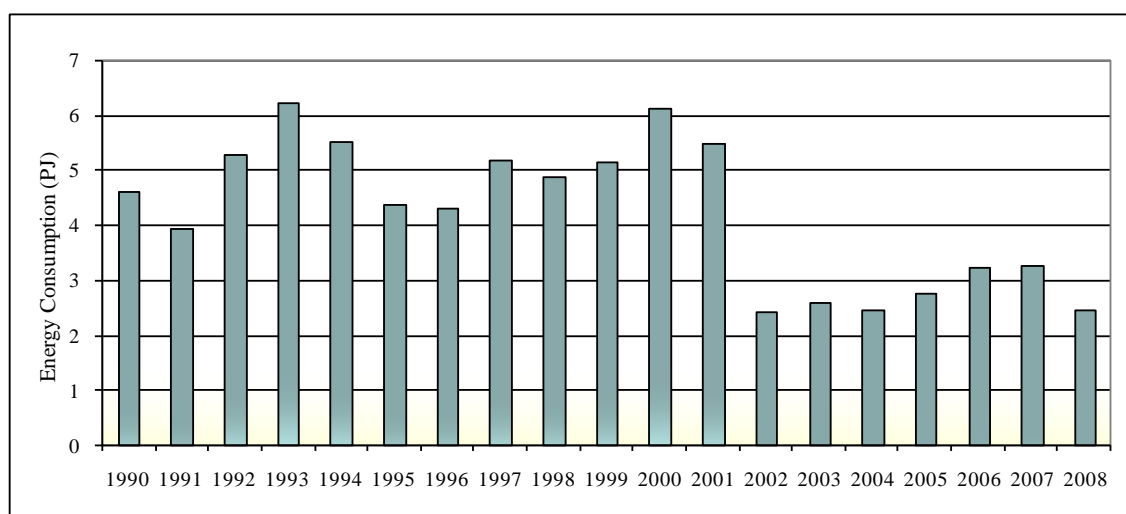
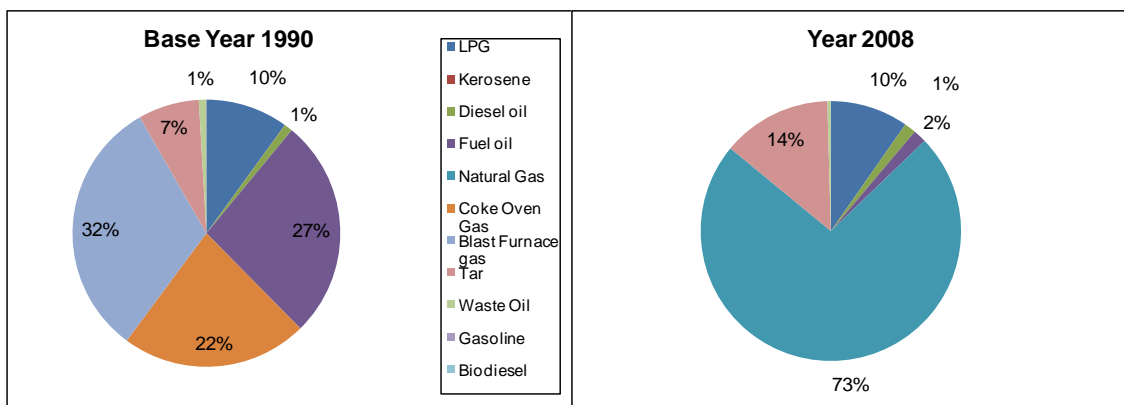


Figure 3.19 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2008



3.2.2.2.1.2.2 Metallurgy Industry

Table 3.20 – Low Heating Values/ Net Calorific Value (LHV/NCV) in Metallurgy Industry

	Steam Coal	Coal Coke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Biomass	Biodiesel
LHV (MJ/kg)	29.3	28.0	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.21 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	Steam Coal	Coal Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	132 885	381 367	525 854	372	14 478	1 162 634	0	142 678	0
1991	121 039	240 217	520 401	3	19 577	958 101	0	140 167	0
1992	30 883	240 167	596 416	0	19 777	1 059 136	0	138 033	0
1993	50 846	0	495 034	0	20 288	720 875	0	135 272	0
1994	6 192	0	526 065	0	22 378	554 304	0	135 314	0
1995	0	0	588 223	0	18 312	387 206	0	135 314	0
1996	0	0	634 504	0	32 207	479 883	0	143 515	0
1997	0	0	548 772	0	28 707	78 937	1 086	143 515	0
1998	0	0	491 977	544	28 159	75 028	31 177	143 818	0
1999	0	0	375 463	1 577	44 159	66 644	178 134	144 351	0
2000	0	0	241 731	7	43 857	81 157	441 236	143 515	0
2001	0	0	317 650	8	77 585	99 020	486 797	143 515	0
2002	0	0	340 485	0	70 917	68 489	510 836	143 515	0
2003	0	0	331 882	0	54 538	60 392	614 115	223 898	0
2004	0	0	325 001	0	56 557	67 776	585 376	227 897	0
2005	0	0	297 918	16	83 155	64 658	633 516	232 894	0
2006	0	0	286 025	0	67 990	68 828	663 806	235 900	902
2007	19 163	0	276 276	42	60 555	80 795	690 020	239 874	3 151
2008	0	0	335 314	0	64 806	29 791	986 045	239 874	1 785

Table 3.22 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	0	14 478	0
1991	254	19 577	0
1992	678	19 777	0
1993	3 602	20 288	0
1994	6 461	22 378	0
1995	7 119	18 312	0
1996	8 205	32 207	0
1997	8 404	28 707	0
1998	7 042	28 159	0
1999	3 189	44 159	0
2000	310	43 857	0
2001	10 972	77 585	0
2002	729	70 917	0
2003	807	54 538	0
2004	331	56 557	0
2005	349	83 155	0
2006	209	67 990	902
2007	0	60 555	3 151
2008	0	64 806	1 785

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 3.20 – Total Energy Consumption in the Metallurgy Industry between 1990 and 2008

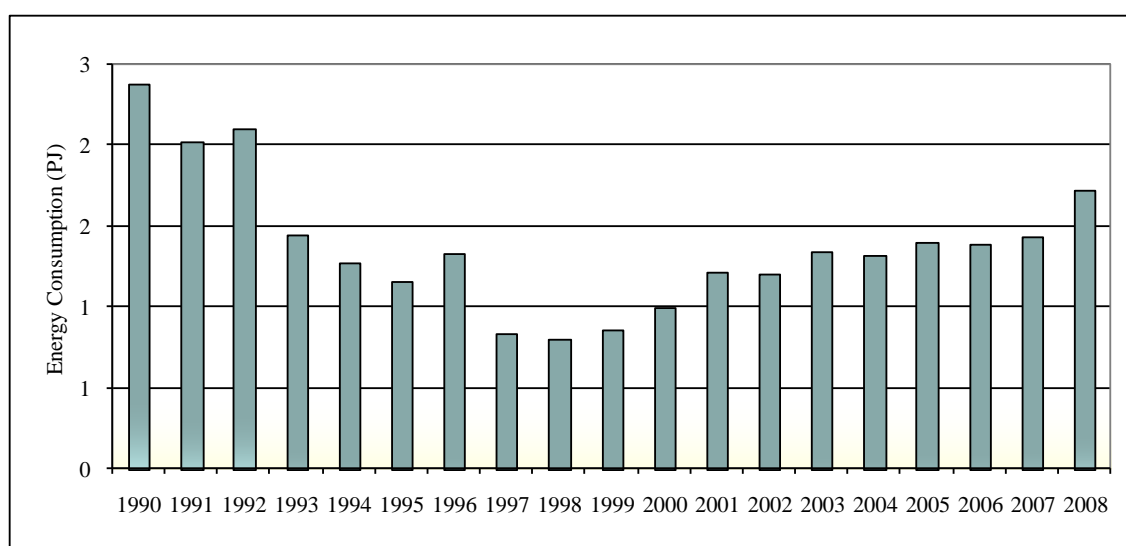
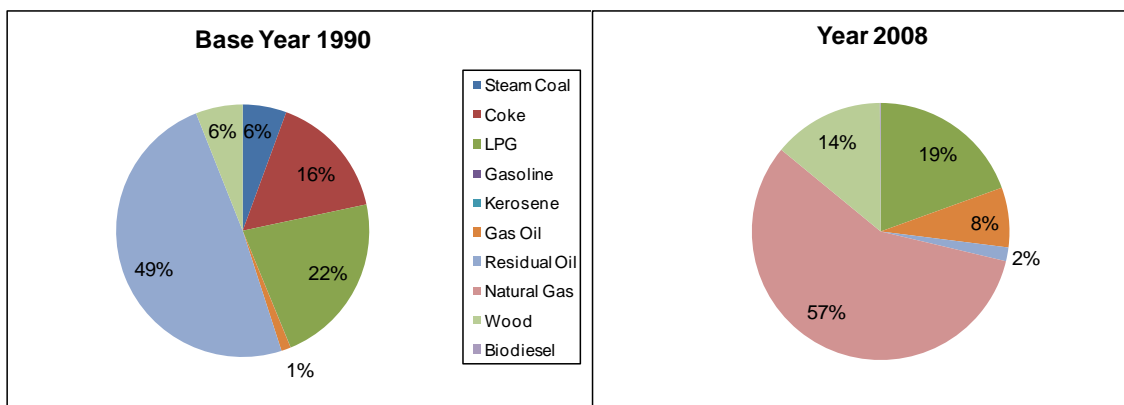


Figure 3.21 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2008



3.2.2.2.1.2.3 Chemical and Plastics Industry

Table 3.23 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Chemical and Plastics Industry

	Coal	Coal Coke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil*	Natural Gas (MJ/Nm ³)	Biomass	Fuel Gas ²¹	Flare Gas ²²	Biodiesel
LHV (MJ/kg)	29.3	28.0	47.3	44.8	43.7	43.3	39.3-40.2	38.7	12.6	2.0-52.8	47.8-53.1	37.0

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

²¹ Several streams of intermediate gaseous products and tail gases that are used as energy source

²² Several streams of intermediate gaseous products and tail gases that are used as energy source

Table 3.24 - Fuel consumption in Chemical and Plastics Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	Steam Coal	Coke	LPG	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas	Wood	Fuel Gas	Biodiesel
1990	261 080	196 711	291 344	1 179	77 593	9 952 224	0	1 051 213	11 323 355	0
1991	198 665	276 550	127 766	515	122 788	11 674 756	0	1 032 803	9 037 651	0
1992	0	467 066	126 259	333	107 192	10 345 087	0	1 017 238	10 865 528	0
1993	0	427 538	223 054	118	99 230	7 774 578	0	996 904	10 235 002	0
1994	0	460 562	1 127 569	97	148 472	8 440 716	0	996 904	9 394 520	0
1995	0	491 903	1 608 177	54	166 877	10 479 504	0	996 904	10 383 010	0
1996	0	469 533	1 033 488	87	209 489	10 187 639	0	1 058 033	9 105 271	0
1997	0	404 607	872 311	9 752	166 805	10 746 350	0	1 058 033	11 603 903	0
1998	0	520 946	474 136	19 442	212 257	11 132 967	572 351	1 060 272	12 313 880	0
1999	0	520 946	419 501	45 537	211 827	11 173 745	1 674 434	1 343 390	12 666 161	0
2000	0	2 139 767	341 329	12 388	115 805	11 691 591	2 083 315	1 360 854	13 108 321	0
2001	0	576 452	584 584	5 889	173 599	11 254 082	2 362 443	1 360 837	9 084 613	0
2002	0	580 910	1 524 084	3 675	120 311	9 508 308	4 349 056	1 360 837	8 957 584	0
2003	313 321	283 250	789 047	3 091	99 524	8 033 235	6 347 178	1 414 358	10 140 357	0
2004	413 652	238 097	2 067 644	2 773	92 461	7 661 120	6 953 496	1 442 345	11 772 593	0
2005	482 261	135 654	1 182 681	2 359	97 943	7 791 007	5 736 630	1 471 332	12 933 275	0
2006	687 573	99 916	3 592 008	2 343	70 485	6 378 643	6 108 842	1 493 305	12 204 318	822
2007	533 222	118 619	4 685 230	2 176	41 975	6 128 286	8 775 114	1 536 318	13 604 362	2 922
2008	536 276	106 778	5 899 121	879	24 667	5 932 044	7 359 372	1 536 318	10 490 997	1 745

Table 3.25 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Fuel oil	Biodiesel
1990	7 798	80 087	160 712	0
1991	24 195	128 919	274 906	0
1992	66 690	115 582	425 762	0
1993	67 416	105 718	588 618	0
1994	107 715	151 617	203 808	0
1995	165 896	172 985	379 018	0
1996	131 633	214 675	321 823	0
1997	190 721	172 202	334 966	0
1998	188 166	218 030	358 303	0
1999	161 516	219 722	489 977	0
2000	48 125	123 646	486 645	0
2001	72 064	179 854	378 123	0
2002	56 451	127 242	418 988	0
2003	47 912	106 543	424 255	0
2004	32 174	98 872	387 517	0
2005	12 341	104 787	413 694	0
2006	3 724	76 866	385 694	822
2007	0	48 921	419 862	2 922
2008	293	30 422	347 885	1 745

Table 3.26 - Fuel consumption in Chemical and Plastics Industry – Flares (GJ) (1990-2008)

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	1 061 809
2005	1 133 536
2006	1 056 813
2007	1 150 436
2008	953 217

Two industrial plants in this sector were treated as Large Point Sources, representing a substantial component of total energy consumption, but for confidentiality constrains plant specific information cannot be published individually. In the beginning of the period under analysis, fuel consumption²³ 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 3.22. The consumption of coke time series presents an anomalous value in 2000. When questioned about this, the energy balance team at DGEG could not justify the inconsistent value.

²³ 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.

Figure 3.22 – Total Energy Consumption in the Chemical and Plastic Industry between 1990 and 2008

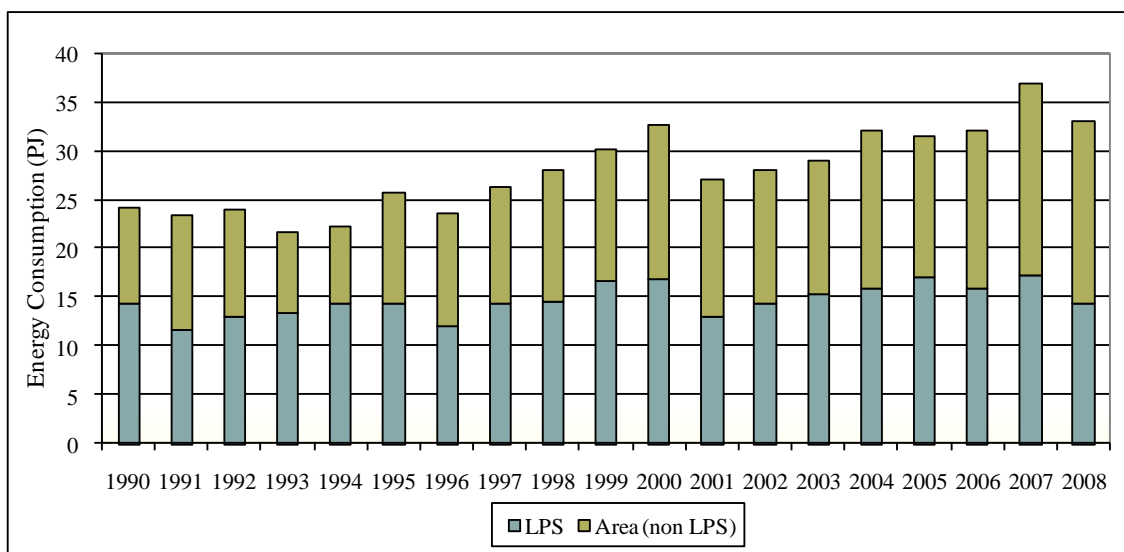
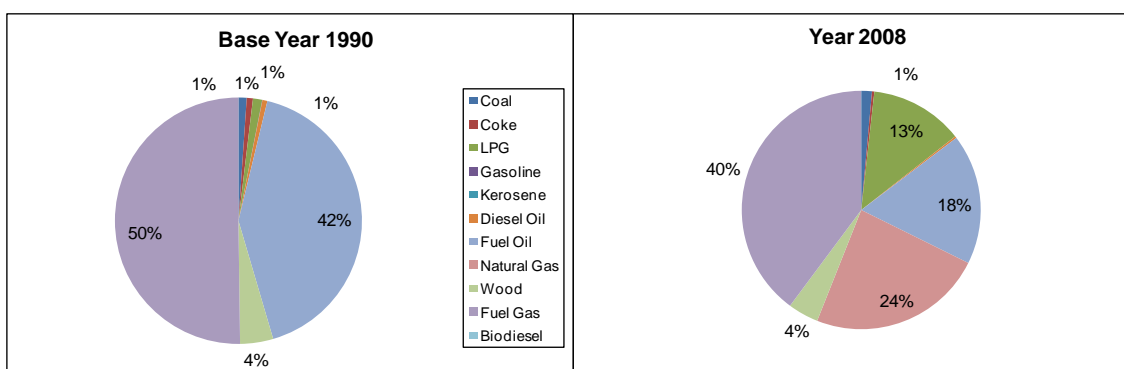


Figure 3.23 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2008



3.2.2.2.1.2.4 Paper and Paper Pulp Industry

Table 3.27 – LHV/NCV in the Paper and Paper Pulp Industry (MJ/kg)

LPG	Gasoline	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas (MJ/Nm ³)
47.3	44.8	43.7	43.3	40.0-40.6	37.9

Wood & Wood Wastes	Liquor	Biogas	NCG (MJ/Nm ³) ²⁴	Tall oil	Biodiesel
12.6-35.6	7.4-15.8	34.7	0.007	34.0	37.0

²⁴ Non condensable gases

Table 3.28 - Fuel consumption in the Paper and Paper Pulp Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Liquors	Wood & Wood wastes	Other	Biodiesel
1990	103 357	7	90 115	9 445 240	0	24 607 749	5 105 745	39 843	0
1991	190 436	51	78 814	10 256 587	0	28 333 851	5 982 805	51 714	0
1992	236 264	32	76 148	11 226 888	0	28 687 604	7 348 581	59 667	0
1993	199 374	7	70 927	11 614 805	0	27 141 730	8 660 247	51 766	0
1994	271 869	4	66 278	13 357 452	0	26 583 344	6 868 103	57 140	0
1995	282 906	23	72 499	11 185 917	0	27 204 795	7 656 588	61 007	0
1996	301 572	5	71 699	12 232 629	0	27 078 923	7 115 364	62 394	0
1997	325 960	6	80 280	12 496 996	0	30 006 253	7 684 886	63 796	0
1998	345 875	0	60 994	11 886 705	7 065	29 923 805	7 616 532	64 649	0
1999	265 142	0	59 581	12 053 420	305 186	30 849 031	8 180 982	64 457	0
2000	248 947	26	54 727	12 645 880	2 145 436	32 197 744	6 823 719	59 271	0
2001	240 115	109	79 587	9 792 101	4 342 236	31 773 314	6 283 184	60 912	0
2002	103 112	78	76 841	8 962 765	5 232 845	31 878 552	6 889 244	61 927	0
2003	99 442	79	77 100	7 916 137	5 976 615	29 750 587	6 005 965	62 942	0
2004	96 921	81	75 006	7 253 814	5 971 077	34 740 185	7 930 862	63 957	0
2005	92 341	55	81 243	5 941 589	7 461 300	35 415 852	7 539 382	82 827	0
2006	60 837	126	80 627	4 863 879	8 360 191	36 129 057	8 137 259	133 654	1 089
2007	55 188	84	76 657	4 200 200	8 627 607	36 860 250	9 100 511	92 214	2 026
2008	74 812	126	75 842	4 778 022	8 376 053	37 106 712	8 348 813	100 167	1 942

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal from 1990 to 2008 (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 almost continuous in the period. 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 3.29 - Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ)

Year	Gasoline	Diesel Oil	Biogas	Biodiesel
1990	2 677	90 115	0	0
1991	6 335	78 814	0	0
1992	8 803	76 148	0	0
1993	4 832	70 927	0	0
1994	10 998	66 278	0	0
1995	6 133	72 499	0	0
1996	5 359	71 699	0	0
1997	9 478	80 280	0	0
1998	8 922	60 994	0	0
1999	7 697	59 581	0	0
2000	795	54 727	9 705	0
2001	24 295	79 587	17 804	0
2002	1 069	76 841	19 632	0
2003	1 282	77 100	19 056	0
2004	890	75 006	24 469	0
2005	910	81 243	28 895	0
2006	586	80 627	33 042	1 089
2007	335	76 657	31 230	2 026
2008	167	75 842	40 780	1 942

Figure 3.24 – Total Energy Consumption in the Paper and Paper Pulp Industry between 1990 and 2008

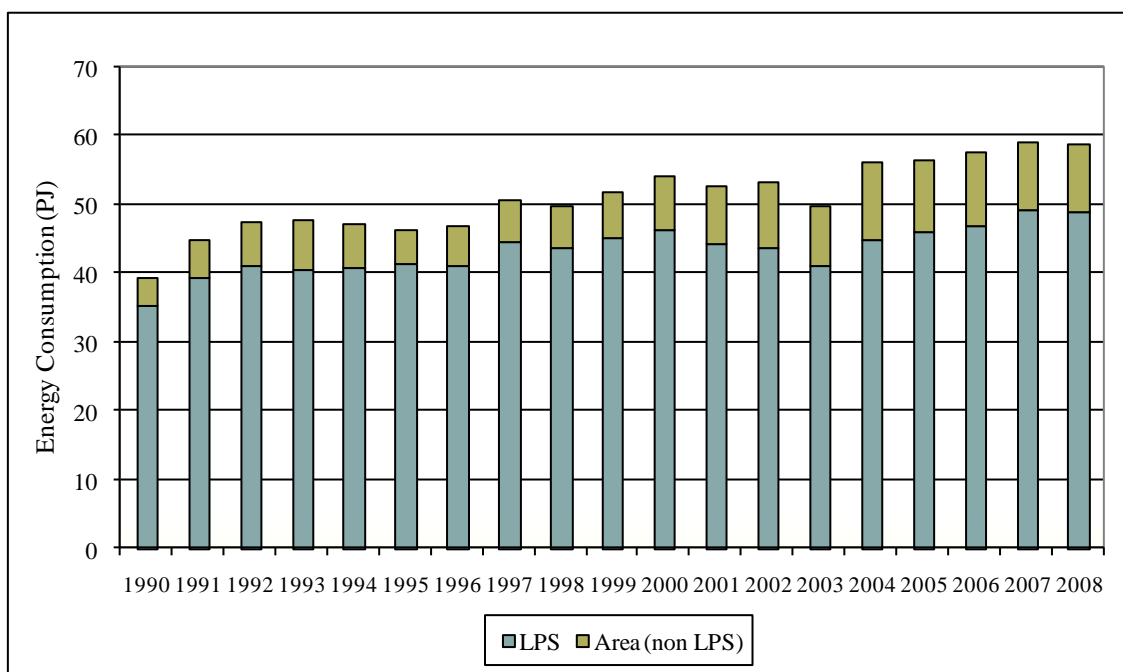
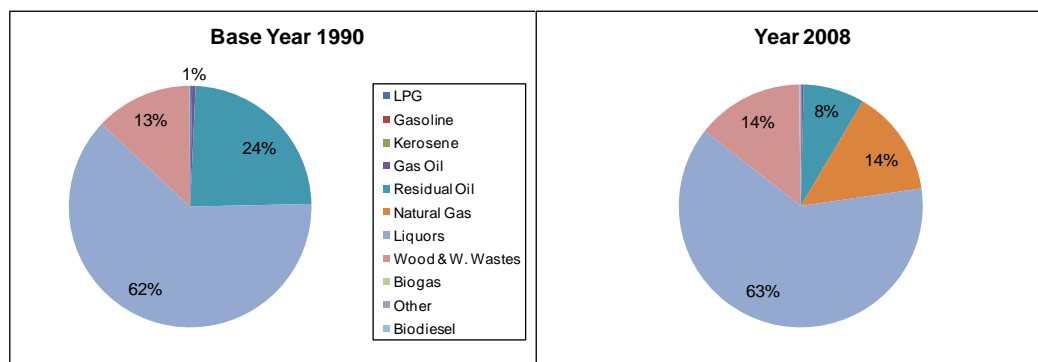


Figure 3.25 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2008



3.2.2.2.1.2.5 Food Processing, Beverages and Tobacco Industries

Table 3.30 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Food processing, Beverages and Tobacco Industries

	Steam Coal	LPG	Kerosene	Gasoline	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Wood	Biodiesel
LHV (MJ/kg)	29.3	47.3	43.7	44.8	43.3	40.2	38.7	12.6	37.0

Table 3.31 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ) (1990-2008)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas	Wood	Biodiesel
1990	12 408	905 695	13 310	545 296	8 896 746	0	3 981 464	0
1991	6 637	1 042 493	6 712	590 327	9 650 972	0	3 911 799	0
1992	432	1 146 947	7 581	682 889	9 552 680	0	3 852 887	0
1993	0	1 216 337	7 657	687 994	9 008 711	0	3 775 816	0
1994	0	1 362 783	6 219	728 047	8 940 015	0	3 775 858	0
1995	0	1 461 882	5 075	735 477	9 393 613	0	3 775 858	0
1996	0	1 625 730	2 129	798 171	9 397 656	0	4 006 695	0
1997	0	1 964 696	4 592	747 369	11 117 217	3 497	4 006 695	0
1998	0	1 942 985	5 537	719 673	11 353 423	355 065	4 015 170	0
1999	0	1 898 545	6 933	812 840	10 589 139	1 081 711	3 391 460	0
2000	0	1 698 723	1 728	668 841	9 378 846	1 625 761	3 435 549	0
2001	0	1 810 872	906	738 249	9 499 661	2 314 912	3 435 146	0
2002	0	1 702 062	801	650 188	9 548 553	3 467 625	3 435 146	0
2003	0	1 631 026	802	633 690	9 034 076	4 610 651	3 652 342	0
2004	0	1 437 151	741	677 596	6 539 384	4 440 777	3 642 346	0
2005	0	1 230 464	5	752 614	5 795 198	2 512 195	3 714 314	0
2006	0	1 117 280	0	660 127	6 979 540	3 091 801	3 769 289	8 728
2007	0	1 030 879	0	645 041	6 564 561	3 619 088	3 883 222	17 795
2008	0	1 021 883	42	529 260	5 964 561	6 078 325	3 883 222	15 144

Table 3.32 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	17 576	545 296	0
1991	27 154	590 327	0
1992	68 216	682 889	0
1993	50 870	687 994	0
1994	103 895	728 047	0
1995	109 204	735 477	0
1996	118 030	798 171	0
1997	192 021	747 369	0
1998	174 508	719 673	0
1999	171 400	812 840	0
2000	117 866	668 841	0
2001	224 395	738 249	0
2002	101 308	650 188	0
2003	89 264	633 690	0
2004	73 129	677 596	0
2005	68 837	752 614	0
2006	53 808	660 127	8 728
2007	40 084	645 041	17 795
2008	27 071	529 260	15 144

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 3.26 – Total Energy Consumption in the Food processing, Beverages and Tobacco Industry between 1990 and 2008

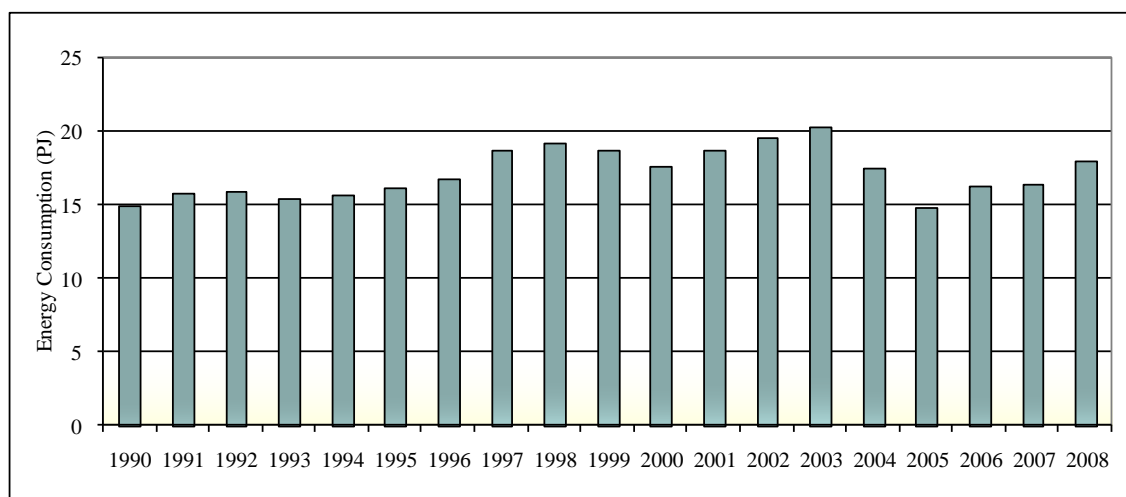
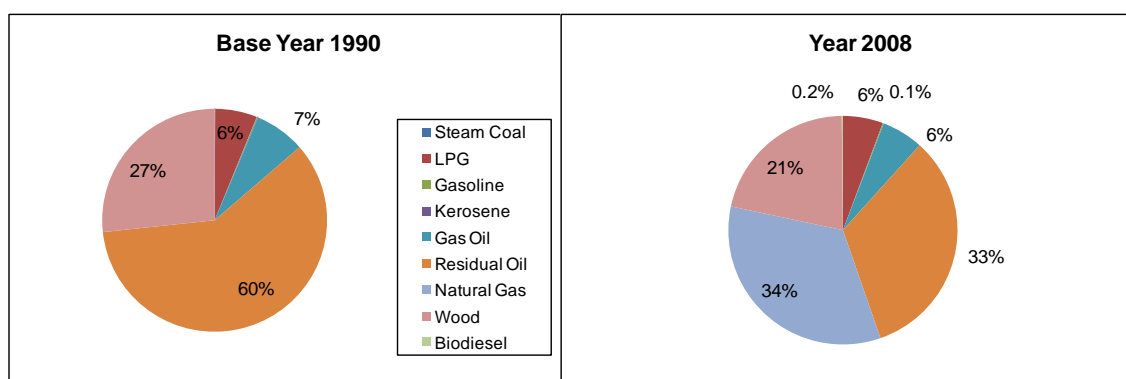


Figure 3.27 - Fuel consumption per fuel type in the Food processing, Beverages and Tobacco Industries in 1990 and 2008



3.2.2.2.1.2.6 Textile Industry

Table 3.33 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Textile Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Biomass	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.34 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass	Biodiesel
1990	211 079	125	27 561	10 398 463	0	1 136 569	0
1991	260 039	113	28 133	8 869 912	0	1 116 695	0
1992	313 352	104	31 054	8 137 910	0	1 099 874	0
1993	308 947	65	31 611	7 368 260	0	1 077 866	0
1994	326 923	24	37 253	8 355 456	0	1 077 866	0
1995	375 672	4	37 309	8 873 230	0	1 077 866	0
1996	446 316	6	40 465	11 399 097	0	1 143 933	0
1997	554 583	180	50 824	14 710 345	0	1 143 933	0
1998	658 367	175	52 454	14 158 114	14 207	1 146 353	0
1999	714 187	8	51 536	11 696 369	565 827	2 033 077	0
2000	507 677	0	75 300	11 329 974	3 789 968	2 059 507	0
2001	450 357	0	67 930	9 257 887	5 583 570	2 059 498	0
2002	405 987	0	90 966	9 173 383	7 160 629	2 059 498	0
2003	394 399	0	100 352	7 734 712	8 183 262	2 140 028	0
2004	415 072	0	114 151	7 112 971	7 786 363	2 183 009	0
2005	362 382	4	108 604	7 290 657	7 586 130	2 225 989	0
2006	310 962	0	87 444	7 210 460	5 257 445	2 258 954	1 093
2007	250 544	84	62 891	5 986 736	5 595 357	2 328 954	1 483
2008	160 460	42	53 863	4 414 686	8 005 851	2 328 954	1 180

Table 3.35 – Fuel consumption in Textile Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline (GJ)	Gas Oil (GJ)	Biodiesel
1990	4 313	27 561	0
1991	4 723	28 133	0
1992	12 058	31 054	0
1993	9 225	31 611	0
1994	18 616	37 253	0
1995	18 900	37 309	0
1996	19 241	40 465	0
1997	21 787	50 824	0
1998	22 716	52 454	0
1999	18 431	51 536	0
2000	66 347	75 300	0
2001	60 095	67 930	0
2002	59 015	90 966	0
2003	63 433	100 352	0
2004	50 081	114 151	0
2005	43 094	108 604	0
2006	37 699	87 444	1 093
2007	30 335	62 891	1 483
2008	2 636	53 863	1 180

Figure 3.28 – Total Energy Consumption in the Textile Industry between 1990 and 2008

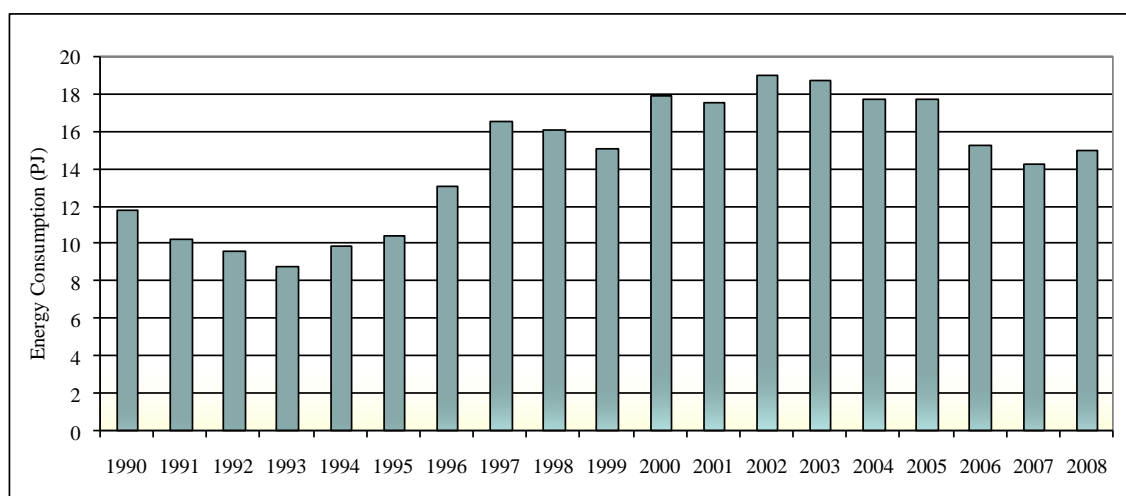
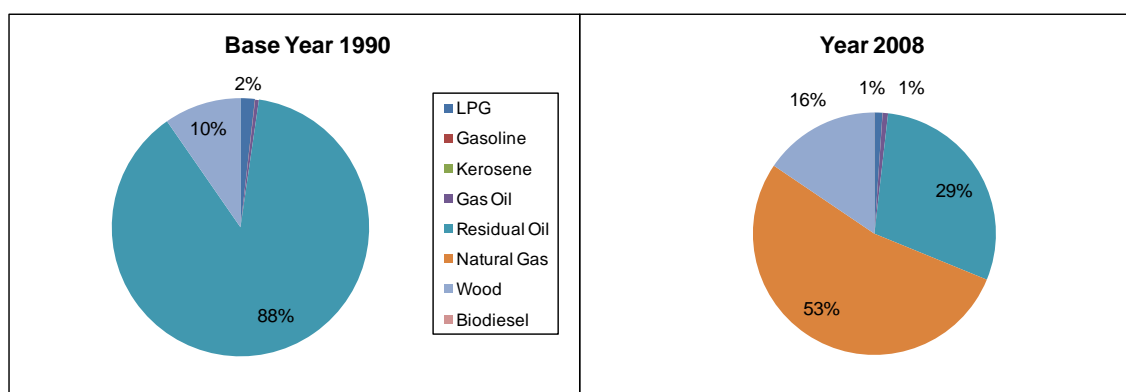


Figure 3.29 – Fuel consumption per fuel type in Textile Industry in 1990 and 2008



3.2.2.2.1.2.7 Ceramic Industry

Table 3.36 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Ceramic Industry

	Steam Coal	Pet Coke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Wood	Biodiesel
LHV (MJ/kg)	29.3	31.0	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.37 - Fuel consumption in the Ceramic Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	Steam Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	6 552	0	6 146 949	28	128 005	3 299 724	0	12 476 234	0
1991	2 254	0	6 719 549	213	156 721	3 538 468	0	12 257 950	0
1992	0	0	7 323 141	4 320	157 274	3 340 715	0	12 073 347	0
1993	0	0	7 654 449	1 395	131 328	3 188 908	0	11 831 925	0
1994	0	0	8 221 720	109	133 500	3 286 663	0	11 831 883	0
1995	0	0	8 786 548	0	130 225	3 725 069	0	11 831 883	0
1996	0	0	9 077 042	1	135 835	3 920 669	0	12 556 485	0
1997	0	0	8 142 938	0	188 039	6 033 415	1 439 341	12 556 485	0
1998	0	0	4 497 803	0	199 550	5 880 619	6 583 568	12 583 047	0
1999	0	0	2 506 160	7	177 680	4 475 511	11 576 243	13 336 945	0
2000	0	0	1 409 302	347	181 120	3 752 353	14 214 380	13 510 325	0
2001	0	0	1 458 360	244	215 096	3 036 675	15 722 639	13 510 335	0
2002	0	0	1 119 759	256	171 336	2 073 502	16 527 884	13 510 335	0
2003	0	0	838 921	299	155 446	912 218	17 950 583	13 782 248	0
2004	0	552 404	690 903	193	157 661	825 504	15 820 660	14 059 122	0
2005	0	353 071	539 832	166	125 937	810 086	15 062 930	14 345 992	0
2006	0	0	439 247	209	98 545	549 498	14 511 785	14 562 887	1 330
2007	0	125 619	419 582	167	86 201	812 594	14 593 239	15 008 075	2 273
2008	0	209 209	366 736	209	80 559	692 259	13 847 218	14 826 904	2 058

Table 3.38 – Fuel consumption in the Ceramic Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	38 507	128 005	0
1991	41 454	156 721	0
1992	51 427	157 274	0
1993	50 694	131 328	0
1994	53 041	133 500	0
1995	48 814	130 225	0
1996	34 936	135 835	0
1997	30 024	188 039	0
1998	30 567	199 550	0
1999	20 668	177 680	0
2000	17 187	181 120	0
2001	17 677	215 096	0
2002	19 138	171 336	0
2003	21 409	155 446	0
2004	19 907	157 661	0
2005	435	125 937	0
2006	126	98 545	1 330
2007	0	86 201	2 273
2008	0	80 559	2 058

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 2008 (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 2007 and 2008 the value reported in the energy balance for the consumption of this fuel was 0 GJ.

Figure 3.30 – Total Energy Consumption in the Ceramic Industry between 1990 and 2008

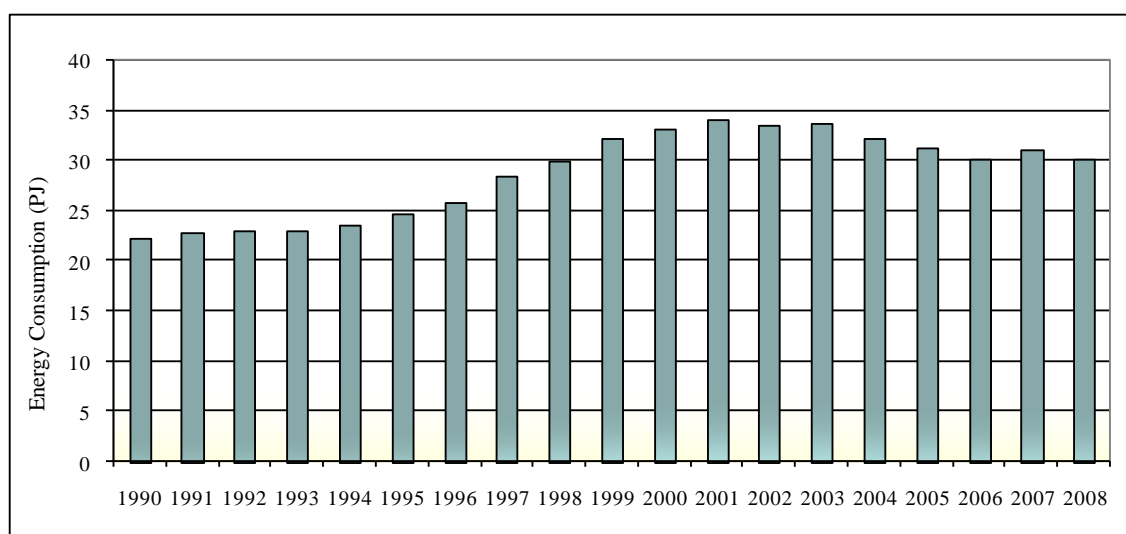
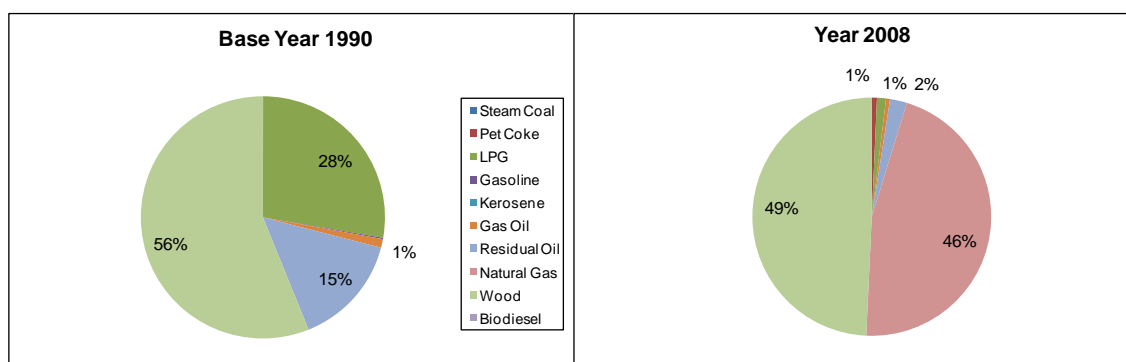


Figure 3.31 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2008



3.2.2.2.1.2.8 Glass Industry

Table 3.39 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Glass Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Wood	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.40 – Fuel consumption in the Glass Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	1 159 858	0	25 165	4 401 250	0	1 381	0
1991	1 247 925	0	23 607	5 440 438	0	1 339	0
1992	1 141 691	0	24 959	5 497 786	0	1 339	0
1993	1 132 445	0	16 936	6 016 685	0	1 297	0
1994	1 264 640	0	14 531	6 347 126	0	1 297	0
1995	1 380 459	0	21 312	6 492 308	0	1 297	0
1996	1 548 047	0	35 659	6 782 680	0	1 381	0
1997	1 732 774	0	29 326	7 563 906	29 108	1 381	0
1998	1 109 224	0	27 044	8 069 679	822 074	1 384	0
1999	566 874	0	31 071	5 588 831	2 913 173	1 381	0
2000	343 676	7	23 561	3 446 039	5 428 725	1 381	0
2001	240 621	0	35 074	3 055 480	6 218 824	1 381	0
2002	156 419	0	24 358	2 623 142	6 527 015	1 381	0
2003	134 267	0	25 980	1 989 232	7 422 992	1 381	0
2004	45 353	0	30 284	1 850 783	6 941 531	1 381	0
2005	20 868	0	19 269	1 733 688	6 865 351	1 381	0
2006	25 732	0	9 397	928 954	7 303 712	1 381	122
2007	21 967	0	8 357	546 527	8 747 890	0	221
2008	22 092	0	25 518	385 983	8 897 000	0	654

Table 3.41 – Fuel consumption in the Glass Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	3 998	25 165	0
1991	3 986	23 607	0
1992	5 226	24 959	0
1993	5 585	16 936	0
1994	4 930	14 531	0
1995	3 646	21 312	0
1996	3 814	35 659	0
1997	3 576	29 326	0
1998	4 313	27 044	0
1999	2 700	31 071	0
2000	1 030	23 561	0
2001	1 122	35 074	0
2002	283	24 358	0
2003	152	25 980	0
2004	171	30 284	0
2005	174	19 269	0
2006	126	9 397	122
2007	0	8 357	221
2008	0	25 518	654

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. The introduction of natural gas has almost replaced fully the consumption of LPG and most of the consumption of residual fuel oil that was in dominance in 1990.

Figure 3.32 – Total Energy Consumption in the Glass Industry between 1990 and 2008

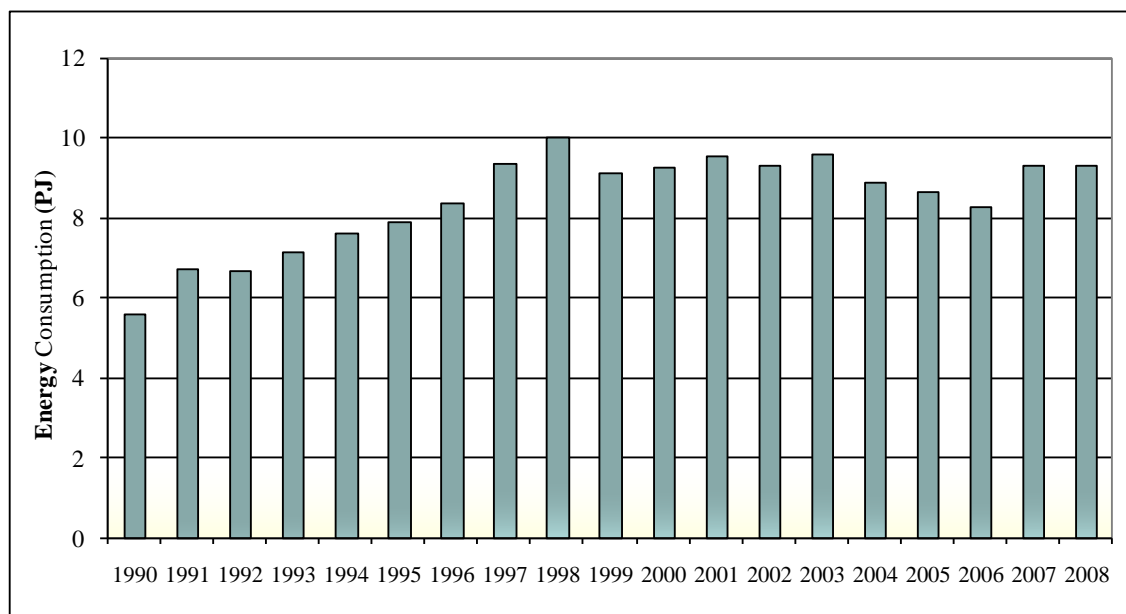
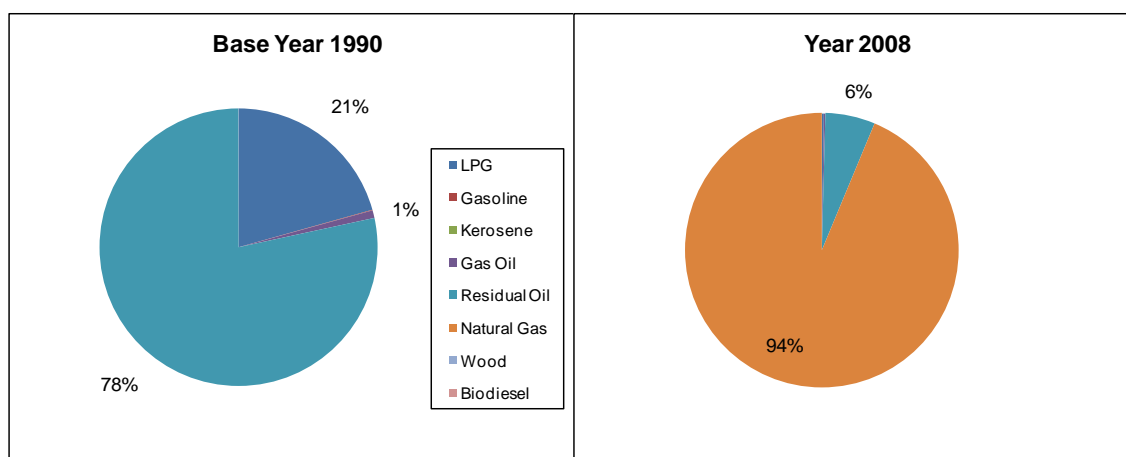


Figure 3.33 – Fuel consumption per fuel type in Glass Industry in 1990 and 2008



3.2.2.1.2.9 Cement Industry

For this inventory's submission 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 desegregated by fuel type.

Table 3.42 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry (MJ/kg) (1/2)

Steam Coal	Coke	Tires	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Biodiesel
26.1	31.6	23.9	47.3	44.8	43.7	43.3	40.2	38.7	37.0

Table 3.43 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry (MJ/kg) (2/2)

Industrial Waste	Hazardous Industrial Waste	Animal + Wood Waste
20.6	16.7	14.4

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 3.34 – Total Energy Consumption in the Cement Industry between 1990 and 2008

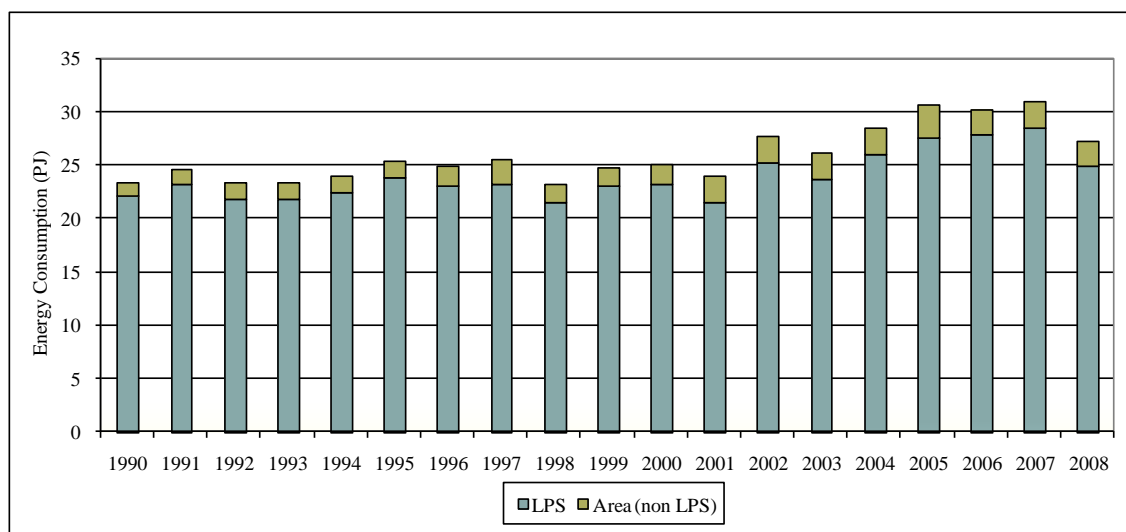
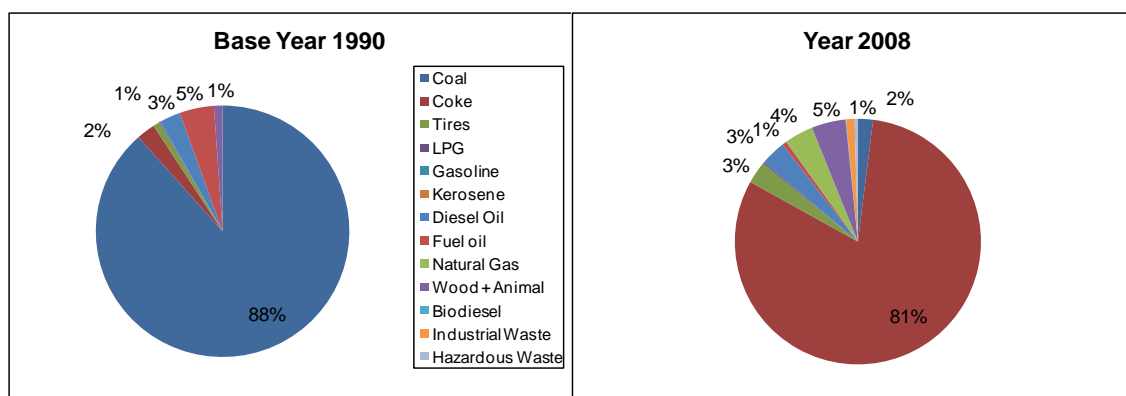


Figure 3.35 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2008



3.2.2.2.1.2.10 Clothing, Shoes and Leather Industries

Table 3.44 – Low Heating Values/ Net Calorific Values (LHV/NCV) in clothing, shoes and leather Industries

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Wood	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.45 – Fuel consumption in the clothing, shoes and leather Industries – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	56 700	28	27 647	765 605	0	279 958	0
1991	111 282	42	27 348	857 242	0	275 063	0
1992	162 079	35	25 753	1 391	0	270 921	0
1993	206 088	7	24 405	1 825	0	265 523	0
1994	221 966	0	25 331	1 335	0	265 481	0
1995	239 020	0	22 316	704 376	0	265 481	0
1996	305 465	0	24 033	791 071	0	281 590	0
1997	313 963	0	19 935	775 571	0	281 590	0
1998	329 960	0	20 217	714 440	7 916	282 186	0
1999	312 795	0	19 259	646 429	34 646	282 427	0
2000	225 900	0	15 069	349 856	152 751	282 636	0
2001	314 991	0	17 792	370 295	388 035	282 636	0
2002	297 297	0	14 765	466 138	266 962	282 636	0
2003	259 827	0	12 894	333 169	447 383	0	0
2004	241 927	0	11 749	323 514	487 088	0	0
2005	231 030	8	11 601	241 409	434 915	0	0
2006	212 594	0	8 236	244 812	463 940	0	111
2007	183 640	0	3 975	244 142	518 225	0	147
2008	201 925	0	4 651	263 096	664 070	0	286

Table 3.46 – Fuel consumption in the clothing, shoes and leather Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	1 961	27 647	0
1991	2 750	27 348	0
1992	7 810	25 753	0
1993	7 113	24 405	0
1994	9 394	25 331	0
1995	8 662	22 316	0
1996	8 247	24 033	0
1997	7 984	19 935	0
1998	7 524	20 217	0
1999	6 185	19 259	0
2000	3 833	15 069	0
2001	13 192	17 792	0
2002	2 320	14 765	0
2003	1 362	12 894	0
2004	800	11 749	0
2005	464	11 601	0
2006	209	8 236	111
2007	0	3 975	147
2008	0	4 651	286

Figure 3.36 – Total Energy Consumption in the clothing, shoes and leather Industries between 1990 and 2008

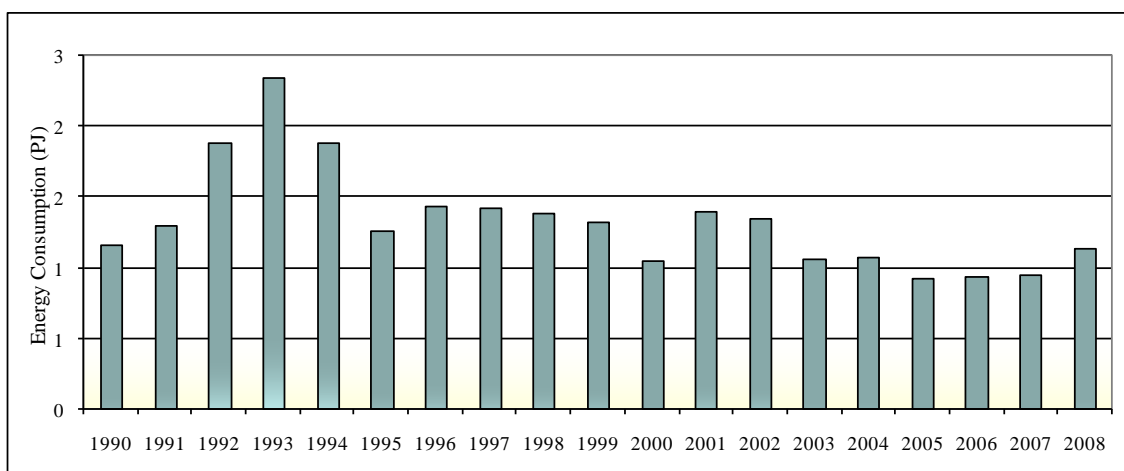
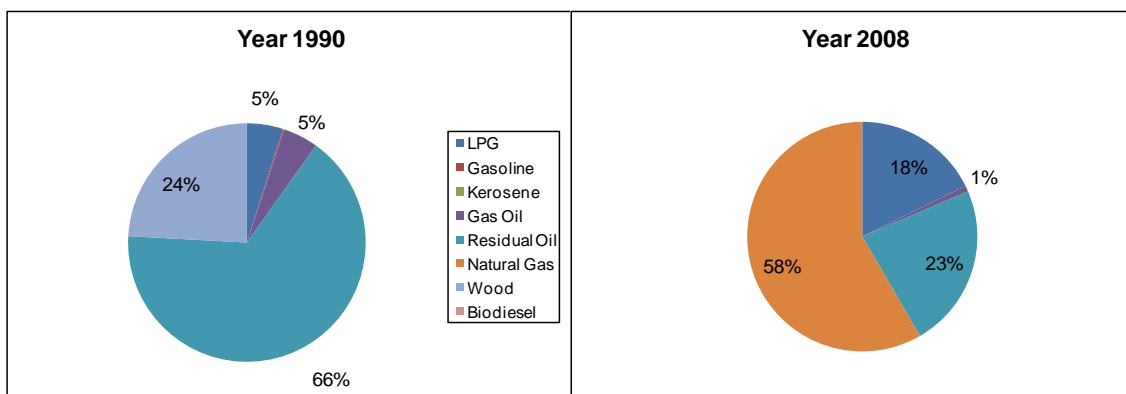


Figure 3.37 - Fuel consumption per fuel type in the clothing, shoes and leather Industries in 1990 and 2008



3.2.2.1.2.11 Wood Industry

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

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Wood	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.48 – Fuel consumption in the Wood Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	85 257	69	250 246	1 345 541	0	1 309 205	0
1991	100 153	57	246 290	1 275 845	0	1 286 318	0
1992	96 584	11	208 089	688 924	0	1 266 946	0
1993	110 646	22	179 398	1 074 773	0	1 241 590	0
1994	115 817	21	184 980	1 785 181	0	1 241 590	0
1995	115 223	0	192 129	3 034 466	0	1 241 590	0
1996	131 520	0	204 520	3 085 937	0	1 317 573	0
1997	330 118	1 912	479 619	2 897 581	0	1 317 573	0
1998	343 317	2 900	577 975	2 838 039	12	1 320 360	0
1999	378 236	74	497 917	2 842 876	35 845	895 593	0
2000	467 589	85	206 123	2 937 801	243 872	907 236	0
2001	444 713	81	255 226	1 741 058	315 564	903 766	0
2002	426 429	84	208 142	2 118 219	354 951	618 075	0
2003	381 836	73	202 161	1 998 170	452 243	1 637 257	0
2004	303 397	57	322 906	2 070 544	540 499	1 693 231	0
2005	260 445	1 126	215 491	1 997 453	625 009	1 632 259	0
2006	208 577	1 632	239 103	2 030 962	527 911	1 656 234	3 116
2007	183 473	1 506	235 477	2 023 180	575 089	1 706 234	5 782
2008	55 397	42	158 083	1 644 017	447 588	1 706 234	5 080

Table 3.49 – Fuel consumption in the Wood Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	792	250 246	0
1991	1 831	246 290	0
1992	3 552	208 089	0
1993	3 622	179 398	0
1994	9 242	184 980	0
1995	11 009	192 129	0
1996	11 948	204 520	0
1997	132 822	479 619	0
1998	169 127	577 975	0
1999	129 553	497 917	0
2000	4 047	206 123	0
2001	30 937	255 226	0
2002	3 231	208 142	0
2003	2 502	202 161	0
2004	1 594	322 906	0
2005	1 372	215 491	0
2006	418	239 103	3 116
2007	0	235 477	5 782
2008	0	158 083	5 080

Although total consumption of energy from combustion has increased from 1990 to 2008, 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 3.38 – Total Energy Consumption in the Wood Industry between 1990 and 2008

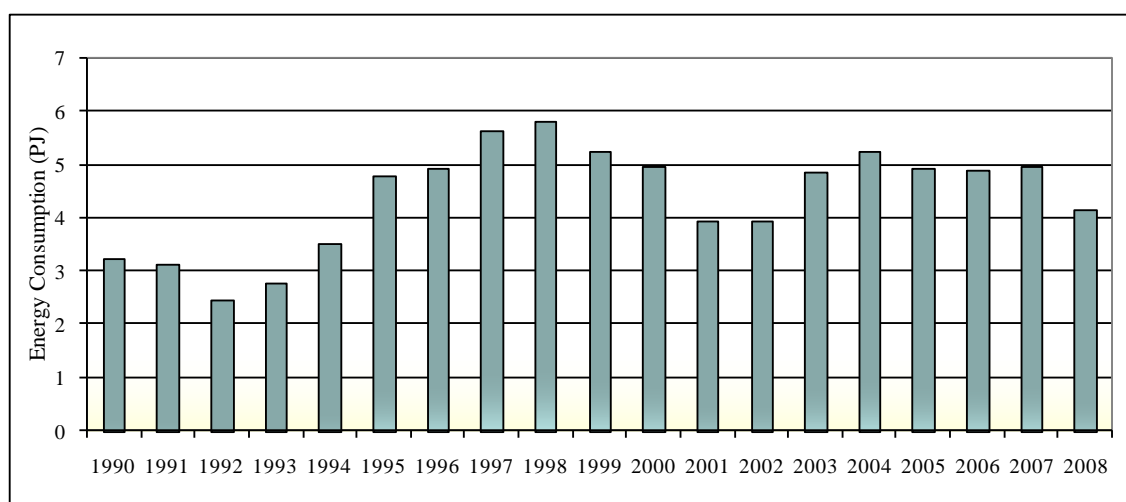
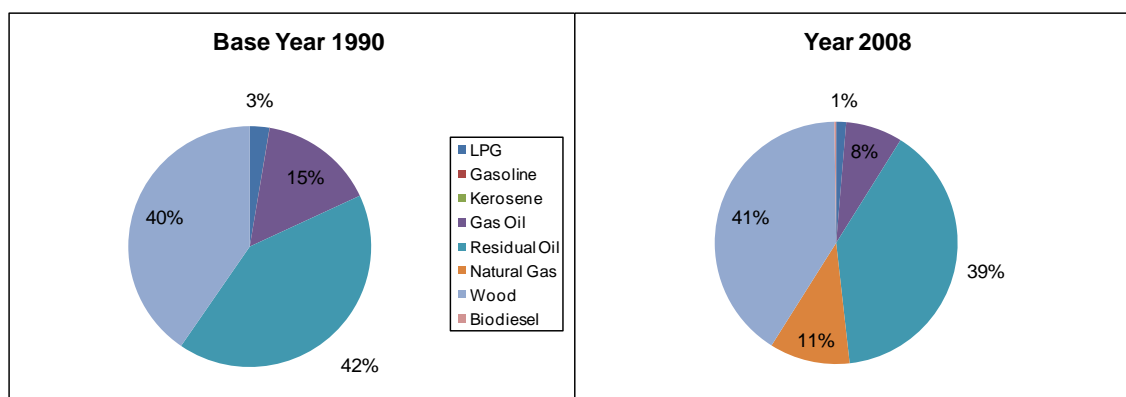


Figure 3.39 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2008



3.2.2.2.1.2.12 Rubber Industry

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

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Wood	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.51 – Fuel consumption in the Rubber Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	27 671	240	5 478	571 116	0	46 820	0
1991	30 069	268	6 781	462 204	0	45 983	0
1992	28 308	223	13 604	344 038	0	45 314	0
1993	27 882	188	13 622	286 765	0	44 393	0
1994	30 736	118	14 576	262 449	0	44 393	0
1995	33 265	135	13 461	270 483	0	44 393	0
1996	39 185	168	14 008	268 019	0	47 280	0
1997	71 109	60	11 586	281 207	0	47 280	0
1998	27 993	28	11 869	307 506	373	47 380	0
1999	26 017	13	16 800	352 751	1 614	47 322	0
2000	28 093	48	29 560	379 685	35 797	47 280	0
2001	35 377	15	33 365	203 195	141 557	47 280	0
2002	29 338	0	29 323	87 426	278 541	47 280	0
2003	27 662	1	24 544	67 610	356 714	0	0
2004	19 790	0	25 387	50 847	413 590	0	0
2005	20 533	0	1 313	27 090	431 024	0	0
2006	17 448	0	268	17 448	496 401	0	4
2007	11 925	42	3 129	11 423	489 643	0	30
2008	6 109	0	3 119	17 908	115 018	0	19

Table 3.52 – Fuel consumption in the Rubber Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	0	5 478	0
1991	0	6 781	0
1992	1 641	13 604	0
1993	2 359	13 622	0
1994	3 486	14 576	0
1995	4 725	13 461	0
1996	5 170	14 008	0
1997	7 280	11 586	0
1998	6 989	11 869	0
1999	20 478	16 800	0
2000	57 411	29 560	0
2001	53 084	33 365	0
2002	48 393	29 323	0
2003	43 541	24 544	0
2004	43 983	25 387	0
2005	48	1 313	0
2006	0	268	4
2007	0	3 129	30
2008	0	3 119	19

The figure below shows a significant decrease in the total fuel consumption in 2008. The main fuel that contributes to this decrease is Natural Gas.

Figure 3.40 – Total Energy Consumption in the Rubber Industry between 1990 and 2008

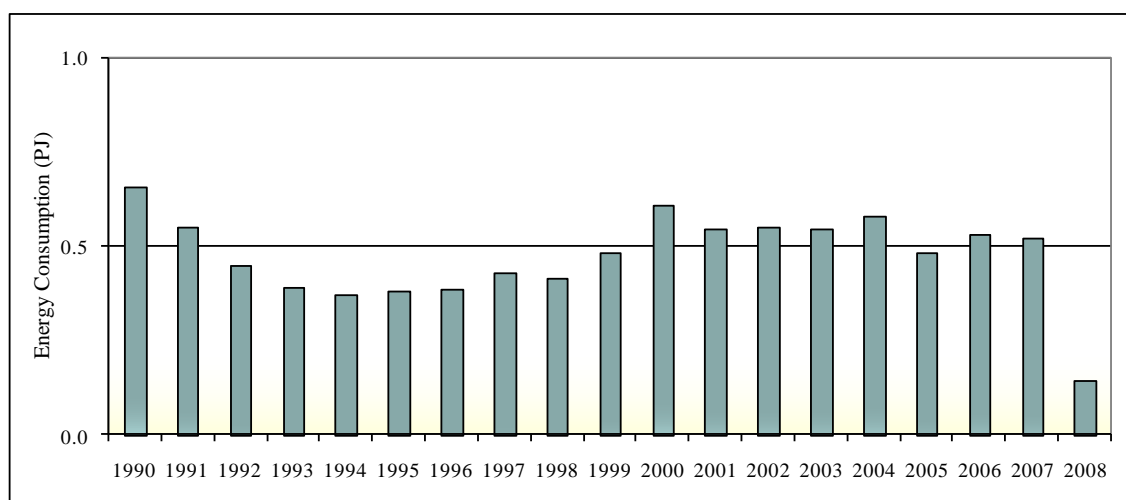
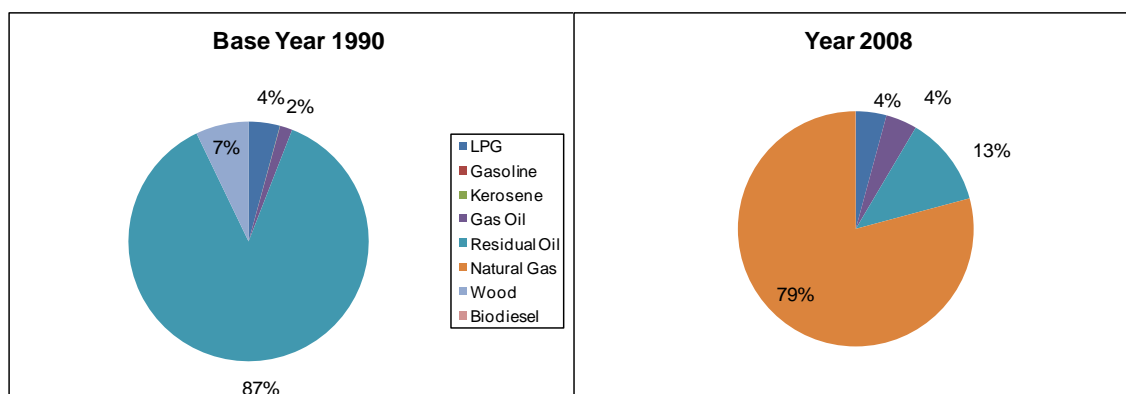


Figure 3.41 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2008



3.2.2.2.1.2.13 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	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm ³)	Wood	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6	37.0

Table 3.54– Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Boilers and Furnaces (GJ) (1990-2008)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	1 463 621	5 897	165 914	885 427	0	28 368	0
1991	1 512 383	2 696	163 350	814 743	0	27 866	0
1992	1 534 223	1 232	176 085	862 680	0	27 448	0
1993	1 512 254	429	159 784	535 701	0	26 904	0
1994	1 619 962	106	154 794	647 603	0	26 904	0
1995	1 605 495	77	210 767	508 242	0	26 904	0
1996	1 628 553	206	254 552	1 021 508	0	28 452	0
1997	2 370 280	208	217 276	727 924	167 933	28 452	0
1998	2 456 009	238	250 241	975 620	445 869	28 512	0
1999	2 268 829	377	238 777	650 999	730 723	15 993	0
2000	1 783 872	323	117 590	770 132	1 219 492	16 201	0
2001	1 674 634	136	175 163	494 440	1 606 199	16 192	0
2002	1 421 680	182	170 510	401 219	1 763 389	16 192	0
2003	1 330 280	110	151 271	331 183	2 133 290	16 992	0
2004	1 326 956	111	135 478	281 725	2 117 108	17 992	0
2005	1 292 911	296	142 399	215 389	2 180 384	16 992	0
2006	1 223 515	209	169 604	249 916	2 214 349	17 992	2 260
2007	1 101 548	126	164 092	213 598	2 280 812	16 987	4 258
2008	1 032 050	126	154 895	4 142	2 268 501	16 987	4 020

Table 3.55 – Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	43 694	165 914	0
1991	50 417	163 350	0
1992	84 252	176 085	0
1993	69 992	159 784	0
1994	95 095	154 794	0
1995	101 273	210 767	0
1996	165 257	254 552	0
1997	162 860	217 276	0
1998	157 108	250 241	0
1999	138 921	238 777	0
2000	45 657	117 590	0
2001	100 547	175 163	0
2002	49 713	170 510	0
2003	104 160	151 271	0
2004	20 182	135 478	0
2005	10 944	142 399	0
2006	37 406	169 604	2 260
2007	30 628	164 092	4 258
2008	32 050	154 895	4 020

Figure 3.42 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry between 1990 and 2008

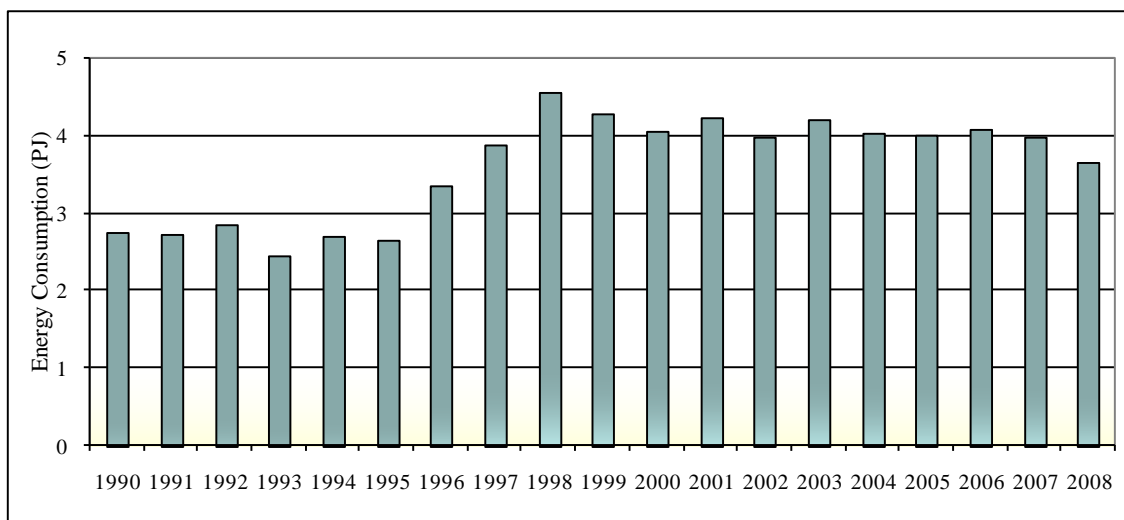
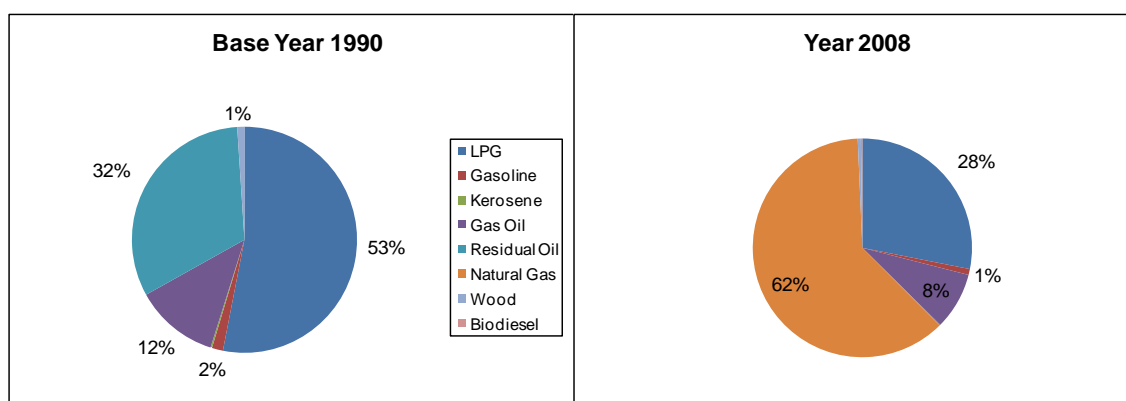


Figure 3.43 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2008



3.2.2.2.1.2.14 Other Transformation Industry

Table 3.56 – Low Heating Values/ Net Calorific Values (LHV/NCV) in other transformation industry

	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas (MJ/Nm ³)	Biomass	Biodiesel
LHV (MJ/kg)	17.2	47.3	44.8	43.7	43.3	40.2	15.7	38.7	12.6	37.0

Table 3.57 – Fuel consumption in other transformation industry – Boilers and Furnaces (GJ) (1990-2008)

Year	Lignite	LPG	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas	Wood	Biodiesel
1990	446	152 386	4 088	169 274	1 449 574	78	0	6 234	0
1991	206	203 448	3 982	219 224	1 386 088	2 746	0	6 109	0
1992	34	234 555	3 310	238 538	1 260 654	6 360	0	6 025	0
1993	463	340 825	2 197	363 460	938 562	64 686	0	5 900	0
1994	711	395 903	1 008	292 137	811 178	55 941	0	5 900	0
1995	0	430 781	37	180 548	168 320	55 690	0	5 900	0
1996	0	490 663	1 051	262 280	179 097	61 914	0	6 276	0
1997	0	114 667	0	20 021	331	72 929	0	6 276	0
1998	0	96 638	0	31 761	0	68 724	429	6 289	0
1999	0	128 737	0	27 403	0	60 544	18 688	6 276	0
2000	0	79 442	0	17 835	0	44 451	111 958	6 276	0
2001	0	49 970	30	24 944	0	6 056	148 858	6 276	0
2002	0	40 456	0	8 164	0	0	154 903	6 276	0
2003	0	33 267	0	7 449	0	0	209 904	33 985	0
2004	0	37 656	0	9 784	0	0	197 964	32 985	0
2005	0	33 747	0	8 018	0	0	203 814	34 984	0
2006	0	37 113	0	3 757	0	0	209 460	35 983	51
2007	0	36 485	0	0	0	0	233 910	34 979	0
2008	0	104 310	167	33 331	69 121	0	122 594	34 979	1 335

Table 3.58 – Fuel consumption in other transformation industry – Static Engines (GJ) (1990-2008)

Year	Gasoline	Gas Oil	Biodiesel
1990	307	169 274	0
1991	4 849	219 224	0
1992	221 092	238 538	0
1993	895 944	363 460	0
1994	503 491	292 137	0
1995	51 507	180 548	0
1996	88 067	262 280	0
1997	28 516	20 021	0
1998	32 759	31 761	0
1999	23 936	27 403	0
2000	2 620	17 835	0
2001	14 198	24 944	0
2002	3 592	8 164	0
2003	3 246	7 449	0
2004	3 020	9 784	0
2005	2 704	8 018	0
2006	1 046	3 757	51
2007	0	0	0
2008	0	33 331	1 335

Figure 3.44 – Total Energy Consumption in other transformation Industry between 1990 and 2008

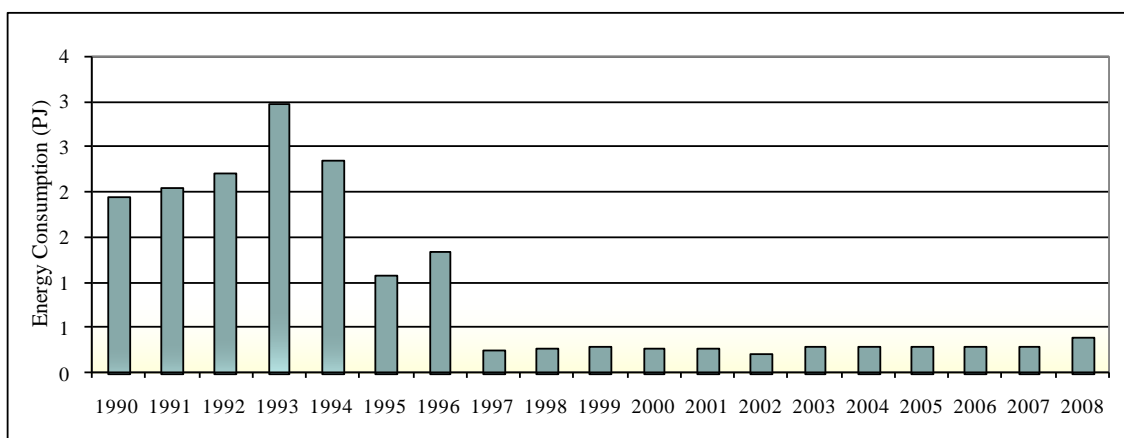
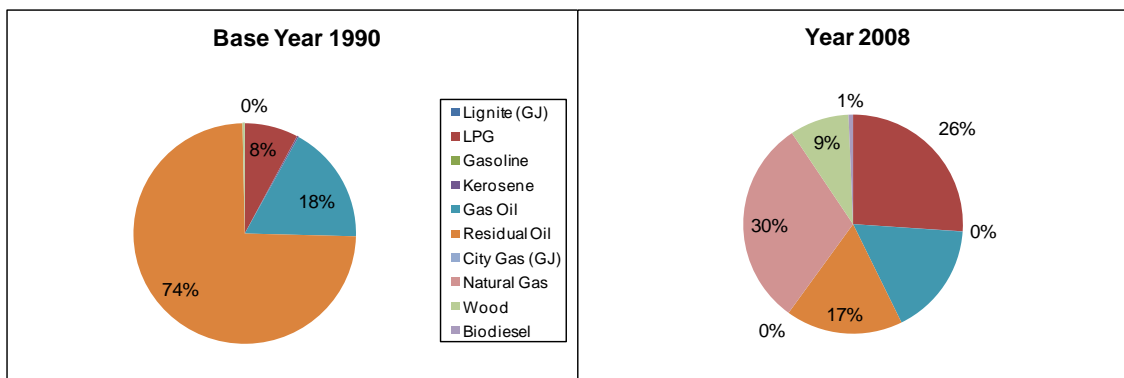


Figure 3.45 – Fuel consumption per fuel type in other transformation industry in 1990 and 2008



3.2.2.2.1.2.15 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	Natural Gas (MJ/kg)	Biodiesel
LHV (MJ/kg)	17.2	47.3	44.8	43.7	43.3	40.2	46.0	37.0

Table 3.60 – Fuel consumption in the extractive industry – Boilers and Furnaces (1990-2008)

Year	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	75 290	0	1 929	484 511	110 565	0	2 402	0
1991	76 218	0	14	523 943	254 930	0	2 608	0
1992	74 950	18	1 274	598 314	156 191	0	1 904	0
1993	83 878	24	605	626 105	80 907	0	1 184	0
1994	100 845	8	625	469 123	49 864	0	412	0
1995	103 573	0	625	484 376	49 378	0	0	0
1996	124 108	0	202	583 210	52 824	0	0	0
1997	182 831	0	553	916 115	124 033	0	0	0
1998	199 683	0	520	816 776	103 756	0	0	0
1999	192 150	6	213	822 117	80 694	9 817	0	0
2000	172 033	29 133	0	1 034 421	95 513	13 539	0	0
2001	209 533	0	4	979 018	138 961	404 228	0	0
2002	138 743	7 376	0	924 267	110 817	52 009	0	0
2003	102 359	4 850	0	990 731	82 789	50 421	0	0
2004	65 690	2 992	0	988 134	0	778 833	0	0
2005	70 130	2 932	0	948 434	401 924	259 523	0	0
2006	71 755	2 552	0	878 114	129 980	250 030	0	10 948
2007	116 859	711	2 050	899 110	326 017	253 509	0	22 758
2008	157 652	0	0	987 407	42 382	271 207	0	25 191

Table 3.61– Fuel consumption in the extractive industry – Static Engines (1990-2008)

Year	Gasoline (GJ)	Gas Oil (GJ)	Biodiesel
1990	16 243	453 879	0
1991	15 821	492 320	0
1992	10 436	532 648	0
1993	8 638	530 086	0
1994	6 424	450 284	0
1995	2 036	482 069	0
1996	3 126	580 542	0
1997	5 729	912 961	0
1998	19 899	813 863	0
1999	30 243	820 769	0
2000	20 667	736 750	0
2001	82 104	979 018	0
2002	38 758	877 376	0
2003	25 136	876 411	0
2004	57 481	875 106	0
2005	22 453	857 781	0
2006	20 209	806 189	10 948
2007	30 878	866 474	22 758
2008	17 280	986 653	25 191

Figure 3.46 – Total Energy Consumption in the Extractive Industry between 1990 and 2008

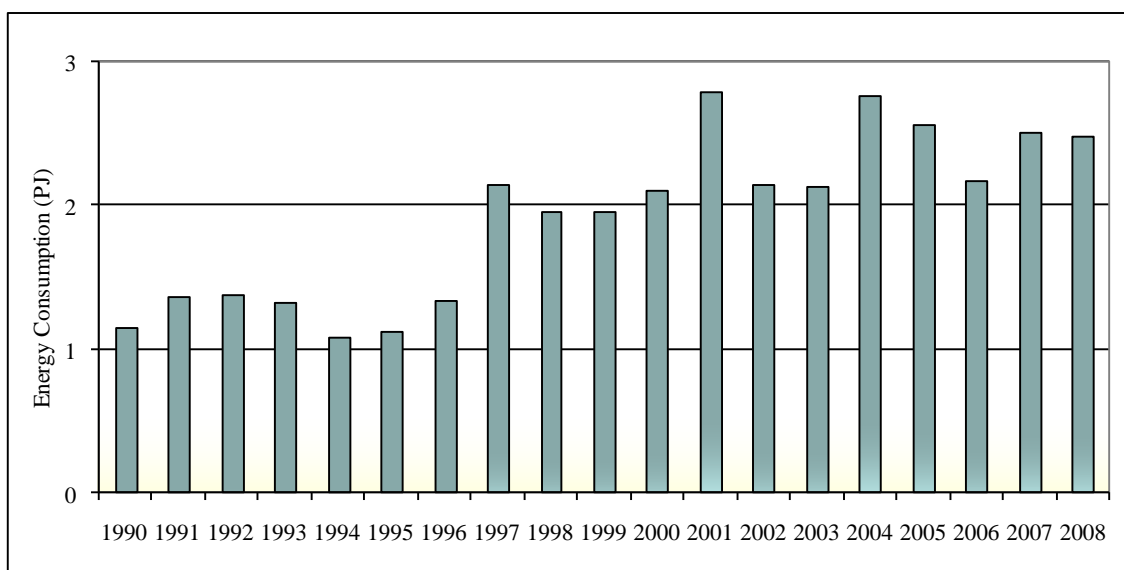
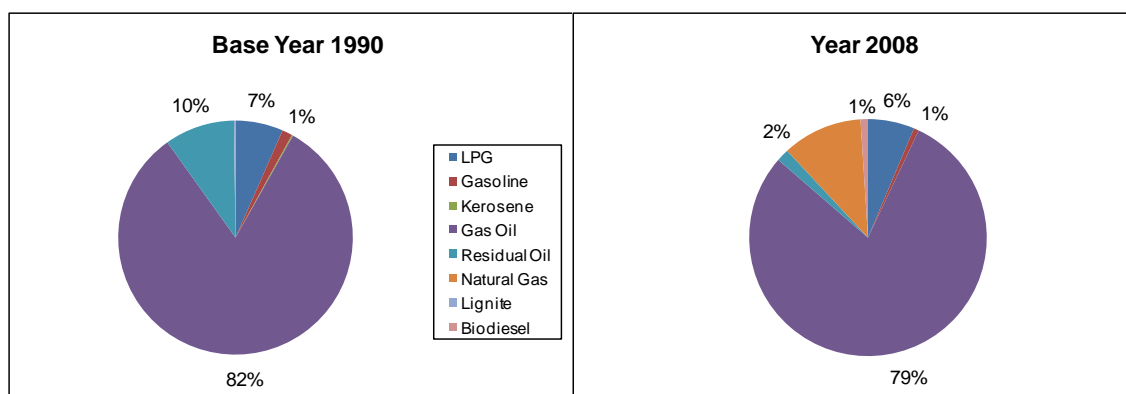


Figure 3.47– Fuel consumption per fuel type in the extractive industry in 1990 and 2008



3.2.2.2.1.2.16 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 (MJ/kg)	Biodiesel
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	46.0	37.0

Table 3.63 – Fuel consumption in the Construction and Building Industry (GJ) (1990-2008)

Year	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	233 005	28 161	6 855	5 961 423	671 304	0	0
1991	206 098	54 264	333	6 751 708	884 706	0	0
1992	264 421	168 067	2 106	6 463 826	876 008	0	0
1993	462 221	217 517	2 772	6 589 927	1 775 969	0	0
1994	696 370	363 631	1 179	7 154 205	1 412 975	0	0
1995	912 385	455 546	640	7 705 986	1 763 816	0	0
1996	1 066 771	682 700	177	7 929 141	1 353 841	0	0
1997	646 260	380 360	1 796	8 255 251	1 892 148	0	0
1998	574 093	355 521	11 044	8 251 931	2 008 223	610	0
1999	578 294	301 584	228	8 116 581	1 429 069	2 718	0
2000	560 826	73 801	130	7 673 442	1 473 144	7 637	0
2001	843 368	396 140	389	9 525 562	1 637 796	286 481	0
2002	547 284	61 620	279	9 463 552	1 856 172	570 473	0
2003	495 233	57 695	104	8 773 984	1 295 338	823 671	0
2004	496 078	55 810	93	10 191 948	1 572 038	816 157	0
2005	423 557	68 579	184	9 286 778	1 724 975	804 870	0
2006	407 657	69 038	1 464	7 224 725	1 307 406	726 797	96 135
2007	363 766	60 879	84	6 547 275	1 089 540	808 439	181 049
2008	516 025	91 841	167	5 948 663	1 138 536	2 489 829	156 883

Figure 3.48 – Total Energy Consumption in the Construction and Building Industry between 1990 and 2008

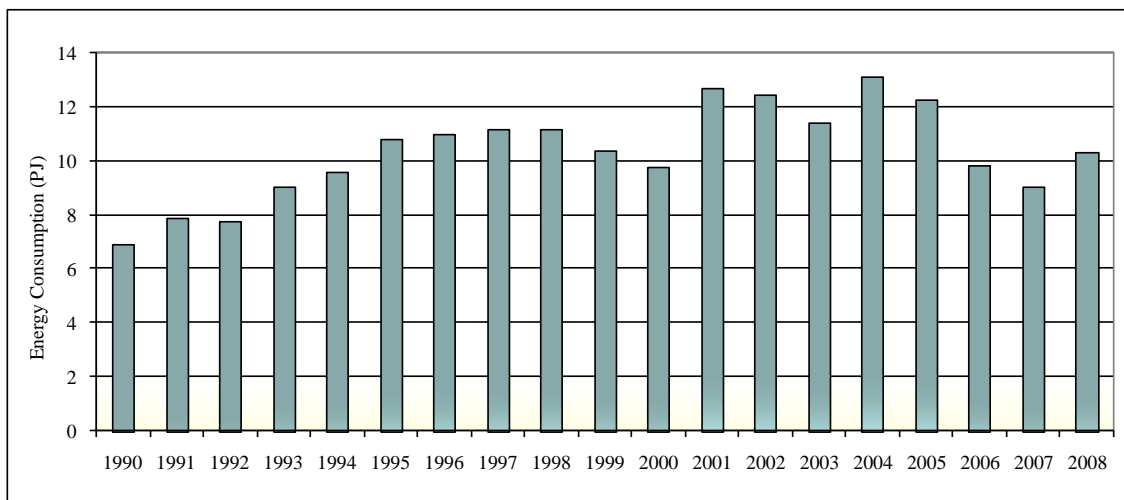
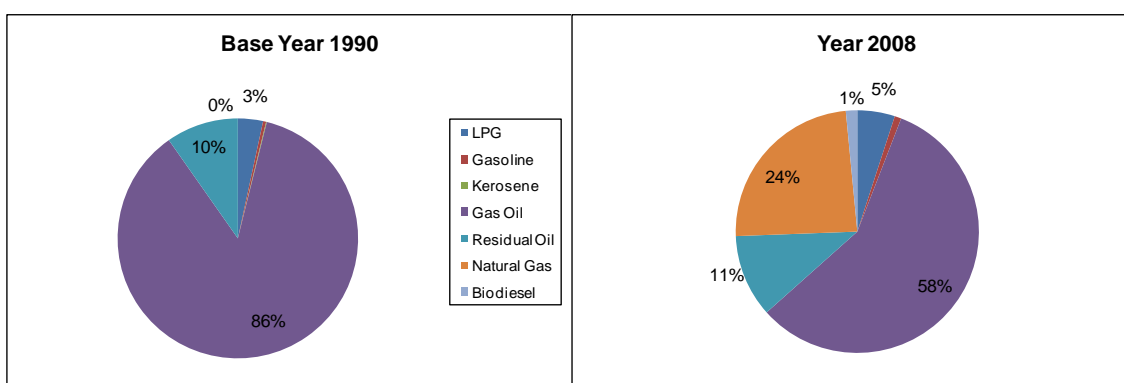


Figure 3.49 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2008

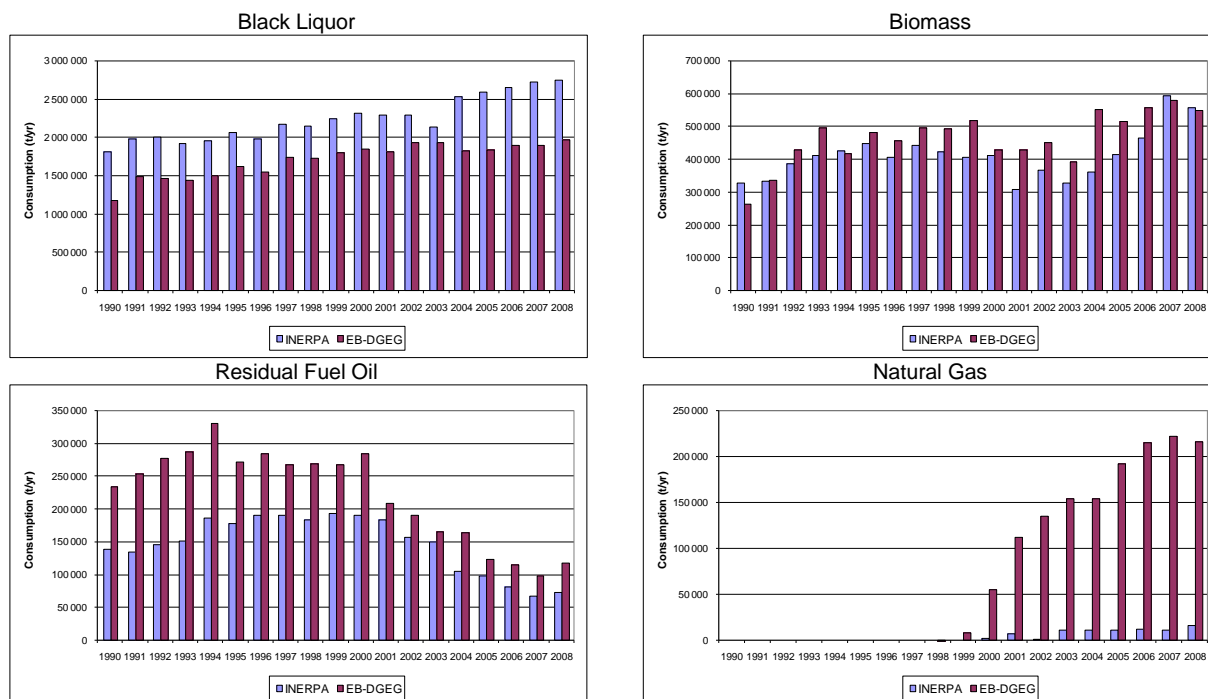


3.2.2.2.1.3 Comparison of LPS data vs. Energy Balance

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.

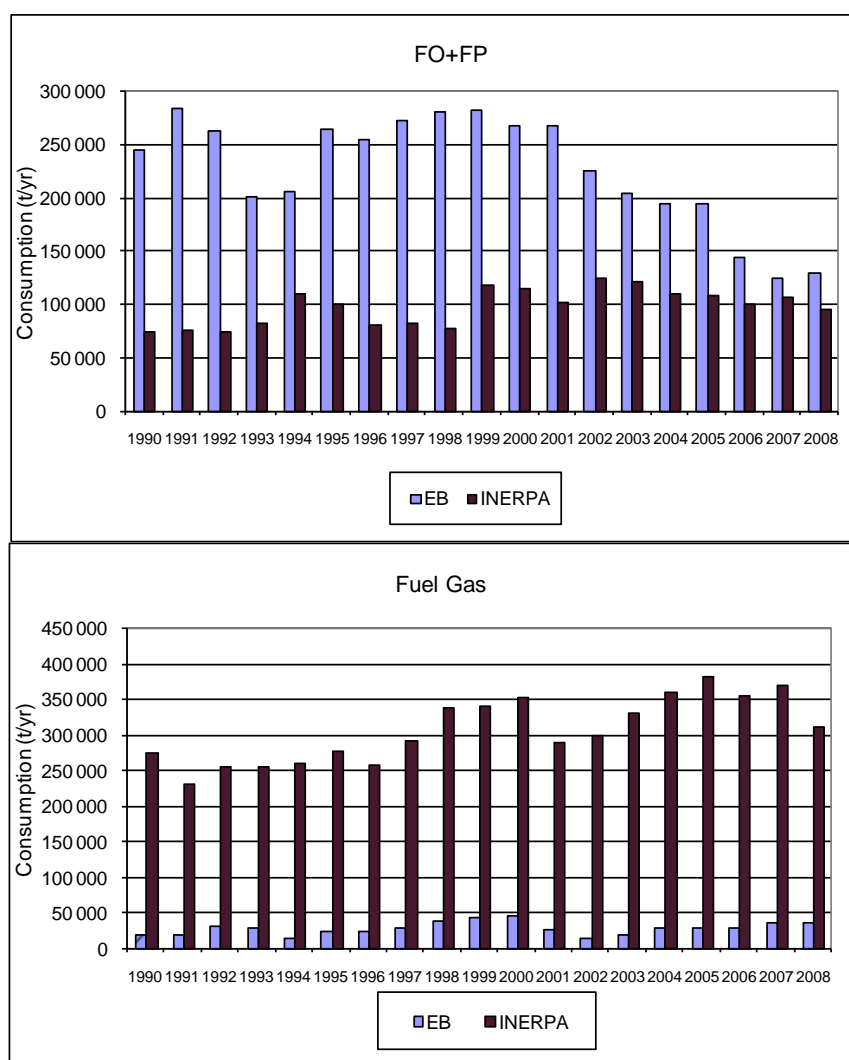
Before hand, it must be realized that to conclude for consistency between both distinct datasets, the comparison should result in higher or equal consumption in the EB than in the inventory, because apart from specific fuels (black liquor in the paper and pulp industry, coke oven gas and blast furnace 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 3.50 – Comparison of total LPS consumption in Paper Pulp units with the reported consumption in the EB for the sector “Paper pulp and paper production” (1990-2008)



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 part of the differences 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 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 3.51 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector “Chemical and Plastics”²⁵ (1990-2008)



For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil²⁶ is about 50% in most recent 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.

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

²⁶ 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 3.52 – 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”²⁷ (1990-2001)

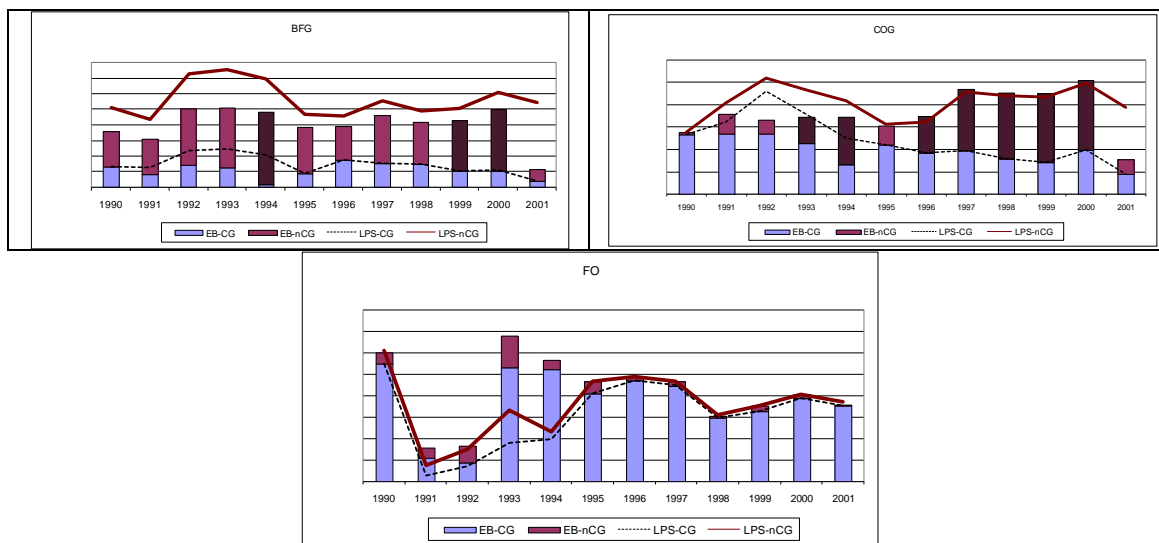
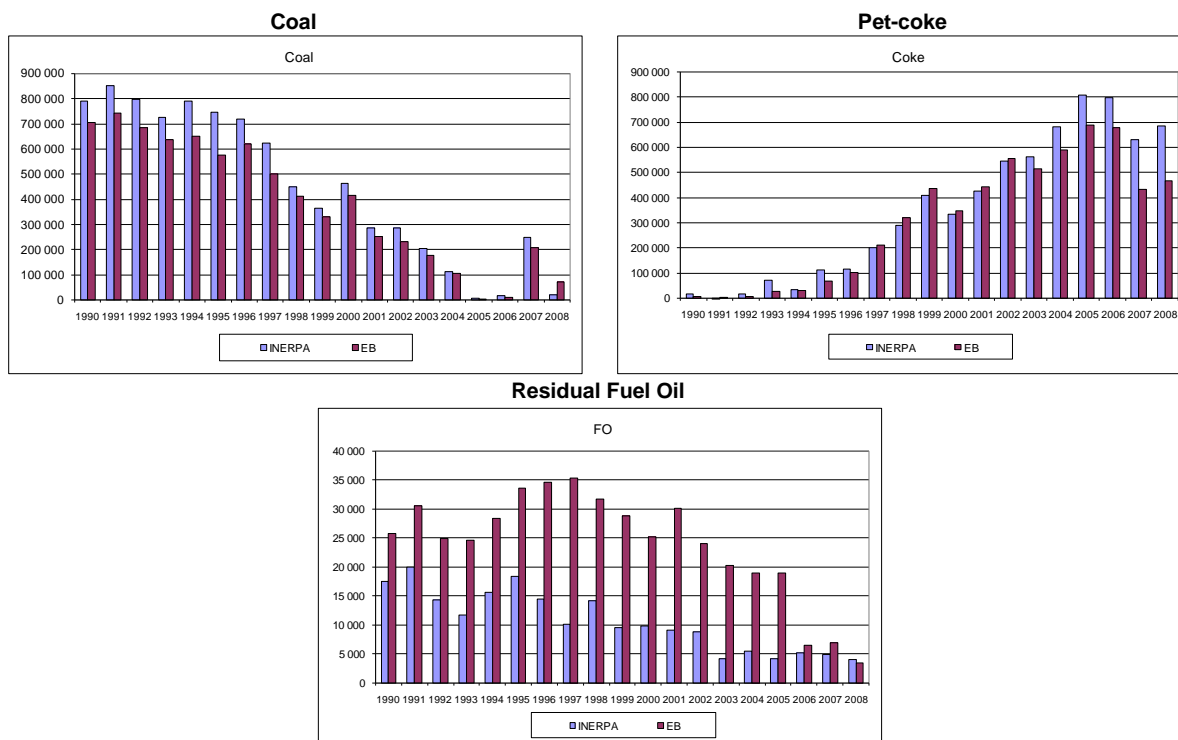


Figure 3.53 – Comparison of total LPS consumption in Cement Plant with the reported consumption in the EB for the sector “Cement and Lime” (1990-2008)



Concerning the cement industry, an acceptable coherence exists between both information sources, except for fuel oil consumption. Also for coke and coal the latest years in the time series show unusual behavior concerning the compatibility between both data sources.

²⁷ Units in the vertical axis are not indicated due to confidentiality issues.

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.

3.2.2.2.2 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.

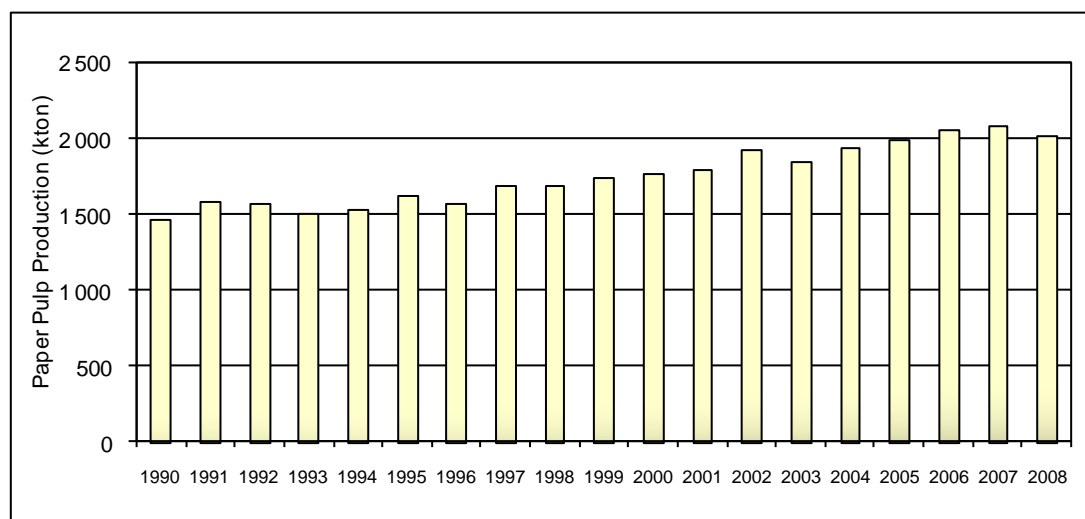
Total production of paper pulp is reported in Table 3.64. Production data for Kraft paper pulp from year 1990 to year 1998 was made available to APA directly from the six operating units, while data for 1999 till 2008 for the same units and the total time series of paper pulp by the acid sulphide process is from CELPA.

Table 3.64 – Total Paper Pulp Production (Kraft and sulphide paper pulp) (1990-2008)

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

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Pulp Production (kton)	1 772	1 805	1 929	1 855	1 946	1 990	2 064	2 092	2 022	-

Figure 3.54 – Total paper pulp production: Kraft and sulphide paper pulp (1990-2008)



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

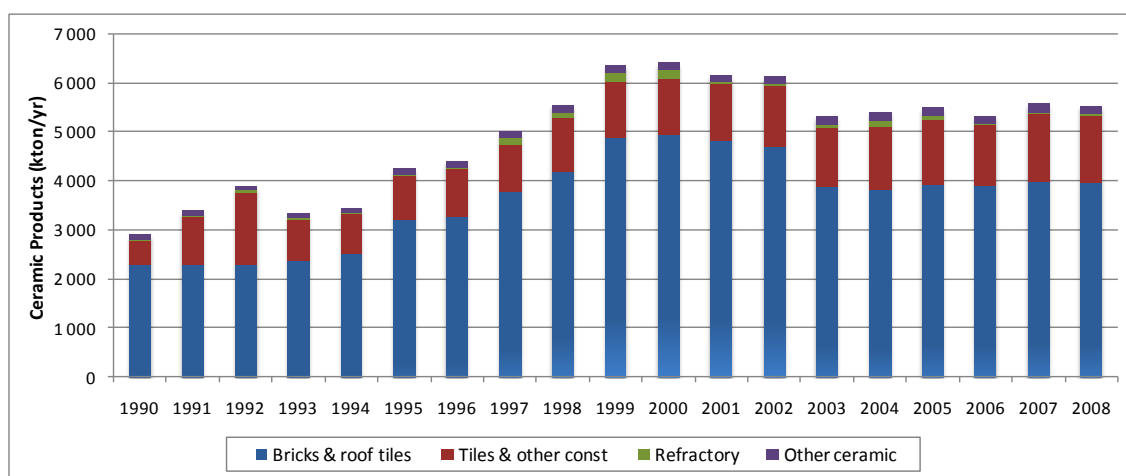
Data on annual manufacturing of ceramic products is available from 1990 to 2007 from INE statistical database. Values from 2008 were forecast using the existing time series. Time series for total production may be seen in Table 3.65 and Figure 3.55, according to type of ceramic.

Table 3.65 – Ceramic Production according to type of ceramic (kton) (1990-2008)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Bricks & roof tiles	2 290	2 290	2 290	2 367	2 513	3 200	3 261	3 786	4 203	4 874
Tiles & other const	478	980	1 483	856	822	921	982	958	1 077	1 170
Refractory	31	33	34	28	26	27	32	125	134	153
Other ceramic	104	90	76	87	93	107	114	124	135	141

	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Bricks & roof tiles	4 932	4 834	4 697	3 873	3 831	3 923	3 917	3 993	3 953	-
Tiles & other const	1 170	1 155	1 253	1 221	1 289	1 327	1 224	1 377	1 378	-
Refractory	167	32	30	49	103	100	39	40	41	-
Other ceramic	143	125	140	164	167	152	147	150	150	-

Figure 3.55 – Ceramic Production according to type of ceramic (1990-2008)



The Production values for container glass, lead crystal glass and other glass are presented in Figure 3.56 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 3.56 - Glass production by glass type (excluding flat glass production)

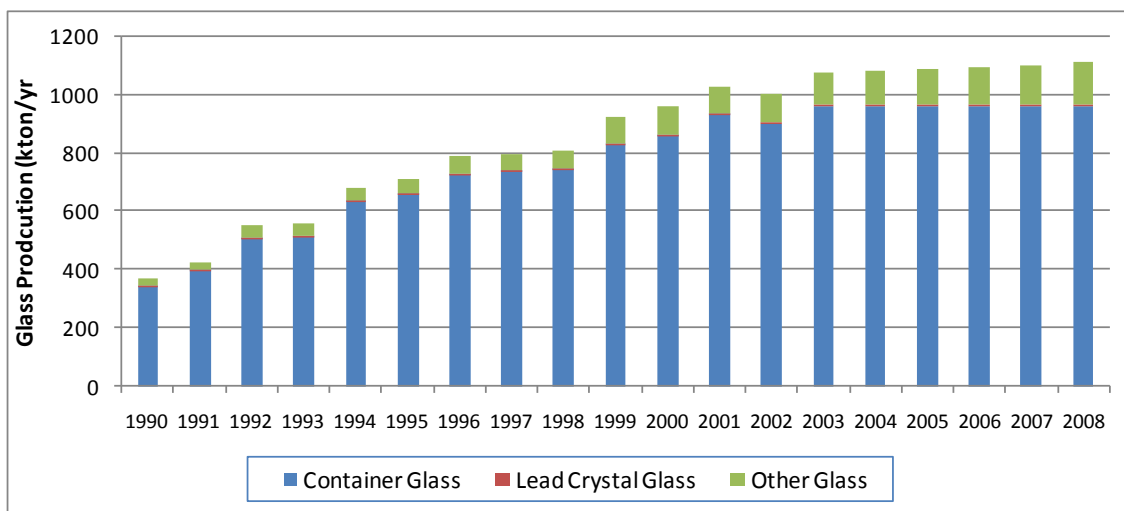


Table 3.66- Glass production by glass type (kton/yr) excluding flat glass production (1990-2008)

Type of Glass	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Container Glass	345	400	510	519	640	663	730	741	751	835
Lead Crystal Glass	0.1	0.2	0.5	0.3	0.4	0.5	0.6	0.9	0.8	0.9
Other Glass	26	28	41	40	39	47	61	54	58	90

Type of Glass	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Container Glass	864	936	904	965	965	965	965	965	965	-
Lead Crystal Glass	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	-
Other Glass	100	95	102	109	116	124	131	138	145	-

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

3.2.2.3 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);
- 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.

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	74.04	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	73.1	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	62.8	0.995	100	1.5	1.4
	Gasoline	L	208	68.6	0.990	100	0.1	0.6
	Kerosene	L	206	71.1	0.990	100	0.6	0.6
	Diesel Oil	L	204	73.3	0.990	100	0.6	0.6
	Residual Oil	L	203	76.6	0.990	100	1.4	0.6
	Natural Gas	G	301	55.8	0.995	100	1.4	1.4
	Lignite	S	105	99.2	0.980	100	2.4	0.7
Static Engines	Gasoline	L	208	68.6	0.990	100	60	0.6
	Gas Oil	L	204	73.3	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	40.79	0.995	100	2.5	1.4
Sintering	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
Blast Furnace Cowpers	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
	Blast furnace gas	S	305	296.23	0.995	100	2.5	1.4
Rolling mills	Residual oil	L	203	76.59	0.990	100	3.0	0.6
	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
Thermo-Electric Power plant	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
	Blast furnace gas	S	305	296.23	0.995	100	2.5	1.4
	Residual oil	L	203	76.59	0.990	100	3.0	0.6
	Tar	L	299	79.86	0.990	100	3.0	0.6
Heat power plant	LPG	L	303	62.75	0.995	100	4.0	1.4
	Tar	L	299	79.86	0.990	100	3.0	0.6
	Waste oils	O	115	76.59	0.990	100	3.0	0.6
Lime kiln	Residual Oil	L	203	76.59	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	77.37	0.990	100	3	0.6
	Pyrolysis Fuel Oil	L	203	77.37	0.990	100	3	0.6
	Fuel Gas	L	307	50.05	0.995	100	2.5	1.4
Furnaces	Fuel Gas	L	307	50.05	0.995	100	2.5	1.4
	Propane	L	303	63.07	0.995	100	2.5	1.4
Static Engines	Residual Fuel Oil	L	203	77.37	0.990	100	60	0.6
	Diesel Oil	L	204	74.07	0.990	100	60	0.6
Flares	Flare Gas	L	307	59.2-65.6	0.995	100	-	-

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

Equipment	Fuel	NAPFUE		CO ₂		CH ₄			N ₂ O g/GJ
				kg/GJ	% C fossil	Approach	EF	Unit	
Recovery Boilers	Residual Oil	L	203	76.6	100	EA	3	g/GJ	0.6
	Black Liquor	B	215	73.3	0	PA	0.49	kg/ton pulp	0.6
	Bisulfite Liquor	B	215	73.3	0	PA	0.625		0.6
Biomass Boilers	Bark/ Wood Wastes	B	111	100.8	0	EA	30	g/GJ	4.3
	Residual Fuel Oil	L	203	76.6	100	EA	3	g/GJ	0.6
	Natural Gas	G	301	55.8	100	EA	1.4	g/GJ	1.4
	LPG	L	303	62.4	100	EA	0.72	g/GJ	1.4
Auxiliary Boilers	Residual Oil	L	203	76.6	100	EA	3	g/GJ	0.6
Lime Kiln	Residual Oil	L	203	76.6	100	PA	0.065	kg/ton pulp	0.6
	Gasified Biomass	B	-	100.8	0				4.3
	Tall-Oil	B	-	73.3	0				0.6
	NCG	B	-	73.3	100				1.4
Flares	LPG	L	303	62.4	100	EA	0.72	g/GJ	1.4

Estimation Approach: EA – Energy App.; PA – Production App.
NCG- Non-condensable gases

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 3.73 – 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% of VOC emissions; (b) EU-ETS

Table 3.74 – 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 3.75 – 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.

3.2.2.4 *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% for energy intensive industrial sectors (iron and steel, cement, paper pulp, glass and ceramics) and 5% for all other sources;
- if fuel consumption, other than biomass, results from statistical information gathered from the National Energy balances then uncertainty is 5% for energy intensive sectors and 10% 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%.

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

3.2.2.5 *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. Following the fuel classification presented in the IEA website, three fuels types were analyzed: coal and peat, petroleum products and natural gas. It was only possible to compare values for 2007 since this is the only year with data publicly available in IEA. For coal and peat and natural gas the differences between fuel consumption reported in both data sources are very small. Data concerning petroleum products shows a tendency to be higher in IEA for combustion in the industrial sector and lower than DGEGs for co-generation plants. Two factors may be influencing this variation:

- IEA might be using an older version of DGEG's energy balance (2007 EB was revised this year);
- there might be differences in the fuels aggregated under petroleum products reported by IEA and the DGEG values considered in this comparison.

Also important to note that during a general revision of this sector emissions estimation procedures inconsistent values were found concerning LHV for non combustible gas. These values were corrected.

3.2.2.6 *Recalculations*

There were several recalculations to this source category:

- Revision of diesel oil consumption data (only for 2006), used in the estimation of biodiesel incorporation. This revision also affects sector 1A4;
- Inclusion of new fuels in the Cement Industry (2004-2007);
- Revision of the fraction of biomass for several fuel types, classified as other fuels in the Cement Industry, as a result from streamline procedures with EU-ETS;
- Revision of LHV and fuel consumption values for several combustion equipments in Pulp and Paper Industrial sector;
- Revision of the fuel consumption and LHV values for non combustible gases from Pulp and Paper industry (1991-2007), following QA/QC procedures applied to this sector;
- Production data update for the Ceramic Industry (IATI update 2001-2007).

3.2.3 Transport (CRF 1.A.3.)

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

3.2.3.1.1 Overview

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 Other Emissions.

The method to estimate emissions from jet fuel consumption is a Tier 3A method. 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 green house gases emissions inventory which is reported to the EU²⁸ and to the UNFCCC, emissions from flights to and from the autonomous regions of Azores and Madeira islands are included in national totals.

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.

Table 3.76 – 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.

3.2.3.1.2 Methodology

The methodology that is used in the inventory is coherent with good practices from IPCC and is equivalent to the Tier 3A for jet fuel and Tier 1 for aviation gasoline. Emissions are calculated separately for:

²⁸ Decision 2004/280/CE

- 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.

3.2.3.1.2.1 Landing/Take-off

The general approach to estimate emissions during LTO is:

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

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.

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

$\text{EF}_{\text{Departure}(p,s)}$ – 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;

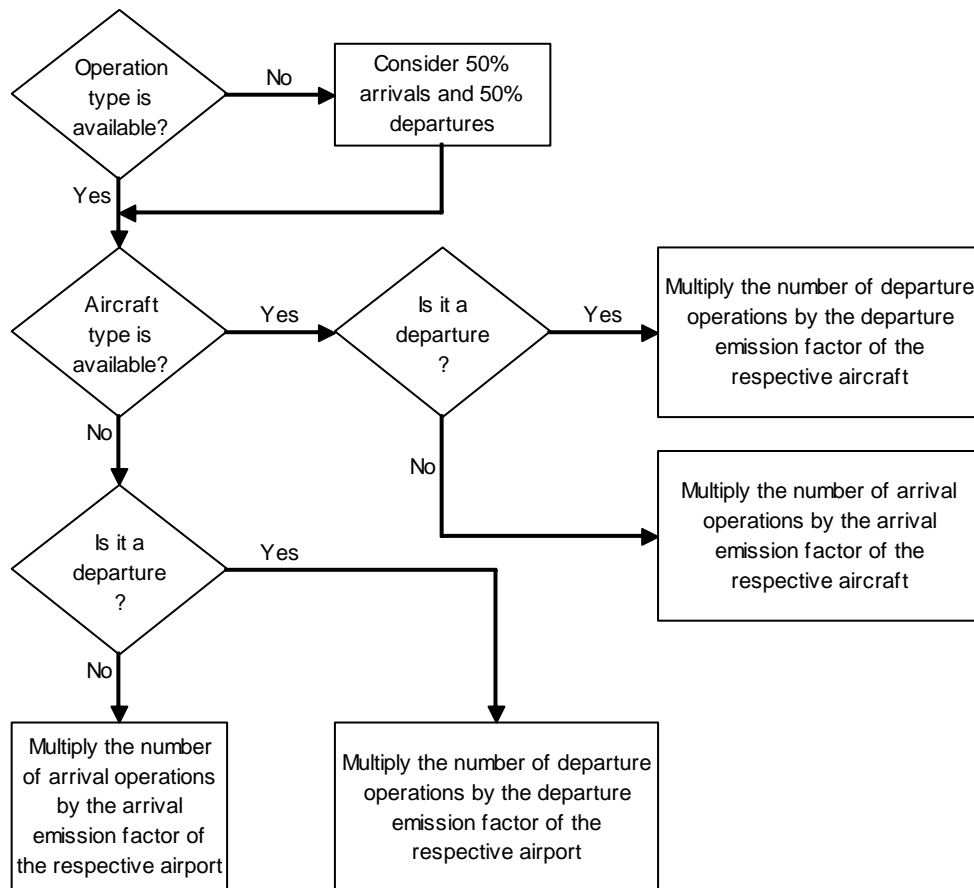
y – year.

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

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

Figure 3.57 outlines the process whereby LTO emissions are estimated.

Figure 3.57 – Decision tree for LTO emission calculation



3.2.3.1.2.2 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.

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

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);

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

$EF_{cruise(p,d,a,s,t,y)}$ – 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.

3.2.3.1.3 Emission Factors

3.2.3.1.3.1 LTO

3.2.3.1.3.1.1 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 3.77 - 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

3.2.3.1.3.1.2 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 3.78 – Airport based LTO emission factors (kg/movement).

Airport	Operation	Parameter	1990	1995	2000	2005	2008
Lisboa (LIS)	Take-off	Fuel Consumption	670.2	608.9	567.4	452.6	435.2
		VOC	16.4	14.9	15.2	9.3	7.0
		CO	37.1	33.7	35.4	21.5	18.2
		NOx	26.3	23.9	23.6	16.2	15.1
		PM ₁₀	6.2	5.6	5.2	4.2	4.0
	Landing	Fuel Consumption	291.0	264.4	240.2	204.2	199.1
		VOC	7.0	6.4	6.0	4.4	2.9
		CO	17.8	16.2	16.3	11.1	8.9
		NOx	4.9	4.4	4.3	3.3	3.2
		PM ₁₀	3.1	2.8	2.6	2.2	2.1
Porto (OPO)	Take-off	Fuel Consumption	530.0	481.5	401.1	374.4	369.3
		VOC	8.2	7.5	6.5	4.1	3.7
		CO	26.3	23.9	23.0	13.7	12.6
		NOx	19.1	17.3	15.0	11.9	12.2
		PM ₁₀	4.9	4.5	3.7	3.5	3.4
	Landing	Fuel Consumption	236.2	214.6	181.3	172.9	169.4
		VOC	3.7	3.3	2.9	2.2	1.8
		CO	12.7	11.5	11.1	7.2	6.6
		NOx	3.8	3.5	3.0	2.6	2.7
		PM ₁₀	2.5	2.3	1.9	1.9	1.8
Faro (FAO)	Take-off	Fuel Consumption	514.8	467.7	443.6	348.7	304.8
		VOC	5.3	4.8	4.9	3.0	2.5
		CO	19.2	17.4	17.2	12.2	10.3
		NOx	17.4	15.8	16.0	11.0	8.7
		PM ₁₀	4.8	4.3	4.1	3.2	2.8
	Landing	Fuel Consumption	231.8	210.6	198.9	158.2	140.5
		VOC	2.7	2.5	2.5	1.7	1.5
		CO	10.0	9.1	9.0	6.5	5.7
		NOx	3.5	3.2	3.1	2.3	2.0
		PM ₁₀	2.5	2.3	2.1	1.7	1.5

3.2.3.1.3.2 Cruise Emissions

3.2.3.1.3.2.1 Aircraft Based Cruise Emissions

Cruise emissions were estimated from EMEP/CORINAR 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 3.79 – 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

3.2.3.1.3.2.2 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.

3.2.3.1.3.3 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 3.80 – 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
346	Airbus A340-600	L JeK	L4J	346	340

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
B12	British Aerospace (BAC) One Eleven 200	L JeK	L2J	B12	B11
BES	Beechcraft 1900/1900C	L JeK	L2T	BE1	BE1

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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	L JeK	L2T	DH8	DH8

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
	8Q				
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

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

3.2.3.1.3.4 Fuel dependent emission factors

Fuel dependent emission factors were set for CO₂ and N₂O.

Table 3.81 – Fuel dependent emission factors.

Pollutant	AG	JP
LHV (MJ/kg)	44.77	44.59
CO ₂ (t/TJ) ²⁹	69.51	70.06
N ₂ O (kg/TJ)	2.00	2.00

Source: IPCC; DGEG

3.2.3.1.4 Activity Data

3.2.3.1.4.1 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 2008 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 3.82 – LTO per airport

Region	Airport Code	1990	1995	2000	2005	2008
Mainland	LIS	30 862	34 932	56 073	68 168	72 324
	OPO	11 574	13 348	23 280	25 910	29 002
	FAO	11 252	13 067	18 243	20 397	22 835
	TOTAL	53 688	61 347	97 596	114 475	124 161

Region	Airport Code	1990	1995	2000	2005	2008
Islands	FNC	6 475	9 460	12 040	15 952	12 949
	TER	3 801	4 049	4 501	4 875	5 005
	PDL	2 954	3 382	4 134	7 196	6 405
	PXO	2 403	4 243	3 788	3 688	2 207
	HOR	1 237	1 542	1 756	2 964	2 516
	SMA	634	893	1 557	1 649	1 591
	FLW	281	357	552	1 101	776
	TOTAL	17 785	23 926	28 328	37 425	31 449

Source: INAC

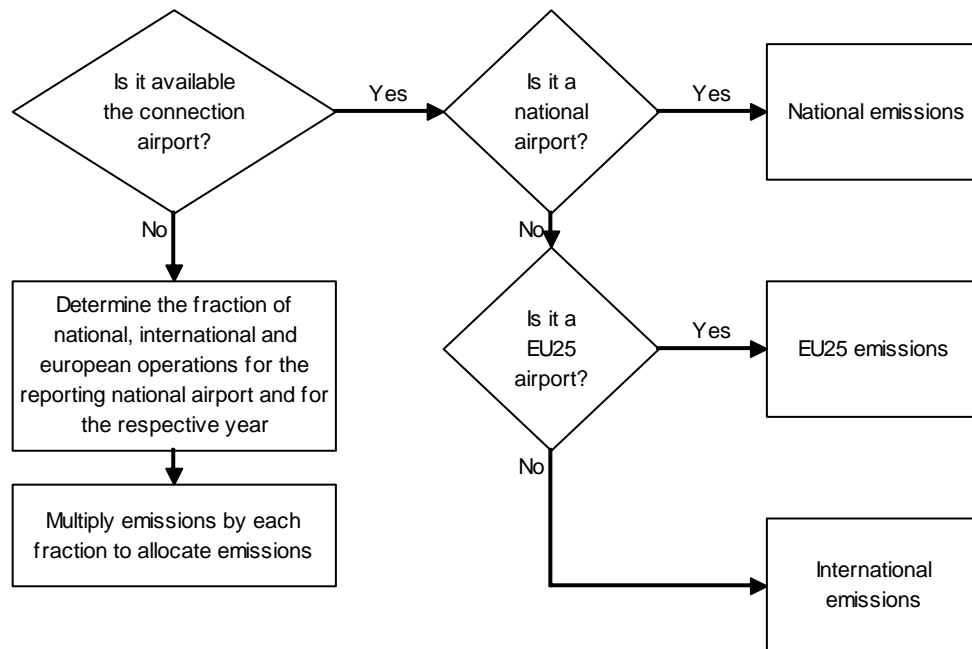
Data concerning aircraft operation characteristics, particularly, the origin/destiny, the aircraft type and the movement type was sometimes not included in the records database. The worse case refers to the period between 1990 and 1994, for this period the only information available was the number of 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.

²⁹ The CO₂ emission factor takes into account an oxidation factor of 0.99.

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.

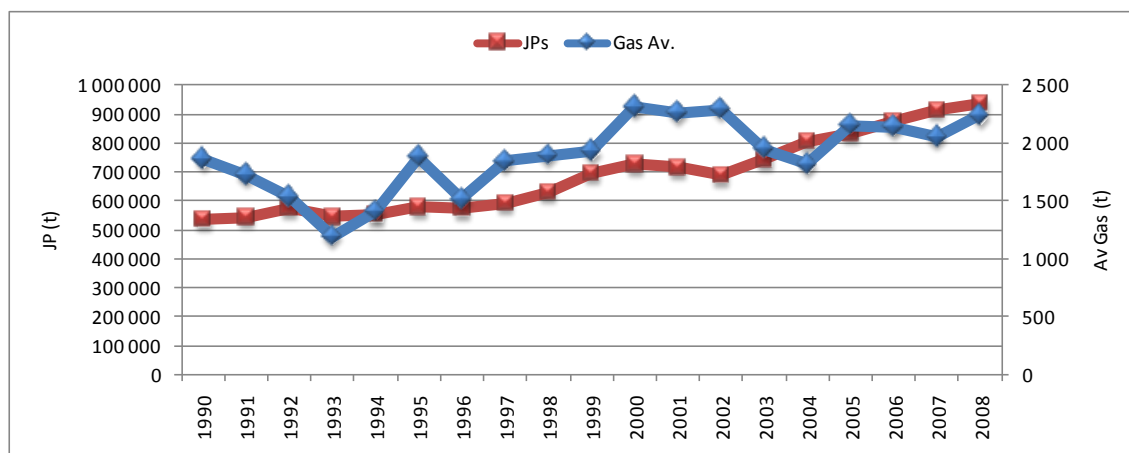
Figure 3.58 – Decision tree for distinction between domestic and international emissions.



3.2.3.1.4.2 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 3.59 – Total Fuel consumption of aviation gasoline (Gas Av.) and jet fuel (JPs)



Source: DGEG, 2010

3.2.3.1.5 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 3.83 – Aviation activity level uncertainty.

Source	Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
All	Uglobal	%	74	71	71	71	72	72	71	72	72	72
Cruise	Ucruise	%	99	99	99	99	99	99	99	99	99	99
LTO	Ulto	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100

Source	Parameter	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008
All	Uglobal	%	35	35	36	36	36	36	36	36	36
Cruise	Ucruise	%	47	48	48	48	49	49	49	49	49
LTO	Ulto	%	48	48	48	48	49	49	49	49	49

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.

3.2.3.1.6 Category-specific QA/QC and verification

Energy consumption is compared with data from the energy balance reported by DGEG. The difference in total fuel was around 0.3% in 2008 which could result from rounding values.

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 2008 ANA Traffic Yearbook reports 5% less flights then 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.

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

3.2.3.2.1 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 18 626.1 kton CO₂e. in 2008 representing an increase of 97.6% when compared to 9 426.6 kton CO₂e., estimated for 1990 (see Table 3.84).

Emissions of N₂O have increased by a factor of 2.9 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 3.84 – Estimated emissions from road transport

Pollutant	Unit	1990	2008	Var (%)
CO2 Fossil	kt	9 245.7	18 346.4	98.4
CH4	t	4 706.8	1 950.4	-58.6
N2O	t	264.4	770.2	191.3
CO ₂ e.	kt	9 426.6	18 626.1	97.6

3.2.3.2.2 Methodology

Emissions from road transportation are estimated using COPERT IV. 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 the 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 3.60 – General scheme of methodology applied for road transport emissions estimates (Passenger cars, light duty vehicles and motorcycles)

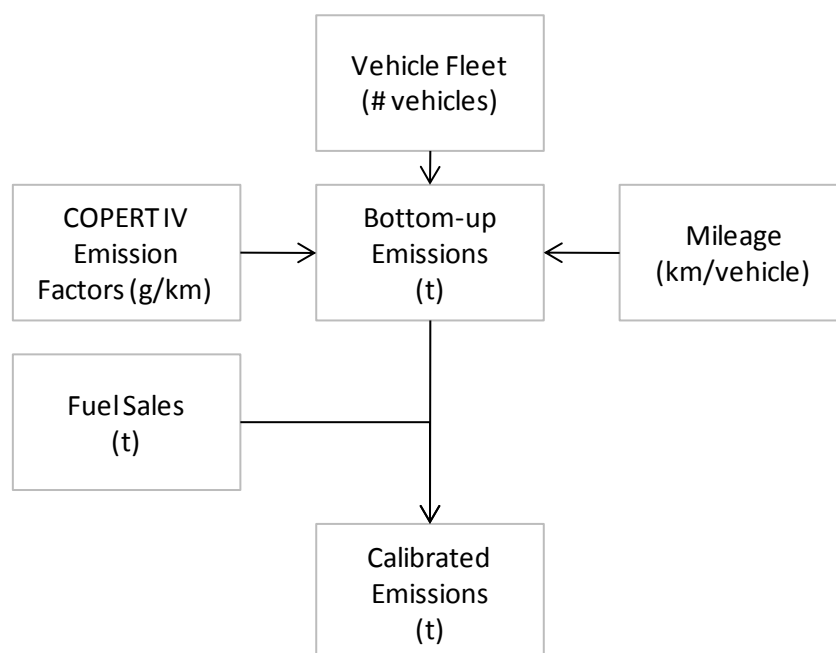
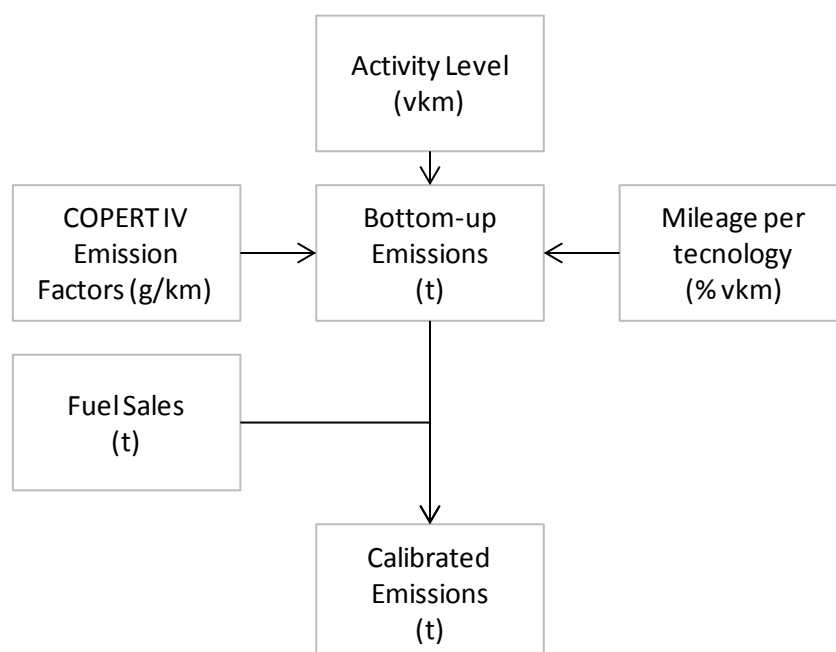


Figure 3.61 – General scheme of methodology applied for road transport emissions estimates (Heavy duty vehicles, buses and coaches)



3.2.3.2.2.1 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 the inspections centers.

3.2.3.2.2.2 Distance Travelled

Distance driven was established from the 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 12000km/year for motorcycles (Bennetts, 2009) and 5000 for mopeds.

Table 3.85 – Km per vehicle obtained from vehicle inspection centres (km/veic).³⁰

SECTOR	Subsector	Tech	1990	1995	2000	2005	2008
Passenger Cars	Gasoline <1,4 l	PRE ECE	1 535	1 437	1 339	1 207	1 080
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	3 107	2 669	2 232	1 772	1 562
Passenger Cars	Gasoline <1,4 l	ECE 15/02	4 932	4 270	3 609	2 962	2 541
Passenger Cars	Gasoline <1,4 l	ECE 15/03	8 408	7 115	5 822	4 606	3 710
Passenger Cars	Gasoline <1,4 l	ECE 15/04	10 837	9 535	8 233	6 975	5 986
Passenger Cars	Gasoline <1,4 l	PC Euro 1 - 91/441/EEC		20 290	14 426	9 959	11 544
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC			18 803	13 090	11 310
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000				18 605	14 414
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005				22 636	19 581
Passenger Cars	Gasoline <1,4 l	PC Euro 5 (post 2005)					
Passenger Cars	Gasoline <1,4 l	PC Euro 6					
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	1 728	1 602	1 477	1 255	1 146
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	3 728	3 148	2 568	1 925	1 679
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	5 741	4 948	4 155	3 413	2 759
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	9 914	8 515	7 117	5 792	4 735
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	13 464	11 842	10 219	8 655	7 382
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC		19 925	15 432	11 800	10 443
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC			18 684	14 338	12 583
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000				19 323	14 840
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005				21 721	19 322
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 (post 2005)					
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6					

³⁰ Legend: PassCar – Passenger Car; LDV – light duty vehicles; HDV – heavy duty vehicles; Moto – Motorcycles; GO – diesel; LPG – liquified petrol gas; CNG – compressed natural gas

SECTOR	Subsector	Tech	1990	1995	2000	2005	2008
Passenger Cars	Gasoline >2,0 l	PRE ECE	1 854	1 662	1 471	1 234	1 021
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	4 404	3 832	3 260	2 857	2 173
Passenger Cars	Gasoline >2,0 l	ECE 15/02	8 526	7 329	6 131	6 821	3 640
Passenger Cars	Gasoline >2,0 l	ECE 15/03	12 119	10 084	8 048	5 746	4 936
Passenger Cars	Gasoline >2,0 l	ECE 15/04	13 155	11 731	10 307	8 796	7 896
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC		19 270	14 892	11 252	9 698
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC			18 526	14 334	12 620
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000				18 589	14 703
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005				21 021	18 843
Passenger Cars	Gasoline >2,0 l	PC Euro 5 (post 2005)					
Passenger Cars	Gasoline >2,0 l	PC Euro 6					
Passenger Cars	Diesel <2,0 l	Conventional	13 573	12 538	11 502	10 578	9 322
Passenger Cars	Diesel <2,0 l	PC Euro 1 - 91/441/EEC		36 284	24 422	16 136	14 027
Passenger Cars	Diesel <2,0 l	PC Euro 2 - 94/12/EEC			33 807	22 788	18 680
Passenger Cars	Diesel <2,0 l	PC Euro 3 - 98/69/EC Stage2000				36 743	24 944
Passenger Cars	Diesel <2,0 l	PC Euro 4 - 98/69/EC Stage2005				41 028	35 082
Passenger Cars	Diesel <2,0 l	PC Euro 5 (post 2005)					
Passenger Cars	Diesel <2,0 l	PC Euro 6					
Passenger Cars	Diesel >2,0 l	Conventional	16 093	14 423	12 753	11 117	9 682
Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC		51 507	31 107	17 954	15 257
Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC			44 269	24 508	20 579
Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000				44 503	27 115
Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005				59 667	48 716
Passenger Cars	Diesel >2,0 l	PC Euro 5 (post 2005)					
Passenger Cars	Diesel >2,0 l	PC Euro 6					
Passenger Cars	LPG	Conventional	6 295	6 059	5 823	5 811	4 909

SECTOR	Subsector	Tech	1990	1995	2000	2005	2008
Passenger Cars	LPG	PC Euro 1 - 91/441/EEC		27 977	22 919	19 433	14 540
Passenger Cars	LPG	PC Euro 2 - 94/12/EEC			21 847	13 070	13 994
Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000				16 773	21 507
Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005				30 000	25 500
Passenger Cars	LPG	PC Euro 5 (post 2005)					
Passenger Cars	LPG	PC Euro 6					
Passenger Cars	2-Stroke	Conventional					
Passenger Cars	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005				15 000	15 000
Passenger Cars	Hybrid Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005				15 000	15 000
Passenger Cars	Hybrid Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005				15 000	15 000
Light Duty Vehicles	Gasoline <3,5t	Conventional	7 740	6 620	5 499	4 363	3 633
Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC		22 506	16 270	9 959	8 090
Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC			21 515	14 026	11 307
Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000				19 001	14 501
Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005				25 000	21 588
Light Duty Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards					
Light Duty Vehicles	Gasoline <3,5t	LD Euro 6					
Light Duty Vehicles	Diesel <3,5 t	Conventional	14 338	12 711	11 083	9 488	8 186
Light Duty Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC		38 283	25 859	17 180	14 463
Light Duty Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC			34 948	22 233	18 850
Light Duty Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000				35 607	29 014
Light Duty Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005				43 253	36 631
Light Duty Vehicles	Diesel <3,5 t	LD Euro 5 - 2008 Standards					
Light Duty Vehicles	Diesel <3,5 t	LD Euro 6					

3.2.3.2.2.3 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.

3.2.3.2.2.4 Speed

Three driving modes were 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 3.86 – 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

3.2.3.2.2.5 Fuel consumption

Fuel consumption was estimated for each fuel type according with the kilometers travelled.

$$FC_{\epsilon,y} = \sum_m \sum_c \sum_t |km_{\epsilon,t,m,f,y}| \times FC_{\epsilon,t,m,f} \times 10^{-6}$$

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.

3.2.3.2.2.6 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.

$$Correc_{Factor(c,y)} = \frac{FuelSales_{(c,y)}}{FuelEstimates_{1stFC(c,y)}}$$

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).

3.2.3.2.2.7 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 3.87 – National specific LHV

Fuel	GJ/ton
Gasoline	44.799
Diesel	43.333
LPG	47.311
CNG	45.967
Biodiesel	37.000

Source: DGEG, 2010

Then national specific CO₂ emission factors (kgCO₂/GJ) provided by DGEG in national legislation (Despacho n.º 17313/2008) were multiplied by the energy consumption.

Table 3.88 - CO₂ emission factor (Source: DGEG, 2008)

Fuel	EF _{CO2} (kg CO ₂ /GJ)
Gasoline	69.2
Diesel	74.0
LPG	63.0
CNG	64.1

Source: DGEG

Emissions factors for CH₄ and N₂O, expressed in g/km, were determined using COPERT IV version 6.1 (February 2009).

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 cinder 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 3.89 – 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 I	1992	1996
	Euro II	1997	2000
	Euro III	2001	2004
	Euro IV	2005	2008
	Euro V ⁽³¹⁾	2009	2014
	Euro VI ⁽¹⁾	2014	...
Light Duty Vehicles	Conv	...	1991
	Euro I	1992	1997
	Euro II	1998	2001
	Euro III	2002	2006
	Euro IV	2006	2009
	Euro V ⁽¹⁾	2010	2015
	Euro VI ⁽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
	97/24/EC Stage I	2000	2003
	97/24/EC Stage II	2004	...
Motorcycles	Conv	...	1999
	97/24/EC	2000	...

³¹ 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. The average trip length, which determines the cold engine emissions, was set at 12 km (L_{trip}) as proposed by COPERT IV.

Emissions factors for SO_2 and heavy metals were estimated from the fraction S and heavy metals in the fuel.

Table 3.90 – Sulphur content in the fuel (%)

Fuel	1990	1995	2000	2005	2008
Gasoline	0.100	0.100	0.015	0.005	0.005
Diesel	0.300	0.200	0.035	0.005	0.005
LPG	0.000	0.000	0.000	0.000	0.000
CNG	0.000	0.000	0.000	0.000	0.000
Biodiesel	0.000	0.000	0.000	0.000	0.000

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 49 monitoring stations of the National Meteorological Institute (IM). The same values were used for all years in analysis.

Table 3.91 – Monthly average ambient temperatures (°C)

Month_	Max.	Min.
January	12.3	4.1
February	13.3	4.7
March	15.3	5.9
April	17.8	7.3
May	20.9	9.9
June	24.6	12.7
July	27.9	14.5
August	27.9	14.2
September	25.5	13.1
October	20.9	10.3
November	15.7	6.4
December	12.6	4.2

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 3.92 – Reid Vapour Pressure (kPa)

Month	1990 to 1995	1996 to 1999	2000 to 2008
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 3.93 – 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: EMEP/CORINAIR)

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 (EMEP/CORINAIR).

Considering that detailed literature data on biodiesel effects is scarce and that the actual blend used for road transportation in Portugal was only about 2,5% in 2008 (Table 3.94), emission factors from biodiesel use were assumed to be the same as for diesel.

Portuguese National Inventory Report 2010	MAOT
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Table 3.94 – National biodiesel blends with diesel (%)

2006	2007	2008
1.3	2.6	2.5

Fuel consumption factors here presented are developed in a similar manner as for emission factors.

3.2.3.2.3 Implied Emission Factors

The implied emission factors are estimated by dividing the estimated emissions by the energy consumption.

Table 3.95 – Road transportation emission factors (kg/GJ)

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2008
CO ₂	Passenger Cars	Gasoline	69.200	69.200	69.200	69.200	69.200
		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	69.200	69.200	69.200	69.200	69.200
		Diesel	74.000	74.000	74.000	74.000	74.000
		LPG	-	-	-	-	-
		CNG	-	-	64.100	64.100	64.100
		Biodiesel	-	-	-	-	0.000
	Motorcycles	Gasoline	69.200	69.200	69.200	69.200	69.200
		Diesel	-	-	-	-	-
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	-
CH ₄	Passenger Cars	Gasoline	0.054	0.036	0.025	0.019	0.016
		Diesel	0.009	0.006	0.004	0.002	0.001
		LPG	0.027	0.028	0.025	0.024	0.021
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.001
	Light Duty Vehicles	Gasoline	-	-	-	-	-
		Diesel	0.006	0.005	0.004	0.002	0.001
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.001
	Heavy Vehicles	Gasoline	0.015	0.015	0.015	0.015	0.015
		Diesel	0.007	0.007	0.007	0.007	0.006
		LPG	-	-	-	-	-
		CNG	-	-	0.093	0.095	0.088
		Biodiesel	-	-	-	-	0.006
	Motorcycles	Gasoline	0.175	0.165	0.145	0.108	0.086
		Diesel	-	-	-	-	-
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	-

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2008
N ₂ O	Passenger Cars	Gasoline	0.004	0.007	0.007	0.005	0.005
		Diesel	0.000	0.001	0.002	0.003	0.003
		LPG	0.000	0.008	0.007	0.007	0.007
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.003
	Light Duty Vehicles	Gasoline	-	-	-	-	-
		Diesel	0.000	0.000	0.001	0.002	0.002
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	0.002
	Heavy Vehicles	Gasoline	0.001	0.001	0.001	0.001	0.001
		Diesel	0.002	0.002	0.002	0.002	0.002
		LPG	-	-	-	-	-
		CNG	-	-	0.000	0.000	0.000
		Biodiesel	-	-	-	-	0.002
	Motorcycles	Gasoline	0.001	0.001	0.001	0.001	0.001
		Diesel	-	-	-	-	-
		LPG	-	-	-	-	-
		CNG	-	-	-	-	-
		Biodiesel	-	-	-	-	-

3.2.3.2.4 Activity Data

3.2.3.2.4.1 Vehicle Fleet

The following table shows the number of vehicles between 1990 and 2008 was based in data available from ACAP, *Instituto de Seguros de Portugal* (ISP) and INE.

Table 3.96 – Vehicle fleet synthesis

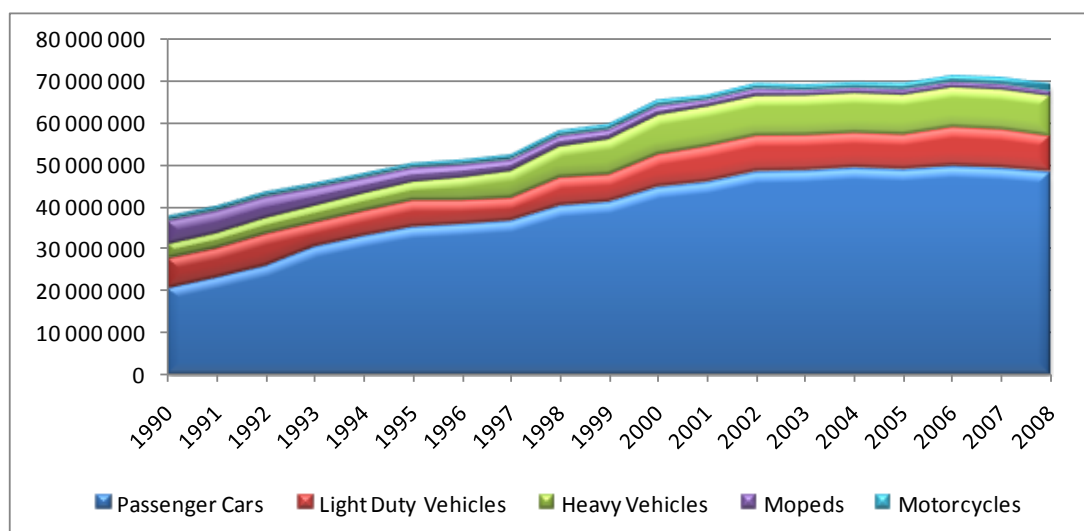
Vehicle Type	1990	1995	2000	2005	2008
Passenger Cars	1 640 086	2 707 738	3 740 845	4 185 358	4 252 869
Light Duty Vehicles	453 744	547 855	686 613	751 699	750 407
Mopeds	834 675	682 031	529 386	330 527	301 285
Motorcycles	66 129	92 238	144 596	157 055	192 631

The growth of gasoline passenger cars has been stagnating 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 stabilized as a small percentage of passenger cars. The number of mopeds is decreasing according with data from ISP.

3.2.3.2.4.2 Distances Travelled

Total road traffic activity has increased 81.2% since 1990.

Figure 3.62 – Kilometers travelled by vehicle type (vkmx10³)



3.2.3.2.4.3 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 3.97.

Table 3.97 – Fuel consumption from road transport sector

Fuel	Unit	1990	1995	2000	2005	2008
Gasoline	t	1 351 651	1 852 198	2 015 378	1 759 447	1 456 151
Diesel	t	1 576 543	2 074 530	3 695 451	4 096 654	4 196 869
LPG	t	21	281	21 711	20 355	23 842
CNG	t	0	0	648	9 572	6 385
Biodiesel	t	0	0	0	0	127 271

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.

3.2.3.2.5 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%.

3.2.3.2.6 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 2008 the estimated fuel consumption compared to sales are: Gasoline +31%; Diesel +46%; LPG -52%; CNG -91%. 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.

3.2.3.2.7 Further Improvements

Nothing to report

3.2.3.3 Railways (CRF 1.A.3.c)

3.2.3.3.1 Overview

Although there has been a growing electrification of railway lines in Portugal during last year's, locomotives, shunting locomotives and railcars are still responsible for substantial part of rail transport and consequent emission of GHG in exhaust.

3.2.3.3.2 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

$\text{Emission}_{(p,y)}$ - Emission of pollutant p in year y (ton/yr);

$\text{EF}_{(f,p)}$ - Quantity of pollutant p emitted from fuel f (kg/ton);

$\text{Cons}_{\text{Fuel}(n,f,y)}$ - consumption of fuel f during in year y (ton/yr).

3.2.3.3.3 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 3.98 - Emission factors in Railways (in kg/ton of fuel)

	Coal	Coke	Diesel-oil	Biodiesel	Fuel-oil
LHV ^(a)	29.3	28.0	43.3	37.0	40.2
CH ₄	0.22 ^(iv)				
U _{CO2}	3 168 ^(iv)				
% 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

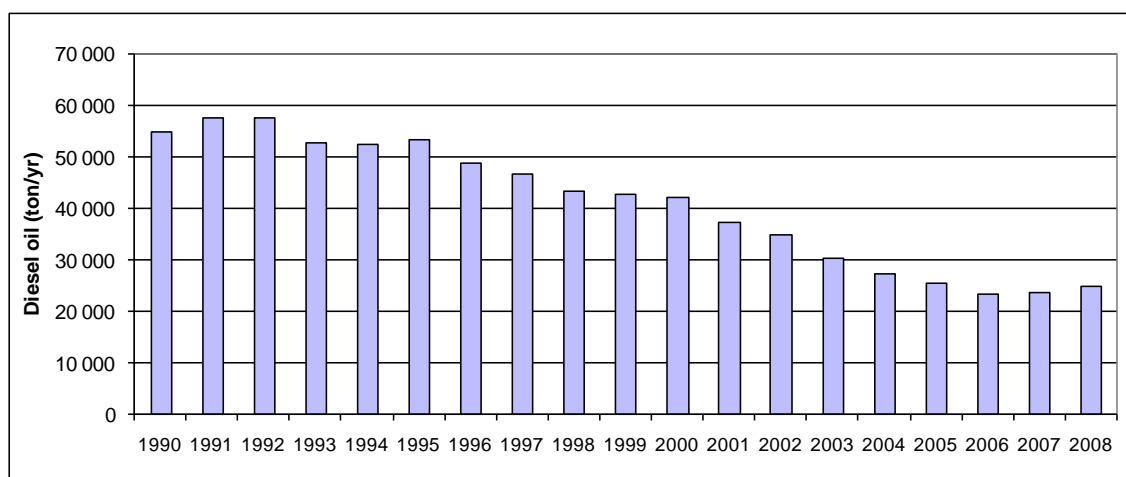
(iv) Average of EMEP/CORINAIR and IPCC;

(v) Average of EMEP/CORINAIR, IPCC and MEET;

3.2.3.3.4 Activity Data

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2008 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 oil³². The quantities that were consumed have been decreasing steadily since 1992, as can be seen in Figure 3.63.

Figure 3.63 - Consumption of diesel oil in the railway transport sector: 1990-2008



3.2.3.3.5 Uncertainty Assessment

The uncertainty of fuel consumption was set equal to the uncertainty that was also considered for road traffic: 5%. In a similar way the uncertainties in methane and nitrous oxide emission factors were set at 40% and 50% respectively, the same values that were used for road traffic. The general error of 5%, set for most combustion sources, was used for the calculation of uncertainties of carbon dioxide emissions.

3.2.3.3.6 Category-specific QA/QC and verification

The QA/QC procedures adopted for this sector: general revision of time series consistency for fuel consumption and emission factors, enabled the discovery of a compilation error in the CO₂ emission factor for hardcoal, coke and fuel oil.

³² Gas oil represents no less than 98.4% of total annual use of combustible energy.

3.2.3.3.7 Recalculation

The only recalculation for this source category corresponds to the CO₂ emission factor correction for hardcoal, coke and fueloil from the QA/QC procedures adopted for this sector. This correction resulted in a small different in CO₂ emissions.

3.2.3.4 *Water Borne Navigation (CRF 1.A.3.d)*

3.2.3.4.1 Overview

This sector refers to domestic ship transport between Portuguese ports including traffic to the Azores and Madeira islands.

3.2.3.4.2 Methodology

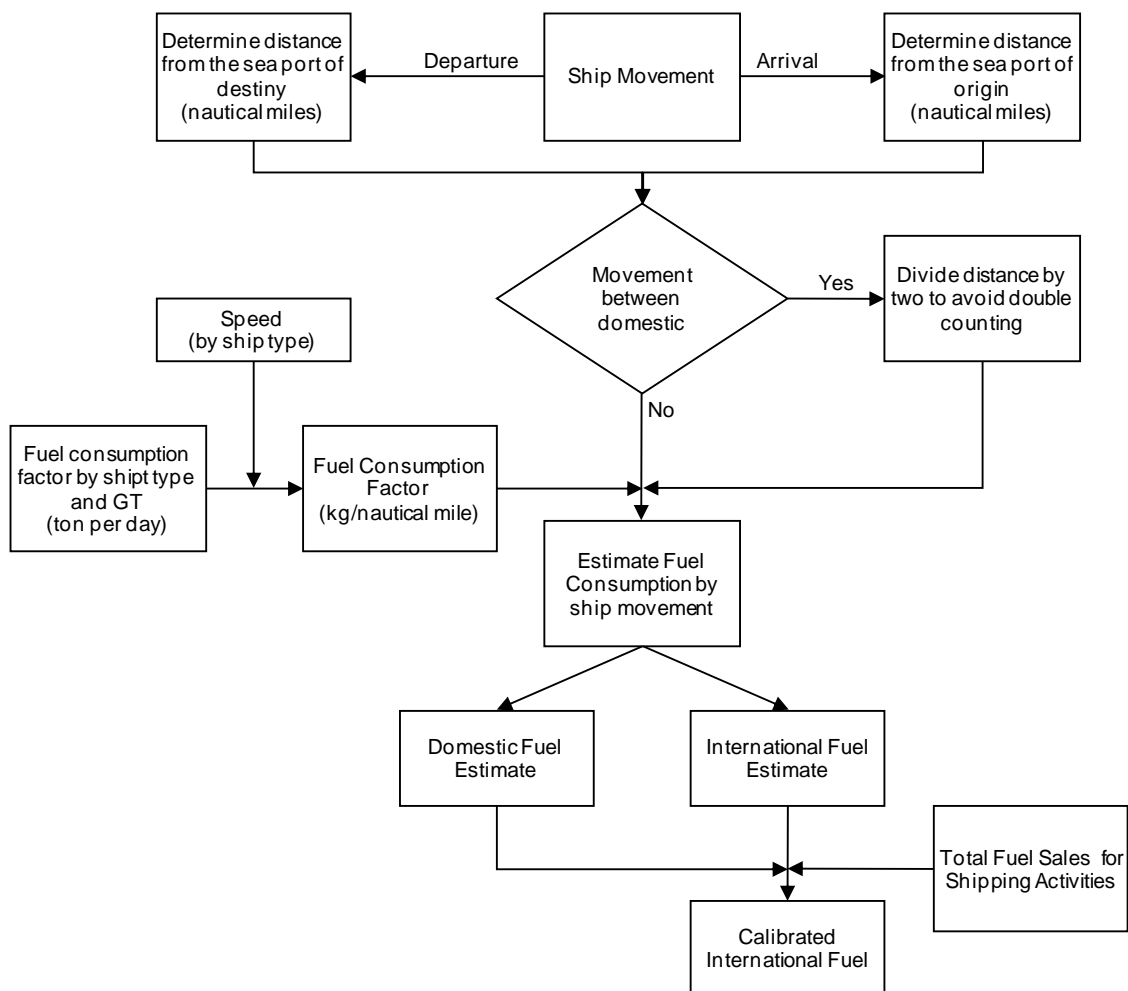
Statistics on fuel used in shipping activities is available at national level as an aggregated figure provided in the energy balance from the energy authority. Detailed ship movements are also available as well as some technical information on the ships such as gross tonnage and ship type.

The methodology used for the calculation of emissions from shipping activities is in accordance with the ship movement methodology from the detailed methodology of the Atmospheric Emissions Inventory Guidebook (Joint EMEP/CORINAIR , European Environmental Agency, Second Edition, 1999).

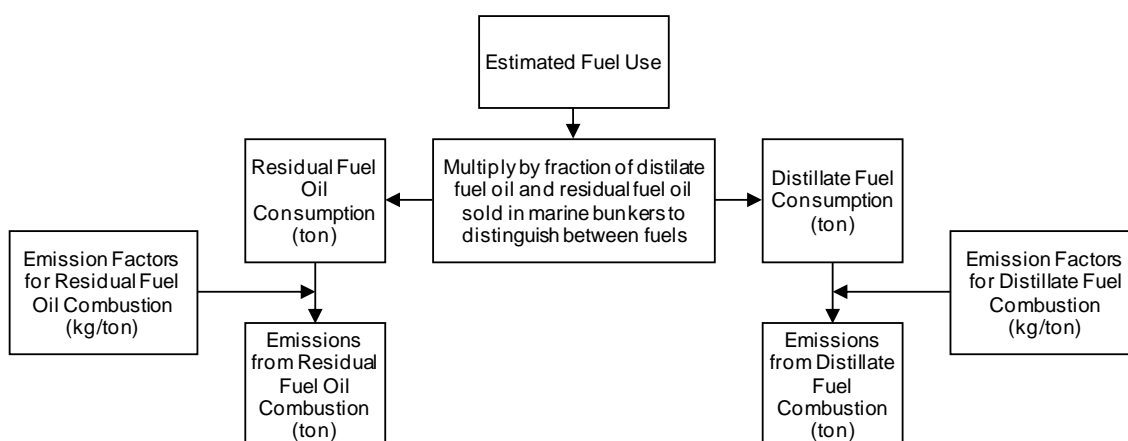
The methodology takes into account the fuel used as well as the type of ship, the distance travelled and the speed of vessel. Therefore, according with IPCC Guidelines, this approach consists in a detailed method (tier 2 or 3). Since fuel consumption is used for top-down calibration, tier 2 method could be regarded as the method used to estimate emissions from shipping activities.

The general approach could be described as follows:

Figure 3.64 – 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:



3.2.3.4.3 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:

$$CO_2 \left[\frac{t}{year} \right] = Energy[TJ] \times CarbonContent \left[\frac{tC}{TJ} \right] \times 0.99 \times \frac{44}{12}$$

Table 3.99 – Emission factors for navigation

Pollutant	Unit	Gas-oil	Residual fuel oil
LHV	MJ/kg	40.17	43.31
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 3.100 – 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: EMEP/CORINAIR

3.2.3.4.4 Activity Data

3.2.3.4.4.1 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 2008. 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 3.101 – Ship docks

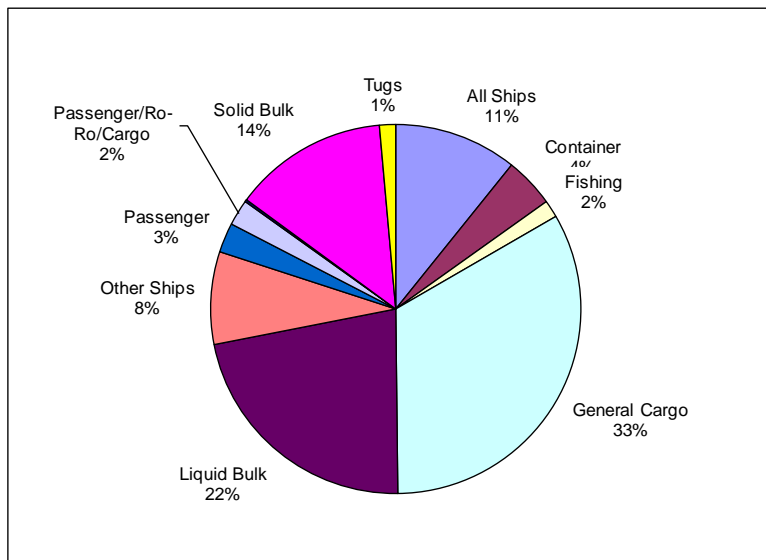
Sea Port	Location	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aveiro	Mainland	docks	876	920	965	1 009	1 054	1 098	1 080	1 062	1 045	1 027
Caniçal	Madeira	docks	76	76	76	76	76	76	76	76	76	76
Faro	Mainland	docks	163	163	163	163	163	163	163	163	163	163
Figueira da Foz	Mainland	docks	315	311	308	304	301	297	299	301	303	305
Funchal	Madeira	docks	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
Lisboa	Mainland	docks	5 586	5 586	5 586	5 586	5 554	4 993	5 332	4 927	4 776	4 323
Ponta Delgada	Azores	docks	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
Porto Santo	Madeira	docks	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
Sines	Mainland	docks	1 038	1 026	1 014	1 003	991	979	945	911	876	842
Viana do Castelo	Mainland	docks	254	315	310	228	247	293	304	315	326	337

Sea Port	Location	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008
Aveiro	Mainland	docks	1 009	1 042	1 021	1 013	1 053	1 028	1 002	977	1 010
Caniçal	Madeira	docks	76	76	57	76	94	76	76	76	76
Faro	Mainland	docks	163	89	69	51	36	32	27	23	17
Figueira da Foz	Mainland	docks	307	309	260	262	292	271	271	271	406
Funchal	Madeira	docks	1 063	1 063	1 076	1 090	1 022	1 063	1 063	1 063	1 063
Leixões	Mainland	docks	3 050	3 113	3 090	2 952	2 815	2 814	2 814	2 813	2 727
Lisboa	Mainland	docks	3 869	3 597	3 735	3 713	3 473	3 474	3 474	3 475	3 455
Ponta Delgada	Azores	docks	1 080	1 080	1 047	1 125	1 067	1 080	1 080	1 080	1 112
Portimão	Mainland	docks	37	24	28	33	56	42	29	15	42
Porto Santo	Madeira	docks	402	402	402	399	398	400	400	400	400
Setúbal	Mainland	docks	1 699	1 625	1 603	1 609	1 669	1 592	1 516	1 439	1 389
Sines	Mainland	docks	808	728	806	753	927	1 124	1 321	1 518	1 518
Viana do Castelo	Mainland	docks	348	369	315	262	208	214	220	226	246

3.2.3.4.4.2 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 3.65 – Ship fleet.



3.2.3.4.4.3 Fuel consumption

Domestic fuel consumption was estimated using a bottom-up approach from fuel consumption factors. International fuel is estimated by subtracting the domestic fuel to the total fuel sales.

Table 3.102 – Total fuel sales (ton)³³

Fuel Sales	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
L ResO	t	405 869	404 260	401 657	333 248	304 310	289 526	304 983	309 705	319 423	414 846
L GasD	t	124 757	121 704	121 807	118 705	112 554	138 883	146 256	135 096	129 999	140 461

Fuel Sales	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008
L ResO	t	473 463	329 770	364 667	442 042	527 365	454 925	513 718	550 300	587 421
L GasD	t	123 431	102 843	93 296	108 812	106 754	108 334	95 374	87 229	112 559

³³ L ResO – Residual fuel oil; L GasD - Diesel

Table 3.103 – Estimated fuel consumption (ton)

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
L ResO	Domestic	61 244	60 348	59 288	58 035	57 009	53 023	55 409	57 417	58 675	52 793
L ResO	International	431 559	440 419	447 543	452 642	451 437	448 722	456 703	442 053	427 589	429 035
L ResO	Total	492 803	500 767	506 831	510 677	508 446	501 744	512 112	499 470	486 264	481 828
L GasD	Domestic	23 132	22 794	22 394	21 921	21 533	20 027	20 929	21 687	22 162	19 940
L GasD	International	163 004	166 351	169 042	170 967	170 512	169 487	172 501	166 968	161 505	162 051
L GasD	Total	186 137	189 145	191 435	192 888	192 045	189 514	193 430	188 655	183 667	181 991

Fuel	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008
L ResO	Domestic	46 988	45 396	47 600	47 939	48 931	48 374	48 505	48 635	49 727
L ResO	International	430 259	412 368	420 785	415 054	423 123	412 442	402 018	391 595	408 911
L ResO	Total	477 247	457 764	468 384	462 993	472 054	460 815	450 523	440 230	458 637
L GasD	Domestic	17 748	17 147	17 979	18 107	18 482	18 271	18 321	18 370	18 782
L GasD	International	162 513	155 756	158 935	156 770	159 818	155 783	151 846	147 909	154 450
L GasD	Total	180 261	172 902	176 914	174 877	178 299	174 055	170 167	166 279	173 232

Table 3.104 – Estimated fuel consumption after top-down calibration (ton).

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
L ResO	Domestic	61 244	60 348	59 288	58 035	57 009	53 023	55 409	57 417	58 675	52 793
	International	344 625	343 912	342 369	275 213	247 301	236 503	249 574	252 288	260 747	362 053
	Total	405 869	404 260	401 657	333 248	304 310	289 526	304 983	309 705	319 423	414 846
L GasD	Domestic	23 132	22 794	22 394	21 921	21 533	20 027	20 929	21 687	22 162	19 940
	International	101 625	98 910	99 413	96 784	91 021	118 856	125 327	113 409	107 837	120 521
	Total	124 757	121 704	121 807	118 705	112 554	138 883	146 256	135 096	129 999	140 461

Fuel	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008
L ResO	Domestic	46 988	45 396	47 600	47 939	48 931	48 374	48 505	48 635	49 727
	International	426 475	284 374	317 067	394 103	478 434	406 551	465 213	501 665	537 694
	Total	473 463	329 770	364 667	442 042	527 365	454 925	513 718	550 300	587 421
L GasD	Domestic	17 748	17 147	17 979	18 107	18 482	18 271	18 321	18 370	18 782
	International	105 683	85 696	75 317	90 705	88 273	90 063	77 053	68 859	93 777
	Total	123 431	102 843	93 296	108 812	106 754	108 334	95 374	87 229	112 559

3.2.3.4.4.3.1 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 3.105. Specific tug fuel consumption factors were supplied by IPTM.

Table 3.105 – 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 3.106 – 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.

3.2.3.4.5 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 3.107.

Table 3.107 – 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%.

3.2.3.4.6 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.

3.2.3.5 Other Mobile Sources (CRF 1.A.3.e)

3.2.3.5.1 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 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 sector are included in 1 A 4 c Agriculture/Forestry/Fisheries.

3.2.3.5.2 Agriculture

3.2.3.5.2.1 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. Although emissions from mobile sources in agriculture and forestry are reported under category source

1A4c, methodology used to estimate emissions from this activity is better presented here together with the other individualized mobile sources. Consumption of biodiesel with gas oil was assumed in the energy balance data, in accordance with the explained in 1A2 methodology chapter.

3.2.3.5.2.2 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).

3.2.3.5.2.3 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.

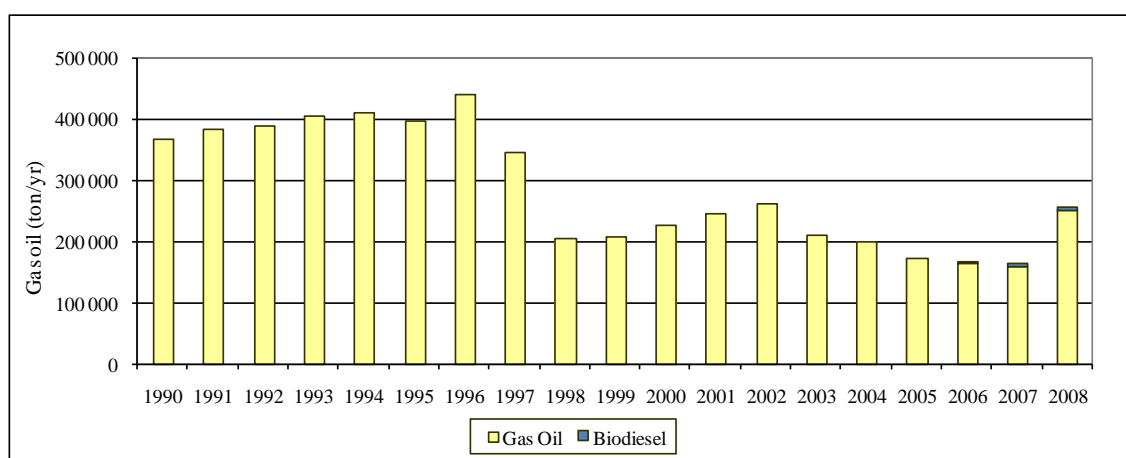
Table 3.108 – Emission factors for gas oil use in agriculture machines and other off-road vehicles

	EF		
Parameter	Gas oil	Biodiesel	Unit
LHV	43.3	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

3.2.3.5.2.4 Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to 2008 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 3.66.

Figure 3.66 - Consumption of gas-oil in machines and other off-road vehicles (1990-2008)



3.2.3.5.2.5 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%. 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.

3.2.3.5.3 Fishing Vessels

3.2.3.5.3.1 Overview

Emissions from fuel consumption in fishing ships and boats are discussed here because of similarities to navigation, although associated emissions are included in 1A.4c Fuel Combustion Activities in Agriculture, fisheries and forestry. Also emissions from additional consumption in fishing industry, aquaculture or sea ports that are realized inland and not in water vessels are not included here but under Fuel Combustion Activities, Other Sectors (1A4) and are discussed in chapter 3.2.A.6.

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.

3.2.3.5.3.2 Methodology

Emissions for all pollutants other than CO₂ are estimated for each ship type using the following formula:

$$\text{Emission}_{(n,p,y)} = \sum_f [\text{EF}_{(n,f,p)} * \text{Cons}_{\text{Fuel}(n,f,y)}] * 10^{-3}$$

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,

Fossil_{CO2(y)} - Emissions of carbon dioxide to atmosphere from combustion of fossil origin from ships of class n (ton);

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

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

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

Cons_{Fuel(n,f,y)} - Consumption of fuel f in year y from ship type n (ton/yr);

LHV_(f) - Low Heating Value (MJ/kg).

3.2.3.5.3.3 Emission Factors

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 3.109 – Emission factors for Water Borne Navigation and Fishing Vessels

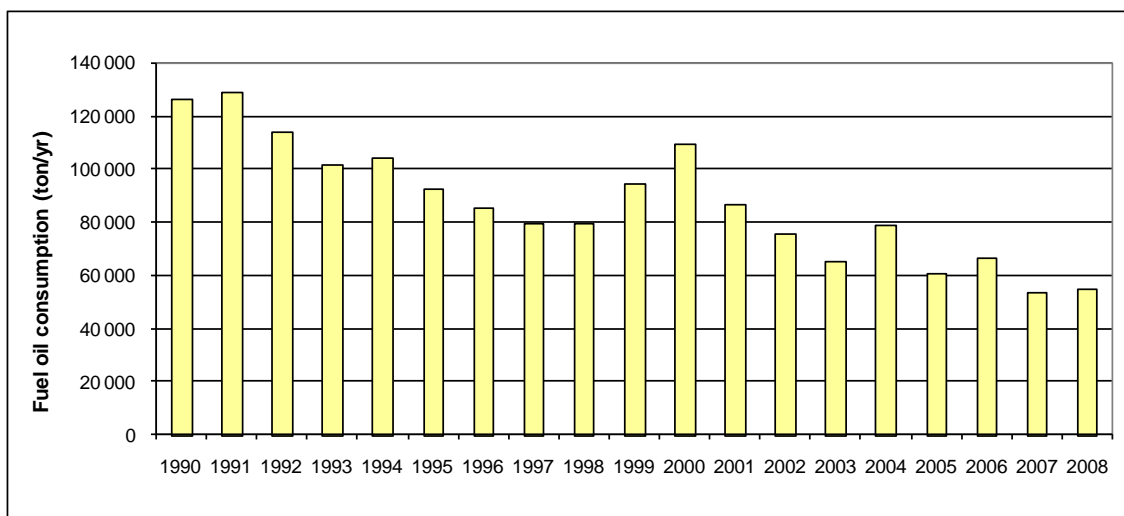
EF	Units	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries
		Gas-oil		Biodiesel		Fuel-oil	
LHV	MJ/kg	43.31		37.0		40.17	
SO _x	%	0.3		0.0		3	
NO _x	g/kg	67.5	87	67.5	87	67.5	87
NM VOC	g/kg	4.9					
CH ₄	g/kg	0.23					
CO	g/kg	21.3	1.9	21.3	1.9	21.3	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					

3.2.3.5.3.4 Activity Data

Total fuel consumption in fishing activities is also available from the energy balance in energy units (toe). Because information from DGEG does not separate energy consumption in ships and in inland static equipments, it was assumed that the totality of diesel oil, biodiesel, gas oil and fuel oil were used as energy sources for ships. All other fuel types (LPG, petrol and kerosene) were used in inland combustion activities. Consumption of gas oil in fishing bunkers is present in the next figure³⁴.

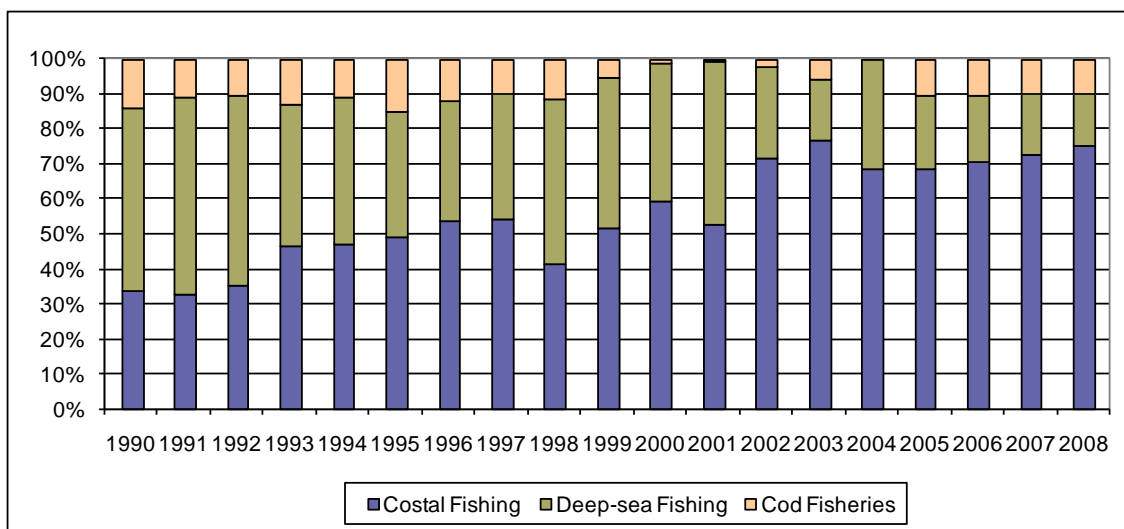
³⁴ Use of diesel oil and fuel oil is insignificant, allways less than 2.5% of gas oil consumption.

Figure 3.67 – Consumption of fuel oil in fishing bunkers (1990-2008)



Additional information in DGEG annual reports, available only until 2001, allow for the division³⁵ of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels³⁶. Percentage for each type of fisheries is presented in next figure.

Figure 3.68 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries (1990-2008)



3.2.3.5.3.5 Uncertainty Assessment

Concerning the uncertainty in fishing activity data the uncertainty was set as 5% in accordance to what was done for the other mobile sources.

³⁵ 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

³⁶ 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.

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% and 1000%.

3.2.4 Other Sectors (CRF 1.A.4.)

3.2.4.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in such activities as residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) sources. All emissions resulting from stationary combustion equipments: boilers, co-generation equipment, machines and static engines are included in sector 1A4. However, emissions estimates from fishery bunkers and off-road vehicles in agriculture and forestry, although included in source category 1A4, are discussed in chapter 3.2.A.5.

3.2.4.2 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:

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

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

where,

$U_{CO2(s,f)}$ - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

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

EF_C - 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).

3.2.4.3 *Activity data*

Data on fuel consumption were obtained from the annual energy balances compiled by DGEG and are presented in the following tables.

Table 3.110 - Fuels consumption in the residential sector (GJ) (1990-2008)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Residual Oil	L	203	63 530	62 097	55 535	51 459	66 691	42 565	43 312	40 271	10 915	3 880
Diesel/Gas Oil	L	204	158 214	210 819	285 505	205 027	190 282	200 936	132 606	91 896	105 979	144 221
Kerosene	L	206	793 373	753 052	626 060	530 505	513 747	355 816	415 879	728 302	761 508	705 271
Motor Gasoline	L	208	6 185	7 785	5 900	5 649	6 252	9 577	13 749	14 898	14 691	6 077
LPG	L	303	22 837 620	24 057 966	25 680 840	27 229 913	27 655 381	27 940 723	30 167 625	29 240 674	30 788 636	32 600 574
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
Natural Gas	G	301	0	0	0	0	0	0	0	31 980	361 961	1 360 508
Wood	B	111	53 770 921	51 344 184	49 611 501	48 513 399	48 000 716	48 033 473	48 172 943	48 326 360	47 907 950	47 280 335
Charcoal	B	112	749 950	738 791	727 632	716 473	705 314	694 155	682 996	671 837	660 678	649 519
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0
Fuel		NAPFUE	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Residual Oil	L	203	2 594	0	0	0	0	0	0	0	0	-
Diesel/Gas Oil	L	204	90 426	82 408	120 300	380 121	666 824	599 849	1 435 824	572 215	330 237	-
Kerosene	L	206	365 327	194 406	147 838	89 780	88 601	50 087	30 795	25 188	28 661	-
Motor Gasoline	L	208	772	93	24 848	36 159	37 346	57	84	0	0	-
LPG	L	303	33 436 221	30 740 137	30 729 805	29 733 968	29 234 481	28 536 176	26 357 931	24 747 505	22 084 767	-
City Gas	L	308	1 212 913	156 763	0	0	0	0	0	0	0	-
Natural Gas	G	301	2 883 241	4 450 418	5 568 369	6 640 771	6 880 762	7 581 594	7 688 057	8 354 918	8 733 026	-
Wood	B	111	47 071 130	47 280 335	47 280 335	48 127 150	48 477 991	48 727 878	48 577 950	48 577 950	48 577 950	-
Charcoal	B	112	638 360	627 201	616 042	604 883	593 724	582 565	571 406	560 247	549 088	-
Biodiesel	B	223	0	0	0	0	0	0	3 886	4 441	2 945	-

Figure 3.69 – Total Energy Consumption in fuels in the residential sector between 1990 and 2008

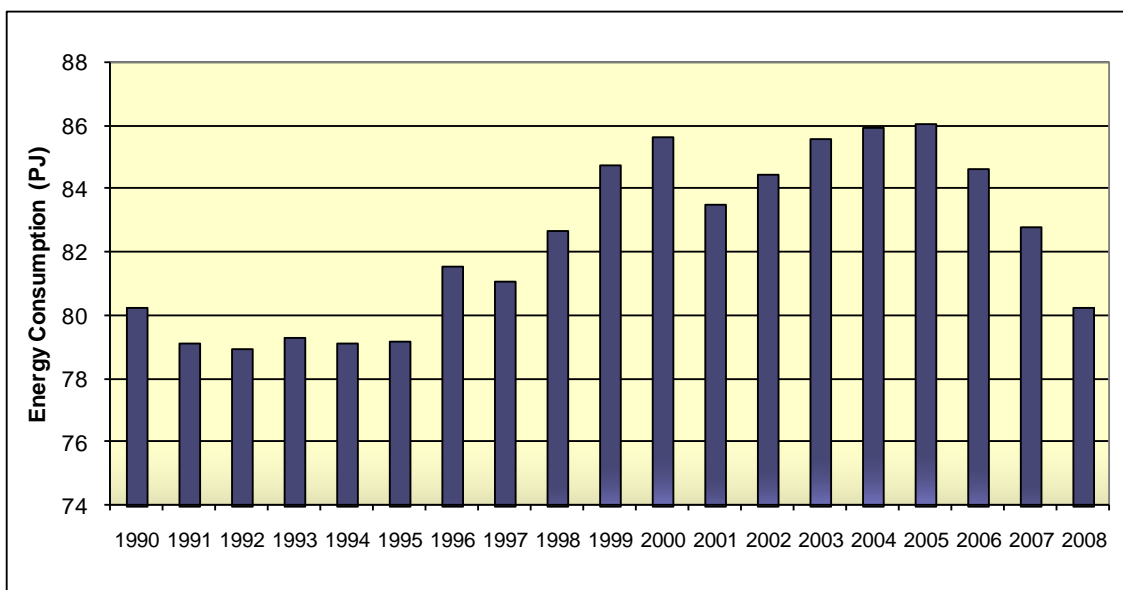


Figure 3.70 – Consumption of energy in fuels in the residential sector in 1990 and 2008

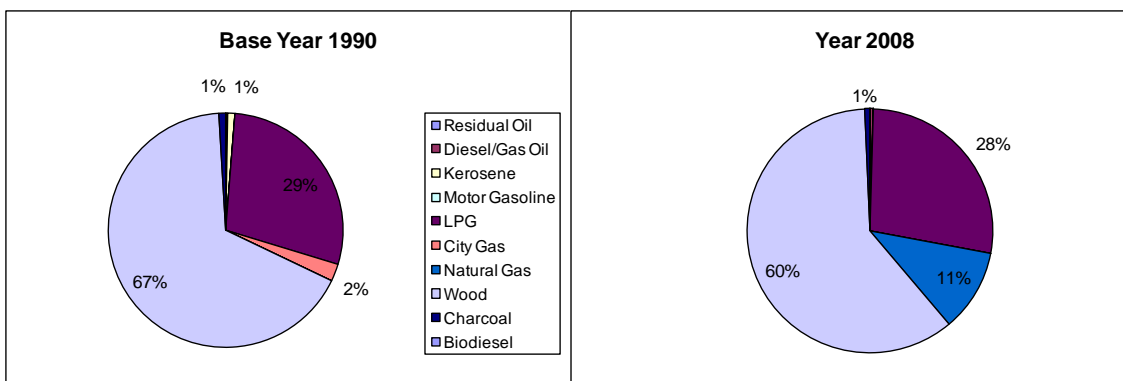


Table 3.111 - Fuels consumed in the commercial, services and institutional sector (GJ) (1990-2008)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Residual Oil	L	203	2 376 335	2 081 213	1 985 815	2 066 483	3 667 114	4 271 661	3 302 636	1 387 822	2 836 712	3 438 705
Diesel/Gas Oil	L	204	5 636 269	6 913 150	8 274 873	8 440 117	8 586 149	7 883 856	8 720 784	13 097 397	16 708 519	18 339 696
Kerosene	L	206	74 874	33 376	64 163	73 739	24 495	13 459	12 677	25 053	27 126	17 190
Motor Gasoline	L	208	579 235	638 264	617 276	604 690	1 035 873	1 174 153	1 418 403	2 592 133	3 260 397	3 216 908
LPG	L	303	1 166 321	1 337 385	1 538 519	1 847 562	1 821 391	1 234 531	2 494 179	3 734 954	3 904 492	4 121 761
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
Natural Gas	G	301	0	0	0	0	0	0	0	14 258	509 290	1 438 849
Biogas	B	309	0	0	0	0	0	0	0	0	0	49 772
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Residual Oil	L	203	3 312 313	3 447 019	3 532 016	2 905 392	3 150 365	3 180 779	3 538 745	3 558 285	2 178 410	-
Diesel/Gas Oil	L	204	18 379 823	21 943 150	24 179 733	29 752 522	33 040 833	33 332 904	18 890 472	19 471 611	12 442 700	-
Kerosene	L	206	6 133	7 568	9 489	7 340	7 211	6 330	8 201	4 561	1 255	-
Motor Gasoline	L	208	2 215 997	2 852 911	2 485 291	2 362 703	2 424 946	1 636 075	1 025 272	688 410	29 289	-
LPG	L	303	4 297 205	5 068 917	4 978 362	5 147 243	5 270 092	4 678 785	4 233 872	4 368 336	4 955 061	-
City Gas	L	308	732 238	69 195	0	0	0	0	0	0	0	-
Natural Gas	G	301	2 330 208	3 651 585	4 653 783	5 932 664	5 954 088	5 862 928	6 633 482	7 322 389	8 526 029	-
Biogas	B	309	101 885	54 356	60 473	48 419	100 729	135 455	128 462	107 992	173 204	-
Biodiesel	B	223	0	0	0	0	0	0	169 308	348 793	275 855	-

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).

Figure 3.71 – Total Energy Consumption in fuels in the commercial/services/institutional sector between 1990 and 2008

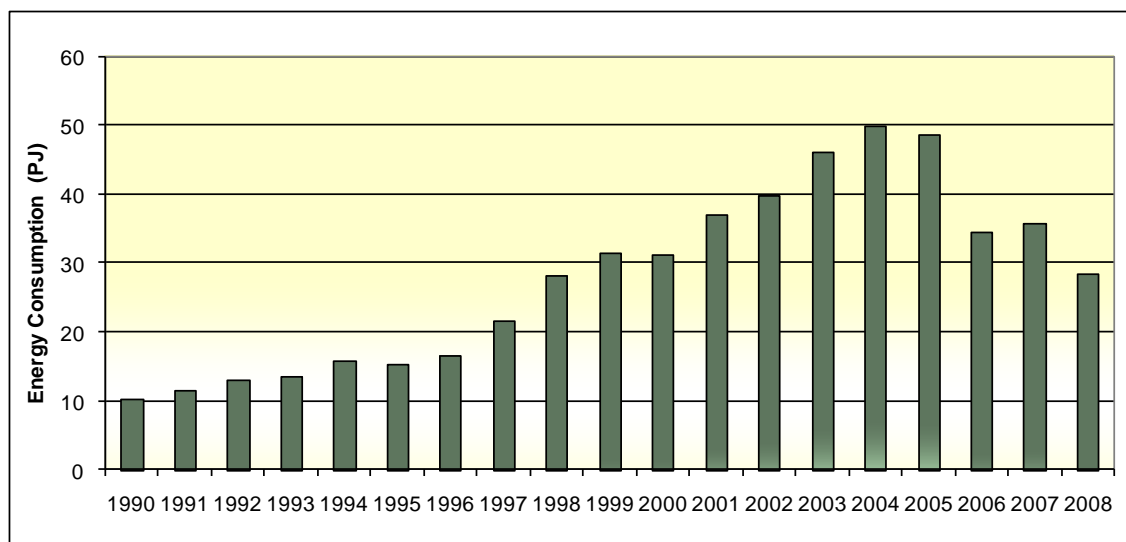


Figure 3.72 – Consumption of energy in fuels in the commercial/services/institutional sector in 1990 and 2008

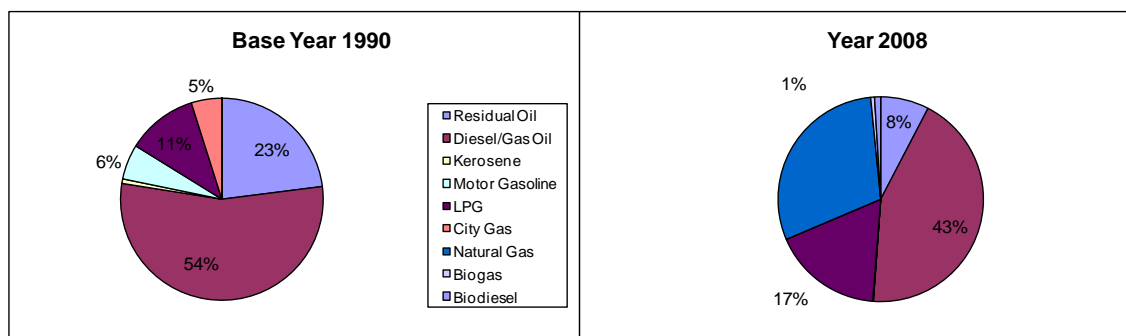


Table 3.112 - Fuels consumed in agriculture and forestry sector (GJ) (excluding mobile sources) (1990-2008)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Residual Oil	L	203	524 287	375 957	286 155	343 465	487 787	427 826	512 374	548 092	475 768	678 844
Kerosene	L	206	350 128	310 857	271 996	207 738	200 860	191 043	183 311	426 745	493 714	24 152
Motor Gasoline	L	208	33 627	35 658	47 375	44 906	134 673	129 562	162 538	197 454	174 300	159 631
LPG	L	303	329 646	405 169	478 657	575 533	580 437	572 079	826 427	559 823	713 407	674 208
Natural Gas	G	301	0	0	0	0	0	0	0	0	32	158
Biogas	B	309	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Residual Oil	L	203	891 798	802 636	1 210 609	1 086 402	758 390	870 746	611 164	300 167	279 749	-
Kerosene	L	206	44 370	47 054	50 254	47 209	48 886	54 548	56 402	32 176	38 912	-
Motor Gasoline	L	208	42 694	119 459	106 749	116 899	117 357	208 416	153 389	131 757	36 067	-
LPG	L	303	496 566	672 831	639 244	532 167	523 118	540 883	493 640	449 121	362 552	-
Natural Gas	G	301	4 423	192 700	257 274	276 779	266 981	258 053	156 364	191 796	381 361	-
Biogas	B	309	9 294	7 773	5 939	6 344	11 122	29 039	26 946	20 251	13 766	-

Figure 3.73 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources) between 1990 and 2008

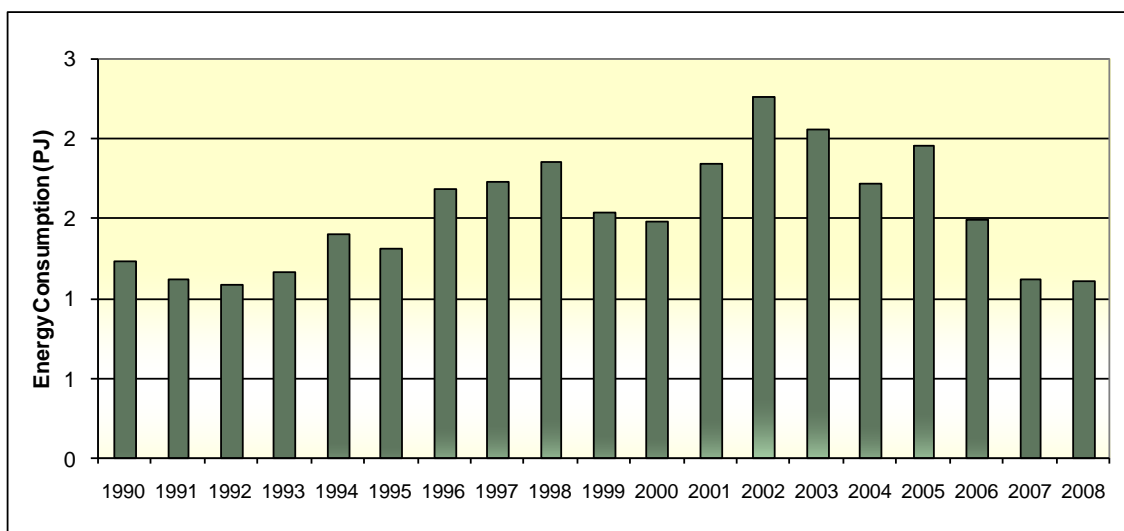


Figure 3.74 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2008

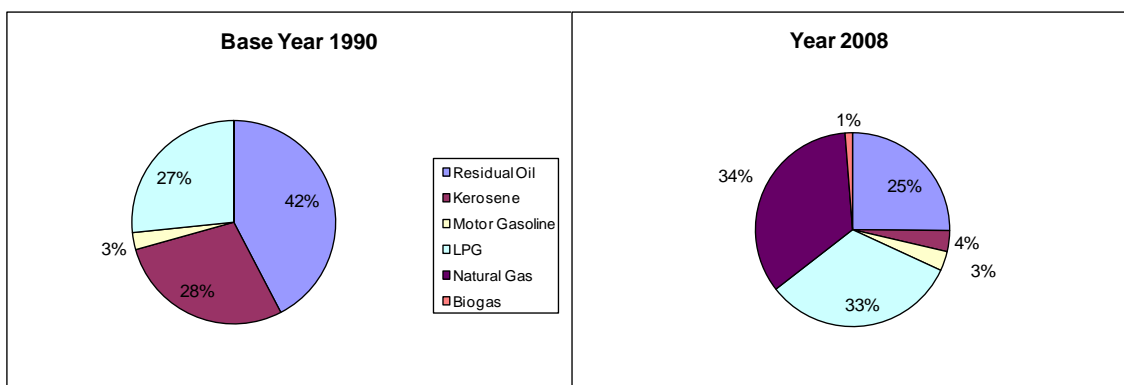


Table 3.113 - Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ) (1990-2008)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Residual Oil	L	203	4 002	5 397	7 454	9 101	5 353	11 778	4 994	8 782	6 225	49 567
Diesel/Gas Oil	L	204	6 346	460	1 018	17	1 003	16 980	1 595	150 903	539 112	0
Kerosene	L	206	7	0	7	7	0	0	0	0	2 651	74 915
Motor Gasoline	L	208	1 405	0	214	85	277	706	985	727	4 038	61 546
LPG	L	303	2 845	5 789	4 074	1 498	2 146	0	110	3 900	2 529	8 429
Natural Gas	G	301	0	0	0	0	0	0	0	0	0	0
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0
Fuel		NAPFUE	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Residual Oil	L	203	6 469	18 044	28 112	25 325	0	0	13 013	0	48 117	-
Diesel/Gas Oil	L	204	1 000 313	2 114 053	1 041 735	548 013	467 760	361 306	394 472	319 383	327 024	-
Kerosene	L	206	10 073	94	47	47	319	15	0	0	0	-
Motor Gasoline	L	208	278 979	286 123	280 695	278 521	260 737	29 899	31 799	26 109	5 565	-
LPG	L	303	20 796	32 627	21 126	20 695	91 236	5 899	5 983	2 301	5 774	-
Natural Gas	G	301	0	0	0	0	0	0	1 248	2 042	2 004	-
Biodiesel	B	223	0	0	0	0	0	0	5 328	8 490	8 372	-

Figure 3.75 – Total Energy Consumption in fuels in fisheries (excluding consumption in fishing vessels) between 1990 and 2008

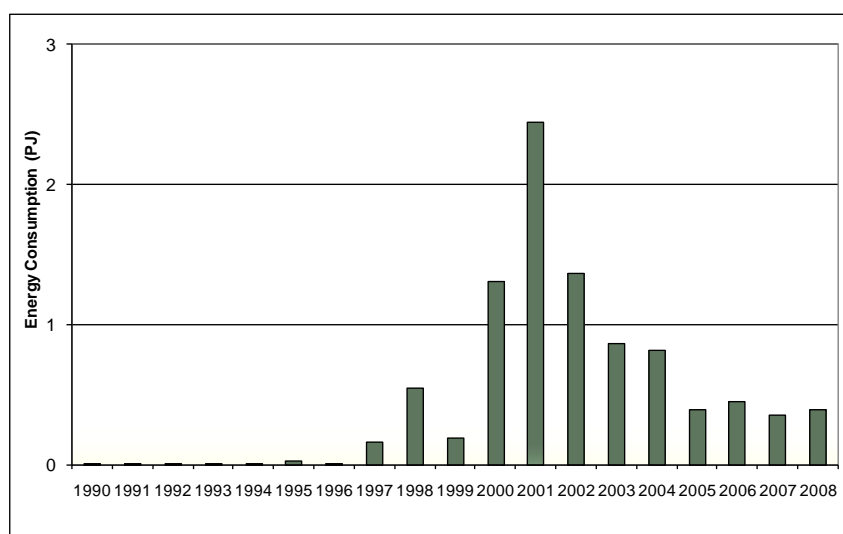
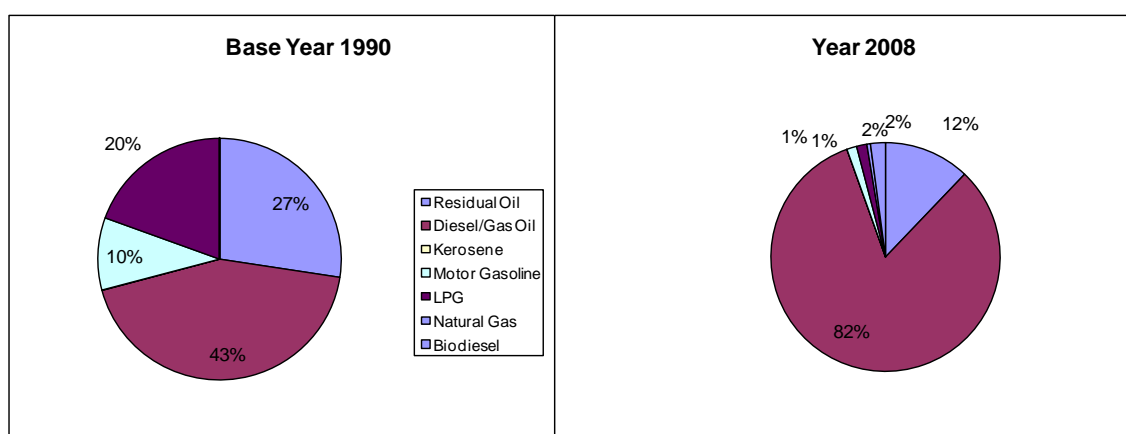


Figure 3.76 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2008



3.2.4.4 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 3.114– Emissions factors for the domestic sector: Low Heating Value (LHV)/Net Calorific Value (NCV) and Greenhouse gases

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	5.1	0.14
Diesel/Gas Oil	L	204	43.31	74.1	0.990	100	5.0	1.55
Kerosene	L	206	43.72	71.9	0.990	100	5.0	1.55
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
City Gas	L	308	15.69	60.0	0.995	100	1.5	1.4
Natural Gas	G	301	45.97	56.1	0.995	100	2.5	0
Wood	B	111	12.55	109.6	1.000	0	300	4.3
Charcoal	B	112	25.10	109.6	1.000	0	300	4.3
Biodiesel	B	223	37.00	73.8	1.000	0	5.0	1.55

Table 3.115 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Low Heating Value (LHV) and Greenhouse Gases

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
Diesel Oil	L	205	43.31	74.1	0.990	100	0.6	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
City Gas	L	308	15.69	60.0	0.995	100	1.5	1.4
Natural Gas	G	301	45.97	56.1	0.995	100	1.2	1.4
Biogas	B	309	34.70	52.0	1.000	0	0.72	1.4
Biodiesel	B	223	37.00	73.9	1.000	0	5.0	0.6

3.2.4.5 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%. 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%.

The uncertainty of CO₂ emission factors was assumed to be 5% 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% and an order of magnitude.

3.2.4.6 Category-specific QA/QC and verification

The comparison between DGEG's energy balance and IEA was also made for this source category. For the residential sector the differences between data sources are very small (0.1% for petroleum products and 0.4% for natural gas). The difference for Commercial and Public Services rises to 4.3% - DGEG values are higher for petroleum products and lower for natural

gas. For Agriculture, Forestry and Fishing the differences rises greatly for both fuel types. There are no apparent reasons for these differences, apart from what was explained in the QA/QC chapter for 1.A.2. Because of this in the next inventory submission (2011) we will contact DGEG for their expert judgment on this issue.

3.2.5 Other (Not Else-where specified) (CRF 1.A.5.)

3.2.6 Mobile (CRF 1.A.5.b)

These emissions comprehend which is classified in the energy balance as “Serviços” and is considered as used for military operations.

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 44.59 MJ/kg reported by the national energy authority.

Table 3.116 – Activity data.

Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Energy	TJ	1344	1504	1127	1065	1188	1149	1471	1413	1474	1127

Parameter	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008
Energy	TJ	1338	1338	939	749	570	1025	1 064	1 026	1 200

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 3.117 – 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

3.2.7 Fugitive Emissions From Fossil Fuels (CRF 1.B.)

3.2.7.1 Fugitive Emissions from Solid Fuels (CRF 1.B.1.)

3.2.7.1.1 Coal Mining and Handling

3.2.7.1.1.1 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). 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, as it is recognized in the GPG. 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.

3.2.7.1.1.2 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:

$$Emi_{CO_2} = 44 / 16 * Emi_{CH_4}$$

3.2.7.1.1.3 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).

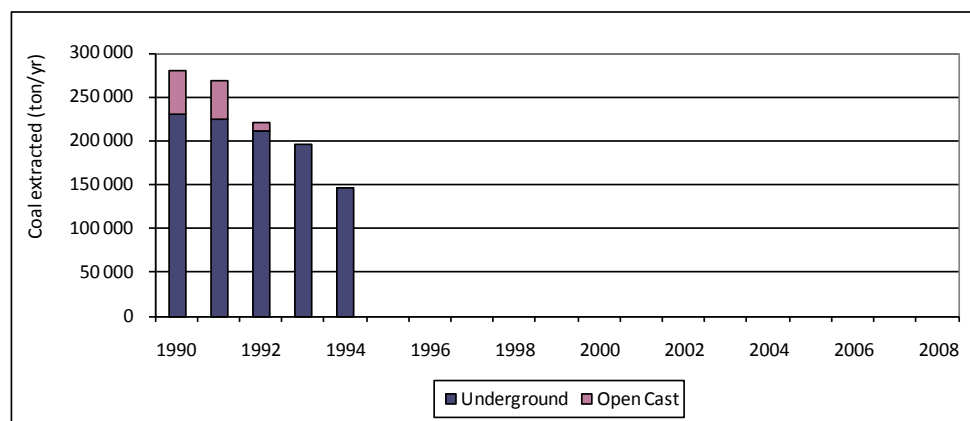
Table 3.118– Emission Factors for coal extraction and processing

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

3.2.7.1.1.4 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 3.77 – Quantities of coal extracted from mines in Portugal (1990-2008)



3.2.7.1.1.5 Uncertainty Assessment

A value of 5% 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% for underground mines and 200% 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.

3.2.7.1.1.6 Recalculations

No recalculations of emissions were made on this source sector.

3.2.7.1.1.7 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.

3.2.7.2 Fugitive Emissions from Oil Production and Refining (CRF 1.B.2.a.)

3.2.7.2.1 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.

3.2.7.2.2 Transport of Crude/ Marine Terminals

3.2.7.2.2.1 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 where 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.

3.2.7.2.2.2 Methodology

Emissions of CH₄ and NMVOC where 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:

$$Emi_{CO2U} = 44/12 * (Emi_{NMVOC} * 0.85 + Emi_{CH4} * 12/16)$$

3.2.7.2.2.3 Emission Factors

Table 3.119– Total Organic Emission Factors for Marine Vessel Loading Operations

Loading Operations	Gasoline (mg/L)	Crude ³⁷ (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:

$$EF_{LL} = 12.46 \times \frac{F_s \times P_v \times M_v}{T} \times \left(1 - \frac{eff}{100}\right)$$

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”.

³⁷ 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.

CH₄ emission factor (60 g/ton of Crude) is obtained from EMEP/Corinair.

3.2.7.2.2.4 Activity data

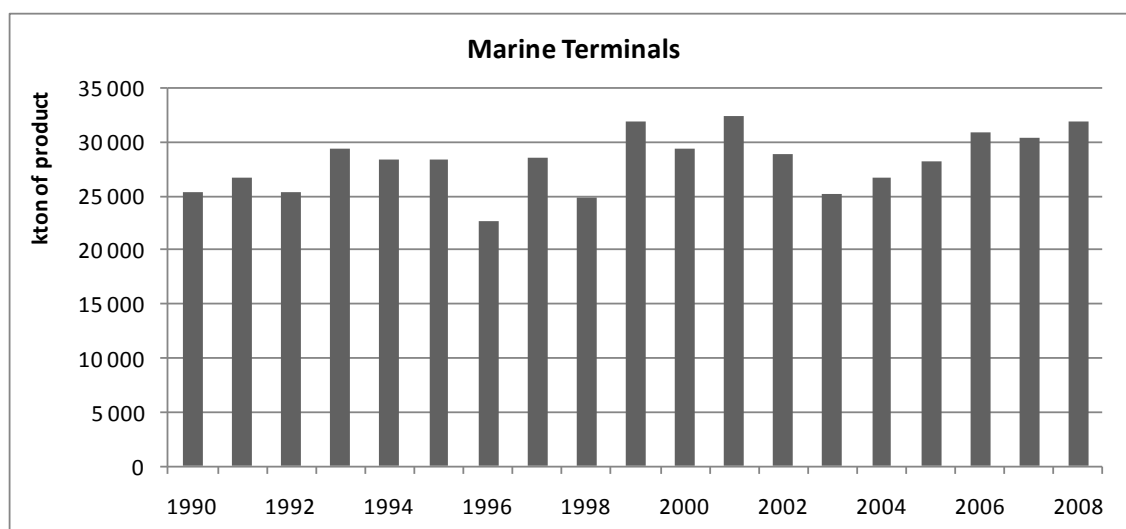
Data was obtained for year 2005, from:

- 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 2006-2008 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 3.78 – Total amounts of loaded and unloaded crude and fuels in Marine Terminals (kton)



3.2.7.2.2.5 Uncertainty Assessment

An uncertainty value (3%) 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%, 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%, 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.

3.2.7.2.2.6 Recalculations

More detailed activity data was obtained from Port Authorities and Depots Companies.

3.2.7.2.3 Refining and Storage

3.2.7.2.3.1 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 hydrosulfurization, 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).

NMVOC and methane emissions may also result from “normal” leaks³⁸ 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 NMVOC emissions resulting from non-condensable

³⁸ Sometimes only these emissions are referred as fugitive emissions from refineries.

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.

3.2.7.2.3.2 Methodology

3.2.7.2.3.2.1 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 2008. This detailed information lead to the establishing of plant specific emission factors, and its evolution, for NMVOC losses from crude oil and oil products storage. Annual emissions of NMVOC (ton/yr) for the remaining time series are 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 activity³⁹.

$$\text{Emission}_{\text{NMVOC}} = \text{EF}_{(y)} * \text{Throughput} * 10^{-6}$$

3.2.7.2.3.2.2 Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations were 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.

3.2.7.2.3.2.3 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:

$$U_{\text{CO}_2} = 44/12 * (0.85 * \text{NMVOC} + 12/16 * \text{CH}_4 + 12/28 * \text{CO}) * 10^{-3}$$

³⁹ This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

3.2.7.2.3.3 Emission Factors

3.2.7.2.3.3.1 Storage/ Tanks

For the period 2002-2008, 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 DGEG'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).

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 seals⁴⁰.

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.

⁴⁰ This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

Table 3.120 – Type of tanks classes distinguished in TANKS4.0 model and percentage of tanks per tank type in Oporto and Sines refineries in 2005 (%).

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:

Table 3.121 – 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 throughput⁴¹ in each refinery, are presented in next table. After 2005 the emission factors were forecasted.

⁴¹ Crude oil input added to input of other materials.

Table 3.122 – 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

3.2.7.2.3.3.2 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 3.123 – 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

3.2.7.2.3.3.3 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% 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.

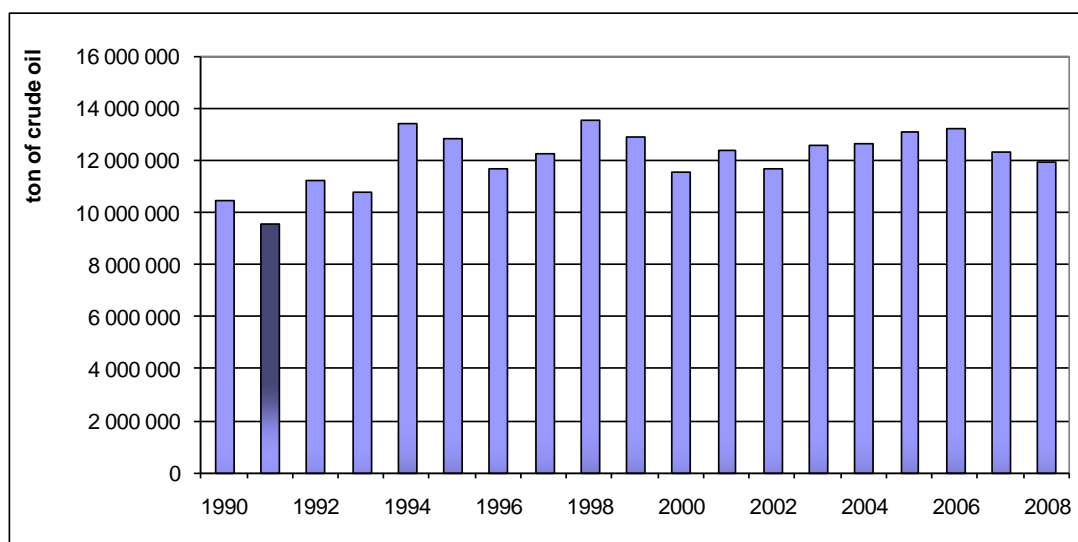
Table 3.124 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Parameter	Emission Factor kg/ton coke
UCO ₂	3 373

3.2.7.2.3.4 Activity data

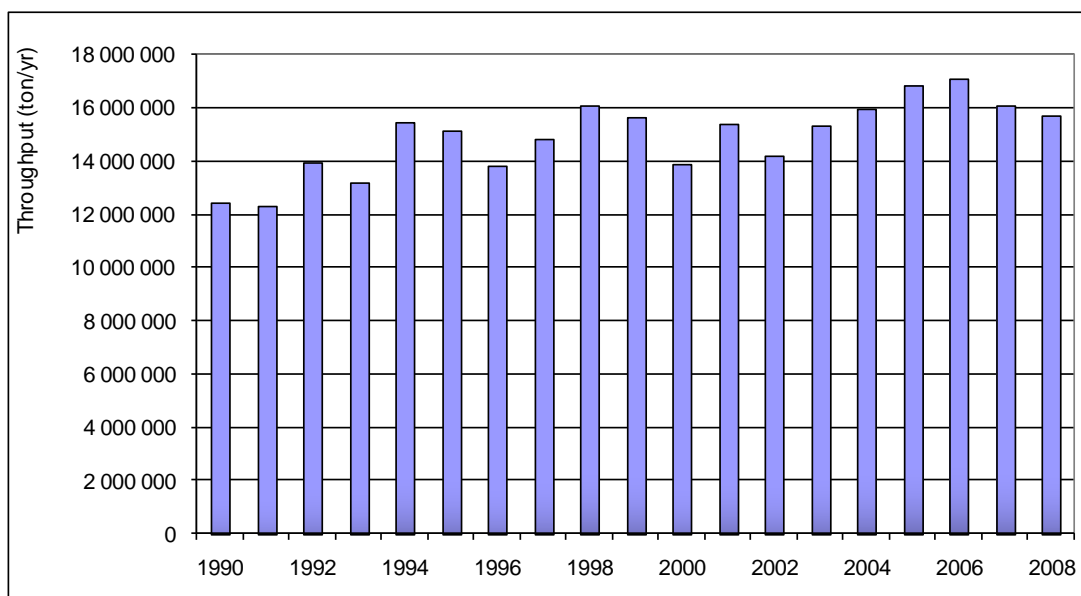
The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed(see next figure).

Figure 3.79 – 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 3.80 – Total throughput entered in Lisbon, Oporto and Sines refineries: 1990-2008



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 1990-2008 period. Total coke burning was obtained from the industrial units and it is considered confidential data.

3.2.7.2.3.5 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% may be assumed for this sub-source in a similar mode to other LPS combustion data.

Uncertainty of emission factors for NMVOC⁴² were set as 50%, 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%)

3.2.7.2.3.6 Recalculations

No modifications were made to this source sector.

3.2.7.2.3.7 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.

3.2.7.2.4 Distribution of Oil Products

3.2.7.2.4.1 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.

⁴² The uncertainty of NMVOC was considered to be the uncertainty of CO₂ emission factor.

3.2.7.2.4.2 Methodology

Ultimate carbon dioxide emissions, are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO_2} = 0.85 * Emi_{NMVOC}$$

3.2.7.2.4.2.1 Filling Underground Tanks (Stage I)

From “Portaria 646/97” it is assumed that since 1997 it is used “balanced submerged filling” with vapour recovering for latter recovering (VRU) or destruction (VDU). Before 1997 it is not known the type of filling used and it is assumed an equitative distribution on the three different categories (splash filling, submerged filling, balanced submerged filling).

Before 1997 emissions estimates are based on:

$$E_{FUT} = V_{splash} \times EF_{splash} + V_{subm} \times EF_{subm} + V_{balanc} \times EF_{balanc}$$

Where,

E_{FUT} - Emissions Filling Underground Tank (Stage I) - (mg)

V_{splash} - Total Volume of fuel using Splash Filling (l)

EF_{splash} - Splash Filling Emission Factor (=1380 mg/l)

V_{subm} - Total Volume of fuel using Submerged Filling (l)

EF_{subm} - Submerged Filling Emission Factor (=880 mg/l)

V_{balanc} - Total Volume of fuel using Balanced Submerged Filling (l)

EF_{balanc} - Balanced Submerged Emission Factor (=40 mg/l)

After 1997, the emissions estimates are based on:

$$E_{FUT} = V_{balanc} \times EF_{balanc}$$

Where,

E_{FUT} - Emissions Filling Underground Tank (Stage I) – (mg)

V_{balanc} - Total Volume of fuel using Balanced Submerged Filling (l)

EF_{balanc} - Balanced Submerged Emission Factor (=40 mg/l)

3.2.7.2.4.3 Emission Factors

3.2.7.2.4.3.1 Filling Underground Tanks (Stage I)

Emission factors were obtained from USEPA AP-42 (table 5.2-7 of Chapter 5.2).

Table 3.125 – Filling Underground Tank (Stage I) NMVOC Emission Factors

Filling Underground Tank (Stage I)	Emission Factor (mg/L)
Splash Filling	1380
Submerged Filling	880
Balanced Submerged Filling	40

3.2.7.2.4.3.2 Underground Tank Breathing and Emptying

The NMVOC emission factor source is USEPA AP42 (table 5.2-7 from chapter 5.2).

3.2.7.2.4.3.3 Vehicle Refuelling Operations (Stage II)

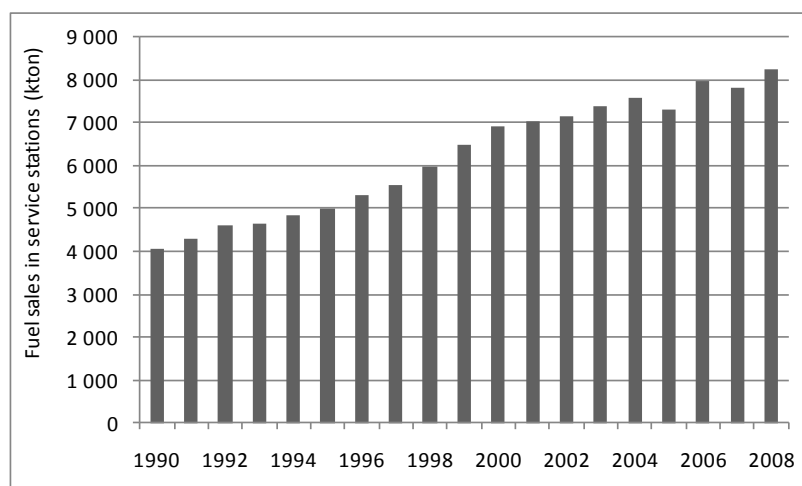
Table 3.126 – Vehicle Refuelling Operations (Stage II) NMVOC Emission Factors

Vehicle Refuelling Operations (Stage II)	Emission Factor (mg/L)
Spillage	80
Displacement Losses (without control measures)	1320
Displacement Losses (with control measures)	132

3.2.7.2.4.4 Activity data

Data on gasoline, diesel and other fuels sales by district is available from DGEG “Informação Energia” publications.

Figure 3.81 – Fuel Sales in Service Stations (ton)



3.2.7.2.4.5 Recalculations

A more detailed methodology was developed using the emission factors described above.

3.2.7.2.4.6 Further Improvements

Efforts should be addressed in order to obtain more detailed information on measures taken before 1997.

3.2.7.2.5 Venting and Flaring in Oil Industry

3.2.7.2.5.1 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.

3.2.7.2.5.2 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).

3.2.7.2.5.3 Emission Factors

Emission factors for all pollutants were set from US-EPA (1991).

Feed density was assumed as of 0.85 kg/l.

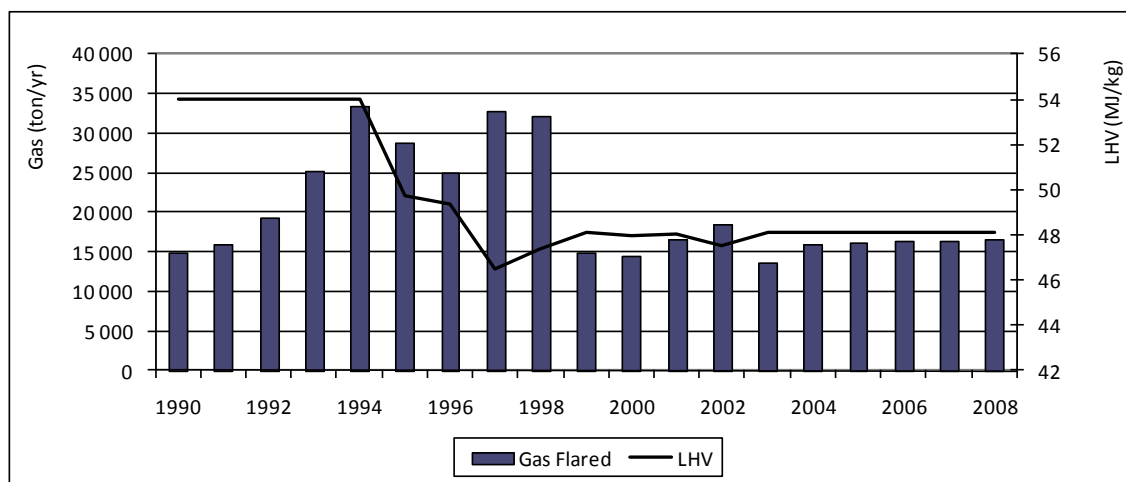
Table 3.127 – Emission Factors for flaring in refineries

Pollutant	EF (g/GJ)
CO ₂ (kg/GJ)	60
NMVOC	12
CH ₄	15

3.2.7.2.5.4 Activity data

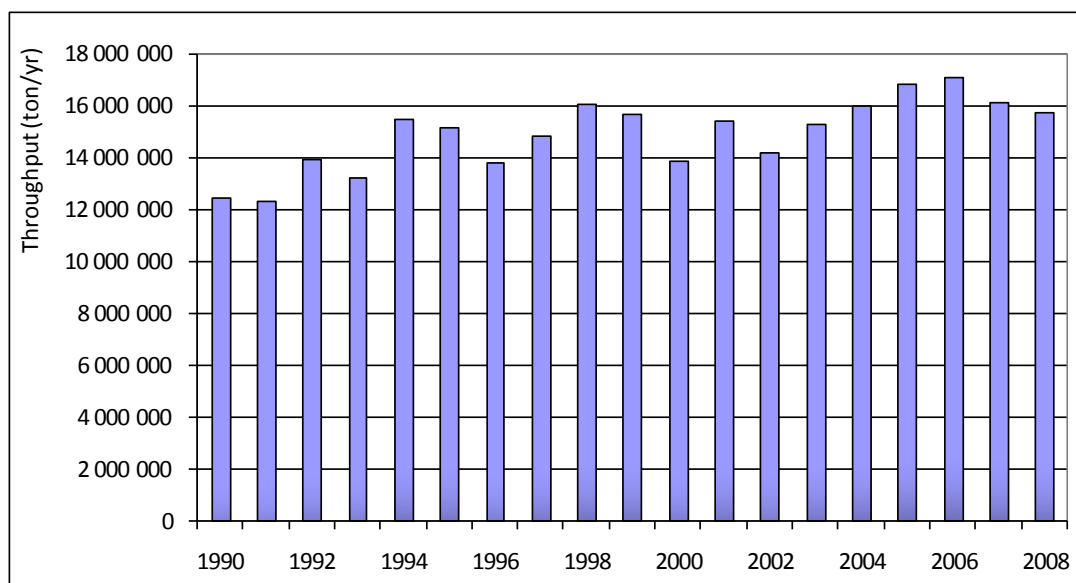
Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL and it is presented in the next figure.

Figure 3.82 – Total consumption of flare gas in Portuguese refineries and Low Heating Value: (1990-2008)



Total throughput (feed) entered in refinery units is available from annual energy publications of (DGEG), and is again presented in the next figure.

Figure 3.83– Total throughput entered in Lisbon, Oporto and Sines refineries (1990-2008)



3.2.7.2.5.5 Uncertainty Assessment

The uncertainty in activity data was considered to be 5%, 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% and the double of that value for methane emissions.

3.2.7.2.5.6 Recalculations

No recalculations were done for this emission source.

3.2.7.3 Fugitive Emissions from Natural Gas (CRF 1.B.2.b.)

3.2.7.3.1 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 centers;
- 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.

3.2.7.3.2 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:

$$\begin{aligned} Emi_{CH_4} &= Pipeline_{Lenght} * EF_{CH_4} \\ Emi_{CO_2direct} &= Pipeline_{Lenght} * EF_{CO_2direct} \\ Emi_{CO_2} &= Emi_{CH_4} * 44/16 + Emi_{CO_2direct} \end{aligned}$$

Where,

Emi_{CH_4} – Emissions of CH₄ from losses of natural gas during transmission, t/yr;

$Emi_{CO_2direct}$ – Direct emissions of CO₂ from leakages, t/yr;

Emi_{CO_2} – Total emissions of CO_2 , including conversion of carbon in methane and other gases in atmosphere, t/yr;

EF_{CH_4} , $EF_{CO_2direct}$ – 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 processes⁴³ as activity data:

$$\begin{aligned} Emi_{CH_4} &= Import_{NG} * EF_{CH_4} / 100 \\ Emi_{CO_2direct} &= Import_{NG} * EF_{CO_2direct} \\ Emi_{CO_2} &= Emi_{CH_4} * 44/16 + Emi_{CO_2direct} \end{aligned}$$

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}):

$$Emi_{DIST} = Emi_{TOTAL} - Emi_{TRANS} - Emi_{GAS}$$

3.2.7.3.3 Emission Factors

The emission factors are based on the IPCC Good Practice (IPCC, 2000), and are reported in Table 3.128.

Table 3.128 – 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 CO_2/CH_4 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% of the natural gas consumed in the distributive systems.

3.2.7.3.4 Activity data

According to the above explained methodology, activity data comprehends:

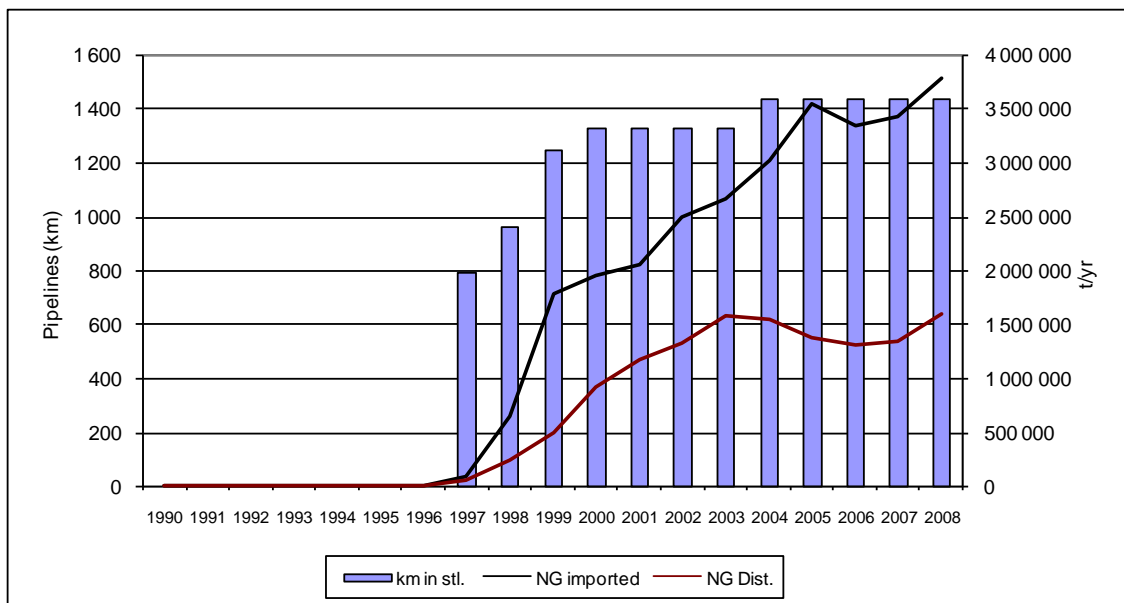
- extension of pipelines for transmission. Total extension of pipelines in kilometers was estimated from the date at which each major pipeline start operation, and its extension. These data was received via DGE from TRANSGAS;

⁴³ Equals imports in Portugal

- 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.

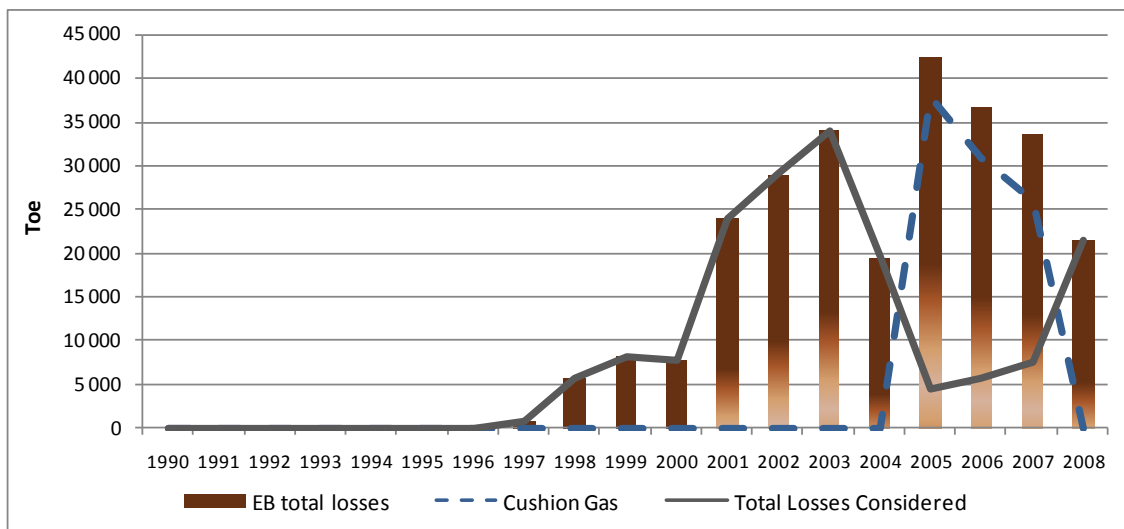
Figure 3.84 – Activity data used to estimate GHG emissions from Natural gas transmission, distribution and transformation (1990-2008)



New data was obtained from DGEG 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, DGEG 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).

Figure 3.85 – Natural gas losses reported in the energy balance compared with the consumption of cushion gas (1990-2008)



After contacting DGEG, 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 a decrease in natural gas consumption in residential and services sectors. Improvements in pipeline quality and other general gains in efficiency also contributed to this natural gas loss decrease;

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.

Emissions from compressor station are included in this source category because they are reported together with losses from other sources in DGEG's energy balance in transmission and distribution category.

3.2.7.3.5 Uncertainty Analysis

The uncertainty in activity data was considered to be 5%, 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%, and the same value was considered for CO₂ emissions which were determined simply from simple conversion of emissions in methane form.

3.2.7.3.6 Category-specific QA/QC and verification

Following an issue raised during the 2009 UNFCCC Centralized Review this source category undergone complete QA/QC scrutiny. All activity data and EF were checked for inconsistencies. An apparent discrepancy exists in the activity data for this source category. DGEG (focal point) provided a clear explanation about the time series behavior, which was included in this report.

Also under QA/QC a comparison between DGEG data and IEA was made. For natural gas losses the differences between both data sources correspond to 2%.

3.2.7.3.7 Recalculations

Changes in this source category result from the inclusion of Cushion Gas and the activity data revision from energy balance 2007.

3.2.7.3.8 Further Improvements

Efforts are being done with DGEG⁴⁴ and the major Portuguese company responsible for gross transport of natural gas⁴⁵, in order to increase the tier level of the methodology. Results and changes in estimates are expected in the coming years.

3.2.7.4 Other Fugitive Emissions (Geothermal Electricity Production) (CRF 1.B.2.d.)

3.2.7.4.1 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).

3.2.7.4.2 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. In the 2010 inventory new data concerning electricity production was received from the Azores environmental entity (time series 2003-2008).

3.2.7.4.3 Emission factors

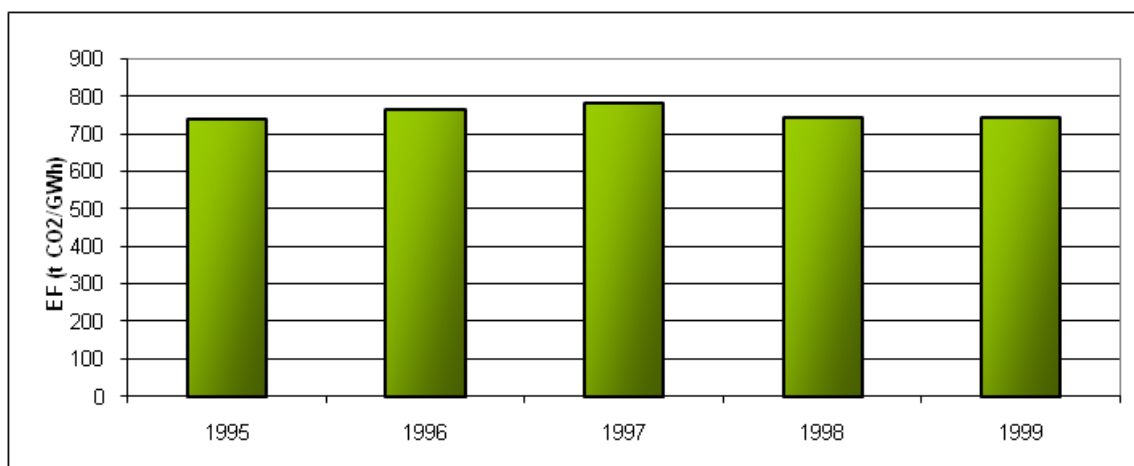
Measurements of carbon dioxide emissions are available from one plant (*Pico Vermelho*) from 1994 till 1999 and provided by the regional authority of the Autonomous Region of Azores⁴⁶. These results were used to estimate an average emission factor applied to the whole period.

⁴⁴ Direcção Geral de Energia e Geologia/ General Directorate of Energy and Geology

⁴⁵ TRANSGAS

⁴⁶ Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia.

Figure 3.86 – Emission Factor of CO₂ emissions calculated for Ribeira Grande Power Plant (1995-1999)

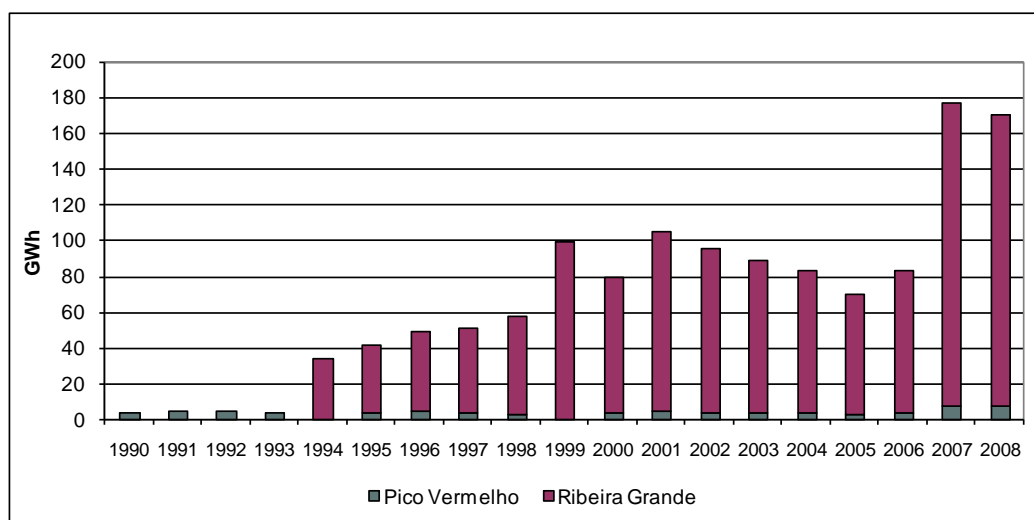


For the other power plant, Pico Vermelho, the regional authority provides estimates that indicate a common emission factor of 500 ton CO₂/GWh.

3.2.7.4.4 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 2003-2008. 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 3.87 – Total Geothermal Production in Azores (1990-2008)



Geothermal production in 2008 more than doubles the 2006 value.

3.2.7.4.5 Uncertainty Analysis

The uncertainty of the activity data is 10% considering that the statistical information is reliable but some extrapolations have to be performed, 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.

3.2.7.4.6 Recalculations

New data from Azores regional authority for 2003-2008 allowed for a revision in the electricity production time series.

3.2.7.4.7 Further Improvements

Efforts will be made with Azores Regional Authority of Economy to obtain revised carbon dioxide released to atmosphere from geothermic units.

3.3 Recalculations

Changes between submissions were not very significant for CO₂. For CH₄ and N₂O the differences between submissions, in CO₂e, were more significant mainly for the transport sector.

Figure 3.88 – Differences between 2009 and 2010 submissions (CO₂, CH₄ and N₂O)

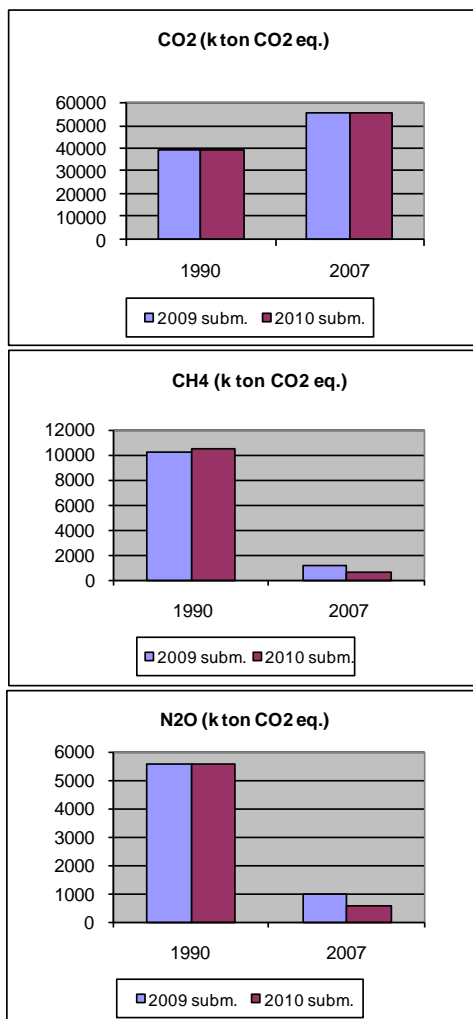


Table 3.129 – Recalculations (differences between 2009 to 2010 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2			CH4			N2O		
	2009 subm.	2010 subm.	Differenc e(1)	2009 subm.	2010 subm.	Differenc e(1)	2009 subm.	2010 subm.	Differenc e(1)
	CO2 equivalent (Gg)	CO2 equivalent (Gg)	(%)	CO2 equivalent (Gg)	CO2 equivalent (Gg)	(%)	CO2 equivalent (Gg)	CO2 equivalent (Gg)	(%)
1990									
1. Energy	39 318.33	39 311.06	-0.02	10 257.43	10 599.13	3.33	5 605.41	5 582.95	-0.40
1.A. Fuel Combustion Activities	39 154.47	39 147.20	-0.02	581.65	608.12	4.55	522.14	463.46	-11.24
1.A.1. Energy Industries	15 944.40	15 944.40	0.00	464.43	490.90	5.70	522.14	463.46	-11.24
1.A.2. Manufacturing Industries and Construction	9 162.02	9 157.32	-0.05	4.33	4.33	0.00	61.04	61.04	0.00
1.A.3. Transport	9 919.64	9 917.07	-0.03	38.03	38.03	0.00	67.21	67.21	0.00
1.A.4. Other Sectors	4 025.13	4 025.13	0.00	73.60	100.07	35.96	156.12	97.44	-37.59
1.A.5. Other	103.28	103.28	0.00	348.30	348.30	0.00	236.92	236.92	0.00
1.B. Fugitive Emissions from Fuels	163.86	163.86	0.00	0.17	0.17	0.00	0.85	0.85	0.00
1.B.1. Solid fuel	8.65	8.65	0.00	117.22	117.22	0.00	NE,NO	NE,NO	
1.B.2. Oil and Natural Gas	155.22	155.22	0.00	66.02	66.02	0.00	NO	NO	
2007									
1. Energy	55 452.22	55 712.91	0.47	1 137.21	636.50	-44.03	993.03	604.37	-39.14
1.A. Fuel Combustion Activities	54 563.77	54 906.81	0.63	435.41	429.37	-1.39	993.03	604.37	-39.14
1.A.1. Energy Industries	19 776.99	19 658.93	-0.60	7.67	7.59	-0.99	129.43	129.10	-0.26
1.A.2. Manufacturing Industries and Construction	10 695.39	10 604.76	-0.85	62.04	60.38	-2.69	102.74	104.21	1.43
1.A.3. Transport	18 838.92	19 296.20	2.43	50.82	46.42	-8.65	610.37	216.13	-64.59
1.A.4. Other Sectors	5 179.85	5 274.30	1.82	314.87	314.97	0.03	149.85	154.29	2.96
1.A.5. Other	72.62	72.62	0.00	0.01	0.01	0.00	0.64	0.64	0.00
1.B. Fugitive Emissions from Fuels	888.46	806.10	-9.27	701.80	207.13	-70.49	NE,NO	NE,NO	
1.B.1. Solid fuel	IE,NO	IE,NO		IE,NO	IE,NO		NO	NO	
1.B.2. Oil and Natural Gas	888.46	806.10	-9.27	701.80	207.13	-70.49	NE,NO	NE,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.

The main recalculations that are affecting this comparison are:

- Revision of the 2007 energy balance by DGEG;
- Fuel consumption update for Tunes power plant (EU-ETS 2006-2007);
- Fuel consumption data revision for energy plants in the autonomous regions (2001-2007);
- Inclusion of new fuels in the Cement Industry (2004-2007);
- Revision of the fraction of biomass for several fuel types, classified as other fuels in the Cement Industry, as a result from streamline procedures with EU-ETS;
- Revision of diesel oil consumption data (only for 2006), used in the estimation of biodiesel incorporation;
- Revision of LHV and fuel consumption values for several combustion equipments in Pulp and Paper Industrial sector;
- Revision of the fuel consumption and LHV values for non combustible gases from Pulp and Paper industry (1991-2007);
- Production data update for the Ceramic Industry (IATI update 2001-2007);
- Correction of the CO₂ emission factor for hardcoal, coke and fueloil in the railways sector;
- Inclusion of Cushion Gas in CH₄ estimations for losses in transport and distribution of Natural Gas (2005-2007);
- Revision of the electricity production associated with geothermal plants from Azores Islands (2003-2007);

- Differences in the road transportation sector refer to the application of COPERT IV and revision of the carbon content used to estimate CO₂ emissions. CO₂ emissions were calculated on an energy basis using country specific emissions factors expressed in kgCO₂/GJ. These emissions factors are provided by fuel type and are published in national legislation (Despacho nº 17313/2008); Activity data was also updated with information from vehicle inspection centres;
- N₂O emissions from road transportation sector were recalculated by using COPERT IV emission factors. Emissions have decreased since N₂O emissions factor from COPERT IV are lower than the emission factors from COPERT III.

3.4 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 intervenients 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;

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"⁴⁷ 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).

⁴⁷ 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.

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.

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 (toe⁴⁸), 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 3.130.

⁴⁸ Ton of oil equivalent

Table 3.130 – 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 3.131.

Table 3.131 – 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

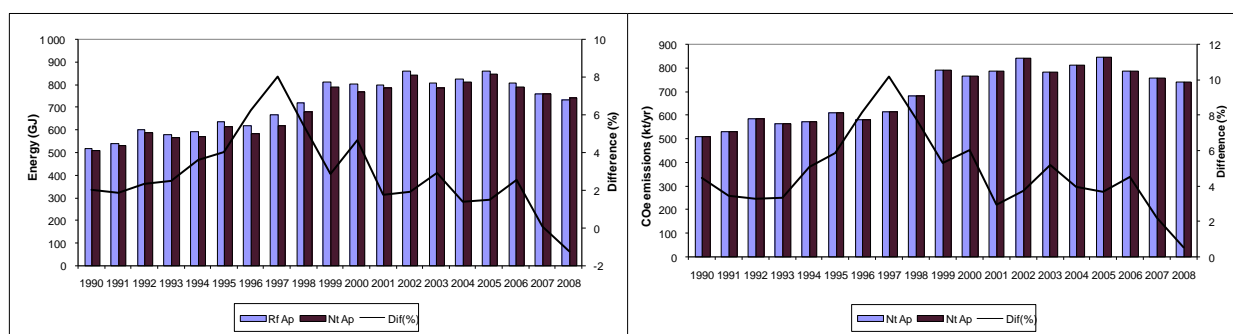
Estimated simply from:

$$\text{CO}_2 \text{ Emission} = 44/12 * (\text{Carbon Content} - \text{Carbon Stored}) * \text{Oxidation Factor}$$

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 3.89.

Figure 3.89 – Comparison of Energy Consumption and CO₂ emissions between the National approach and the Reference Approach (1990-2008)



Differences are mostly explained by:

- 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 classifies fuel sales to aviation and maritime in domestic and international according to the flag of the air-ship and vessel. This disaggregation does not follow the IPCC guidelines, and causes the majority of differences between both approaches.

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. This positive situation is less visible when comparing energy data.

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 production⁴⁹. 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 Report⁵⁰.

In terms of total GHG, emissions from the industrial production sector have increased from about 4.61 Mton CO₂e in 1990 to 6.9 Mton CO₂e in 2008, as may be seen from the figure below, i.e. emissions estimated for 2008 are about 50.2% higher than the emissions estimated for 1990⁵¹. The majority of emissions, expressed in CO₂e, are associated with mineral industry, responsible for 73.4% of total emissions from this sector in 1990, and 66.8% of total emissions from this sector in 2008, as may be seen in Figure 4.2. In second place of importance are the emissions from the chemical industry, which have decreased from 26.2% of emissions from this sector in 1990 toward 17.8% of emissions in 2008. The remaining sub-source sectors (2C, 2D and 2F⁵²) have a lower importance in the beginning years, but they became more relevant toward the end of the period, when they amount to 15.4% of emissions. This increase occurs mostly because of sub-category 2F, consumption of Halocarbons and SF₆, which represents in 2008 about 15.2% of total GHG emissions from this source sector, and shows a fast grow over years.

⁴⁹ 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.

⁵⁰ 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>.

⁵¹ Base year for F-gases is however 1995.

⁵² 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 (1990-2008)

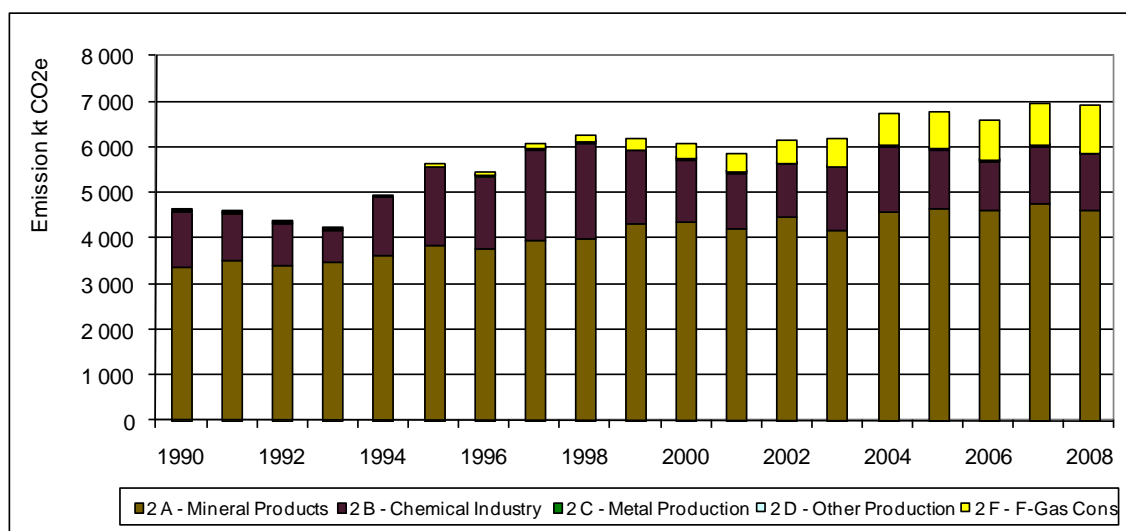
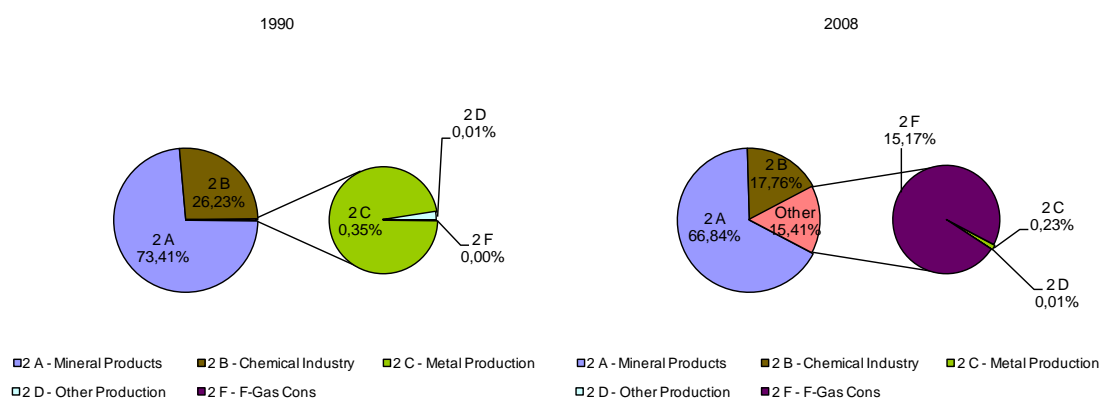
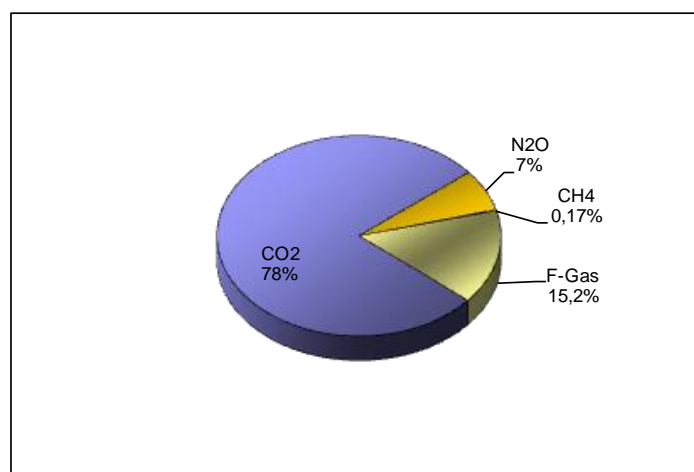


Figure 4.2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2008



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 2008. 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 2008



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 for the period 2001-2008.

Figure 4.4 - Differences between 2009 and 2010 submissions for CO₂, CH₄ and N₂O emissions

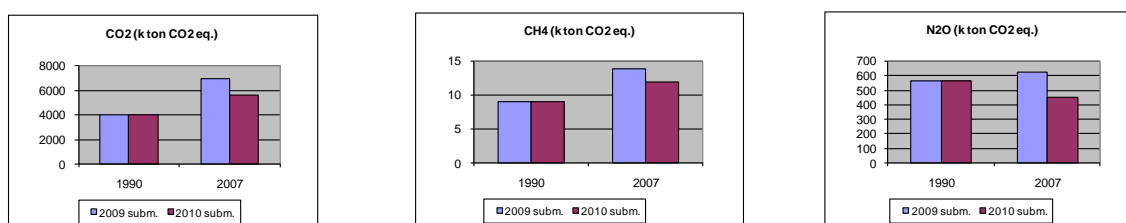


Table 4.1 - Recalculations (differences between 2009 and 2010 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES				CO ₂			CH ₄			N ₂ O		
				2009 subm.	2010 subm.	Difference (1)	2009 subm.	2010 subm.	Difference (1)	2009 subm.	2010 subm.	Difference (1)
				CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)		
1990												
2. Industrial Processes				4 035.28	4 035.28	0.00	9.08	9.08	0.00	566.68	566.68	0.00
2.A.	Mineral Products			3 384.40	3 384.40	0.00	0.76	0.76	0.00	NO	NO	
2.B.	Chemical Industry			634.38	634.38	0.00	8.32	8.32	0.00	566.68	566.68	0.00
2.C.	Metal Production			16.06	16.06	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	
2007												
2. Industrial Processes				6 993.54	5 575.39	-20.28	13.90	11.97	-13.87	626.96	450.57	-28.13
2.A.	Mineral Products			4 845.27	4 751.31	-1.94	1.86	1.80	-3.33	NO	NO	
2.B.	Chemical Industry			2 132.12	807.93	-62.11	12.04	10.17	-15.50	626.96	450.57	-28.13
2.C.	Metal Production			15.71	15.71	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	

(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 1990-2008 period there were six cement production plants operating in Portugal, mostly dedicated to Portland cement production⁵³ 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-calciners⁵⁴. 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 alumino-ferrites 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

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to the mass balance equation 3.1 of GPG:

$$Emi_{CO_2 (y)} = EF_{Clinker} * Prod_{CLINKER (y)} * CKD * 10^{-6}$$

where

$Emi_{CO_2 (y)}$ - emissions of CO₂ from cement production, originated from carbon in mineral constituent materials (kton/yr);

$EF_{Clinker}$ - emission factor (kg/ton clinker);

⁵³ There is also some production of white Portland cement, which is characterized by a lower iron and manganese constant, 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.

⁵⁴ One calciner is a false pre-calciner.

$Prod_{CLINKER(y)}$ - Total production of clinker (ton/yr);

CKD - Cement Kiln Dust correction factor, accounting for the fact that some part of calcinated raw materials and clinker collected at stack air emission control equipment can not be returned to process and is not included in clinker. But because this material includes calcinated constituents, it must be included in the mass balance accounts correcting activity data (clinker production).

4.3.1.1.3 Emission Factors

The CO₂ emission factor was estimated according to the following formula, equivalent to the GPG equation 3.3:

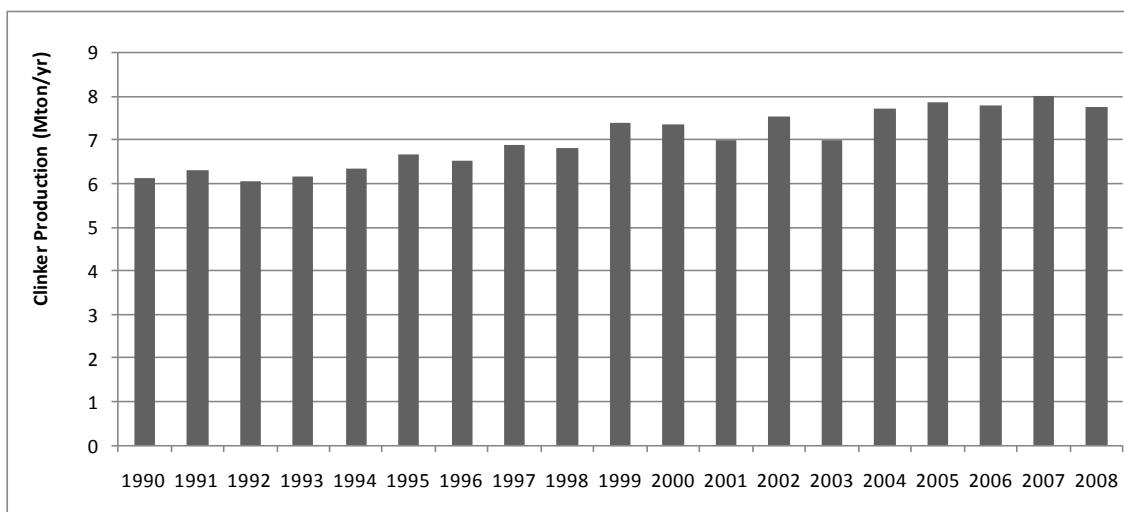
$$EF_{Clinker} = 44.01 / 56.08 * Ratio_{CaO}$$

where $Ratio_{CaO}$ is the Calcium oxide (lime) content of clinker (kg CaO/ kg clinker). The default IPCC CaO fraction in clinker was considered in the inventory (64.6%). Final emission factor is therefore 0.507 ton CO₂/ ton clinker.

4.3.1.1.4 Activity Data

Clinker production, for all the years from 1990 to 2008, was received directly from each industrial plant, and the correspondent time series may be observed in next figure. Total clinker production for 1990-2008 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 (1990-2008)



In accordance to the methodology proposed in the European Commission Decision 29/01/2004 (Annex VII) the formula for calculation of decarbonising emissions should be changed to:

$$EF_{Clinker} = 0.785 * Ratio_{CaO} + 1.092 * Ratio_{MgO}$$

The emission factors would therefore change from 0.507 ton CO₂/ton clinker to 0.525 t CO₂/t clinker, resulting in an increase of emissions of 3.55 %⁵⁵. The CKD correction factor to

⁵⁵ Assuming CaO fraction in clinker of 64.5% and MgO 2%, the default value set by GHP Protocol (WBCSD/WRI).

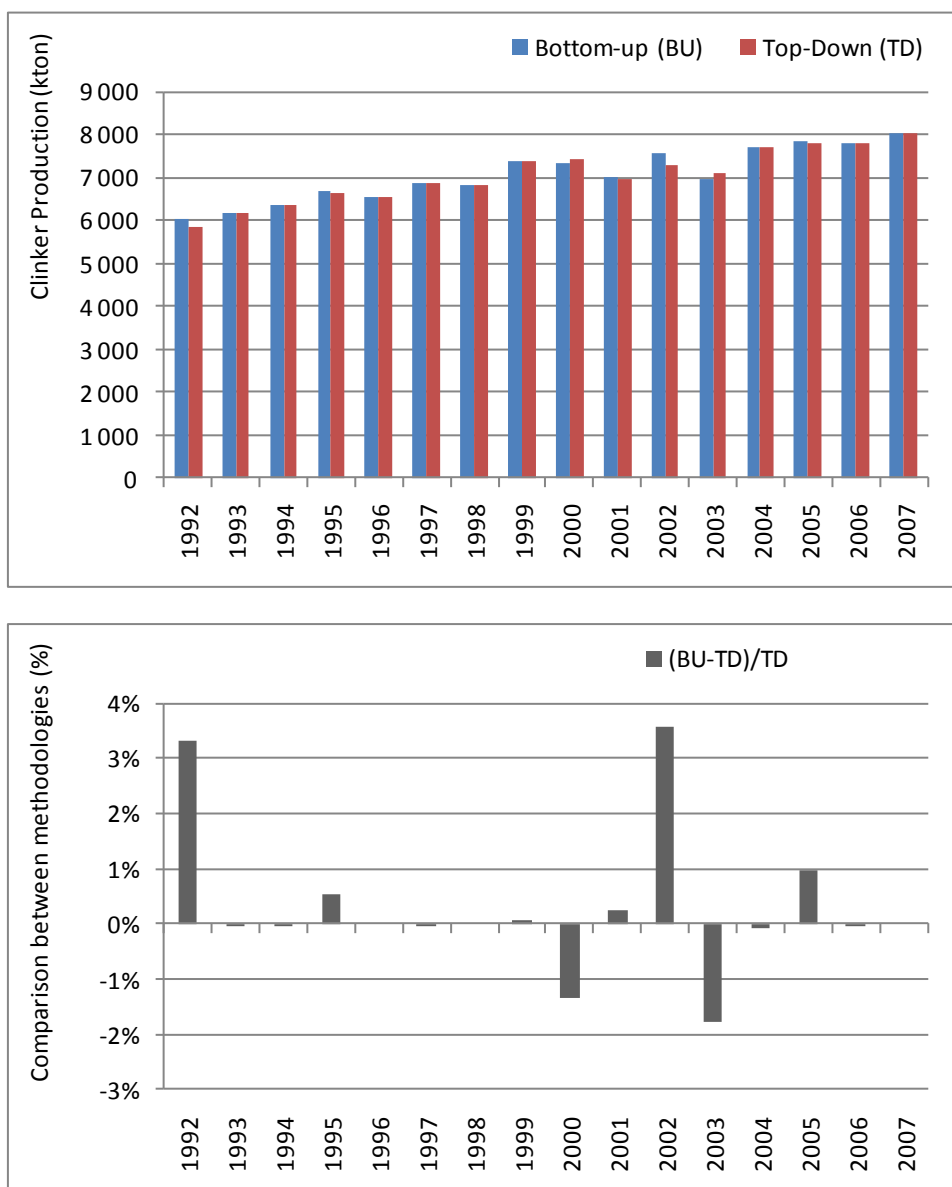
clinker production was not applied, in accordance to information received from industry experts that consider that in all production lines in Portuguese cement plants, dust is fully returned back to the process and incorporated in final product.

4.3.1.1.5 Uncertainty assessment

The uncertainty value of the emission factor was determined to be 10% 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%.

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 1992-2007. There are slight differences using the two different approaches, but, generally, data is fully consistent.



4.3.1.1.7 Recalculations

No recalculations were made.

4.3.1.1.8 Further Improvements

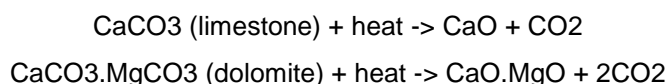
It was envisaged that consumption of raw materials and the knowledge of its carbon content could be used to make estimates of carbon dioxide emissions from consumption of carbon in raw materials. This procedure would result in an alternative estimate method that could at least be useful to uncertainty assessment. In fact, apart from the data that is collected directly from each unit plant concerning clinker production, industrial plants also furnish information about consumption of raw materials (limestone, sand, carbonate shales, ash, gypsum, iron oxides, argyles and flue dust). The information data that was received until now is not sufficient to derive country-specific CaO contents: CaO fractions are not available for all industrial plants; some raw materials, such as carbonate shales, have a very large range of possible carbonate content; and some carbon content materials are only used as fillers and will not result in emissions.

Probably more feasible, efforts are also under way in order to improve the knowledge of carbon content of products, or CaO and MgO content, for all plants with the possible outcome of a country-specific emission factor. Nevertheless it was still not possible to obtain plant specific data to ameliorate the emission estimates.

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 CaCO₃ content (at least 50%) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of Na₂CO₃, NaOH, steel, refractory material, SO₂ absorption, CaC₂, 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% 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 reversion 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

Carbon Dioxide emissions from lime production were estimated from the quantity of lime that was produced, according to the following equation, which is in accordance with equation 3.4 in GP:

$$\text{Emi}_{\text{CO}_2} = (\text{Prd}_{\text{Lime}} * \text{EF}_{\text{Lime}} + \text{Prd}_{\text{Slaked}} * \text{EF}_{\text{Slaked}} + \text{Prd}_{\text{HLime}} * \text{EF}_{\text{HLime}}) * 10^{-3}$$

Where,

Emi_{CO_2} – CO₂ emission from total lime production (kton/yr);

Prd_{Lime} – annual production of lime, either high calcium quicklime or dolomite lime as final product (ton/yr);

$\text{Prd}_{\text{Slaked}}$ – production of slaked lime as final product (ton/yr);

$\text{Prd}_{\text{HLime}}$ – Annual production of hydraulic lime (ton/yr);

EF_{Lime} , $\text{EF}_{\text{Slaked}}$, EF_{HLime} – emission factors applied respectively to lime, slaked lime and hydraulic lime (ton CO₂/ton lime).

4.3.1.2.3 Emission Factors

In the case of lime industry emission factors were determined in accordance with equations 3.5 of GP and using table 3.4 of the same reference. They were calculated for each lime type from:

$$\text{EF} = [(1 - \text{Dol}_{\text{Lime}}) * \text{SR}_{\text{CaO}} * \text{Content}_{\text{CaO}} + \text{Dol}_{\text{Lime}} * \text{SR}_{\text{CaO.MgO}} * \text{Content}_{\text{CaO.MgO}}] * (1 - \text{Content}_{\text{H}_2\text{O}})$$

Where,

Dol_{Lime} – Ratio of total lime produced that is Dolomite Lime (kg/kg);

SR_{CaO} – stoichiometric ratio between CaO and CO_2 during production of pure high calcium quicklime (kg/kg);

$\text{SR}_{\text{CaO.MgO}}$ - stoichiometric ratio between CaO.MgO (50:50) and CO_2 during production of pure Dolomite lime (kg/kg);

$\text{Content}_{\text{CaO}}$ – Content of CaO in high calcium lime as in final product (kg/kg)⁵⁶;

⁵⁶ This parameters have to be multiplied by respective oxide content because lime, or dolomite lime, are seldom composed of pure oxides, but include also a fraction of impurities.

$\text{Content}_{\text{CaO.MgO}}$ - Content of CaO.MgO in Dolomite lime as final product (kg/kg);

$\text{Content}_{\text{H}_2\text{O}}$ – Water content in slaked lime (kg/kg)

The following table presents the values set for each parameter, for each lime type, and the final value for emissions factors. The values in this table are the default values in GP (table 3.4) while Dol_{Lime} is the proportion of both lime types according to GP also (page 3.22). The default water content values in table 3.5 were used to determine the emission factor for slaked lime.

Table 4.2 – Parameters used to derive the Emission Factors for Lime Production

Lime	Dol_{Lime} (%)	$\text{Content}_{\text{CaO}}$	$\text{Content}_{\text{CaO.MgO}}$	$\text{Content}_{\text{H}_2\text{O}}$ (%)	Emission Factor (kgCO ₂ /kg lime)
QuickLime	15	0.95	0.95	0	0.76
Slaked Lime	15	0.95	0.95	27	0.56
Hydraulic Lime	0	0.75	0	-	0.59

Stoichiometric ratios are 0.785 kg CO₂/kg CaO for high calcium lime (SR_{CaO}) and 0.913 kg CO₂/kg CaO.MgO for Dolomite Lime ($\text{SR}_{\text{CaO.MgO}}$).

In the case of the iron and steel industry all lime is high calcium quick lime and the emission factor, obtained from the above equation, is 0.750 kg CO₂/kg lime.

4.3.1.2.4 Activity Data

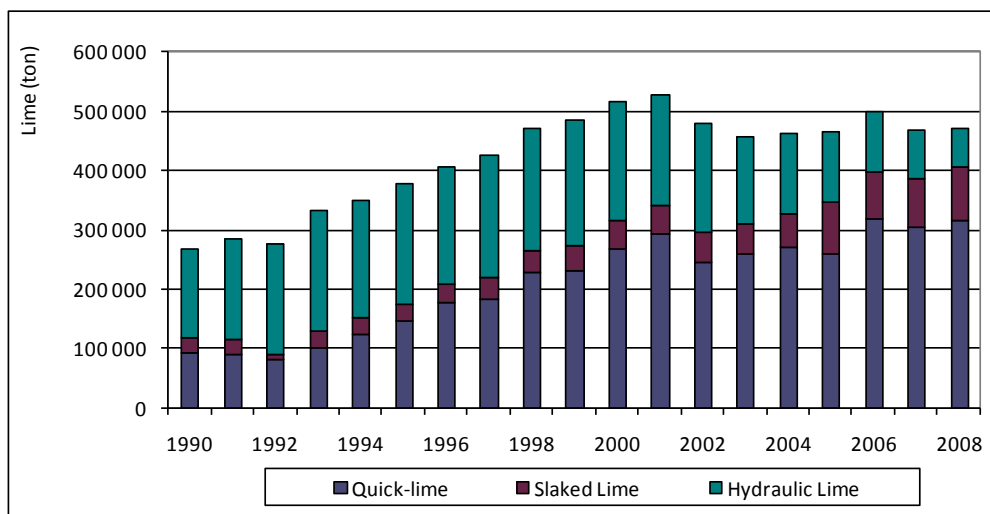
Production of lime products in industrial plants solely dedicated to this activity is available for the period 1989-2000 from National Statistics (INE): for the period 1989-1991 from IAIT industrial survey, and for 1992-2007 from the IAPI industrial survey. In order to avoid double counting of decarbonisation (calcination), only lime sold was quantified but not lime produced for internal consumption in unit plant. Production values for 2008 were estimated as simple linear forecasts from the available statistical time series. From the available information, no distinction could be made between the high calcium lime and dolomite lime for lime produced and sold to market.

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/IAPI 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 1992-2008 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 (147% from 1990 to 2008), 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 (1990-2008)



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% for hydraulic lime and 2% 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%.

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% was therefore used in the uncertainty analysis.

4.3.1.2.6 Recalculations

Activity data time series for the period 2001-2007 were updated based on IAPI survey. The activity data for 2008 was estimated as simple linear forecast from the available statistical time series. Emission values for the period 2001-2008 are due to the changes in activity data for that period.

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 lime⁵⁷ production in the paper pulp industry.

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.

⁵⁷ Or any other process not resulting in decarbonisation.

Because some units producing lime are included in the European carbon trading market (EU-ETS) comparison of National Statistical information with the reports made annually by industrial plants may improve the inventory. The comparison and use of EU-ETS data is envisaged under the efforts that are being made to streamline both inventories.

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 consumption⁵⁸ 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:

$$\text{Emi}_{\text{CO}_2 (y)} = 44/12 * \text{Mat}_{\text{Carb} (m,y)} * C_{\text{content} (m)} * 10^{-3}$$

where

$\text{Emi}_{\text{CO}_2 (y)}$ - emission of carbon dioxide in year y (kton/yr);

⁵⁸ Determined from composition of Blast Furnace Gas given by industry.

$Mat_{Carb}(m,y)$ - 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 stoichiometry⁵⁹:

Table 4.3 - 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

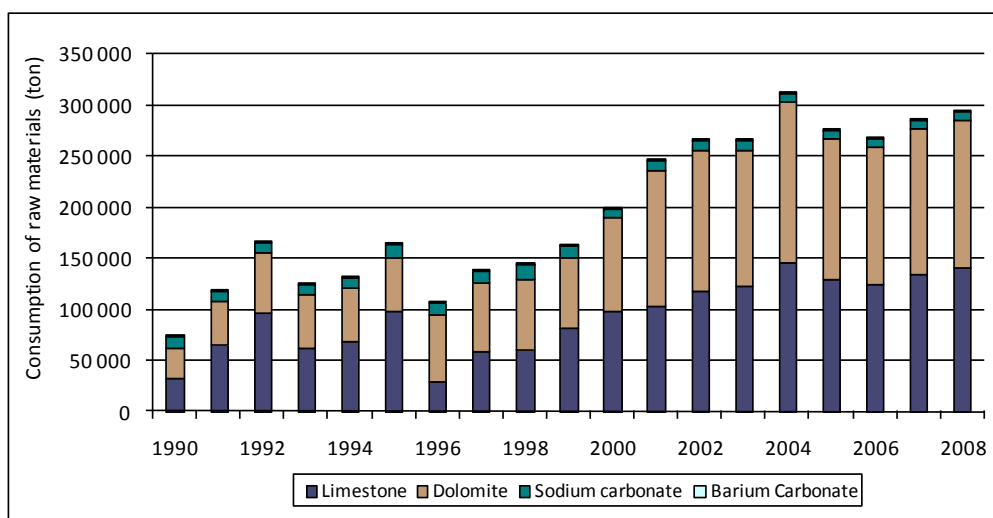
* assumed pure calcium carbonate;# Ca and Mg carbonate in equal share

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 2000 and thereafter forecasted. 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 per fertilizer type was also available from INE database from 1990 to 2007 and forecasted for year 2008. 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. Total carbonate consumption has increase 299% since year 1990.

⁵⁹ It was assumed that limestone was totally pure, which causes over-estimated emissions.

Figure 4.7 - Consumption of carbonate materials in industry (1990-2008)



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%), 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 2001-2007 based on data from INE (IAPI). The activity data for 2008 was estimated as simple linear forecast from the available statistical time series. Emission values for the period 2001-2008 are due to the changes in activity data for that period.

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°)⁶⁰. 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 emulsifiers⁶¹. 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/naphtha (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% 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% 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)⁶². 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 activity⁶³.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible⁶⁴.

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

⁶⁰ That are needed to fluidize the asphalt cement.

⁶¹ And also a solvent in several emulsion types.

⁶² To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

⁶³ It is not possible to distinguish fuel combustion in hot mix production activity.

⁶⁴ 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.

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% composed of VOC (USEPA,2001) and that emitted VOC have on average 85% of carbon⁶⁵:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

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 (m³/m³);

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:

$$Emi_{(p,y)} = Hotmix_{Batch(y)} * EF_{(p)} + Hotmix_{Drum(y)} * EF_{(p)}$$

Where,

$Emi_{(p,y)}$ – Total emissions for pollutant p occurring in year y from Hot mix asphalt production (ton);

⁶⁵ Normal carbon content for medium linear simple hydrocarbons.

$Hotmix_{Batch(y)}$ 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 4.4 - 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 4.5 - Emission Parameters for Hot Mix asphalt production

Pollutant	Continuous	Batch	Unit EF
NMVOC	32.0	22.1	g/ton
CH ₄	12.0	7.4	g/ton

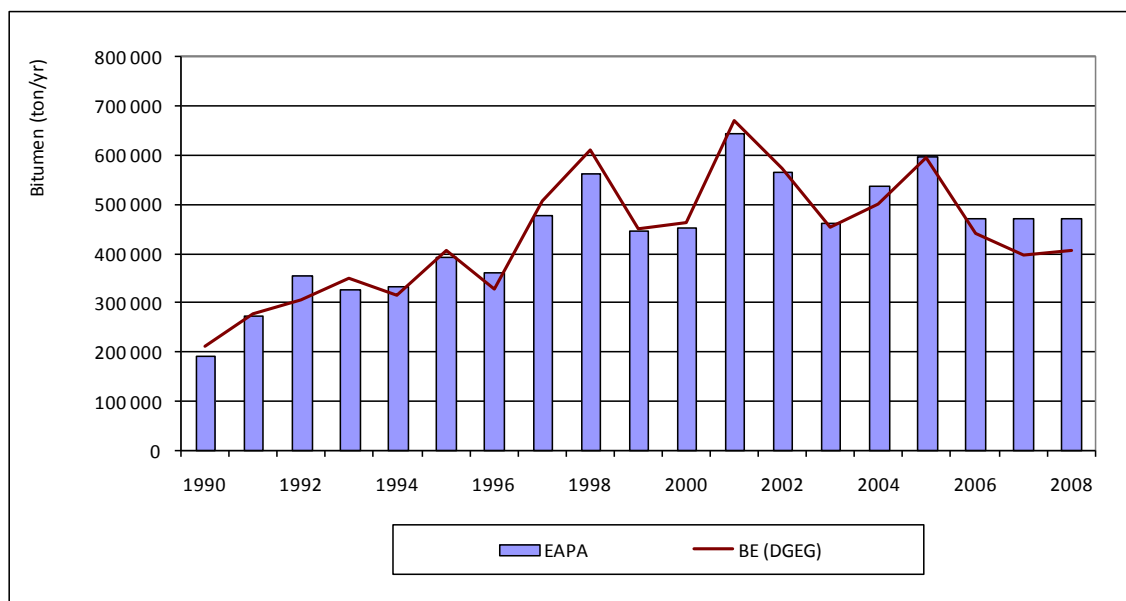
Source: USEPA (2000)

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 surveys⁶⁶, 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.

⁶⁶ 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 4.8 - Total consumption of bitumen in the construction sector according to sales from DGGE and sum of values of asphalt used, according to the inventory (1990-2008)



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% in 1996. Data for Hot mix concrete asphalt production is from EAPA for 1991-2007 and forecasted for 2008. Bitumen in hot mix asphalt was estimated considering that it equals 5% 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 4.6 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (ton)

Asphalt	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998
Cutback	ton	4 100	3 500	2 700	3 100	2 600	676	407	1 232	933
Emulsified	ton	0	10 567	21 133	36 576	49 852	65 025	100 517	110 000	130 000

Asphalt	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cutback	ton	162	576	824	501	340	0	0	0	0	0
Emulsified	ton	95 000	86 000	107 000	116 000	112 665	93 600	65 000	40 500	35 000	35 000

Figure 4.9 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (1990-2008)

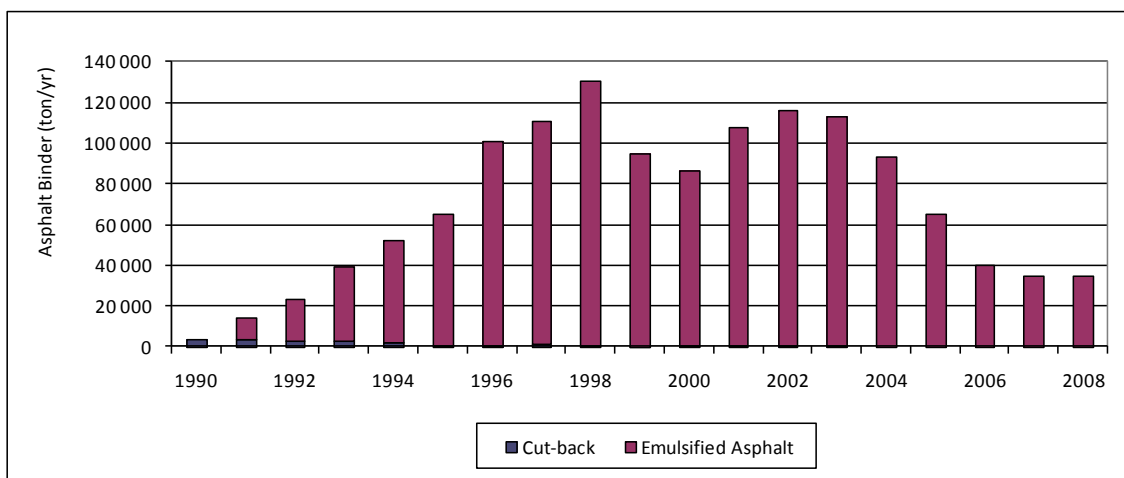
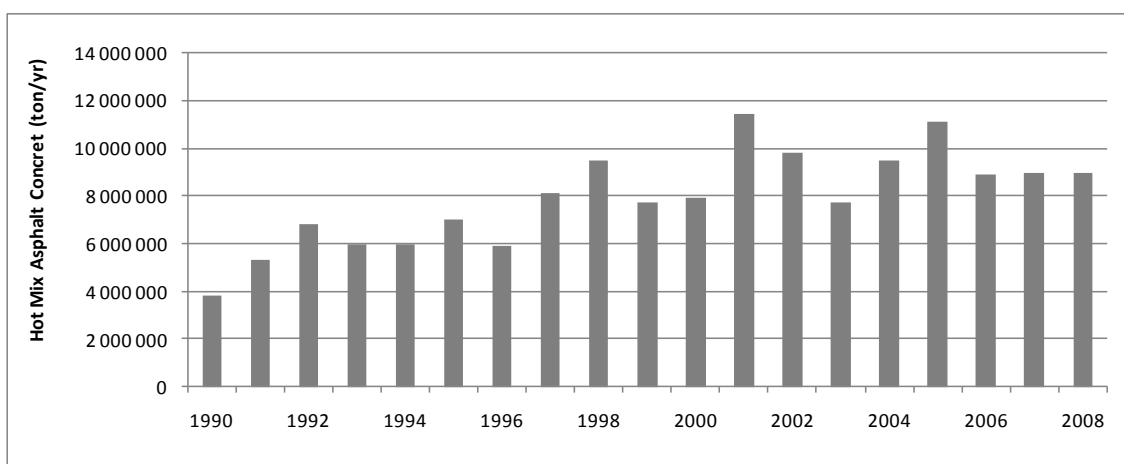


Figure 4.10 – Total Production of Hot Mix Asphalt (1990-2008)



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% continuous equipment and 54% 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%.

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 or 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

The activity data has been revised, leading to some changes in emission values.

4.3.1.4.7 Further Improvements

Interest in GHG emissions for this source sector have diminished since the revision made between submission 2003 and 2004 that result in a substantial downward revision of NMVOC emission estimates from this source sector. Some actions are however planned for the coming years and it is expected that they will result in the improvement of emission estimates. Focus will be made on a better knowledge of the quantities of cut-back that are used, the quantification of emulsification solutions and hence a better division between the three types of asphalt materials. Work is on the way in close contact with the department of industry of the Economy Ministry and APORBET, the Portuguese Association of Producers of Bitumen Materials, under SNIERPA development.

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 here⁶⁷.

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

$\text{Emission}_{\text{CO}_2(t,y)}$ - annual emission of carbon dioxide from specific glass type t in year y (ton/yr);

$\text{ActivityRate}_{(t,y)}$ - Glass of type t produced in a given year y (ton/yr);

$\text{EF}_{\text{CO}_2(t)}$ - emission factor from production of glass of type t (kg/ton)

⁶⁷ They were not used to derive the country specific emission factors for instance.

4.3.1.5.3 Emission Factors

The following emission factors were considered:

Table 4.7 - 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 (m^2) 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 1992 to 2001 from information collected directly from that unit, while for 1990 and 1991 this value was available from INE databases (IATI industrial survey). Statistical information from INE for the period 1992-2000 (IAPI industrial survey) was available in area units (m^2) but was not used because conversion to weight units would lead to high uncertainties. Production values for 2002 to 2008 were forecasted by APA;
- 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 to 1993 and for 2004-2008 was estimated by APA extrapolating CTCV time series and using the full time series of INE as surrogate data;
- Lead Crystal Glass production from 1992 to 2000 was available from INE IAPI industrial survey and was extrapolated, from the available time series, for 1990-1991 and 2001-2008. Original data in INE time series had to be converted from number units to weight units assuming typical weight per object;
- 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 statistical database (IAIT and IAPI industrial surveys).

For some products original units were only available in number and had to be converted to weight. The following conversion table was assumed:

Table 4.8 – 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)

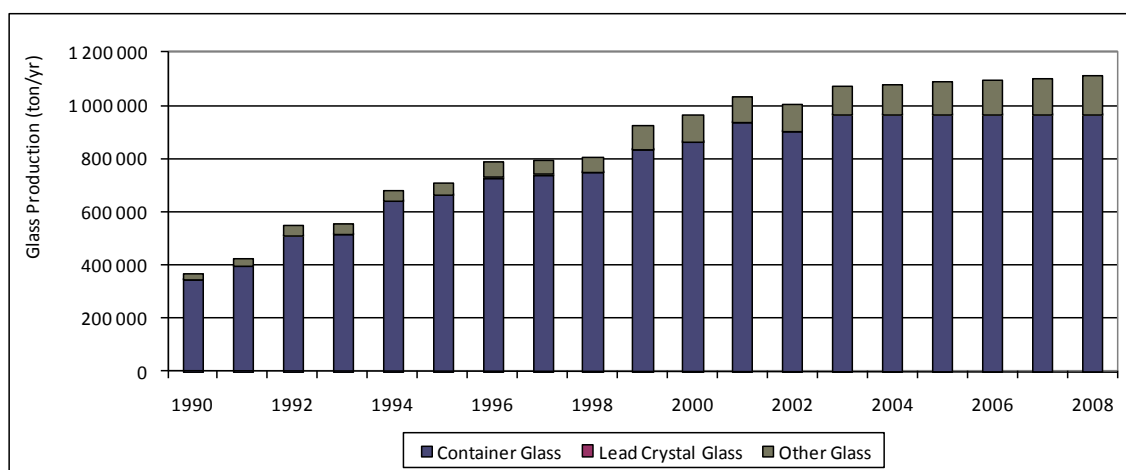


Table 4.9 - Glass production by glass type (excluding flat glass)

Glass	1990	1991	1992	1993	1994	1995	1996	1997	1998
Container Glass	344 967	399 822	509 718	519 111	639 947	663 498	730 342	741 392	751 333
Lead Crystal Glass	149	234	483	332	387	509	583	862	837
Other Glass	26 224	28 311	41 350	39 901	39 411	46 965	61 438	54 183	58 115

Glass	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Container Glass	835 451	863 502	936 471	904 433	965 279	965 279	965 279	965 279	965 279	965 279
Lead Crystal Glass	903	1 009	1 078	1 163	1 247	1 332	1 416	1 501	1 585	1 670
Other Glass	90 141	100 059	94 912	102 081	109 251	116 421	123 591	130 760	137 930	145 100

4.3.1.5.5 Uncertainty Assessment

A 100% 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%.

4.3.1.5.6 Recalculations

No recalculations were made for this source sector since the submission of last year.

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.

It is expected that ongoing contacts with sector experts, under the Methodological Development Plan for the development of the National System, may lead to revision and improvement of the activity data time series and emission factors.

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

Presently only one fertilizer industrial plant manufactures ammonia in Portugal, using Vacuum Residual Fuel Oil (VRF) as source of hydrogen (feedstock). 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:

$$Emi_{CO_2(y)} = 44/12 * Feedstock_{(y)} * C_{Feed(y)} * 10^{-5}$$

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 (%).

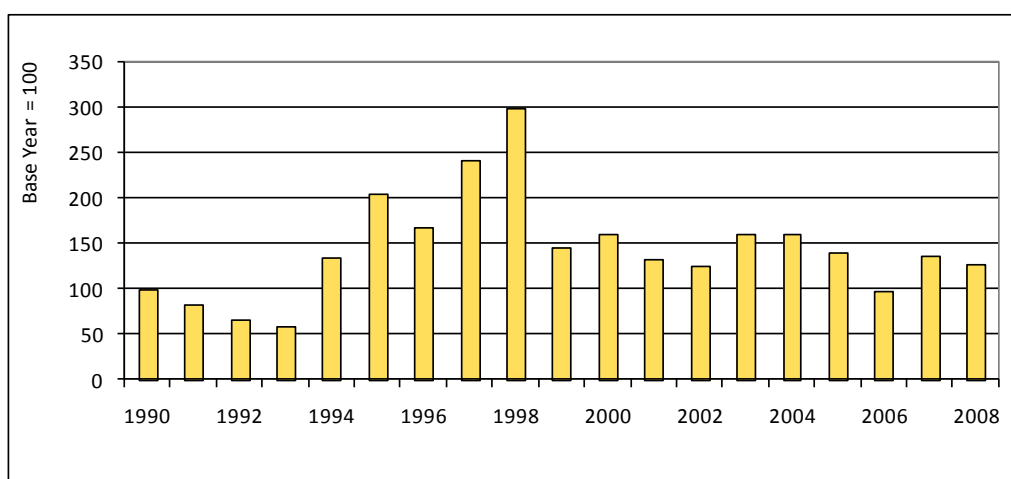
4.3.2.1.3 Emission Factors

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 increase of production since 1990 but with substantial inter-annual changes.

Figure 4.12 - Trend in Ammonia production (1990-2008)



The following sources of information were used to construct the above full time-series.

- total production of ammonia in Portugal is available from INE for the period 1990-2007, resulting from the IAIT survey for 1990 and 1991, and from the IAPI survey thereafter. These correspond to a methodological change done by INE in what concerns industrial surveys. The IAIT industrial survey is available for years 1990-91 and IAPI industrial survey was used thereafter. Changes from IAIT to IAPI include modification in questionnaire, classification of economic activities, product and materials codification. Spatial allocation of economic data has also changed between these two survey processes. Data for 2008 was forecasted;
- 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 conservativeness⁶⁸. The final uncertainty value for activity data was set as 31%.

With the methodology that was used the uncertainty in the emission factor refers only to the uncertainty in the carbon content of feedstock: 5%.

4.3.2.1.6 Recalculations

Recalculations were made for the period 2001-2007, based on new data from IAPI. The activity data for 2008 was estimated as simple linear forecast from the available statistical time series. Emission values for the period 2001-2008 are due to the changes in activity data for that period.

4.3.2.1.7 Future Improvements

The importance of emissions from this source category, particularly in the Industrial Process sector where it only seconds emissions from cement production, implies that better knowledge of activity data is necessary, and particularly for base year. Collection of this information is already planned under: the Methodology Development Plan that is being in the National System; and through cooperation with other entities such as Regional Environment Departments doing regional air emission inventories, the General-Directorate of Industry, Industry Associations, EPER registry and the industrial plant itself.

Information from Regional inventory surveys, EPER, E-PRTR and monitoring under *Autocontrolo* program may also 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 2008, located in Estarreja, Alverca and Lavradio. In all weak nitric acid (60%) 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:

⁶⁸ A further doubling was used to convert from standart deviation to 95% confidence interval.

$$\text{Emission}_{(p,y)} = \text{EF}_{(p)} * \text{ActivityRate}_{(y)} * 10^{-3}$$

where

$\text{Emission}_{(p,y)}$ - annual emission of pollutant p in year y (ton/yr);

$\text{ActivityRate}_{(y)}$ – production of Nitric Acid in year y (ton/yr);

$\text{EF}_{(p)}$ - emission factor for pollutant p (kg/ ton)

4.3.2.2.3 Emission Factors

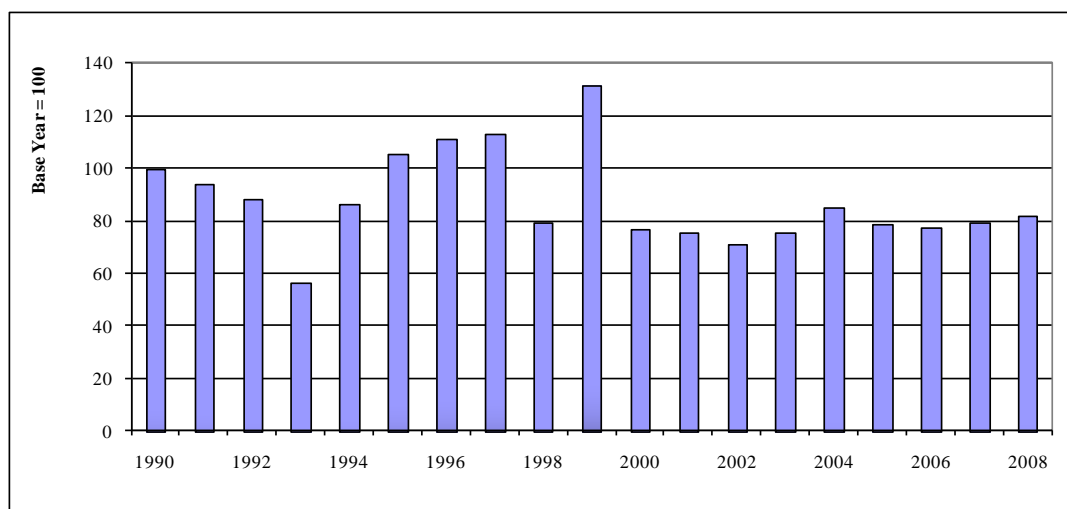
Due to confidentiality constraints it is not possible to publish the chosen emission factors.

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). The sources of information that were used to establish activity data time series are discussed below in the figure, together with the presentation of time trend. Albeit inter-annual variations the average annual production did not show a sustained trends in the period.

The time series was determined according to the following mode:

- Quantities of Nitric acid for year 1990 are available from a specific questionnaire that had been sent to industrial units by IA under Corinair90 project;
- From 1992 to 2007, total national production of Nitric Acid was set from INE statistical database (IAPI survey);
- For 1989-1991 statistical information of Nitric Acid Production is available from the IAIT survey;
- For 2008 the time series was provisionally estimated by a simple linear forecast.

Figure 4.13 - Trend in Nitric Acid production (1990-2008)



4.3.2.2.4 Uncertainty Analysis

The uncertainty value for activity data is 3%, 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% 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.

4.3.2.2.5 Recalculations

Recalculations were made based on updated activity data from INE (IAP) for the period 2001-2007. The activity data for 2008 was estimated as simple linear forecast from the available statistical time series. Emission values for the period 2001-2008 are due to the changes in activity data for that period.

4.3.2.2.6 Future Improvements

Efforts will be made in order that the emission factors that are used, and which are country specific, may be improve in quality by incorporation of monitoring data from more years and for all units. In general better information must be obtained at plant level allowing the consideration of plant specific emission factors. Estimate of air emissions from Nitric Acid Manufacture should be extended to include other pollutants such as ammonia, and preferably also using estimates from plant monitoring.

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 sector⁶⁹:

- Vinyl Chloride Monomer (VCM);
- 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

Emission_(p,y) - annual emission of pollutant p in year y (ton/yr);

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);

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_{Feedstock} – Carbon entered in feedstock (ton C/yr);

C_{AuxFuels} – additional carbon entered into system in fuels (ton C/yr);

C_{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 1993-1994⁷⁰. Emissions estimated for this period were used to determine plant-specific process emission

⁶⁹ 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

factors that were used to estimate emissions for all time series from 1990 to 2001 and using ethylene production as activity rate indicator⁷¹. Emissions from flares and flue gas combustor were included in the emission factors.

Table 4.10 – Emission Factors for determination of process emissions in Borealis (kg/ton)

Description	NMVOC	CH4
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 4.11 – 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)
NMVOC	33.3 ^(a)	2.50 ^(b)	-
CH4	0.80	0.8 + 1.4 ^(b)	-
CO	104	100 + 17 ^(b)	-
N2O	-	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 4.12 - Emission Factors for the production of Phthalic Anhydride

Pollutant	kg/ton
NMVOC	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

⁷⁰ Unpublished.

⁷¹ This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

from 1990 to 2007 from INE Statistical Database (IAIT and IAPI surveys). Production of carbon black and explosives was forecasted for year 2008.

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%. 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% and 20% 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% for Large Point Sources⁷².

4.3.2.3.6 Recalculations

Recalculations were made based on updated activity data from INE (IAPI) for the period 2001-2007. The activity data for 2008 was estimated as simple linear forecast from the available statistical time series. Emission values for the period 2001-2008 are due to the changes in activity data for that period.

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.

⁷² 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 4.13 - 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:

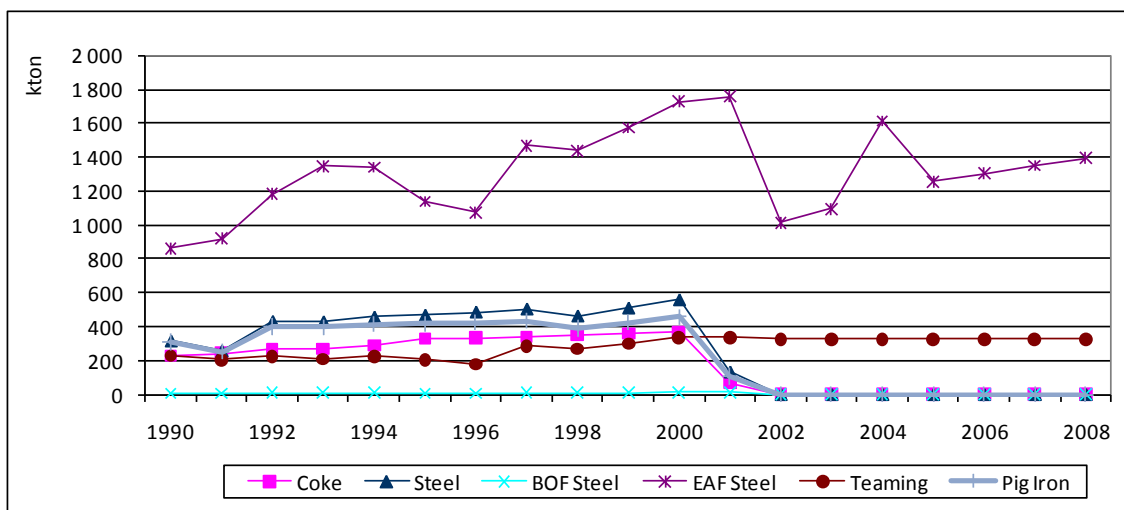
- coke production is available from DGEG (Coquerie Balance) annually from 1990 to 2001. After 2002 the production of coke was interrupted;
- production time series for sinter, pig iron and steel production in blast furnace are available from industrial plant from 1990 to 1994 (APA direct survey). Thereafter 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 plant⁷³ as surrogate data⁷⁴, for the remaining time series;
- 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.

⁷³ Power plant that is part of the iron and steel plant

⁷⁴ They may result not from iron produced at this industrial plant

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 constraints.

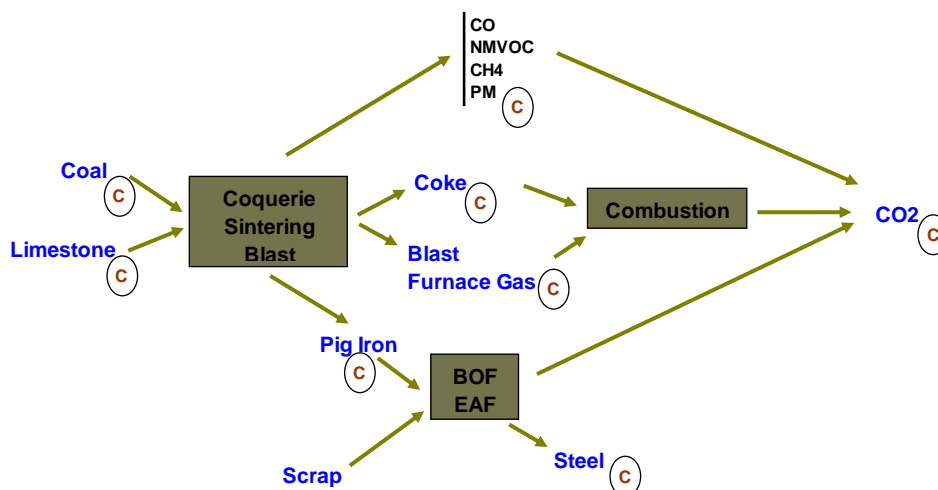
Figure 4.14 - Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2008)



4.3.3.1.5 Balance of Carbon in the Iron and Steel Plant

The information available for the plant that produced iron and steel from ore, up to 2002, allow the elaboration of a balance of carbon. This balance was made to verify the validity of the activity data in use and that the inventory is not departing from actual emissions.

Figure 4.15 – Model for Carbon Balance in the integrated Iron and Steel Plant



Accordingly a comparison between a top-down and a bottom-up approach was made.

1. Top-down.

CO2 emissions estimated from consumption of coal and Lime

$$C \text{ from coal} = \text{coal consumption} * 29.9 \text{ (GJ/ton)} * 96.1 \text{ kg (CO2/ton)}$$

$$C \text{ in limestone} = \text{lime consumption} * 0.75 \text{ kg CO}_2/\text{kg lime (High Ca)}$$

2. Bottom-up

CO₂ emissions estimated from:

- Consumption of derivative gases: COG and BFG

$$\text{CO}_2 \text{ from fuel use} = \text{Consumption (Nm}^3/\text{yr)} * \text{LHV} * \text{EF}$$

- Process emissions (not including other fuels)

Coke Oven leakage, etc

Blast Furnace leakages, etc

BOF

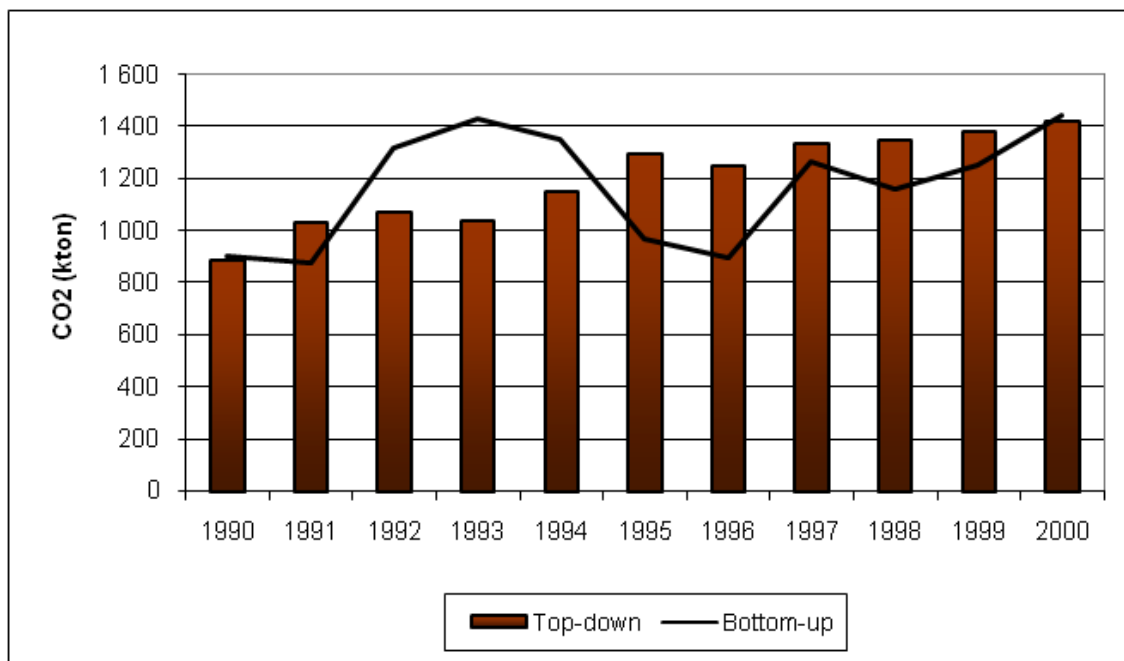
EAF (not including consumption of electrodes)

- Other Carbon itens

Carbon in BOF steel

Results from this comparison are presented in next figure, from where it is possible to verify the approximate match of both approaches, reflecting the quality of bottom-up estimates.

Figure 4.16 – Comparison of bottom-up and top-down approaches in the integrated Iron and steel plant



4.3.3.1.6 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 years 2002 and 2003 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% the major value in the range proposed in GPG. The uncertainty value for the emission factor was determined considering and uncertainty of 25% in the carbon content of both raw materials and final steel and additional 5% in the quantity of reducing agent for EAF.

4.3.3.1.7 Recalculations

No changes were made to this source sector since the submission of last year.

4.3.3.1.8 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 *Ferrous Production (CRF 2.C.2.)*

4.3.3.2.1 Overview

Iron is smelted with other elements, such as silicon, manganese, chromium, molybdenum, vanadium or tungsten, forming alloys that have specific material characteristics requirements.

Usually alloy formation occurs in Electric Arc Furnaces (EAF) and, like the situation described in steel factoring, carbon monoxide and carbon dioxide emissions occur from oxidation of carbon still present in coke - used as raw material - and from consumption of the graphite electrodes.

4.3.3.2.2 Methodology

Emissions are estimated by multiplication of emission factors, because no data is available to estimate oxidation of coke and electrodes:

$$\text{Emission}_{\text{CO}_2(y)} = \text{EF}_{\text{CO}_2} * \text{ActivityRate}_{(y)}$$

where

Emission_{CO₂(y)} - annual emission of carbon dioxide in year y (ton/yr);

ActivityRate_(y) - Indicator of activity in the production process, the quantity of ferro-alloy produced in a given year y (ton/yr);

EF_{CO₂} – carbon dioxide emission factor (ton/ton)

4.3.3.2.3 Emission Factors

The emission factor, 2.5 ton/ton, was set from emission factors proposed by IPCC96 and CITEPA (Draft contribution for Corinair90 Default Emission Factor Handbook).

4.3.3.2.4 Activity Data

Quantity of ferro-alloy produced is only available for 1990 from National Statistical Institute (INE) and a constant production was temporarily assumed for the whole period: 1 049 ton/yr.

4.3.3.2.5 Uncertainty Analysis

The uncertainty of emissions from this source is substantial, not only because there is lack of information concerning production data but also because there is a high level of uncertainty in the specific alloy that is being considered. Therefore the uncertainty value for activity data was set at 100% while uncertainty in emission factor was estimated from the range of emission factors proposed in IPCC (1997) i.e. 0 – 6.5.

4.3.3.2.6 Recalculations

No changes have been made in emission estimates from this source category.

4.3.3.2.7 Further Improvements

Although this is a less important emission source, improvement of emissions estimates will have to be made in future, concerning:

- update of time series since 1990;
- individualization of each ferro-alloys by alloy, and application of specific emission sources.

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 Industry (DGI), 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 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_{NM VOC} - annual emission of NMVOC in year y (ton/yr);

ActivityRate - Indicator of activity in the production process (ton/yr);

EF_{NM VOC} - 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% of carbon:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NM VOC}$$

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, from National Statistics Institute (INE). In 1990 571 kilotons of chipboard were produced in Portugal.

4.3.4.1.5 Recalculations

No changes have been made since last submission.

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.

Time series of chipboard production needs to be updated from statistical information from INE.

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)⁷⁵ 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:

⁷⁵ 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.

- 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.

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 filled⁷⁶;
- 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*

As result of the work being made under the Methodology Development Plan, halocarbons and sulphur hexafluoride emissions have suffered some changes since last submission.

Electric Equipment subsector activity data time series has been revised based on a new survey from "EDP Distribuição". Some equipments classified in last submission as Closed Pressure are now classified as Sealed Pressure, leading to a relevant decrease in SF₆ emission values.

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:

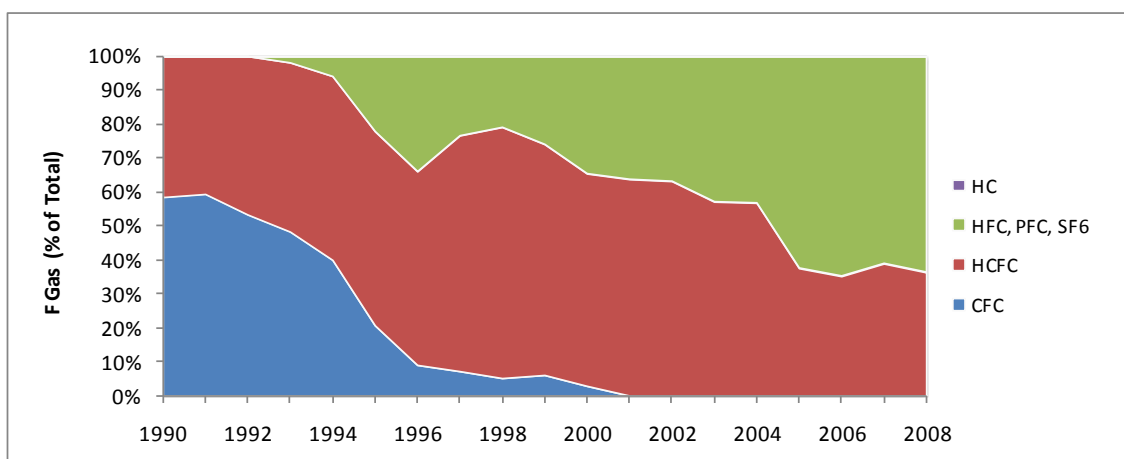
⁷⁶ Assembly emissions could include also emissions during refilling but no data was available to make this distinction

- 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;
- 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.
- Better PFC actual emission estimates should be addressed.

4.3.5.5 Importers Data

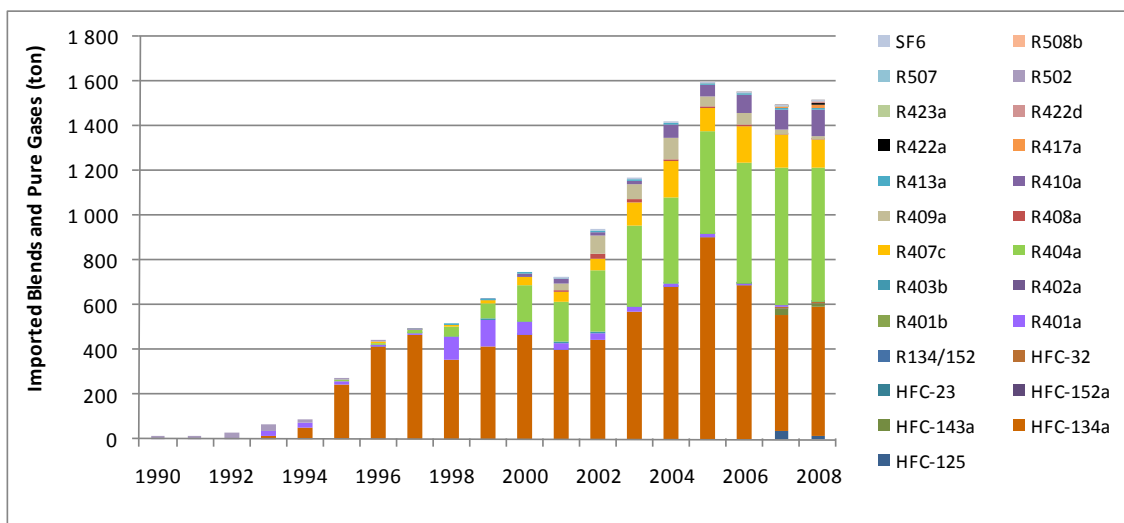
The share of each F-gas used in the assembling of refrigeration equipments was estimated for each year relying on imports data from the major national suppliers of assembled units. Although data from suppliers does not cover the total national market, it was assumed to represent 60% (value agreed upon 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 4.17 - Percentage of imported fluorinated gases (F-Gases) in Portugal by gas type



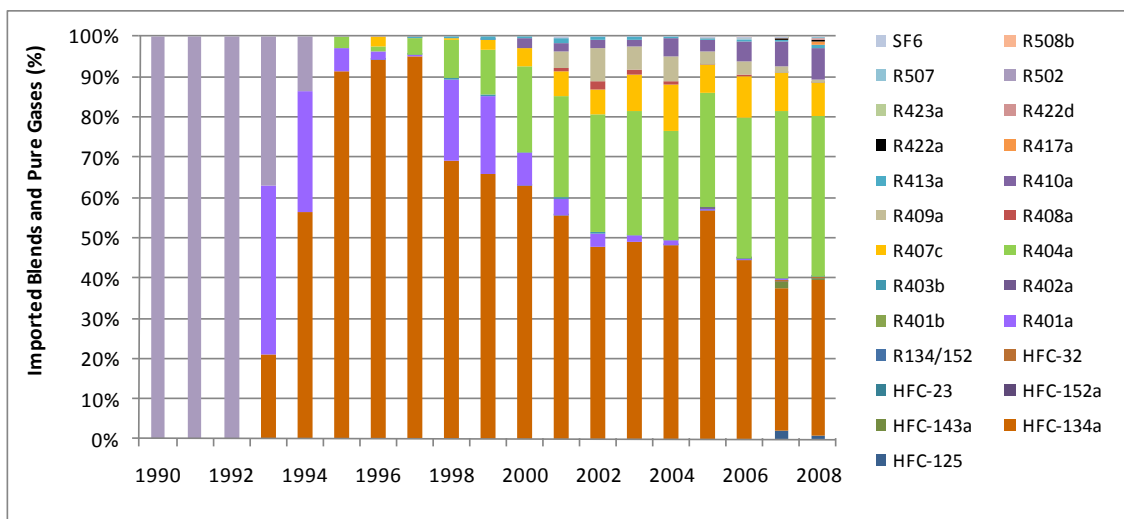
Source: Fluid Suppliers

Figure 4.18 – Imported amounts of pure HFC, PFC, SF₆ and Blends containing HFC and PFC



Source: Fluid Suppliers

Figure 4.19 – Percentual Distribution of pure HFC, PFC, SF₆ and Blends containing HFC and PFC



Source: Fluid Suppliers

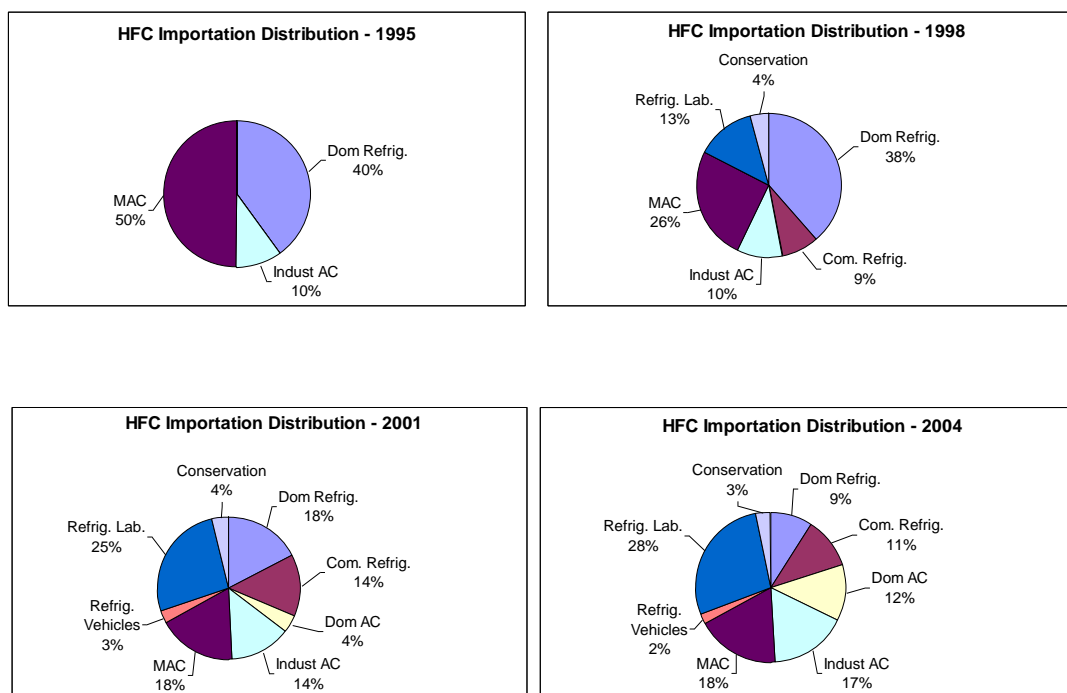
Table 4.14 – Constitution of each blend

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%
	HFC-152a	13%
R-401b	HCFC-22	61%
	HCFC-124	28%
	HFC-152a	11%
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 4.20 - 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 4.15 - 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%, 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.

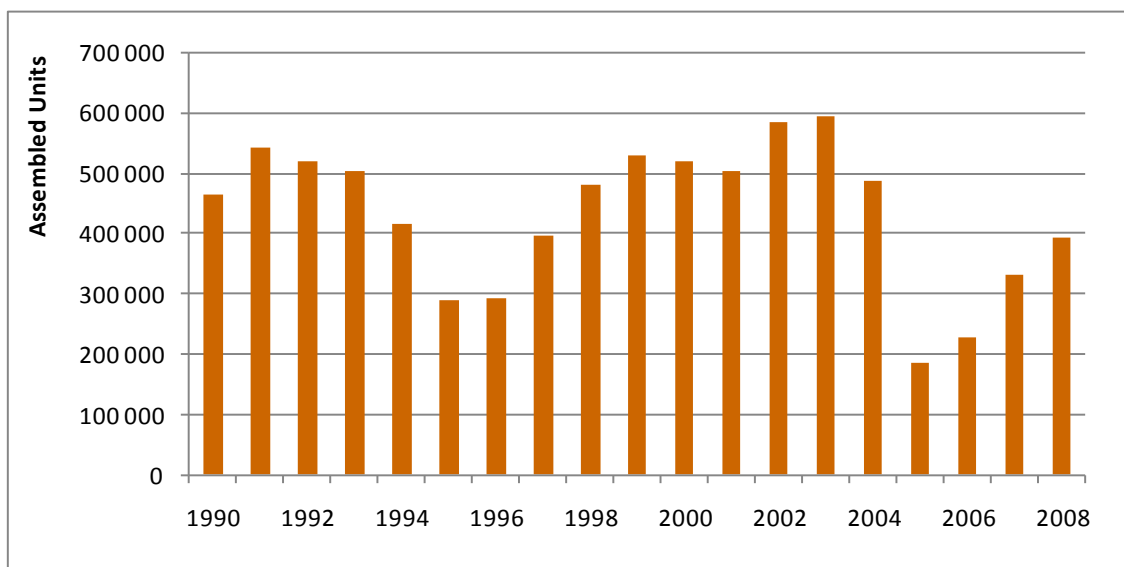
Table 4.16 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000	2008
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 2008 were forecasted by APA based on previous years data.

Figure 4.21 – 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% 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 equipment⁷⁷. 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

Recalculations were made based on updated activity data from INE. The number of assembled refrigeration units reported by INE for the period 2005-2008 is too low when compared to the data reported for the period 1997-2004. This issue should be addressed in next submission.

4.3.5.6.6 Uncertainty Assessment

An uncertainty of 10% was considered for the number of assembled units each year, and 15% 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% 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.

⁷⁷ In consequence no emissions of HFC from disposal are estimated for the reported period.

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 4.17 – 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%).

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

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * F-gas_{\% (j,t)}$$

Operation/ Lifetime

$$\text{Oper}_{\text{Emi}(t,j)} = \text{Oper}_{\text{Emi}(t)} \sum_{y=t}^{t-\text{Lifetime}} [\text{Equip}_{\%(t,y)} \cdot \text{F-gas}_{\%(j,y)}]$$

Disposal

$$\text{Disp}_{\text{Emi}(t,j)} = \text{Disp}_{\text{Emi}(t)} [\text{Equip}_{\%(t,t-\text{lifetime})} \cdot \text{F-gas}_{\%(j,t-\text{lifetime})}]$$

where

$\text{Ass}_{\text{Emi}(t)}$, $\text{Oper}_{\text{Emi}(t)}$, $\text{Disp}_{\text{Emi}(t)}$ - total F-gas emissions at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$\text{Ass}_{\text{Emi}(t,j)}$, $\text{Oper}_{\text{Emi}(t,j)}$, $\text{Disp}_{\text{Emi}(t,j)}$ - F-gas emissions of compound j at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$\text{Equip}_{\text{Assembly}(t)}$ - Equipments assembled at year t;

$\text{Equip}_{\text{Stock}(t)}$ - Existing stock of equipment 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 equipments assembled at year y in the existing stock at year t;

$\text{F-gas}_{\%(j,t)}$ - 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 4.18 - 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% 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% (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 4.19 - 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 4.20 - 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 4.21 - 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 4.22 – 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

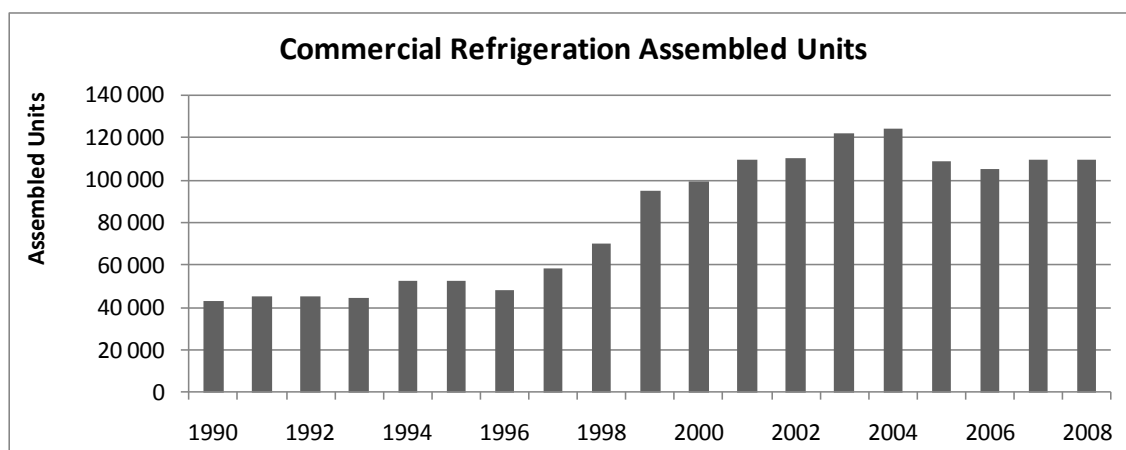
Source: Hypermarket Company

Table 4.23 – 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
Positive Temperature	Big	0	0	0	0	4	7	9	11	14	15	17	18	20	21
	Medium	0	0	0	0	17	27	42	49	53	62	88	98	116	132
	Small	0	0	0	0	34	85	128	161	178	192	224	224	247	264
Negative Temperature	Big	0	0	0	0	0	3	5	7	10	11	13	14	16	17
	Medium	0	0	0	0	0	10	25	32	36	45	71	81	99	115
	Small	0	0	0	0	0	51	94	127	144	158	190	190	213	230

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 4.22 - 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% 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% or overestimated by 200%. 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% uncertainty for stock and 75% 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% 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 mixture⁷⁸, 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. Overall, even with the inclusion of a new source of uncertainty - the composition of the F gas - total uncertainty was reduced by more than an order of magnitude (the combined uncertainty in the previous submission ranged from 5 533 to 5 540%). Apart from the great effort placed in a better knowledge of the stocks, the main cause of the decrease of

⁷⁸ 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.

uncertainty, resulted from the improvement in the knowledge of the initial charge, based on the information received from the fluoride gas importers and the major retail operators in Portugal.

Table 4.24 – 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 emissions⁷⁹ 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

⁷⁹ Assembly emissions are not estimated and they are included in the assembling of other refrigeration equipments

$Oper_{Emi(t)}$, $Disp_{Emi(t)}$ - total F-gas emissions at year t from during Operation (Oper) and Disposal (Disp);

$Oper_{Emi(t,j)}$, $Disp_{Emi(t,j)}$ – 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.

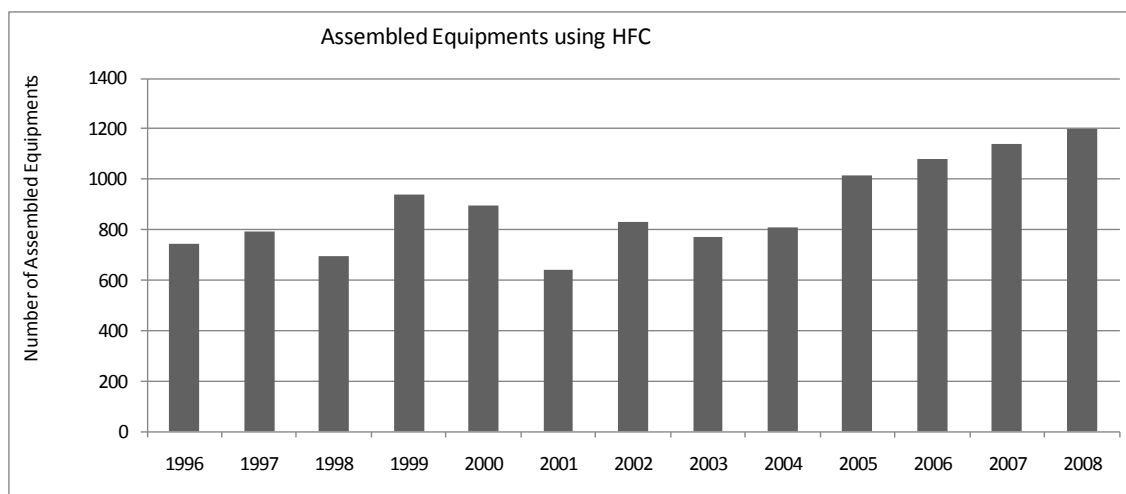
4.3.5.8.2 Emission Factors

Lifetime emissions were assumed to occur with a yearly rate of 32.5 % 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% (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.

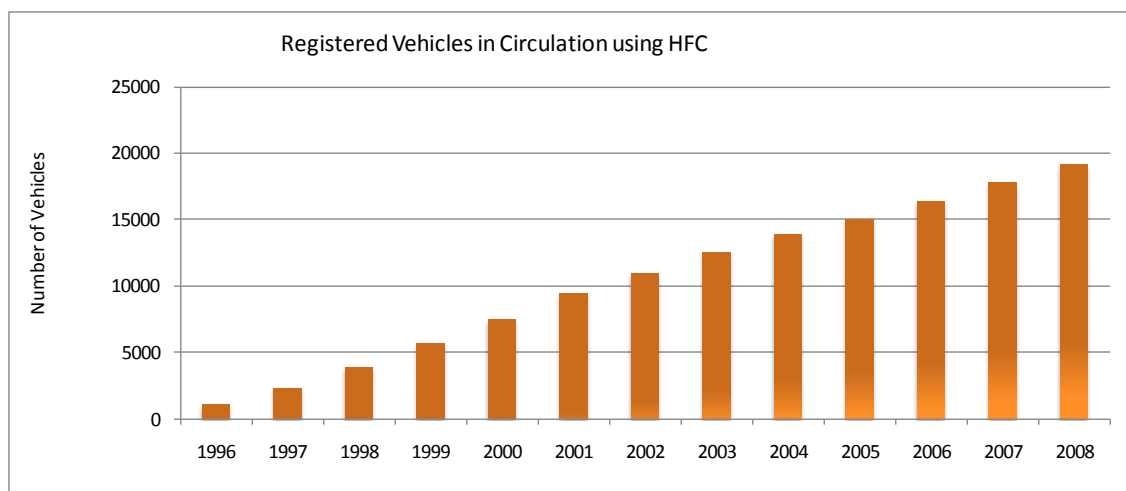
Figure 4.23 – Number of Equipments produced in Portugal (1990-2008)



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 4.24 – Number of Registered Vehicles in circulation in Portugal (1990-2008)



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% 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% (new units), 20% (stock) and up to 50% (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 4.25 – 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% 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% (data from importers) at end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90% (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.

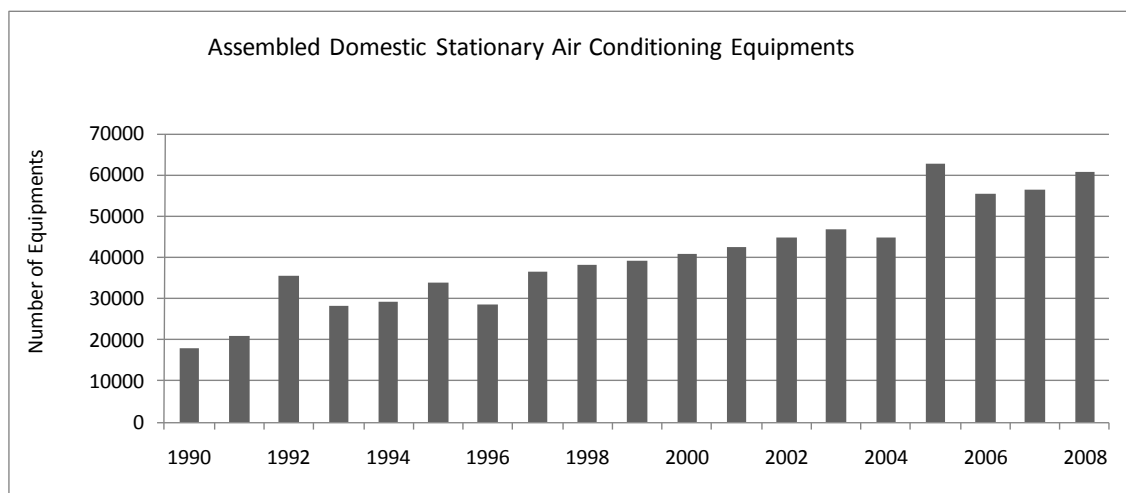
According to the available data from Luís Roriz at Higher Technical Institute (IST-UTL), the following time series (Figure 4.25), from 1990 to 2008, was adopted by the inventory. According to IAIT, 50 821 and 63 108 units were assembled, respectively, in 1990 and 1991⁸⁰.

It was assumed that 90% 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 4.25).

⁸⁰ Due to difference in magnitude order these values from IAIT are not shown in the graph

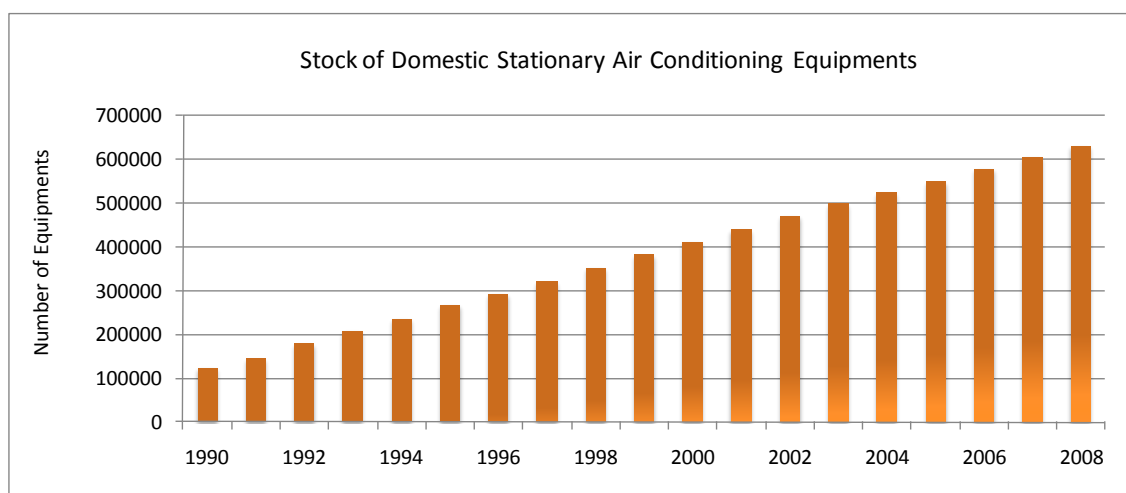
Figure 4.25 - Number of Domestic Stationary Air Conditioning Equipments assembled in Portugal in the period 1990-2008



Source: Prof. Luís Roriz (IST-UTL – Technical Superior Institute)

Annual stock of domestic stationary air conditioning equipments (see Figure 4.26) and yearly disposed units were also available from the same unpublished information received from IST-UTL.

Figure 4.26 - Annual Stock of Domestic Stationary Air Conditioning Equipments in Portugal (1990-2008)



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% 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% was assumed. Regarding stock in existence, an uncertainty of 30% was considered, and a higher value of 75% 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 4.26 – 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% (average of the values suggested by IPCC Guidelines for Chillers). A lifetime emission factor of 3% of initial charge per year, corresponding to the average value from the proposed range in IPCC GPG table 3.22, was considered.

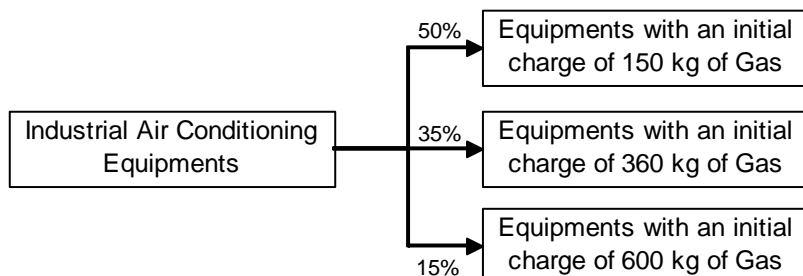
It was assumed a recovery of the gas of 10% (data from importers) at the end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90% (IPCC 1996 Revised Guidelines). It was assumed a lifetime of 15 years for the equipments (values suggested by manufacturers 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% of stocks and assembled air conditioning equipments are included in the industrial category (see Figure 4.27).

Figure 4.27 – 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 2008, was considered in the inventory.

Figure 4.28 – Number of Industrial Stationary Air Conditioning Equipments Assembled in Portugal using F-gases in the period 1993-2008

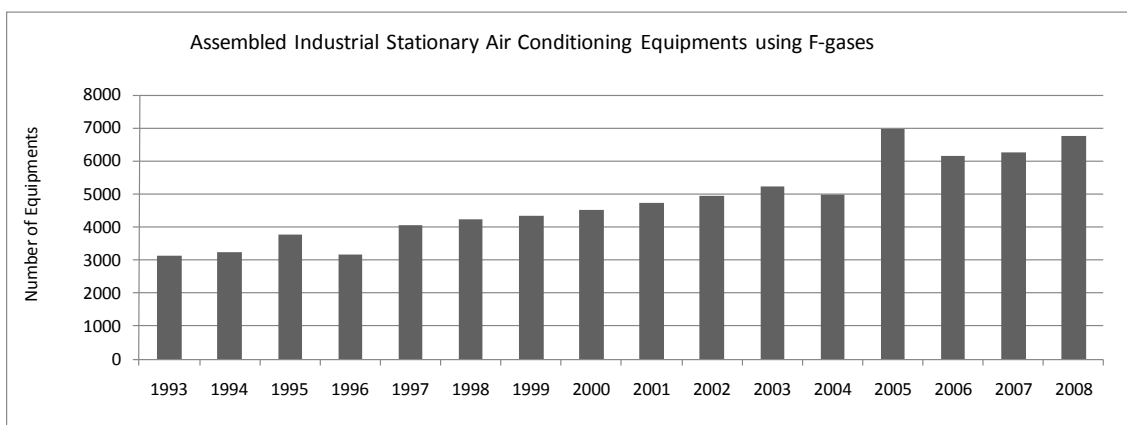
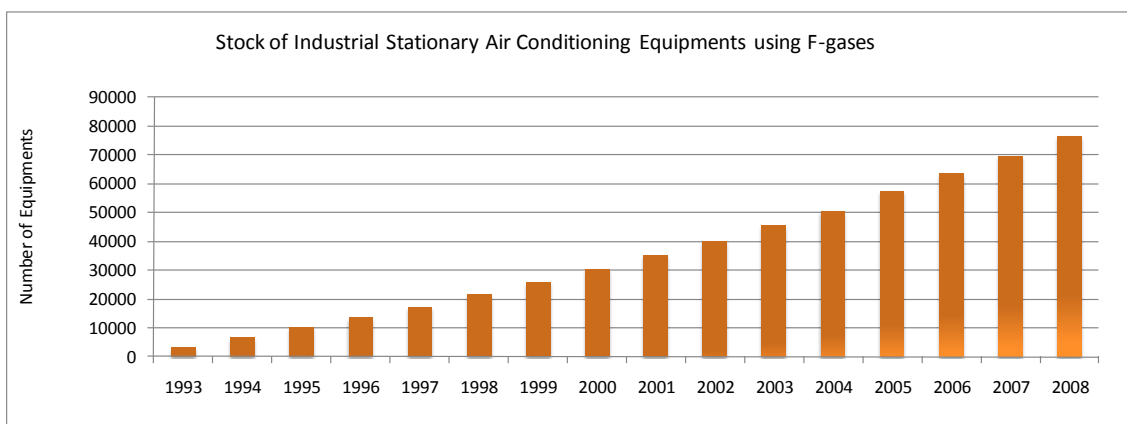


Figure 4.29 – Annual Stock of Industrial Stationary Air Conditioning Equipments in Portugal (1993-2008) using F-gases



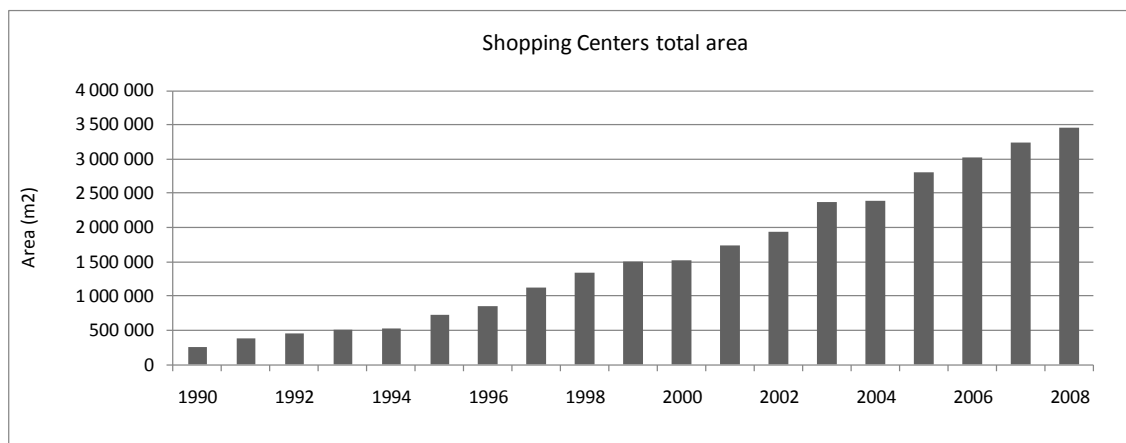
Data on the Temporal Distribution by type of gas was obtained from fluid suppliers.

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 4.30 – 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

$$\text{Oper}_{\text{Emi}}(t,j) = \text{Oper}_{\text{Emi}}(t) \sum_{y=t}^{t\text{-Lifetime}} [\text{Equip}_{\%}(t,y) \cdot \text{F-gas}_{\%}(j,y)]$$

Disposal

$$\text{Disp}_{\text{Emi}}(t,j) = \text{Disp}_{\text{Emi}}(t) [\text{Equip}_{\%}(t,t\text{-lifetime}) \cdot \text{F-gas}_{\%}(j,t\text{-lifetime})]$$

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%, corresponding to the average of the updated default range (10-20%) 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 % (default value in IPCC GPG). Variable z was set to 40% (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 4.32.

Figure 4.31 - % of Assembled Vehicles with AC by class of vehicle (1995-2008)

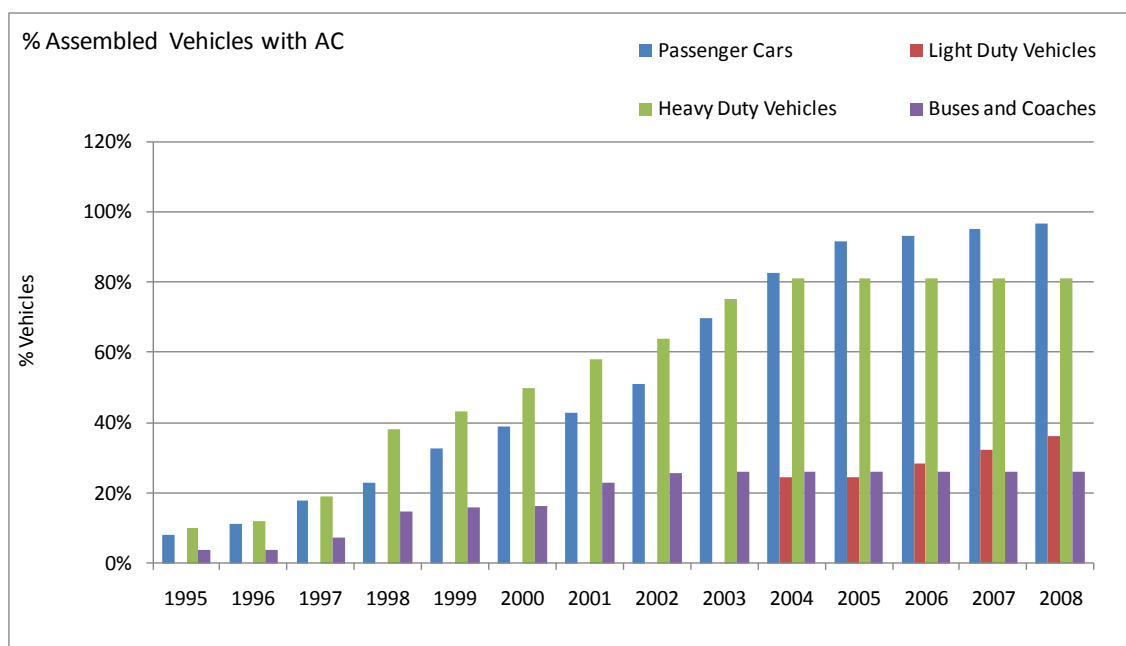
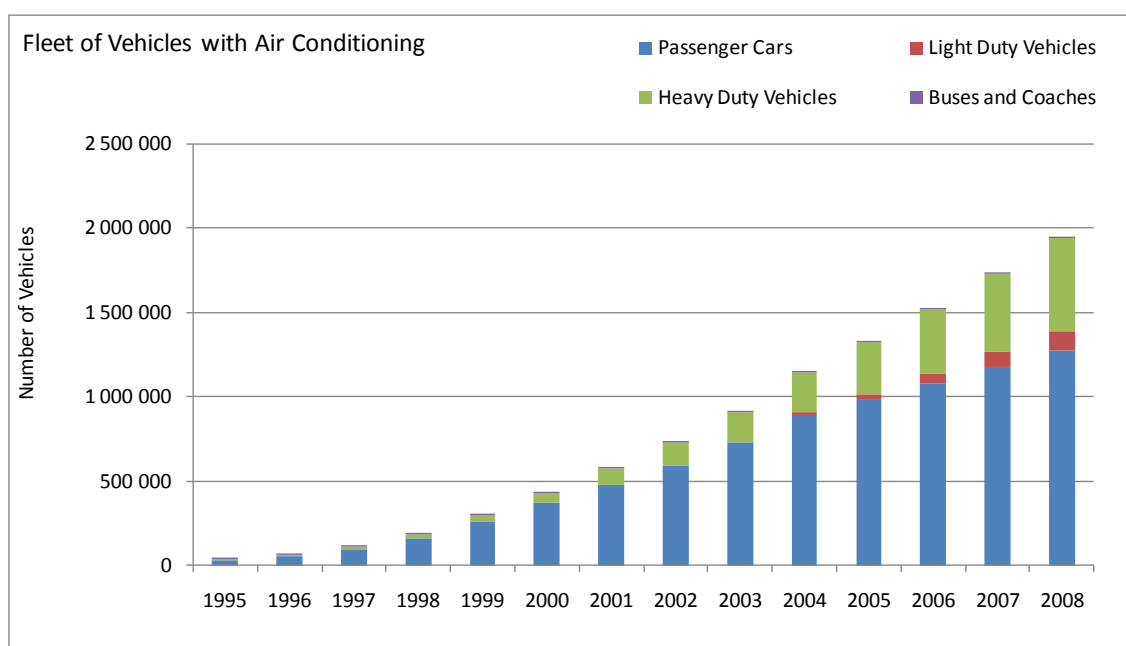


Figure 4.32 – Fleet of Vehicles equipped with AC systems (1995-2008)



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% 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 4.27 – 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:

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- 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

$$FGas_{Emi(t,j)} = FillGas_{Consumption(t)} * HFC_{\%(j,t)} * (k/100)$$

Annual losses.

$$FGas_{Emi(t)} = FGas_{inFoam(t)} * (x/100)$$

$$FGas_{inFoam(t,j)} = \sum_{y=t}^{t-Lifetime} [FillGas_{Consumption(y)} * HFC_{\%(j,y)}]$$

Where:

$FGas_{Emi(t,j)}$ - gas emission at year t of fluorine gas j;

$FGas_{Consumption(t)}$ - 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;

$FGas_{inFoam(t,j)}$ - quantity of F gas j in closed-cell existing in the country at year t⁸¹;

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 larger⁸² than the time between the first use of HFC and 2008.

⁸¹ For the time being the stock is restricted to foam filled in Portugal;

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:

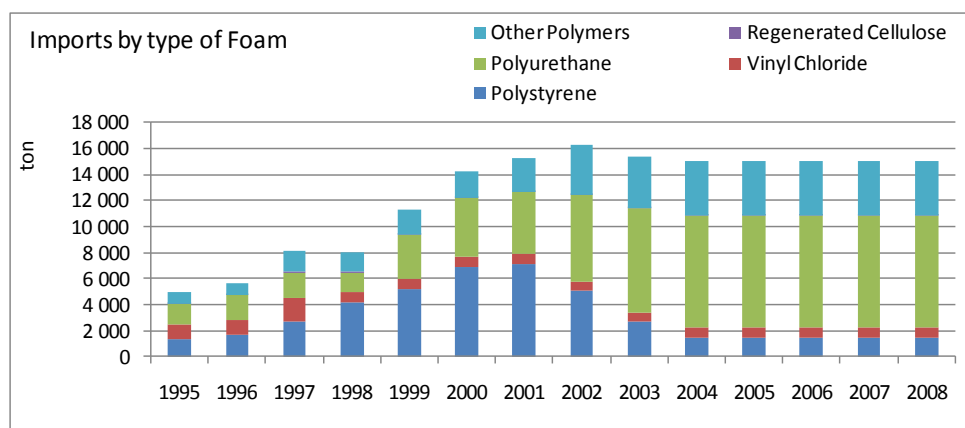
Table 4.28 - Emission Factors to estimate F gas emissions from foam losses

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

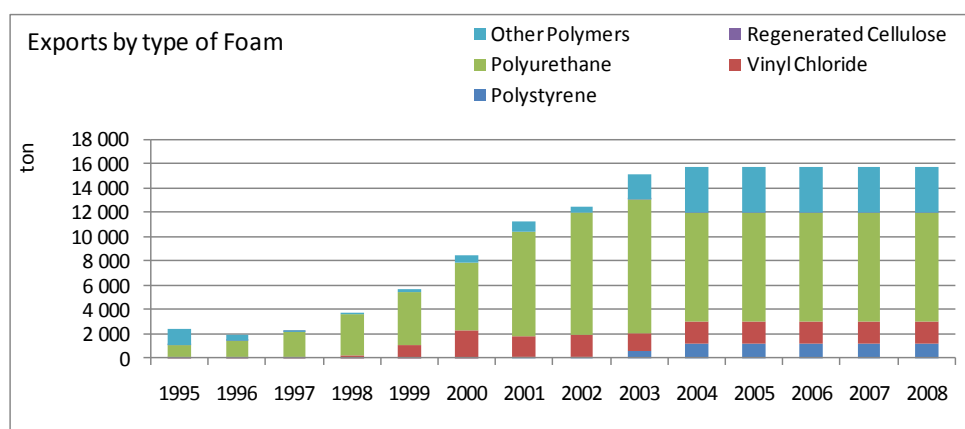
Data on amounts of imported and exported foams (see the two figures below) by type of product were obtained from DGAE (Economic Activities General Directorate) and data on produced amounts of foam were provided by DGAE and manufacturers.

Figure 4.33 – Imports by type of Foam (1995-2008)



Source: DGAE (General Directorate for the Economic Activities)

Figure 4.34 – Exports by type of Foam (1995-2008)

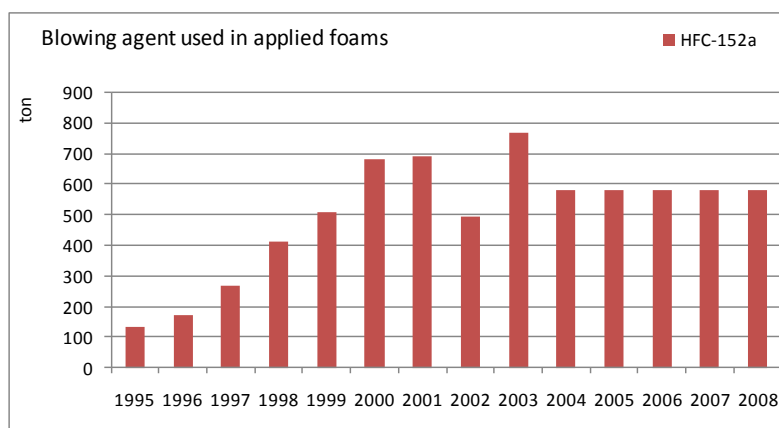


Source: DGE (General Directorate for the Enterprise)

⁸² Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

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 share of each F-gas blowing agent associated to applied foams, from 1995 to 2008, is presented in the figure below.

Figure 4.35 – Amount of blowing agents used in Applied Foams in Portugal (ton/yr)



4.3.5.12.5 Uncertainty Assessment

Improvements in the uncertainty assessment have occurred for this sector since 2007 submission. According to recommendations of GPG for country-specific top-down information, the uncertainty in fill gas consumption was maintained at 50%, but the establishment of a better foam stock time series allowed the reduction of uncertainty in operation from one order of magnitude to 100%.

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 4.29 – 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

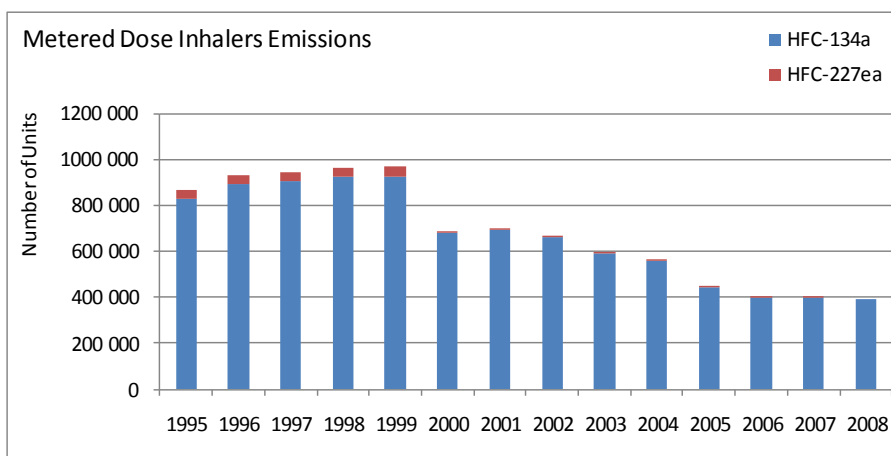
4.3.5.13.3 Emission Factors

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 1995-2008. Information on the % 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 4.36 – 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%, 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)

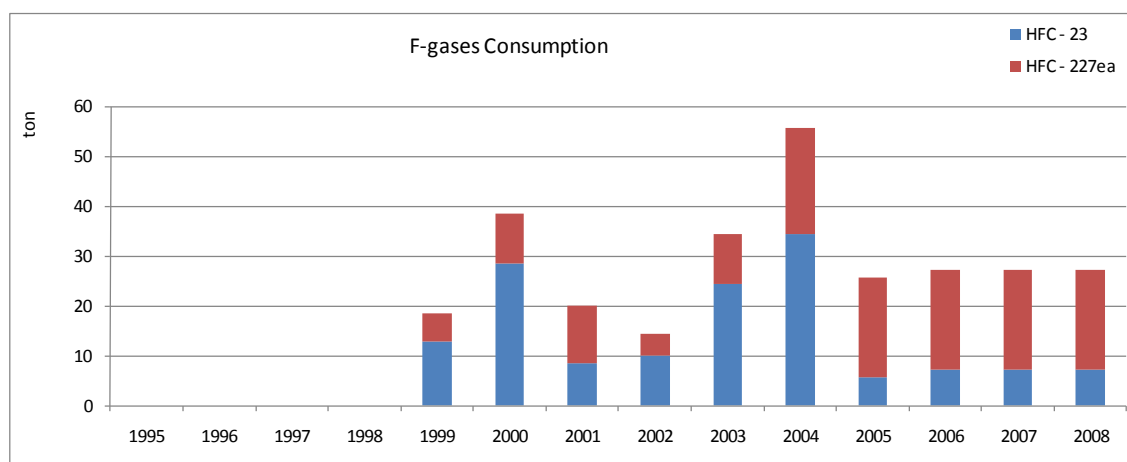
4.3.5.14.3 Emission Factors

It was assumed y equal to 99.99% and z equal to 99%. Annually, 4% 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 2005-2008 period there is a decrease in consumption values associated to market saturation.

Figure 4.37 – 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%, 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%. The final uncertainty value was set at 64%.

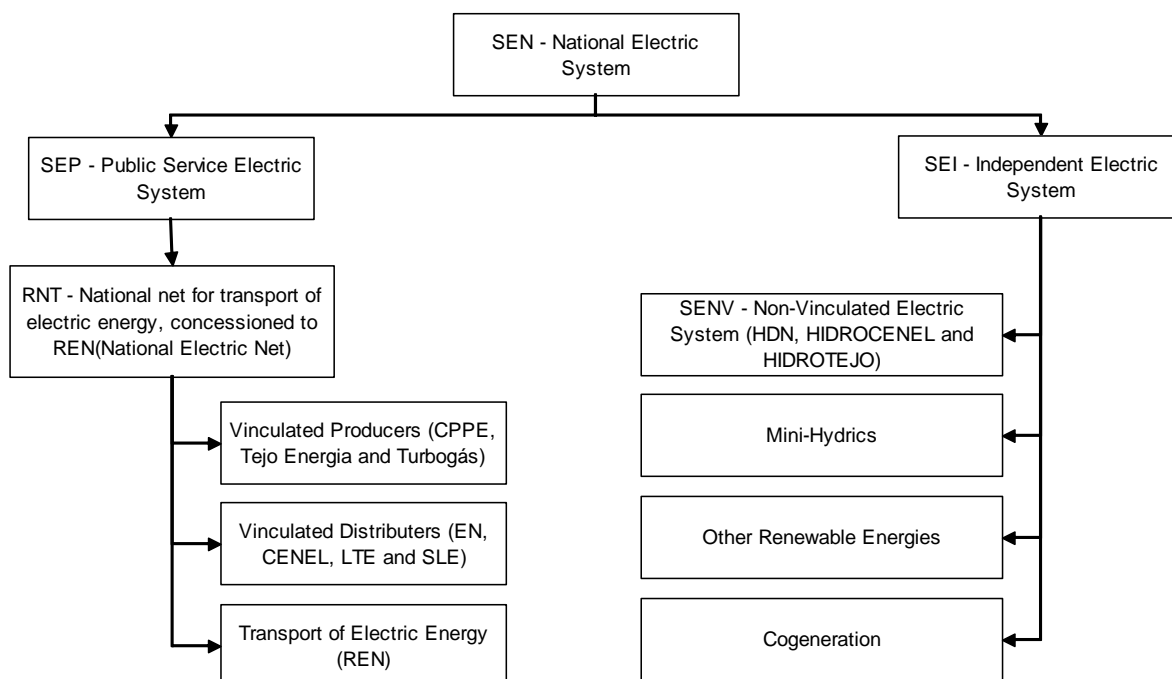
4.3.5.15 Electric Equipment

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.

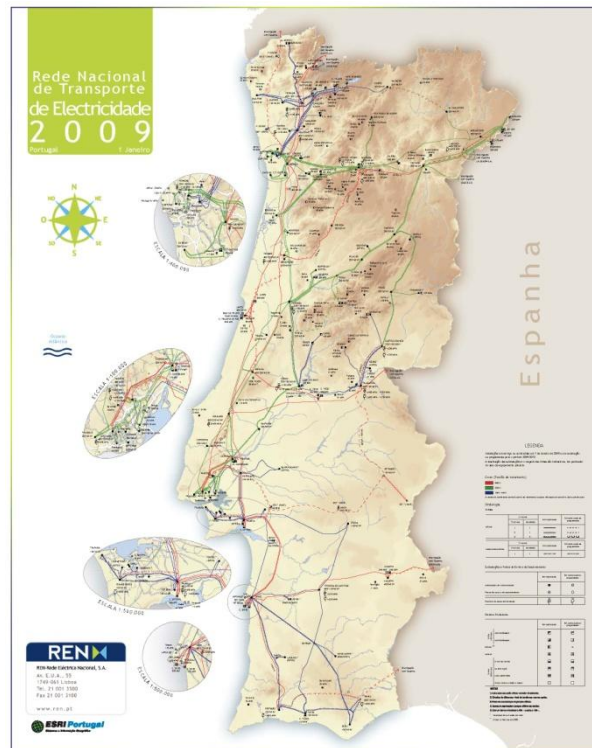
The Portuguese National Electric System (SEN) is comprised by the Public Service Electric System (SEP) and by the Independent Electric System (SEI). In the second semester of 2000 the separation between the network for electricity transport at very high voltage (concession to REN – National Electric Net) and the network for electricity distribution at low, medium and high voltage (EDP Distribuição) took place.

Figure 4.38 - 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 4.39 – 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% of Maximum Pressure);
- Loss of SF₆ below Service Pressure (<70% 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_{SF₆ (t)} - Equipment use emissions, including leakage emissions, servicing and maintenance;

Stock_{SF6 (t)} - total SF₆ gas in existence at year t in all electrical equipments;

EF – Emission Factor, corresponding to the percentage of SF₆ 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 SF₆ repositions by equipment was available for the period 2003-2008. For the period 1995-2002, an average of the estimated loss (0.38%) for the period 2003-2008 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%/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%/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% of equipments are “Sealed Pressure” and 73% are “Closed Pressure”;

the emission factors are 0.2%/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%/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%/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%/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 2000-2007. There is no data related to SF₆ stock in the period 1995-1999 and it is used an average emission factor of 0.93% 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%/year as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”.

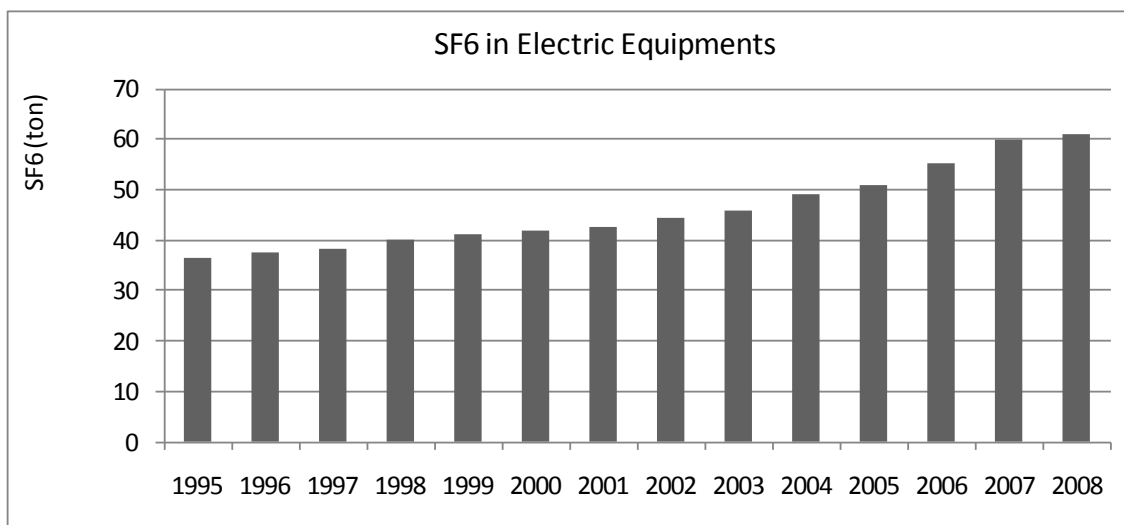
4.3.5.15.4 Activity Data

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 4.30 – 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 4.40 - Total SF6 in stock in electric equipments in Portugal (1995-2008)



4.3.5.15.5 Uncertainty Assessment

The uncertainty of 15% 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%.

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

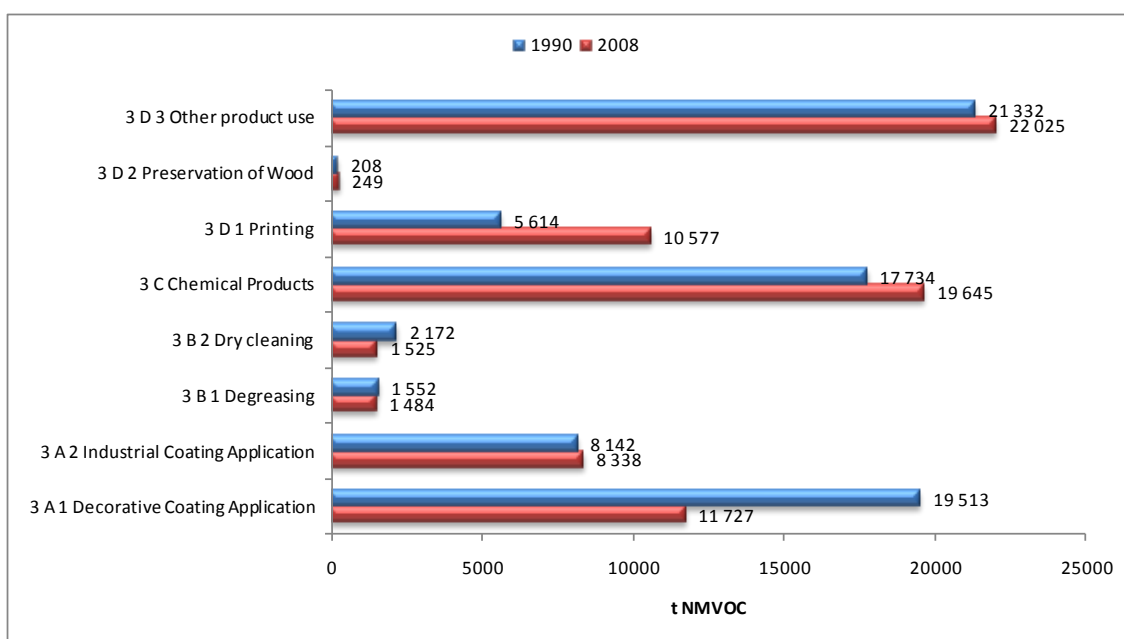
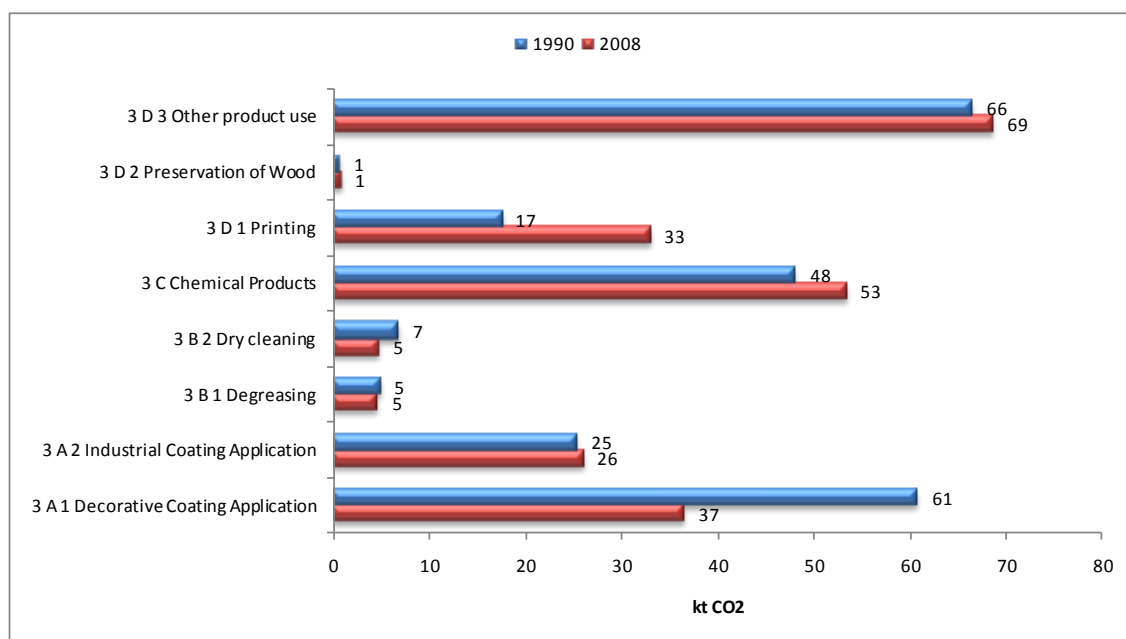


Figure 5.2 – CO₂ emissions from solvents and other product use



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 2009. Emissions reported in 2009 were based in an AD projection. This update resulted in a decrease of CO₂ emissions from solvent use.

Figure 5.3 - Differences between submissions 2009 and 2010 for CO₂ emissions from solvent use

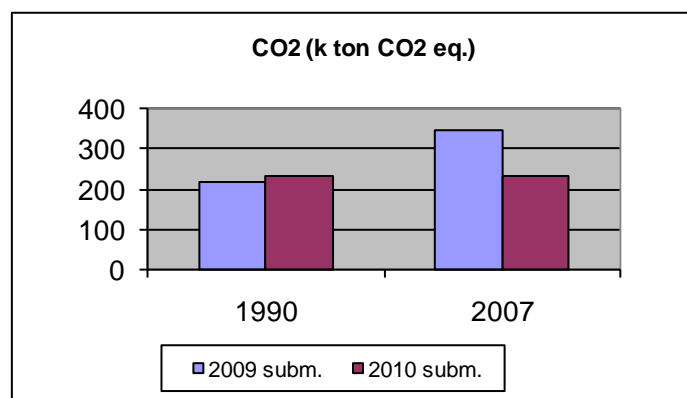


Table 5.1 - Recalculations of emissions of ghg from solvent use: differences between submissions 2009 and 2010

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2009	2010	Difference(2009	2010	Difference	2009	2010	Difference
	subm.	subm.	1)	subm.	subm.	(1)	subm.	subm.	(1)
	CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)		
	(%)			(%)			(%)		
1990									
3. Solvent and Other Product Use	219.71	233.48	6.27				NE,NO	98.58	
A. Paint Application	42.22	86.19	104.16						
B. Degreasing and Dry Cleaning	11.61	11.61	0.00				NO	NO	
C. Chemical Products, Manufacture and Proces	85.62	51.05	-40.38						
D. Other	80.27	84.63	5.44				NE	98.58	
2007									
3. Solvent and Other Product Use	346.26	235.08	-32.11				NE,NO	34.41	
A. Paint Application	104.49	68.34	-34.59						
B. Degreasing and Dry Cleaning	9.40	9.40	0.00				NO	NO	
C. Chemical Products, Manufacture and Proces	152.76	56.72	-62.87						
D. Other	79.61	100.63	26.39				NE	34.41	

(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 appearance⁸³ – 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 chapter 5.3.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).

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.

5.3.1.2 Methodology

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

⁸³ 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.

Where

$Emi_{NMVOC(y)}$ – 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 where 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 CO_{2e}.

$$U_{CO2} = NMVOC * 0.85 * (44/12)$$

where:

U_{CO2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

5.3.1.3 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.

$$EF_{NMVOC(y)} = \sum_t \left(\frac{CS_{(t,y)}}{100} \times \left(1 - \frac{AT_{(t)}}{100} \right) \times EF_{NMVOC(default)} \right)$$

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, EMEP/CORINAIR Tier 1 emission factor for industrial paint application was used. This emission factor is based on the quantity of coating applied.

Table 5.2 – NMVOC Tier 1 emission factor for industrial application (Source: EMEP/CORINAIR 2009)

NFR	NFR Title	Tier 1 EF	EF Unit
3 A 2	Industrial coating application	400	g/kg paint

5.3.1.3.1 Construction and buildings (SNAP 060103)

Table 5.3 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Construction and buildings	g/kg paint	230

Table 5.4 – Abatement technology (Source: EMEP/CORINAIR 2009)

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

Table 5.5 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
Substitution with dispersion/emulsion (2-3 wt-% solvent)	%	0	0	100	50	20
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	80

Table 5.6 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2008
Final EF	g/kg paint applied	221	170	140	105	83

5.3.1.3.2 Wood (SNAP 060107)

Table 5.7 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NM VOC
Wood	g/kg paint applied	960

Table 5.8 – Abatement technology (Source: EMEP/CORINAIR 2009)

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

Table 5.9 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
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	4.5
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	12.2
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	27.4
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	8.1

Table 5.10 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2008
Final EF	g/kg paint applied	528	528	528	528	408
Final EF	t/t	0.5	0.5	0.5	0.5	0.4
Final EF	wt %	52.8	52.8	52.8	52.8	40.8

5.3.1.3.3 Manufacture of automobiles (SNAP 060101)

Table 5.11 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NM VOC
Manufacture of automobiles: Car coating	kg/car	8

Table 5.12 – Abatement technology (Source: EMEP/CORINAIR 2009)

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

Table 5.13 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
Manufacture of automobiles-Vehicles-Process modification and substitution	% Efficiency of abatement technology mix	0	22.5	45	67.5	81

Table 5.14 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2008
Final EF Car coating	kg/car	8.0	6.2	4.4	2.6	1.5

5.3.1.3.4 Truck cabin coating (SNAP 060108)

Table 5.15 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Industrial coating application: Vehicle refinishing	kg/vehicle	8

Table 5.16 – Abatement technology (Source: EMEP/CORINAIR 2009)

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

Table 5.17 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
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

Table 5.18 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2008
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 (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Industrial coating application: leather finishing	g/kg leather	200

Table 5.20 – Abatement technology (Source: EMEP/CORINAIR 2009)

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

Table 5.21 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
Use of water based products (30 wt-% solvent content)	%	0	0	0	10	22
Add on: Thermal oxidation	%	0	0	0	0	0
Add on: Biofiltration	%	0	0	0	0	3
Uncontrolled	%	100	100	100	90	75

Table 5.22 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2008
Final EF leather finishing	g/kg leather	200.0	200.0	200.0	187.0	166.5

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, from INE, 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 – Paint Production in Portugal in ton/yr

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Produced paints	117 961	119 900	112 323	96 858	104 414	99 075	117 633	128 355	146 406	143 824	147 841	160 700	163 208	163 522	163 808	158 490	160 025	178 175

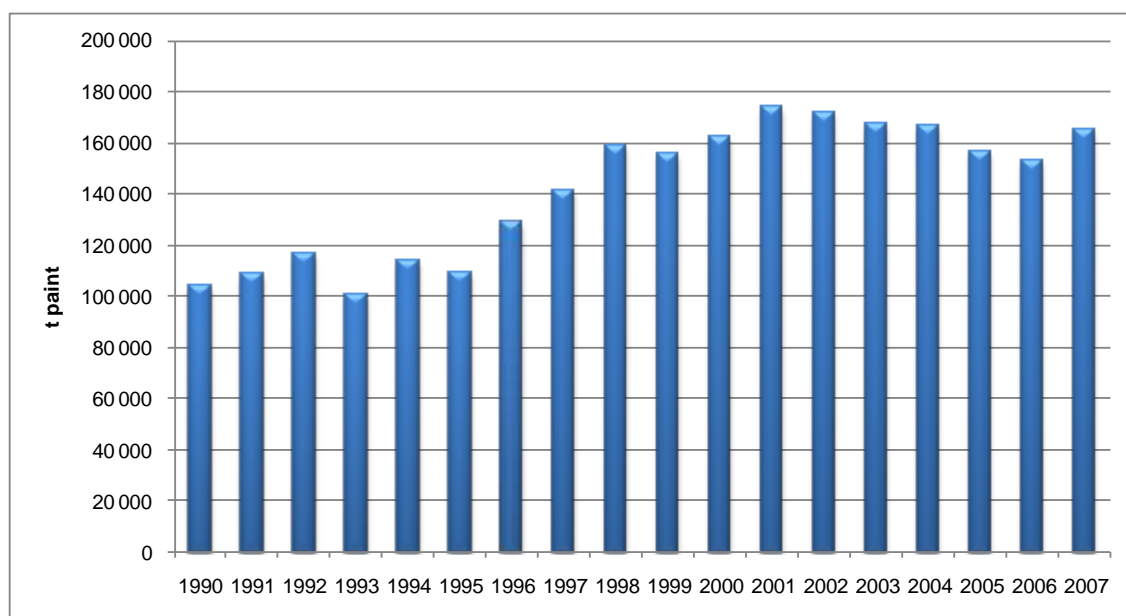
Table 5.24 – Paint import and export in ton/yr

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Import	7 679	10 340	12 211	14 431	21 986	25 084	27 845	28 980	31 912	32 230	35 434	36 885	37 990	36 398	38 680	37 097	37 371	35 624
Exports	5 336	5 626	5 785	5 415	7 534	8 130	12 854	11 614	14 670	13 622	13 823	16 171	20 545	23 827	25 973	34 089	40 749	43 510

Table 5.25 – Estimated paint consumption in ton/yr

Tipo	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total	103 903	108 405	116 372	100 867	113 624	109 554	129 078	141 292	158 718	155 481	162 565	173 761	171 827	167 086	166 434	156 726	152 911	165 345

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 construction⁸⁴.

⁸⁴ No further disaggregation by this uses is possible from available statistical information

Table 5.26 - Paint and varnish consumption by snap

SNAP	NFR Title	SNAP Title	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998
060103	Decorative coating application	Paint application: construction and buildings	t paint	10 738	10 326	9 248	8 388	8 760	8 486	9 447	9 225	7 761
060104	Decorative coating application	Paint application: domestic use (except 060107)	t paint	77 636	82 235	92 521	77 542	90 276	87 986	102 494	110 932	129 445
060101	Industrial coating application	Paint application: manufacture of automobiles	t paint	111	111	111	111	111	249	709	1 142	1 143
060107	Industrial coating application	Paint application: wood	t paint	6 508	6 824	5 583	5 917	5 567	4 061	4 813	5 057	4 626
060108	Industrial coating application	Other industrial paint application	t paint	8 475	8 475	8 475	8 475	8 475	8 475	11 609	15 400	16 351
060108	Industrial coating application	Other industrial paint application: truck cabin coating	t paint	391	391	391	391	391	391	562	523	381
060108	Industrial coating application	Other industrial paint application: leather finishing	t paint	154	154	154	154	154	154	154	154	154

SNAP	NFR Title	SNAP Title	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007
060103	Decorative coating application	Paint application: construction and buildings	t paint	7 069	8 399	7 866	7 524	7 328	7 328	7 328	7 328	7 328
060104	Decorative coating application	Paint application: domestic use (except 060107)	t paint	124 673	129 479	146 430	146 918	144 596	147 043	137 133	129 017	144 887
060101	Industrial coating application	Paint application: manufacture of automobiles	t paint	1 130	2 595	1 528	1 528	1 528	1 274	1 232	1 346	1 540
060107	Industrial coating application	Paint application: wood	t paint	3 849	2 836	3 862	3 872	3 740	2 945	2 699	2 452	2 206
060108	Industrial coating application	Other industrial paint application	t paint	19 319	20 891	14 867	12 827	10 787	8 746	9 074	13 489	10 061
060108	Industrial coating application	Other industrial paint application: truck cabin coating	t paint	391	391	391	391	391	391	562	523	381
060108	Industrial coating application	Other industrial paint application: leather finishing	t paint	154	154	154	154	154	154	154	154	154

Table 5.27 Final activity data used for paint application emission calculation

NFR	SNAP Title	Unit	1990	1995	2000	2005	2007
3 A 1	Paint application: construction and buildings	t paint	10 738	8 486	8 399	7 328	7 328
3 A 1	Paint application: domestic use (except 060107)	t paint	77 636	87 986	129 479	137 133	144 887
3 A 2	Paint application: manufacture of automobiles	n vehicles	134 109	100 170	195 309	146 340	173 864
3 A 2	Paint application: wood	t paint	6 508	4 061	2 836	2 699	2 206
3 A 2	Other industrial paint application	t paint	8 475	8 475	20 891	9 074	10 061
3 A 2	Other industrial paint application: truck cabin coating	n vehicles	9 608	2 557	6 929	6 203	5 935
3 A 2	Other industrial paint application: leather finishing	t leather	834	534	2 386	8 932	16 043

Table 5.28 Final NMVOC emission factors data used for paint application emission calculation

NFR	SNAP Title	Unit	1990	1995	2000	2005	2007
3 A 1	Paint application: construction and buildings	g/kg paint applied	220.8	170.2	140.3	104.7	90.4
3 A 1	Paint application: domestic use (except 060107)	g/kg paint applied	220.8	170.2	140.3	104.7	90.4
3 A 2	Paint application: manufacture of automobiles	kg/car	8.0	6.2	4.4	2.6	1.9
3 A 2	Paint application: wood	g/kg paint	527.9	527.9	527.9	527.9	448.0
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	173.4

5.3.1.5 *Uncertainty Assessment*

The uncertainties from the emission reported in 2010 were not calculated in time to include in this report. The uncertainties provided concerns emissions reported in 2009.

The uncertainty factor of the emission factor for NMVOC and CO₂ expresses the uncertainty of the solvent content of paints. From the information that was collected from national suppliers of paint the error for water based paints was estimated to be 350% and the error for solvent based paints is 67%. The overall uncertainty value for CO₂/NMVOC emission factor is therefore calculated to be 261% for all uses of paint.

There is a great uncertainty associated with the activity data due to the fact that was estimated at APA from production data and importation and exportation. An overall uncertainty value of 30% may be assumed.

5.3.1.6 *Recalculations*

Modifications have been made in emission estimates from this source sector since last year's submission. Updated emissions factors from EMEP/CORINAIR were used. Activity data based on IATI survey was updated for the years 2001-2007.

5.3.1.7 *Further Improvements*

Activity data based on IATI survey should be updated for the years 2008-2009.

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, rubber⁸⁵, 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.

⁸⁵ Emissions from degreasing in this industry are included under rubber processing

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.

Table 5.29 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	1992-2007
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)⁸⁶ imported to Portugal is used in dry-cleaning⁸⁷ activity and that all PER used is imported (no national production). Annual importation, which is available from INE's statistical databases on external trade from 1990 to 2002, was therefore assumed as equal to solvent use. The full time series, forecasted for the years after 2002, is presented in table below.

Table 5.30 - Annual importation/consumption of PER (Tetra-chloro-ethylene) in Portugal (ton/yr)

Parameter	Unit	1990	1995	2000	2005	2008
PER Consumption	t	2 172	1 155	1 649	1 549	1 525

Source: INE.

5.3.2.4 Uncertainty Assessment

The uncertainties from emissions reported in 2010 were not calculated in time to include in this report. The uncertainties provided concerns emissions reported in 2009.

⁸⁶ 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.

⁸⁷ There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

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

Modifications have been made in emission estimates from this source sector since last year's submission. Updated emissions factors from EMEP/CORINAIR were used. Activity data based on IATI survey was updated for the years 2001-2007.

5.3.2.6 Further Improvements

Activity data based on IATI survey should be updated for the years 2008-2009.

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:

$$Emi_{CO2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

5.3.3.3 Polymer processing

Processing of polymers to produce plastic materials involve organic compounds emission to atmosphere resulting from leakage of some monomers still present in the polymer mass, some

polymer decomposing, evaporation of additives - such as phthalic anhydride - but mostly from solvents used in the production process.

Synthetic fiber production emits NMVOC that result from solvent use, for example to dissolve the polymer prior to extrusion.

Emissions from foam blowing result from the application of hydrocarbons as blowing agents which are used as CFC substitutes.

5.3.3.3.1 Activity Data

Information about activity data for this sector is scarce and limited to year 1990, from National Statistics Institute (INE). However, because some polymers and fibers are produced in a restricted number of industrial units, confidentiality constraints avoid their publication in NIR.

5.3.3.3.2 Emission Factors

Emission factors applied to polymer processing and fiber production were set from AP42 (US-EPA), and from CORINAIR/EMEP, and are presented in next table:

Table 5.31 – Emission factors of NMVOC from Polymer Processing

Material	Polymer	NMVOC
Synthetic Fibers	Rayon	0 ^(a)
	Polyamides	3.93 ^(a)
	Polyester	0.6 ^(a)
	Polyethylene	5 ^(a)
	Polypropylene	5 ^(a)
	Vynion	150 ^(a)
	Acrylics	40 ^(a)
Plastics	Polyester	40
	PVC	40
Foam Blowing	Poly-urethane	6.0 ^(b)
	Poly-Styrene	6.0 ^(c)
^(a) USPEPA (1990) c06s09 ^(b) Rentz et al, 1993 in EMEP/CORINAIR 3r ed (File B633); ^(c) Achermann, 1992 in EMEP/CORINAIR 3r ed (File B633)		

5.3.3.3.3 Uncertainty Assessment

The uncertainty in activity data was considered high, 100%, expressing the reduced number of available years. Although an uncertainty of 50% could be considered for NMVOC/CO₂ emission factors, considering that quality rate is mostly C in original bibliographic references, the double of that value was assumed using a conservative approach and reflecting the difficulties in making a direct match between the conditions that emission factors apply and the conditions that prevail in national industry.

5.3.3.4 Rubber processing

5.3.3.4.1 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.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RUBBER(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from rubber processing (t/yr);

EF_{NMVOC} – NMVOC default emission factor for rubber processing (g/kg rubber produced);;

$Prod_{RUBBER(p,y)}$ – Production of rubber in year y (t/yr).

5.3.3.4.2 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 5.32 – NMVOC rubber processing emission factor

SNAP	Unit	NMVOC
Rubber processing	g/kg rubber produced	8

Source: EMEP/CORINAIR 2009, 3.C Chemical products, table 3-5, pp18

5.3.3.4.3 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 5.33 –Rubber processed

SNAP Title	Unit	1990	1995	2000	2005	2007
Rubber processed	t rubber	26 871	24 484	29 915	32 818	37 318

Source: INE

5.3.3.4.4 Uncertainty Assessment

The uncertainties from emissions reported in 2010 were not calculated in time to include in this report.

5.3.3.4.5 Recalculations

Modifications have been made in emission estimates from this source sector since last year's submission. Updated emissions factors from EMEP/CORINAIR were used. Activity data based on IATI survey was updated for the years 2001-2007.

5.3.3.4.6 Further Improvements

Activity data based on IATI survey should be updated for the years 2008-2009.

5.3.3.5 *Paints, Inks and Glue Manufacturing*

5.3.3.5.1 Methodology

Emissions from paints, inks and glue manufacturing were estimated according with EMEP/CORINAIR Guidebook.

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.

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

5.3.3.5.2 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 abatment technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_t \left(\frac{CS_{(t,y)}}{100} \times \left(1 - \frac{AT_{(t)}}{100} \right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatment technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatment technology t (%);

t – abatment technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

Table 5.34 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Paints, Inks and Glue Manufacturing	g/kg product	11

Table 5.35 – Abatement technology (Source: EMEP/CORINAIR 2009)

Abatement Technology	Unit	Efficiency
Use of good practices	%	27

Table 5.36 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
Use of good practices	%	0	0	0	50	80
No control	%	100	100	100	50	20

Table 5.37 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2008
Final EF	g/kg product	11	11	11	10	9

5.3.3.5.3 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 5.38 – Production of paints, inks and glue

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2007
060307	Paints manufacturing	t paint	117 961	99 075	147 841	158 490	178 175
060308	Inks manufacturing	t ink	3 677	1 166	3 266	2 262	1 769
060309	Glues manufacturing	t glue	29 666	23 451	79 466	60 524	61 785

Source: INE

5.3.3.5.4 Uncertainty Assessment

The uncertainties from emissions reported in 2010 were not calculated in time to include in this report. The uncertainties provided concerns emissions reported in 2009.

An uncertainty of 10% was considered for the activity data, a higher accuracy for production when in comparison to consumption. In the original document the emission factors are reported to have a C rate quality, which translated in uncertainty value represents 50%.

5.3.3.5.5 Recalculations

Modifications have been made in emission estimates from this source sector since last year's submission. Updated emissions factors from EMEP/CORINAIR were used. Activity data based on IATI survey was updated for the years 2001-2007.

5.3.3.5.6 Further Improvements

Activity data based on IATI survey should be updated for the years 2008-2009.

5.3.3.6 *Manufacture of Tyres*

5.3.3.6.1 Methodology

Emissions from tyre manufacturing were estimated according with EMEP/CORINAIR Guidebook.

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.

NMVOC emissions were estimated from the number of tyres produced according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC(y)} \times Tyres_{(y)} \times 10^{-6}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC emissions from manufacturing of tyres during year y (t/yr);

$EF_{NMVOC(y)}$ – NMVOC emission factor for manufacturing of tyres in year y (g/tyre);

$Tyres_{(y)}$ – Number of tyres produced in year y (n./yr);

y - year

5.3.3.6.2 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 abatment technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_t \left(\frac{CS_{(t,y)}}{100} \times \left(1 - \frac{AT_{(t)}}{100} \right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatment technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatment technology t (%);

t – abatment technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

Table 5.39 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Tyre production	g/kg tyre	10

Table 5.40 – 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 5.41 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2008
Process optimisation: Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent)	%	0	21.5	43	43	43
New processes: Use of 25% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvents)	%	0	28.5	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 5.42 – Final NMVOC emission factor

Parameter	Unit	1990	1995	2000	2005	2008
Final EF	g/kg tyre	10	7	4	4	4
Final EF	g/tyre	150	108	67	67	67

5.3.3.6.3 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 5.43 – Production of tyres

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2007
060314	Manufacture of tyres	tyres	4 218 714	5 891 971	11 605 755	14 748 990	16 824 887

Source: INE

5.3.3.6.4 Uncertainty Assessment

Uncertainties from emissions reported in 2010 were not calculated in time to include in this report.

5.3.3.6.5 Recalculations

Modifications have been made in emission estimates from this source sector since last year's submission. Updated emissions factors from EMEP/CORINAIR were used. Activity data based on IATI survey was updated for the years 2001-2007.

5.3.3.6.6 Further Improvements

Activity data based on IATI survey should be updated for the years 2008-2009.

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 2004) and EUROSTAT (2005 to 2006). For 2007 and 2008 emissions are assumed equal to 2006.

Table 5.44 – N₂O activity data (ton)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production	108	63	61	59	147	151	95	55	0	0
Import	211	193	275	193	179	181	251	340	157	164
Export	1	1	3	0	1	2	1	2	2	2
Apparent Consumption	318	255	333	252	325	330	345	393	155	162

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Production	0	0	0	0	0	0	0	0	0
Import	177	183	139	108	216	243	125	125	125
Export	5	16	0	2	2	5	14	14	14
Apparent Consumption	172	167	139	106	214	238	111	111	111

Source: INE, EUROSTAT

5.3.4.1.4 Uncertainty Assessment

No uncertainty assessments have been made for this category.

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

This is the first time this source-specific category is reported.

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).

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.

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 2008.

Table 5.45 – 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 5.46 – Consumption of inks in printing industry

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2007
060403	Printing Industry	t ink	5 372	5 372	9 290	8 722	10 649

Source: INE

5.3.4.5.2.5 Uncertainty Assessment

The uncertainties from emissions reported in 2010 were not calculated in time to include in this report. The uncertainties provided concerns emissions reported in 2009.

It was considered that the activity data time trend have a medium quality due to the use of different sources of information for its determination. An overall uncertainty of 25% was considered. Concerning the emission factor for CO₂, or NMVOC, the original emission factors had quality rates that varied from B to C and, therefore, the worst case uncertainty of 50% was considered, in conservative way.

5.3.4.5.2.6 Recalculations

Modifications have been made in emission estimates from this source sector since last year's submission. Updated emissions factors from EMEP/CORINAIR were used. Activity data based on IATI survey was updated for the years 2001-2007.

5.3.4.5.2.7 Further Improvements

Activity data based on IATI survey should be updated for the years 2008-2009.

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 olives⁸⁸. 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.

⁸⁸ Classified as virgin olive oil

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.

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);

$MakeUp_{Solvents}(y)$ - 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 carbon⁸⁹ 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 5.47, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole 1990-2007 time period. Because in IAPI survey (1992-2000) it was not possible to distinguish production of edible oils from production of non-edible soils, it was decided just to use a global emission factor.

⁸⁹ From hexane chemical formula

Table 5.47 – 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 production data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2000. Production data for 2001-2007 was forecasted at APA from previous years. All annual values are reported in Table 5.48, together with olive oil production, although that product does not cause NMVOC emissions. Total grain processed is also reported in Table 5.48. Total extraction of edible and non-edible oil is also shown in table below.

Table 5.48 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1990-2007)

Parameter	1990	1995	2000	2005	2007
Olive Oil Production	9 883	8 368	16 948	NA	NA
Oil refining	201 569	223 330	136 230	115 230	108 351
Grain processed	672 382	1 042 605	968 898	1 142 098	1 173 336

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

No modifications were made to estimates of emissions from this source since last submission.

5.3.4.5.4 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.

$$Cons_{Nat} = Prod_{Nat} - Exp$$

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 5.49 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5.50). 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 5.49 - 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 5.50 - 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 5.51 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	1992 - 2007
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 an 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 5.52 - 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 Perfumes and Cosmetics Use

5.3.4.5.6.1 Methodology

Lipsticks, brilliantine, beauty creams and milks, depilatories, deodorants, hair sprays, sun lotions, tanner products, shampoos, tooth-cleaning, hair coloration and nail varnishes, among others, were considered in perfume, personal hygiene or cosmetic product. Emissions are estimated from:

$$\text{NMVOC} = \text{Use} * \text{FE}_{\text{Prod+use}}$$

where:

NMVOC - Emissions of NMVOC associated to the production and use of perfumes (ton)

Use - Use of perfumes (ton);

$\text{FE}_{\text{Prod+use}}$ - Emission factor associated to the production and use of perfumes (ton)

5.3.4.5.6.2 Emission Factors

Since there are no available VOC emission factor for this activity an emission factor for VOC emission during the production and the use of these products was calculated. It was estimated by the ratio of the amount of solvents consumed during the manufacture process with the amount of perfumes, personal hygiene and cosmetic products manufactured.

$$\text{FE}_{\text{Prod+use}} = \text{Solvents} / \text{National Production}$$

where:

$\text{FE}_{\text{Prod+use}}$ = Emissions of NMVOC associated to consumption of perfume and cosmetics use (ton)

Solvents = Solvent content of perfumes (ton)

National Production = National production values of perfumes (ton)

Table 5.53 - Calculated emission factor (kg/ton).

1989	1990	1991	Average
162	170	184	172

5.3.4.5.6.3 Activity Data

Table 5.54 - Activity data associated to Perfumes Use (ton)

Year	1990	1991	1992-2007
National Production (ton)	21 587	19 540	20 957
Imports (ton)	10 830	15 210	13 020
Exports (ton)	3 829	4 201	4 015
Solvents (ton)	3 665	3 590	3 595

Source: National Statistics Institute (INE)

5.3.4.5.6.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors. It was assumed to be 100% in both cases.

5.3.4.5.6.5 Recalculations

No recalculations were made for this source sector.

5.3.4.5.7 Waxes and polishing products

5.3.4.5.7.1 Methodology

The Methodology is similar to the one that was used for Perfume Use.

5.3.4.5.7.2 Emission Factors

The national emission factor, obtained in the same mode, was (kg/ton):

Table 5.55 – Emission factors

1989	1990	1991	Average
525	299	293	372

5.3.4.5.7.3 Activity Data

Table 5.56- Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2007
National Production (ton)	3 963	3 781	3 312
Imports (ton)	12 390	12 429	12 410
Exports (ton)	983	403	693
Solvents (ton)	1 185	1 106	1 147

Source: National Statistics Institute (INE)

5.3.4.5.7.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors. It was assumed to be 100% in both cases.

5.3.4.5.7.5 Recalculations

No recalculations were made for this source sector.

5.3.4.5.8 Soaps and Detergents

5.3.4.5.8.1 Methodology

The Methodology is similar to the one that was used for Perfume Use.

5.3.4.5.8.2 Emission Factors

The national emission factor (kg/ton), obtained in the same mode kg/ton is:

Table 5.57 – Emission factors

1990	1991	Average
2	2	2

5.3.4.5.8.3 Activity Data

Table 5.58 - Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2007
National Production (ton)	209 575	185 681	197 628
Imports (ton)	57 488	59 831	58 660
Exports (ton)	34 710	23 972	29 341
Solvents (ton)	461	426	437

Source: National Statistics Institute (INE)

5.3.4.5.8.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors. It was assumed to be 100% in both cases.

5.3.4.5.8.5 Recalculations

No recalculations were made for this source sector.

5.3.4.5.9 Uses of solvents from biomass

There are two organic substances used as solvents: ethanol and rosin derivatives that may be emitted to atmosphere when used. Emissions may be estimated from consumption of these substances. However, in some activities, such as beverage and food industry, use of alcohol does not contribute to air emissions because it is ingested, and it is not included in emissions.

5.3.4.5.9.1 Methodology

Emissions are therefore estimated from:

$$\text{NMVOC} = \text{TotalConsumption} - \text{Cons}_{\text{NONEMI}}$$

Where

NMVOC – Emission (ton/yr);

TotalConsumption – Total consumption of biological solvent in all activities (ton/yr);

Cons_{NONEMI} – Consumption of biological solvents in activities where solvents are not emitted to atmosphere (ton/yr).

For rosin derivatives total consumption is obtained from industrial production corrected from imports and exports:

$$\text{TotalConsumption} = \text{IndustrialProduction} + \text{Imports} - \text{Exports}$$

Because these two compounds have a biological origin NMVOC emissions are not added to ultimate carbon dioxide emissions accounting.

5.3.4.5.9.2 Activity Data

Industrial production of ethanol is presented in Table 5.59, which may be considered, neglecting foreign trades, equal to the consumption of alcohol. Industrial consumption of alcohol in 1989 is shown in Table 5.60 by use. Statistical data is from INE in both cases.

Table 5.59 - Industrial production of ethanol (ton).

1989	1990	1991
7 754	9 941	8 027

Table 5.60 - Industrial consumption of alcohol in 1989 (ton).

Use	ton
Food and beverage industry	2 185
Manufacture of perfumes, personal hygiene and cosmetic products	1 913
Manufacture of waxes and polishing products	235
Total	4 333

Rosin derivatives include turpentine oil, α -pinene, etc. The annual production of rosin derivatives is presented in Table 5.61 and foreign trades values in Table 5.62. Statistical information is from the National Statistical Institute (INE).

Table 5.61- Rosin derivatives production (ton).

1989	1990	1991
13 362	12 145	11 299

Table 5.62 - Foreign trades of rosin derivatives (ton).

Imports (ton)		Exports (ton)	
1990	1991	1990	1991
722	700	11 558	13 692

5.3.4.5.10 Other uses of synthetic solvents from fossil fuels

5.3.4.5.10.1 Methodology

$$\text{NMVOC} = \text{Produced Solvents}$$

where:

NMVOC = Emissions of NMVOC (ton)

Consumed Solvents = quantity of produced solvents(ton)

The calculation of Global CO₂ emissions is made according to:

$$U_{CO_2} = NMVOC * 0.85 * (44 / 12)$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

5.3.4.5.10.2 Activity Data

Table 5.63 - Synthetic solvents consumption in other industries (ton)

Year	1990	1991	1992 - 2004
Solvents (ton)	3 885	4 014	3 950

Source: General Directorate for Geology and Energy (DGEG)

5.3.4.5.10.3 Uncertainty Assessment

Activity data is very scarce and doubtful and the overall uncertainty was assumed to be 1000%.

5.3.4.5.10.4 Recalculations

No recalculations were made for this source sector.

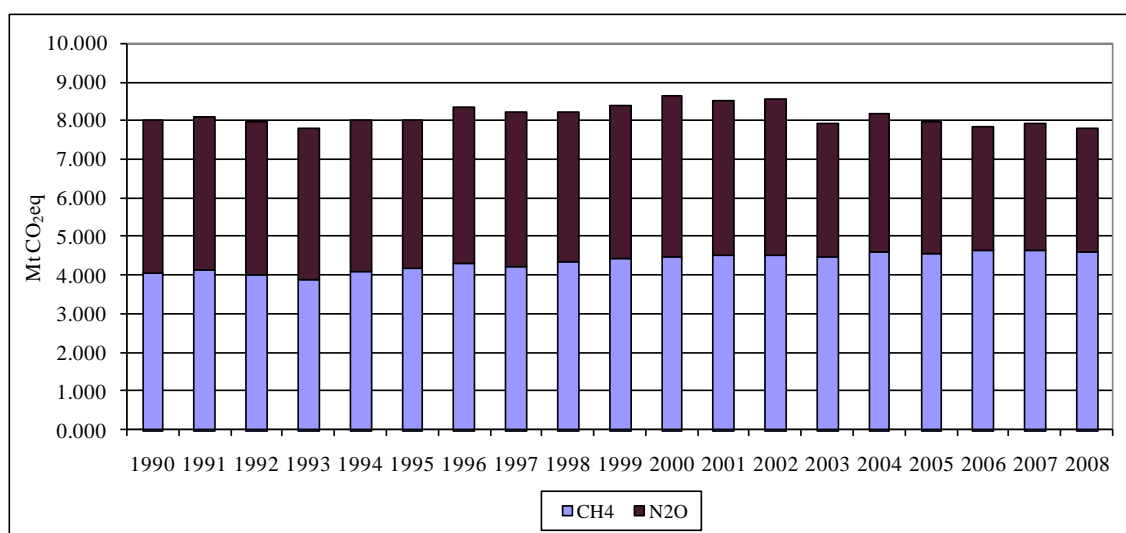
6 AGRICULTURE (CRF 4.)

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). Emissions of N₂O resulting from the liberation of carbon from organic matter in soils is also discussed in chapter LULUCF, although emissions are reported in CRF category 4, Agriculture (CRF table 4Ds1).

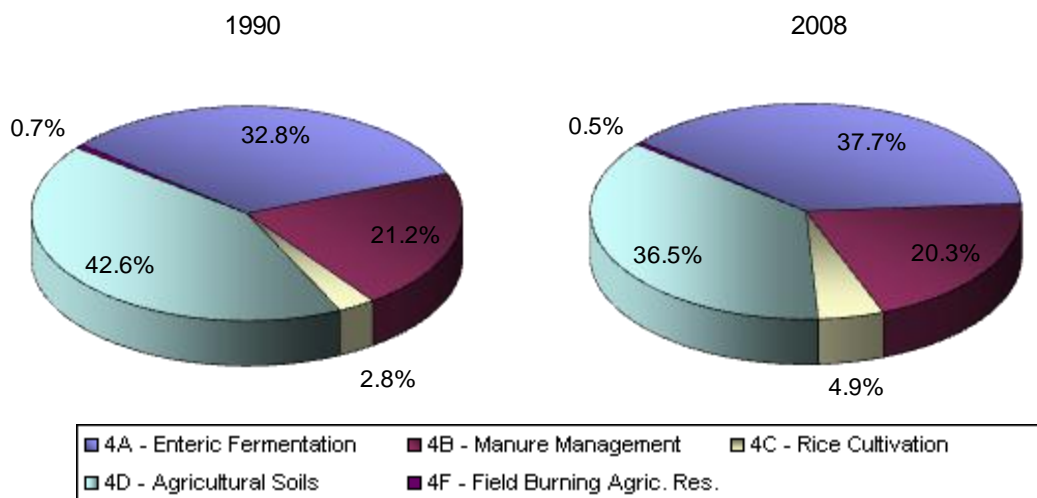
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 13.6% in 1990 to 10.0% in 2008. This decrease in importance is followed by a decrease of 2.5% in the total emissions from 1990 to 2008: 8.0 Mton of CO₂eq in 1990 and 7.8 Mton CO₂eq in 2008 (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 50.7% in 1990 to 59.1% in 2008.

Figure 6.1 – Total Greenhouse Gas Emissions from Agriculture. Trends by GHG (1990-2008)



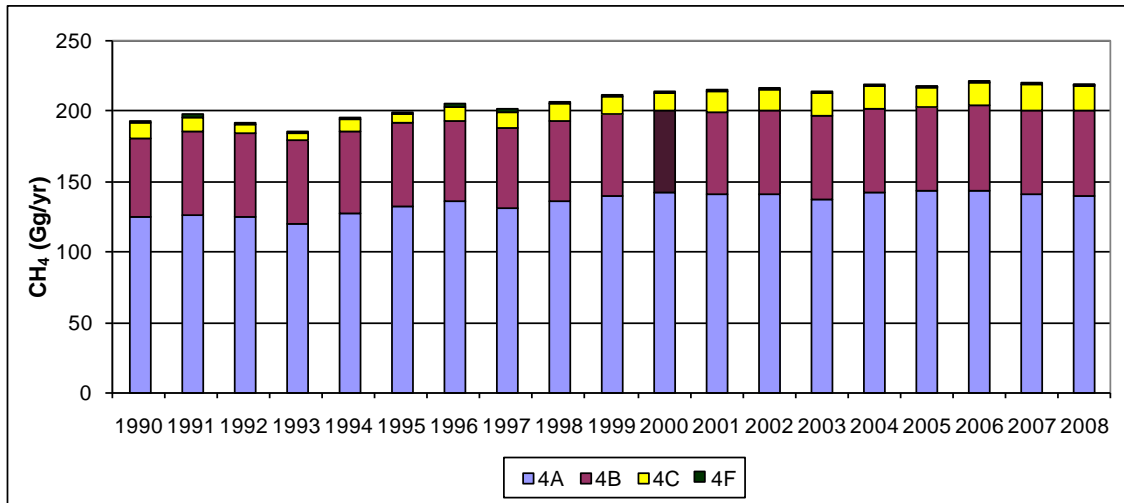
The majority of emissions from agriculture are the result of only 3 sub-source sectors. Methane emissions from Enteric Fermentation are the prevalent in 2008 followed by Agriculture Soils, and Manure Management (Figure 6.2).

Figure 6.2 - Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2008



Emissions of CH₄ from agriculture have increased 10.5% from 1990 to 2008 (Figure 6.3). Enteric Fermentation was responsible, in 2008, for 63.9% of the sectoral emissions and Manure Management accounted for 27.3% of the sectoral emissions in the same year. The remaining 8.8% of emissions result mostly from rice cultivation, with only a very small contribution from field burning of residues, only 0.4% of total emissions in the same year.

Figure 6.3 - Methane emissions from agriculture (1990-2008)

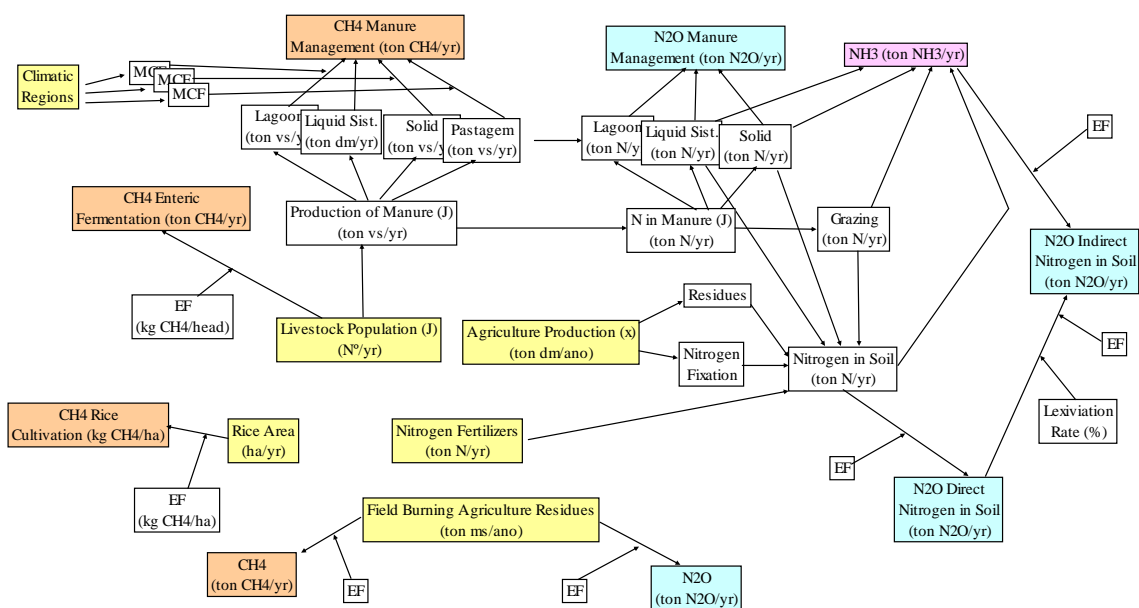


Following an opposite trend, N₂O emissions have decreased by 19.1% from 1990 to 2008 (Figure 6.4). Nevertheless, it is visible a major increase from 1990 to 2002 while the subsequent decrease was the result of a drought period that occurred in 2003 and 2004, with the consequent decrease in agricultural production and use of fertilizers. The great majority of emissions in 2008 were associated with direct and indirect emissions from agricultural soils (89.3%), manure management is responsible for 10.2% of emissions, while the small remaining fraction results from field burning of agricultural residues (0.5%).

Stacked bar chart showing N_2O emissions (Gg/yr) from 1990 to 2008. The y-axis ranges from 0 to 16 Gg/yr. The legend indicates three categories: 4B (dark blue), 4D (light blue), and 4F (black). Emissions are relatively stable until 2003, then show a general downward trend.

Year	4B (Gg/yr)	4D (Gg/yr)	4F (Gg/yr)	Total (Gg/yr)
1990	1.7	11.0	0.0	12.7
1991	1.7	11.0	0.0	12.7
1992	1.7	10.9	0.0	12.6
1993	1.6	10.9	0.0	12.5
1994	1.6	11.0	0.0	12.6
1995	1.6	10.7	0.0	12.3
1996	1.6	11.5	0.0	13.1
1997	1.6	11.4	0.0	13.0
1998	1.6	10.9	0.0	12.5
1999	1.6	11.1	0.0	12.7
2000	1.6	11.8	0.0	13.4
2001	1.6	11.4	0.0	13.0
2002	1.6	11.5	0.0	13.1
2003	1.3	9.9	0.0	11.2
2004	1.3	10.2	0.0	11.5
2005	1.2	9.8	0.0	11.0
2006	1.2	9.0	0.0	10.2
2007	1.2	9.4	0.0	10.6
2008	1.1	9.3	0.0	10.4

Figure 6.5 - Overview of Methodology



6.2 Recalculations

- Revision of the Nitrogen Excretion rates for all animal types;
- Revision of the manure management system shares for each animal type;

- General update of livestock time series (2007);
- Revision of the livestock time series for Hens, Broilers and Rabbits (1990-2007);
- Revision of the agriculture area and crop data from INE (2007);
- Full time series revision of the agriculture area and crop data from FAO (2007);
- Fertilizers consumption update for 2007.

Figure 6.6 - Differences between submission 2009 and submission 2010 for CH₄ and N₂O emissions from agriculture

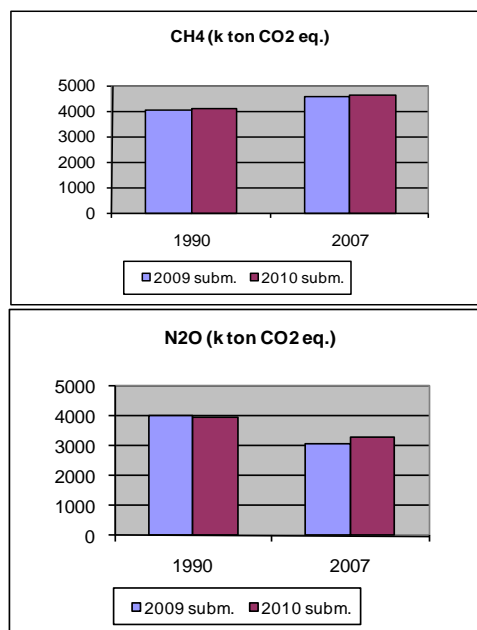


Table 6.1 – Recalculations. Differences between submission 2009 and submission 2010 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES				CO ₂			CH ₄			N ₂ O		
				2009 subm.	2010 subm.	Difference (1)	2009 subm.	2010 subm.	Difference (1)	2009 subm.	2010 subm.	Difference (1)
				CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)			CO ₂ equivalent (Gg)		
1990												
4.	Agriculture						4,054.76	4,076.04	0.52	4,033.58	3,962.03	-1.77
4.A.	Enteric Fermentation						2,621.88	2,637.22	0.59			
4.B.	Manure Management						1,175.66	1,181.60	0.51	575.15	519.54	-9.67
4.C.	Rice Cultivation						226.76	226.76	0.00			
4.D.	Agricultural Soils						NE,NO	NE,NO		3,436.64	3,420.70	-0.46
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	
2005												
4.	Agriculture						4,560.48	4,645.59	1.87	3,077.82	3,299.37	7.20
4.A.	Enteric Fermentation						2,979.37	2,971.13	-0.28			
4.B.	Manure Management						1,169.55	1,264.04	8.08	572.64	339.30	-40.75
4.C.	Rice Cultivation						391.88	390.78	-0.28			
4.D.	Agricultural Soils ⁽²⁾						NE,NO	NE,NO		2,488.53	2,943.44	18.28
4.E.	Prescribed Burning of Savannas						NO	NO		NO	NO	
4.F.	Field Burning of Agricultural Residues						19.67	19.64	-0.16	16.64	16.63	-0.07
4.G.	Other						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.

6.3 Source categories

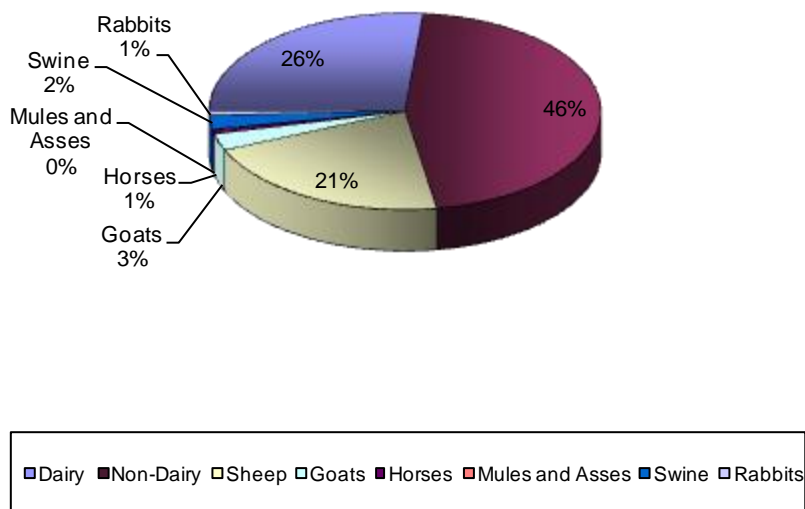
6.3.1 CH₄ Emissions from Enteric Fermentation in Domestic Livestock (CRF 4.A.)

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 is 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% to 30% of total CH₄ emissions from Enteric Fermentation, while non-dairy cattle represents about 39 to 46% of total CH₄ from enteric fermentation. Together, in 2008 cattle was responsible for about 72% of total CH₄ emissions from enteric fermentation.

Figure 6.7 - Relative Importance of emissions of CH₄ from Enteric Fermentation per each animal species in 2008



Sheep is also an important source of methane, for which emissions have oscillated between 20.8% and 23.6% of total CH₄ from Enteric Fermentation. Emissions from goats were 2.5 to 4.4% of total enteric fermentation and swine represented 2.2 to 3.0% of emissions. Total emissions of methane for all other species varied between 1.7 and 2.9%, for the same period and have less importance.

6.3.1.2 *Methodology*

Emissions were estimated for each animal type⁹⁰ 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;

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.

⁹⁰ 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.

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_{CH₄} - 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)):

$$EF_{CH_4} = 0.0126 * Y + 40.207 \quad (r^2 = 0.961)$$

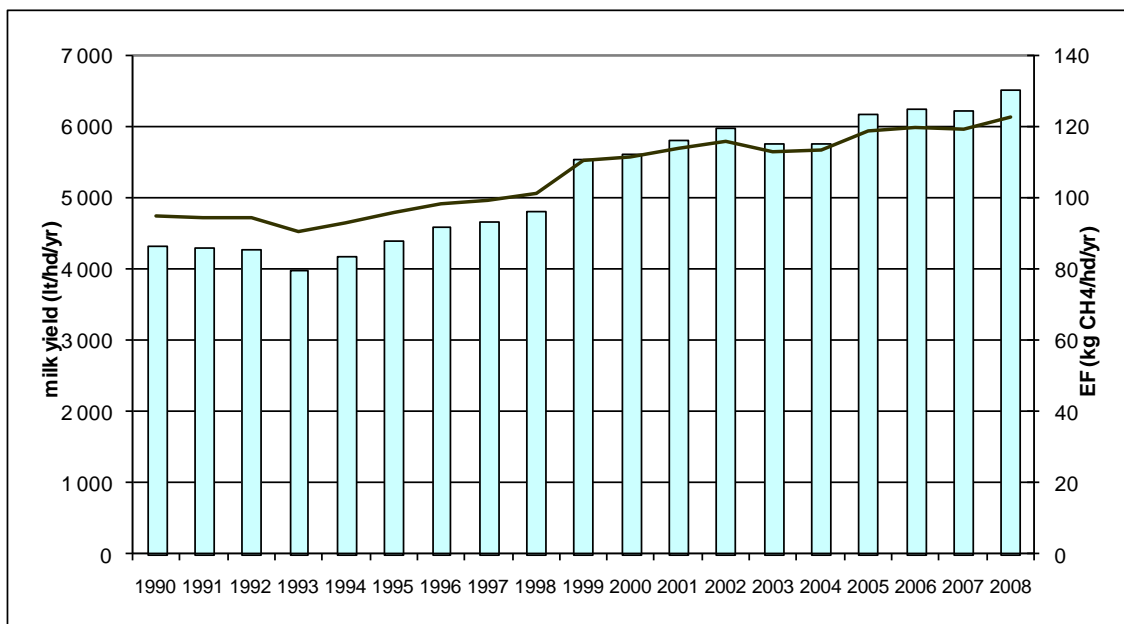
Where,

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 production⁹¹, 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) (1990-2008)



Assuming a constant methane conversion rate of 0.6% (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 16.9 kg dm/hd/day, in 2008. This trend in increase in the feed intake was used, in a consistent way, in the determination of the annual manure

⁹¹ The same time series used in the inventory but not averaged over 3 years.

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% 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.

	Beef Calfs
<1 yr	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:

$$\begin{aligned}
 NE_m &= CF_i * (Weight)^{0.75} \\
 NE_a &= C_a * NE_m \\
 NE_w &= 0.10 * W_{hour} \\
 NE_g &= 4.18 * \{0.0635 * [0.891 * (Weight * 0.96) * (478/(C_g * MW))]^{0.75} * (WG * 0.92)^{1.097}\} \\
 NE_l &= milk_{Yield} * (1.47 + 0.40 * Fat) \\
 NE_p &= C_{pregnancy} * NE_m
 \end{aligned}$$

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.

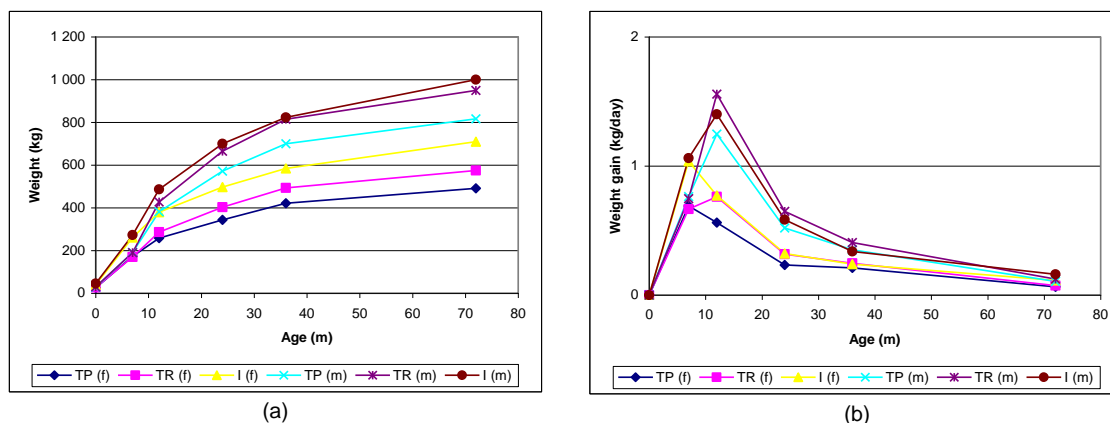
For each cattle breed the values chosen for parameters, such as weight, weight gain and feeding situation, were established from the available information. Three different cattle types were considered: (1) Imported breeds; (2) Traditional breeds on pasture; (3) Traditional breeds on range⁹². The difference between traditional animals on pasture and range depends on the

⁹² Imported breeds are Charolês; Limousine; Simmental Fleckvieh and Salers. Breeds in traditional pasture are: Arouquesa, Barrosã, Marinhova, Maronesa, Minhota/ Galega, Cachena, Ramo Grande and Mirandesa. Traditional range breeds are: Alentejana, Garvonesa, Brava, Mertolenga and Preta.

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 factor⁹³. The average values of the parameters and the average values of the values calculated are presented in Table 6.4 though Table 6.7.

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	NEa (MJ/day)	Cg	NEg (MJ/day)
Beef calfs (<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

⁹³ 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 6.5 – 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)	8.0
F (Fat content of Milk) (%)	4
NE _i (MJ/day)	3.8
C _{pregnancy}	0.1
NE _p (MJ/day)	3.5

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

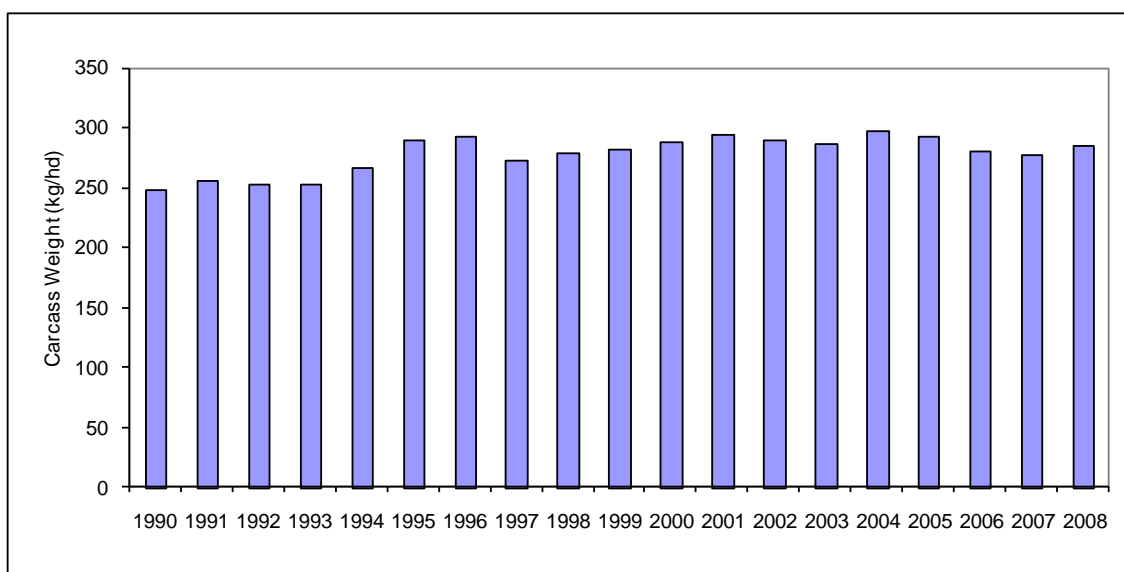
Table 6.7 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Ym) and Emission Factor of CH₄ emissions from Enteric Fermentation for non-dairy cattle. Weighted averages from individual breeds.

sub-class	NE (MJ/day)	NEma/DE	NEga/DE	DE (%)	GE (MJ/day)	FI (kg dm/day)	Ym	FE CH ₄ (g/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 2008, 10.9% 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 (1990-2008)



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

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 twelve⁹⁴ native Portuguese breeds of sheep and the five native Portuguese breeds of goats⁹⁵. Three imported breeds of sheep⁹⁶ 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:

⁹⁴ 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.

⁹⁵ Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

⁹⁶ Assaf, Ile de France and Merino Precoc.

$$\begin{aligned} NE_m &= CF_i * (Weight)^{0.75} \\ NE_a &= C_a * Weight \\ NE_g &= \{WG_{Lamb} * [a + b * BW]\} \\ NE_l &= milk_{Yield} * EV_{milk} / 365 \\ NE_p &= C_{pregnancy} * NE_m \\ NE_{wool} &= Wool_{Prod} * EV_{wool} / 365 \end{aligned}$$

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:

$$\begin{aligned} NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\ NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\ GE &= \{[(NE_m + NE_a + NE_l + NE_p)/(NE_{ma}/DE)] + [(NE_g + NE_{wool}) / (NE_{ga}/DE)]\} / (DE/100) \\ FI &= GE / ED \end{aligned}$$

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 $a + b \cdot BW$, 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 6.8 – 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	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	-

Table 6.9 – 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

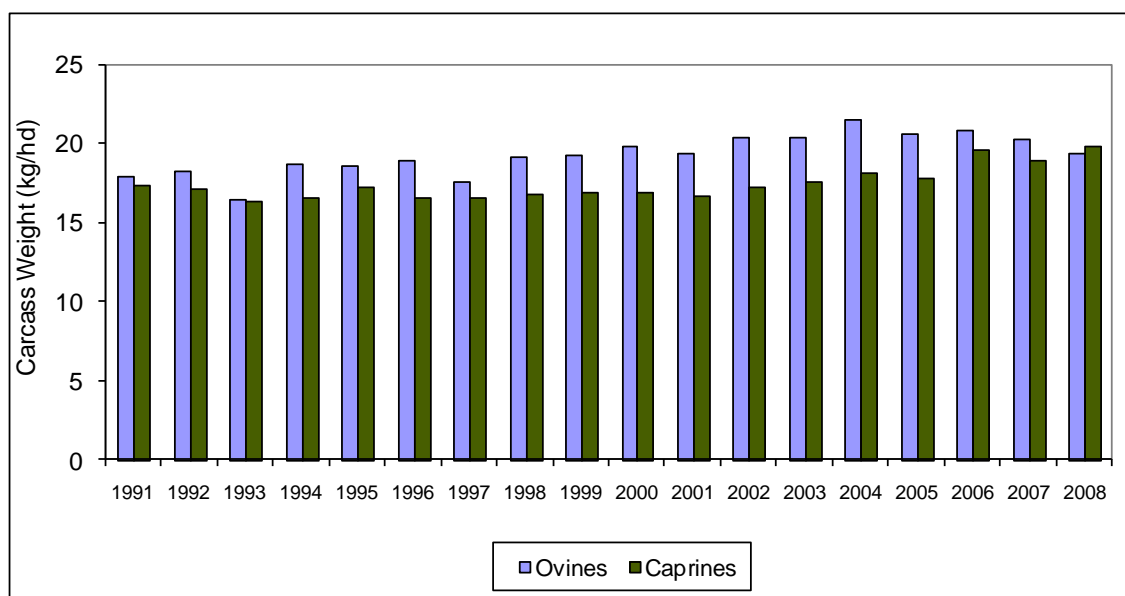
Table 6.10 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Ym) and Emission Factor of CH₄ emissions from Enteric Fermentation for sheep and goats. Weighted averages of individual breeds.

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		
FE (g 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 $Cweight_{base}$) by the power function used for NEm. This procedure resulted in the CH₄ emission factors for ovine per animal being 8.5% higher in 2008 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 (1990-2008).



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

6.3.1.3.1.4 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 6.11.

Table 6.11 – 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 (g 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

6.3.1.3.1.5 Poultry⁹⁷

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.

⁹⁷ 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

Table 6.12 – 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

6.3.1.4 Activity Data

Periodic census to agriculture⁹⁸ 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 and 1999. 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.

Periodic agriculture census are 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” was 636 870 units whereas the sample for control was 15 000 units, 2.4%.

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 2008 for cattle, swine, sheep, goats, horses, mules and donkeys, disaggregated per region⁹⁹, 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 conduct every two year 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 procedure were undertaken to adjust this new data to our emission estimation requirement:

⁹⁸ Referred in Portuguese as Recenseamento Geral da Agricultura (RGA)

⁹⁹ 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.

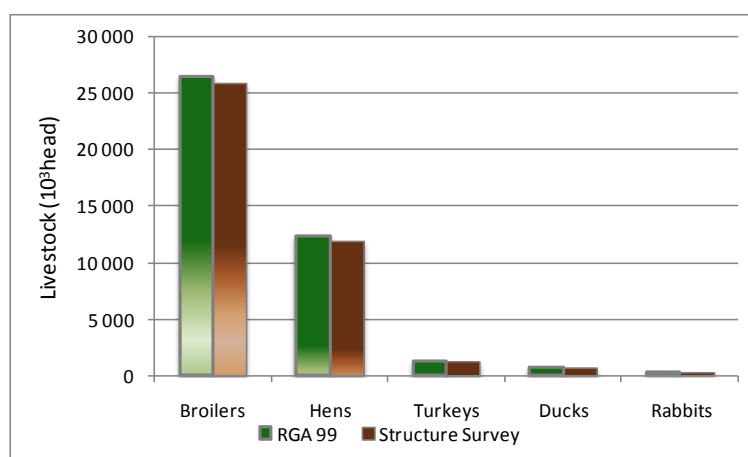
- Data provided comprises total livestock for Portugal. RGA 99 regional values were used for desagregations proposes;
- Gaps in the livestock time series were corrected with linear interpolation;
- Desegregation between hens for industrial egg production and hens for production of chicks had to be made 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% higher than the values reported in the Regional Agriculture Statistics, reflecting the consideration, in the RGA99 census only, of animal 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;
- 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:

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

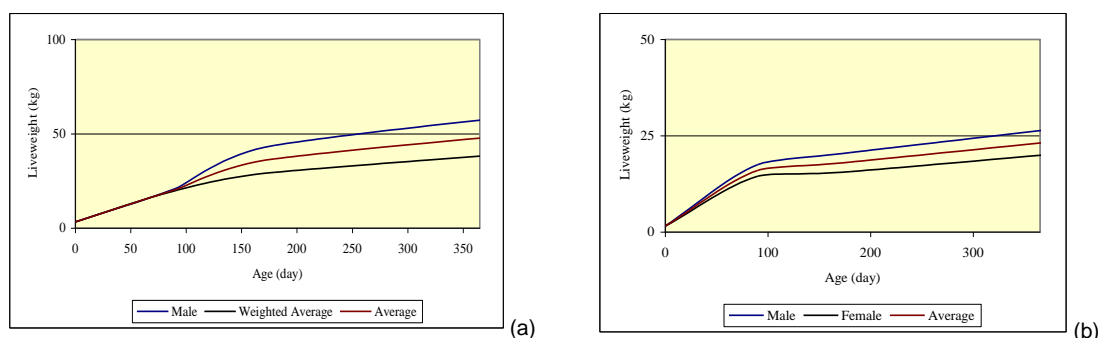
annual population. The seasonal correction was found not to be necessary for the other animal types.

The annual number of lambs and kids was set from the number of registered slaughtered animals, as published by the Regional Statistics, for which a correction factor was applied to account for the slaughtering that occurs outside normal market (auto-consumption). GPPAA (2004) reports a doubling factor for both sheep and goats (Correction Factor = 2). The number of lambs and kids reported as activity data represents the equivalent annual average of animals, i.e.:

$$\text{lambs/kids (hd)} = \text{Annual Slaughter (hd/yr)} * \text{CorrectionFactor} * \text{Age_Slaughter (days)} / 365$$

The age at which slaughter occurs (Age_Slaughter) was determined from the inverse function of the growth models¹⁰⁰ 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.

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.

¹⁰⁰ Model set from the information on the breeds existent in Portugal, complemented by information in Jarrige (1988) concerning growth pattern.

Figure 6.14 – Average carcass weight at slaughtering. Lambs and Kids (1990-2008).

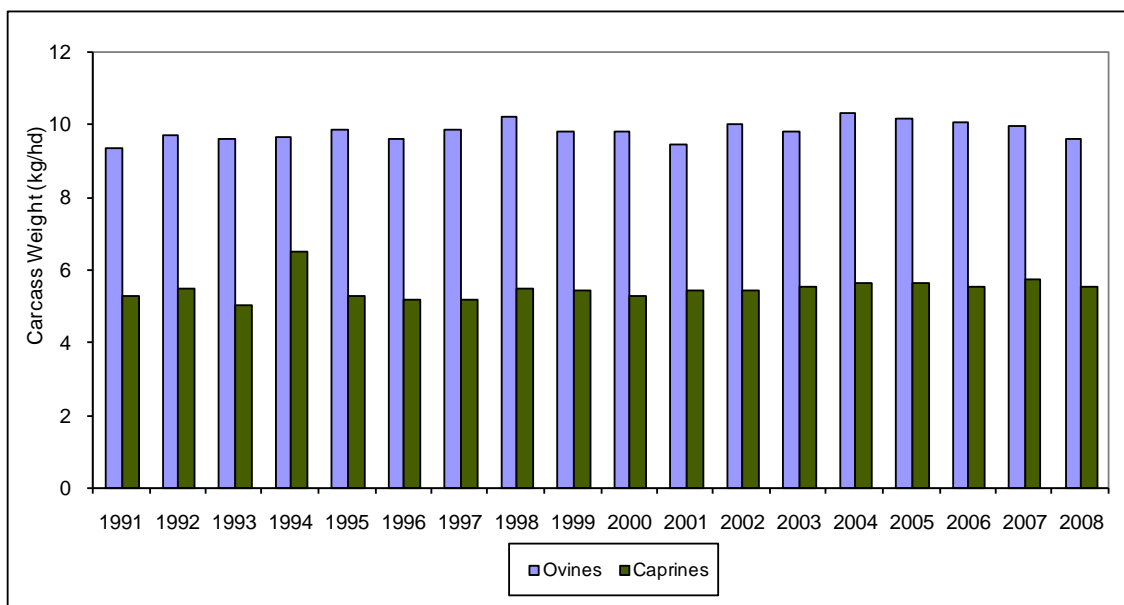


Figure 6.15 – Number of slaughtered young animals in each month for the years 2001 and 2002

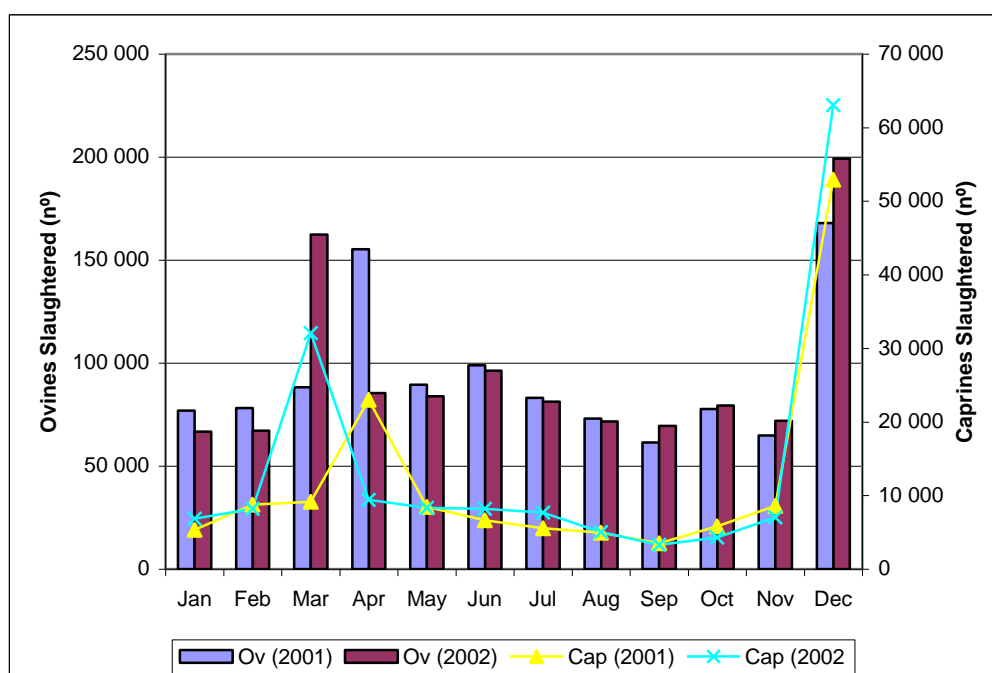


Table 6.13 - Livestock Numbers (Thousands) (1990-2008)

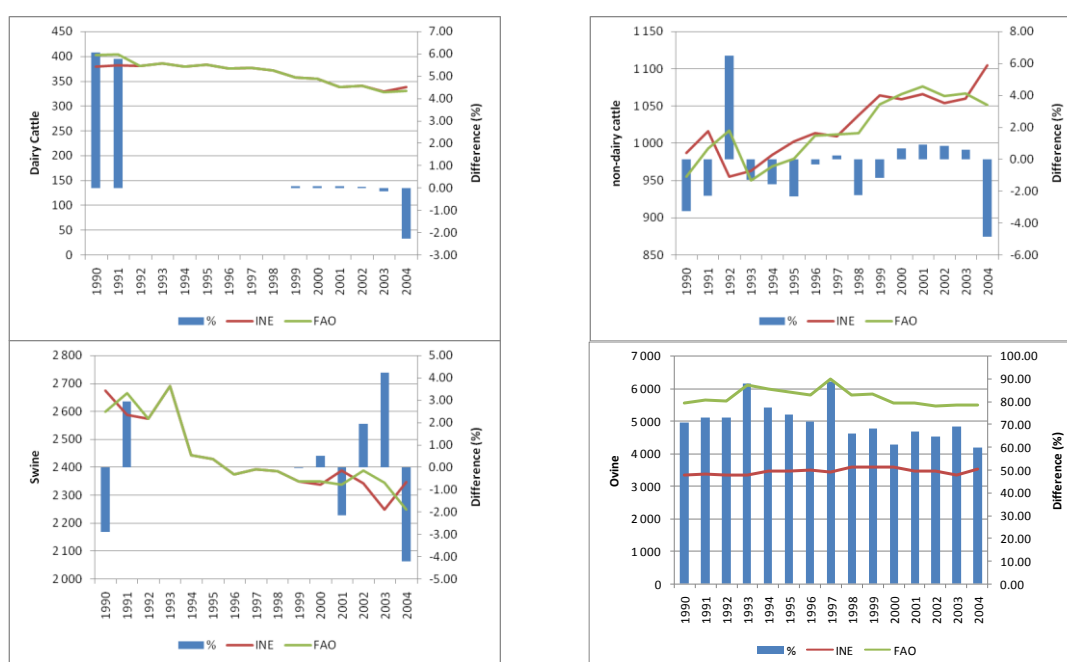
Animal	sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Dairy-Cattle	Dairy cows	394	388	381	383	382	383	380	379	375	369	361	350	344	336	336	330	323	312	304
Non-dairy cattle	Beef calves (<1 yr)	46	52	53	53	58	60	64	64	65	66	67	72	72	70	73	79	85	86	87
	Calves M.Rep. (<1 yr)	186	185	182	176	167	162	155	151	149	149	149	149	150	155	153	148	140	139	137
	Calves F Rep. (<1 yr)	177	178	178	174	164	158	152	152	155	165	171	173	172	169	168	164	161	159	156
	Males 1-2 yrs	112	114	114	108	103	103	105	101	95	86	82	80	78	79	78	79	76	73	72
	Beef Fem. 1-2 yrs	18	19	20	22	22	22	24	24	24	20	17	15	15	15	16	17	17	16	17
	Females rep. 1-2 yrs	111	115	112	109	106	109	112	109	108	116	126	133	133	130	132	131	134	135	137
	Steers (>2 yrs)	38	38	36	37	35	33	33	31	31	29	27	25	23	22	22	24	28	30	31
	Heifers Beef (>2 yrs)	4	5	7	9	10	10	9	9	9	7	5	4	5	5	5	6	5	5	5
	Heifers rep. (>2 yrs)	45	46	45	48	50	52	51	50	52	60	67	67	60	55	57	60	62	62	64
	non-dairy cows	242	245	238	241	252	273	296	316	332	338	342	345	351	360	371	385	399	412	420
Swine	Piglets (<20 kg)	727	756	756	750	735	726	703	701	695	691	685	684	686	678	676	681	691	701	703
	Fatt. Pigs (20-50 kg)	662	675	660	671	668	660	633	631	633	623	610	596	589	575	567	570	573	581	575
	Fatt. Pigs (50-80 kg)	537	558	557	553	542	530	505	496	492	498	501	502	494	483	481	474	466	457	460
	Fatt. Pigs (80-110 kg)	209	217	216	214	203	194	179	177	174	176	176	190	205	216	221	222	230	231	235
	Fatt. Pigs (> 110 kg)	42	43	44	44	43	43	40	39	38	38	39	43	43	42	39	40	43	44	44
	Boars (>50 kg)	26	28	27	28	28	26	24	23	23	22	21	20	20	18	17	15	14	13	12
	Sows, pregnant	210	219	218	220	216	211	204	204	202	201	199	206	210	213	209	208	207	203	200
	Sows, non-pregnant	124	131	135	136	134	132	127	128	127	127	126	118	111	102	103	104	106	107	106
Ovines	Ewes	2 211	2 251	2 257	2 268	2 303	2 339	2 376	2 368	2 367	2 388	2 417	2 403	2 350	2 304	2 297	2 319	2 303	2 253	2 163
	Other Ovines	395	398	402	420	430	433	414	401	431	430	422	352	303	301	374	450	535	539	511
	Lambs	592	610	606	578	565	568	592	598	604	615	639	674	725	702	669	621	616	603	579
Caprines	Does	600	581	556	538	528	517	509	498	485	472	461	441	419	393	383	381	381	374	367
	Other Caprines	44	42	41	39	39	38	37	36	35	34	34	32	31	29	28	28	28	27	27
	kids	102	102	96	92	89	82	77	72	73	73	66	76	83	85	73	65	65	64	62
Equides	Horses	33	38	40	42	44	48	52	54	56	57	58	59	59	58	56	52	49	47	46
	Asses and Mules.	118	116	114	114	109	103	96	90	82	75	69	63	57	51	45	39	35	32	29
Poultry	Hens, reproductive	3 421	3 300	3 116	2 941	2 947	3 271	3 477	3 390	2 982	2 636	2 644	2 708	2 803	2 776	2 669	2 480	2 295	2 195	2 184
	Hens eggs	7 539	7 695	7 932	8 159	8 143	7 745	7 392	7 322	7 859	8 627	9 060	9 161	8 955	8 870	8 527	7 925	7 334	7 013	6 978
	Broilers	18 524	18 812	19 243	19 674	19 530	18 813	18 355	18 733	20 538	22 936	24 374	24 259	22 590	20 921	19 620	18 686	17 885	16 848	16 000
	Turkeys	603	623	643	693	757	827	886	937	1 069	1 180	1 283	1 288	1 285	1 150	1 068	1 020	1 093	1 146	1 156
	Ducks, Geese and Guinea Fowl	804	804	804	804	804	804	804	804	804	804	804	804	804	804	804	804	804	804	804
Other	Rabbits	475	464	447	430	415	401	384	363	346	338	336	332	325	318	306	289	270	254	247

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, that explain the trends¹⁰¹.

Livestock numbers¹⁰² as considered in the inventory, as collected from National Statistics, were compared to livestock numbers for years 1990-2004 for dairy cattle, no-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 turkeys¹⁰³ 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

¹⁰¹ Reports available at (<http://www.min-agricultura.pt/mediateca>)

¹⁰² Annual values, not 3 year averages.

¹⁰³ 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 annex104, 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 sheeps 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-series¹⁰⁵ was used an indicator of the uncertainty of livestock numbers, and they are presented in table Table 6.14.

¹⁰⁴ In the original document to the UNFCCC only.

¹⁰⁵ The comparison was done without 3 year averages were calculated.

Table 6.14 - 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	323
Hens	60
Broilers	59
Turkeys	771
Other	771

The uncertainty of the emission factor was assumed to be 20% for all animals where tier 2 was used and 50% 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 only update to this source category refers to the livestock number revision for poultry (except for turkeys and duck) and rabbits. This update affected all time series values.

6.3.1.8 *Further Improvements*

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.

6.3.2 **CH4 Emissions from Manure Management (CRF 4.B.)**

6.3.2.1 *Overview*

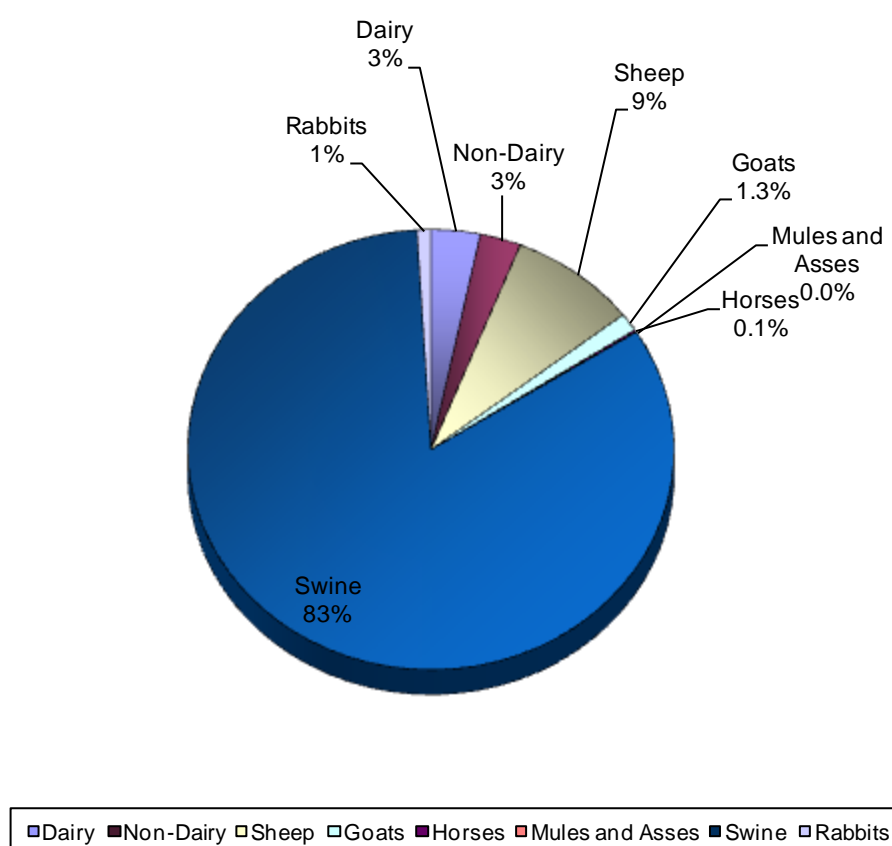
Methane emissions from manure occur when the organic material it contains, either solid or dung or liquid as urine, decomposes, during storage or treatment, in anaerobic environments by the action of methanogenic bacteria. The quantity that is emitted depends mostly of the existence of anaerobic conditions 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 category¹⁰⁶.

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 83% of emissions in 2008, as may be seen in Figure 6.17, and according to the Good Practice rule of thumb this specie is the only significant source.

Figure 6.17 - Relative Importance of emissions of CH₄ from Manure Management per each animal species in 2008



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.

$$Emi_{CH_4} = \sum_i \sum_c [EF_{(i,k)} * N_{(i,k)}]$$

¹⁰⁶ 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.

where, for each specie:

Em_{CH_4} = methane emissions from manure management, kg CH_4 /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 6.15 – 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 guess¹⁰⁷, 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, Table 6.17.

The values for the fraction of manure handled in each MMS were revised for the 2010 submission by the Ministry of Agriculture technical personnel¹⁰⁸. 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 6.16 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;

¹⁰⁷ Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005.

¹⁰⁸ 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 6.16 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990, 2008 and 2010.

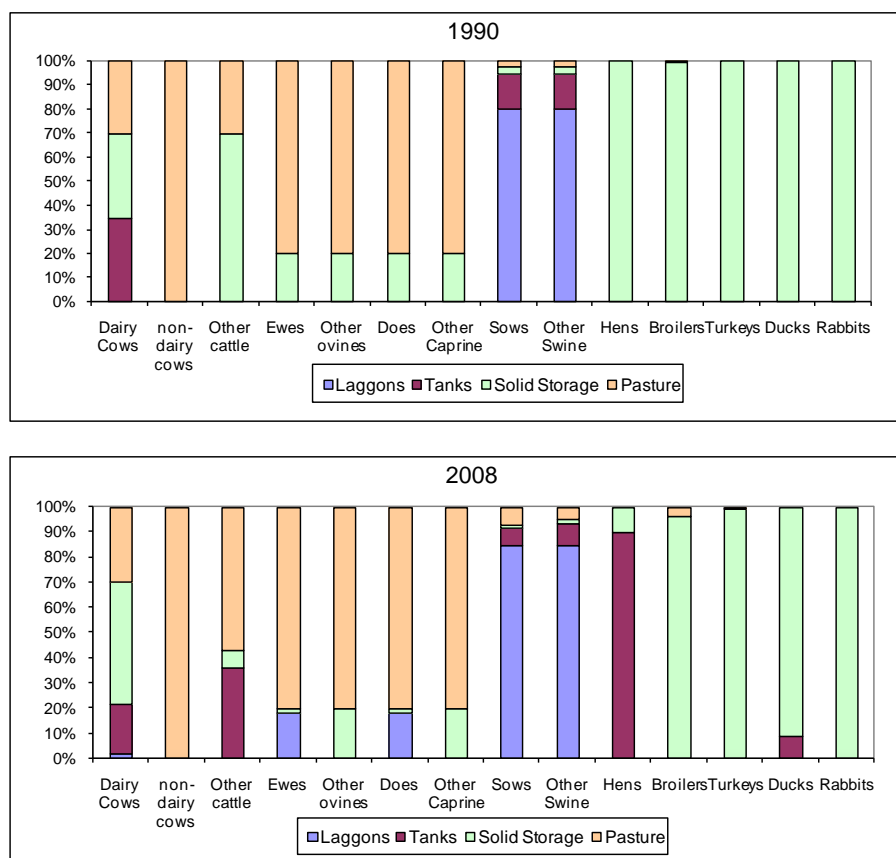
Animal Type	1990					2008					2010				
	Laggons	Tanks	Solid Storage	Pasture	Total	Laggons	Tanks	Solid Storage	Pasture	Total	Laggons	Tanks	Solid Storage	Pasture	Total
Dairy Cows	-	35	35	30	100	1.8	19.7	48.5	30	100	2	18	50	30	100
Non-dairy cows	-	-	-	100	100	-	-	-	100	100	-	-	-	100	100
Other cattle	-	-	70	30	100	-	36	7	57	100	-	40	-	60	100
Ewes	-	-	20	80	100	18.0	-	2	80	100	20	-	-	80	100
Other ovine	-	-	20	80	100	-	-	20	80	100	-	-	20	80	100
Does	-	-	20	80	100	18.0	-	2	80	100	20	-	-	80	100
Other caprine	-	-	20	80	100	-	-	20	80	100	-	-	20	80	100
Sows	80	15	3	2	100	84.5	6.9	1.2	7.4	100	85	6	1	8	100
Other Swine	80	15	3	2	100	84.5	8.7	2.1	4.7	100	85	8	2	5	100
Hens	-	-	100	-	100	-	90	10	-	100	-	100	-	-	100
Broilers	-	-	99.9	0.1	100	-	-	96.4	3.6	100	-	-	96	4	100
Turkeys	-	-	100	-	100	-	-	99.9	0.1	100	-	-	99.9	0.1	100
Ducks	-	-	100	-	100	-	9.0	91	-	100	-	10	90	-	100
Rabbits	-	-	100	-	100	-	-	100	-	100	-	-	100	-	100

Table 6.17 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type.

Animal Type	Laggon	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	-	-	-	-

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 2008



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:

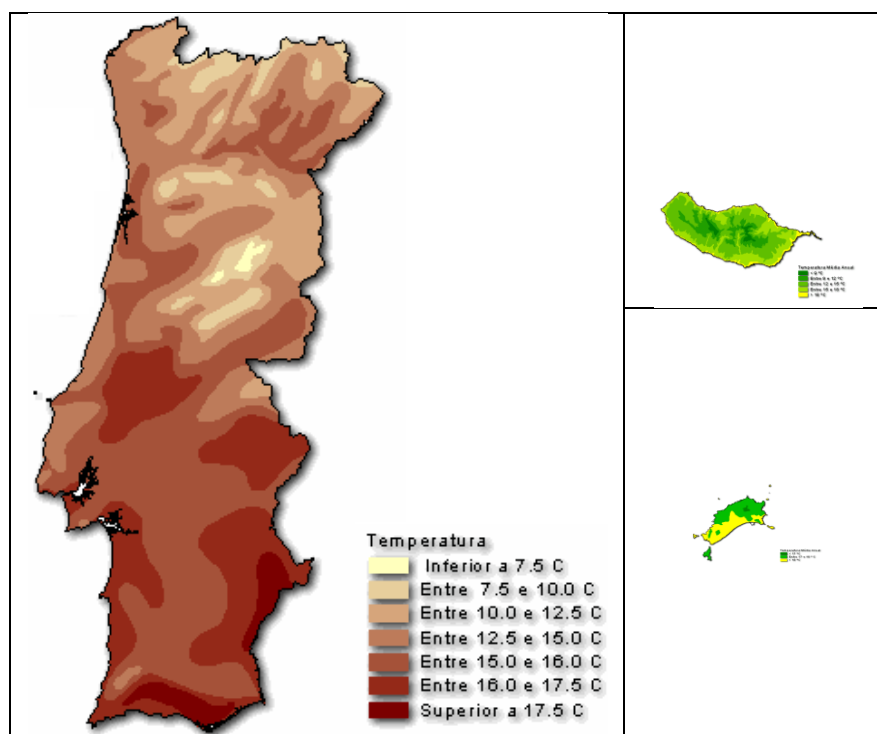
- the percentage of livestock numbers at each climate region was determined for each *concelho* territorial unit¹⁰⁹ and for each animal sub-type. Within each *concelho* territorial area a homogenous distribution of animals was assumed;
- for each *Concelho* territorial area in mainland Portugal and Madeira 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 RGA99¹¹⁰. Data for 1999 was 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 are percentage, and always assuming an homogeneous distribution of animals in the *Concelho* territorial area. Animal numbers were summed at each Administrative Region (Região)¹¹¹ 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.

¹⁰⁹ 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.

¹¹⁰ Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

¹¹¹ 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.

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 2008, obtained in accordance with the above explained procedure, is presented in Table 6.18.

Table 6.18 – Percentage of livestock population living in climate cool regions in Portugal in years 1990 and 2008.

Animal Type	1990	2008
Dairy Cows	48	42
Other Cattle	43	26
Sheep	29	31
Goats	50	52
Horses	34	42
Mules and Asses	58	67
Swine	22	20
Poultry	41	43
Other	65	65

All the Methane Conversion Factors are the defaults for temperate regions of Western Europe and developed countries:

Table 6.19 - Methane Conversion Factors (MCF), per cent, for determination of CH₄ emissions from Manure Management

MMS	Temperate	Cool
Laggons	45	39
Tanks	0	0
Solid Storage	1.5	1
Pasture	1.5	1

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%, 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 patterns¹¹². This error was combined with the error associated with the MCF parameter: the uncertainty was assumed to be 100% 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% 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% for horses up to 22% 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

¹¹² 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.

livestock numbers that are classified as either cool or temperate. Territorial units under each climate class could easily change as much as 30% 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 6.20 – 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

6.3.2.6 Recalculations

Several recalculations were made to this source sector:

- revision of the fraction of total manure handled with each Manure Management System;
- revision of livestock values for several animal types as described in CH₄ from enteric fermentation;

6.3.2.7 Further Improvements

Improvements are expected on the shares of total manure handled with each Manure Management System for Equines. Other general ameliorations are expected.

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 trough 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 ($\text{g/m}^2/\text{yr}$);

Rice_{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 ($\text{g/m}^2/\text{yr}$);

E_{fc} - Seasonally integrated emission factor for continuously flooded fields without organic amendments ($\text{g/m}^2/\text{yr}$);

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 ($20 \text{ g/m}^2/\text{yr}$) was not used, but replaced by a regional specific E_{fc} that was determined by reference to Schutz et al (1989)¹¹³. Considering the information in tables in the original document¹¹⁴, the E_{fc} more adjusted to the Portuguese conditions is $31.9 \text{ g/m}^2/\text{yr}$. This value is slightly lower than the value that is proposed by IPCC96 in table 4-13 for Italy ($36 \text{ g/m}^2/\text{yr}$).

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:

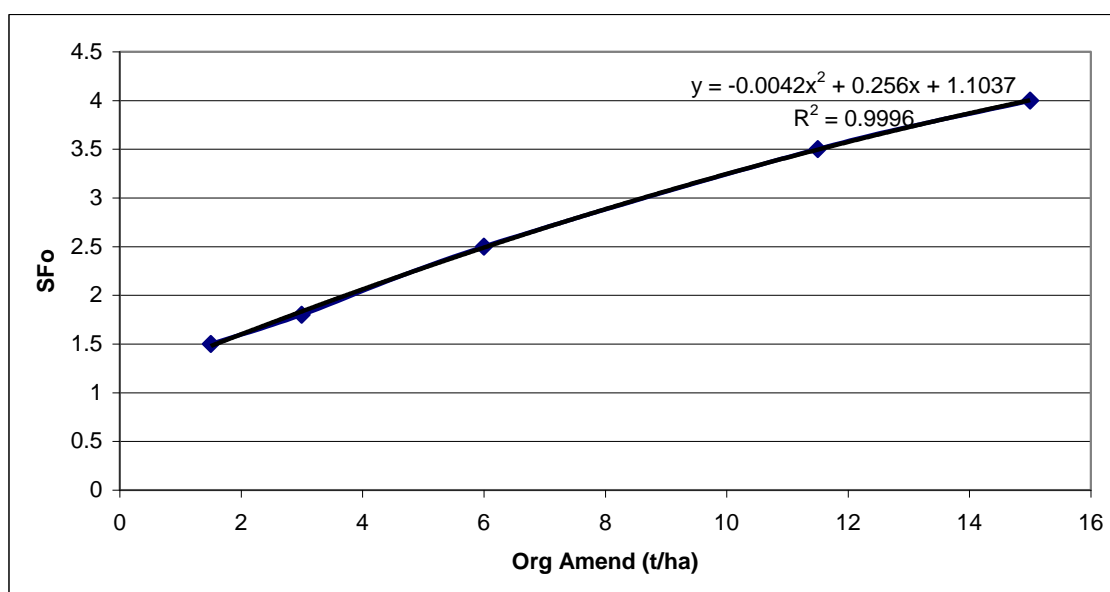
¹¹³ This is one of the original references in IPCC (1997) with specific values for Italy, which conditions, in terms of climate and management, are similar to those in Portugal. Reference to: Schütz, H., A. Holzapfel-Pschorn, R. Conrad, H. Rennenberg and W. Seiler (1989a), "A 3-year continuous record 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.

¹¹⁴ 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).

- 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. It became more common to left the straw on ground and incorporate it into soil by plowing. This procedure is the only allowed if Techniques of Integrated Production and Protection¹¹⁵ are used;
- the area subjected to “Techniques of Integrated Production and Protection” occupied about 60% of rice paddies in 2004. Today the area burnt occupies only about 30%–40% of total area;
- it may be assumed that, in 1990, 100% of rice paddies were burnt and no organic amendments were added to soil. In 2008 the area subjected to burning was reduced to only about 33%.

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%) (table 4.16 IPCC’s GP). Using this information SF_o, the scaling factor for organic amendments, was determined using the data in table 4.21 of the GPG¹¹⁶. The following regression was set from the original table.

Figure 6.20 – Relation between SF_o and the quantity of organic amendments added to soil.



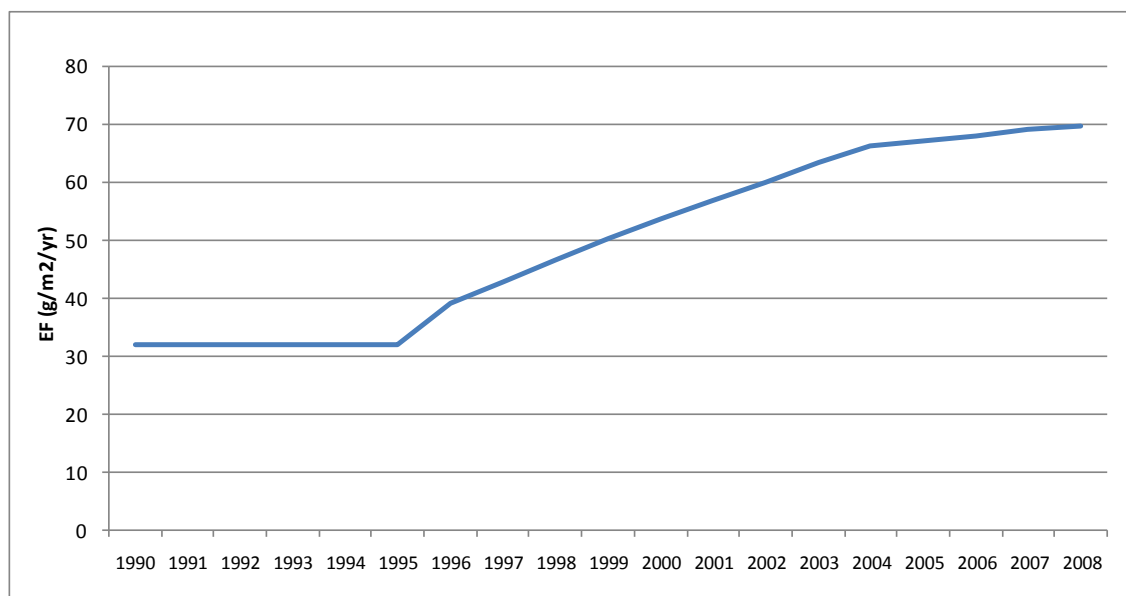
Finally, no information is available to establish influence of soil type and SFs was also set to one.

The overall EF changed over time according to the following graph.

¹¹⁵ “modos de protecção e produção integrada” in the original in Portuguese.

¹¹⁶ The available data in Schutz et al (1989) could not be used to estimate this factor in accordance with EF_c.

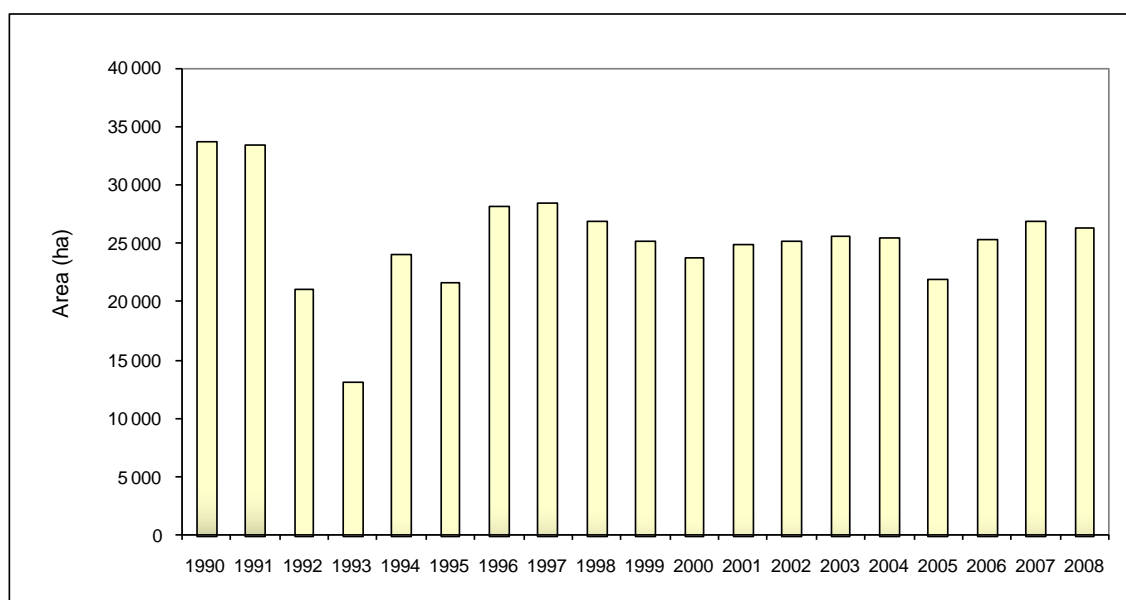
Figure 6.21 – Emission Factor EF used to estimate CH₄ emissions from rice paddies in Portugal (1990-2008)



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 (1990-2008)



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%, 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%.

6.3.3.6 *Recalculations*

No significant recalculations were made apart from updating the rice cultivated area time series for 2007.

6.3.3.7 *Further Improvements*

No improvements in methodology are expected in near future. 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 feces 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 1990-2008 period 95.4% of total N₂O emissions from Manure Management. The rest comprehends 2.5% of emissions from anaerobic lagoons and 2.1% of total emissions from liquid systems. In terms of origin by animal type¹¹⁷, emissions are dominated by poultry (48.8%¹¹⁸), non dairy cattle (19.2%) and dairy cattle (11.5%), which together comprehend about 79.4% of total emissions, as may be seen in Figure 6.24 for the year 2008.

¹¹⁷ 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.

¹¹⁸ 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 2008

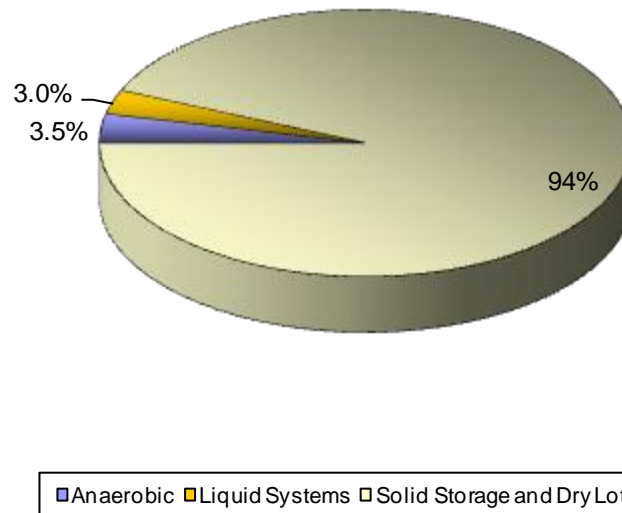
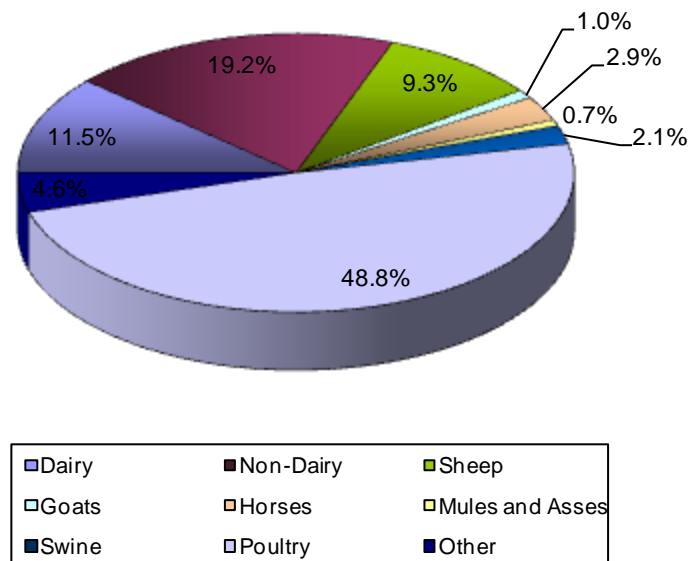


Figure 6.24 – Distribution of total N₂O emissions from Manure Management per animal species as origin of manure in year 2008



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;

$N_{ex(i)}$ - 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;

$EF3_{(s)}$ - N_2O emission factor for Manure Management System s ($kg\ N_2O-N/kg\ N$).

This formulation follows the one proposed in GPG (equation 4.18).

The following Manure Management Systems were considered for the calculation of total N_2O emissions from manure management, in accordance with the expert information received from the Ministry of Agriculture (MADRAP). The following table presents the original classes from the MADRAP and the correspondent classes in CRF table 4.D.

Table 6.21– Classification of Manure Management Systems in Portugal, for the

MADRAP	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 N_2O 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 $N_{(i)}$, $N_{ex(i)}$ 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

N_2O 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 6.22 – N_2O from Manure Management: Emission factors per Manure Management System

MMS	EF3 ($kg\ N_2O-N/kg\ N$)
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 Agriculture¹¹⁹. 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);
- make consistent and coherent calculations 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.

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% for every 1000 kg less of milk production;
- The Nex increases 2% for every 1000 kg extra of milk production.

¹¹⁹ 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.

Milk production presented in Table 6.23, were provided by INE.

Table 6.23 – Milk production values for the 1990-2008 time series.

Year	Milk per Cow (kg/hd/yr)
1990	4 330
1991	4 306
1992	4 279
1993	3 988
1994	4 192
1995	4 419
1996	4 604
1997	4 668
1998	4 824
1999	5 546
2000	5 633
2001	5 696
2002	5 985
2003	5 764
2004	5 774
2005	6 190
2006	6 267
2007	6 240
2008	6 515

The previous table shows that the milk production per cow, for all time series, is below 7000 kg/hd/yr. Because of that the nitrogen excretion will also be below 115 kg N/hd/yr:

Table 6.24 – Nitrogen excretion rate for dairy-cattle (1990-2008)

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	101.2
2001	102.0
2002	105.4
2003	102.8
2004	102.9
2005	107.8
2006	108.7
2007	108.4
2008	111.7

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 6.25 – N excretion rate per head and by animal species/category (Nex)

Animal Class	Animal type	Nex (kg N/hd/yr)				
		Sub 2010	Sub 08-09	Sub 06-07	Sub 2005	IPCC Default
Dairy-cattle	Dairy Cows	111.7	87.6	87.6	108.07	100
non dairy cattle	Beef calves (<1 yr)	25.0	26.3	26.3	54.03	70
	Calfs, Males for Rep. (<1 yr)					
	Calfs, 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	25
	Other Ovines	6.6				
	Lambs	0				
Caprine	Does	7.0	7.0	7.0	4.93	
	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 2010 represents the value for latest year reported in that submission (2008).

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.

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to year 2008, is presented in Table 6.26.

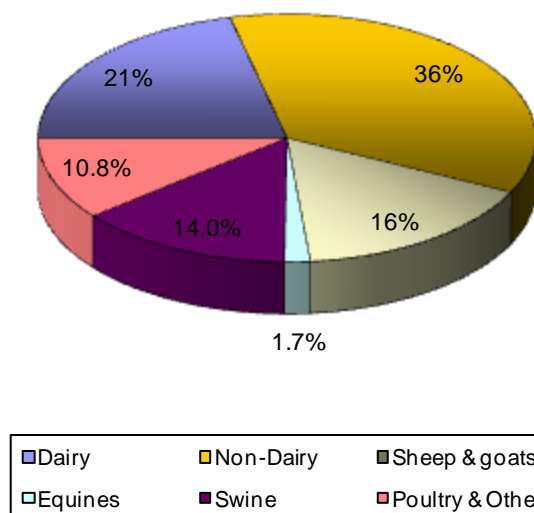
Table 6.26 – Total Nitrogen in Manure produced by livestock in Portugal (ton N/yr) (1990-2008)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy	33 830	33 177	32 457	31 305	32 147	33 262	33 803	34 031	34 364	36 929
Non-Dairy	43 438	44 308	43 599	43 602	43 888	45 511	47 217	48 392	49 477	50 316
Sheep	22 875	23 269	23 353	23 568	23 962	24 306	24 523	24 359	24 555	24 736
Goats	4 488	4 348	4 157	4 028	3 950	3 868	3 808	3 723	3 626	3 535
Horses	1 447	1 666	1 750	1 842	1 953	2 094	2 272	2 396	2 485	2 527
Mules and Asses	2 599	2 560	2 513	2 499	2 393	2 273	2 104	1 969	1 812	1 658
Swine	24 739	25 750	25 750	25 881	25 368	24 815	23 711	23 554	23 388	23 373
Poultry	17 095	17 286	17 569	17 864	17 821	17 407	17 071	17 157	18 218	19 757
Other	4 273	4 172	4 022	3 872	3 733	3 605	3 452	3 263	3 113	3 041
Total	154 784	156 537	155 171	154 460	155 215	157 142	157 963	158 845	161 037	165 871

Animal Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Dairy	36 558	35 661	36 297	34 496	34 537	35 548	35 073	33 825	33 984	-
Non-Dairy	51 134	51 526	51 504	51 841	52 817	54 297	55 445	56 458	57 193	-
Sheep	24 945	24 353	23 548	23 116	23 534	24 235	24 652	24 219	23 214	-
Goats	3 449	3 299	3 132	2 942	2 864	2 850	2 854	2 801	2 746	-
Horses	2 556	2 576	2 575	2 553	2 450	2 303	2 156	2 068	2 024	-
Mules and Asses	1 514	1 380	1 249	1 114	981	865	777	704	638	-
Swine	23 225	23 155	22 971	22 530	22 414	22 330	22 443	22 369	22 327	-
Poultry	20 805	20 874	20 013	19 114	18 150	17 112	16 203	15 445	15 033	-
Other	3 023	2 984	2 923	2 862	2 754	2 599	2 429	2 290	2 219	-
Total	167 209	165 809	164 213	160 569	160 500	162 140	162 033	160 179	159 377	-

The major contributors to total nitrogen from livestock in Portugal in 2008 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 2008, 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 Management¹²⁰.

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

¹²⁰ 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%, considering an intermediate situation between the uncertainty values recommended by GPG for default N-excretion rates (50%) and the lower uncertainty when country-specific values are based on accurate national statistics (25%). 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% for anaerobic lagoons and liquid systems to around 10% for solid systems and pasture. The overall uncertainty values range from 37.5% to 39%.

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% for all MMS.

6.3.4.6 *Category-specific QA/QC and verification*

The application of QA/QC procedures for the nitrogen excretion rates were considered a priority for this source category, following the extensive work done to revise the values previously used in the inventory. Nitrogen excretion values were thus compared with the corresponding IPCC default and also with the values used in previous inventories - Table 6.25. For quality assurance purposes all changes made to the Nex were documented.

6.3.4.7 *Recalculations*

The major recalculation on this sector corresponds to the revision of all nitrogen excretion rates. Also the updates in the livestock numbers and the revision of the MMS shares, already described in previous chapters, affected the emissions from this source category.

6.3.4.8 *Further Improvements*

No new improvements are expected apart from specific corrections on the nitrogen excretion rates that are considered necessary.

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 include the following sub-categories:

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- 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 make 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: N_2O , CH_4 and NH_3 .

The inventory of N_2O from Direct Soil Emissions from Agricultural Soils is almost complete, except the non inclusion of estimates for N_2O from the application of sewage sludge, due to the unavailability of data. However, this source is probably minor in importance.

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. Emissions due to application of sewage sludge as a soil amendment is also not included in the inventory, as there are no reliable statistics for this activity, which is considered nevertheless negligible.

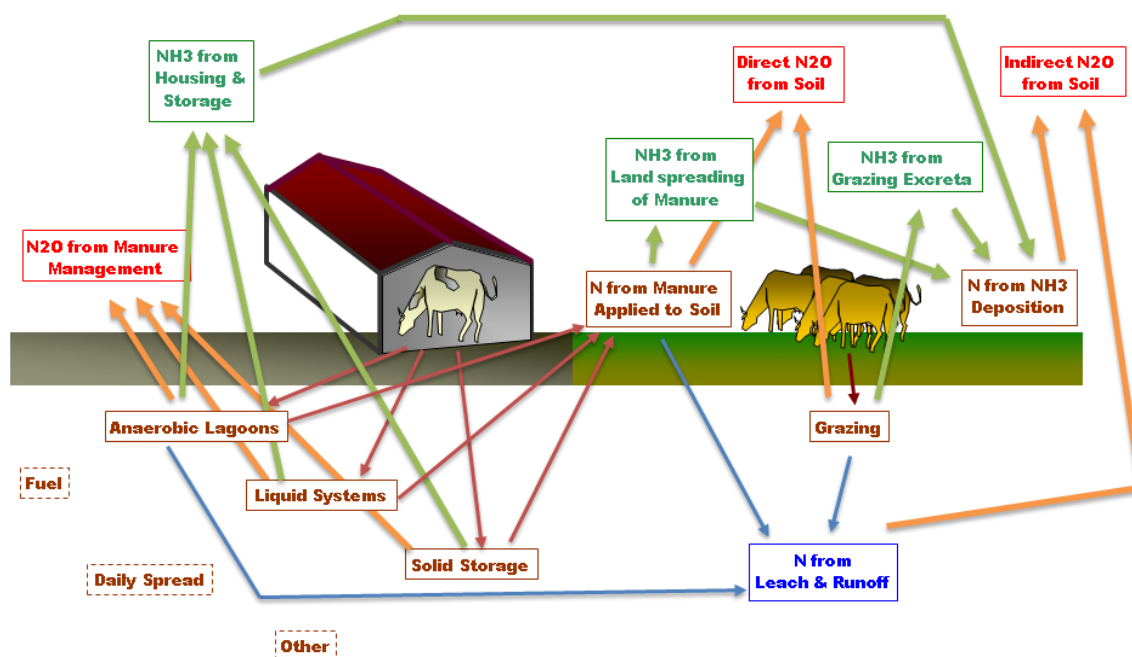
It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

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.

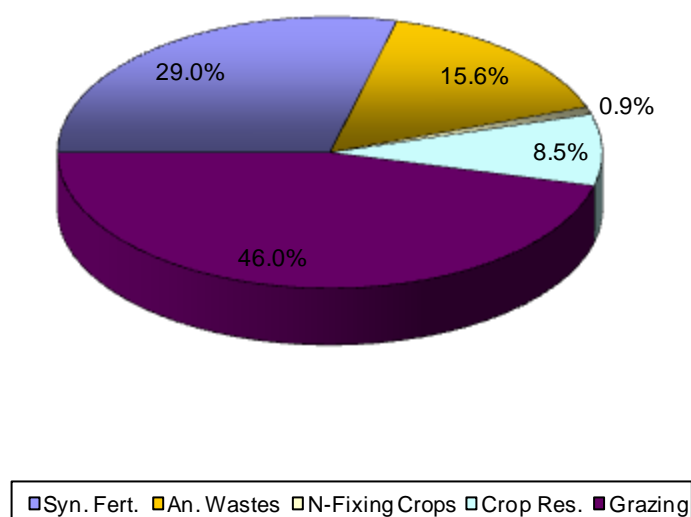
The following figure synthesizes the livestock system in what concerns nitrogen fluxes and direct and indirect N_2O emissions.

Figure 6.26 – Nitrogen fluxes from livestock system



The comparative importance of the several sub-source activities for 2008 is shown in Figure 6.27, from where it is evident the major contribution from direct deposition (Grazing 46.0%) and synthetic fertilizers (Syn. Fert with 29.0%) 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 15.6% of emissions.

Figure 6.27– Contribution of the various sub-sources to total N₂O emissions from Direct agricultural soil emissions in 2008



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 soil¹²¹.

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)

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 NH₃ 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;

¹²¹ However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$N_{ex(i)}$ - 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 N₂O from Pasture Range and Paddock there is no need to account for the amount that volatilizes as NH₃.

6.3.5.3 Emission Factors

EF₁, the emission factor relating N input to soil with N₂O emissions, was set equal to the IPCC default value of 0.0125 kg N₂O-N/kg N input (table 4.17 of GPG and table 4.18 of IPCC96)¹²².

The emission factor of N₂O for Pasture, Range and Paddock (EF₃) was set at 0.02 kg N₂O-N/kg N which is the default IPCC96 emission factor (table 4-22) that is also maintained in GPG (table 4.12).

¹²² Which is the same as stating that 1.25% of nitrogen input to soil is emitted as N₂O

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 N₂O emissions, are shown in Table 6.27 below and the percent contribution of each one in year 2008 is also represented graphically in Figure 6.28.

For the last year in the inventory (2008) there are two categories that represent the majority of nitrogen added to soil: Synthetic Fertilizers (35%) and direct droppings during grazing in Pasture (35%). Also important to note the contributions of Animal Waste apply to the soil as fertilizer (18.8%) and Crop Residue a apply to the soil (10.3%). The contribution of N-Fixing Crops is marginal (1.1%). Total nitrogen added to agricultural soils in Portugal increased slightly along years up to 2002, but after 2003 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 2008 about 19.8% lower than what it was applied in 1990, although for the year 2002, application of nitrogen was 3.1% higher than in base year.

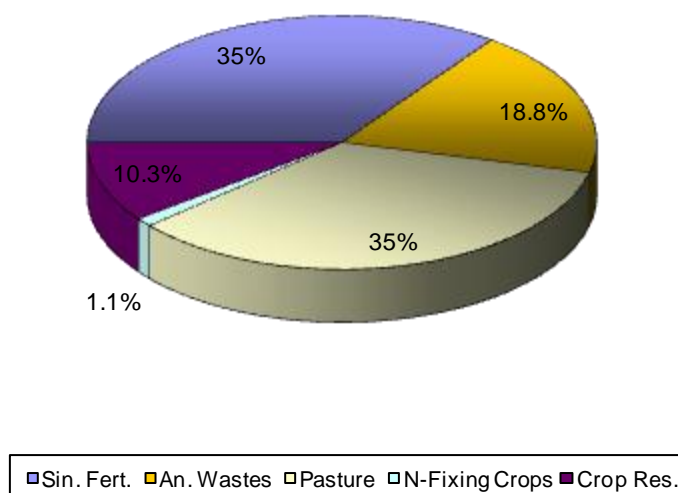
Table 6.27 - Total quantities of Nitrogen Added to Agricultural Soils that which is activity data for direct N₂O emissions: 1990-2008¹²³

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Synthetic Fertilizer	149 856	149 856	149 939	151 322	149 721	137 628	158 325	153 963	140 850	139 979
Animal Manure	54 467	54 830	54 289	53 744	53 465	53 251	52 488	52 023	52 327	54 152
Pasture Range	67 883	68 833	68 201	68 215	69 447	71 782	73 946	75 483	77 113	79 004
Fixed by Crops	5 032	4 701	4 272	3 906	3 740	3 780	3 667	3 411	3 045	2 840
Crop Residues	26 568	25 213	23 526	23 421	24 288	25 955	25 547	26 121	26 361	26 700
Total	303 808	303 433	300 227	300 608	300 661	292 396	313 973	311 001	299 696	302 675

ton N/yr	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Synthetic Fertilizer	160 265	148 504	154 529	103 834	118 648	96 793	78 147	92 784	85 233	-
Animal Manure	54 391	53 525	52 558	50 394	49 470	49 061	48 028	46 493	45 875	-
Pasture Range	79 855	79 653	79 489	79 163	80 501	82 772	84 196	84 641	84 710	-
Fixed by Crops	2 672	2 646	2 611	2 625	2 553	2 554	2 582	2 667	2 690	-
Crop Residues	25 849	24 913	24 126	25 080	24 148	24 125	23 479	24 528	25 076	-
Total	323 031	309 242	313 313	261 097	275 320	255 304	236 432	251 114	243 584	-

¹²³ 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 2008



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 Silva¹²⁴ and ADP¹²⁵, 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 census¹²⁶. Data of Imports and Exports is also from INE. The available time series is presented in Figure 6.29.

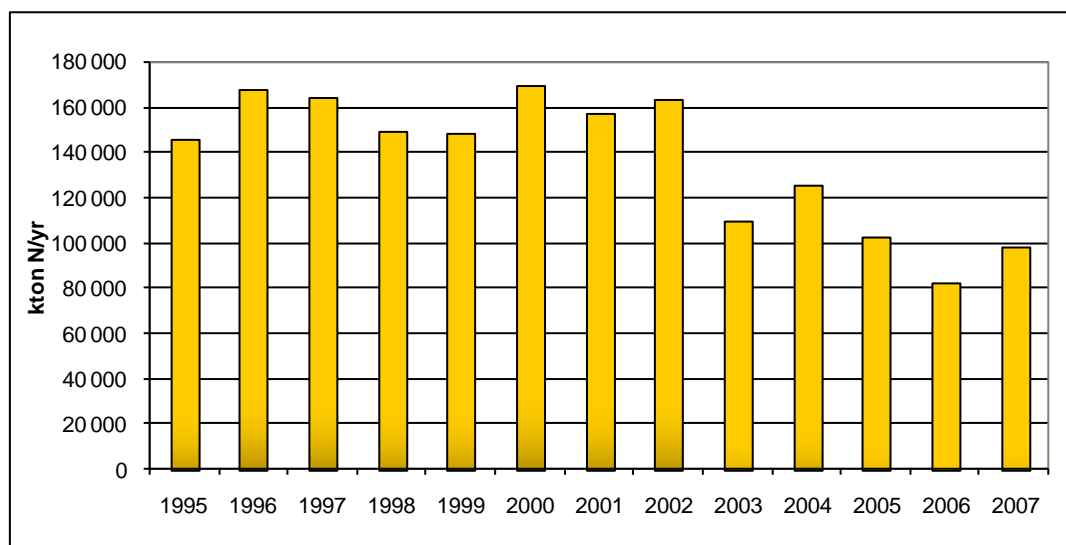
Two simplifications were made: (1) Only inorganic fertilizers were considered; (2) The effect of losses and stock variation was not accounted. According to INE (2004) this factors have no significant influence in the outcome.

¹²⁴ Laboratório Químico Agrícola Rebelo da Silva is a public laboratory, under the Ministry of Agriculture, and proceeds to soil, plant and fertilizer analysis.

¹²⁵ ADP, Adubos de Portugal, S.A., is the main producer of fertilizers in Portugal, and responsible for about 75% of fertilizer sales (INE,2004)

¹²⁶ 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 2007 (ton N/yr)



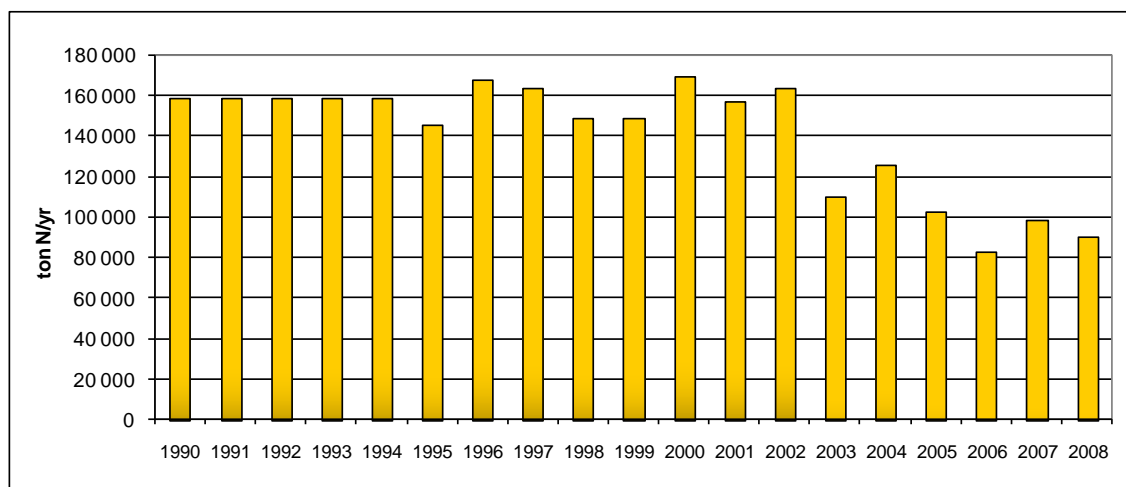
Because of the limited time period requested by the OECD/EUROSTAT survey (1995-2003), and the unavailability of IAPI data prior to 1992 the time trend of this series is limited in time, and not covering the Inventory base year (1990).

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. More recent data for 2007 was obtained from INE. The value for 2008 was forecasted using 2004-2007 data.

The line that was obtained, Figure 6.30, shows an increasing trend until 2002, being the value of that year 3.1% 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 38.1%, from 1995 till 2007.

Figure 6.30 - Use of Nitrogen Fertilizers in Portugal, estimated from INE data - Using a simple average value for 1990-1994 and a forecast for 2008 (ton N/yr)

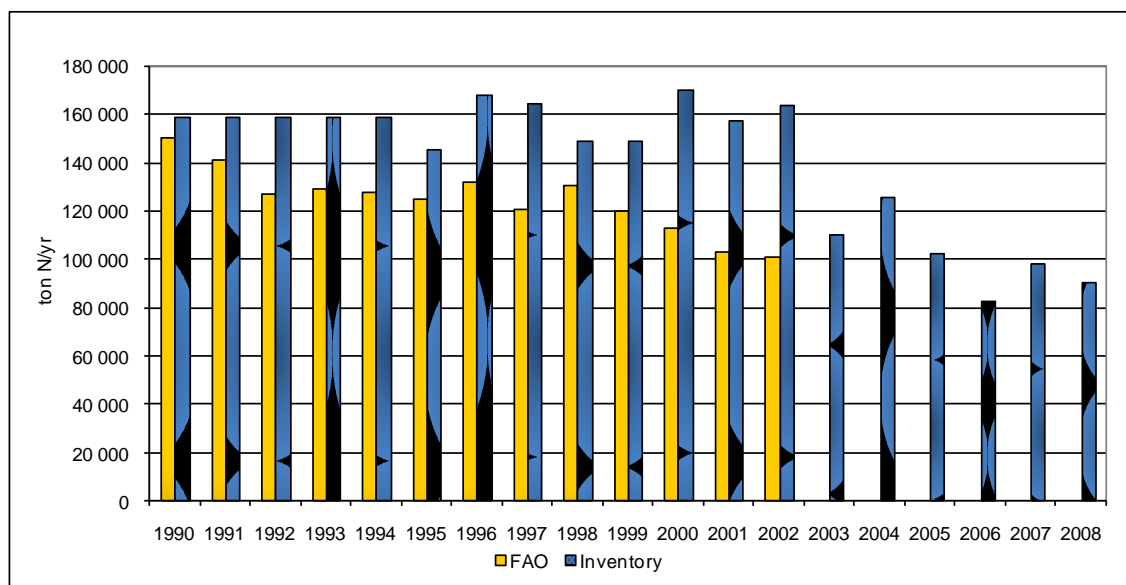


Losses of nitrogen from volatilisation of NH_3 and NO_x were estimated using a time variable and country-specific fraction $\text{Frac}_{\text{GASF}}$, which varies between 0.053 and 0.064 kg $\text{NH}_3\text{-N/kg N}$, and which are almost half the default value from table 4-19 of IPCC96 (0.1 kg $\text{NH}_3\text{-N/kg N}$). 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%. 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) (1990-2008)



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% of effluent is added to soil as fertilizer¹²⁷, in accordance with a characterization study made in Portugal (Bicudo & Albuquerque, 1995; LNEC, 1996; GPPAA, 2001)¹²⁸. 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 6.31 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.

¹²⁷ 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.

¹²⁸ 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 6.28 – 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 6.29 and in detail in chapter 6.2.8. The Fraction of livestock nitrogen excreted that is directly deposited onto soil during grazing is constant and equals 28%.

Table 6.29 – 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 excreted¹²⁹.

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 6.30 for leguminous crops and in Table 6.31 for non leguminous crops. For each year a

¹²⁹ 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 used¹³⁰. 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.

Table 6.30 – Annual (three year average) production of Leguminous Crops (metric tons) (1990-2008)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Peanut ⁽¹⁾ after 1995	29	32	29	26	20	17	20	23	27	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
Broad Beans, green	32 000	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	17 070	13 553	12 679	11 722	10 756	8 951	7 456
Chick-Peas	3 563	3 081	2 583	2 101	1 937	1 899	1 815	1 810	1 478	1 198
Lupins	48	43	35	37	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
Carobs ⁽¹⁾	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
Total	133 236	126 850	120 292	114 949	118 377	123 646	123 886	113 917	102 114	94 195

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Peanut ⁽¹⁾ after 1995	25	25	25	25	25	25	27	29	31	-
Broad Beans ⁽¹⁾ 95-96	6 902	7 108	6 703	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	6 157	5 883	5 478	5 073	4 198	3 960	3 746	3 805	3 592	-
Chick-Peas	968	1 012	1 167	1 318	1 132	899	749	788	825	-
Lupins	34	34	34	34	34	34	34	34	34	-
Peas Green ⁽¹⁾	6 974	7 000	7 000	7 000	7 000	7 000	7 233	7 544	7 817	-
Carobs ⁽¹⁾	20 000	20 000	20 000	20 000	20 000	20 667	21 667	23 222	23 833	-
Beans Green ⁽¹⁾	18 107	16 679	16 833	16 563	16 563	16 563	16 563	16 563	16 563	-
Total	89 166	87 742	87 240	87 553	86 492	86 688	87 559	89 525	90 235	-

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

¹³⁰ 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 6.31 – Annual Production of non-leguminous Crops (metric tons) (1990-2008)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Wheat	510 519	425 761	467 499	415 445	414 741	409 403	364 982	295 345	277 452	285 933	286 823	307 120	238 743	285 168	174 673	208 016	144 486	185 079	152 814
Triticale	61 983	61 350	67 167	74 463	70 552	63 141	47 680	37 354	29 787	30 216	29 849	27 295	17 622	17 779	12 062	21 716	24 563	35 661	33 373
Maize	666 832	666 596	667 567	685 982	698 177	738 450	789 109	877 874	926 044	930 023	905 264	859 531	833 755	794 677	699 263	611 489	549 857	612 960	652 090
Barley	95 691	88 545	95 201	85 904	82 590	73 074	50 600	41 648	28 096	30 613	26 075	22 982	15 208	19 759	21 842	52 684	70 842	95 362	90 270
Rye	98 612	82 120	72 195	66 673	55 594	51 326	43 625	42 367	42 930	44 851	42 086	34 980	28 481	29 505	24 655	23 604	22 084	22 906	22 458
Oats	91 718	64 436	65 868	66 907	71 084	65 778	54 137	44 496	57 578	80 278	83 605	70 852	46 394	53 934	41 829	57 859	58 099	80 523	77 231
Rice Paddy	156 939	145 418	116 394	103 482	108 432	142 842	153 658	166 064	159 204	152 012	146 731	144 816	146 546	147 654	139 079	139 369	141 685	151 852	153 442
Sunflower	46 954	48 644	43 418	45 355	37 061	34 806	30 466	34 319	27 399	27 928	23 242	24 443	20 926	17 690	11 443	6 809	6 871	11 472	15 152
Hops	194	112	68	45	88	129	131	107	72	52	51	50	48	42	35	35	35	33	32
Tomatoes	714 563	657 940	552 343	612 691	742 308	877 383	848 629	931 862	963 897	996 516	937 512	889 848	891 044	987 509	1 060 059	1 089 729	1 101 497	1 122 342	1 191 918
Tobacco	5 072	4 901	4 108	3 855	4 059	5 283	5 665	6 310	6 170	6 267	5 895	5 834	5 700	5 565	5 280	4 135	2 786	1 656	1 335
Tea (1) until 2002	170	127	73	43	48	62	57	37	56	88	120	115	114	115	118	121	126	137	144
Chicory (1)	2 203	2 533	2 761	3 035	2 855	2 644	2 391	2 290	2 342	2 220	2 633	2 700	2 767	2 500	2 500	2 517	2 550	2 600	2 625
Potatoes	1 374 093	1 448 989	1 445 498	1 428 786	1 374 603	1 329 139	1 159 229	996 255	913 913	874 442	795 252	739 309	737 055	762 294	691 709	650 184	612 448	611 457	611 559
Sugar Beet	12 225	14 627	21 051	33 769	46 346	46 492	79 635	123 188	280 829	384 902	415 982	462 161	469 632	584 857	571 863	517 160	392 988	237 029	195 524
Yams (1) after 1994	1 294	1 438	1 369	1 314	1 182	1 176	1 535	1 770	2 091	2 100	2 100	2 100	2 100	2 100	2 100	2 233	2 417	2 706	2 808
Sugar Cane (1) after 1991	3 760	3 878	3 996	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 333	4 700	5 300	5 450
Sweet Potatoes (1)	27 000	26 667	28 000	27 333	26 333	23 667	22 667	22 000	22 000	22 000	22 000	22 000	22 000	22 000	22 000	23 000	24 333	26 444	27 167
Maize for Forage (1)	3 398 333	3 545 000	3 883 333	4 228 333	4 511 667	4 633 333	4 766 667	4 926 667	4 966 667	5 000 000	5 000 000	5 000 000	5 000 000	5 000 000	5 016 667	5 020 000	5 023 333	5 010 000	5 010 000
Sorghum for Forage (1)	331 667	363 333	361 667	356 667	341 667	346 667	360 000	360 000	360 000	360 000	360 000	360 000	360 000	360 000	363 333	364 000	364 667	362 000	362 000
Roots Fodder (1)	378 333	383 333	388 333	393 333	386 667	395 000	401 667	418 333	420 000	420 000	420 000	420 000	420 000	420 000	423 333	424 000	424 667	422 000	422 000
Forage (1)	6 300 000	6 033 333	5 833 333	6 033 333	6 433 333	6 866 667	6 933 333	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 216 667	7 220 000	7 223 333	7 210 000	7 210 000
Pumpkins (1)	4 200	4 200	4 033	3 867	6 600	9 700	12 600	12 600	12 167	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 500	13 167	13 750
Lettuce (1) until 1996	32 000	33 000	35 667	41 000	49 267	56 367	62 761	74 069	84 876	79 469	66 190	54 680	57 424	59 192	59 192	59 192	59 192	59 192	59 192
Garlic (1)	1 667	1 667	1 533	1 467	1 467	1 467	1 433	1 400	1 400	1 400	1 400	1 400	1 400	1 400	1 400	1 433	1 567	1 756	1 883
Eggplants (1)	6 667	6 667	6 100	5 833	5 833	5 833	5 667	5 500	5 500	5 500	5 500	5 500	5 500	5 500	5 500	5 667	6 167	6 889	7 333
Onions (1) until 1996	57 200	57 200	68 133	82 400	101 933	107 900	109 540	104 479	108 760	85 286	62 362	34 474	35 335	37 079	37 079	37 079	37 079	37 079	37 079
Carrots (1) until 1996	82 667	83 000	83 000	83 000	97 700	128 133	139 062	144 900	144 646	123 294	90 898	49 775	49 255	50 170	50 170	50 170	50 170	50 170	50 170
Cauliflower (1) until 1996	19 667	20 000	20 000	20 000	23 300	26 700	29 441	29 823	31 140	26 201	20 378	14 715	15 966	17 161	17 161	17 161	17 161	17 161	17 161
Cabbages (1) until 1996	166 667	166 667	153 333	146 667	150 000	150 000	195 705	248 032	316 469	268 789	209 110	153 837	165 642	179 489	179 489	179 489	179 489	179 489	179 489
Spinach (1)	16 667	16 667	15 333	14 667	14 667	14 667	14 333	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 333	15 000	16 000	16 500
Watermelons (2) until 1996	64 385	43 959	32 427	22 478	24 772	26 355	35 514	45 463	55 412	43 959	32 427	22 478	24 772	26 355	26 355	26 355	26 355	26 355	26 355
Melons (2) until 1996	127 281	109 970	91 754	73 780	80 667	85 122	95 546	109 307	127 281	109 970	91 754	73 780	80 667	85 122	85 122	85 122	85 122	85 122	85 122
Cucumbers (1)	8 333	8 333	7 667	7 333	7 333	7 333	7 167	7 000	7 000	7 000	7 000	7 000	7 000	7 000	7 000	7 333	8 000	9 000	9 500
Chillies (2) until 1996	51 662	48 786	45 088	44 346	49 506	52 461	50 178	50 920	51 662	48 786	45 088	44 346	49 506	52 461	52 461	52 461	52 461	52 461	52 461
Mushrooms (1)	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 017	1 039	1 058
Quinces	4 567	4 067	3 560	3 793	3 148	2 647	1 916	1 819	1 990	2 110	2 203	2 090	2 061	2 068	2 077	2 077	2 077	2 256	2 345
Loquat	1 528	1 594	1 527	1 622	1 606	1 666	1 552	1 388	1 142	948	888	903	885	869	851	851	851	832	822
Pomegranate	1 803	1 803	1 770	1 737	1 667	1 636	1 422	1 142	743	527	411	411	403	395	387	387	387	411	424

Agriculture

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Pineapples (1) after 1992	1 476	1 760	1 927	2 093	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 167	2 500	3 000	3 250
Bananas (1) after 1993	43 648	41 156	38 300	37 667	35 000	32 667	31 667	31 667	33 333	31 667	31 667	30 000	30 000	30 000	30 000	30 667	32 000	34 000	35 000
Peach	90 123	94 948	97 090	95 860	90 813	85 731	83 124	71 005	69 346	62 671	53 891	50 153	47 930	56 357	52 706	50 422	50 766	51 139	51 671
Apples	270 551	275 635	269 502	252 390	237 011	234 541	259 108	234 168	246 816	227 159	261 999	263 940	284 190	288 425	272 292	262 588	252 562	248 139	243 018
Kiwi	3 406	5 863	8 403	9 808	9 412	9 554	9 960	8 711	8 822	8 315	9 148	9 237	9 774	10 859	10 903	11 568	12 033	11 934	11 629
Pears	93 580	96 660	97 790	110 070	104 094	108 363	127 956	140 384	147 176	131 057	138 305	136 302	118 911	134 175	135 819	164 245	148 793	170 414	168 150
Sour Cherries	642	682	713	677	630	606	444	268	110	95	91	64	42	42	42	42	42	44	46
Fig	15 100	14 683	13 583	10 809	8 330	6 656	5 548	4 700	3 952	3 840	3 790	3 632	3 634	3 594	3 056	2 940	2 825	3 077	3 029
Kaki	4 650	4 633	4 460	4 393	3 633	2 785	1 582	994	1 240	1 799	2 591	2 810	3 030	3 162	3 229	3 229	3 229	3 383	3 460
Apricots	4 543	4 610	4 480	4 695	4 812	4 956	4 904	4 507	4 956	5 148	4 742	4 242	3 907	4 614	4 670	4 807	4 873	4 965	4 971
Cherry	11 795	13 333	13 940	13 291	11 425	10 892	10 841	9 044	10 786	9 506	12 123	13 201	15 368	16 758	15 299	15 774	13 521	11 826	9 959
Plum	16 332	16 639	15 935	16 747	17 162	17 757	17 812	16 743	16 975	16 214	15 108	14 478	14 893	16 544	16 526	17 503	18 638	20 462	20 837
Avocados (1)	20 967	20 333	18 667	16 233	14 100	13 000	13 000	13 000	13 000	13 000	13 000	13 000	13 000	13 000	13 000	13 667	14 667	16 222	16 833
Strawberries (1)	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 550	2 650	2 800	2 875
Raspberries (1)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	233	367	589	633
Berries nes (1)	100	133	133	133	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Tangerine	25 125	25 623	26 741	29 525	32 194	34 769	34 906	35 814	39 763	42 052	44 924	48 097	53 997	58 428	59 061	58 774	57 422	59 401	59 633
Lemon	10 117	10 438	10 518	10 791	10 906	10 402	9 981	9 301	9 864	10 516	11 260	11 447	12 019	12 328	12 546	11 810	11 535	11 564	11 713
Orange	169 155	174 974	173 802	179 825	190 173	191 883	199 290	219 960	231 015	245 725	229 659	251 633	258 756	268 176	248 276	234 123	220 938	207 457	193 958
Pomelo	4 950	5 267	5 550	5 909	6 320	6 769	6 863	6 868	5 816	4 788	3 774	4 021	4 150	4 207	3 941	3 459	3 075	2 704	2 697
Grapefruit	832	800	760	852	924	996	964	880	657	471	306	287	265	262	242	252	267	291	292
Walnut	5 610	5 283	4 508	3 550	3 105	3 053	3 245	3 331	3 740	3 880	4 322	4 323	4 530	4 570	4 426	4 392	4 238	4 099	3 928
Chestnuts	19 052	17 358	15 266	17 174	19 602	23 316	24 956	26 981	28 880	31 200	30 135	30 273	30 257	31 901	28 933	28 140	25 119	24 925	21 945
Hazelnuts	1 993	1 900	1 690	1 435	1 116	976	865	802	752	668	641	614	596	572	493	441	414	426	419
Almonds	50 377	48 375	47 548	38 783	31 320	26 406	31 049	31 464	33 263	28 821	25 804	24 539	23 470	22 873	17 246	13 494	12 778	11 391	10 801
Olives (Oil)	302 638	246 248	266 260	200 115	256 993	269 537	298 497	269 950	285 190	237 880	235 516	199 086	221 014	248 407	278 115	300 699	300 699	312 626	318 589
Olives (fruit)	21 400	19 900	16 821	12 491	9 823	9 156	9 248	9 275	10 160	9 253	10 947	10 952	12 199	11 453	10 227	10 161	9 112	9 573	8 812
Wine grapes (1)	1 285 581	1 285 582	997 133	826 044	834 841	1 036 179	1 015 820	818 094	753 157	832 301	959 631	938 409	886 815	920 871	907 417	953 681	898 580	831 297	758 638
Grapes	52 752	54 418	52 867	52 112	53 445	55 401	58 131	52 392	52 370	49 675	53 888	54 641	54 338	55 405	52 397	52 421	48 221	45 669	42 261

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 6.32

Table 6.32 – 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 6.32). 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 6.33 - 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% 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% due to the uncertainty in the percentage of manure that ends up in soil;
- An uncertainty error of 25% 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%. From that range an uncertainty of 500% 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% 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% 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*

Changes in the N_2O emission from this source category are the consequence of:

- Update of national statistics concerning livestock and crop data (mainly for 2007) reporter by INE and FAO;
- Update of national statistics concerning the use of fertilizers (also mainly for 2007) reported by INE;
- Revision of the nitrogen excretion rates and shares of manure management systems.

6.3.5.8 *Further Improvements*

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.

Although the lack of suitable statistical information, efforts will continue to quantify the nitrogen in sewage sludge that is used as soil fertilizer.

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 N₂O 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 NH₃ emissions from other emissions sources may settle in soil and water and result in similar N₂O emissions. However, estimates of indirect emissions from these sources are not included in the Portuguese inventory.

Indirect emissions of N₂O from ammonia and NO_x volatilisation where estimated from ammonia volatilised whether actual indirect N₂O emissions occurred in the Portuguese territory or not. In the case of N₂O 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 waters¹³¹.

Even though this nitrogen flow is evident in Figure 6.26, it's important to stress the fact that indirect emissions of N₂O from volatilization result from 2 volatilization processes: the first as direct NH₃/NO_x emission and the second as N₂O indirect emission. Between these two processes occurs deposition of nitrogen from NH₃/NO_x direct emissions.

Figure 6.37 shows the percent importance of each sub-source for year 2008, where:

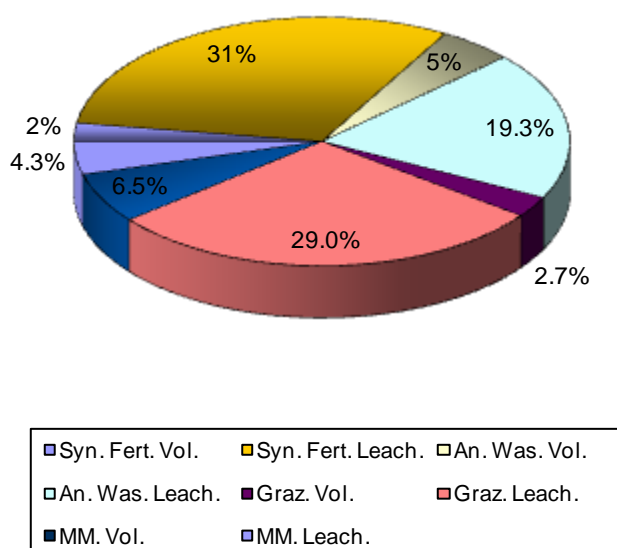
- Syn. Fert. Vol. – Synthetic Fertilizers N volatilization;
- Syn. Fert. Leach - Synthetic Fertilizers N resulting from leaching and runoff;
- An. Was. Vol. – Volatilization of N from Animal Waste (manure) applied to soil as fertilizer;

¹³¹ In fact, part of indirect N₂O 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.

- 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 N₂O indirect emission in this source category.

Figure 6.32 – Relative importance of Indirect emissions of N₂O from agriculture in year 2008



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 input¹³², 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

¹³² 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.

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);

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 occurs 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% of the effluent from anaerobic lagoons is used as soil fertilizer whereas the remaining 20% 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.

EQUATION 10.28
N LOSSES DUE TO LEACHING FROM MANURE MANAGEMENT SYSTEMS

$$N_{\text{leaching-MM}} = \sum_s \left[\sum_T \left[\left(N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)} \right) \cdot \left(\frac{\text{Frac}_{\text{leachMS}}}{100} \right)_{(T,S)} \right] \right]$$

EQUATION 10.29
INDIRECT N₂O EMISSIONS DUE TO LEACHING FROM MANURE MANAGEMENT

$$N_2O_{L(mm)} = (N_{\text{leaching-MM}} \cdot EF_5) \cdot \frac{44}{28}$$

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).

EQUATION 10.34
MANAGED MANURE N AVAILABLE FOR APPLICATION TO MANAGED SOILS, FEED, FUEL OR CONSTRUCTION USES

$$N_{\text{MM}_\text{Avb}} = \sum_s \left\{ \sum_T \left[\frac{\left(N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)} \right) \cdot \left(1 - \frac{\text{Frac}_{\text{leachMS}}}{100} \right)}{\left[N_{(T)} \cdot MS_{(T,S)} \cdot N_{\text{beddingMS}} \right]} \right] \right\}$$

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% 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 discharged¹³³. In general terms the 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 system¹³⁴;

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 6.34 – 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.

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 6.35 and which contribution of sub-sources in year 2008 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 40% of total deposition in 2008. The following most important components are nitrogen in manure applied to soil as fertilizer (30%) and nitrogen in droppings during grazing (16.4%). Nitrogen volatilised from synthetic fertilizers is

¹³³ Total contribution, not assuming volatilization or leaching rates.

¹³⁴ MSSW in the case of Anaerobic Lagoons is equal to 1-MSSD.

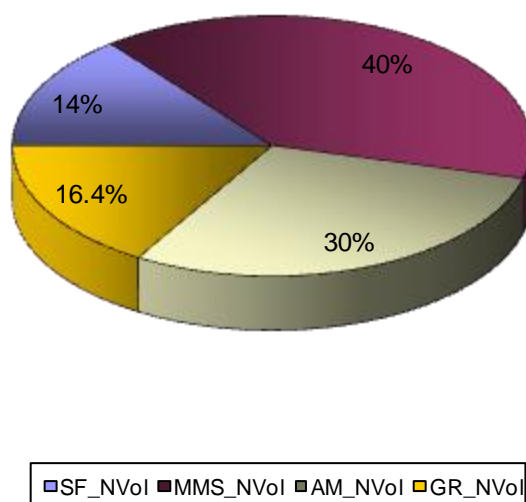
a less important source with 14% of total contribution in 2008. Total ammonia emissions and deposition have decreased about 16% from base year to last year in the inventory.

Table 6.35 – Nitrogen added to soil from Ammonia volatilisation, by emission source/component, which is activity data for Indirect N₂O emission (1990-2008)

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SF_NVol	9 089	9 089	9 006	7 623	9 224	8 187	9 904	10 325	8 453	8 965
MMS_NVol	16 788	16 965	16 843	16 724	16 601	16 469	16 154	16 029	16 163	16 747
AM_NVol	12 558	12 634	12 505	12 367	12 295	12 240	12 051	11 949	12 035	12 504
GR_NVol	4 554	4 621	4 572	4 569	4 656	4 834	5 001	5 130	5 255	5 400
Total	42 988	43 309	42 926	41 284	42 777	41 729	43 111	43 433	41 906	43 617

ton N/yr	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
SF_NVol	9 744	9 007	9 372	6 298	7 196	5 871	4 740	5 627	5 169	-
MMS_NVol	16 878	16 682	16 394	15 763	15 458	15 275	14 954	14 515	14 355	-
AM_NVol	12 577	12 396	12 196	11 688	11 473	11 380	11 135	10 781	10 666	-
GR_NVol	5 462	5 468	5 485	5 479	5 575	5 735	5 835	5 886	5 925	-
Total	44 662	43 553	43 447	39 228	39 702	38 260	36 663	36 810	36 115	-

Figure 6.33 – Percent importance of nitrogen added to soil from volatilization of ammonia, by emission source/component (2008)



The fraction of nitrogen input to soil that is lost through leaching and runoff (Frac_{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 oxide¹³⁵.

The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in Table 6.36 and in, for each component that is considered in

¹³⁵ Which explains the fact that in CRF table 4Ds2, the "implicit" Frac_{LEACH} is a little higher than the default.

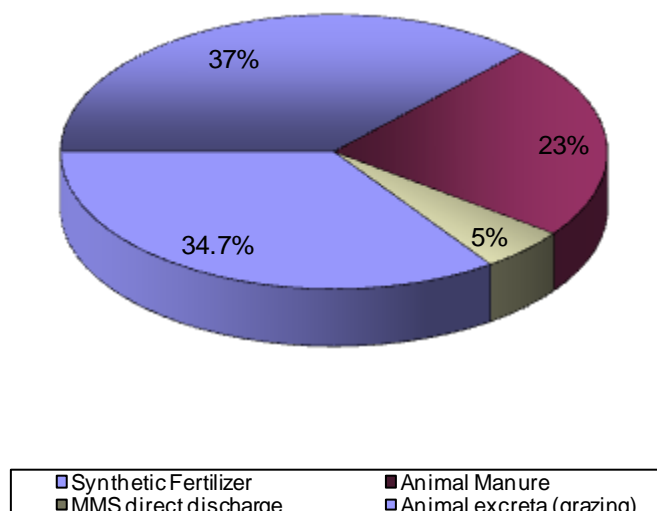
lixiviation/runoff estimate: FSN (Synthetic Fertilizers), FAM (Animal Manure), FGR (Grazing) and direct discharge to the water system. Nitrogen added to soil in synthetic fertilizers is the major lixiviation/runoff source. From 1990 to 2008 nitrogen deposited into soil has decreased by 19.3%.

Table 6.36 – Nitrogen lost from soil from lixiviation and runoff (t N/yr)

Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Synthetic Fertilizer	47 684	47 684	47 684	47 684	47 684	43 745	50 469	49 286	44 791	44 683
Animal Manure	20 107	20 239	20 038	19 833	19 728	19 647	19 362	19 192	19 309	19 997
MMS direct discharge	3 088	3 274	3 334	3 409	3 406	3 399	3 323	3 361	3 399	3 463
Animal excreta (grazing)	20 365	20 650	20 460	20 464	20 834	21 535	22 184	22 645	23 134	23 701
Total	91 244	91 847	91 516	91 391	91 652	88 326	95 337	94 484	90 633	91 844

Description	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Synthetic Fertilizer	51 003	47 253	49 170	33 040	37 753	30 799	24 866	29 523	27 121	-
Animal Manure	20 090	19 776	19 426	18 625	18 283	18 132	17 749	17 182	16 962	-
MMS direct discharge	3 507	3 552	3 576	3 560	3 599	3 652	3 720	3 748	3 771	-
Animal excreta (grazing)	23 956	23 896	23 847	23 749	24 150	24 832	25 259	25 392	25 413	-
Total	98 557	94 478	96 019	78 973	83 785	77 415	71 593	75 847	73 267	-

Figure 6.34 – percent importance of sub-sources of Nitrogen Lost from soil from lixiviation and runoff in 2008



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% 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%.

6.3.6.6 *Recalculations*

The recalculations made in this source category were the same that were reported for Direct N₂O emission:

- Update of national statistics concerning livestock (mainly for 2007) reported by INE;
- Update of national statistics concerning the use of fertilizers (also mainly for 2007) reported by INE;
- Revision of the nitrogen excretion rates and shares of manure management systems.

6.3.6.7 *Further Improvements*

No major modifications are expected for this source sector.

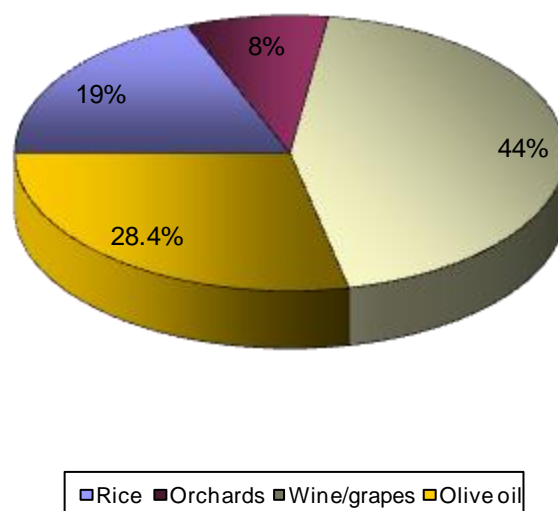
6.3.7 *Field Burning of Agriculture Residues (CRF 4.F.)*

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. This 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 2008



6.3.7.2 Methodology

Emissions of in-site burning of agriculture residues were estimated from the following equation:

$$\text{Emission}_{(p,crop,y)} = EF_{(p,crop)} * \text{Crop}_{\text{BURN}(crop,y)} * 10^{-3}$$

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);

$EF_{(p,crop)}$ - 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, 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:

$$EF_{(\text{pol}, \text{crop})} = C_{\text{Fraction (Crop)}} * \text{Frac}_{\text{RESOXI (crop)}} * ER_{(\text{crop}, \text{pol})} * \text{MWC}_{(\text{Pol})}$$

For nitrogen containing compounds the equation is:

$$EF_{(\text{pol}, \text{crop})} = C_{\text{Fraction (Crop)}} * \text{Frac}_{\text{RESOXI (crop)}} * \text{NC}_{\text{Ratio (crop)}} * ER_{(\text{crop}, \text{pol})} * \text{MWC}_{(\text{Pol})}$$

where

$EF_{(\text{pol}, \text{crop})}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$C_{\text{Fraction (Crop)}}$ - 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);

$ER_{(\text{crop}, \text{pol})}$ - 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);

$\text{MWC}_{(\text{Pol})}$ - 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 6.37 – Parameters used for determination of emission factors for field burning of agricultural residues

Crop	C_{fraction}	$\text{Frac}_{\text{RESOXI}}$	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 6.38 – 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

The emission factors for NMVOC are those proposed by AP-42 (USEPA,1992), which are reproduced in Table 6.39, together with final emission factors for all other pollutants and all crops.

Table 6.39 – Final emission factors for field burning of agricultural residues by pollutant and crop (kg/ha)

Crop	CH ₄	N ₂ O	NO _x	CO	NMVOC
Rice	2.1	0.14	5	44.2	15.6
Fresh Fruits	0.4	0.04	1.3	9.1	2.0
Citrines	0.4	0.04	1.3	9.1	4.0
Dry fruits	0.4	0.04	1.3	9.1	2.4
Wine/grapes	1.8	0.12	4.3	37.8	7.5
Olive oil	0.7	0.04	1.6	14.2	2.6

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 orchards¹³⁶ 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. 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 Protection¹³⁷ are used;

¹³⁶ Comprehending fresh fruit, citrines and dry fruits (nuts)

¹³⁷ “modos de protecção e produção integrada” in the original in Portuguese.

- The area subjected to “Techniques of Integrated Production and Protection” occupied about 50% of rice paddies in 2004. Today the area burnt occupies only about 30-40% of total area;
- It may be assumed that, in 1990, 100% of rice paddies were burnt and no organic amendments were added to soil. In 2008 the area subjected to burning was reduced to only about 33%.

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 6.40. Final activity data expressed in crop area dry matter content may be seen in Table 6.40 and Table 6.41.

Table 6.40 – Parameters used for the estimation of the quantity of burnt crop residues

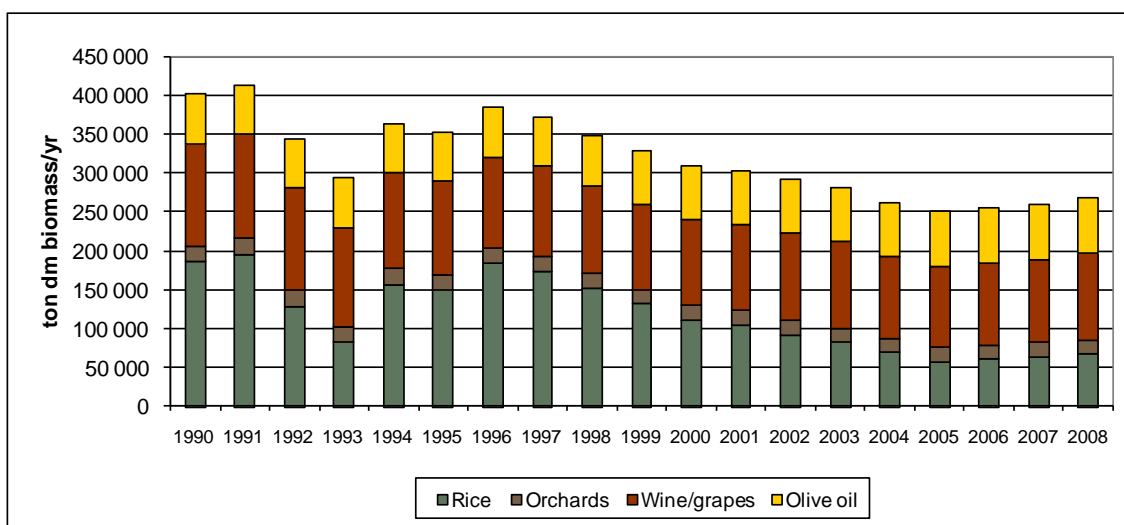
Crop	$\text{Resid}_{\text{PROD}}$	$\text{Frac}_{\text{RESBURN}}$	DMContent
	kg live weight/ha	%	%
Rice	3 900	30-100	85
Orchards	800	30	50
Wine/Grapes	2 500	40	50
Olive oil	375	100	50

Table 6.41 – Crop area per crop (ha)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Rice	33 824	33 466	21 118	13 200	24 051	21 726	28 278	28 540	27 020	25 307
Orchards	164 147	166 120	168 101	166 838	165 690	164 748	163 842	162 336	161 382	157 122
Wine/grapes	264 359	271 160	264 062	254 528	247 615	241 964	236 654	232 226	226 497	219 444
Olive oil	337 189	333 757	338 947	340 579	340 672	333 144	336 621	338 414	347 271	368 974
Total	799 519	804 503	792 228	775 145	778 028	761 582	765 395	761 516	762 169	770 847

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Rice	23 859	24 936	25 216	25 657	25 587	21 938	24 421	26 903	29 386	-
Orchards	157 698	157 909	157 985	158 152	158 362	157 152	155 636	154 667	155 170	-
Wine/grapes	220 356	222 569	222 620	222 446	210 486	210 464	210 371	210 337	222 682	-
Olive oil	369 162	369 314	369 858	374 154	374 474	376 524	379 421	379 616	380 714	-
Total	771 075	774 728	775 679	780 409	768 909	766 078	769 848	771 523	787 952	-

Figure 6.36 – Estimated total quantities of burnt crop residues per crop (1990-2008)



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% was therefore considered.

The uncertainty range in emission factors was set at 20% in accordance with recommendations from GPG (IPCC,2000).

6.3.7.6 Recalculations

No significant changes were made to this category apart from updating the crop area time series for 2007.

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 for inventory clarification.

Ammonia volatilisation from the application of synthetic fertilizers (SN_{NH_3}) is calculated using the following formula:

$$SN_{NH_3} = N_{Fert} * Fra_{GASF}$$

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:

$$AM_NH_3 = \sum_t \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

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;

$EF_{NH_3SD(i)}$ - 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:

$$GZ_NH_3 = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * EF_{NH_3(i)}]$$

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;

$EF_{NH_3(i)}$ - 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 constrains 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 constrains 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 equation¹³⁸. 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

¹³⁸ This estimates are only preliminary guesses and are being revised together with INE and the Ministry of Agriculture.

prone to nitrogen volatilization, represented about 17% of nitrogen added as fertilizer to soils.

$$\text{Consumption}_{(f)} = \text{Production}_{(f)} + \text{Import}_{(f)} - \text{Export}_{(f)}$$

where,

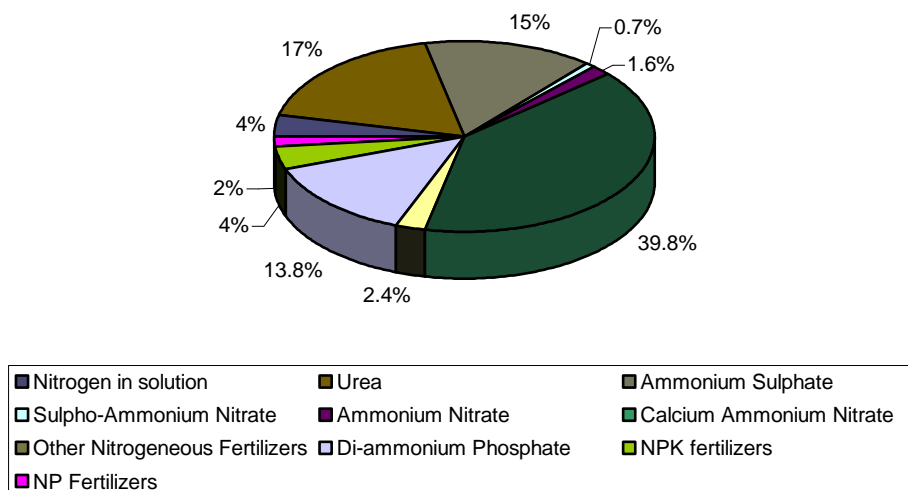
Consumption_(f) – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

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 6.42.

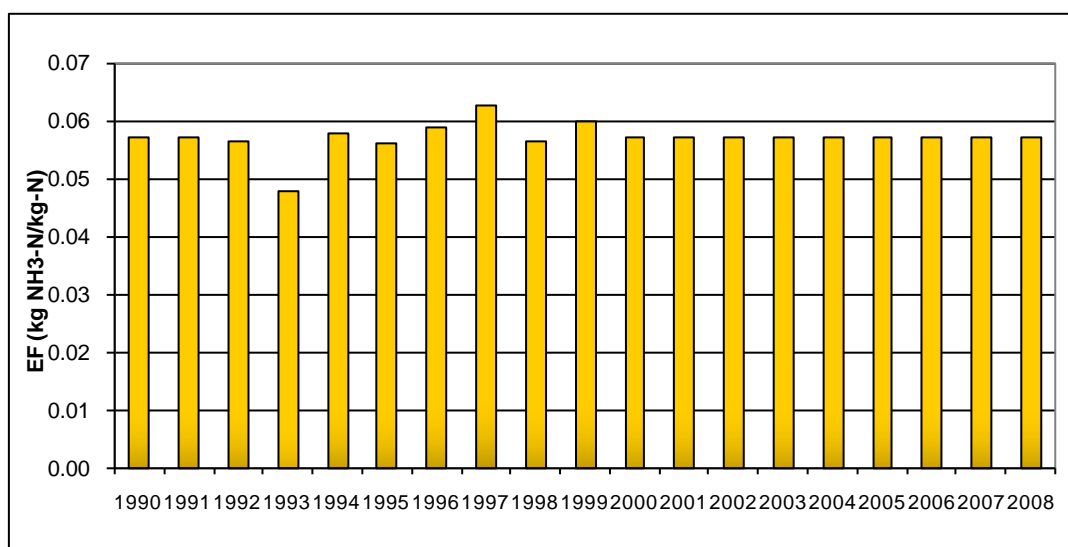
Table 6.42 – Volatilization rates for each nitrogen fertilizer

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 2001-2008. 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 (1990-2008)



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 6.43. 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 6.43 - Emission factors used for calculation of NH₃ volatilisation from animal housing, land spreading and grazing in pasture (kg N-NH₃/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 $Frac_{GASM}$ that are different and higher than the default value for $Frac_{GASM}$ (0.2 kg N-NH₃ + N-NO_x/ kg of N excreted, in table 4-19 of IPCC96).

6.3.8.3 Activity Data

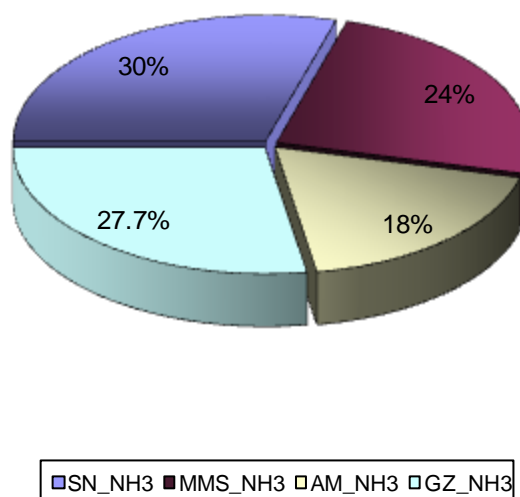
The quantity of nitrogen that is subjected to volatilisation through direct emission is presented in Table 6.44, and Figure 6.39.

Table 6.44 – Nitrogen subjected to volatilization from each emission source/component, which is activity data for NH₃ emissions (1990-2008)

Source	ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
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
M.M.S.	MMS_NH ₃	86 900	87 704	86 970	86 245	85 768	85 360	84 016	83 362	83 925	86 867
Animal Manure	AM_NH ₃	67 025	67 464	66 794	66 111	65 761	65 492	64 539	63 972	64 362	66 656
Grazing/ Pasture	GZ_NH ₃	67 883	68 833	68 201	68 215	69 447	71 782	73 946	75 483	77 113	79 004
Total	-	380 754	382 947	380 910	379 517	379 920	368 449	390 731	387 105	374 702	381 471

Source	ton N/yr	2000	2001	2002	2003	2004	2005	2006	2007	2008	-
Synthetic Fertilizers	SN_NH ₃	170 009	157 511	163 902	110 132	125 844	102 663	82 887	98 411	90 402	-
M.M.S.	MMS_NH ₃	95 095	95 568	94 110	92 669	90 008	89 485	89 106	88 818	87 517	-
Animal Manure	AM_NH ₃	66 968	65 922	64 754	62 083	60 943	60 441	59 163	57 274	56 541	-
Grazing/ Pasture	GZ_NH ₃	74 593	75 177	74 702	74 022	73 662	74 708	76 139	77 290	77 442	-
Total	-	404 186	389 241	392 868	332 784	347 287	325 244	304 083	315 865	306 320	-

Figure 6.39 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation in 2008



For the last inventory year (2008) the majority of nitrogen added to soil, that contribute to NH_3 emissions, resulted from the application of Synthetic Fertilizers (30%). Direct droppings during grazing in Pasture (27.7%) and Manure Management System (24%) 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

Changes to activity date time series already discussed in previous chapters. Also changes in estimates of emission of ammonia reflect indirectly the changes in nitrogen excreted by livestock and the quantity of nitrogen in synthetic fertilizers and manure that is added to soil as fertilizer. All these changes were already explained in previous chapters.

6.3.8.5 Further Improvements

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.)

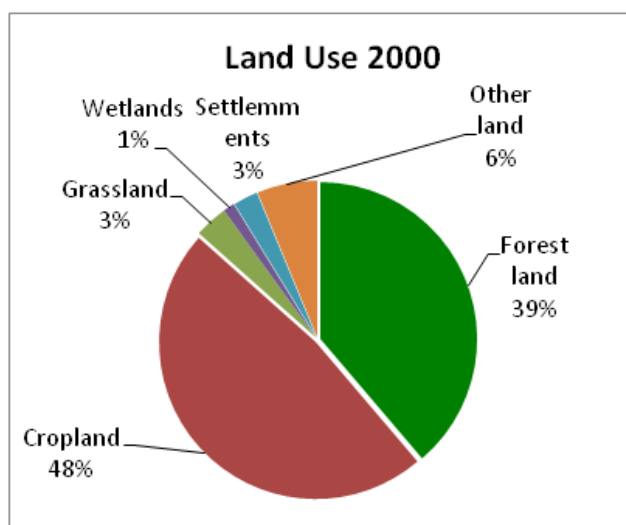
7.1 Overview

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 2003 IPCC Good Practice Guidance for LULUCF (GPG LULUCF) was applied to the extent possible.

The six GPG LULUCF categories are: Forest Land (5A), Cropland (5B), Grassland (5C), Wetlands (5D), Settlements (5E) and Other Land (5F). According to the reporting guidelines these categories should be reported individually. However, it was considered more transparent and consistent to report common considerations under the same chapter – Land Use Conversion. Therefore, only Forest Land Remaining Forest (FF) is reported separately, while for the other categories only a reference to the Land Use Conversion sub-chapter is made.

With the exception of FF, CO₂ emissions/removals estimates made for all other land use categories which maintain the same classification refer only to the situations where cover changes occur (e.g. crop changes). The major part of the areas that maintain the same land use C stocks were considered to be in equilibrium, and therefore the respective emissions/removals were estimated to be zero.

Figure 7.1 – Land Use categories in Mainland Portugal



Carbon stock changes in forest land have been estimated for living biomass (above and below ground). 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. Concerning land-use changes and conversions within the six GPG LULUCF categories, all carbon pools (above and belowground biomass, dead organic matter, and soil organic matter) have been assessed.

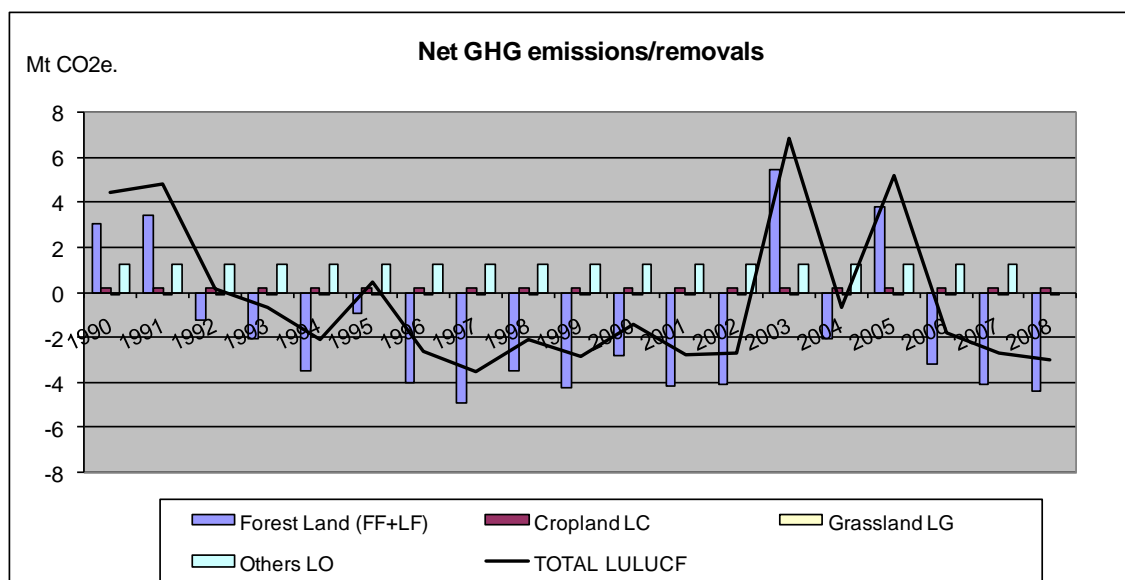
N₂O emissions from nitrogen fertilisation of forest soils have not been estimated separately as they are already included in the chapter on Agriculture. This is mostly due to the fact that statistical information does not distinguish between fertilizer use in forest and agricultural areas.

N₂O emissions from enhanced mineralization of soil organic matter associated with land-use conversion to cropland are estimated.

CO₂ emissions from lime application are still not considered in the inventory.

According to the last estimates, the sector shifted from a net emitter in 1990 to a sink in 2008, and was responsible for the sequestration of 2.96 Mt of CO₂ e. in 2008.

Figure 7.2 –Net Annual CO₂ Change from LULUCF (Mt CO₂e.) 1990-2008



7.2 Source categories

7.2.1 Forest Land (CRF 5.A.)

The estimation of carbon stock changes in Forest Land remaining Forest Land has been estimated for two carbon pools - aboveground and belowground biomass. No estimates have been calculated for dead wood, litter or soil organic matter, except in what concerns emissions from wildfires. The IPCC Guidelines do not require estimate dead wood or litter carbon stocks, considering that the average value of these pools remains constant in time, with inputs to dead matter pools balanced by outputs. Concerning carbon stocks in soils, Tier 1 considers that when forest remains forest the carbon stock in soils does not change, despite e.g. changes in forest management and forest type.

Carbon stock changes in Lands converted to Forest Land have been calculated for all carbon pools (aboveground, belowground biomass, dead organic matter, and soil organic matter).

7.2.1.1 Forest Land remaining Forest Land (FF)

7.2.1.1.1 Methodology

The methodology used is based on the IPCC 1996 Guidelines and GPG LULUCF, and relies on the carbon flux approach. It assesses net CO₂ flux due to changes in forest carbon stocks taking account of emissions caused by biomass carbon loss (e.g. tree fellings and other losses), and carbon uptakes from the atmosphere due to tree growth.

The general equation, which estimates the annual emissions or removals from FF with respect to changes in carbon pools, is given in the following equation:

$$\Delta C_{FF} = (\Delta C_{FFLB} + \Delta C_{FFDOM} + \Delta C_{FFSoils})$$

where:

ΔC_{FF} - annual change in carbon stocks from forest land remaining forest land, t C yr⁻¹;

ΔC_{FFLB} - annual change in carbon stocks in living biomass (includes above and belowground biomass) in forest land remaining forest land, t C yr⁻¹;

ΔC_{FFDOM} - annual change in carbon stocks in dead organic matter (includes dead wood and litter) in forest land remaining forest land, t C yr⁻¹;

$\Delta C_{FFSoils}$ - annual change in carbon stocks in soils in forest land remaining forest land, t C yr⁻¹.

As ΔC_{FFDOM} and $\Delta C_{FFSoils}$ were assumed as zero, the equation simplifies to:

$$\Delta C_{FF} = \Delta C_{FFLB}$$

7.2.1.1.1.1 CHANGE IN CARBON STOCKS IN LIVING BIOMASS

The methodology that was used follows the method 1 (default method) of GPG LULUCF.

$$\Delta CFF_{LB} = \Delta CFF_G - \Delta CFF_L$$

where:

ΔC_{FFG} - annual increase in carbon stocks due to biomass growth, t C yr⁻¹

ΔC_{FFL} - annual decrease in carbon stocks due to biomass loss, t C yr⁻¹

7.2.1.1.1.1.1 BIOMASS INCREMENT

The **annual increase in carbon stocks** due to biomass increment was calculated as follows:

$$\Delta CFF_G = \sum_i (A_i \cdot G_{TOTALi}) \cdot CF$$

where:

ΔCFF_G - annual increase in carbon stocks due to biomass increment in forest land remaining forest land by forest type (i), t C yr⁻¹;

A_i - area of forest land remaining forest land, by forest type (i), ha;

G_{TOTALi} - average annual increment rate in total biomass in units of dry matter, by forest type, t d.m. ha⁻¹ yr⁻¹;

CF - carbon fraction of dry matter, t C /t d.m.

The **average annual increment in total biomass** (above and below ground) was obtained from the annual aboveground biomass increment and the root-shoot ratio (the ratio of belowground biomass to aboveground biomass).

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

where:

G_{TOTAL} - average annual biomass increment above and below ground, t d.m. ha⁻¹ yr⁻¹

G_W - average annual aboveground biomass increment, t d.m. ha⁻¹ yr⁻¹

R - root-to-shoot ratio

The **average annual aboveground biomass** increment was calculated as follows:

$$G_W = IV \cdot BEF$$

where:

G_W - average annual aboveground biomass increment, t d.m. ha⁻¹ yr⁻¹;

IV - average net annual growth rate, m³ ha⁻¹ yr⁻¹;

BEF = Biomass expansion factor for above ground biomass (t d.m. m⁻³)

7.2.1.1.1.2 BIOMASS LOSS

The annual carbon loss in living biomass was estimated as the sum of losses from commercial fellings and carbon losses from fires as follows:

$$\Delta C_{FFL} = L_{\text{fellings}} + L_{\text{Wildfires}}$$

where:

ΔC_{FFL} - annual decrease in carbon stocks due to biomass loss in forest land remaining forest land, t C yr⁻¹;

L_{fellings} - annual carbon loss due to commercial fellings, t C yr⁻¹;

$L_{\text{Wildfires}}$ - annual carbon losses due to wildfires, t C yr⁻¹;

The IPCC Guidelines considers also biomass losses from fuelwood gathering. However this part has not been considered in the Portuguese estimates, as it has been assumed that forest biomass used in heat production (domestic firewood or industrial) is a forest sub-product resulting from forest harvesting practices, and consequently is not consider *per se* as a depletion of carbon sequestration capacity. Non-CO₂ emissions from combustion of this biomass fuel are accounted in other sectors (CRF 1 Energy) on the basis of biomass data from energy balances (DGEG data).

7.2.1.1.1.2.1 Annual carbon losses due to commercial fellings

The equation used to estimate annual carbon losses due to commercial fellings is:

$$L_{\text{fellings}} = H \cdot BEF \cdot (1+R) \cdot CF$$

where:

L_{fellings} - annual carbon losses due to commercial fellings, t C yr⁻¹;

H - annual volume of commercial fellings, roundwood, m³ yr⁻¹;

BEF = Biomass expansion factor for above ground biomass (t d.m. m⁻³);

R - root-to-shoot ratio

CF - carbon fraction of dry matter, t C/t dm⁻¹.

For the estimation of biomass loss from commercial fellings, the IPCC default was considered: it was assumed that all carbon in harvested volumes is emitted in the year of removal, and consequently that there is no biomass left to decay in forest (transferred to dead organic matter).

In all cases managed with coppice systems (notably eucalyptus plantations) this corresponds to an overestimation of emissions, as roots, in particular large roots, are not killed when the trees are harvested.

This approach leads to an overestimation of emissions in the year of harvest and an underestimation of emissions in subsequent years. This is due to the fact that some biomass will decay over the period of some years and this method considers that all oxidation of organic matter happens in the year of harvest.

Non-CO₂ gases are not considered and this results in an underestimation of emissions, by excluding emissions resulting from the natural decay of harvesting residues and roots left onsite.

7.2.1.1.1.2.2 Annual carbon losses due to wildfires

The LULUCF GPG recommends to estimate CO₂ emissions resulting from carbon losses due to disturbances as wildfires, when the uptake of carbon by regrowing vegetation is also taken into account in calculations.

The level of disturbances on a forest varies with the type and severity of the fire, the conditions under which they occur and the characteristics of the ecosystem. Most forest ecosystems in Portugal are relatively resistant and resilient to forest fires. Different tree species have different strategies to cope with the effects of fire and the actual mortality caused by fires can be smaller than in other ecosystem types or climatic zones. Nevertheless there is always some tree mortality, which results in carbon emissions either during the fire itself or through the natural decay of dead organic matter following fires.

Another aspect to be considered is the post fire management of burnt areas, where it is common practice to salvage some wood for industrial or biomass use. Wood production statistics in Portugal do not differentiate between “normal” harvest and salvaged wood. As a consequence, harvesting totals refer to the sum of all wood used for different purposes, regardless of origin. Therefore, harvesting emissions include, by definition, emissions from salvage wood (see details of calculation of harvesting emissions in section 7.2.1.1.1.2.1). To avoid double counting, CO₂ emissions from salvaged wood are not considered under fire emissions.

In the event of a disturbance, the generic IPCC proposed method assumes the complete destruction of forest biomass, considering “stand-replacing” disturbances only. The approach used for harvesting emissions was also used for the estimation of carbon fire emissions, i.e., the loss of the entire dead tree at the time of fire (instant oxidation) was considered. It includes therefore leaves, branches, wood, bark and roots.

In all cases managed with coppice systems (notably eucalyptus plantations) or where fire regeneration happens through root resprouting, this corresponds to an overestimation of emissions, as roots, in particular large roots, are not killed by fire.

This approach leads to an overestimation of emissions in the year of harvest and an underestimation of emissions in subsequent years. This is due to the fact that some biomass will decay over the period of some years after fire and this method considers that all oxidation of organic matter happens in the year of harvest (instant oxidation).

Table 7.1 - Carbon pools and greenhouse gases considered in estimation of emissions and removals from forest fires

Carbon Pool	Carbon Gains	Carbon Losses	Other GHG Emissions
Above ground tree biomass	Not-Included	Partially Included (non-salvaged trees) (CO ₂)	During Fire Included (CH ₄ , N ₂ O) Decay of Dead Wood Not-Included (CH ₄ , N ₂ O)
Below ground tree biomass	Not-Included	Partially Included (non-salvaged trees) (CO ₂)	Not-Included
Other living biomass (understorey cover)	Not-Included	Not-Included	During Fire Included (CH ₄ , N ₂ O) Decay of Dead Wood Not-Included (CH ₄ , N ₂ O)
Litter	Not-Included	Not-Included	During Fire Included (CH ₄ , N ₂ O) Decay of Dead Wood Not-Included (CH ₄ , N ₂ O)
Dead wood	Not-Included	Not-Included	Not-Included
Soil carbon	Not-Included	Not-Included	Not-Included

The annual carbon loss in living biomass resulting from wildfires was estimated in two stages: as direct and indirect carbon loss.

$$L_{\text{Wildfires}} = L_{\text{Direct}} + L_{\text{Indirect}}$$

Direct carbon loss was calculated as follows:

$$L_{\text{Direct}} = \sum A_{\text{disturbance}} \cdot B_W \cdot \%AV_{\text{TS}} \cdot CF$$

where:

$A_{\text{disturbance}}$ - forest area affected by wildfires, ha yr⁻¹

B_W - average above ground biomass stock of the forest component (litter, understorey, leaves and small branches), t d.m. ha⁻¹

$\%AV_{\text{TS}}$ = percentage of biomass affected (combustion factor) by fires for each forest component considered (litter, understorey, leaves and small branches)

CF - carbon fraction of dry matter, t C (t d.m.)⁻¹

Indirect carbon loss was calculated as follows:

$$L_{\text{Wildfires}} = \sum A_{\text{disturbance}} \cdot V_W \cdot BEF \cdot (1+R) \cdot \%AV \cdot CF \cdot (1 - L_{\text{Direct}}) \cdot (1 - \%SW)$$

where:

$A_{\text{disturbance}}$ - forest areas affected by wildfires, ha yr⁻¹

V_W - average above ground biomass volume of forest areas, m³ ha⁻¹

BEF = Biomass expansion factor for above ground biomass for each tree species (t d.m. m⁻³);

R - root-to-shoot ratio

%AV = percentage of biomass affected (mortality) by fires for each tree species

%SW = percentage of affected biomass recovered as salvage wood after fires for each tree species

CF - carbon fraction of dry matter, t C (t d.m.)⁻¹

In previous submissions, the calculation of annual carbon loss in tree above ground biomass was estimated, for the two most representative species (pinus pinaster and eucalyptus) in terms of industrial wood consumption, assuming that the affected trees were harvested as salvaged wood and used in the industry, and were considered included in the harvest volumes. For the other species, the calculation of annual carbon loss of the above ground biomass referred to the estimated fraction of biomass affected by the disturbance, based on the assumption that these species do not have the same economic importance and the trees are left in the burnt areas and that they regenerate in majority after the fire.

The most recent UNFCCC review reports raised, however, the potential underestimation of CO₂ emissions from forest fires, due to the assumptions concerning the percentage of biomass burned or the consideration of total salvage volumes in harvest quantities. In order to answer to the UNFCCC observations, several parameters and assumptions were revised in the present submission.

The average biomass for each of the forest components considered (litter, understorey cover and leaves and fine branches) was revised, following a review on the topic by Rosa (2009). Litter values result from a literature review of data available for Portugal or similar forests in other countries. Shrub average biomass was calculated using data collected in the last national forest inventory, using an equation calibrated for Portuguese conditions (Silva *et al.*, 2006). Average biomass for leaves was calculated using data collected in the last national forest inventory, using equations calibrated for each of the main species considered (Tomé *et al.*, 2007, Correia *et al.*, 2008 e Montero *et al.*, 2005). Average biomass for fine branches was calculated using data collected in the last national forest inventory, using equations calibrated for each of the main species considered considering all branches with a diameter smaller than 2cm (Montero *et al.*, 2005).

The combustion factor or the fraction of the biomass affected by the wildfires was revised based on the information taken from the same study and were derived from a literature review for each of the different biomass components identified above. This information is summarized in the next table.

Table 7.2 – Estimated biomass loss in forest fires: direct emissions

	Average biomass (Mg/ha)				Combustion factor (%)			
	Litter	Understorey cover	Leaves	Fine branches	Litter	Understorey cover	Leaves	Fine branches
Pinus pinaster	7.81	8.24	4.26	7.27	75%	72%	88%	58%
Quercus suber	4.55	3.09	0.41	0.70	75%	72%	88%	58%
Eucalyptus	3.93	4.96	3.80	3.06	75%	72%	88%	58%
Quercus ilex	4.69	1.80	0.25	0.42	75%	72%	88%	58%
Other hardwood	4.64	6.15	1.42	3.69	75%	72%	88%	58%
Other softwood	7.01	4.07	4.88	7.63	75%	72%	88%	58%

Source: Rosa (2009)

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The estimates consider also emissions that result from tree mortality, as a consequence of fires.

The approach used for indirect carbon fire emissions considered the loss of the entire dead tree at the time of fire (instant oxidation), including therefore leaves, branches, wood, bark and roots.

Another aspect that has been revised, is the consideration that only a fraction of the burnt trees (salvage wood) is included in the harvest (wood production statistics). Consequently, this inventory includes CO₂ emissions from non-salvaged wood.

In post-fire management it is common for forest owners to try to salvage as much wood as possible in order to recover the maximum possible value from the lost trees. This is limited by two types of factors: wood value (limited by size of the tree and level of fire damage) and timing of salvage (limited by the availability of machinery and the consumption capacity by the industry). It is therefore common to have significant amounts of burnt wood remaining in the forest after fire. In the absence of statistics to characterize the share of salvage in total wood affected by fires, a panel of experts, composed of representatives from the industry, forest owners federation and national forest authority, was called in December 2009 to provide expert estimates of these values.

Parameters used in the calculation of indirect CO₂ emissions are presented in the following table.

Table 7.3 – Estimated biomass loss in forest fires: indirect emissions

	Average volume (IFN2005) (m ³ /ha)	Mortality	Salvaged wood
Pinus pinaster	91.0	70.0%	40%
Quercus suber	34.4	30.0%	40%
Eucalyptus	58.9	50.0%	50%
Quercus ilex	19.3	10.0%	40%
Other hardwood	40.0	30.0%	40%
Other softwood	41.7	35.6%	40%

Concerning the forest undergrowth cover and GHG emissions from the combustion of biomass, only non-CO₂ emissions were included in estimates. As previously mentioned, despite the fact that GPG for LULUCF considers good practice to estimate both CO₂ and non-CO₂ emissions, it is also accepted that, if the method applied in the quantification of carbon sequestration (increment) does not consider the removals by re-growth after the disturbances (which has not been estimated), it is not mandatory to report the CO₂ emissions associated with the disturbance events.

7.2.1.1.1.2 CHANGE IN CARBON STOCKS IN DEAD ORGANIC MATTER

Tier 1 IPCC Guidelines do not require estimation on dead organic matter, in a situation where it is assumed that inputs balance outputs of these pools. The inventory did not consider these pools in the case of forest remaining forest that was not affected by wildfires. The change in these pools have been considered in LUC and in forest land affected by wildfires.

7.2.1.1.1.3 CHANGE IN CARBON STOCKS IN SOILS

IPCC provides guidance for two types of forest soil carbon pools: 1) the organic fraction of mineral forest soils, and 2) organic soils.

Under Tier 1, it is assumed that when forest remains forest the carbon stock in soil organic matter does not change, regardless of changes in forest management, types, and disturbance regimes, considering that the carbon stock in mineral soils remains constant so long as the land remains forest. This pool was taken into account using GPG Guidance defaults in the quantification of emissions/removals from LUC.

In Portugal organic soils are considered negligible and so they have not been considered.

7.2.1.1.1.4 NON-CO2 GREENHOUSE GAS EMISSIONS

7.2.1.1.1.4.1 GREENHOUSE GAS EMISSIONS FROM WILDFIRES

The estimates of non-CO2 gas emissions are based on the IPCC 1996 Revised Guidelines (IPCC,1997) methodology, which are based on ratios to carbon released during combustion ($L_{Wildfires}$).

The carbon trace gas emissions (CH₄, CO and NMVOC) are calculated using direct ratios to total carbon. To estimate nitrogen trace gas releases (N₂O and NO_x), the total carbon released is first multiplied by the N/C ration (0.01) to get the total nitrogen released; the emissions of N₂O and NO_x are then calculated multiplying the total N released by the N₂O and NO_x emissions ratios to the total N released.

Emissions ratios:

IPCC 1996 - CH₄: 0.012; CO: 0.06; N₂O: 0.007; NO_x: 0.121
AP-42 - NMVOC: 0.0068

Emissions estimation:

Emissions CH₄ = $L_{Wildfires}$ * emission ratio * 16/12
Emissions NMVOC (expressed as CH₄) = $L_{Wildfires}$ * emission ratio * 16/12
Emissions CO = $L_{Wildfires}$ * emission ratio * 28/12
Emissions N₂O = $L_{Wildfires}$ * ratio N/C (0.01) * emission ratio * 44/28
Emissions NO_x = $L_{Wildfires}$ * ratio N/C (0.01) * emission ratio * 46/14

7.2.1.1.2 Activity data and parameters

7.2.1.1.2.1 AREA OF FOREST LAND

Data for forest area are largely based on data from periodic forest surveys which refer to Mainland: National Forestry Inventories (NFI) conducted by the National Forestry Authority /Ministry of Agriculture, Rural Development and Fisheries (Autoridade Florestal Nacional (AFN)/ Ministério da Agricultura, do Desenvolvimento Rural e das Pescas (MADRP)).

Available inventory surveys for the period analysed (1990-2006) are the NFI 2nd revision (1982) the NFI 3rd revision (1995¹³⁹) and the NFI 2005/06. Forest area data for 1990 is based on

¹³⁹ The 3rd Revision was based on the 1995 national aerial photo coverage and on field work developed in 1997/98. The inventory covered 35 attributes of the Portuguese forests for continental Portugal. The results were published in 2001: DGF(2001), Inventário Florestal Nacional – Portugal Continental, 3ª revisão 1995-98.

estimates from the General Direction for Forestry Resources based on NFIs. Data from 1996 to 2000 refer to estimates performed by APA as explained below, data from 2001 to 2004 refer to interpolations based on 2000 and 2005 (NFI 2005/06), and 2006 to 2008 refer to 2005.

Forest definition used by AFN is based on the UNECE/FAO definition: Forest is defined as vegetation formations constituted by woody trees having crown cover with more than 10%, minimum area of 0.5 ha and 20 m width, and trees having a potential to reach a minimum height of 5 meters. Areas under afforestation and reforestation which will reach in the future a minimum crown density of 10% and a minimum height of 5 meters are also included under this definition.

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.

The National Forest Inventory classifies forests according to the ensemble of tree species present in each sampling plot. Areas are allocated to a particular forest species whenever that species is either the only species present in the area (pure stands) or is the dominant species (mixed stands of two or more tree species).

The calculation and reporting of emissions and removals is subdivided into the four main tree species, which represented 82% of the total forest area in 2005. All other species were considered in two additional categories: "other broadleaves", covering about 12% of forest area, and "other coniferous", representing the remaining 6% of forest area.

Table 7.4 –Disaggregation of forest areas by tree species used in this report

Scientific name		English common name	Portuguese common name
Pinus pinaster		Maritime Pine	Pinheiro Bravo
Quercus suber		Cork Oak	Sobreiro
Eucalyptus spp.	E. globulus E. camaldulensis	group of species, mostly Tasmanian Blue Gum Red Gum	Eucalipto Glóbulo Eucalipto Vermelho
Quercus rotundifolia		Holm Oak	Azinheira
Other broadleaves	Acacia spp. Arbutus unedo Betula spp. Castanea sativa Ceratonia siliqua Quercus faginea Quercus pyrenaica Quercus robur Quercus spp. Salix spp. Ulmus spp. Other broadleaves	group of species including Acacias Strawberry Tree Birches Chestnut Tree Carob Tree Portuguese Oak Pyrenean Oak Pedunculate Oak Other Oaks Willows Elms Other broadleaves	Acácias Medronheiro Bétulas Castanheiro Alfarrobeira Carvalho Português Carvalho Negral Carvalho Alvarinho Outros Carvalhos Salgueiros Ulmeiros Outras folhosas
Other coniferous	Cupressus spp. Pinus halepensis Pinus pinea Pinus sylvestris Pinus spp. Pseudotsuga menziesii Other coniferous	group of species including Cypresses Aleppo Pine Umbrella Pine Scots Pine Other Pines Douglas Fir Other coniferous	Ciprestes Pinheiro de Alepo Pinheiro Manso Pinheiro de Casquinha Outros Pinheiros Pseudotsuga Outras Resinosas

The following table refer to National Forest Inventories (NFI) data for the Portugal Mainland. For the first time, the estimates include also the two Autonomous Regions of Açores and Madeira, which represent respectively 68000 ha and 35000 ha of forest area.

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Table 7.5 – Forest area from National Forest Inventories (1000 ha): Portugal Mainland

	1982 (NFI 2nd rev.)	1990 (AFN estimates)	1995 (NFI 3rd rev.)	2005/6 (IFN 2005/06)
<i>Pinus pinaster</i>	1217	1069	976	936
<i>other softwood</i>	104	104	105	192
<i>Eucalyptus</i>	366	554	672	781
<i>Quercus suber</i>	662	693	713	692
<i>Quercus ilex</i>	464	462	462	403
<i>other Quercus</i>	109	123	131	147
<i>Castanea sativa</i>	30	37	41	29
<i>other hardwood</i>	89	98	102	259
Total	3041	3140	3201	3439

Note: Other woody biomass and other wooded land were not considered in the estimates.

Sources:

1982, 1995 and 2005/06: National Forestry Inventory.

1990: estimates from AFN (Autoridade Florestal Nacional).

Table 7.6 – Forest area (1000 ha): Autonomous Regions

	1990	2006
AÇORES Islands		
<i>Cryptomeria japonica</i>	15.075	11.926
<i>Eucalyptus</i>	1.510	3.626
<i>other hardwood</i>		0.523
<i>Robinea</i>		0.003
<i>Natural vegetation</i>		22.527
<i>Acacia</i>	6.540	3.490
<i>Pittosporum undulatum</i>		21.911
<i>Pinheiro janonês</i>		0.124
<i>Pinus pinaster</i>	1.450	0.791
<i>other softwood</i>		0.111
<i>Myrica faya</i>		2.362
<i>Persea indica</i>		0.162
<i>Camaeciparis</i>		0.020
<i>Mix hardwood and softwood</i>	1.395	
<i>Mix natural vegetation</i>	42.120	
total	68.090	67.576
MADEIRA Island		
<i>Pinus pinaster</i>	9.000	9.000
<i>Cryptomeria japonica</i>	2.000	2.000
<i>other softwood</i>	2.000	2.000
<i>Eucalyptus</i>	3.000	3.000
<i>Castanea sativa</i>	1.000	1.000
<i>Quercus</i>	1.000	1.000
<i>other hardwood</i>	1.000	1.000
<i>Laurissilva (natural forest)</i>	15.000	15.000
<i>Acacia</i>	1.000	1.000
total	35.000	35.000
Autonomous Regions TOTAL	103.090	102.576

Note: 1) Data refer to 1987.

Furthermore, GPG Guidelines require separate estimates and reporting for Forest Land remaining Forest Land from Land converted to Forest Land.

To separate Forest Land remaining Forest Land from Land converted to Forest Land, the information from a cartographic product – CLC Changes – was used. This cartography on land cover changes was developed having as a basis CLC-R (CORINE Land Cover 90 reviewed) referring to information from 1985/86/87, and CLC2000 (Project IMAGE and CORINE Land

Cover (I&CLC2000) having the reference year of 2000. This cartography refers only to Portugal's Mainland (i.e. excludes the Azores and Madeira islands).

The procedure used for estimation of FF for the years 1990 and 1995 are based on forest area from NFI for each specie deducted with data from land converted to forest land from CLC Changes weighed by plantations (new forest areas) by forest type in the year, and can be summarized as follows (data from 1991 to 1994 are interpolated):

$$FF_{ni} = A_{F_{ni}} - (LF * plant_{ni} / \Sigma plant_n)$$

Where:

FF_{ni} - Forest Land remaining Forest Land in year n for forest type i;

$A_{F_{ni}}$ - Forest type (i) area from NFI;

LF - Land converted to Forest Land in the period 1986/2000;

$plant_{ni}$ - plantations (new forest areas) in year n for forest type i;

$\Sigma plant_n$ - total of plantation area in year n.

Figures from 1996 to 2000 are estimates based on 1995 NFI data, summed up with CLC Changes data on Land converted to Forest Land (CF, GF, WF, SF, OF) weighted with data on forest type from forestry plans, and discounted with data from Forest Land converted to Other Uses (FC, FG, FW, FS, FO).

To estimate the FF from 1996 on the procedure was slightly different to consider either Land converted to Forest and Forest converted to other land:

$$FF_{ni} = FF_{n-1i} + ((LF - FL) / 14 \text{ years} * plant_n / \Sigma plant_{ni})$$

Where:

FF_{ni} - Forest Land remaining Forest Land in year n for forest type i;

FF_{n-1i} - Forest Land remaining Forest Land in year n-1 for forest type i;

LF - Land converted to Forest Land in the period 1986/2000, weighted by the plantations/new forestry areas by forest type in the year n;

FL - Forest Land converted to Other Uses in the period 1986/2000, weighted by the plantations/new forestry areas by forest type in the year n;

$plant_{ni}$ - plantations (new forest areas) in year n for forest type i;

$\Sigma plant_{ni}$ - total of plantation area in year n.

CLC-Changes are based on a comparison of data for 1985/86/87 and 2000. For the calculation of the annual cover changes a period of 14 years was considered (1986 being the reference year assumed for the first cartography), assuming a constant land use change during the 14 years. A more complete description of this statistical information source is provided in the chapter 7.1.

Table 7.7 – Forest Land (1000 ha) used in calculus (Mainland Portugal)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
<i>Pinus pinaster</i>	1064	1049	1034	1019	1004	989	989	988	988	987	987	970	953	935	918	901	901	901	901
<i>other softwood</i>	84	84	84	84	84	83	85	87	88	90	91	85	79	72	66	60	60	60	60
<i>Eucalyptus</i>	558	584	610	637	663	689	690	692	693	694	695	712	729	746	764	781	781	781	781
<i>Quercus suber</i>	679	678	677	676	675	674	677	680	683	686	690	676	662	648	634	620	620	620	620
<i>Quercus ilex</i>	470	467	464	461	458	455	455	456	457	458	458	446	433	421	408	396	396	396	396
<i>other Quercus</i>	126	128	129	131	133	134	134	134	134	134	133	136	139	141	144	147	147	147	147
<i>Castanea sativa</i>	38	39	39	40	41	42	42	41	41	41	41	39	36	34	32	29	29	29	29
<i>other hardwood</i>	76	78	81	84	86	89	90	91	92	93	94	123	152	181	210	239	239	239	239
Forest remaining Forest Land (FF)	3095	3107	3119	3131	3142	3154	3161	3169	3176	3183	3190	3186	3183	3179	3176	3172	3172	3172	3172
FF with changes	16.5																		
Land converted to Forest Land	137																		
Forest land converted to other uses	56																		
Mainland forest	3249	3261	3272	3284	3296	3308	3315	3322	3329	3337	3344	3340	3337	3333	3329	3326	3326	3326	3326
Autonomous Regions forest	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103	103
TOTAL Forest	3352	3364	3375	3387	3399	3411	3418	3425	3432	3439	3446	3443	3439	3436	3432	3429	3428	3428	3428

Sources: APA estimates based on National Forest Inventories (NFI), CLC-Changes cartography and data on plantations, Autonomous Regions Forest Inventories.

Data concerning afforestation was mostly derived from data on public programmes supporting afforestation. Data sources are: AFN, IFADAP (PAF, Reg 797, PDF, Reg 2080, Modelo 47, Projecto Florestal Português do Banco Mundial, Fundo Fomento Florestal). For eucalyptus plantations, afforestation also refers private sector investments with no public support.

Table 7.8 – Area of plantations by forest type (1000 ha)

	1990-1994	1995-2000
<i>Pinus pinaster</i>	24	12
<i>other softwood</i>	17	26
<i>Eucalyptus</i>	30	29
<i>Quercus suber</i>	24	60
<i>Quercus ilex</i>	3	20
<i>other Quercus</i>	0	0
<i>Castanea sativa</i>	0	0
<i>other hardwood</i>	19	17
Total	117	162

Sources: AFN, IFADAP (PAF, Reg 797, PDF, Reg 2080, Modelo 47, Projecto Florestal Português do Banco Mundial, Fundo Fomento Florestal); eucalyptus refer to private afforestation.

Part of the Portuguese forest is characterised by having an undergrowth cover, which could also be considered as a potential sink source. However, as data available for harvest do not include these materials, and to avoid overestimation, the carbon sequestered in this pool has not been quantified.

Other wooded land (bushes, shrubs) had not been quantified, as they are generally non-managed areas.

Growth rates are expressed as volumes of roundwood over bark per ha and per year. Conversion of stem volumes into biomass above and below ground requires the use of coefficients. The BEF considered in this submission have been revised and result from a review by Faias (2009), using biomass equations on data collected during the last National Forest Inventory. National values for these parameters are presented in the next table.

Table 7.9 – Parameters used in the calculations of forest increment

	Growth Rates (m ³ /ha/yr)	Biomass Conversion Factor into		Root-shot ratio
		above ground biomass (t ms/m ³)	total biomass	
<i>Pinus pinaster</i>	5.6	0.52	0.69	0.320
<i>Pinus pinea</i>	5.6	1.26	1.66	0.320
other softw ood	5.0	0.52	0.69	0.320
<i>Eucalyptus</i>	9.5	0.615	0.77	0.249
<i>Quercus suber</i>	0.5	1.1	1.57	0.430
<i>Quercus ilex</i>	0.5	1.1	1.57	0.430
other <i>Quercus</i>	0.5	0.57	0.82	0.430
<i>Castanea sativa</i>	2.9	0.57	0.82	0.430
other hardw ood	2.9	0.57	0.82	0.430
<i>Cryptomeria japonica</i>	23.0	0.52	0.93	0.320
<i>Acacia</i>	9.5	0.615	0.88	0.249
<i>Pittosporum undulatum</i>	9.5	0.615	0.52	0.249
<i>Robinea</i>	2.9	0.57	0.71	0.430
<i>Myrica faya</i>	2.9	0.57	0.71	0.430
<i>Perseo indica</i>	2.9	0.57	0.71	0.430
<i>Pinheiro janonês</i>	2.0	0.56	0.93	0.430
Natural Vegetation	0.5	0.57	0.71	0.430

Sources:

Growth rates: AFN; APA estimates.

BEF: Faias, 2009

Root-Shoot ratio: LULUCF GPG, Table 3A.1.8; excepting *Eucalyptus* (Soares and Tomé, 2004).

The carbon fraction of dry matter considered are presented in the table below.

Table 7.10 – Wood carbon content

Wood carbon content (%C)	
<i>Pinus pinaster</i>	0.51
<i>Pinus pinea</i>	0.51
other softw ood	0.51
<i>Eucalyptus</i>	0.48
<i>Quercus suber</i>	0.48
<i>Quercus ilex</i>	0.48
other <i>Quercus</i>	0.48
<i>Castanea sativa</i>	0.48
other hardw ood	0.48

7.2.1.1.2.2 BIOMASS LOSS

7.2.1.1.2.2.1 FELLINGS

The amount of biomass lost in forest land due to biomass harvest is quantified on the basis of tree harvesting data. These data is based on annual statistical data of wood consumption and refer mainly to the species - *pinus pinaster* and *eucalyptus*, which was obtained from FAO database. Furthermore, it has been assumed that forest biomass used in heat production (domestic firewood or industrial) is a forest sub-product resulting from forest management practices (mostly forest harvesting), and consequently is already reflected in harvesting

emissions. Non-CO2 emissions from combustion of this biomass fuel are accounted in other sectors (CRF 1 Energy) on the basis of biomass data from energy balances (DGGE data).

Values for tree feelings refer to roundwood over bark and do not include residues from exploration, i.e. branches, etc. To account for the whole tree volume, the expansion factors used were: for softwood 1.24; hardwood 1.2. The conversion to dry matter was done using the same parameters used for increment growth estimates.

Table 7.11 – Volumes of harvested wood (1000 m3 over bark) (1990-2008)

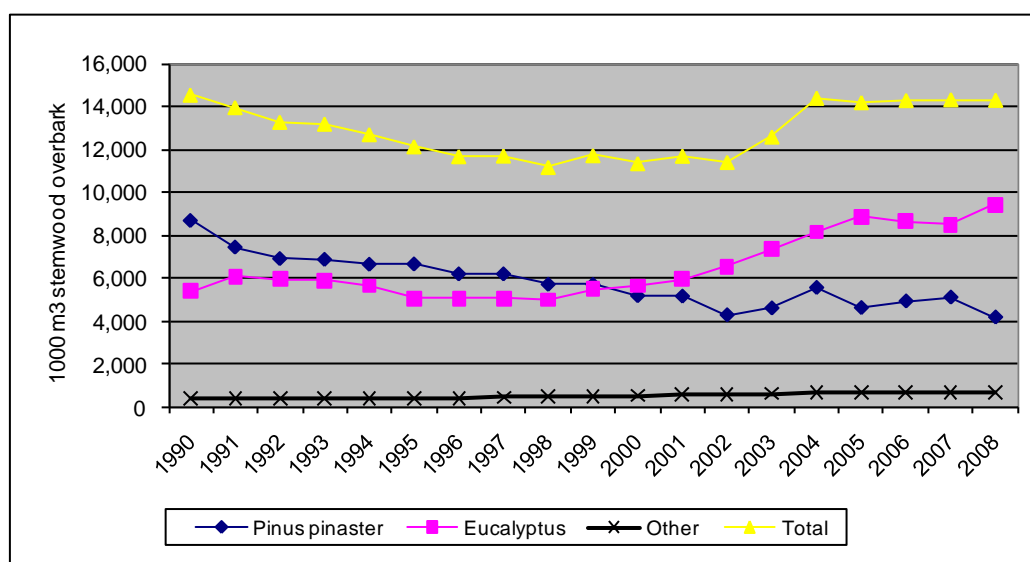
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Pinus pinaster	8,716	7,467	6,925	6,889	6,659	6,672	6,207	6,207	5,717	5,711	5,182	5,161	4,284	4,606	5,569	4,624	4,935	5,116	4,180
other softwood	133	134	134	134	134	135	145	156	166	177	187	198	209	219	230	240	240	240	240
Eucalyptus	5,423	6,098	5,959	5,907	5,653	5,078	5,060	5,060	4,995	5,516	5,649	5,984	6,546	7,367	8,161	8,876	8,663	8,519	9,428
Quercus suber	89	89	90	90	91	91	91	90	90	89	89	88	88	87	87	87	87	87	87
Quercus ilex	59	59	59	59	59	59	58	57	57	56	55	54	53	52	51	50	50	50	50
other Quercus	16	16	16	16	17	17	15	13	12	10	8	7	5	3	2	0	0	0	0
Castanea sativa	28	28	29	29	30	30	27	24	21	18	15	12	9	6	3	0	0	0	0
other hardwood	73	73	74	75	75	76	100	124	148	172	196	219	243	267	291	315	315	315	315
Total	14,537	13,964	13,285	13,199	12,718	12,158	11,703	11,732	11,205	11,749	11,381	11,723	11,437	12,608	14,394	14,192	14,290	14,327	14,300

Source: FAO, AFN

Harvest wood data considered for Açores and Madeira Islands were respectively 80767 m³ and 32000 m³ for the whole period.

The analysis of the last 30 years time series for tree harvesting, shows that 1990 corresponds to a peak driven by a period of steady economic growth and expansion of the paper and pulp industries.

Figure 7.3 – Volumes of harvested wood (1000 m³ over bark) (1990-2008)



Source: AFN; FAO

7.2.1.1.2.2.2 WILDFIRES

Forest wildfires have a substantial impact on Portuguese forest. Yearly fluctuations of burned areas are a consequence of climatic factors. Nevertheless, it is generally acknowledged that adequate forestry and forest management, mainly a consequence of forestland structure (land tenure, size of forest holdings) and socio-demographic factors (private owners old age, low

literacy or absenteeism), constitute severe constraints and contribute to the high magnitude of yearly burned areas.

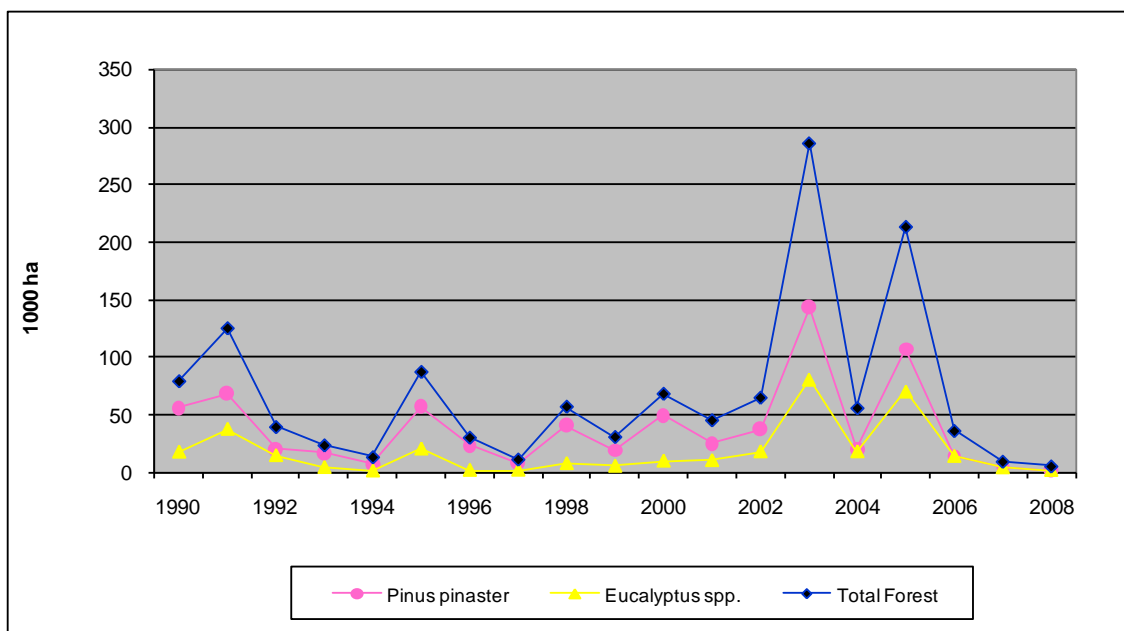
All the forestland in Portugal is considered as non-natural / managed and was considered in the estimates. Areas of other wooded land ("matos" - bush land, shrubs) are mostly non-managed areas and were not accounted.

IPCC (2000) for LULUCF considers good practice to estimate CO₂ and non-CO₂ emissions from biomass burning on managed forestland.

The estimates consider the above and below ground biomass for forest trees, undergrowth cover (only for non-CO₂ emissions), and biomass from litter existing in forest land.

Yearly data on burnt area are available from AFN (National Authority for Forest).

Figure 7.4 – Wildfires: forest land (1000 hectares) (1990-2008)



Source: AFN

Table 7.12 – Forest Wildfires: forest land (1000 hectares) (1990-2008)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Pinus pinaster	56	68	20	17	7	57	23	8	41	19	49	25	38	144	20	107	14	4	2
Quercus suber	2	8	2	1	2	4	2	1	4	3	4	4	4	25	7	14	3	0	1
Eucalyptus spp.	18	38	15	4	1	21	2	2	8	5	10	10	18	81	18	71	14	4	2
Quercus rotundifolia	2	5	1	1	1	3	1	0	2	2	2	3	2	15	4	8	2	0	0
other broadleaves	1	4	1	1	1	2	1	0	2	2	2	2	2	15	4	9	2	0	0
other coniferous	0	1	0	0	0	1	0	0	1	1	1	1	1	6	2	4	1	0	0
Total	80	126	40	24	14	88	31	12	57	31	69	46	65	286	56	214	36	10	6

Source: AFN

Emissions of air pollutants depend on the fuel type and fuel loading, among other factors. Previously, the calculations were done keeping data for the combustible material constant, considering the same characterisation of the burnt species for all the years considered.

In this submission, the estimates consider the tree species burnt and their respective biomass volumes and dry matter content.

Typically, Portuguese forest has undergrowth cover. To take this into account, the estimation of combustible material in forestland also included the quantification of shrub and bush biomass under the forest trees. The area considered in the estimates refers to the forest total area.

In previous submissions, the calculation of annual carbon loss in tree above ground biomass was estimated, for the two most representative species (*pinus pinaster* and *eucalyptus*) in terms of industrial wood consumption, assuming that the affected trees were harvested as salvaged wood and used in the industry, and were considered included in the harvest volumes. For the other species, the calculation of annual carbon loss of the above ground biomass referred to the estimated fraction of biomass affected by the disturbance, based on the assumption that these species do not have the same economic importance and the trees are left in the burnt areas.

The most recent UNFCCC review reports raised, however, the issue of the potential underestimation of CO₂ emissions from forest fires, due to the assumptions concerning the percentage of biomass burned or the consideration of total salvage volumes in harvest quantities.

In order to answer to the UNFCCC observations, several parameters and assumptions were revised in the present submission.

The average biomass for each of the forest components considered (litter, understorey cover and leaves and fine branches) was revised, following a review on the topic by Rosa (2009). Litter values result from a literature review of data available for Portugal or similar forests in other countries. Shrub average biomass was calculated using data collected in the last national forest inventory, using an equation calibrated for Portuguese conditions (Silva *et al.*, 2006). Average biomass for leaves was calculated using data collected in the last national forest inventory, using equations calibrated for each of the main species considered (Tomé *et al.*, 2007, Correia *et al.*, 2008 e Montero *et al.*, 2005). Average biomass for fine branches was calculated using data collected in the last national forest inventory, using equations calibrated for each of the main species considered considering all branches with a diameter smaller than 2cm (Montero *et al.*, 2005).

The combustion factor or the fraction of the biomass affected by the wildfires was revised based on the information taken from the same study and were derived from a literature review for each of the different biomass components identified above. This information is summarized in the next table.

Table 7.13 – Estimated biomass loss in forest fires: direct emissions

	Average biomass (Mg/ha)				Combustion factor (%)			
	Litter	Understorey cover	Leaves	Fine branches	Litter	Understorey cover	Leaves	Fine branches
<i>Pinus pinaster</i>	7.81	8.24	4.26	7.27	75%	72%	88%	58%
<i>Quercus suber</i>	4.55	3.09	0.41	0.70	75%	72%	88%	58%
<i>Eucalyptus</i>	3.93	4.96	3.80	3.06	75%	72%	88%	58%
<i>Quercus ilex</i>	4.69	1.80	0.25	0.42	75%	72%	88%	58%
Other hardwood	4.64	6.15	1.42	3.69	75%	72%	88%	58%
Other softwood	7.01	4.07	4.88	7.63	75%	72%	88%	58%

Source: Rosa (2009)

The estimates consider also emissions that result from tree mortality, as a consequence of fires.

The approach used for indirect carbon fire emissions considered the loss of the entire dead tree at the time of fire (instant oxidation), including therefore leaves, branches, wood, bark and roots.

Another aspect that has been revised, is the consideration that only a fraction of the burnt trees (salvage wood) is included in the harvest (wood production statistics). Consequently, this inventory includes CO₂ emissions from non-salvaged wood.

In post-fire management it is common for forest owners to try to salvage as much wood as possible in order to recover the maximum possible value from the lost trees. This is limited by two types of factors: wood value (limited by size of the tree and level of fire damage) and timing of salvage (limited by the availability of machinery and the consumption capacity by the industry). It is therefore common to have significant amounts of burnt wood remaining in the forest after fire. In the absence of statistics to characterize the share of salvage in total wood affected by fires, a panel of experts, composed of representatives from the industry, forest owners federation and national forest authority, was called in December 2009 to provide expert estimates of these values.

Parameters used in the calculation of indirect CO₂ emissions are presented in the following table.

Table 7.14 – Estimated biomass loss in forest fires: indirect emissions

	Average volume (IFN2005) (m ³ /ha)	Mortality	Salvaged wood
Pinus pinaster	91.0	70.0%	40%
Quercus suber	34.4	30.0%	40%
Eucalyptus	58.9	50.0%	50%
Quercus ilex	19.3	10.0%	40%
Other hardwood	40.0	30.0%	40%
Other softwood	41.7	35.6%	40%

Concerning the forest undergrowth cover and GHG emissions from the combustion of biomass, only non-CO₂ emissions were included in estimates. As previously mentioned, despite the fact that GPG for LULUCF considers good practice to estimate both CO₂ and non-CO₂ emissions, it is also accepted that, if the method applied in the quantification of carbon sequestration (increment) does not consider the removals by re-growth after the disturbances (which has not been estimated), it is not mandatory to report the CO₂ emissions associated with the disturbance events.

7.2.1.2 Land Converted to Forest Land (LF)

Methodologies, activity data and parameters for this category are presented in chapter 7.2.7 which refer to Land Use Conversion.

7.2.2 Cropland (CRF 5.B.)

7.2.2.1 Cropland Remaining Cropland (CC)

Methodologies, activity data and parameters for this category are presented in chapter 7.2.7 which refer to Land Conversion. Data on CO₂ emissions/removals for CC refer only to the situations where changes in cultures occur, but the area maintains the same classification.

The CO₂ emissions/removals estimates for the big majority of cropland that remain cropland are not estimated, as they are considered in equilibrium and are considered as no major sources of emissions/removals.

7.2.2.2 Land Converted to Cropland (LC)

7.2.2.2.1 Overview

In accordance with the GP-LULUCF (IPCC, 2003) emissions of N₂O from soil are to be estimated as anthropogenic GHG emissions if they are enhanced by human activity, namely when soil use is converted to cropland, and nitrogen is liberated of nitrogen in the form of ammonia or nitrate as consequence of the mineralization of mineral soil organic carbon (SOM). IPCC assumes that this increase in available nitrogen results in the same emitting process than other addition of nitrogen to soil.

Differently to what is proposed in the GP-LULUCF and the CRF tables emissions, emissions of N₂O were also estimated in the case where settlements are converted to croplands, albeit this represents a minimal quantity. Also, in some situations when soil use remains agriculture, changes in carbon in soil, and consequently N₂O emissions, may nevertheless occur in the case when a reduction of carbon in soil occurs, such as when perennial croplands are converted to annual croplands.

7.2.2.2.2 Methodology

The methodology follows equation 3.3.1.13 and 3.3.1.14 in IPCC (2003), which were applied in the following mode:

$$Emi_{N_2O} = 44/28 * \sum_c \{A_{LC} * \max(0, (C_{SOM,L} - C_{SOM,C}) * T_e / T_e / C:N\} * F_1$$

Where,

Emi_{N₂O} - Emissions of N₂O emissions from disturbance associated with land-use conversion to cropland (t/yr);

A_{LC} - Annual area of land converted to soil use L to cropland (ha/yr);

C_{SOM,L} - Soil Organic Carbon in original soil use L. L could be F,C,G,S, W or O (tC);

C_{SOM,C} -Equilibrium Soil Organic Carbon in Cropland. Different values apply for annual cropland or perennial cropland (tC);

C:N - The ratio of carbon to nitrogen in soil organic matter;

T_e - time to carbon stock to reach equilibrium, yr;

F₁ - N₂O emission factor (kg N₂O-N/kg N).

7.2.2.2.3 Emission Factors

In accordance to what is recommended in the GP-LULUCF, the emission factor (F₁) is assumed equal to the IPCC default emission factor used to calculate emissions from agricultural land caused by other sources of nitrogen, (synthetic fertilisers, manure, nitrogen fixation and crop residues) i.e. 0.0125 kg N₂O-N/kg N).

7.2.2.2.4 Activity Data

The same information that was used to estimate CO₂ emissions from LUC was used to estimate N₂O emissions. Emissions were estimated for each individual area in the CLC enhanced database (CLC changes plus soil type, climate conditions and forest cover) that is explained in chapter 7.1.

The same assumption that CLC changes represents a stable situation was considered and therefore annual emissions were assumed to be constant over the all period.

Considering the absence of better data the default C:N ratio (15) was used for all soil use conversions in order to estimate nitrogen in SOM.

7.2.3 Grassland (CRF 5.C.)

Methodologies, activity data and parameters for this category are presented in chapter 7.2.7 which refer to Land Conversion. Data on CO₂ emissions/removals for GG refer only to the situations where changes occur, but the area maintains the same classification.

The CO₂ emissions/removals estimates for the big majority of grassland that remain grassland are not estimated, as they are considered in equilibrium and are considered as no major sources of emissions/removals.

7.2.4 Wetlands (CRF 5.D.)

Methodologies, activity data and parameters for this category are presented in chapter 7.2.7 which refer to Land Use Conversion. Data on CO₂ emissions/removals for WW refer only to the situations where changes occur, but the area maintains the same classification.

The CO₂ emissions/removals estimates for the big majority of wetlands that remain wetlands are not estimated, as they are considered in equilibrium and are considered as no major sources of emissions/removals.

7.2.5 Settlements (CRF 5.E.)

Methodologies, activity data and parameters for this category are presented in chapter 7.2.7 which refer to Land Use Conversion. Data on CO₂ emissions/removals for SS refer only to the situations where changes occur, but the area maintains the same classification.

The CO₂ emissions/removals estimates in settlements are not estimated.

7.2.6 Other Land (CRF 5.F.)

Methodologies, activity data and parameters for this category are presented in chapter 7.2.7 which refer to Land Use Conversion. Data on CO₂ emissions/removals for other land refer only to the situations where changes occur, but the area maintains the same classification.

The CO₂ emissions/removals estimates in other land are not estimated.

7.2.7 Land Use Conversion

7.2.7.1 Overview

The information on methodologies, emission factors, parameters and activity data is presented here concerning several categories that are quantified under Forest Land (5A), Cropland (5B), Grassland (5C), Wetlands (5D), Settlements (5E) and Other Land (5F). Though according to the reporting guidelines should be reported individually it was considered to be more transparent and consistent to report common considerations under the same chapter. Therefore, from all LULUCF categories only Forest Land Remaining Forest (FF) is reported separately, while for the others only a reference to this chapter is made.

Nevertheless, the detail that was used to determine land use conversion is made at a lower level of detail than the major LULUCF categories, and as consequence some emissions reported as Land use remaining the same land use (FF or CC for example) are estimated according to the methodology explained in this chapter. That is to say, for example, that if the forest species planted in a land unit is changed then emissions from removal of former cover and sinks of subsequent grow of the new formation are estimated according to the methodology

in this chapter, albeit net emissions/sinks are reported as FF, Forest remaining forest. Care has been taken to avoid double counting in these cases.

In order to shorten explanatory text the abbreviated nomenclature proposed by the LULUCF-GP (IPCC,2003) was extensively used. This procedure follows the rules:

- major source land uses are referenced by the first letter (F-Forest; C-Cropland; G-Grassland; W-Wetland; S-Settlements and O-Other land);
- each unit of land is given a unique code composed of two letters XY, where X represents the land use in the beginning of the period and Y the use at the end of the period¹⁴⁰;
- for each land unit that undergone no change in land use, a double equal letter is used (FF,CC,GG,WW,SS,OO). For example CC refers to Cropland remaining cropland;
- the other cases are listed in the following table.

Table 7.15 – Land Use nomenclatures

		To					
		Forest	Cropland	Grassland	Wetland	Settlements	Other
From	Forest	FF	FC	FG	FW	FS	FO
	Cropland	CF	CC	CG	CW	CS	CO
	Grassland	GF	GC	GG	GW	GS	GO
	Wetland	WF	WC	WG	WW	WS	WO
	Settlements	SF	SC	SG	SW	SS	SO
	Other	OF	OC	OG	OW	OS	OO

The release and uptake of carbon for the following carbon pools was considered in the estimates made. However, dead wood is not considered separately:

Table 7.16 – Carbon pools

Pool	Definition
Living above-ground biomass	All living biomass above the soil biomass, including stems, stumps, branches, bark, seeds, and foliage. In the case of forests includes under storey. In case of mixed systems, such as forest with agricultural or grazing below, includes crops or grass together with trees.
Living below-ground biomass	Living biomass of live roots. The lower limit of root diameter is not explicitly defined.
Dead Organic Matter (DOM)	All non-living biomass above the top layer of soil, in various states of decomposition. Includes the litter, humic, humic layers, but also dead wood. Verificar
Soil Organic Carbon (SOC)	Includes organic carbon in mineral soils to a depth of 30 cm.

7.2.7.2 Methodology

The methodology used can be considered to follow the equations 3.1.1 (default approach, or the Annual Carbon Stock Change in a Given Pool as a Function of Gains and Losses) of the LULUCF-GP (IPCC,2003), where areas are multiplied by rates of carbon loss and gain¹⁴¹:

¹⁴⁰ Sequences of more than 2 letters could in principle occur. Nevertheless, considering the methodology that was used, the determination of these occurrences could not be detected.

$$\Delta C = \sum_{csLL} [A_{csLL} * (C_g - C_L)_{csLL}]$$

Where:

ΔC - carbon stock change in the pool, t C/yr;

A_{csLL} - area of land, for a specific climate type c, for the specific conversion LL, and in soil type s (ha/yr)

C_g - rate of gain of carbon for the area converted, t C/ha/yr

C_L - rate of loss of carbon for the area converted, t C/ha/yr

Considering that, as a general rule, gains in carbon release occur when the previous land use is finalized, while carbon is stored during the development of the new land use, calculation is made individually for land use termination or abandonment and land use formation or initiation¹⁴². For a specific land conversion LL, net emissions (ΔC_{net}) are determined from removals (ΔC_L) and uptake (ΔC_g):

$$\Delta C_{net} = A_{csLL} * (\Delta C_L - \Delta C_g)$$

$$\Delta C_{net} = A * [(\sigma C_{LAB} + \sigma C_{LBB} + \sigma C_{DOM}) - (\delta C_{LAB} + \delta C_{LBB} + \delta C_{DOM}) * T_e + (C_{SOC,t} - C_{SOC,i}) * T_e / T_e]$$

Where:

A_{csLL} - area of land, for a specific climate type c, for the specific conversion LL, and in soil type s (ha/yr);

σC_{LAB} - Carbon stock in Living Aboveground Biomass in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was terminated, t C/ha;

σC_{LBB} - Carbon stock in Living Belowground Biomass (Roots) in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was terminated, t C/ha;

σC_{DOM} - Carbon stock in Dead Organic Matter (DOM) existing in an unitary land area in climate condition c, soil type s and land use L when land use was terminated, t C/ha;

δC_{LAB} - Annual accumulation of carbon in Living Aboveground Biomass in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was initiated, t C/ha/yr;

¹⁴¹ The use of land use data at two points in time could lead to the impression that the alternative approach (equation 3.1.2 of the LULUCF-GP) was used. Nevertheless, in fact, because the methodology only makes a balance of the areas under a certain use and does not make estimates stock of carbon in the overall system, the methodology should be better defined as equation 3.1.1. Stock changes is used however to estimate annual releases and gains of carbon from unitary land use areas.

¹⁴² This assumption is not valid for SOC, soil organic carbon, were in fact there is a shift from the previous carbon content to a new carbon content in a period to reach equilibrium. Nevertheless, if one assumes a linear trend between the two values, it may be simulated by a decrease of the initial period to zero and a concomitant increase from zero to the final value, during the equilibrium period. This procedure decouples the land conversion and simplifies calculations with no reflex in results.

δC_{LBB} - Annual accumulation of carbon stock in Living Belowground Biomass (Roots) in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was initiated, t C/ha/yr;

δC_{DOM} - Annual accumulation of carbon stock in Dead Organic Matter (DOM) existing in an unitary land area in climate condition c, soil type s and land use L when land use was initiated, t C/ha/yr;

$C_{SOC,t}$ - Soil Organic Carbon (SOC) at equilibrium for an unitary land area in climate condition c, soil type s and land use L under termination, t C/ha;

$C_{SOC,i}$ - Soil Organic Carbon (SOC) at equilibrium for an unitary land area in climate condition c, soil type s and land use L resultant from the conversion (initiated), t C/ha;

T_e - time to carbon stock to reach equilibrium, yr.

Finally, emission and uptake of CO_2 to the atmosphere, are determined from the increase in storage or the release of carbon for each pool:

$$Emi_{CO_2} = 44/12 * \Delta C_L$$

$$Sink_{CO_2} = 44/12 * \Delta C_g$$

Some assumptions were assumed in the inventory process, which is important to mention:

- when forest is converted to other use, including a different type of forest, all carbon in living biomass and DOM is assumed to be converted to CO_2 ;
- in all cases it was assumed that carbon stock when the land use was terminated is the average value for that specific land use;
- the rate of conversion of areas, either abandonment or creation, occurs at the same rate during the period 1985/86/87 to 2000, with no time variations. The annual area converted (A) was estimated though dividing the total area converted in the period by the time interval from 1986 to 2000, i.e. 14 years;
- it was assumed that the rate of change in land use in the period 1985/86/87 to 2000 is representative of the pattern also in previous years. This is important to assume an equilibrium state in past actions, and not that only actions started in the period under analysis are accounted. Otherwise a variation in rates along years would have to be introduced. Therefore, the increase in carbon gain or release from areas in previous years includes the cumulative effect of all areas converted before until an age equal to the equilibrium state for that specific conversion and pool¹⁴³;
- the rate of carbon change in soil organic carbon (SOC) occurs in each parcel at a rate $(C_i - C_t)/T_e$, were C_t and C_i are the SOC at equilibrium, respectively for the land use terminated and initiated. However, the consideration of an equilibrium state, implies the consideration of the conversions in past periods until the equilibrium time (T_e) is reached. Assuming variation at constant rate, the annual change in all areas is therefore simply $(C_i - C_t)$;

¹⁴³ This scheme is valid under the Convention, but must be different for the reporting of emissions and uptakes under article 3.3 of the Kyoto protocol, which only accounts for conversions occurring after 1990.

- the accumulation of DOM is not considered in forest areas and similar land uses, being assumed that this seldom occurs when the vegetation is young. It was considered to occur only in bush lands;
- for the soil pool the IPCC default time to equilibrium (Te) was considered, 20 years (IPCC,2003) for all land uses. For the living biomass pool, the time to reach equilibrium depends on type of land use being initiated and will be documented under emission factors and other parameters;
- storage of carbon in live biomass pools (aboveground and belowground) in forest trees, either in dense forests, mosaic forest and Montados is only accounted until they are considered new plantations when attaining the age of 15 years. Thereafter, removals and emissions of carbon are estimated according to the methodology explained in chapter "Forest Land Remaining Forest Land";
- the consideration of the case when, in the period 1985/86/87 to 2000, a land use conversion occurs followed by another land conversion, cannot be detected from the available data and it is not considered. It causes a slight over-estimation of carbon uptake.

According to the level of detail of the activity data used and the use of country specific carbon rates for some pools, the methodology is better defined to be of second tier level (Box 3.1.1 of the LULUCF-GP). The use of this level is in accordance of the decision tree in the Figure 3.1.1 of the LULUCF-GP.

7.2.7.3 *Emission Factors and Parameters*

7.2.7.3.1 Living Biomass

Living biomass comprehends two pools: above ground living biomass and below ground living biomass. Generally, below ground biomass was established from above ground biomass by the application of shoot-to-root ratios. Two different situations apply, following the explanations given in the description of the methodology, and two set of parameters are given: when a specific land use is being terminated, biomass stock is emitted; when a new land use is initiated and the annual carbon increment in the pool is considered. The values herewith considered were chosen to be in coherence with the values of the parameters considered in "Forest land remaining forest land".

The carbon content in live biomass per unit areas when a given land use is being terminated and converted to other use is presented in Table 7.17, together with a short description of their origin (documentation). Country specific values were considered for the aboveground live biomass of forest (forest species and bush species in undergrowth) and bush land areas and also for the below ground biomass of eucalyptus plantations. For the remaining parameters the lack of suitable information lead to the use of default GP-LULUCF values.

When a given land use is initiated the methodology considers that each year, until equilibrium is reached, an annual increment is added to the soil unit. The individual values for Te, time to equilibrium, are presented in Table 7.18. In the case of the establishment of forest vegetation, the period is not the time to equilibrium of the forest, but only the time frame of the CLC change period, and the growth of live-biomass after that period is accounted in Forest Land Remaining Forest Land. The set of values that was considered for each land use, for both the aboveground live biomass and the below ground fractions, is presented also in Table 7.18. Again, country specific values, were used for forest species and bushes, in under-growth and in bush-lands, while the remaining values were set from the GP-LULUCF. The same root-to-shoot ratios that

apply to biomass stock were used to estimate below ground increment, considering the lack of a differentiation both in national studies and GP-LULUCF.

Table 7.17 - Biomass Carbon Stocks Present on Land Previous to Land Use Change

			Above ground (tonnes C ha ⁻¹)	Below ground (tonnes C ha ⁻¹)	Root-shoot ratio	Documentation
Forest Land	Forest	Pinus pinaster (Maritime Pine)	45.06	14.42	0.32	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002); aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8: Conifer Forest Plantation function of ALB per ha
		Eucalyptus	23.31	5.80	0.25	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002); aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: Soares & Tomé (2004)
		Quercus Suber (Cork Oak)	14.58	6.27	0.43	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002)
		Quercus Rotundifolia (Holm Oak)	9.73	4.19	0.43	corrected to include only forest>30% cover; aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8: Temperate BroadLeaf forest function of ALB per ha
		Forest, mixed or other	28.53	12.27	0.43	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002) average of all species; aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8: Temperate BroadLeaf forest function of ALB per ha
	Montado	Q. suber: Cold Temp. - Wet	3.92	5.97	1.52	Sum of biomass loss from trees and under canopy grassland; aboveground tree biomass from Pereira et al (2002) corrected to include only forest10-20% cover
		Q. suber: Warm Temp. - Dry	3.52	3.41	0.97	
		Q. rotundifolia: Cold Temp. - Wet	3.26	5.69	1.74	
		Q. rotundifolia: Warm Temp. - Dry	2.86	3.13	1.09	
		Mixed: Cold Temp. - Wet	3.59	5.83	1.62	
		Mixed: Warm Temp. - Dry	3.19	3.27	1.02	
Cropland	-	Permanent Crops	21.00	IE	NA	GP-LULUCF table 3.3.8: Temperate (all moisture regimes). Assuming 10 year average age (GP-LULUCF table 3.3.2 recommends 30 years, but that time interval appears too large for the dominant permanent crops in Portugal, orchards and vineyards.). Below ground: assumed already included in above ground biomass.
		Annual cropland	5.00	IE	NA	GP-LULUCF table 3.3.8: Annual Cropland. Below ground: assumed already included in above ground biomass.
		Mosaic Agriculture with P. Pinaster	9.42	3.14	NA	Sum of biomass in forest/undercover (10%), according to forest specie, bush land (10%), and annual cropland (80%)
		Mosaic Agriculture with Eucalytus	7.41	2.15	NA	
		Mosaic Agriculture with Q. Suber	6.46	1.76	NA	
		Mosaic Agriculture with Q. Rotundifolia	6.07	1.59	NA	
		Mosaic with all other types	9.56	1.96	NA	
Grassland	-	Grasslands: Cold Temp. - Wet	1.20	4.80	4.00	Above ground biomass: GP-LULUCF, Table 3.4.2, considering the default carbon fraction of dry matter (0.5); Root-shoot ratio: GP-LULUCF Table 3.4.3 Root-to-Shoot Ratios for the Major Savannah/Rangeland Ecosystems of the World.
		Grasslands: Warm Temp. - Dry	0.80	2.24	2.80	
		Sparce Vegetation: Cold Temp. - Wet	0.60	2.40	4.00	Sparce vegetation assumed half the biomass of grassland
		Sparce Vegetation: Warm Temp. - Dry	0.40	1.12	2.80	
Settlements	-	Artificial Areas (General)	NO	NO	-	Assumed equal to Mixed Montado
		Gardens, parks, etc: Cold Temp. - Wet	3.59	5.83	1.62	
		Gardens, parks, etc: Warm Temp. - Dry	3.19	3.27	1.02	
		Disc. Urban Farbic: Cold Temp - Wet	1.80	2.91	1.62	Intermediate value between Continuous Urban Fabric and Gardens
		Disc. Urban Farbic: Warm Temp. - Dry	1.60	1.63	1.02	
Other Land	-	Bushlands	4.63	13.11	2.83	Aboveground: equation $yr = -0.1177 yr^2 + 1.8511 yr + 1.9582$ from Santos Pereira (2002) for full-grow (8 yr); Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8 Shrubland
Wetlands	-	-	NO	NO	-	Assuming negligible vegetation. Areas mostly salt pans, salt marshes, etc
Water	-	-	NO	NO	-	

Table 7.18 - Annual growth of living biomass

			Above ground (t C/ha/yr)	Below ground (t C/ha/yr)	Root-shoot ratio	Te (yrs)	Documentation
Forest Land	Forest	Pinus pinaster (Matitime Pine)	1.77	0.57	0.32	15	Includes biomass increase in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002); aboveground undergrowth increase from bush (Mato) but corrected for the adult stock of undergrowth for each specie
		Eucalyptus	3.02	0.75	0.25	15	
		Forest, mixed or other	1.22	0.53	0.43	15	
		Quercus Suber (Cork oak)	0.44	0.19	0.43	15	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002) corrected to include only forest>30% cover; ; aboveground undergrowth increase from bush (Mato) but corrected for the adult stock of undergrowth for each specie
		Quercus Rotundifolia (Holm oak)	0.38	0.16	0.43	15	
	Montado	Quercus suber (trees only)	0.05	0.02	0.43	15	Sum of biomass increase from trees and under canopy grassland; aboveground tree biomass from Pereira et al (2002) corrected to include only forest10-20% cover
		Quercus rotundifolia (trees only)	0.06	0.03	0.43	15	
		Mixed Montado (trees only)	0.05	0.02	0.43	15	
		Undercanopy: Cold Temp. - Wet	1.20	4.80	4.00	1	
		Undercanopy: Warm Temp. - Dry	0.80	2.24	2.80	1	
Cropland		Permanent Crops	2.10	IE	NA	10	GP-LULUCF table 3.3.8: Temperate (all moisture regimes). Assuming 10 year average age (GP-LULUCF table 3.3.2 recommends 30 years, but that time interval appears too large for the dominant permanent crops in Portugal, orchards and vineyards.)
		Annual cropland	5.00	IE	NA	1	GP-LULUCF table 3.3.8: Annual Cropland
		Mosaic Agriculture with P. Pinaster					Sum of biomass in forest/undercover (10%), according to forest specie, bush land (10%), and annual cropland (80%). Te in accordance with individual land uses
		Mosaic Agriculture with Eucalytus					
		Mosaic Agriculture with Q. Suber					
		Mosaic Agriculture with Q. Rotundifolia					
		Mosaic with all other types					
Grassland		Grasslands: Cold Temp. - Wet	1.20	4.80	4.00	1	Above ground biomass: GP-LULUCF, Table 3.4.2, considering the default carbon fraction of dry matter (0.5)
		Grasslands: Warm Temp. - Dry	0.80	2.24	2.80	1	
		Sparce Vegetation: Cold Temp. - Wet	0.60	2.40	4.00	1	Sparce vegetation assumed growing at half the rate of grassland
		Sparce Vegetation: Warm Temp. - Dry	0.40	1.12	2.80	1	
Settlements		Artificial Areas (General)	NO	NO	-	-	
		Gardens, parks, etc: Cold Temp. - Wet					Assumed equal to Mixed Montado, according to the climate region
		Gardens, parks, etc: Warm Temp. - Dry					
		Disc. Urban Farbic: Cold Temp - Wet					Average between Continuous Urban Fabric and Gardens
		Disc. Urban Farbic: Warm Temp. - Dry					
Other Land		Bushlands (Mato)	2.71	7.68	2.83	8	Aboveground: average from equation $yr = -0.1177 yr^2 + 1.8511 yr + 1.9582$ from Pereira et al (2002) considering full-grow at 8 yr
Wetlands		-	NO	NO	-	-	Assuming negligible vegetation. Areas mostly salt pans, salt marshes, etc
Water		-	NO	NO	-	-	

7.2.7.3.2 Dead Organic Matter (DOM)

The estimates refer only to the litter part of DOM, while dead wood was not estimated due to unavailability of information. The following considerations were assumed to establish the quantity of DOM that is removed when land use is terminated and the annual increase in DOM when land use is established, presented in :

- when a given land use is converted to other use all DOM is liberated and converted to CO₂;
- accumulation of DOM in areas converted to forest is usually negligible in the first years and was quantified as zero. However, accumulation of DOM was quantified in areas converted to bushland, in accordance with the faster grow period;
- no DOM is considered in croplands, either annual crops or permanent crops, considering the usual practice of frequent tillage. DOM is also considered to be non existent in agro-forestry systems (Montados);
- DOM previous to land use conversion is considered to exist in forest areas, excluding Montados, and heterogeneous agriculture mixed with forestry (but only in the proportion of land use that is forest, i.e. 20% of the area);
- no DOM is considered in other land uses such as artificial areas, wetlands and water bodies, including urban areas, urban parks, discontinuous urban areas.

The quantity of litter in stock in mature forest areas was obtained from Silva et al (unpublished) from studies made in Portugal and other Mediterranean places. The original information sources are presented in Table 7.19.

Table 7.19 - Litter biomass stocks by forest type

Forest Type	Litter Stock (t dm/ha)	Litter Stock (t C/ha)	Litter Increment (t dm/ha/yr)	Litter Increment (t C/ha/yr)	Documentation Source
Pinus Pinaster	10.0	5.0	NO	NO	Botelho et al. 1994, Dimitrakopoulos 2002, Fernandes et al. 2002, Montero et al. 1999.
Eucalyptus	6.0	3.0	NO	NO	Cruz & Viegas 1998, Madeira et al. 2002.
Quercus Suber	7.0	3.5	NO	NO	Fernandes et al. 2000
Q. Rotundifolia	7.0	3.5	NO	NO	Fernandes et al. 2000
Forest, mixed or other	8.0	4.0	NO	NO	Average value for maritime pine and eucalyptus
Bushlands (Matos)	2.8	1.4	0.22	0.11	litter production determined as ratio from biomass stock from Simões et al (2001); leaf biomass from Rambal (2001); total biomass from Pereira et al (2002)

7.2.7.3.3 Soil Organic Carbon

Soil Organic Carbon refers to the carbon in soil at the top 30 cm of soil.

The carbon stock at equilibrium is obtained in accordance with GP-LULUCF (IPCC,2003), from:

$SOC = SOC_{ref} * F_{LU} * F_{MG} * F_I$	
Portuguese National Inventory Report 2010	MAOT

were:

SOC - soil organic carbon stock at equilibrium, for a given soil type, climatic conditions, land use and management conditions, t C/ha

SOC_{ref} - the reference carbon stock for a given soil, t C/ha;

F_{LU} - stock change factor for land use or land-use change type;

F_{MG} - stock change factor for management regime;

F_I - stock change factor for input of organic matter.

Tillage factors represent the impact of changing management from a conventional tillage system, in which the soil is completely inverted, to conservation practices, including no-till and reduced till. The input factors represent the effect changing carbon input to the soil by planting more productive crops, cropping intensification, or applying amendments; input factors include cropping systems categorised as low, medium, high, and high w/manure amendments. Tillage and input factors represent the effect on carbon stocks after 20 years since the management was changed.

For the time being it was not possible to establish SOC_{ref} values representative of conditions in Portugal. Hence, the default values for warm temperate regions, Table 7.20. The additional parameters for SOC determination (F_{LU}, F_{MG} and F_I) are presented below for agricultural soils (Table 7.21) and for grazing lands (Table 7.22). Soils under dense forest (FOR) and bushlands (BUSH) are considered to have carbon in equilibrium conditions when removed or attain such levels in 20 years. For open forest areas, such as mosaic forest (MOSC) and Montados (MONT), the soil carbon stock and dynamics is mostly influenced by the agricultural and grassland activities made in the under-cover, and parameters were set accordingly. Parks, gardens and low density areas are assumed to have conditions equal to low density forests. Finally it was considered that under dense urban areas (URB), wetlands (WET) and water (H₂O) no soil carbon is stored.

Table 7.20 - Default Reference Soil Organic Carbon Stocks (SOC_{ref}) for Mineral Soils (ton per ha for 0-30 cm depth)

Region	HAC soils	LAC soils	Sandy soils	Spodic soils	Volcanic soils	Wetlands soils
Warm temperate, dry	38	24	19	115	70	88
Warm temperate, moist	88	63	34	115	80	88

Note: (1) All values default IPCC's GPG-LULUCF (table 3.2.3 (IPCC,2003));(2) for Spodic Soils the value of SOC_{ref} for Cold Temperate Moist was considered for all other climate conditions.

Table 7.21 - Relative Stock Change Factors (F_{LU} , F_{MG} and F_I) used for Portuguese cropland and low density forest (MOSC)

Factor	Level	Moisture Regime	GPG revised default	Notes
Land use (F_{LU})	Long-term cultivated	Dry	0.82	
		Wet	0.71	
Land use (F_{LU})	Paddy rice	All	1.10	
Tillage (F_{MG})	Full	All	1.00	Assuming widespread tillage
Input (F_I)	Low	Dry	0.92	Assuming low input in the drier regions in south
Input (F_I)	High - with manure	Wet	1.38	Assuming high input in the wetter regions in the north

Note: (1) All values default IPCC's GPG-LULUCF (table 3.3.4 (IPCC,2003)), for temperate regions

Table 7.22 - Relative Stock Change Factors (F_{LU} , F_{MG} and F_I) used for Portuguese grassland management

Factor	Level	GPG revised default
Land use (F_{LU})	All	1.00
Management (F_{MG})	Natural Grasslands (PRAI)	1.00
	Severely degraded (CHARN)	0.70
	Moderately degraded (MONT)	0.95
	Improved grassland (GRASS)	1.14
Input (F_I)	Nominal	1.00

Note: (1) All values default IPCC's GPG-LULUCF (table 3.4.5 (IPCC,2003)), for temperate regions

7.2.7.4 Activity Data

Data on Land Use changes is based on the cartographic product – CLC Changes (Caetano et al 2005). This cartography on land cover changes was developed having as a basis CLC-R (CORINE Land Cover 90 reviewed) referring to information from 1985/86/87, and CLC2000 (Project IMAGE and CORINE Land Cover (I&CLC2000) for the year 2000.

The set of polygons was further divided for consideration of variables originally not considered in the CLC Changes database:

- Soil cartography, using data from the Environment Atlas¹⁴⁴ (IA,1971);
- Total annual precipitation, using data from the Environment Atlas (IA, 1974);
- Forest land cartography on forest types, from AFN.

The intersecting of these products resulted in 42 000 polygons which were used to quantify the carbon stocks using some GPG Guidelines defaults and national parameters according to the changes occurred. The final set of polygons in continental Portugal is observable from Figure 7.5.

¹⁴⁴ Atlas do Ambiente (<http://www.ambiente.pt>)

Figure 7.5 - Total individual polygons identified in continental Portugal



The collection of activity data is classified as a polygon approach 3 of the LULUCF-GP.

7.2.7.4.1 CLC Changes

7.2.7.4.1.1 Information Data Source

The CORINE program (Co-ordination of Information on the Environment) was created in 1985 by the European Union for the surveillance of the quality of the environment in Europe. The CORINE Land Cover 1990 (CLC90) was one important component of this program, which aim was to obtain the cartography of the land use in Europe for 1990¹⁴⁵.

Later, the Portuguese project CORINE Land Cover 2000 (CLC2000) was developed under the project: IMAGE and CORINE Land Cover 2000 (I&LC2000), launched by EEA and JRC for the European Commission (EC) (EEA,2002b). The aim was to upgrade the land use cartography for the year 2000. The work was coordinated by the Instituto Superior de Estatística e Gestão de Informação (ISEGI) in collaboration with the Instituto Geográfico Português (IGP). Several additional information sources were used to improve the cartography, which are described in detail in Painho & Caetano (2005), as well as some field work done in 2003 and 2004.

¹⁴⁵ The reference year could vary from 1985 to 1995.

In Portugal both CORINE products (CLC90 and CLC2000) rely on data from the Landsat satellite¹⁴⁶, follow 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 CLC2000 products comprises 3 cartographic products:

- CLC90-R. Geometric and thematic review of the CORINE Land Cover of 1990;
- CLC2000. Land use cartography in the year 2000;
- CLC - Changes¹⁴⁷. Land use changes between 1985/86/87 and 2000.

Land use data for the CLC90 reflects the land use in the years 1985-1987, while CLC2000 refers only to the year 2000.

The minimum land use area detected by CLC90-R and CLC2000 is 25 ha. However, for the CLC-Changes cartographic product, the minimum size at which areas were detected is 5 ha for the increase or decrease of pre-existent areas and 25 ha for fully new areas not contiguous to others of the same class in CLC90-R¹⁴⁸.

The CLC information source covers only continental Portugal and not the autonomous regions of Madeira and Azores.

Land use areas in CLC Changes are classified according to a hierarchic nomenclature, with 3 levels and 44 classes¹⁴⁹ at the lowest (3rd) level, as presented in the next table.

¹⁴⁶ Thematic Mapper (TM) and Multispectral Scanner (MSS) from Landsat-5 (1985-87) and Enhanced Thematic Mapper (ETM+) from Landsat-7 (2000)

¹⁴⁷ CLC-alterações in Portuguese.

¹⁴⁸ The limitation due to this low resolution was corrected to 1 ha, in order to obtain a better consistency with the methodology that is being prepared for the detection of land units covered by article 3.3 of the Kyoto Protocol. This will be explained in more detail in subsequent chapters.

¹⁴⁹ 42 classes were used in the Portuguese cartography (Painho & Caetano, 2005).

Table 7.23 - Land Use Nomenclature in CLC products

Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Artificial areas	Urban Fabric	Continuous Urban Fabric	Forest and semi-natural areas	Forests	Broadleaved forest
		Discontinuous Urban Fabric			Coniferous forests
	Industrial, commercial and transport units	Industry or commercial units			Mixed forests
		Road and rail networks and associated land		Shrubs and/or herbaceous vegetation associations	Natural grasslands
		Port areas			Moors and heathland
		Airports			Sclerophyllous vegetation
	Mine, dump and construction sites	Mineral extraction sites			Transitional woodland/shrub (Forest areas degraded, recently harvested and new plantations)
		Dump sites		Open spaces with little or no vegetation	Beaches, dunes and sand plains
		Construction sites			Bare rock
	Artificial non-agricultural vegetated areas	Green urban areas			Sparsely vegetated areas
		Sport and leisure facilities			Burnt areas
					Glaciers and perpetual snow
Agricultural areas	Arable land	non irrigated arable land	Wetlands	Inland wetlands	Inland marshes
		Permanently irrigated land			Peatbogs
		Rice fields		Coastal wetlands	Salt marshes
	Permanent crops	Vineyards			Salines
		Fruit trees and berry plantations			Intertidal flats
		Olive groves	Water bodies	Inland waters	Water courses
	Pastures	Pastures			Water bodies
	Heterogeneous Agricultural areas	Annual crops associated with permanent crops		Marine waters	Coastal laggons
		Complex cultivation patterns			Estuaries
		Agriculture and natural areas			Sea and Ocean
		Agro-Forestry areas			

A more detailed explanation of the definition of each land use can be found in EEA (2002b), Bosard et al (2000) and in Painho & Caetano (2006).

It is important to mention that, following the EEA technical guidelines, the cartographic products were subjected to a quality control and a validation by the technical team of the EEA (Painho & Caetano, 2005).

7.2.7.4.1.2 Analysis of CLC Changes Data

During the period of analysis of the CLC changes project, substantial changes have occurred in the land use pattern in Portugal (Painho & Caetano, 2005). In absolute terms it is noticeable the increase in artificial areas from 1.9% to 2.7% (66 738 ha). Slight increases were also verified in

what concerns Forest areas, 38% to 39%, and water bodies, 0.8% to 0.9%. By the contrary, agricultural areas decreased from 48.3% to 47.5%. Finally wetland areas remain constant, 0.3% of the continental territory. Nevertheless, at a more detailed level (level 3), about 11% of the territory has suffered changes in land use, which mainly expresses changes in forest and agricultural activities.

The table below summarizes the land-use changes among the six LULUCF categories which have occurred during the period 1986-2000. The meaning of FF (Forest Land remaining Forest Land) or CC (Cropland remaining Cropland) in the table means Forest or Cropland that have suffered changes despite the fact they remained in the same Land Use classification.

Table 7.24 – Matrix for land use change (1000 ha): annual averages 1986-2000

		2000					
1986		F	C	G	W	S	O
	F	1.2	1.5	0.0	0.1	1.5	0.9
	C	3.6	9.2	0.5	0.3	3.0	0.6
	G	0.7	1.5	0.0	0.0	0.1	0.0
	W	0.0	0.0	0.1	0.0	0.0	0.0
	S	0.0	0.0	0.0	0.0	0.3	0.0
	O	5.4	0.7	0.0	0.1	0.2	0.6
Total annual LUC		11.0	12.9	0.6	0.5	5.1	2.2

Source: CLC-Changes cartography.

7.2.7.4.1.3 Quality Control

In accordance with the EEA (2002) technical guidelines, a set of procedures were developed to guarantee the quality of the product. The set of procedures are explained in more detail in Painho & Caetano (2005), basically consisting of:

- thematic and geometric revision of the CLC products at the end of the project, comparing polygons in the final product with classification in the original CLC90 product, auxiliary cartography and field work;
- revision (2003 and 2004) by European Technical Teams

7.2.7.4.1.4 LUC after 2000

CORINE 1990 and 2000 were used in estimating the land use changes. For the years after 2000, it was used the same pattern of LUC as for the 1990-2000 period. This approach assumes that the rate of area conversion is the same, with no time variations, and that this rate is representative of the pattern in previous years.

These estimates will be revised in the future, with a new cartography - Land Cover Cartography (Carta de Ocupação do Solo – COS) - that is presently under production, and is based on the aerial images of 2007. The technical specifications of this cartography (COS2007), i.e. Minimum Cartographic Unit (MCU), minimum distance between lines (MDBL), and nomenclature, were approved by the cartography's Advisory Committee, which included representatives of SNIERPA, in order to ensure that the cartography would match Portugal's reporting requisites under the UNFCCC and the KP. The country also envisages using other cartography/information for forest change monitoring (forest fires, harvest and replanting),

based on satellite imagery, and other available land cover/use databases (e.g. Agro-Environmental subsidies).

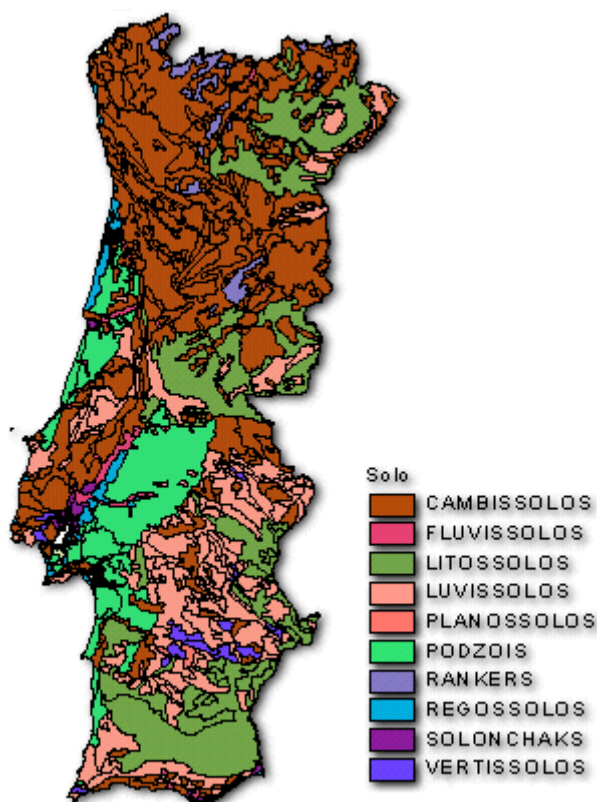
7.2.7.4.2 Soil Classes

The soil cartography follows the FAO -UNESCO soil classification system (World Reference Base for Soil Resources - WRB, IUSS, 1998). Other classes are available in Portugal (Ferreira, 1965), more detailed in soil types and geographic disaggregation, but do not cover the whole national territory.

Table 7.25 - Soil Types used in calculation of carbon release/uptake from the soil pool

Soil	Qualifiers	Association with	Soil	Qualifiers	Association with
Fluvisols	eutric	Fluvisols calcaric	Luvisols	orthic	
	eutric			rhodo-chormic	
	calcaric			rhodo-chormic calcic	
	dystic			rhodo-chormic calcic vertic	
Regosols	eutric			calcic vertic	
	dystic			vertic	
Litosols	eutric			ferric	
	eutric	ultra-basic rocks		Plinthic	
	eutric	Luvisols		gleyic	
Rankers	-			gleyic albic	
Vertisols	Pellic		Podzols	orthic	
	chromic			orthic	Regosols eutric
	chromic calcaric			orthic	Cambisols dystic
Solonchaks	gleyic			orthic	Cambisols eutric
Cambisols	dystic			orthic	Luvisols gleyic
	dystic	shales and quartzits (Ordovician)		orthic	Cambisols calcaric
	dystic	post-paleozoic sedimentary rocks	Planosols	eutric	
	humic	eruptive rocks			
		Cambisols dystic (eruptive rocks)			
		shales			
		shales, luvisols strong atlantic influence			
		shales, luvisols weak atlantic influence			
		shales, luvisols strong atlantic influence			
		shales and quartzits (Ordovician). Moderate atlantic influence			
		post-paleozoic sedimentary rocks			
	humic chromic				
	eutric	eruptive rocks			
	eutric	shales and quartzits (Ordovician)			
	eutric	post-paleozoic sedimentary rocks			
	calcic				
	chromic				
	chromic calcaric				
	chromic calcaric vertic				

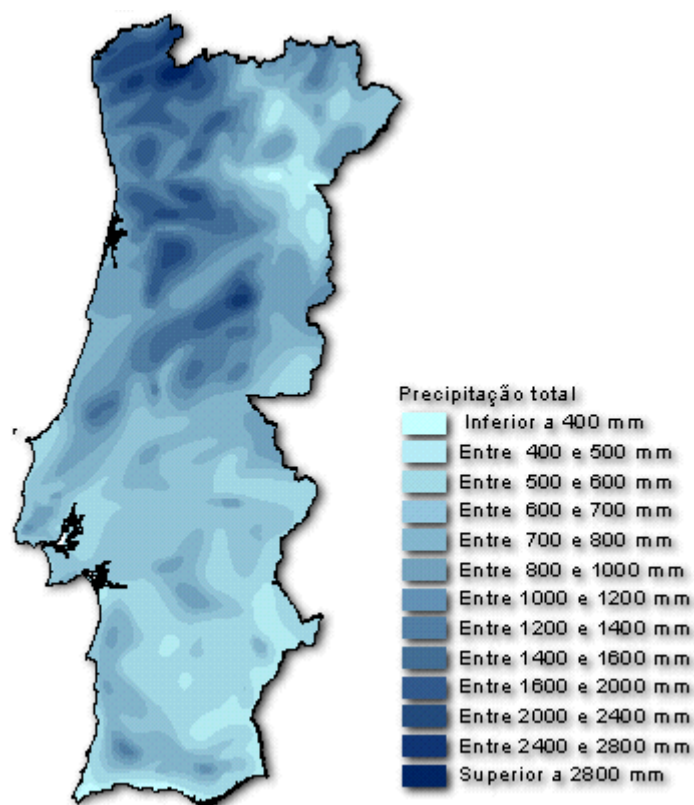
Figure 7.6 - Soil Classes according to the FAO-UNESCO classification scheme in Continental Portugal (APA,1971)



7.2.7.4.3 Climatic Zones

The delimitation of climatic zones is important for the choice of the default parameters for stock and gains in the carbon pools. In terms of average annual temperature, all Portuguese territory was defined as Warm Temperate, following the generic rules set in the LULUCF-GP (Figure 3.1.3 in IPCC,2003): Mean Annual Temperature (MAT) 10-20°C. The differentiation between dry zones from wet zones considers the mean annual total precipitation from the Environment Atlas (<http://www.iambiente.pt>), and presented in Figure 7.7. Wet areas were considered to be those where annual precipitation exceeds 1000mm/yr, whereas areas with lower annual precipitation totals are classified as dry. Therefore, only two climatic zones were considered: Warm Temperate dry and warm temperate wet.

Figure 7.7 - Mean Annual Total Precipitation in Continental Portugal (IA,1974)



7.2.7.4.4 Forest types

The original classes in the CLC changes product were not detailed enough for a full consideration of tree species, making only a distinction between coniferous forests, broadleaved forests and mixed forests. The only possible way to overcome this limitation was to use the data from the last National Forest Inventory for the year 1995 (AFN, 2000). Though this inventory is made by sampling in geographically located points and not by polygon wall to wall mapping, it represents clearly the geographical distribution of forest species. The closest point to the land unit was used to establish the classification. For the situations where it was not possible to identify a forest type, a mixed forest was assumed.

The following tree species were available from the AFN mapping in next table.

Table 7.26 - Individual forest type formations

Forest	Specie	Code
Maritime Pine	Pinus pinaster	Pb
Umbrella pine	P. Pinea	Pm
Other coniferous	-	Rd
Cork oak	Quercus suber	Sb
Holm oak	Q. Rotundifolia	Az
Other oaks	Quercus sp.	Qc
Gum tree	Eucalyptus sp.	Ec
Chestnut	Castanea sativa	Ct
Other broadleaved	-	Fd
Other/ mixed woods	-	mx

7.2.7.4.5 Aggregation of Soil Uses

All land use areas identified in CLC-changes having suffered a conversion of land use were considered in estimation of carbon release and update¹⁵⁰. Nevertheless the actual calculation was done at a level more aggregated than the one available from the crossing of the CLC-change cartography, with the cartographies of soil type; climate and forest species. These classes represent the adequate level of detail considering the detail of cartography and also the specificities of the parameters that were used in actual calculation. They represent, in fact, the fundamental land use types that actually have different values of carbon stocked or carbon release/ uptake rates, in one or more carbon pools. These intermediate classes are presented in Table 7.27, also showing the rules of conversion from the original cartography classes. All land use types in Table 7.27 were further classified according to soil type, Table 7.25, and, for forestall systems, also in accordance with the dominant tree, Table 7.28. Concerning climate type, the division was only between moist climate and dry climate. Therefore, each land use, corresponding to a land use conversion is codified as the string:

$$USE_i \times USE_f \times CLIM \times SOIL \times TREE$$

Where

USE_i - Land use before the conversion of land use (Table 7.27);

USE_f - Land use resultant from the conversion of land use (Table 7.27);

CLIM - Climate conditions (MOIST/DRY) prevailing in the land use area;

SOIL - Soil type existing in the land use area (Table 7.25);

TREE - Dominant tree species in forest areas or land uses including forest species (Table 7.28).

¹⁵⁰ exception made to some changes in land cover that are only apparent and temporary and are not land use changes, as will be explained later in the chapter Soil Conversion Exclusions.

Table 7.27 - Individual land use types, used in calculation and definition of each class from land use classes of CLC-changes (Level 3)

Code	Land Use	CLC-Changes Level 3	Code	Land Use	CLC-Changes Level 3
CRPPER	Croplands with Perennial/Wooddy Crops	Vineyards	URB	Urban Areas	Continuous Urban Fabric
		Fruit trees and berry plantations			Industry or commercial units
		Olive groves			Road and rail networks and associated land
		Complex cultivation patterns			Port areas
CRPANN	Arable land	non irrigated arable land			Airports
		Permanently irrigated land			Mineral extraction sites
		Annual crops associated with permanent crops			Dump sites
RICE	Rice Paddies	Rice fields			Construction sites
GRASS	Managed Grasslands	Pastures			Sport and leisure facilities
PRAI	Natural Grasslands	Natural grasslands	SURB	Mixed urban areas and parks	Discontinuous Urban Fabric
CHARN	Sparsely vegetated areas	Sparsely vegetated areas	WET	Wetlands	Peatbogs
FOR	Forest	Broadleaved forest			Salt marshes
		Coniferous forests			Salines
		Mixed forests	H2O	Water bodies	Inland marshes
		Transitional woodland/shrub (Forest areas degraded, recently harvested and new plantations)			Intertidal flats
		Burnt areas			Water courses
MONT	Grasslands with Dispersed trees (Montado)	Agro-Forestry areas			Water bodies
MOSC	Agriculture Areas mixed with forest	Agriculture and natural areas			Coastal lagoons
BUSH	Bush areas (Matos)	Moors and heathland			Estuaries
		Sclerophyllous vegetation			Sea and Ocean
GAR	Urban gardens & parks	Green urban areas	OTH	Other Land Uses	Beaches, dunes and sand plains
					Bare rock
					Glaciers and perpetual snow
					unclassified

Note: "Matos" and "Montado" are the traditional name used for the particular type of vegetation/land use. They are mentioned in brackets due to the lack of an appropriate English term and due to the widespread reference to this terms in statistics and bibliographic references.

Table 7.28 - Forest types considered in calculation

Specie	Forest Structure		
	Forest	Montado	Mosaic
P. Pinaster	FOR-Pb		MOSC-Pb
Eucalyptus	FOR-Ec		MOSC-Ec
Quercus Suber	FOR-Sb	MONT-Sb	MOSC-Sb
Q. Rotundifolia	FOR-Az	MONT-Az	MOSC-Az
mixed or other	FOR-mx	MONT-mx	MOSC-mx

To be reported in the CRF tables the land use areas used in the calculus process had to be aggregated in the final 6 classes to be reported in the GHG inventory: Forest (F); Cropland (C); Grazing Land (G); Wetlands (W); Settlements (S) and Other Land (O). The conversion rules are expressed in the next table.

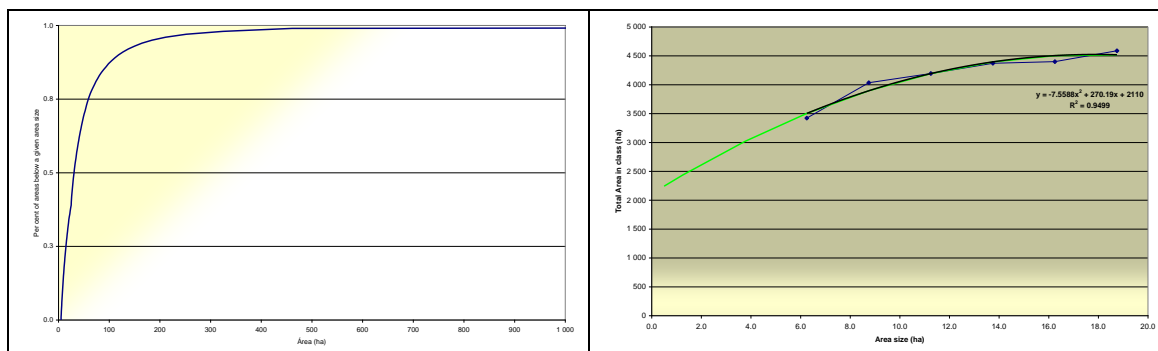
Table 7.29 - Conversion of Land Use Classes in calculus to Land Use Classes under the Inventory

LL Code	CRF class	Code	Class
F	Forest	MONT	Grasslands with Dispersed trees (Montado)
		FOR	Forest Areas
C	Cropland	CRPPER	Croplands with Perennial (Woody) Crops
		CRPANN	Arable land
		RICE	Rice Paddies
		MOSC	Agriculture Areas mixed with forest (<30%)
G	Grazing Land	GRASS	Managed Grasslands
		PRAI	Natural Grasslands
		CHARN	Sparce grassland
S	Settlements	URB	Urban Areas
		GAR	Gardens urban parks
		SURB	Mixed urban areas and parks
W	Wetlands	WET	Wetlands
		H2O	Water
O	Other	BUSH	Bush areas (matos)
		OTH	Other land uses

7.2.7.4.6 Correction of the minimum detection threshold

The fact that areas that have changed soil use are not accounted if they size is below 25ha/5 ha might have caused the underestimation of emissions and removals. To overcome this situation a simple procedure was implemented to determine the per cent of area below five ha that could also under come change but was not quantified. The per cent distribution of areas in CLC change under given area limits was plotted in graph (Figure 7.8) and a second order polynomial equation was adjusted to the resultant curve. Calculation of the remaining area, between 5 ha and down to 1 ha, indicates that the total area could be about 1.27% of total. This per cent was applied for all estimated of all land use changes.

Figure 7.8 - Distribution of area sizes in CLC changes and adjustment of curve to the lower range of areas



7.2.7.4.7 Soil conversions exclusions

Some of the soil conversion areas detected in CLC changes are only land cover changes and do not correspond to a definitive change in land use, according to the rules of LULUCF and were not considered. These correspond to the cases when a land unit that was formerly classified as forest is at the end of the period classified as land subjected to fire or forest areas subjected to cuts, new plantations or degradation and vice versa. These changes in CLC class does not result in change in land use, while changes in stock due to these actions (fire, harvesting, degradation, plantations, forest grow, re-grow or recovering) are already considered under category Forest remaining forest and should emissions/removals should not be double counted here.

7.3 Recalculations

Recalculations are related to the revision of several assumptions and parameters used in the calculations, which included: changes in BEF for the above ground living biomass; revision of harvest to include roots; and recalculation of emissions from wildfires on the basis of new assumptions for share of salvaged in harvest quantities, revision of combustion factors, inclusion of roots in the estimates, and the consideration of annual variation of average biomass according to the forest species burnt.

These changes had a significant impact in the overall emission/removal levels of this sector.

Figure 7.9 – Differences between 2009 and 2010 submissions (CO₂, CH₄ and N₂O)

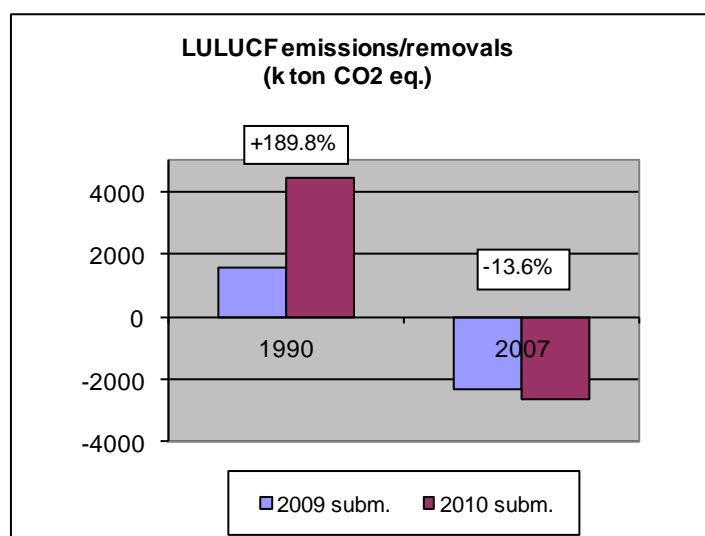


Table 7.30 – Recalculations (differences between 2009 and 2010 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO ₂			CH ₄			N ₂ O		
		2009 subm.	2010 subm.	Diff. (1)	2009 subm.	2010 subm.	Difference (1)	2009 subm.	2010 subm.	Diff. (1)
		CO ₂ equivalent (Gg)		(%)	CO ₂ equivalent (Gg)		(%)	CO ₂ equivalent (Gg)		(%)
1990										
5. Land Use, Land-Use Change and Forestry (net)		1,365.93	4,194.48	207.08	137.08	227.63	66.06	40.23	49.41	22.85
S.A.	Forest Land	-50.43	2,778.12	5,608.43	137.08	227.63	66.06	13.91	23.10	66.06
S.B.	Cropland	190.38	190.38	0.00	NO	NO		24.24	24.24	0.00
S.C.	Grassland	-24.74	-24.74	0.00	NO	NO		NO	NO	
S.D.	Wetlands	104.75	104.75	0.00	NO	NO		NO	NO	
S.E.	Settlements	1,113.65	1,113.65	0.00	NO	NO		NO	NO	
S.F.	Other Land	32.33	32.33	0.00	NO	NO		NO	NO	
S.G.	Other	NO	NO		NO	NO		2.07	2.07	0.00
2007										
5. Land Use, Land-Use Change and Forestry (net)		-2,370.48	-2,692.02	-13.56	18.45	24.16	30.95	28.19	28.77	2.06
S.A.	Forest Land	-3,786.84	-4,108.38	-8.49	18.45	24.16	30.95	1.87	2.45	30.95
S.B.	Cropland	190.38	190.38	0.00	NO	NO		24.24	24.24	0.00
S.C.	Grassland	-24.74	-24.74	0.00	NO	NO		NO	NO	
S.D.	Wetlands	104.75	104.75	0.00	NO	NO		NO	NO	
S.E.	Settlements	1,113.65	1,113.65	0.00	NO	NO		NO	NO	
S.F.	Other Land	32.33	32.33	0.00	NO	NO		NO	NO	
S.G.	Other	NO	NO		NO	NO		2.07	2.07	0.00

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).

7.4 Uncertainty Analysis

The uncertainty in forest area, for each specific species, is the uncertainty reported in the National Forestry Inventory Report for Forest stands, 0.72%.

Concerning the areas reported as land use conversions, association pairs of the 6 land use classes defined in the GP-LULUCF: Forest (F), Cropland (C), Grazing Land (G), Settlements (S), Wetlands (W) and Other Land uses (O), the overall uncertainty combines the error from Remote Sensing, 12.5% according to GP-LULUCF¹⁵¹, with the biased error of the not consideration of areas below 5 ha, which were determined from extrapolation of the probability of areas under a given area interval in the vicinities of the lower identification limit.

The uncertainty of livebiomass (above-ground and below-ground) in Forest remaining Forest (FF) includes the following individual uncertainties propagated in accordance to:

$$U_{\text{Total}} = \sum \{ [A_i * (U_{Ai}^2 + U_{Gi}^2 + U_{BEFi}^2 + U_{RSi}^2 + UC^2)]^{0.5} / \sum A_i$$

Where,

A_i - Total National Area of Forest of specie I;

U_{Ai} - the uncertainty in total national area for the given forest specie I, according to the 3rd National Forestry Inventory (DGF,2002);

U_{Gi} - Uncertainty of the growth rate of specie I, from GP-LULUCF tables 3.A.1.5 to 3.A.1.7;

U_{BEFi} - Composed uncertainty of both density of biomass and BEF, set as 32% from GP-LULUCF;

U_{Ri} - Uncertainty of the root to shoot ratio (GP-LULUCF);

¹⁵¹ According to Painho & Caetano (2005) the global thematic accuracy was estimated to be 82.84%, following the methodology defined in the EEA (2002) Technical Guidance for the I&CLC2000 Project.

U_{Gi} - Uncertainty in carbon content of biomass. A constant value of 30% was assumed for all species.

The uncertainty in the change in carbon in live-biomass for a given LL pair considers the individual components of uncertainty in carbon in aboveground biomass (U_C) and root to shoot ratio (U_R) in the initial land use under termination (i) and the new land use that results from the conversion (f):

$$U_{LL} = [(U_{Ci}^2 + U_{Ri}^2) + (U_{Cf}^2 + U_{Rf}^2)]^{0.5}$$

The individual uncertainties were established from the default values in GP-LULUCF except the case of land use forest, that was established using the same procedure explained before for Forest land remaining forest land.

For all soil types the same uncertainty error of 95% was set from IPCC. The uncertainty in DOM was calculated from the range of values proposed by the GP-LULUCF, for the land use under termination, and the double of that value for the land use being initiated.

The final uncertainties in activity data and emission factors (Carbon factors) are presented in the table below.

Table 7.31 – Uncertainty Values for Land Use Change and Forestry

LL	U AD	U EF Live	U EF DOM	U EF SOC
Forest	0.7	40	30	95
FF	13.0	27	29	95
CF	15.1	42	26	95
GF	12.9	86	26	95
WF	12.5	20	26	95
SF	20.4	23	26	95
OF	12.7	45	36	95
CC	13.9	53	0	95
FC	30.2	42	13	95
GC	13.4	92	0	95
WC	36.6	38	0	95
SC	53.4	40	0	95
OC	16.0	55	26	95
GG	12.5	119	0	95
FG	21.3	86	13	95
CG	13.4	92	0	95
WG	13.8	84	0	95
SG	21.2	85	0	95
OG	18.4	93	26	95
WW	21.7	7	0	95
FW	20.5	19	13	95
CW	16.2	38	0	95
GW	16.8	84	0	95
SW	45.3	13	0	95
OW	19.1	41	26	95
SS	14.9	18	0	95
FS	26.4	22	13	95
CS	27.0	40	0	95
GS	14.2	85	0	95
WS	35.9	13	0	95
OS	21.1	43	26	95
OO	20.3	58	36	95
FO	12.6	45	29	95
CO	14.4	55	26	95
GO	15.7	93	26	95
WO	32.0	41	26	95
SO	12.5	43	26	95

Uncertainty associated with CH₄ and N₂O emissions from fires was established in the following mode:

- The uncertainty in activity data, according to GP LULUCF, and "Because of increased accuracy and global coverage of area burned by fire, uncertainty is relatively small, in the range of 20-30%." The highest value in the range was considered;
- The uncertainty in CO₂ associated with this class represents the biomass that is not included in harvest. The error is therefore equal to the error in Harvest and determined comparing, in per cent terms, the maximum area subjected to fire that was not included in harvest (because it was not maritime pine or eucalyptus) from 1990 to 2004. The uncertainty was estimated as 93%;
- The uncertainty in CH₄ and N₂O, both 70%, are those proposed by GP LULUCF, pag 3.50.

7.5 Further Improvements

Efforts are still on going to improve the methodology that will be used to report emissions under the Kyoto Protocol. Although these efforts aim mainly the Kyoto Protocol, the methodology that will be used under the Convention will be further revised accordingly, as much as possible, in order to maintain consistency between the two reports.

The main actions that are under way and that could affect the estimates under the Convention are in particular the revision of the carbon content of soils, with the inclusion of country specific studies and monitoring, and new information on LUC.

The production of a new Land Cover Cartography (Carta de Ocupação do Solo – COS) is presently under production, based on the aerial images of 2007. The technical specifications of this cartography (COS2007), i.e. Minimum Cartographic Unit (MCU), minimum distance between lines (MDBL), and nomenclature, were approved by the cartography's Advisory Committee, which included representatives of SNIERPA, in order to ensure that the cartography would match Portugal's reporting requisites under the UNFCCC and the KP. COS2007 will be used to assess the forest, agriculture and grazing land area in the beginning of the first commitment period (2008), and to identify the afforested/reforested and deforested areas between 1990 (COS1990) and the beginning of the CP.

The country also envisages to complement this coverage with forest change monitoring (forest fires, harvest and replanting), based on satellite imagery, and other available land cover/use databases (e.g. Agro-Environmental subsidies).

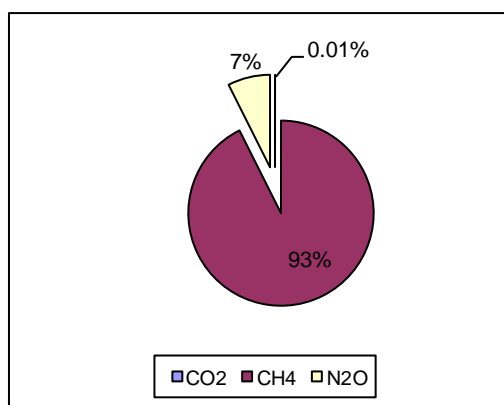
8 WASTE (CRF 6.)

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 (2008)



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 favours 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% CH₄ and 50% 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.

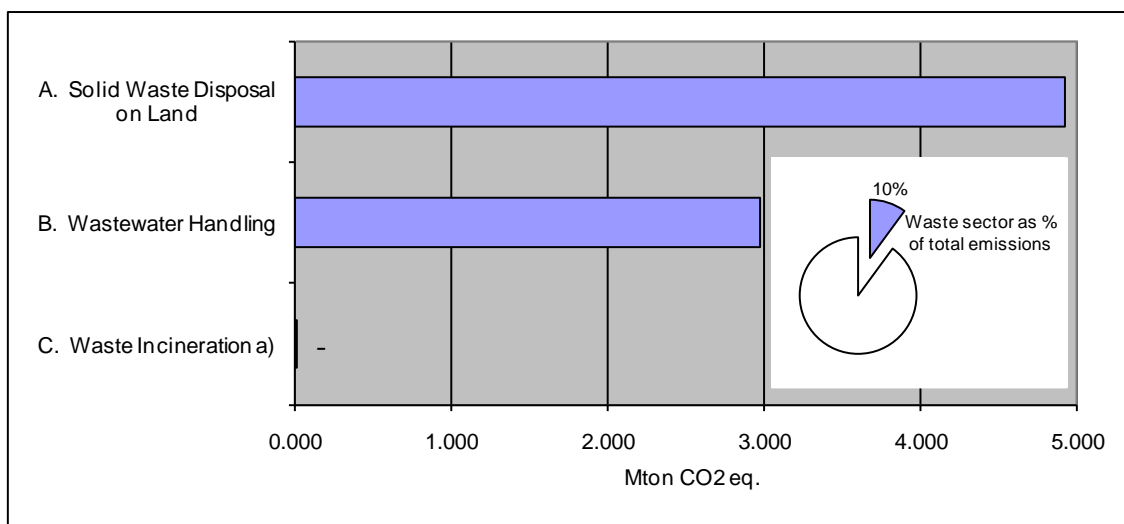
Incineration of solid wastes originates emissions of CO₂, CH₄, N₂O, CO, NO_x and NMVOC. Out of the direct GHG, CH₄ emissions are considered to be the less significant due to combustion conditions in incinerators. According to the IPCC Guidelines (IPCC,1997), only CO₂ emissions resulting from the incineration 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 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 after a thorough analysis of the incineration conditions and equipments used.

Emissions generated from waste activities represented in 2008 10% of total GHG emissions (excluding LULUCF). The biggest sub-category within the sector refers to solid waste disposed on land – 4.9 Mt CO₂e. - corresponding to 62% of the sector emissions.

Figure 8.2 – Sources of GHG in waste sector (2008)



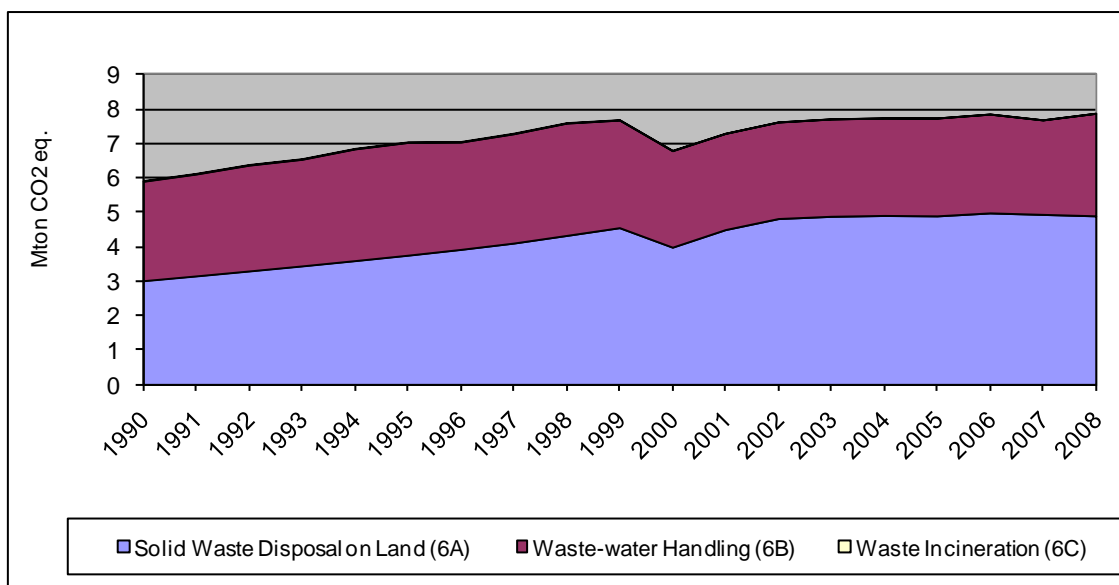
Note: a) Incineration refers only to hospital waste, generating small amounts of emissions (few quantities of waste incinerated).

In the period 1990-2008 GHG emissions from waste activities are estimated to have increased approx. 33%, having reached a peak in 1999. 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)¹⁵².

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.

¹⁵² APED, Anuário da Distribuição Portuguesa 1999.

Figure 8.3 – Emission trends of GHG from waste



The start of operation of two incineration units dedicated to MSW incineration in Portugal Mainland, and another incineration unit the Autonomous Region of Madeira in 2001/02, leads to a decrease in the emissions from SWDS reflecting a transfer of MSW final disposal between these two disposal types. This effect is however not reflected here, as urban waste incineration occurs with energy recovery and is accounted in category CRF 1.

Furthermore, the category CRF 6A registers a stagnation in emissions in recent years, which is also related to biogas flaring in landfills. Landfill gas 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.

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 to 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 CO₂¹⁵³. 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:

$$L_0 = \text{MCF} * \text{DOC} * \text{DOC}_F * F * 16/12$$

where:

MCF - CH₄ correction factor (fraction);

DOC - degradable organic carbon (fraction) (Mg C/Mg waste);

DOC_F - 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.

$$\text{DOC} = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)$$

where:

¹⁵³ Although not ultimate CO₂.

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 (DOC_F) 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 CH₄¹⁵⁴.

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 2008, the management of municipal solid waste (MSW) in Portuguese mainland was under the responsibility of 29 management systems (multi-municipal and 18 inter-municipal systems). In the Autonomous Region of Azores, municipality authorities are the responsible 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

¹⁵⁴ Other gases exist in lesser quantities however.

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 judgement 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:

$$[\text{Population (inhabitants)} * \text{Annual per capita generation rate (ton/inhabitants/year)}]$$

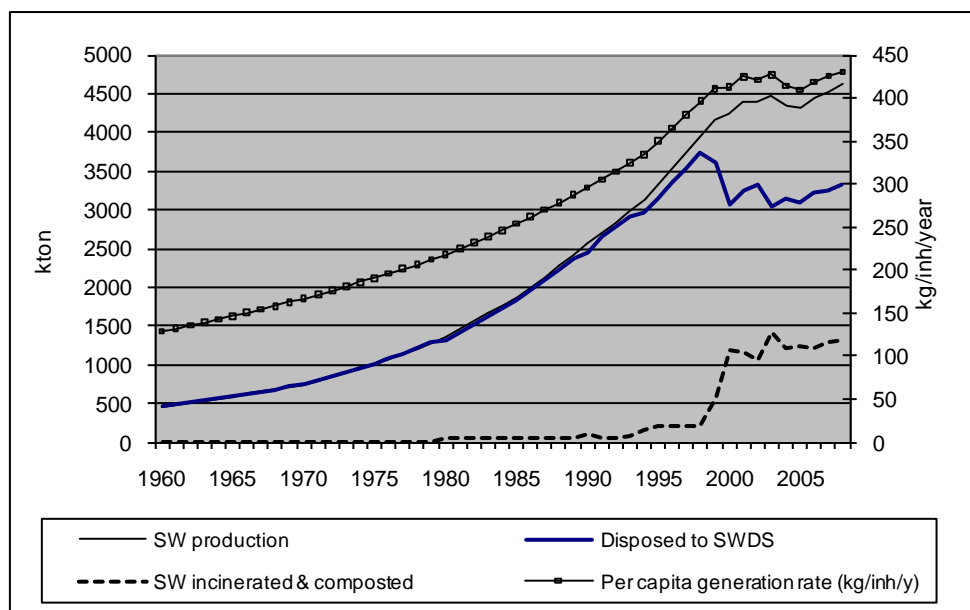
Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991 and 2001. Data for intermediate years were estimated, by interpolation, for each municipality. Figures for 2001 onwards are forecasts.

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:

$$\begin{aligned} \text{Waste disposed to SWDS} = & [\text{Population} * \text{Annual per capita generation rate} * \\ & \text{Percentage of Population served by waste collection}] \\ & - \text{Quantity of incinerated waste} - \text{Quantity of composted waste} \end{aligned}$$

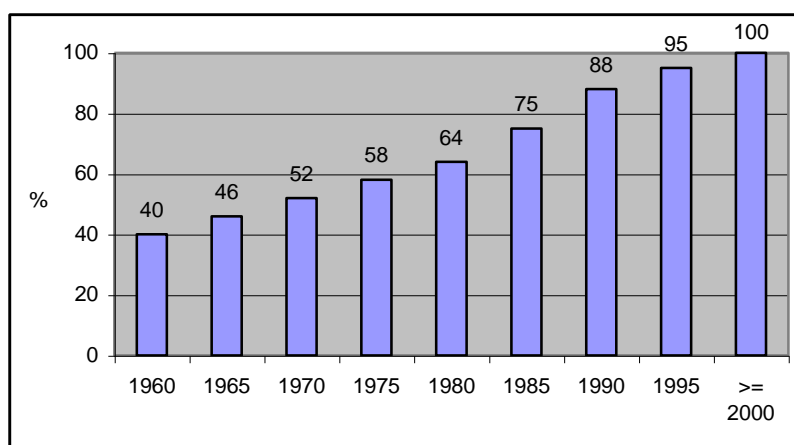
Next figure presents the trends of the per capita generation rates, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series. For the more recent years (for 1994, and since 1999) the information refers to data effectively collected. 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) in the period 1960-2008



Notes: 2006 and 2007 data for Azores: include estimates; 2007 and 2008 data for Mainland: refer to provisional data.
Source: APA estimates; INR; Quercus study

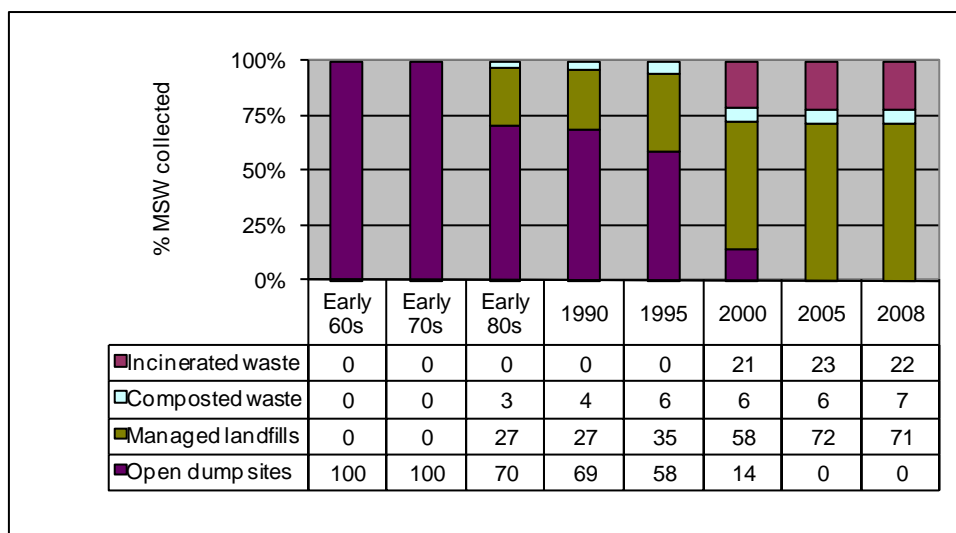
Figure 8.5 - Population served by solid waste collection systems



Source: INR

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 2008 this figure fall to 71.4%, and the percentage of waste incinerated represents 22%).

Figure 8.6 – Final disposal of waste (% of municipal solid waste without selective collection)



Source: APA estimates; Quercus; INR

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
	Percentage of weight					
Paper and textiles (fraction A)	22.5	22.5	22.5	24.9	25.8	29.0
Non-food fermentable materials (fraction B)	0.0	0.0	0.0	13.4	18.7	17.4
Food waste (fraction C)	59.9	59.9	59.9	42.0	34.8	26.5
Wood or straw (fraction D)	0.0	0.0	0.0	0.2	0.3	0.5
DOC	18.0	18.0	18.0	18.6	18.8	18.7

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: INR

8.2.1.1.2.1.3 Other parameters

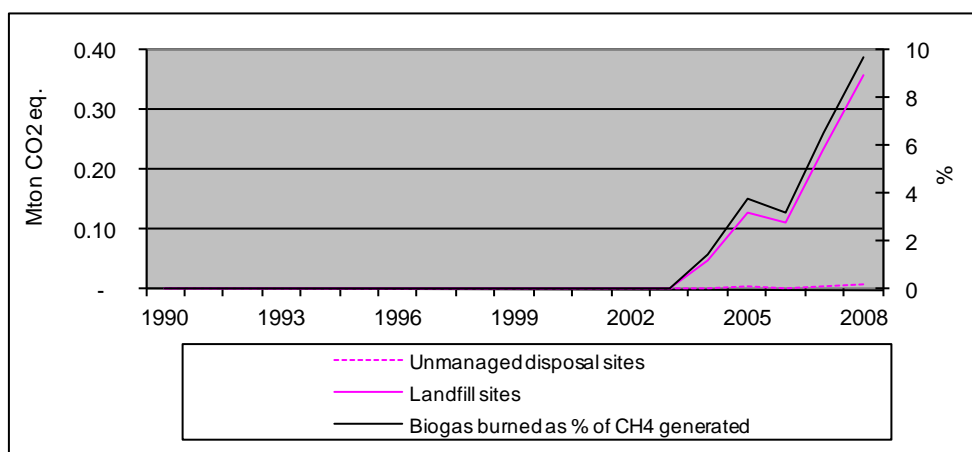
The value of CH₄ generation rate constant (k) depends on several factors as the composition of the waste and the conditions of the SWDS. In the absence of national studies to determine this parameter, and following the recommendations of the in-depth review, the values used in previous submissions were 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 refer to the amounts of biogas consumed in electrical production in landfill 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 where converted into CH₄ amounts, considering a density of 0.72 kg/m³ and a percentage of 60% of CH₄ in biogas.

Figure 8.7 – Quantities of CH₄ recovered and combusted (SWDS)



Source: Quantities based on DGEG data.

Concerning uncontrolled dumping sites, it was considered that there is gas burning when a dumping site has been closed and is associated with a managed landfill having recovery of CH₄.

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

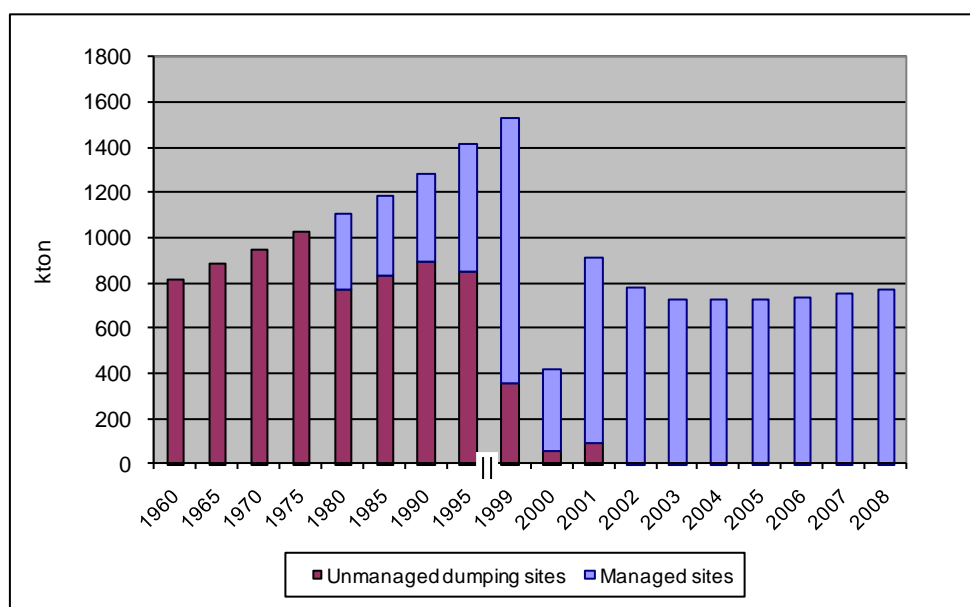
8.2.1.1.2.2 Quantities of waste landfilled

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 judgement.

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 years 2001, 2004 to 2008 are also estimates based on interpolation (2001) and last available data (2004-08 refer to 2003 data).

All industrial waste generated was consider to be disposed in SWDS together with urban waste. However, as there is no available information concerning final industrial waste disposal, 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 (include estimates)

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), 0.29 for 2002, and 0.26 for 2003 to 2008 (2003 data).

Available data on industrial waste production come from INR (Waste Institute) and refer to annual registries from industrial units declarations. This information are classified according to the European Waste Catalogue list (EWC) and are disaggregated by disposal type. From this database the APA selected (by expert judgement) 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 8.3– 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 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 wastewater treatment systems which were compiled by INAG (National Institute for Water, 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 domestic 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 (Bo) 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.

$$M = \sum_i (TOW_i \times EF_i - MR_i)$$

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

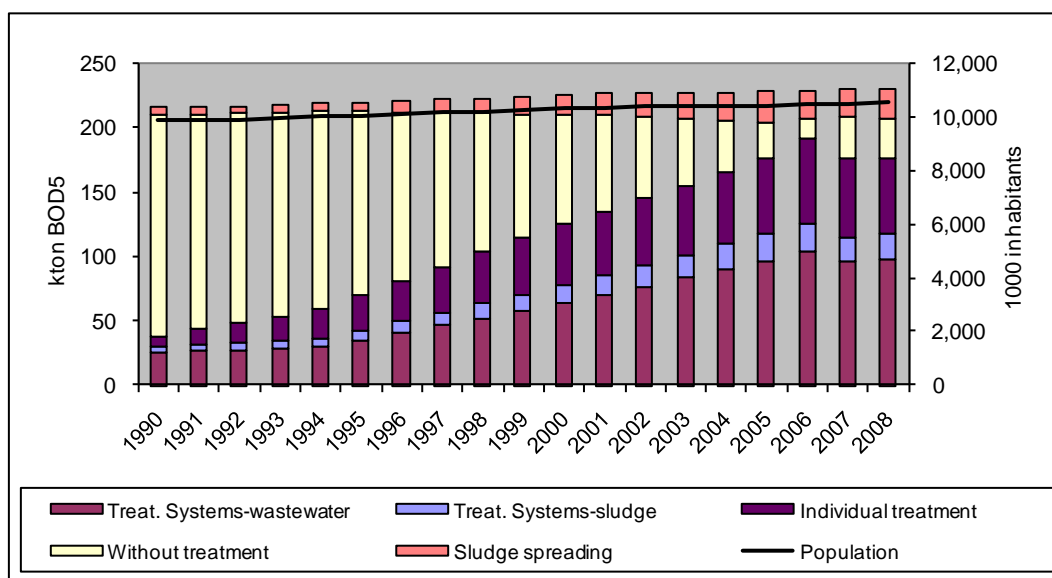
Total organic content of domestic sewage (TOW_{dom}) was determined multiplying the total population for each year by a per capita wastewater BOD₅ production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991 and 2001; intermediate years 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 (National Institute for Water, 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 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 (Figure 8.9), 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 (Table 8.5).

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 private and collective septic tanks.

Without treatment: refer to discharge into the ocean, inland waters and soil, without sewerage (latrines) 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 8.4 - Percentage of population by wastewater handling system

Wastewater handling systems		1990	1994	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
		% 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
1.2-	% Pop: individual treatment (private septic tanks)	1.5	8.2	14.8	15.8	16.7	17.7	18.7	19.6	20.6	21.5	22.5	22.5
Population with sewerage													
2.1-	% de Pop: with discharge into the ocean, without treatment	6.5	6.5	6.5	6.0	5.4	4.9	4.3	3.8	3.2	1.5	1.9	1.3
2.2-	% de Pop: with discharge into inland waters, without treatment	36.8	40.8	30.3	26.3	22.4	18.4	14.5	10.6	6.6	3.7	3.1	1.8
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
2.4-	% de Pop: unknown disposal	0.0	0.0	0.0	0.5	0.9	1.4	1.8	2.3	2.7	1.6	9.0	10.3
3-	% Pop: with treatment	18.2	21.1	42.0	46.1	50.2	54.4	58.5	62.6	66.7	71.7	63.5	64.0
3.1-	% Pop: collective septic tanks	2.2	2.3	5.0	5.1	5.1	5.2	5.2	5.3	5.3	7.2	4.3	3.3
3.2-	% Pop: with preliminary treatment	0.0	0.0	0.0	0.5	1.0	1.5	2.0	2.6	3.1	7.4	7.8	7.8
3.3-	% Pop: with primary treatment	5.2	5.2	9.0	8.4	7.8	7.3	6.7	6.1	5.5	3.1	5.6	5.6
3.4-	% Pop: with secondary and tertiary treatment	10.8	13.6	28.0	32.1	36.3	40.4	44.5	48.7	52.8	53.9	45.8	47.3
3.4.1-	Biodisks w ith 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
3.4.2-	Biodisks without anaerobic sludge digestion	0.0	0.0	0.0	0.1	0.3	0.4	0.6	0.7	0.8	0.8	0.7	0.2
3.4.3-	Activated sludge with anaerobic sludge digestion	1.4	2.0	4.6	6.9	9.2	11.5	13.8	16.1	18.5	18.9	16.0	17.0
3.4.4-	Activated sludge without anaerobic sludge digestion	1.4	2.0	4.6	5.8	6.9	8.1	9.3	10.5	11.7	11.9	10.1	11.7
3.4.5-	Laguning, w ith anaerobic pond	1.7	1.9	3.6	3.0	2.5	1.9	1.3	0.8	0.2	0.2	0.2	0.3
3.4.6-	Laguning, without anaerobic pond	0.6	0.6	1.2	1.9	2.6	3.3	4.0	4.6	5.3	5.5	4.6	6.1
3.4.7-	Percolation beds w ith anaerobic sludge digestion	3.6	4.6	8.8	8.0	7.1	6.3	5.4	4.5	3.7	3.7	3.2	3.0
3.4.8-	Percolation beds without anaerobic sludge digestion	0.0	0.0	0.0	0.6	1.3	1.9	2.6	3.2	3.9	4.0	3.4	2.8
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	0.9
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
3.4.11-	Oxidation ponds without anaerobic sludge digestion	0.3	0.4	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.6	1.3	1.4
3.4.12-	Other treatment w ith anaerobic sludge digestion	0.0	0.0	0.0	0.4	0.8	1.1	1.5	1.9	2.3	2.3	2.0	2.3
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	0.2	0.3
3.4.14-	With unspecified treatment	0.0	0.0	0.0	0.4	0.9	1.3	1.7	2.2	2.6	2.6	2.3	0.6

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 8.5 presents MCF factors used for each wastewater treatment system considered.

Table 8.5 - 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, with anaerobic pond	d)	0.20	0.00	100%	-	
3.4.6-	Laguning, without 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-	Innhoff 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).

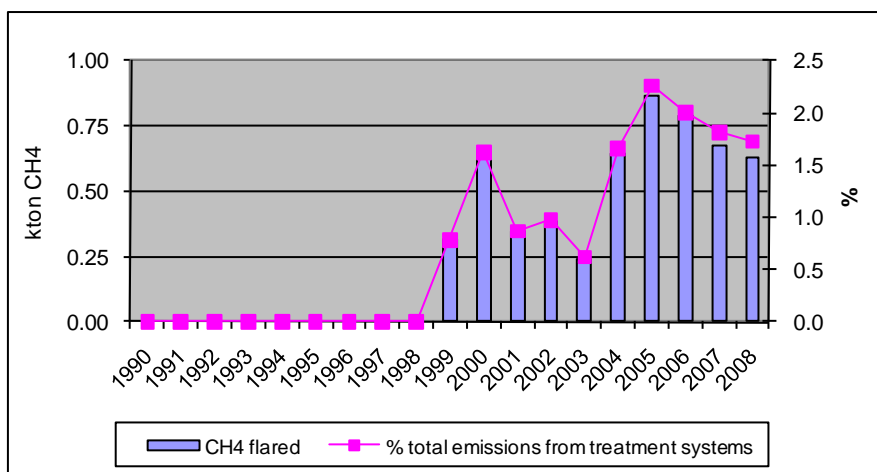
c) Wastewater: expert judgement, assuming a value between "well management" and "aerobic treatment plant, not well managed".

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 where 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



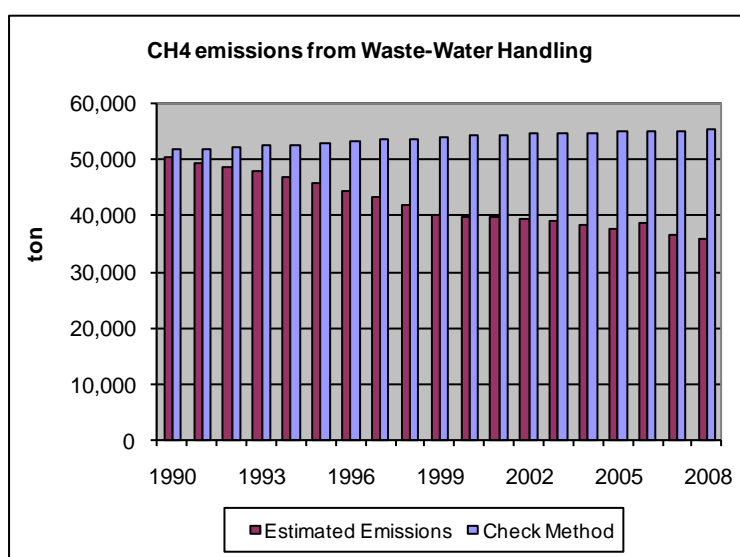
Source: Quantities based on data DGEG data.

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 2008 (~ 55 kton) was around 35% 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 1990-2008 is contradictory. The “check method” accounts for a 7% increase in the 1990-2008 period, as a result of the population growth, while the national reported emissions are estimated to decrease around 29%.

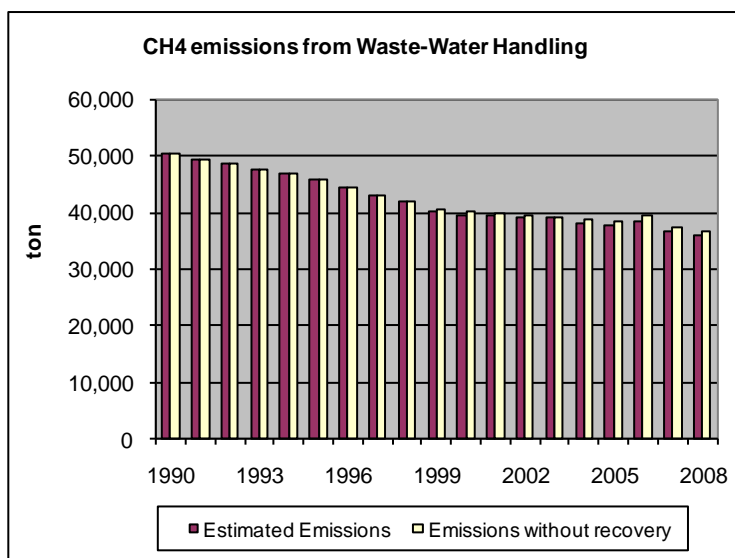
The variables Population (P), Organic load in biochemical oxygen demand per person (D), and the EF (g CH₄/g BOD, default = 0.6) are the same in both approaches. Consequently the differences result from other parameters, i.e., the fraction of BOD that degrades anaerobically, and the consideration of CH₄ 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 judgement (Table 8.4), 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 not significant as the percentage of the estimated recovery amounts represent only a small part of the total emissions generated in treatment systems (in 2008 they represented less than 2% of emissions generated in municipal wastewater systems).

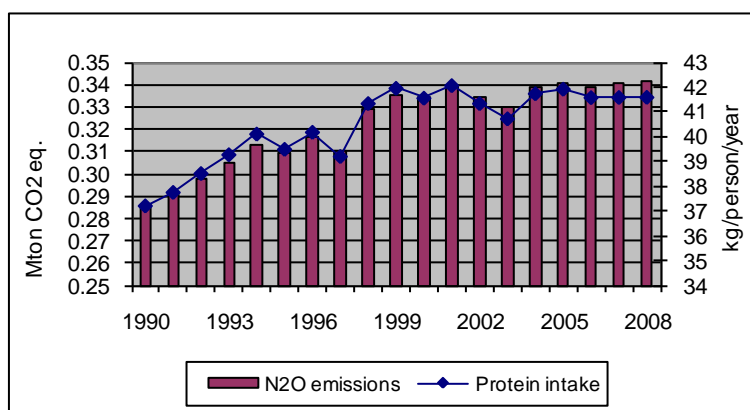
Figure 8.12– Comparison between CH₄ domestic emissions with and without recovery



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: FAO database (December 2009); 2006-08 figures: 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.

$$N_2O_{(S)} = \text{Protein} * \text{Fra}_{C_{NPR}} * \text{Pop} * \text{EF} * 44/28$$

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 .

8.2.2.1.3.2 Activity data and parameters

Activity data results of protein intake, according to FAO database (Table 8.6), multiplied by total population, from the National Statistical Office (INE) Census for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation.

Other parameters considered for the estimations are based on IPCC (1997) defaults.

Table 8.6 - Data and parameters used calculation of N_2O emissions from wastewater

Parameter	Explanation	Values considered	
		Year	Value (kg/person/year)
Annual per capita protein intake	FAO data (December 2009)	1990	37.2
		1991	37.7
		1992	38.5
		1993	39.3
		1994	40.1
		1995	39.5
		1996	40.2
		1997	39.2
		1998	41.4
		1999	42.0
		2000	41.6
		2001	42.1
		2002	41.4
		2003	40.7
		2004	41.8
		2005	41.9
		2006	41.6
		2007	41.6
		2008	41.6
Fraction of nitrogen in protein	IPCC96 default	16%	(constant)
Emission factor	IPCC96 default	0.01 kg N_2O -N/kg N	(constant)

Note: 2006-08 figures: 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 system¹⁵⁵ 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

¹⁵⁵ 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 sectors¹⁵⁶. 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 CQO load.

¹⁵⁶ -Cork Granulation; Aliphatic hydrocarbons; Cyclic hydrocarbons; Kraft pulping; Synthetic fertilizers; Acid sulphite pulping.

Table 8.7 – 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
Choline 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 2006. 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 2006;
- Production of paper pulp was available directly from the individual industrial plants, for the all period.

Tables Table 8.8 and Table 8.9 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 2007, 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 information¹⁵⁷. 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.

¹⁵⁷ 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 8.8 - Sources of Information used to define the time-series of industrial production (1/2)

Industry	IAIT CAE rev1	IAPI PRODCOM	Infoline	Note
Slaughter House			1990-2007	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2007	
Slaughter House, Poultry			1990-2007	Broilers, Turkeys, ducks, quails, ostrich, guinea-fowl, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200	-	
Milk processing	3112		1994-2007	
Cheese	3112	15510	-	
Other dairy products	3112		1994-2007	Cream, yogurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2007	
Tomato juice			1994-2007	
Fruit Juices	3131+3132		1994-2007	
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			1993-2007	
Ethanol	313110	159101070; 1592011	-	
Spirits Distillation	3131+3132	1591010-159101070+1592012	-	
Wine Cellars	3131+3132	15930; 15950	2001-2007	
Beer	3133	1596010	-	
Mineral water and similars			1993-2007	

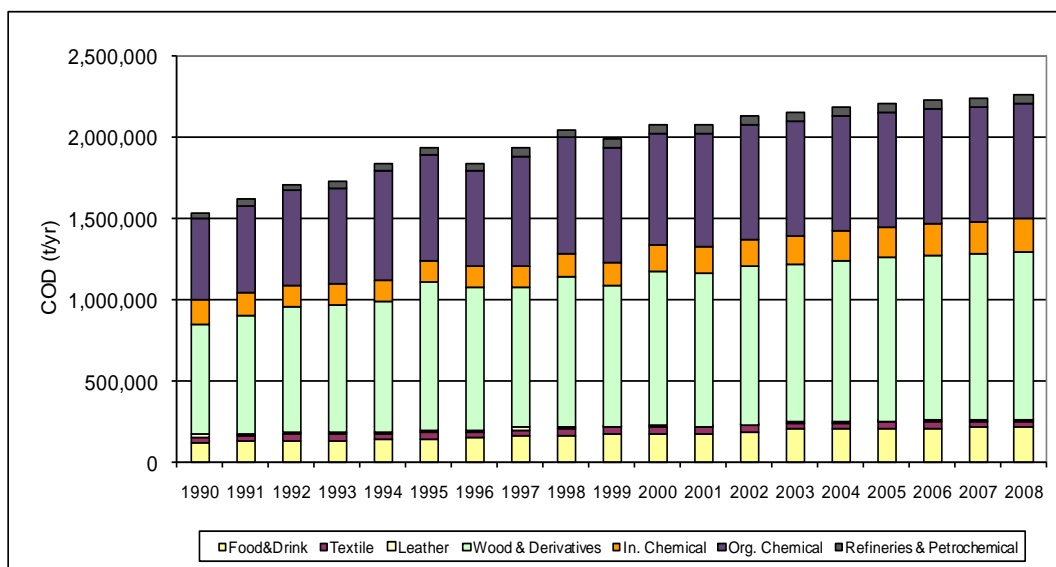
Table 8.9 - Sources of Information used to define the time-series of industrial production (2/2)

Industry	IAIT CAE rev1	IAPI PRODCOM	Infoline	Note
Wool production		171002021	-	
Wool processing		171002027; 1710042; 1710053	-	
Synthetic fibres processing	321130	171003031; 171003039; 17100523 1/32/33/39/91/92/93/99; 1710055	171003039+17100523 1/32/33/39/91/92/93/99+1710055	
Artificial fibres processing	321130	171003050; 1710054/5	-	
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		24130111; 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			1998-2007	
Soaps		2451131	-	
detergents		2451120/32	-	
Petroleum refining			-	Energy Balance (DGGE): 1990-2007

Note: 2008 data refer to estimates.

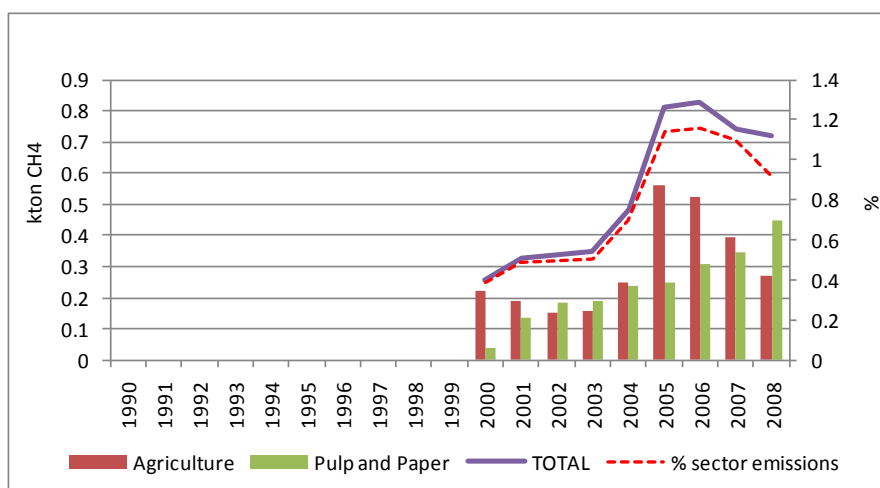
Total wastewater load aggregated per industrial group is presented in Figure 8.14 below, from where it is evident the continuous growth of discharge from 1990 to 2007, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry.

Figure 8.14 - Industrial Wastewater load, expressed in COD, from major groups of industrial activity



This submission considers for the first time methane recovery in Industrial Wastewater Handling Systems. 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*¹⁵⁸ and a *Specific Plan of Elaboration*¹⁵⁹. 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:

- 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;

¹⁵⁸ Caracterização da Situação Ambiental, in the original Portuguese nomenclature.

¹⁵⁹ Plano Específico de Adaptação, in the original Portuguese nomenclature.

- 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 2007.

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 8.10 - 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 13% in 2004. 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 14% in 2004.

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 possible¹⁶⁰, the comparison of the PC of Cartaxo et al (1985) (named CS) were compared with the equivalent IPCC in the next table¹⁶¹:

¹⁶⁰ The level of detail of the IPCC Pollutant Coefficients is not so detailed as the CS data set.

¹⁶¹ 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.

Table 8.11 – 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.

Figure 8.16 - Comparison between COD estimates using CS PC and IPCC defaults.

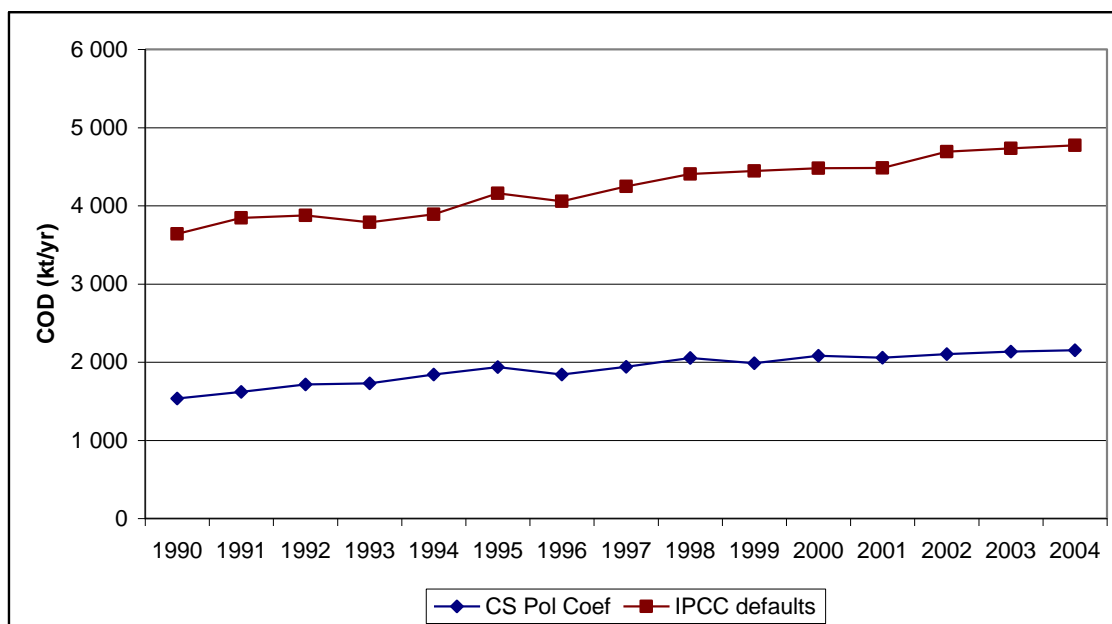
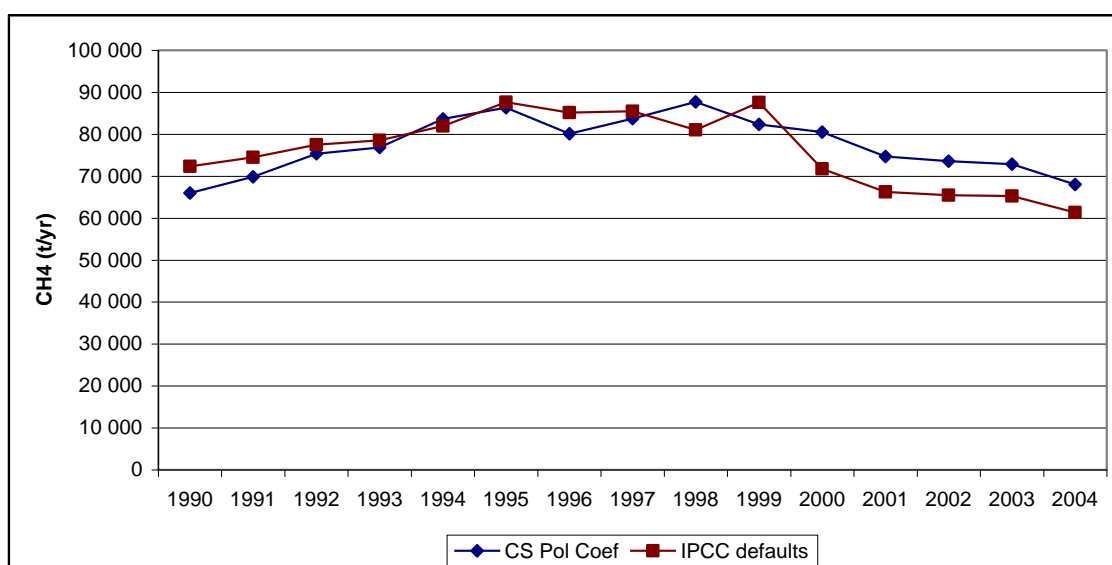


Figure 8.17 - Comparison between CH₄ emission estimates using CS PC and IPCC defaults.



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

Substantial changes have been done in the submission of 2007, following the recommendations from the in-country review of IIR under the Kyoto Protocol.

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;

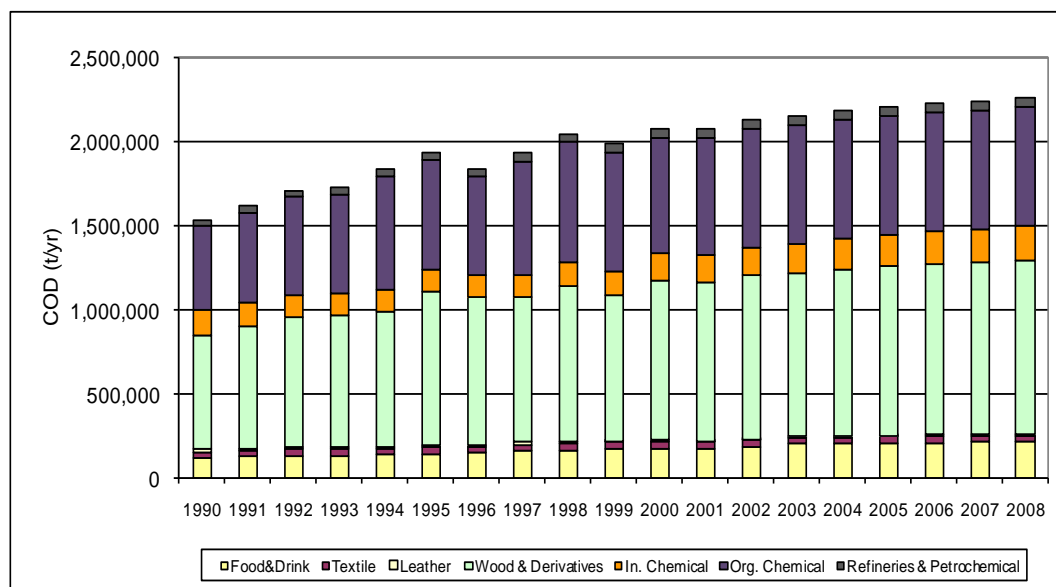
$TLH_{(j)}$ – Total Wastewater Load generated from industrial sector j, expressed in inhabitants-equivalent;

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. This source was wrongly reported in previous submissions as open burning on land in category 6D. This change results from the detection of a problem concerning an erroneous classification of this disposal category.

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;

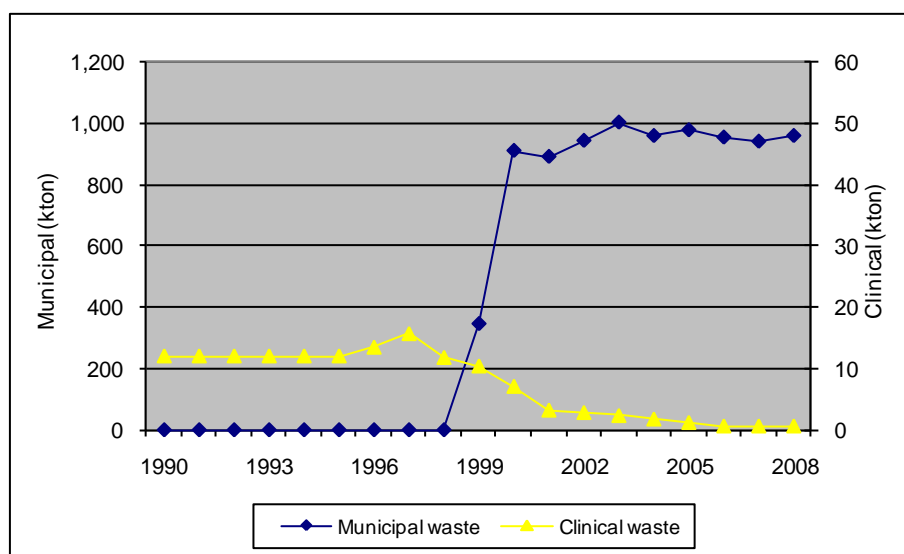
EF_i - Burn out efficiency of combustion of incinerators for waste of type i (fraction).

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 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



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 start 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 fibbers, 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 MSW, and clinical waste. Data are presented in the following table.

Table 8.12 - Parameters considered

	Unit	MSW	Clinical waste
C content of waste	%	30 a)	60 b)
Fraction of fossil carbon in waste	% total C	37 a)	40 b)
Efficiency of combustion	%	95 b)	

Notes: a) National figure; b) 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.

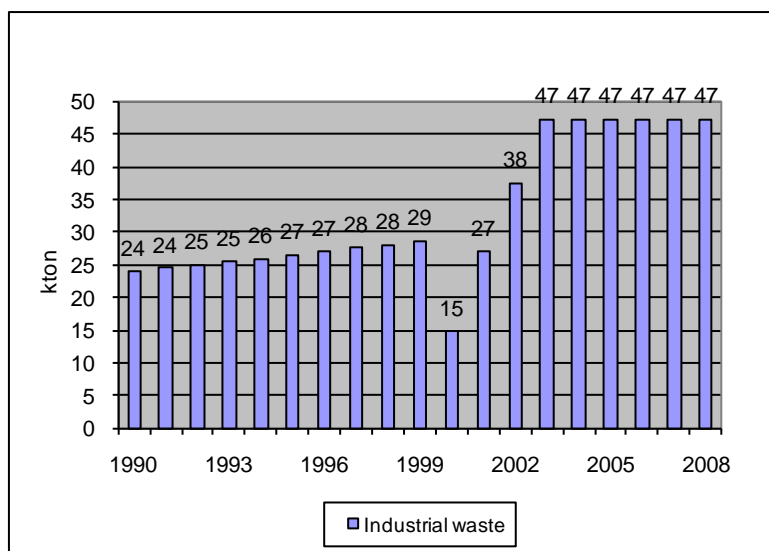
Table 8.13– Base table for MSW C content estimation

	C content		Waste composition (% of weight)			
	Non-biogenic	Total C	1990	1994	1999	>=2000
Paper/ Card	0	40	21.1	22.7	28.3	26.4
Glass	0	0	4.4	5.1	7.0	7.4
Plastics	85	85	9.2	11.7	11.2	11.1
Metals	0	0	2.8	2.7	2.7	2.75
Food waste	0	15	42.0	34.8	27.9	26.5
Textiles	40	80	3.8	3.1	2.7	2.6
Non-food fermentable materials	0	17	13.4	18.7	17.6	17.4
Wood	0	30	0.2	0.3	0.5	0.5
Other	0	0	3.2	0.8	4.6	5.35
C content in Plastics and Textiles (1)			9.3	11.2	10.6	10.5
Total C of waste (2)			27.9	30.0	30.3	29.2
% non-biogenic C in waste (1)/(2) * 100			33.5	37.3	35.0	35.9

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 2000, 2002 and 2003 refer to industrial units declarations. The figure for 2001 is interpolated, and 2004-07 refer to latest available data (2003). 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%.

Figure 8.20– Quantities of combusted industrial waste (1990-2008)



Source: APA (include estimates).

Table 8.14- Parameters considered

	Unit	Industrial Solid Waste
C content of waste	%	14-18 a)
Fraction of fossil carbon in waste	% total C	20.5-0.3 a) c)
Efficiency of combustion	%	95 b)

C content of waste: until 1999 - 14; 2000 - 18; 2002 – 17.

IPCC default.

% total C: until 1999 - 20.5; 2000 - 0.3; 2002 - 1.0.

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 judgement (please see Table 8.3). 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 8.15 - 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 NOx 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 8.16 - 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 NOx 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 8.17 - 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 NOx 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

8.2.3.2.2.2 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 for the next submission, after an accurate analysis of the information concerning the conditions and technologies used by industrial units where incineration occurs.

Table 8.18 - 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 NO _x 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)

8.3 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 must be considered high not only because is estimated for each year from population and per capita waste production ratio but mostly because of the low accuracy in the backcast establishment of past solid wastes disposal since 1960. An uncertainty of 25% was therefore 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 an even lower accuracy than Municipal Solid Wastes, because the time trend since 1960 was established with information only collected after 1999. Comparison of the production of industrial solid wastes from 1999 till 2002 show unexpected expressive annual variations, which indicate that annual production could have an uncertainty of about 68%. 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 constant¹⁶². 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.

¹⁶² 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.

8.4 QA/QC and verification

QC 1 procedures including checks on: data units, calculation procedures, and data fields relationships were applied. One relation error was detected and corrected (emissions CH_4 Solid Waste Unmanaged).

QC2 applied referred mainly to: analysis of implied emissions factor (IEF) using the graph tool of the CRF Reporter; and comparison of national IEF with IEF from other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2009/

FCCC/WEB/SAI/2009). Significant deviations were observed for category 6B. These differences should be analysed more deeply for the next inventory submission.

8.5 Recalculations

The changes for this sector refer in majority to CH₄ emissions and result basically from:

- AD updates of % population served by handling systems and type of treatment

Other differences refer to the revision of protein intake data from FAO, resulting in slight recalculations of N₂O emissions from domestic sewage. Synthesis of changes may be observed in figure and table below.

Figure 8.21 – Differences between 2009 and 2010 submissions (CO₂e)

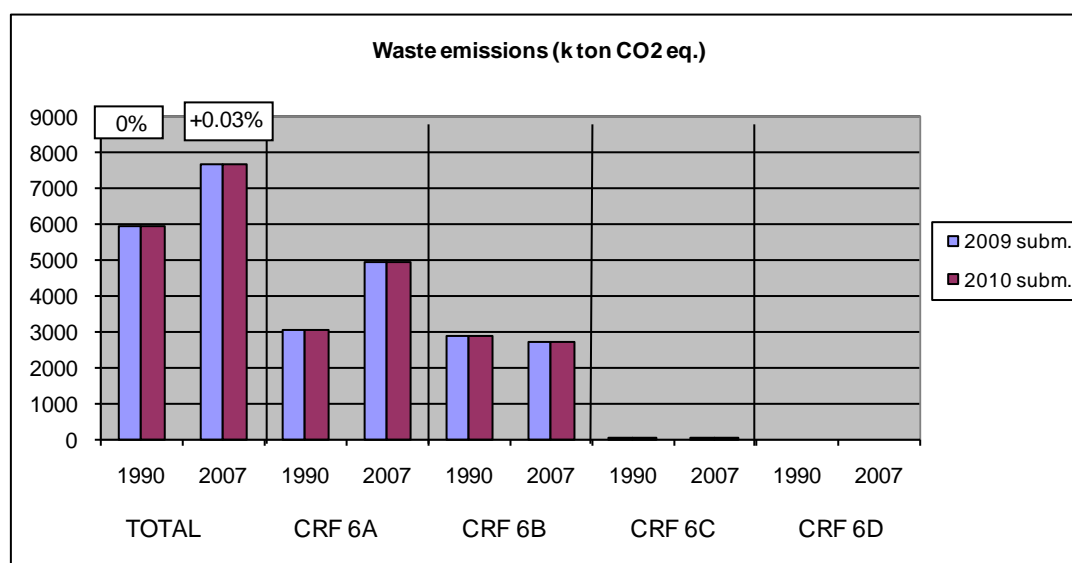


Table 8.19 – Recalculations (differences between 2009 to 2010 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES				CO2			CH4			N2O		
				2009 subm.	2010 subm.	Diff. (1)	2009 subm.	2010 subm.	Difference (1)	2009 subm.	2010 subm.	Diff. (1)
				CO2 equivalent (Gg)			(%)	CO2 equivalent (Gg)			(%)	CO2 equivalent (Gg)
1990												
6. Waste				10.10	10.10	0.00	5 474.86	5 474.86	0.00	442.79	442.79	0.00
6.A.	Solid Waste Disposal on Land			NA	NO		3 032.57	3 032.57	0.00			
6.B.	Wastewater Handling						2 442.25	2 442.25	0.00	441.67	441.67	0.00
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			NA	NO		NA	NO		NA	NO	
2007												
6. Waste				0.60	0.60	0.00	7 103.82	7 120.96	0.24	580.20	565.20	-2.59
6.A.	Solid Waste Disposal on Land			NA	NO		4 945.39	4 958.34	0.26			
6.B.	Wastewater Handling						2 158.38	2 162.56	0.19	578.65	563.65	-2.59
6.C.	Waste Incineration			0.60	0.60	0.00	0.05	0.05	0.00	1.55	1.55	0.00
6.D.	Other			NA	NO		NA	NO		NA	NO	

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 knowledge of the situation of industrial wastewater. It is expected that the situation will improve

in the future, after the implementation of a new survey system and data base by the National Water Institute.

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 with N₂O emissions related with land disposal and sewage treatment.

8.7 Background Data Tables

Table 8.20 – National population, per capita generation rates, and urban waste production: 1960-2008

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	10,405,014	421.2	100	4,382.7	27.8	3,294.7	116.2	943.9
2003	10,453,911	427.1	100	4,464.6	25.9	3,019.2	416.1	1,003.4
2004	10,502,808	414.3	100	4,351.6	22.3	3,118.9	250.6	959.7
2005	10,551,705	409.1	100	4,316.2	0.0	3,091.0	246.9	978.4
2006	10,600,602	418.6	100	4,437.8	0.0	3,229.0	253.8	954.6
2007	10,649,499	425.9	100	4,535.2	0.0	3,238.0	300.4	996.8
2008	10,698,396	430.0	100	4,626.3	0.0	3,302.8	306.9	1,016.6

Notes:

Selectively collected wastes (deviated to recycling) excluded.

Sources:INE; APA estimates; Quercus Study

Table 8.21 – Fermentable industrial waste disposal: 1960-2008

Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills
	kton			kton			ton	
1960	819	0	1976	1,040	0	1992	860	473
1961	832	0	1977	1,055	0	1993	876	483
1962	844	0	1978	1,071	0	1994	835	551
1963	857	0	1979	1,087	0	1995	850	565
1964	870	0	1980	773	330	1996	848	594
1965	883	0	1981	782	338	1997	810	661
1966	896	0	1982	794	343	1998	594	907
1967	909	0	1983	806	348	1999	358	1,173
1968	923	0	1984	818	354	2000	59	365
1969	937	0	1985	830	359	2001	95	815
1970	951	0	1986	842	365	2002	5	773
1971	965	0	1987	854	370	2003	4	723
1972	980	0	1988	867	376	2004	4	723
1973	994	0	1989	880	382	2005	0	727
1974	1,009	0	1990	893	388	2006	0	741
1975	1,024	0	1991	843	463	2007	0	756
						2008	0	771

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 8.22 – Quantities of CH₄ recovered and combusted (Urban waste): 1990-2008

	Unmanaged disposal sites	Landfill sites	Unmanaged disposal sites	Landfill sites	Biogas burned as % of CH ₄ generated
	kton CH ₄		Mton CO ₂ eq.		%
1990	0.00	0.00	-	-	0
1991	0.00	0.00	-	-	0
1992	0.00	0.00	-	-	0
1993	0.00	0.00	-	-	0
1994	0.00	0.00	-	-	0
1995	0.00	0.00	-	-	0
1996	0.00	0.00	-	-	0
1997	0.00	0.00	-	-	0
1998	0.00	0.00	-	-	0
1999	0.00	0.00	-	-	0
2000	0.00	0.00	-	-	0
2001	0.00	0.00	-	-	0
2002	0.00	0.00	-	-	0
2003	0.00	0.00	-	-	0
2004	0.09	2.29	0.00	0.05	1
2005	0.22	6.06	0.00	0.13	4
2006	0.16	5.39	0.00	0.11	3
2007	0.31	11.16	0.01	0.23	7
2008	0.41	17.13	0.01	0.36	10

Source: APA estimates based on data DGEG data

Table 8.23 – National population and wastewater BOD produced by handling systems: 1990-2008

	Population (1000 inhabitants)	BOD5 produced (kton/year)					
		Total	Treatment systems		Individual treatment	Without treatment	Sludge spreading
			wastewater	sludge			
1990	9,864	216	24	5	8	173	5
1991	9,867	216	25	5	12	168	5
1992	9,916	217	26	6	15	164	6
1993	9,965	218	27	6	19	160	6
1994	10,014	219	29	6	23	155	6
1995	10,063	220	34	8	27	144	8
1996	10,112	221	40	9	31	132	9
1997	10,161	223	45	10	36	121	11
1998	10,209	224	51	12	40	109	12
1999	10,258	225	57	13	44	97	14
2000	10,307	226	63	14	47	86	15
2001	10,356	227	70	16	50	75	17
2002	10,375	227	76	17	52	64	19
2003	10,393	228	83	18	54	52	20
2004	10,412	228	89	20	57	41	22
2005	10,430	228	95	21	59	29	24
2006	10,463	229	103	22	66	15	22
2007	10,497	230	96	19	62	32	21
2008	10,530	231	97	20	59	31	23

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 8.24 – Quantities of CH₄ flared from municipal wastewater handling systems: 1990-2008

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	1.0
2003	0.24	0.6
2004	0.65	1.7
2005	0.87	2.3
2006	0.79	2.0
2007	0.68	1.8
2008	0.63	1.7

Source: Quantities based on data DGEG data

Table 8.25 – Quantities of waste incinerated: 1990-2008

Year	MSW quantities incinerated	Clinical waste quantities incinerated	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	346	10	29
2000	911	7	15
2001	892	3	27
2002	944	3	38
2003	1,003	2	47
2004	960	2	47
2005	978	1	47
2006	955	1	47
2007	941	1	47
2008	960	1	47

Note: Estimates in italics

Sources: APA (include estimates); DGS

Table 8.26 – Comparison between estimates for CH₄ emissions from waste-water handling and IPCC check-method

Year	CH ₄ emissions			National CH ₄ emissions	
	Check method	National estimates	% difference	w ithout recovery	recovered
	ton	ton	%	ton	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	39,636	26.8	40,290	654
2001	54,432	39,674	27.1	40,023	349
2002	54,529	39,247	28.0	39,635	388
2003	54,626	39,002	28.6	39,245	243
2004	54,723	38,207	30.2	38,853	646
2005	54,820	37,592	31.4	38,460	869
2006	54,996	38,575	29.9	39,366	791
2007	55,171	36,593	33.7	37,271	678
2008	55,347	35,902	35.1	36,534	632
% variation 1990-2008	6.8	-28.6	-	-27.4	-

9 RECALCULATIONS AND IMPROVEMENTS

This section presents an overview of the recalculations made in the 2010 submission.

The recalculations made result mostly from the recommendations issued during the UNFCCC reviews and updates of activity data. However some additional recalculation and improvements were performed by the inventory team, namely:

- A revised 2007 Energy Balance has been given by DGEG since the last submission. The corresponding values were update in the inventory;
- Update of the fuel consumption time series for several industrial plants (mainly pulp/paper production), couple with a revision of LHV values In some cases this update affects values for the 2004-2007 time series
- Production data update for the Ceramic Industry (IATI update 2001-2007);
- Fuel consumption update for Tunes power plant (EU-ETS 2006-2007)
- Crop data revision for the years 2006 and 2007.
- General update of livestock time series (2007). Revision of the livestock time series for Hens, Broilers and Rabbits (1990-2007)
- Fertilizers consumption update for 2007.
- CRF 5: recalculations are primarily related to a thorough revision of several assumptions and parameters considered. These concern: changes in BEF for the above ground living biomass; revision of harvest to include roots; and recalculation of emissions from wildfires on the basis of new assumptions for share of salvaged in harvest quantities, revision of combustion factors, inclusion of roots in the estimates, and the consideration of annual variation of average biomass according to the forest species burnt.
- Recalculations refer to updates of activity data in Waste sector.

9.1 Listing of recalculations

The listing below concerns the review from 2009. Some questions raised during the 2008 review which are still under development and are also listed.

The final ERT Review Report from 2009 was made available to the inventory team just recently therefore there could be additional ERT comments which are yet not included in the list below. This will be updated in the NIR to be submitted in April 15th, 2010.

Table 9.1 Overview of the responses to the UNFCCC review 2009

CRF	Comment	Portugal's response	Where in NIR
ERT 2009 Final Report			
Completeness	Categories reported as "NE": N2O emissions from the use of N2O for anaesthesia (3.D.1), fire extinguishers (3.D.2), aerosol cans (3.D.3), and CO2 emissions from agricultural lime application	N2O emissions were estimated for the 2010 submission.	Section 5.3.4.1 Use of N2O for Anaesthesia (3.D.1), page 5-14
Energy	Improving the order and descriptions of the energy sector categories (particularly for transport), following the recommendations of the UNFCCC reporting guidelines in full		<p>Section 3.2.3 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.</p> <p>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).</p> <p>To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made. Following the fuel classification presented in the IEA website,</p>

CRF	Comment	Portugal's response	Where in NIR
			<p>three fuels types were analyzed: coal and peat, petroleum products and natural gas. It was only possible to compare values for 2007 since this is the only year with data publicly available in IEA. For coal and peat and natural gas the differences between fuel consumption reported in both data sources are very small. Data concerning petroleum products shows a tendency to be higher in IEA for combustion in the industrial sector and lower than DGEGs for co-generation plants. Two factors may be influencing this variation:</p> <ul style="list-style-type: none"> - IEA might be using an older version of DGEG's energy balance (2007 EB was revised this year); - there might be differences in the fuels aggregated under petroleum products reported by IEA and the DGEG values considered in this

CRF	Comment	Portugal's response	Where in NIR
			<p>comparison.</p> <p>Also important to note that during a general revision of this sector emissions estimation procedures inconsistent values were found concerning LHV for non combustible gas. These values were corrected.</p> <p>9.1.1.1 <i>Recalculations</i></p> <p>There were several recalculations to this source category:</p> <ul style="list-style-type: none"> - Revision of diesel oil consumption data (only for 2006), used in the estimation of biodiesel incorporation. This revision also affects sector 1A4; - Inclusion of new fuels in the Cement Industry (2004-2007); - Revision of the fraction of biomass for several fuel types, classified as other fuels in the Cement Industry, as a result from streamline

CRF	Comment	Portugal's response	Where in NIR
			<p>procedures with EU-ETS;</p> <ul style="list-style-type: none"> - Revision of LHV and fuel consumption values for several combustion equipments in Pulp and Paper Industrial sector; - Revision of the fuel consumption and LHV values for non combustible gases from Pulp and Paper industry (1991-2007), following QA/QC procedures applied to this sector; - Production data update for the Ceramic Industry (IATI update 2001-2007). <p>Transport (CRF 1.A.3.), page 3-90 onwards</p>

Recalculations and Improvements

CRF	Comment	Portugal's response	Where in NIR
	Including a separate section on international bunkers	This will be addressed during the next submissions	This will be addressed during the next submissions
	Improving the clarity of the division between civil aviation, navigation, military aviation, military navigation, military ground transport, aviation bunkers and marine bunkers	This will be addressed during the next submissions	This will be addressed during the next submissions
	Improving Reference Approach analysis by splitting domestic and international fuel consumption for navigation and aviation in line with IPCC good practice guidance.	This will be addressed during the next submissions	This will be addressed during the next submissions
Agriculture	Revise digestability values for dairy-cows.	Efforts will be made to revise this issue for the next submission	Efforts will be made to revise this issue for the next submission
	Revise EF for anaerobic lagoons.	Efforts will be made to revise this issue for the next submission	Efforts will be made to revise this issue for the next submission
LULUCF	Recommendation to improve the consistency and accuracy of the reporting of land areas subjected to land-use changes in its next annual inventory submission.	Portugal intends to deeply revise the current CRF 5 estimates using these new cartographic products and on the basis of the ongoing studies under development by the SNIERPA/WG on 3.3_3.4 (e.g. forest simulators, C on soil). All these undergoing developments should be more stabilised for the 2011 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.		A description of the methods and assumptions currently used are included in the NIR (7.2.1.2, Land Converted to Forest Land (LF), page 7-18). However, an effort will be done in future submissions to ameliorate the explanations provided.
	Encouragement to provide a clear explanation of the assumptions underlying the estimates of carbon losses due to fires in its next annual inventory submission.	The assumptions used for estimating emissions from forest fires have been deeply revised for the 2010 submission. Several assumptions have been revised, including: combustion factors, % salvaged used in industry; % tree mortality caused by fires; average biomass values; consideration of annual variation of species	7.2.1.1.1.2.2 Annual carbon losses due to wildfires, page 7-5, and 7.2.1.1.2.2.2 WILDFIRES, page 7-15

CRF	Comment	Portugal's response	Where in NIR
		burnt. Explanations and descriptions of changes have been included in the NIR 2010.	
	Recommendation to revise its estimates of the amount of biomass consumed by wildfires in its next inventory submission.	Same as previous	Same as previous
	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 category		A description of the methods and assumptions currently used are included in the NIR (7.2.1.2, Land Converted to Forest Land (LF), page 7-18). However, an effort will be done in future submissions to ameliorate the explanations provided.
	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		No new developments were made concerning this issue.
Supplementary information required under Art. 7.1 of KP	Demonstration that carbon pools not accounted for are not sources of GHG emissions; information on factoring out removals from elevated concentrations of CO ₂ , from nitrogen 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.		Efforts will be made in future submissions to comply with the mandatory required information
Waste	Recommendation to make efforts to use country-specific parameters in the FOD model for its next annual inventory submission.	There are no national studies that enable the use of country-specific parameters. The development of these can represent significant economic resources not available at present.	
Sent to ERT in 19-10-2009 Mail: 1st centralized review 2009 - Portugal: Underestimates and completeness issues Doc: Completeness (NE) and underestimates email to PRT_20091019_excel 2003.doc			

CRF	Comment	Portugal's response	Where in NIR
Energy	Categories reported as "NE": CO ₂ , CH ₄ and N ₂ O emissions from other transportation (1.A.3.e) are reported as NO. Since Portugal is reporting fugitive emissions from transmission of natural gas and distribution of oil products, the ERT considers that emissions should be occurring under this category, for example emissions from compressor stations for natural gas transport	For characterizing fugitive emission from Natural Gas we use activity data from the Energy Balance (EB) reported under Losses in Transport and Distribution. This EB category already includes losses in compressor stations. The associated emissions are reported in 1B2. Accordingly, the notation key "NO" used for 1.A.3.e was wrong and was changed to "IE". This issue is addressed in 2010 Inventory.	Section 3.2.7.3 Fugitive Emissions from Natural Gas (CRF 1.B.2.b.)
Industrial Processes	Categories reported as "NE": Actual emissions of PFCs for refrigeration and air conditioning (2.F.1). Potential emissions for this category are reported, but notation key "NO" is used for actual emissions	The notation key used "NO" is wrong; it should be changed to "NE"	
4.B manure management - N ₂ O 4.D.1 Direct soil emissions - N ₂ O 4.D.3 Indirect emissions - N ₂ O	Possible underestimates of GHG: The N ₂ O emission from cattle and pigs in Portugal are partly based on national data collected by Laboratório Químico Agrícola Rebelo da Silva (LQARS) and partly based on expert information from LQARS. Dairy cows: For dairy cows is used a standard Nitrogen excretion rate (Nex) of 87.6 kg/dairy cow/yr for all years since 1990 regardless that the average milk yield in the same period growth from app. 4800 litres/dairy cow/yr to 6000 litres/dairy cow/yr. The need for increased feed to produce the increased milk production is well reflected in the calculation of energy intake for enteric fermentation but not in the calculation of nitrogen intake and a subsequently increase in Nex. The default Nex for Western European conditions in the 1996 Revised IPCC guidelines is 100 kg Nex/dairy cow/yr. During the review in 2008 as written in the ARR, Portugal was "encouraged to make efforts to generate country-specific values for the N excretion rate of dairy cattle for each year in the time series". In the 2009 submission for the year 2007 no changes have occurred in the estimation of Nex and no further references to scientific literature on how Nex has been estimated were included in the NIR. The ERT raised the same question to Portugal during the 2009 centralized review. The answer from Portugal was: "These questions are being revised by both the	These questions were addressed in this inventory submission. The Nex rates for all animal types were revised.	Section 6.3.4 N ₂ O Emissions from Manure Management (CRF 4.B.)

CRF	Comment	Portugal's response	Where in NIR
	<p>INERPA team and the GPP experts (from the Agriculture Ministry). We expect to arrive at a conclusion soon. Because of this, the recommendations presented in these paragraphs will only be included in the 2010 submission."</p> <p>Despite this the ERT considers this issue as a potential problem for underestimating the N₂O emission from manure management and a subsequently underestimation of N₂O emission from agricultural soils, both direct emissions and indirect emissions.</p>		
<p>4.B manure management - N₂O</p> <p>4.D.1 Direct soil emissions - N₂O</p> <p>4.D.3 Indirect emissions - N₂O</p>	<p>Possible underestimates of GHG:</p> <p>Pigs: For pigs Portugal used a country specific methodology where Nex is based on "Results of analysis of Manure Composition" made by LQARS, Table 6.23 in the NIR. The figures are used to estimate the average Nex from all pigs in Portugal to 7.99 kg N/head/yr in 1990 and to 7.89 kg N/head/yr in 2007. The default IPCC value is 20 kg N/head/yr. The figures in Table 6.23 are not followed by a thoroughly documentation. The ERT has requested a full documentation for the used values. Portugal has not been able to supply the ERT with the requested documentation. The Portuguese values for Nex, according to Table 6.23, are taken from fattening pigs. The ERT believes that this value for nitrogen content in the manure, total N of 0.49 % w/w, is more likely a value for the N content in liquid pig slurry after ammonia volatilisation in stables and storages, which can be very high and not a proper value for the nitrogen excretion</p>	<p>These questions were addressed in this inventory submission. The Nex rates for all animal types were revised.</p>	<p>Section 6.3.4 N₂O Emissions from Manure Management (CRF 4.B.)</p>
<p>Sent to ERT in 19-10-2009</p> <p>Mail: 1st centralized review 2009 - Portugal: Underestimates and completeness issues</p> <p>Doc: Energy_Additional Answers By DGEG_20090910.doc</p>			
<p>Energy</p>	<p>NIR page 3-75. In figure 3.46, total energy consumption in the extractive industry, a large jump in energy consumption is shown for 2007 but not explained in the NIR. Could you please check this figure and provide an explanation for the increase in 2007?</p>	<p>PT inventory team previous answer:</p> <p>We found a problem in the column label (the values are correct). From left to right should read: Year, LPG, Gasoline, Kerosene, Gas Oil, Residual Oil, Natural Gas, Lignite and Biodiesel. Fuel consumption data for the extractive industry was obtained solely from the Energy Balance (EB) publication. From what we know DGEG (EB</p>	<p>Section 3.2.2.2.1.2.15 Extractive Industry</p>

Recalculations and Improvements

CRF	Comment	Portugal's response	Where in NIR
		producer) uses data from fuel suppliers to derive fuel consumption values for all industrial sectors. It's difficult to explain the extractive industry fuel consumption behaviour because of this lack of facility level data. However we will contact DGEG for expert judgment on this matter. PT inventory team additional comments: After revising the EB data, DGEG found that a fuel supplier inadvertently mixed the fuel consumption data from different economic activity classes. DGEG assured that the 2007 energy balance has been corrected.	
Energy	NIR section 3.2.5.4.4 page 3-174 Geothermal production in 2007 has more than doubled. As written in the NIR, you indicated that you will contact the data provider (DGEG) for an explanation. The ERT would like to know if you have received any response yet?	PT inventory team previous answer: We have no new information to provide about this issue. However we will contact DGEG to try to obtain an answer. PT inventory team additional comments: DGEG explained that this increment results from the fact that the installed power capability in the Azores Islands has doubled from 2006 to 2007. Additional Comments: We received data directly from the Azores Autonomous Regions environmental authorities that confirms the DGEG values.	Section 3.2.7.4 Other Fugitive Emissions (Geothermal Electricity Production) (CRF 1.B.2.d.)
Energy	Reiterating question from S&A report about CRF 1B2b: The inter-annual changes of CH ₄ emissions from Transmission for 1997-2007 (ranging from -42.2% to 207.6%) have been identified as outliers. The trend is unstable and fluctuates. We have not received any response on this. When studying the time series, it seems that something might be wrong with the data, at least for 2004. - Could you please verify the data for this source? - What procedures do you use for QA/QC for this source?	PT inventory team previous answer We actually report together the categories Transmission and Distribution. The identified inter-annual changes result from the Transport/Distribution Losses reported in the Energy Balance. We will contact DGEG to obtain further clarification on this matter. PT inventory team additional comments DGEG doesn't see the 2000 value as a problem. As specified in the response given by DGEG to our inquiry, from 2000 to 2004 there was a great increase in the NG distribution infrastructure (domestic consumption almost tripled). This resulted in an increase in the distribution losses. This issue is addressed in 2010 Inventory.	Section 3.2.7.3 Fugitive Emissions from Natural Gas (CRF 1.B.2.b.)
Sent to ERT in 5-9-2009 Mail: 1st centralized review 2009 - ERT questions to Portugal: Energy and LULUCF			

CRF	Comment	Portugal's response	Where in NIR
LULUCF	<p>The uncertainties for areas of land converted to forest have been reported in the 2009 NIR as ranging from 12.5 to 20.4 %. However, considering the fact that a fixed annual rate of conversion to forest land (137,000 ha) has been assumed and that the spatial resolution of CLC data is relatively low (25 ha), it seems unlikely that estimates have such low uncertainties.</p> <p>Could the Party provide additional information on how the uncertainties were derived for areas of land converted to forest? The ERT would also appreciate any comments from Portugal on the planned improvements of the accuracy of these estimates.</p>	<p>The uncertainties presented in NIR table 7.28 page 7-43 were calculated from the combination of the common error from remote sensing methods, 12.5% according to GP-LULUCF, with the error of not considering areas below 5ha, which were determined from extrapolation of the probability of areas under this interval until the lower identification limit.</p> <p>The following figure that was taken from 2009 Portuguese Voluntary Submission on Artº.3.3 and 3.4 under the UNFCCC resumes the methodology/sources foreseen to account for activities under Artº. 3.3. and 3.4 in the 1st CP. These Land Use Maps (COS) are based on aerial images: Minimum mapping unit: 1 ha; minimum distance between lines: 20 m For details about the technical COS2007 specifications please see: http://www.igeo.pt/gdr/projectos/cos/ Portugal is performing a deep revision of the current CRF 5 estimates using these new cartographic products and on the basis of the ongoing studies under development by the SNIERPA/WG on 3.3_3.4 (e.g. forest simulators, C on soil). The thematic accuracy of COS2007 which is at present under production by IGP (Portuguese Geographic Institute) is expected to be $\geq 85\%$. The existing COS90 is envisaged to be further geometrically corrected. Specific studies are foreseen in order to estimate the uncertainties and sensitivity analyses of the estimates.</p>	
	Emissions from application of lime: Could Portugal indicate the reasons for not having reported this category?	Data are not yet available to estimate this source. Portugal intends to develop efforts to estimate CO2 emissions from this source in future submissions, and has included this issue in its MDP.	
Sent to ERT in 4-9-2009 Mail: First Centralized Review 2009 - Questions to Portugal: Agriculture Doc: AGRIC_v2_Prel ERT Questions_PRT_20090904_Word 2003.doc			

Recalculations and Improvements

CRF	Comment	Portugal's response	Where in NIR
Agriculture	When will an update of stable type and manure management distribution be available?	We expect to have stable values (acknowledged by all SNIERPA sectoral experts) in the next submission Additional Comments: Adding to the Nex revision, improvements were made to the percentage of manure management systems (MMS) attributed to each animal type.	Section 6.3.2 CH ₄ Emissions from Manure Management (CRF 4.B.)
	Mineral fertiliser The NIR states: "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 fertilisers". The Portuguese inventory is mainly based on data from INE. Why is there used an estimated for N in mineral fertiliser based on IAPI data for 2003 to 2007 as INE has annually published the consumption of "Azoto" in its annual statistical agricultural publication: Estatísticas Agrícolas (www.ine.pt) . The data from Statistics Portugal are higher than the used ones in the inventory. Which data are the most precise, which data will be used in future what is the explanation for this choice?	We acknowledge the need to improve the NIR concerning the descriptions of the procedures to gather activity data for this sector. Data from 1995-2003 was available from the study described in the NIR (INE – page 6-55). Fertilizer consumption was back-cast for the 1990-1994 time period using data from the INE study. Since 2002 data for the consumption of "Azoto" was available from the publication "Estatísticas Agrícolas" (also from INE). As this document is published every year, we adopted it as our main source of information for this sector (since 2002). In this way there are two sources both from INE: OECD/EUROSTAT study (1990-2001), "Estatísticas Agrícolas" (2002-2007). The difference between the values from the latest "Estatísticas Agrícolas" (2008) and the 2009 NIR, resulted from annual INE revisions for the values for the previous 2 years. The values used in the NIR 2009 were the following (from "Estatísticas Agrícolas" (2007)) According to INE's explanation received on 3rd Sept. 2009, data has been revised either because the figures were provisional (2006 and 2007) or because they have suffered a revision based on new information received from the enterprises. Accordingly the emissions estimates were revised for the 2010 submission to consider the most updated data (please see the following table from "Estatísticas Agrícolas 2008").	Section 6.3.5 Direct N ₂ O Emissions from Agricultural Soil (CRF 4.D.1.)
	FracR is in the CRF tables given to 0.71. This should be 0 as no crop residues are removed from the field according 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	The inventory team has no further comments to add concerning this issue. Additional Comments: No new developments were made concerning this issue.	

CRF	Comment	Portugal's response	Where in NIR
Sent to ERT in 4-9-2009 Mail: First Centralized Review 2009 - Questions to Portugal: Industrial Processes Doc: IP questions to PRT_20090904_Word 2003.doc			
Industrial Processes	The NIR states that there is currently not enough data on CaO and MgO contents to derive a country-specific EF. In light of the currently available data, does the default look reasonable?	This issue is still under development	
	The NIR states that the AD will be updated for the years 2001 - 2007. Do you plan to do this in the 2010 submission?	This question was addressed in the 2010 inventory submission.	Section 4.3.1.1 Cement Production (CRF 2.A.1.), page 4-4 onwards
	The 2001 - 2007 data is based on extrapolation, but the report states that the AD will be updated for these years. Do you plan to do this in the 2010 submission?	This question was addressed in the 2010 inventory submission.	Section 4.3.1.1 Cement Production (CRF 2.A.1.), page 4-4 onwards
	The NIR states that the AD will be updated for the years 2001 - 2007. Do you plan to do this in the 2010 submission?	This question was addressed in the 2010 inventory submission.	Section 4.3.1.1 Cement Production (CRF 2.A.1.), page 4-4 onwards
	The N ₂ O emission factor is based on monitoring data from one of the three production units. Did you evaluate the applicability of the EF to the other two plants?	Efforts are being made in order to obtain monitoring data for all units.	
	The NIR describes lack of activity data and subsequently the need to use surrogate methods, interpolation and extrapolation. The NIR also states that the main activities have been stopped. Do you think it is possible to improve data, given the closure of production?	Efforts are being made in order to improve the quality of emission estimates, in particular those related to electric arc furnaces.	
	The following "percentage change from previous year" are observed in the reported HFC data: 182.7% (2003), -34.7% (2006). Are these due to new production plant (2003) and calculation error (2006)?	This question was addressed in the 2010 inventory submission.	Section 4.3.5.12 Foam Blowing, page 4-62 onwards

CRF	Comment	Portugal's response	Where in NIR
	In table 2(II)s2, the amount of potential SF6 reported is about 28.9 million tonnes CO2-eq. for 2007. Similar magnitudes are reported for other years. This leads to a potential to actual emissions ratio of about three million. Are the potential SF6 emissions reported correctly?	This question was addressed in the 2010 inventory submission.	CRF Table 2(II)s2
Sent to ERT in 3-9-2009 Mail: 1st centralized review 2009 - ERT questions to Portugal: Energy Doc: ENERGY_2_3_questions_PRT_Energy v3 clean_20090904_word 2003.doc			
	Reiterating question from S&A report about CRF 1B2a: The inter-annual changes of CO2 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?	We did not receive any answers yet	
Sent to ERT in 2-9-2009 Mail: 1st centralized review - Preliminary ERT questions: Energy Doc: ENERGY_Prel_ERT questions_PRT_Energy_20090902.docx			

CRF	Comment	Portugal's response	Where in NIR
	It is not clear from the NIR how the migration from COPERT 3 to COPERT 4 will influence N ₂ O emissions from road transport. Could Portugal provide more explanations on this based on the preliminary results obtained?	<p>N₂O emissions calculated with COPERT IV are expected to be lower when comparing with results using COPERT III. This results from new emissions factors provided by COPERT IV which are more reliable than the ones from COPERT III.</p> <p>The preliminary results were obtained from the COPERT IV methodology. As stated in EMEP/CORINAIR Guidebook (2009 version), there were "several methodological revisions, including extended vehicle classification and pollutant coverage, emission factors and corrections for road gradient and vehicle load, etc, as well as new PM, N₂O, NH₃ emission information and new emission factors for passenger cars including hybrids, heavy-duty vehicles and two-wheel vehicles."</p> <p>Under COPERT III, N₂O emissions were "roughly estimated on the basis of literature review for all vehicle categories". The guidebooks states that N₂O data is "quite unreliable and need further confirmation by measurements".</p> <p>In 2007, N₂O emissions estimates using COPERT IV were about 66% lower when compared with estimated made with COPERT III. On the other hand NO_x emissions have increased about 28%.</p>	Table 3.95 – Road transportation emission factors (kg/GJ)
	Given that Portugal is migrating to COPERT 4 (currently under implementation) for estimating road transport related CO ₂ emissions and that under COPERT 3 it uses country-specific lower-heating values, could Portugal explain how it intends to use country specific carbon content for each fuel that corresponds to the country specific lower-heating value so as to improve the consistency of the inventory?	CO ₂ emissions should be calculated on an energy basis using country specific emissions factors expressed in kgCO ₂ /GJ. These emissions factors are provided by fuel type and are published in national legislation (Despacho nº 17313/2008).	Table 3.88 - CO ₂ emission factor (Source: DGEG, 2008)

Table 9.2 Overview of the responses to the UNFCCC review 2008

CRF	Comment	Portugal's response	Where in NIR
Energy	Emissions have been estimated and reported for practically all categories, except for N ₂ O from flaring.	This question should be addressed in the near future.	
	The ERT encourages Portugal to continue its efforts to incorporate plant-specific data into its inventory and recommends that Portugal continue to provide detailed explanations, in its next annual inventory submission, on how exactly these data have been incorporated, the resulting changes and its efforts to maintain time-series consistency	More plant specific data has been added to the inventory with every submission.	
	The CO ₂ implied emission factors (IEFs) for solid fuels for public electricity and heat production for 1990–2006 (ranging from 90.16 to 90.60 t/TJ) were found to be below the IPCC default range (94.6 to 106.7 t/TJ). The value of 90.16 t/TJ was kept constant for the period 1998–2006. During the centralized review, Portugal explained that 1997 was the year in which an old coal power plant was decommissioned in northern Portugal. The EFs used for this power plant differed from those applied to the other two plants, hence the variation in the IEF from 1990 to 1997. Since, for the remaining two coal power plants, the CO ₂ EFs used were the same (values validated with direct monitoring data), the CO ₂ IEFs remained constant between 1998 and 2006. The net calorific value (NCV) varied from plant to plant and within the period 1990–2006. Taking into account this information, the ERT considers that CO ₂ EFs cannot be constant. The ERT recommends that Portugal provide clear trend-related explanations and revise its estimates, if necessary, in its next annual inventory submission.	No new developments were made concerning this issue.	
	Emissions of CO ₂ and sulphur oxides may occur as a result of mining activity when burning of coal deposits occurs or when flaring is used to control air emissions or recover energy. Currently, Portugal reports the occurrence of coal burning on-site and flaring in its mines as unknown and hence emissions of these gases for this category are not included in	No new developments were made concerning this issue.	

CRF	Comment	Portugal's response	Where in NIR
	the inventory. The ERT recommends that Portugal make an effort to acquire the related AD in order to be able to include estimates of the corresponding emissions in its next annual inventory submission.		
Agriculture Manure management – CH ₄	<p>After the centralized review, Portugal provided information which confirmed that: (a) breeding cows for beef are mostly kept outdoors all year, as the winters are mild in Portugal; and (b) liquid systems refer to “Open pits below animal confinements” as noted in the NIR, that, according to the experts from the Ministry of Agriculture, refer typically to short retention time pits. For this reason an MCF of 0% was used in the estimates following the recommendation in the IPCC good practice guidance for “Pit storage below confinements < 1 month”. Nevertheless, the ERT believes that the period for which manure is stored (more or less than one month) has a major effect on the level of CH₄ emissions and recommends that Portugal document this assumption more thoroughly in the NIR of its next annual inventory submission. The distribution of animal waste management systems (AWMS) applied in the Portuguese inventory is based on expert judgement from the Ministry of Agriculture and is predominately a reflection of the situation in 1990. Portugal is aware, however, that the real shares of the different AWMS have changed since then. In the course of the centralized review, Portugal explained to the ERT that an extensive agricultural survey, beginning in 2009 and conducted by the INE, will enable it to monitor the actual situation and future developments. The ERT welcomes Portugal's intention to update this information and recommends that Portugal document the relevant results of this survey in detail in its future NIRs</p>	The MCF and the share of AWMS were revised in this inventory submission.	Section 6.3.2 CH ₄ Emissions from Manure Management (CRF 4.B.)

CRF	Comment	Portugal's response	Where in NIR
Waste Solid waste disposal on land – CH ₄	The amount of industrial solid waste disposed decreased sharply in 2000. During the centralized review, Portugal explained to the ERT that this was a result of the market demand for different types of waste, and of policies and measures implemented in the waste sector. The ERT recommends that Portugal 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.	
Waste Wastewater handling – CH ₄ and N ₂ O	The ERT recommends that Portugal make efforts to update the country-specific data used in its calculations and verify its assumptions on CH ₄ recovery in its next annual inventory submission.		
Waste Human sewage – N ₂ O	Emissions of N ₂ O 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	No new developments were made concerning this issue.	

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 which in summary show that:

- CO₂ emissions recalculations are primarily related to a thorough revision of several assumptions and parameters considered in CRF sector 5. These concern: changes in BEF for the above ground living biomass; revision of harvest to include roots; and recalculation of emissions from wildfires on the basis of new assumptions for share of salvaged in harvest quantities, revision of combustion factors, inclusion of roots in the estimates, and the consideration of annual variation of average biomass according to the forest species burnt.
- Changes in CO₂ emissions for categories 2A2 (Lime Production), 2B1 (Ammonia Production), 2B2 (Nitric Acid), 2B5 (Organic Chemical Industry) and 2D2 (Other Production) for the period 2001-2008 are related to the revision of AD time series from INE.
- Changes in F-Gases potential emissions values are due to a correction on a unit error.
- SF₆ emissions decrease due to changes in the classification of equipments. Some switchgears previously wrongly classified as “closed pressure equipments” are now classified as “sealed pressure equipments”:
- Changes in CO₂, CH₄ and N₂O emission from 1A1a and 1A2 are mainly due to the revision of the 2007 energy balance by DGEG and fuel consumption update for Tunes power plant;
- Changes in CO₂, CH₄ and N₂O emission from 1A2 result from: revision of the 2007 energy balance by DGEG, inclusion of new fuels in the Cement Industry, revision of LHV and fuel consumption values for several combustion equipments in Pulp and Paper Industrial sector and production data update for the Ceramic Industry;
- The differences in CH₄ reporter for sector 1B2b result from the revision of the 2007 energy balance by DGEG and the inclusion of Cushion Gas in the emissions estimates;
- For sector 1B2b CO₂ emissions were recalculated after new activity data was made available by the Azores Environmental authorities;
- Changes in CH₄ and N₂O emission from Manure Management result from the revision of the manure management system shares. Also for this source category the nitrogen excretion rates were revised which affect N₂O emissions. These two major changes also affect N₂O emission from Agricultural Soils (4D)
- For 4A, 4B and 4D livestock number concerning poultry and rabbits were revised. This affect both CH₄ and N₂O emissions.
- CO₂ emissions recalculations from solvent use are mainly related to the revision of AD time series from National Statistics which were made available during 2009. Emissions reported in 2009 were based in an AD projection. This update resulted in a decrease of CO₂ emissions from solvent use.
- Differences in the road transportation sector refer to the application of COPERT IV and revision of the carbon content used to estimate CO₂ emissions. CO₂ emissions

were calculated on an energy basis using country specific emissions factors expressed in kgCO₂/GJ. These emissions factors are provided by fuel type and are published in national legislation (Despacho nº 17313/2008); Activity data was also updated with information from vehicle inspection centres;

- N₂O emissions from road transportation sector were recalculated by using COPERT IV emission factors. Emissions have decreased since N₂O emissions factor from COPERT IV are lower than the emission factors from COPERT III.

Table 9.3 – Recalculation difference for CO₂ emissions (values in kt CO₂eq.)

CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total National Emissions and Removals		2,835	4,244	1,891	1,645	1,292	4,040	2,512	1,789	3,707	2,687	4,433	2,197	2,469	-623	-153	3,783	-1,230	-1,590
1. Energy		-7	-14	-19	-24	-18	-12	-7	12	41	56	88	110	67	0	-55	-132	159	261
1.A.	Fuel Combustion Activities	-7	-14	-19	-24	-18	-12	-7	12	41	56	88	110	67	0	-55	-41	237	343
1.A.1.	Energy Industries	0	0	0	0	0	0	0	0	0	0	0	-2	-39	-111	-173	-174	-66	-118
1.A.2.	Manufacturing Industries and Construction	-5	-4	-1	-3	-2	-2	-3	-3	-3	-2	-2	-2	-3	-5	-9	-4	-6	-91
1.A.3.	Transport	-3	-10	-17	-21	-15	-10	-4	16	43	58	90	114	110	117	127	137	309	457
1.A.4.	Other Sectors	0	0	0	0				0	0	0	0	0	0	0	0		0	94
1.A.5.	Other	0	0	0	0														
1.B.	Fugitive Emissions from Fuels		0	0	0	0	0	0	0	0	0		0	0	-1	0	-91	-78	-82
1.B.1.	Solid fuel	0																	
1.B.2.	Oil and Natural Gas	0	0	0	0	0	0	0	0	0	0		0	0	-1	0	-91	-78	-82
2. Industrial Processes		0	0	0	-1	-83	-157	-118	-198	-260	-95	-111	-740	-897	-834	-925	-1,161	-1,486	-1,418
2.A.	Mineral Products	0	0	0	0	0	0	0	0	0	0	0	22	2	-30	-24	-64	-60	-94
2.B.	Chemical Industry	0	0	0	-1	-83	-157	-118	-198	-260	-95	-111	-762	-898	-804	-901	-1,097	-1,426	-1,324
2.C.	Metal Production	0		0	0	0		0	0	0		0	0						0
2.D.	Other Production																		
2.G.	Other																		
3. Solvent and Other Product Use		14	6	-7	-15	-26	-36	-38	-40	-38	-36	-37	-49	-58	-73	-88	-100	-104	-111
4. Agriculture																			
4.A.	Enteric Fermentation																		
4.B.	Manure Management																		
4.C.	Rice Cultivation																		
4.D.	Agricultural Soils (2)																		
4.E.	Prescribed Burning of Savannas																		
4.F.	Field Burning of Agricultural Res.																		
4.G.	Other																		
5. Land Use, Land-Use Change and Forestry (net)		2,829	4,253	1,917	1,686	1,419	4,245	2,675	2,014	3,964	2,761	4,493	2,876	3,356	285	915	5,176	200	-322
5.A.	Forest Land	2,829	4,253	1,917	1,686	1,419	4,245	2,675	2,014	3,964	2,761	4,493	2,876	3,356	285	915	5,176	200	-322
5.B.	Cropland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Recalculations and Improvements

CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
5.C.	Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.D.	Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.E.	Settlements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.F.	Other Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.G.	Other																		
6. Waste																			
6.A.	Solid Waste Disposal on Land																		
6.B.	Wastewater Handling																		
6.C.	Waste Incineration																		
6.D.	Other																		
Memo Items:																			
International Bunkers		-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	1	2	2
Multilateral Operations																			
CO2 Emissions from Biomass		0	0	0	0	0	0	0	0	0	0	0	-14	-26	-16	-28	6	-17	-7

Table 9.4 – Recalculation difference for CH₄ emissions (values in kt CO₂e)

CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total National Emissions and Removals		138	162	91	67	41	119	60	42	103	78	144	118	148	320	133	-267	-450	-395
1. Energy		26	27	29	11	0	-7	-13	-9	-5	-2	-1	-3	-5	-5	-6	-699	-592	-501
1.A.	Fuel Combustion Activities	26	27	29	11	0	-7	-13	-9	-5	-2	-1	-3	-5	-5	-6	-4	-4	-6
1.A.1.	Energy Industries	0		0	0	0	0	0		0		0	0	0	0	0	0	0	0
1.A.2.	Manufacturing Industries and Construction	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	-1	-1	-2
1.A.3.	Transport	26	27	29	11	0	-7	-13	-9	-5	-2	-1	-3	-4	-5	-5	-3	-3	-4
1.A.4.	Other Sectors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.5.	Other	0		0		0													
1.B.	Fugitive Emissions from Fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-694	-588	-495
1.B.1.	Solid fuel	0																	
1.B.2.	Oil and Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-694	-588	-495
2. Industrial Processes					0	0		0			0		0	-1	0	0	0	-1	-2
2.A.	Mineral Products																		0
2.B.	Chemical Industry				0								0	-1	0	0	0	-1	-2
2.C.	Metal Production																		
2.D.	Other Production																		
2.G.	Other																		
3. Solvent and Other Product Use																			
4. Agriculture		21	25	29	30	33	35	38	39	45	51	58	62	70	73	80	81	87	85
4.A.	Enteric Fermentation	15	14	13	11	8	6	3	2	0	-1	-2	-2	-3	-3	-4	-6	-7	-8
4.B.	Manure Management	6	11	16	19	25	29	35	37	45	52	60	64	73	76	85	86	94	94
4.C.	Rice Cultivation															0			-1
4.D.	Agricultural Soils (2)																		
4.E.	Prescribed Burning of Savannas																		
4.F.	Field Burning of Agricultural Res.	0	0	0	0	0	0	0	0		0	0		0	0				0
4.G.	Other																		
5. Land Use, Land-Use Change and Forestry (net)		91	109	33	26	8	92	35	13	63	29	78	40	62	225	30	328	20	6
5.A.	Forest Land	91	109	33	26	8	92	35	13	63	29	78	40	62	225	30	328	20	6
5.B.	Cropland																		

Recalculations and Improvements

CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
5.C.	Grassland																		
5.D.	Wetlands																		
5.E.	Settlements																		
5.F.	Other Land																		
5.G.	Other																		
6. Waste		0	0	0	0	0		0	0	0	0	9	19	23	27	29	23	37	17
6.A.	Solid Waste Disposal on Land	0	0		0	0	0	0	0	0	0	10	17	16	16	16	12	15	13
6.B.	Wastewater Handling	0	0	0	0	0	0	0	0	0	0	-1	2	7	11	13	11	23	4
6.C.	Waste Incineration	0	0	0	0	0	0	0	0	0			0			0	0	0	0
6.D.	Other																		
Memo Items:																			
International Bunkers		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Multilateral Operations																			
CO2 Emissions from Biomass																			

Table 9.5 – Recalculation difference for N₂O emissions (values in kt CO₂eq.)

CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total National Emissions and Removals		-22	-57	-65	-132	-144	-170	-198	-232	-361	-363	-407	-586	-651	-658	-609	-583	-683	-296
1. Energy		-59	-59	-64	-62	-82	-97	-110	-145	-192	-230	-275	-296	-328	-341	-346	-354	-365	-361
1.A.	Fuel Combustion Activities	-59	-59	-64	-62	-82	-97	-110	-145	-192	-230	-275	-296	-328	-341	-346	-354	-365	-361
1.A.1.	Energy Industries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.2.	Manufacturing Industries and Construction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1.A.3.	Transport	-59	-59	-64	-62	-82	-97	-110	-145	-192	-229	-275	-296	-328	-341	-345	-354	-366	-367
1.A.4.	Other Sectors	0		0	0	0	0		0	0			0	0	0	0	0	0	4
1.A.5.	Other	0	0	0		0													
1.B.	Fugitive Emissions from Fuels																		
1.B.1.	Solid fuel																		
1.B.2.	Oil and Natural Gas																		
2. Industrial Processes					0		0	0		0	0	0	-156	-185	-167	-121	-164	-179	-176
2.A.	Mineral Products																		
2.B.	Chemical Industry				0		0	0		0	0	0	-156	-185	-167	-121	-164	-179	-176
2.C.	Metal Production																		
2.D.	Other Production																		
2.G.	Other																		
3. Solvent and Other Product Use																			
4. Agriculture		-72	-89	-108	-151	-164	-180	-195	-206	-218	-175	-179	-176	-173	-183	-198	-159	-160	222
4.A.	Enteric Fermentation																		
4.B.	Manure Management	-56	-68	-80	-102	-117	-134	-150	-162	-175	-169	-177	-179	-183	-189	-200	-208	-222	-233
4.C.	Rice Cultivation																		
4.D.	Agricultural Soils (2)	-16	-21	-28	-49	-47	-46	-45	-44	-42	-7	-3	3	11	5	2	49	62	455
4.E.	Prescribed Burning of Savannas																		
4.F.	Field Burning of Agricultural Res.				0				0		0				0	0		0	0
4.G.	Other																		
5. Land Use, Land-Use Change and Forestry (net)		9	11	3	3	1	9	4	1	6	3	8	4	6	23	3	33	2	1
5.A.	Forest Land	9	11	3	3	1	9	4	1	6	3	8	4	6	23	3	33	2	1
5.B.	Cropland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Recalculations and Improvements

CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
5.C.	Grassland																		
5.D.	Wetlands																		
5.E.	Settlements																		
5.F.	Other Land																		
5.G.	Other																		
6. Waste		0	0	0	0	0	-4	-4	-4	-6	-11	-13	-14	-15	-22	-14	-12	-15	-15
6.A.	Solid Waste Disposal on Land																		
6.B.	Wastewater Handling	0	0	0	0	0	-4	-4	-4	-6	-11	-13	-14	-15	-22	-14	-12	-15	-15
6.C.	Waste Incineration	0	0	0	0	0		0		0			0			0		0	0
6.D.	Other																		
Memo Items:																			
International Bunkers		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Multilateral Operations																			
CO2 Emissions from Biomass																			

Table 9.6 - Recalculation difference for F-gases emissions (values in kt CO₂eq.)

CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total National Emissions						0	0	0	0
Total Actual Emissions						0	0	0	0
HFCs									
PFCs						0	0	0	0
SF6						-15496455	-16034756	-16618249	-17172944
Potential Emissions from Consumption						-38	-25	-4	-261
HFCs									
PFCs						-15496417	-16034730	-16618244	-17172682
SF6						0	0	0	0

CATEGORIES	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total National Emissions	0	0	0	0	0	0	-2	20	-4
Total Actual Emissions	0	0	0	0	1	0	-1	21	-3
HFCs									
PFCs	0	0	0	0	0	0	0	0	0
SF6	-20676729	-21418405	-21913641	-22908164	-23948340	-24803095	-25804034	-28091983	-28936295
Potential Emissions from Consumption	-304	-152	-76	-76	-51	-34	-20	-12	-15
HFCs				0				0	
PFCs	-20676426	-21418253	-21913565	-22908088	-23948289	-24803062	-25804014	-28091971	-28936279
SF6	0	0	0	0	0	0	-2	20	-4

Figure 9.1 Recalculation of total CO₂, CH₄ and N₂O emission (LULUCF excl.)

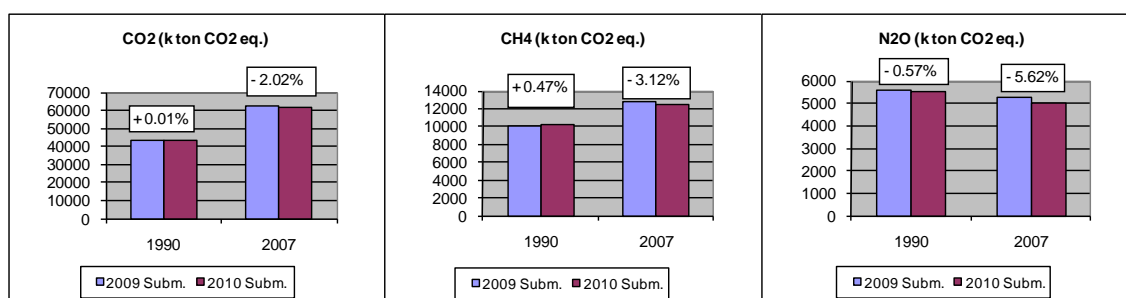


Table 9.7 – Recalculation of total CO₂, CH₄ and N₂O emission (LULUCF excl.)

Year	CO ₂			CH ₄			N ₂ O		
	2009 Subm.	2010 Subm.	Difference (%)	2009 Subm.	2010 Subm.	Difference (%)	2009 Subm.	2010 Subm.	Difference (%)
	(kt CO ₂ e)			(kt CO ₂ e)			(kt CO ₂ e)		
1990	43,583	43,590	0.01	10,120	10,168	0.47	5,565	5,534	-0.57
1991	45,320	45,311	-0.02	10,392	10,445	0.51	5,584	5,516	-1.23
1992	49,437	49,412	-0.05	10,515	10,572	0.55	5,573	5,504	-1.23
1993	48,040	47,999	-0.09	10,530	10,571	0.39	5,473	5,338	-2.46
1994	49,228	49,102	-0.26	11,009	11,042	0.30	5,738	5,593	-2.53
1995	53,202	52,998	-0.39	11,254	11,282	0.24	5,816	5,637	-3.08
1996	50,322	50,159	-0.32	11,368	11,393	0.22	6,127	5,925	-3.30
1997	53,615	53,390	-0.42	11,566	11,596	0.25	6,133	5,900	-3.80
1998	58,320	58,063	-0.44	12,014	12,054	0.33	5,879	5,512	-6.24
1999	64,945	64,870	-0.11	12,239	12,288	0.40	6,305	5,939	-5.81
2000	63,751	63,691	-0.09	11,364	11,430	0.58	6,279	5,865	-6.60
2001	65,080	64,402	-1.04	12,169	12,248	0.64	6,300	5,710	-9.37
2002	69,283	68,396	-1.28	12,601	12,688	0.69	6,377	5,719	-10.31
2003	64,626	63,718	-1.40	12,723	12,818	0.75	5,799	5,118	-11.75
2004	66,969	65,901	-1.60	12,591	12,694	0.82	5,973	5,361	-10.25
2005	69,678	68,285	-2.00	13,007	12,411	-4.58	5,739	5,123	-10.73
2006	65,228	63,798	-2.19	13,057	12,588	-3.60	5,541	4,856	-12.36
2007	62,793	61,524	-2.02	12,815	12,415	-3.12	5,278	4,981	-5.62

9.3 Implications in emissions trends

A very slighter difference upwards in the base year (1990: +0.04%) as compared with the reduction in 2007: -2.4%, resulted in a decrease of the growing trend from 38.1% (2009 submission without LULUCF) to 34.7% (2010 submission without LULUCF) .

Figure 9.2 – Recalculation of total emission levels (LULUCF excl.)

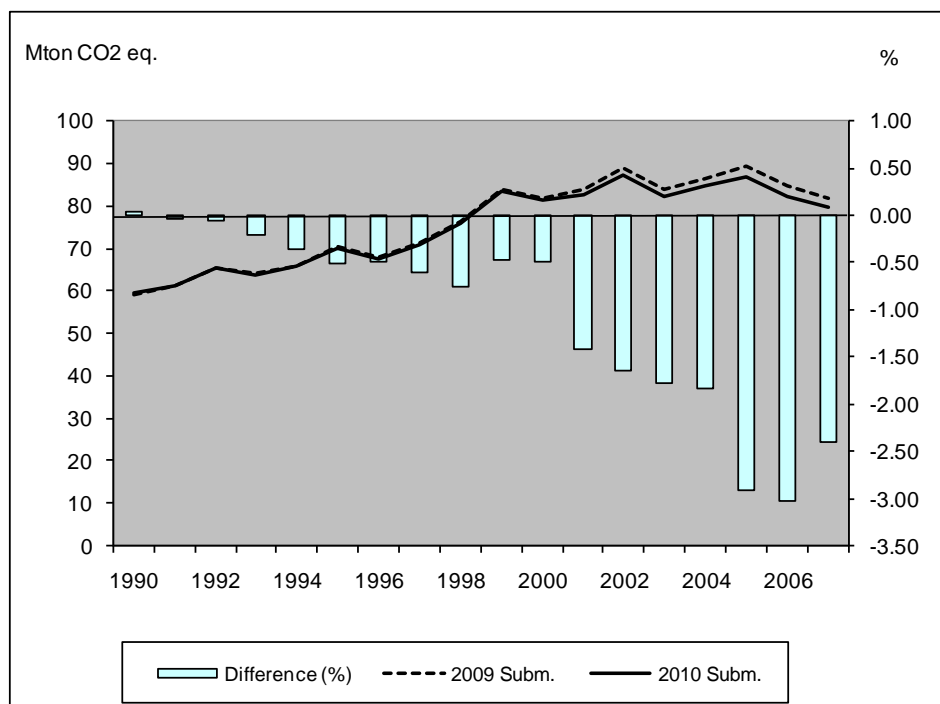


Table 9.8 – Recalculation of total emissions trends (LULUCFs excl.)

Year	2009 Submission (kt CO ₂ e)	2010 Submission (kt CO ₂ e)	Difference (%)
1990	59269	59292	0.04
1991	61296	61272	0.0
1992	65525	65489	-0.1
1993	64043	63908	-0.2
1994	65975	65737	-0.4
1995	70334	69977	-0.5
1996	67899	67559	-0.5
1997	71433	71004	-0.6
1998	76377	75793	-0.8
1999	83716	83324	-0.5
2000	81710	81301	-0.5
2001	83959	82769	-1.4
2002	88776	87318	-1.6
2003	83774	82281	-1.8
2004	86237	84660	-1.8
2005	89229	86622	-2.9
2006	84694	82129	-3.0
2007	81841	79872	-2.4

If the LULUCF sector is considered, the comparison of 2010 GHG emissions with the previous 2009 submission, indicates a difference in the overall trend from 30.8% to 21.1%.

9.4 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, under an

external consultancy with Ecoprogresso and InventAr, 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

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10.1 Summary

This report results from the work of the Working Group settled in the framework of the Portuguese National Inventory System (SNIERPA) with the aim of defining a methodological approach to tackle the reporting needs of article 3, paragraphs 3 and 4 of the Kyoto Protocol (WG 3.3&3.4).

The entities involved, in the context of the Portuguese National System (SNIERPA), in this process have agreed that the following methods are the appropriate for the fulfillment of the additional information reporting obligations under Article 7.1 of the Kyoto Protocol dictated by the Article 3.3 (Afforestation, Reforestation and Deforestation – ARD) and Article 3.4 (Forest Management – FM, Cropland Management – CM and Grassland Management – GM), considering the existing information and the cost/benefit ratio in terms of Kyoto's obligations fulfillment. The methodology defined to identify the areas and account for the emission/removals during the first commitment period is different for ARF and FM and the remaining GM and CM activities and encompasses.

ARD and FM

- In Portugal the 1990 Land Use Map (COS'90), based on aerophoto obtained in August 1990, is available with 1 ha resolution; this cartography was corrected for some errors and used to determine land use/cover in that year;
- Portugal is producing COS2007, based on aerophoto from 2007, which will be used to assess the forest area in the beginning of the first commitment period (2008) and to identify the afforested/reforested and deforested areas between 1990 and the beginning of the commitment period; the later areas will be classified within the scope of Article 3.3163.
- Considering the need to warrant that the time period is appropriate to gather, interpret and handle the base data (aerial photography), to minimize costs and to guarantee the consistency with the National Forestry Inventory (NFI), the collection of land use/cover data during the commitment period must be anticipated. Therefore, a new COS will be produced with reference to 2010 or 2011, which will allow the results to be available in 2013. The comparison of COS2010/2011 with COS2007 will permit the determination of the land use changes occurred in the commitment period.
- AFN's cartography on forest fires which is annually produced through satellite images will be used to identify the burnt areas during the commitment period.
- The treefellings assessment can be done using data from NFI 2005, through growth models and subsequent NFIs or, eventually and if necessary, using data from an IGP

¹⁶³ . In the case that COS2007 is not available in a timely manner (end of 2009), the data to be used to report 2008 will be the photo-points from NFI, referring to 2005

project also based on satellite imagery; in the later case the methodology still has to be developed.

- Biomass in forest areas and annual increments will be assessed in detail using regional simulators that use the NFI 2005 data, subsequent exercises to predict its evolution, and biomass models per species. Simulators are being developed by the Technical University of Lisbon/Agronomic Institute for the AFN.

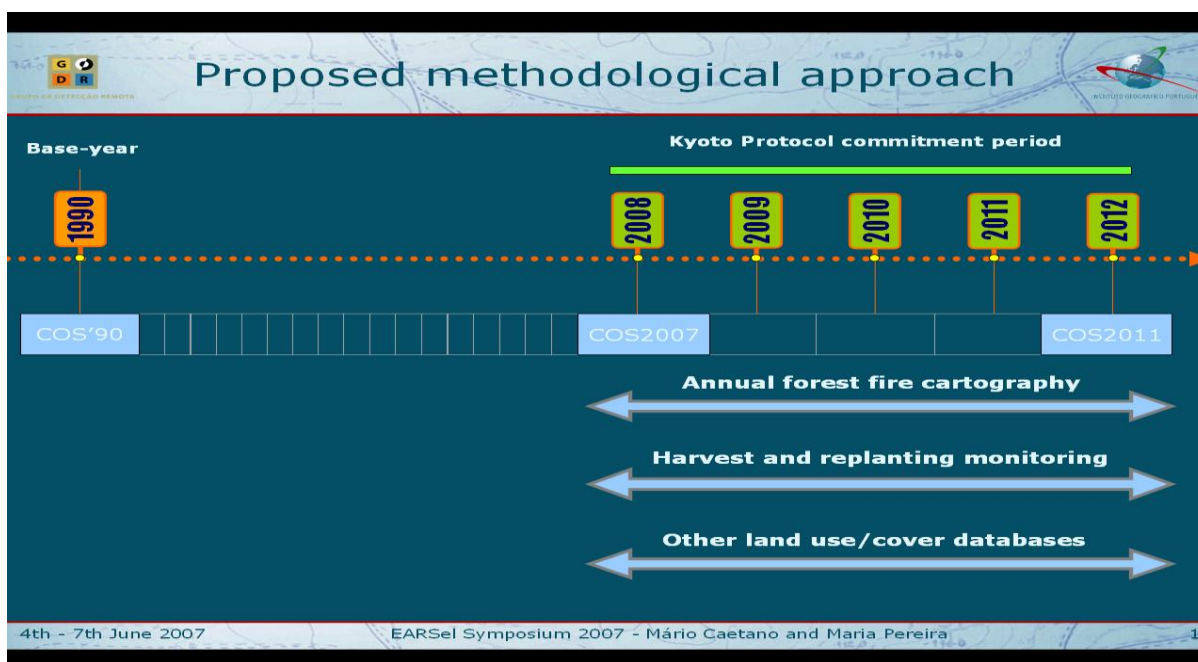
CM and GM

The assessment of carbon change covers all cropland and grazing land areas in Portugal, but using differentiated methodological detail.

- Areas with specific cropland management or grassland management practices (no-tillage or sown biodiverse pastures rich in legumes)
 - The identification of the areas with CM or GM, activities that are expected to improve carbon storage significantly, will use the data base from the IFAP the paying agency for CAP. These areas are georeferenced;
 - The determination of the changes on land use and practices in these areas will be done with the information from IFAP and COS90;
 - The soil carbon sequestration of both management practices is determined using results of scientific studies published in the literature, using a country-specific Tier 2 approach.
- Other cropland or grassland areas hereafter referred as “without such specific management practices” areas
 - These areas will be identified using COS (1990, 2007 and in subsequent year during the first commitment period). The cropland and grassland areas with specific management activities (based on IFAP’s database) will be subtracted from the national total identified on COS, to avoid double-counting;

The soil carbon content will be determined by a model which is being developed, which indicates that carbon is either stationary or increasing in managed areas.

Figure 10.1 - Cartographic products and additional information for the identification of areas to be used in future submissions



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

- APA – Portuguese Agency for the Environment (<http://www.apambiente.pt>)
- MADRP - Ministry of Agriculture/ Ministério da Agricultura, do Desenvolvimento Rural e das Pescas
 - GPP – Gabinete de Planeamento e Políticas (<http://www.gpp.pt>)
 - AFN - Forestry National Authority/ Autoridade Florestal Nacional/MADRP (<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/ School of Engineering of the Technical University of Lisbon (<http://www.ist.utl.pt>)
- UE – Universidade de Évora

- Ecoprogresso (<http://www.ecoprogresso.pt>)
- InventAr (<http://www.inventar-environment.com>).

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.

10.2 General information

10.2.1 Definition of forest and any other criteria

Portugal adopted a forest definition according to the following parameters:

- Minimum tree cover: 10%
- Minimum land area: 1.0 ha
- Minimum tree height: 5 m
- Minimum width: 20 m.

The parameters chosen for the definition of forest are within the agreed values in decision 16/CMP.1. Portugal states 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.

10.2.2 Elected activities under Article 3.4

Portugal accounts for Article 3.3 activities (mandatory) – ARD, and has elected the following Article 3.4 activities –FM, CM and GM (FCCC/IRR/2007/PRT).

10.2.3 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 activities of ARD and FM were applied consistently over time. The areas of AD were obtained from overlaying COS90 with NFI 2005/2006. The following strata were considered as “Forest”:

- in the COS90: all the combinations of B* (cork oak), Z* (holm oak), N* (sweet chestnut), T* (wild chestnut), Q* (oak sps), E* (eucalypt), F* (other broadleaved), P* (maritime pine), M* (umbrella pine) and R* (other conifers sps) and degree of cover higher than 10%;
- in the photo-points of the NFI2005/2006: all the photo-points associated to land use code “1. Forest stands”.

To estimate the areas associated to ARD and FM, the proportion of the photo-points associated to each category to the total number of photo-points in forest land was calculated and multiplied by the total forest area of Portugal mainland.

All the areas that were classified as Forest before 1 January 1990 and remained as Forest were classified as FM.

On the other hand, GM and CM included the areas affected with sown biodiverse permanent pastures rich in legumes (SBPPRL) and those under no-tillage (with or without mulching), respectively.

These approaches were applied during all the time series – 1990-2008.

10.2.4 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

In accordance with the previously established, in cases of coexistence of agriculture and forestry practices, for reasons of methodological approach, GM and CM should have precedence on FM. Therefore, the agro-forestry system *Montado*, predominant in the Southern Portugal, would be classified either as Cropland or Grassland, according to the agriculture practice.

This has three main justifications:

- agriculture activities (either crops or pastures) are developed under the canopy of trees, usually with a very low tree cover (up to 20%);
- the tree system is, in most cases, almost at equilibrium with a very low rate of carbon sequestration (Dominant Mature trees);
- carbon stock changes are mainly determinate from agricultural practices in under-cover.

However, in this submission, *Montado* is classified as Forest and, therefore, included in activities such as ARD or FM. This is based on the NFI definition of Forest, which includes *Montado*. On future submissions this inconsistency will be solved.

10.3 Land related information

IGP is the authority that has the major role in the production and analysis of geographical information in the scope of the WG3.3&3.4. The role of IGP in the reporting process is related essentially with land use and land-use change area estimation for use in further calculations by other entities, in view of obtaining the estimates of CO₂ and other Greenhouse Gases (GHG) emissions and/or removals. Other land related information is also provided by AFN, and IFAP, namely the NFI and the burnt areas cartography and the areas subjected to specific CM and GM activities, respectively

10.3.1 Future submissions

In order to fulfill the country's reporting obligations in what refers to land cover/use data, the WG 3.3&3.4 has decided to consider all data sources available to assess its applicability and utility to identify the national areas classified as Article 3.3 or 3.4 activities. In a cost-benefit perspective the group has decided:

- COS'90
 - determine forest and “non-managed” areas in 1990
- COS2007
 - determine forest and “non-managed” areas at the beginning of the commitment period

- identification of forested, deforested and “non-managed” areas since 1990
- COS2010/2011
 - identification of forested, deforested and “non-managed” areas since the beginning of the commitment period
 - determine changes in forest management areas in terms of surface and forest species during the commitment period
- Additional Information
 - Annual detection of fires, clear-cut and new plantations: Biomass at Deforestation, Harvesting and Fires: Stocks, age from National Forest Inventory (NFI) (Plots)
 - Biomass increment: Growth rates: NFI and Forest simulators (ISA)
 - New forest plantations (FEADER)
 - rural development incentives DB (units of land monitored annually; 5 years).

Art. 3.4 CM and GM activities will be assessed using a two tier methodology:

- Georeferenced DB on agro-environmental incentives under FEADER and on other CAP support schemes (obtained from IFAP – Portuguese CAP payment agency) - Level Detail A - for Specific C Management Activities (No tillage; Sown biodiverse permanent pastures rich in legumes (SBPPRL)
 - Annual identification of land units
 - Land units continually tracked
 - Identification of the beginning of the activity
- COS - Level Detail B – “Non-Managed” Areas (Remaining Agriculture and Grassland areas - soil carbon is in equilibrium)
 - Detection of change in land use according to the following types:
 - annual crop land irrigated/non-irrigated
 - perennial crop land
 - permanent pasture.

It should be mentioned that the technical specifications of COS2007 (Caetano *et al.*, 2007) like the Minimum Cartographic Unit (MCU), Minimum Distance Between Lines (MDBL), and nomenclature, were approved by the cartography's Advisory Committee, which included representatives from SNIERPA, in order to ensure that the cartography would match Portugal's reporting requisites under the UNFCCC and the KP.

In the case of CM and GM, for methodological reasons, the WG 3.3&3.4 has decided to identify separately the management practices with high potential for soil carbon sequestration, which constitute potential CO₂ sinks. In Portugal those practices (hereafter designated specific management practices) receive funding through the EU agro-environmental measures, under certain conditions, and correspond to no-tillage practice in CM and to biodiverse pastures in GM and are reported by IFAP, on the basis of applications to the support schemes, made by the farmers.

The characteristics of both COS'90 and COS2007 are those described in table below.

Table 10.1 - Main technical specifications of COS'90 and COS2007 (both covering Continental Portugal)

	COS2005/2007	COS90
Base images	Digital aerial ortho-images	False colour aerial photos
Reference year	2004/2005 or 2007	1990
Format	Polygon	Polygon
MCU (ha)	1	1
MDBL (m)	20	40
Nomenclature	Type: <i>A priori</i> and hierarchical (five levels)	Type: <i>A posteriori</i> and non-hierarchical
Accuracy	Thematic: ≥ 85 % Geometric: ≥ 5,5 m	Not determined at the time of production

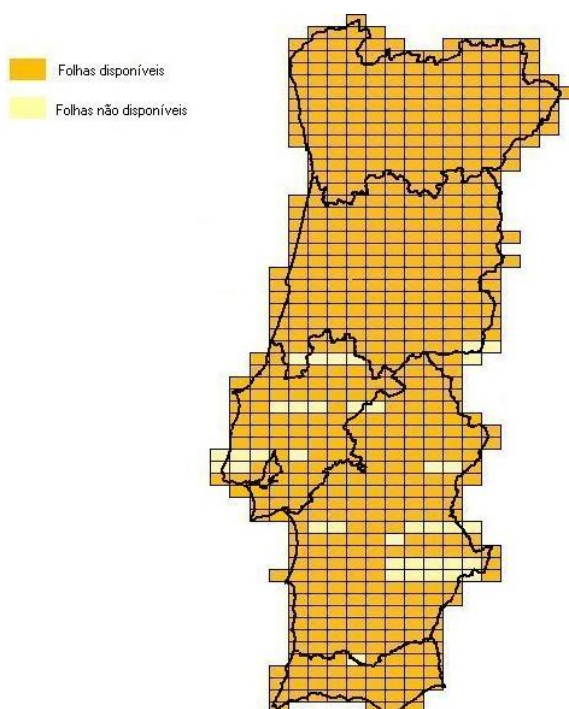
10.3.2 Current submission

10.3.2.1 COS'90 and NFI

To determine the areas affected to Afforestation, Reforestation and Forest Management, This report used data from the three last National Forest Inventories in Portugal: NFI 1990/1992, NFI 1995/1997 and NFI 2005/2006.

NFI 1990/1992 produced the Land Use Cartography of Portugal mainland for 1990, designated as COS90 (Caetano, 2008; IGEO web site, 2009). COS90 was based on aerial photography that used false colour infrared film captured in July-August 1990. Aerial photography was photo-interpreted by strata delimitation – classification included land use and, for forest land, the main and secondary tree species (see Caetano 2008 for details) – resulting in 1:25000 land use cartography with 638 units/maps that do not cover all the country as some of the units/maps are not available (Figure 10.2). This cartography was used as the basis for the identification of land converted to forest (Kyoto act. 3.3 – afforestation) and of areas that were converted from forest land to other uses (Kyoto act. 3.3 – deforestation). No field work from this NFI was used here.

Figure 10.2 - Land Use Cartography of Portugal Mainland (IGEO, 2002).



Data from the two last Portuguese NFIs (1995/1997 and 2005/2006), were the basis for the estimation of carbon stock changes.

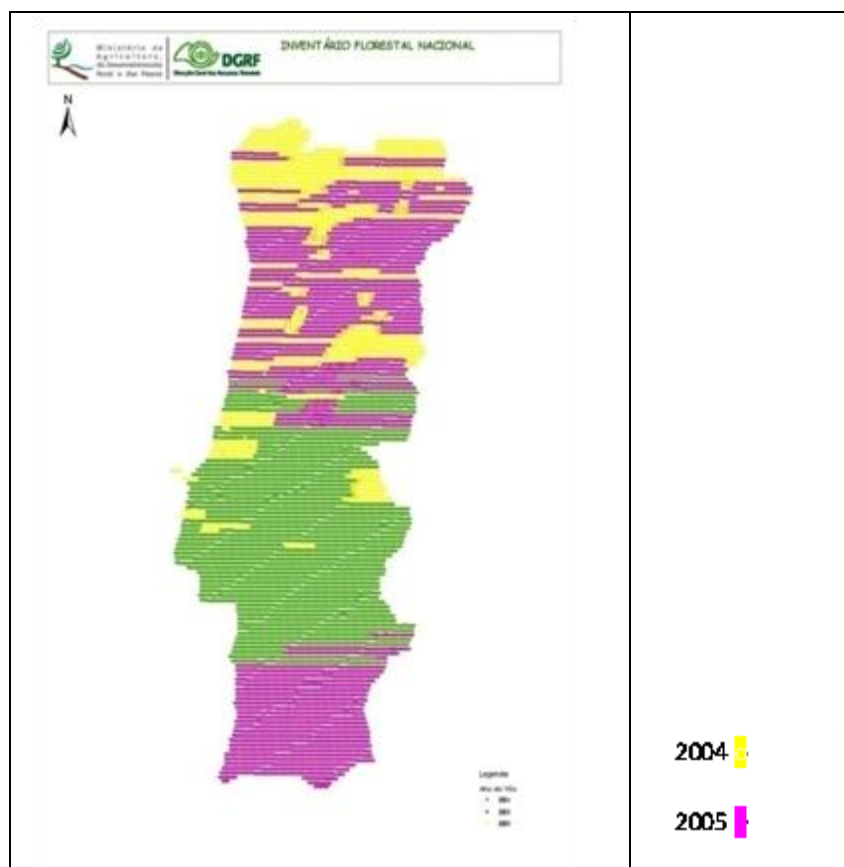
NFI 1995/1997 was based on aerial photography captured in 1995 after summer and field work undertaken between July 1997 and April 1998, most of it in 1998. Based on the images obtained, digital ortophotos were produced and used as a basis for the photo-interpretation work. The areas, estimated by qualitative sampling, are assumed to characterize the country forest resources at the end of 1995. The field work is assumed to characterize the forest stands at the end of 1997. In order to match the forest areas and the field work, the areas were updated to the end of 1997 by adding to the 1995 area twice the average annual planting rate and decreasing twice the average annual deforestation rate (see below how these rates were estimated).

NFI 2005/2006 was based on aerial photography taken in three periods, the first in 2004, and the other two in 2005 and 2006 (Figure 10.3). Field measurements took place between December 2005 and December 2006, most of the measurements taking place before the end of June 2006. The forest areas estimated in this inventory, again by qualitative sampling, are assumed to represent forest resources at the end of 2005 while the field work is reported to the end of 2006. The match between the two data sources was achieved by updating forest areas one year as had been done for the NFI 1995/1997.

The two forest inventories had different characteristics and intensities. Forest areas obtained in the NFI 1995/1997 were based on the photo interpretation of 136836 points and subsequent area estimation by qualitative sampling while the NFI 2005/2006 was based on the photo interpretation of 355737 points (grid with distance between points equal to 500 m). Photo-points were identified and characterized according to land use and, in forest land, for the main and secondary tree species and crown cover (see DGRF, 2006 for details on the strata). Area estimations were also based on qualitative sampling.

During field work 2211 and 6897 field plots were measured in each one of the inventories. The plots measured in the two inventories were independent and of a different type. In the NFI 1995/1997 a combined plot (250, 500 and 1000 m² for 7,5≤d<17,5 cm, 17,5≤d<27,5 cm and d≥27,5 cm, respectively) was used (except for evergreen oaks in which a fixed area plot of 2000 m² was used) while the NFI 2005/2006 used fixed area plots of 500 m² (except for evergreen oaks where the plot area was 2000 m²).

Figure 10.3 - Years of the flights to obtain images used in the National Forest Inventory 2005/2006.



10.3.2.2 *Databases of areas with specific management practices – CM and GM*

The Institute for Funding of Agriculture and Fisheries (IFAP) supplied to IGP the data on the specific management areas of the year 2008, in the form of two databases, one for no-tillage and one for biodiverse pastures. The agri-environmental measures that funded these specific practices and the components of each database are presented in Table 10.2 and Table 10.3. In total, the no-tillage database had 2454 records and the biodiverse pasture database had 2559 records. The no-tillage and biodiverse pasture databases are built upon information that is declared by the farmers and afterwards is subject to different types and levels of quality control. The spatial distribution of the IFAP data is shown in Figure 10.4.

Table 10.2 - Agri-environmental measures that funded the no-tillage practice in Continental Portugal and no tillage database components.

Agri-environmental measure	No-tillage database component
No-tillage RURIS 2008	Parcels and sub-parcels applying for measure 15 RURIS/Agri-environmental and areas
No-tillage PRODER 2008	Parcels and sub-parcels applying to additional aid 100 PRODER (every agri-environmental measure) and areas Parcels and sub-parcels applying to additional aid 111 PRODER (every parcel converting to biological agriculture) and areas
Other measures	Parcels and sub-parcels applying for measure 16 RURIS/Agri-environmental and areas Parcels and sub-parcels applying to additional aid 42, measure 10 and 19 RURIS/Agri-environmental and areas

PRODER – Rural Development Programme for the Continente 2007 - 2013

RURIS – Rural Development Plan 2000 - 2006

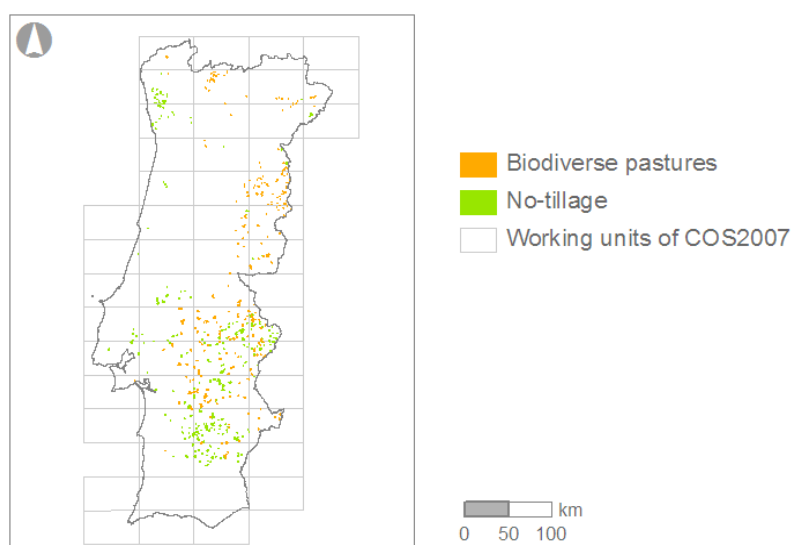
Table 10.3 - Agri-environmental measures that funded the biodiverse pastures in Continental Portugal and biodiverse pasture database components.

Agri-environmental measure	Biodiverse pasture database component
Biodiverse pastures 2008	Parcels and sub-parcels applying to Integrated Production (C01) at eligibility group 309, culture code 143, coverage 03 or 04 and areas Parcels and sub-parcels applying to Biological Production (C02) at eligibility group 319, culture code 143 e coverage 03 or 04 and areas Parcels and sub-parcels applying outside eligibility groups, with culture code 143 and coverage 03 or 04 and areas Parcels applying to ITIs with coverage codes 998 or 999 and areas.

ITIs – Integrated Territorial Interventions

It should be mentioned that, for biodiverse pastures, the correspondent database distinguishes between spontaneous and planted pastures. The WG 3.3&3.4 decided to identify separately, in view of the reporting, solely one particular sown type of biodiverse pastures. The sown biodiverse pastures occur in 29.8% of the total area of biodiverse pastures in the study area. In the remainder of the document sown biodiverse permanent pastures rich in legumes will be, for reasons of simplicity, referred to as biodiverse pastures.

Figure 10.4 - Spatial distribution of the specific management areas in Continental Portugal for 2008.



10.3.3 Spatial assessment unit used for determining the area of the units of land under Article 3.3 (in accordance with paragraph 3 of the annex to decision 15/CP.1) and Article 3.4

Article 3.4 is included since Portugal has elected the activities FM, CM and GM

10.3.3.1 *Future Submissions*

The activities related to Art. 3.3 will be identified using various information sources (COS'90, COS2007 and COS2010/2011). These cartographic products have a MMU of 1 ha. These same sources will be used to identify FM areas. On what concerns CM and GM, besides those sources of information (for the areas with no specific management practices), the IFAP's database will be used to determine the areas with specific management practices (see 10.3.1).

10.3.3.2 *Current Submission*

10.3.3.2.1 Forest land (Afforestation, Reforestation, Deforestation and Forest Management)

In order to estimate areas affected to the different forest activities considered by the Kyoto Protocol during the period 1990-2005, two data sources were used:

- COS90, Land Use Cartography of Portugal mainland for 1990;
- Photo interpretation of aerial photographs from NFI 2005/2006 (355737 photo-points).

COS90 cartography was overlapped with the 2005 photo-points and the identification of the photo-points affected to act. 3.3 and act. 3.4 was done (Table 10.4). The photo-points (NFI 2005/2006) located in areas not available in the COS90 were excluded, resulting in a total number of 334261 photo-points that could be used to estimate 3.3 and 3.4 areas.

Table 10.4 - Classification of the photo-points according to act. 3.3 and 3.4 of the Kyoto Protocol.

	Act. 3.3 afforestation	Act. 3.3 deforestation	Act. 3.4 forest management
COS90	Not forest	Forest	Forest
IFN2005	Forest	Not forest	Forest

The following strata were considered as "Forest":

- in the COS90: all the combinations of B* (cork oak), Z* (holm oak), N* (sweet chestnut), T* (wild chestnut), Q* (oak sps), E* (eucalypt), F* (other broadleaved), P* (maritime pine), M* (umbrella pine) and R* (other conifers sps) and degree of cover higher than 10%;
- in the photo-points of the NFI2005/2006: all the photo-points associated to land use code "1. Forest stands".

This analysis was carried on for the Forest Land as a whole and also by species and strata. Table 10.5 exemplifies the criteria used for eucalyptus. The same criteria were used for the other species mentioned in this report.

Table 10.5 - Classification of the eucalyptus photo-points according to act. 3.3 and 3.4 of the Kyoto Protocol.

	Act. 3.3 afforestation	Act. 3.3 deforestation	Act. 3.4 forest management
COS90	not forest	Pure eucalyptus stands Eucalyptus as main species Eucalyptus as second species	forest (independently of the species and composition)
NFI 2005/2006	Pure eucalyptus stands Eucalyptus as main species Eucalyptus as second species	not forest	Pure eucalyptus stands Eucalyptus as main species Eucalyptus as second species

To estimate the areas associated to act. 3.3 and act. 3.4, the proportion of the photo-points associated to each category to the total number of photo-points in forest land was calculated and multiplied by the total forest area of Portugal mainland area. In the NFI 2005/2006, forest areas estimates from photo interpretation were corrected for photo interpretation errors detected during the field work for validation. These corrections were needed mainly for Holm oak (classified in the photo-interpretation as Agriculture), cork oak (two situations: classified in the photo-interpretation as Cork oak but in the field as Shrubs and classified in the photo-interpretation as Agriculture or Shrubs) and young regeneration of maritime pine (classified in the photo-interpretation as Shrubs). Therefore the correction was subtracted or added to the areas affected to act. 3.3 – deforestation. Results are presented in Table 10.8 to Table 10.16 to all the species or group of species considered, respectively for Eucalyptus, Maritime pine, Cork oak, Holm oak, Umbrella pine, Chestnut, Other oaks, Other conifers and Other broadleaved.

10.3.3.3 *Estimation of afforestation and deforestation rates*

In order to estimate areas affected to the different forest activities considered by the Kyoto Protocol during the period 1990-2005, two data sources were used:

- COS90, Land Use Cartography of Portugal mainland for 1990;
- Photo interpretation of aerial photographs from NFI 2005/2006 (355737 photo-points).

COS90 cartography was overlapped with the 2005 photo-points and the identification of the photo-points affected to act. 3.3 and act. 3.4 was done (Table 10.6). The photo-points (NFI 2005/2006) located in areas not available in the COS90 were excluded, resulting in a total number of 334261 photo-points that could be used to estimate 3.3 and 3.4 areas.

Table 10.6 - Classification of the photo-points according to act. 3.3 and 3.4 of the Kyoto Protocol.

	Act. 3.3 afforestation	Act. 3.3 deforestation	Act. 3.4 forest management
COS90	Not forest	Forest	Forest
IFN2005	Forest	Not forest	Forest

The following strata were considered as “Forest”:

- in the COS90: all the combinations of B* (cork oak), Z* (holm oak), N* (sweet chestnut), T* (wild chestnut), Q* (oak sps), E* (eucalypt), F* (other broadleaved), P* (maritime pine), M* (umbrella pine) and R* (other conifers sps) and degree of cover higher than 10%;
- in the photo-points of the NFI2005/2006: all the photo-points associated to land use code "1. Forest stands".

This analysis was carried on for the Forest Land as a whole and also by species and strata. Table 10.7 exemplifies the criteria used for eucalyptus. The same criteria were used for the other species mentioned in this report.

Table 10.7 - Classification of the eucalyptus photo-points according to act. 3.3 and 3.4 of the Kyoto Protocol (e.g. Eucalyptus)

	Act. 3.3 afforestation	Act. 3.3 deforestation	Act. 3.4 forest management
COS'90	not forest	Pure eucalyptus stands Eucalyptus as main species Eucalyptus as second species	forest (independently of the species and composition)
NFI 2005/2006	Pure eucalyptus stands Eucalyptus as main species Eucalyptus as second species	not forest	Pure eucalyptus stands Eucalyptus as main species Eucalyptus as second species

To estimate the areas associated to Art. 3.3 and Art. 3.4 (referring to Forest Management), the proportion of the photo-points associated to each category to the total number of photo-points in forest land was calculated and multiplied by the total forest area of Portugal mainland area. In the NFI 2005/2006, forest areas estimates from photo interpretation were corrected for photo interpretation errors detected during the field work for validation. These corrections were needed mainly for Holm oak (classified in the photo-interpretation as Agriculture), cork oak (two situations: classified in the photo-interpretation as Cork oak but in the field as Shrubs and classified in the photo-interpretation as Agriculture or Shrubs) and young regeneration of maritime pine (classified in the photo-interpretation as Shrubs). Therefore the correction was subtracted or added to the areas affected to act. 3.3 – deforestation. Results are presented in Table 10.8 to Table 10.16 to all the species or group of species considered, respectively for Eucalyptus, Maritime pine, Cork oak, Holm oak, Umbrella pine, Chestnut, Other oaks, Other conifers and Other broadleaved.

Table 10.8 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) – Eucalyptus.

		number photo- points	proportion over stand type area	correction of photo- interpretati on errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Ec pure	4150	0,176		110126	110126
	Ec main species	666	0,198		18228	15129
	Ec second species	729	0,183		18497	12023
	Ec burned	420	0,203		7482	7482
	Ec clear-cut	121	0,153		3110	3110
	Total Ec	6086	0,180		157443	147871 (*)
	Total country	28081	0,239		800888	
3.3 deforestation	Ec pure	2179		-12000	45887	45887
	Ec main species	963			25583	21234
	Ec second species	1671			44391	28854
	Total Ec	4813			115861	95975 (**)
	Total country	44717		-247617	940319	
3.4 forest management	Ec pure	19411	0,824		515099	515099
	Ec main species	2703	0,802		73979	61403
	Ec second species	3260	0,817		82715	53765
	Ec burned	1648	0,797		29359	29359
	Ec clear-cut	671	0,847		17247	17247
	Total Ec	27693	0,820		718400	676873
	Total country	89269	0,761		2546009	

(*) annual afforestation = 9858 ha

(**) annual deforestation rate = 0,81%

Table 10.9 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) - Maritime pine.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Pb pure	4878	0,217		156533	156533
	Pb main species	1518	0,225		32429	24104
	Pb second species	1104	0,231		28454	18980
	Pb burned	466	0,263		13267	13267
	Pb clear-cut	57	0,135		1530	1530
	Total Pb	8023	0,222		232213	214413 (*)
	Total country	28081	0,239		800888	
3.3 deforestation	Pb pure	15056		-104808	295165	295165
	Pb main species	4730		-3200	122455	91018
	Pb second species	2136			56744	37850
	Total Pb	21922			474364	424033 (**)
	Total country	44717		-247617	940319	
3.4 forest management	Pb pure	17584	0,783		564263	564262
	Pb main species	5216	0,775		111431	82823
	Pb second species	3673	0,769		94666	63145
	Pb burned	1304	0,737		37124	29359
	Pb clear-cut	366	0,865		9824	17247
	Total Pb	28143	0,778		817308	757179
	Total country	89269	0,761		2546009	

(*) annual afforestation = 14294 ha

(**) annual deforestation rate = 2,6%

Table 10.10 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) - Cork oak.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Sb pure	2753	0,137		78406	78406
	Sb main species	631	0,131		15598	11231
	Sb second species	656	0,167		17238	8619
	Sb burned	14	0,175		302	302
	Sb clear-cut	3	0,500		75	75
	Total Sb	4057	0,140		111619	98632(*)
	Total country	28081	0,239		800888	
3.3 deforestation	Sb pure	4223		-247617	61383	61383
	Sb main species	2695		-50804	61594	44347
	Sb second species	2141		-10001	56877	28439
	Total Sb	9059			179854	134169(**)
	Total country	44717		-247617	940319	
3.4 forest management	Sb pure	17311	0,863		493018	493018
	Sb main species	4201	0,869		103848	74770
	Sb second species	3268	0,833		85875	42937
	Sb burned	66	0,825		1424	1424
	Sb clear-cut	3	0,500		75	75
	Total Sb	24849	0,860		684239	612224
	Total country	89269	0,761		2546009	

(*) annual afforestation = 6575,5 ha

(**) annual deforestation rate = 1,22 %

Table 10.11 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) - Hoalm oak.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Az pure	1103	0,154		55191	55191
	Az main species	318	0,150		6706	6287
	Az second species	446	0,151		11657	5100
	Az burned	1	0,125		19	19
	Az clear-cut	0	0,000		0	0
	Total Az	1868	0,153		73573	66597(*)
	Total country	28081	0,239		800888	
3.3 deforestation	Az pure	6259		-77206	89069	89069
	Az main species	1678			44577	41791
	Az second species	1203			31959	13982
	Total Az	9140			165604	144842(**)
	Total country	44717		-247617	940319	
3.4 forest management	Az pure	6051	0,846		302774	302774
	Az main species	1798	0,850		37914	35545
	Az second species	2502	0,849		65396	28611
	Az burned	7	0,875		131	131
	Az clear-cut	0	0,000		0	0
	Total Az	10358	0,847		406215	367061
	Total country	89269	0,761		2546009	

(*) annual afforestation = 4439,8 ha

(**) annual deforestation rate =2,02 %

Table 10.12 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) – Umbrella pine.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Pm pure	834	0,345		28510	28510
	Pm main species	151	0,133		4050	3174
	Pm second species	164	0,099		4459	1687
	Pm burned	3	0,250		69	69
	Pm clear-cut	0	0,000		0	0
	Total Pm	1152	0,220		37087	33440 (*)
	Total country	28081	0,239		800888	
3.3 deforestation	Pm pure	350			9298	9298
	Pm main species	374			9936	7787
	Pm second species	544			14452	5468
	Total Pm	1268			33686	22553(**)
	Total country	44717		-247617	940319	
3.4 forest management	Pm pure	1586	0,655		54217	54217
	Pm main species	982	0,867		26336	20642
	Pm second species	1488	0,901		40457	15308
	Pm burned	9	0,750		206	206
	Pm clear-cut	10	1,000		0	0
	Total Pm	4075	0,780		121217	90373
	Total country	89269	0,761		2546009	

(*) annual afforestation = 2229,3 ha

(**) annual deforestation rate = 1,27 %

Table 10.13 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) – Chestnut.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Ct pure	570	0,567		14255	14255
	Ct main species	74	0,454		1851	655
	Ct second species	61	0,313		1518	158
	Ct burned	0	0,000		0	0
	Ct clear-cut	0	0,000		0	0
	Total Ct	705	0,512		17624	15068(*)
	Total country	28081	0,239		800888	
3.3 deforestation	Ct pure	355			9431	9431
	Ct main species	122			3241	1148
	Ct second species	168			4463	465
	Total Ct	645			17135	11044(**)
	Total country	44717		-247617	940319	
3.4 forest management	Ct pure	436	0,433		10904	10904
	Ct main species	89	0,546		2226	788
	Ct second species	134	0,687		3334	347
	Ct burned	13	1,000		525	525
	Ct clear-cut	0	0,000		0	0
	Total Ct	672	0,488		16989	12564
	Total country	89269	0,761		2546009	

(*) annual afforestation = 1004,5 ha

(**) annual deforestation rate = 3,32 %

Table 10.14 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) - Other oaks.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Qc pure	1333	0,379		38762	38762
	Qc main species	780	0,351		15489	10128
	Qc second species	833	0,328		20456	9441
	Qc burned	48	0,314		722	722
	Qc clear-cut	0	0,000		0	0
	Total Qc	2994	0,355		75429	59053(*)
	Total country	28081	0,239		800888	
3.3 deforestation	Qc pure	2325		-14001	47764	47764
	Qc main species	880		11601	34979	22871
	Qc second species	1517			40300	18600
	Total Qc	4722			123043	89235(**)
	Total country	44717		-247617	940319	
3.4 forest management	Qc pure	2187	0,621		63596	63596
	Qc main species	1443	0,649		28655	18736
	Qc second species	1710	0,672		41992	19381
	Qc burned	105	0,686		1579	1579
	Qc clear-cut	2	1,000		0	0
	Total Qc	5447	0,645		135822	103292
	Total country	89269	0,761		2546009	

(*) annual afforestation = 3936,9 ha

(**) annual deforestation rate = 2,87 %

Table 10.15 - Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) – Other conifers.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Rx pure	246	0,381		6305	6305
	Rx main species	30	0,357		768	253
	Rx second species	27	0,303		683	579
	Rx burned	0	0,000		0	0
	Rx clear-cut	1	0,500		25	25
	Total Rx	304	0,363		7781	7162(*)
	Total country	28081	0,239		800888	
3.3 deforestation	Rx pure	537			14266	14266
	Rx main species	120			3188	1049
	Rx second species	115			3055	2591
	Total Rx	772			20509	17906(**)
	Total country	44717		-247617	940319	
3.4 forest management	Rx pure	400	0,619		10251	10251
	Rx main species	54	0,643		1383	455
	Rx second species	62	0,697		1568	1330
	Rx burned	17	1,000		450	450
	Rx clear-cut	1	1,500		25	25
	Total Rx	534	0,637		13677	12511
	Total country	89269	0,761		2546009	

(*) annual afforestation = 477,5 ha

(**) annual deforestation rate = 4,69 %

Table 10.16. Forest areas for the Kyoto Protocol activities (period 1990–2005): deforestation (act. 3.3); afforestation and reforestation (act. 3.3); and forest management (act. 3.4) – Other broadleaved.

		number photo- points	proportion over stand type area	correction of photo- interpretation errors	area estimation (ha)	area equivalent to pure stands (ha)
3.3 afforestation	Fx pure	1545	0,564		32547	32547
	Fx main species	444	0,440		11809	15047
	Fx second species	830	0,378		21372	6549
	Fx burned	41	0,265		483	483
	Fx clear-cut	3	0,750		19	19
	Total Fx	2863	0,469		66229	54645(*)
	Total country	28081	0,239		800888	
3.3 deforestation	Fx pure	1239		12801	45716	45716
	Fx main species	584			15514	19768
	Fx second species	1235			32809	10054
	Total Fx	3058			94039	75538 (**)
	Total country	44717		-247617	940319	
3.4 forest management	Fx pure	1194	0,436		25153	25153
	Fx main species	564	0,560		15001	19114
	Fx second species	1367	0,622		35199	10787
	Fx burned	114	0,735		1343	1343
	Fx clear-cut	1	0,250		6	6
	Total Fx	3240	0,531		76701	56403
	Total country	89269	0,761		2546009	

(*) annual afforestation = 3643 ha

(**) annual deforestation rate = 4,11 %

Between 1990 and 2005 the balance of afforestation and deforestation for the whole forest area is negative (-139431 ha, which corresponds to -9295 ha.year⁻¹). Table 10.17 shows the land use of the areas classified as Deforestation. Deforestation areas became mainly “Shrubland” and “Agriculture”. The conversion of “Forest land” to “Agriculture” is not a real one: corresponds to the sparse oak stands (namely holm oak and, to a certain extent, cork oak) that have a crown cover close to the limit between forest and non-forest (10%). Additionally, to be considered Deforestation, land use should be different from forest during at least 5 years. With the methodology used in this analysis it is only possible to detect if a photo-point classified as forest in the COS90 is or not forest in 2005. As a consequence deforestation area shown on Table 10.8 to Table 10.16 may be overestimated. For instance, a large proportion of “Shrubland”, with a large representation after large forest fires that occurred in Portugal in 2003/2005, will become forest in less than 5 years, either as consequence of natural regeneration or by planting. Part of the area classified as Deforestation can be, in a near future, re-classified as Forest. The same problem may have affected the estimation of afforestation rate: some of the photo-points classified as not forest in 1990 could in fact correspond to natural regeneration of forest stands. This problem seems difficult to solve but efforts are being put towards the improvement of the estimates of afforestation and deforestation annual rates.

Table 10.17 - Land use found in the areas classified as Deforestation

Land use - 2005	number of photo-points	number of photo-points (after area correction)
Deforestation	44717	35110
Other wooded land	402	402
Shrubland	28600	23766
Agriculture	13015	8242
irrigated	1774	1774
rain fed	8030	3257
vinyards	332	332
fruit orchards	656	656
pastures	190	190
fallow land	1112	1112
other	921	921
Other uses	2236	2236
Water	464	464

The Institute for Funding of Agriculture and Fisheries (IFAP) supplied to IGP the data on the specific management areas of the year 2008, in the form of two databases, one for no-tillage and one for biodiverse pastures. The agri-environmental measures that funded these specific practices and the components of each database are presented in Table 10.18 and Table 10.19. In total, the no-tillage database had 2454 records and the biodiverse pasture database had 2559 records. The no-tillage and biodiverse pasture databases are built upon information that is declared by the farmers and afterwards is subject to different types and levels of quality control. The spatial distribution of the IFAP data is shown in Figure 10.5.

Table 10.18. Agri-environmental measures that funded the no-tillage practice in Continental Portugal and no tillage database components.

Agri-environmental measure	No-tillage database component
No-tillage RURIS 2008	Parcels and sub-parcels applying for measure 15 RURIS/Agri-environmental and areas
No-tillage PRODER 2008	Parcels and sub-parcels applying to additional aid 100 PRODER (every agri-environmental measure) and areas Parcels and sub-parcels applying to additional aid 111 PRODER (every parcel converting to biological agriculture) and areas
Other measures	Parcels and sub-parcels applying for measure 16 RURIS/Agri-environmental and areas Parcels and sub-parcels applying to additional aid 42, measure 10 and 19 RURIS/Agri-environmental and areas

PRODER – Rural Development Programme for the Continente 2007 - 2013

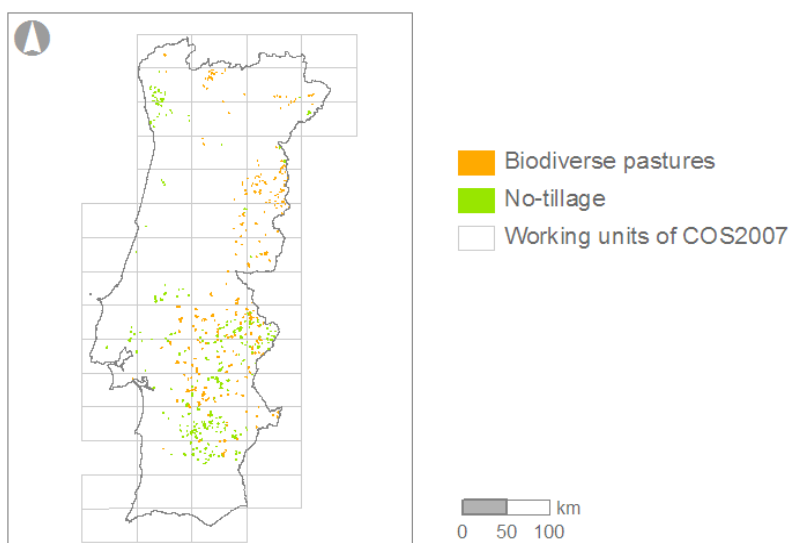
RURIS – Rural Development Plan 2000 - 2006

Table 10.19. Agri-environmental measures that funded the biodiverse pastures in Continental Portugal and biodiverse pasture database components.

Agri-environmental measure	Biodiverse pasture database component
Biodiverse pastures 2008	Parcels and sub-parcels applying to Integrated Production (C01) at eligibility group 309, culture code 143, coverage 03 or 04 and areas Parcels and sub-parcels applying to Biological Production (C02) at eligibility group 319, culture code 143 e coverage 03 or 04 and areas Parcels and sub-parcels applying outside eligibility groups, with culture code 143 and coverage 03 or 04 and areas Parcels applying to ITIs with coverage codes 998 or 999 and areas

ITIs – Integrated Territorial Interventions

Figure 10.5 - Spatial distribution of the specific management areas in Continental Portugal for 2008.



It should be mentioned that, for biodiverse pastures, the correspondent database distinguishes between spontaneous and planted pastures. The WG 3.3&3.4 decided to identify separately, in view of the reporting, solely the planted biodiverse pastures. The sown biodiverse pastures occur in 29.8% of the total area of biodiverse pastures in the study area. In the remainder of the document sown biodiverse permanent pastures rich in legumes will be, for reasons of simplicity, referred to as biodiverse pastures.

10.3.4 Methodology used to develop the land transition matrix in table NIR 2

10.3.4.1 *Future submissions*

The land use change matrix will be obtained through the use of various information sources (as fully described in section 10.3.1) that will be used to define the land use for 1990, 2007 and 2012. These will be compared in order to obtain the land use's transitions in the different time periods: base year (1990) and the commitment period (2008-2012).

10.3.4.2 *Current submission*

10.3.4.2.1 Land-use change matrices

In this point of time, for AD and FM, the LUC matrix was obtained through the comparison of NFI2005/2006 with COS'90.

Between 1990 and 2005 the balance of afforestation and deforestation for the whole forest area is negative (-139431 ha, which corresponds to -9295 ha.year⁻¹). Table 10.20 shows the land use of the areas classified as Deforestation. Deforestation areas became mainly "Shrubland" and "Agriculture". The conversion of "Forest land" to "Agriculture" is not a real one: corresponds to the sparse oak stands (namely holm oak and, to a certain extent, cork oak) that have a crown cover close to the limit between forest and non-forest (10%). Additionally, to be considered Deforestation, land use should be different from forest during at least 5 years. With the methodology used in this analysis it is only possible to detect if a photo-point classified as forest in the COS90 is or not forest in 2005. As a consequence deforestation area shown on Table

10.8 to Table 10.16 may be overestimated. For instance, a large proportion of “Shrubland”, with a large representation after large forest fires that occurred in Portugal in 2003/2005, will become forest in less than 5 years, either as consequence of natural regeneration or by planting. Part of the area classified as Deforestation can be, in a near future, re-classified as Forest. The same problem may have affected the estimation of afforestation rate: some of the photo-points classified as not forest in 1990 could in fact correspond to natural regeneration of forest stands. This problem seems difficult to solve but efforts are being put towards the improvement of the estimates of afforestation and deforestation annual rates.

Table 10.20. Land use found in the areas classified as Deforestation.

Land use - 2005	number of photo-points	number of photo-points (after area correction)
Deforestation	44717	35110
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Agriculture	13015	8242
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rain fed	8030	3257
vinyards	332	332
fruit orchards	656	656
pastures	190	190
fallow land	1112	1112
other	921	921
Other uses	2236	2236
Water	464	464

The areas of CM and GM were obtained from IFAP.

10.3.5 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations, all of which can be provided electronically

The maps and databases used to identify the geographical locations and the system of identification codes are described above.

10.4 Activity-specific information

The estimation of carbon stock changes in living biomass (above and belowground) in Forest Land is based on the resulting LUC matrix, using specific forest simulators/models for the main forest species (Eucalyptus, Pinus pinaster and new plantations of Quercus suber). Biomass accounting for the remaining species will be based on the use of average Production Yield Tables.

The simulators are based on yield tables that were built with NFI data in a way that reproduces the evolution of stands with an average site index and with a normal stock.

The identification of CM and GM areas will also be based on the LUC matrix, and the associated biomass will be accounted using national or IPCC default averages.

In what refers the soil pool, work has been developed in order to obtain country specific figures for soil organic carbon in forest, croplands and grassland.

This includes:

- analysis of data from a systematic network of sampling points. There are two sampling years for forestland, namely 1995 and 2007/08. As for croplands, all samples were collected in 1999;
- the statistical treatment of data in order to determine a model explaining the soil organic carbon;
- work referring to 2 specific activities: sown biodiverse permanent pastures rich in legumes (SBPPRL), under the grassland management item, and no-tillage, under the cropland management item.

Regarding SBPPRL, two research papers have been published to account its carbon sequestration potential. The first one, Teixeira *et al.* (2008a), focused on the determination of soil organic matter dynamics in different pasture types. The second one, Teixeira *et al.* (2008b), picks up on the first and converts soil organic matter increases into carbon sequestration, and discusses the carbon balance of the SBPPRL integrated system. Both studies use country-specific data.

Regarding no-tillage, several studies by the University of Évora in Portugal have measured soil organic carbon in test conditions for crops under conventional tillage and no-tillage. These studies show a significant difference in carbon stocks if crop residues are maintained as soil cover after harvesting. They are country-specific, since tests were conducted in Herdade da Revilheira (Évora, Portugal).

As regards dead organic matter (litter) data is available through the National Forestry Inventory and this data is presently being analyzed.

For dead wood there are available data from two pilot areas.

10.5 Article 3.3

10.5.1 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

Portugal considers that all its forest is managed; therefore, all the occurring changes in the period are human induced.

10.5.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Deforestation will occur when the period of 5 years from the clear cut, according to the definition of forest above, is exceeded and the forest is not restored.

10.5.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested.

It is planned to use image satellite data obtained through a COSMIC project to monitor the clear cuts. The minimum area will be at least 1 ha.

10.6 Article 3.4

10.6.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

CM and GM areas will be assessed using IFAP database. These activities are subjected to incentives since 1994 (CM) and 2008 (GM) and are monitored on an annual basis, so only the ones occurring after 1990 will be identified and accounted once data was collected later.

10.6.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

In 1990, the areas of SBPPRL and no-tillage in Portugal were not yet reported. However, there were already other management practices associated with cropland and grasslands in place.

10.6.3 Information relating to Forest Management

Forest managed areas are identified using COS (90, 2007 and 2011), therefore FM areas are coherent with the definition of forest according to the definition given in section 10.2.1 above.

10.7 Other information

10.7.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

To be provided later.

10.8 Information relating to Article 6

Portugal has no activities of the Article 6 of the KP in its territory.

10.9 Further Developments

As mentioned in the introduction, some improvements are expected on the methodology presented in this report referring to the estimation of Carbon Stocks.

One of the most important improvements relates to the estimation of afforestation and deforestation annual rates: i) the COS90 cartography is being improved and the problem of units/maps not available (see figure 1) will be solved; ii) A new land use cartography for Portugal mainland (COS2007) is being made based on new aerial photography captured in 2007. When this cartography will be available the methodology described under 2.3 (Estimation of afforestation and deforestation rates) will be changed as the estimates of annual afforestation and deforestation rates will be based on the overlap of the two cartographies (1990 and 2007). The methodologies described under 2.5 and 2.6 do not need to be changed after the new method for afforestation and deforestation annual rates will be implemented but the simulator will have to be run with corrected scenarios.

Another improvement deals with the regional simulator SIMYT that is being used to predict the growth of the Eucalyptus, Maritime pine, Cork oak, and Holm oak stands. This simulator is based on an “average” yield table and to Eucalyptus and Maritime pine, treats the non-industrial and uneven-aged stands with an “average” growth rate. Due to the intrinsic non-linearity of forest growth, the use of average values may lead to biased estimations.

There are some simplifying assumptions in the simulator that can be improved in the future: 1) even-aged stands are harvested starting from the oldest to the successively younger ages, an alternative algorithm considering probabilities of harvest for each age is being implemented; 2) the simulator assumes that all the burned stands that are not abandoned (deforestation) are

immediately harvested and planted next year, a more variable time between fire, harvest and replanting can be considered in future simulations; 3) similarly the simulator assumes that the stands that are harvested and not abandoned (deforestation) are replanted next year, a more variable time between harvest and replanting can be considered in future simulations.

If the wood demand will is not achieved after the simulation of carbon stock changes in forest land that remained forest land (article 3.4 activities) then it can be possible to work in an iterative repetition of simulations 3.3 and 3.4 till the wood demand is approximately achieved.

There is ongoing research in Portugal towards the development of a regional simulator that is based on the projection of each NFI plot and that includes a growth model for the projection of uneven-aged stands. The same simulator will be available for the other species.

Other improvements are expected in a near future to overcome limitations detected:

- Substitution of biomass equations in the SUBER model; it is also important to stress that the outputs from model SUBER are extremely dependent from the assumption of increment/maintenance of the crown cover.
- A detailed analysis in order to improve the estimates presented for Cork oak and Holm oak: the values presented for C changes result from the direct application of the models used for that species; in some cases this method shows some incoherencies: for example the mortality rate found in Cork oak yield table ($S=15,7$) is greater than the one found in Holm oak ($S=10,8$).
- Improvement of age estimation in eucalyptus stands; the field plots were revisited by fields crews specifically trained by CELPA (Association of Pulp and Paper Industry) for age estimation approximately one year after being measured during the 2005/2006 NFI; negotiations in order to have access to these data are starting.
- The method used for assessing C changes for Other species (based on yield tables and constant values of C stock and C sequestration), when compared with the methodology used for the main Portuguese species, overestimates the values of C gains.

Other than the improvements expected on the methodology, the statistics on wood demand must also be improved. For instance, at the moment there is a reasonable external trade with eucalyptus wood (either export to Spain and import from Latin America) that makes estimation of wood consumption more difficult. Better estimates on wood demand should be obtained in the short term as they are crucial for the estimation of carbon stock changes. Definitive statistics of forest fire areas by specie are also needed.

In what concerns soil organic carbon, work is ongoing to develop a model which determines that it is stationary or increasing in managed areas, including the parameters that should be taken into account.

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 2009 has been submitted to the UNFCCC Secretariat electronically (SEF_PT_2010_1_14-18-58 4-3-2010.xls). This information is presented in 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 2009 was 378,502,751 AAUs, of which 321,367,458 units were in the Party holding account, 29,212,224 units in the entity holding accounts, and 27,923,069 units in the retirement account.

There was 4,267,740 CERs in the registry at the end of 2009: 2,282,367 CERs were held in the entity holding accounts and 1,985,373 CERs were held in the retirement account.

The registry did not contain any ERUs, 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 382,770,491 tonnes CO₂e. Portuguese assigned amount is 386,956,503 tonnes CO₂e.

11.3 Discrepancies and notifications

A list of discrepant transactions is presented in table R2 of the annexed RRITL worksheet (SIAR_Reports_PT_2009_R2_R5.xls). An explanation on how this problem was handled is also provided in the R2 worksheet.

No CDM notifications were received, no non replacements occurred and no invalid units were identified during the 2009.

11.4 Publicly Accessible Information

The public information was made available in the Registry site in the middle of 2009 and since then no changes occurred in the reported year. 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 request its disclosure.

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

Changes in the national system concern the arrangements put in place to deal with the additional requirements under Kyoto Protocol concerning Art. 3.3 and 3.4.

An inter-institutional working 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. Many of this entities involved in this WG were already considered in the first organizational arrangement settled by the legal agreement that put in place SNIERPA (RCM 68/2005). However, additional institutions were involved: IFAP (ex-INGA) - Instituto Financiamento da Agricultura e Pescas (www.ifap.min-agricultura.pt) responsible for providing data on agro-incentives measures, portuguese universities: ISA - Instituto Superior de Agronomia / Technical University of Lisbon (<http://www.isa.utl.pt>), IST – Instituto Superior Técnico/ Technical University of Lisbon (<http://www.ist.utl.pt>) and UE – Universidade de Évora.

The decision from the Superior Statistical Council (Conselho Superior de Estatística (CSE)) on the provision of confidential industrial data is an additional agreement within the SNIERPA that foresees the annual deliver of confidential information to the APA.

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 2009, the only major change made in the Portuguese registry occurred on 15th July, when the registry software was updated to CR v3.2. This new version makes use of a new generic webservice to connect to CITL through ITL (AccountManagementService). This change has been preceded with intense testing, some internal and others coordinated by the EU COM and the UNFCCC secretariat. The formal ETS test was performed on 7th July and its results are presented in section 13.7, together with the final internal tests results.

In addition to this major software update, minor bugs have been detected and corrected 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:

- 9th September;
- 12^h October;
- 11th December.

The communication infra-structure has been improved by establishing an independent second link from the secondary datacenter to the ITL. As previously reported, in February 2009 Portugal improved its communication infrastructure to better manage emergency situations and reduce the risk of long non operating periods. An independent PIX has been installed in the secondary datacenter to implement a quasi independent second link to ITL. The connection to the secondary datacenter is still routed to a common firewall infrastructure (with two redundant nodes) linked to the backbone of the Portugal Telecom network. No changes have occurred 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 three and a half years period of operation of the registry no discrepancies have been found between the registry, the ITL and the CITL. No complaint has also been reported by the registry users regarding a hypothetical discrepancy in their accounts.

13.5 Security measures

No changes have occurred in the way the registry deals with security issues. No security breaches have occurred.

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. Further disaster recovery tests are planned for 2010.

13.7 Test results on registry software upgrade to CR v3.2

13.7.1 Internal Tests

Summary

Environment: ITL DEV

Tester: Joana Simões

Dates: April-July 2009

Changes in National Registry

Test	Description	Date	Result	Comment
Account creation	Creation of government account PT-100	15th April 2009	OK	Usernames are First_nameLast_name now New column with account status
Account update	Update of the city of primary authorized representative	15th April 2009	+/-	Incorrect body text in email sent
Add people	Add an additional representative of the government account	15th April 2009	NOK	Error stating role is mandatory, but I have chosen that role!
Account creation	OHA creation PT-120		OK	New field in the form: Permit nr (repeated) Possibility of getting account holder info from permit New field: Permit entry date – MANDATORY When the new installation is created the Permit Mgt is automatically updated with the permit id and start and expiry dates
Add people	Add an additional representative of the OHA		NOK	Error stating role is mandatory, but I have chosen that role! ???pt.form.field.account.role=Role??? É obrigatório Corrected in 29th April
Replace people	Replaced the primary authorized representative of OHA	15th April 2009	OK	
Reconciliation	ITL started reconciliation PT10010827	16th April 2009	+/-	Validated status
Project creation	Creation of a project	16th April 2009		
Conversion	Conversion of 25 AAU to ERU (project ID PT13390)	16th April 2009	OK	
Account blocking (DB) – is_frozen='Y'	Internal transfer to that account was successful Logged in as PAR – everything worked fine	16th April 2009	NOK	Blocking accounts in the database continues not to have any effects
Account Blocking (DB) Article27_blocked_flag='Y'	The account gets a key lock (cadeado), but everything is possible also. Manual intervention does not change anything	16th April 2009	NOK	No effects. Needs to happen automatically when the date is due
Password change as a user	Rules for password change: 8 alphanumeric characters	16th April 2009	OK	Displays a red rectangle with errors and I haven't clicked anything
Emission of RMU	Emission of 1500 RMU to government account	16th April 2009	OK	
Allowance allocation	Allocation for 2010 to inst 1 and 2	16th April 2009	OK	The operation has destination account blank
Verified emission insertion	Manual insertion of verified emissions	16th April 2009	NOK	Error. Permit must be from the previous year (entry into force date)
Allowance conversion	Error	16th April 2009	NOK	Error. After surrendering it works, but the national account are PT-100-50 and PT-100-600. They do not exist in DEV.
Retirement	New combobox Retirement Type with 3 options Kyoto Protocol Retirement Surrendered allowances retirement Unallocated allowances retirement	16th April 2009	+/-	Field is mandatory
Allowance surrender	Surrendered EUA	16th April 2009	+/-	If default_surrender_account is not defined it doesn't display the allowance surrender. There is an error. After defining that account, it works just fine.

Changes in National Registry

Test	Description	Date	Result	Comment
Log off button	Page goes blue and login and other options disappear	16th April 2009	NOK	CORRECTED
User block	Unable to block an user without changing password	16th April 2009	NOK	
Message Sent to ITL	Message was sent to the ITL and they received it	16th April 2009	OK	
Type 9 notifications	Type 9 notification sent by ITL automatically completed in CR	29th April 2009	OK	Date is correctly changed
Type 5 notifications	Type 5 notification sent by ITL (ICERs for project PW35)			
Remove people	Remove additional representative	29th April 2009	OK	
Type 4 notification	Project id KP34	29th April 2009	OK	
Allowance conversion	Error	5th May 2009	OK	After correction, tested. Only works after 30th June 2013. Changed the clock. Worked
Type 1 notifications	Type 1 notifications sent to ITL	6th May 2009	OK	
Account closure	No units	6th May 2009	OK	Closed accounts disappear from accounts search
Account closure	With units	6th May 2009	OK	Not possible. Error stating there are still units in that account
Account closure	For installation: no units	6th May 2009	NOK	Not possible. Error. Should be possible without submitting VE for 2008. Since it belongs to NAP, it makes sense not allowing
Account creation	Longitude and Latitude not mandatory fields Permit 2004	6th May 2009	OK	
Internal transfer of ICER, tCER, ERU, CER, RMU to operator holding account, EUA, AAU from PartyHA to OHA		12th May 2009	OK	
Internal transfer of ICER, tCER, ERU, CER, RMU to operator holding account, EUA, AAU from OHA to OHA		12th May 2009	OK	
Surrendering (check 7367)		12th May 2009	OK	It works as it is supposed. I tried to surrender 5001 CER (total CER and ERU surrender: 5000) and it gave me error 7367. I then surrendered 250 CER and 25 ERU. Transactions completed. Then I tried to surrender 5000 CER: error 7367. Finally, I surrendered 4725 CER and the transaction was submitted and completed. Last test: surrender 1 ERU or 1 CER. Error 7367. Surrender CER and ERU for different year: error 7367. The check is working fine.
Internal transfer of ICER, tCER,		12th May 2009	OK	

Test	Description	Date	Result	Comment
ERU, CER, RMU to operator holding account, EUA, AAU from PartyHA to PHA				
Internal transfer of ICER, tCER, ERU, CER, RMU to operator holding account, EUA, AAU from PHA to OHA		12th May 2009	OK	
Internal transfer of ICER, tCER, ERU, CER, RMU to operator holding account, EUA, AAU from PHA to PHA		12th May 2009	OK	
Internal transfer of ICER, tCER, ERU, CER, RMU to operator holding account, EUA, AAU from OHA to PHA		12th May 2009	OK	
ETS testing 2009		15th May 2009 18th May 2009	+/-	Problems in NAP update uploads and allowance conversion
PAR functionalities		21st May 2009	OK	PAR can transfer units and check operations from and to his account. He can also submit VE but cannot approve them
SAR functionalities		21st May 2009	OK	SAR can transfer units and check operations from and to his account. He can also submit VE but cannot approve them
AAR functionalities		21st May 2009	+/-	AAR cannot transfer units. He cannot check notifications (error: Occorreu um erro durante a execução do pedido). He can only check operations and compliance
Verifier		21st May 2009	OK	Verifier can only check compliance and submit and approve VE

13.7.2 ETS Testing

Summary

Environment: ITL REG

Tester: Joana Simões

Date: 7th July 2009

Subject	Test case	Name	Description	Result
Account creation	2-1	Party holding accounts creation	creation of accounts 100, 230 (CP1), 300 (CP1), 300 (CP2)	OK
	2-2	Operator and party holding accounts creation	creation of 3 OHA accounts, 2 PHA accounts	OK
NAP upload	3-1	NAP upload for CP1	upload NAP for inst 1 (4*15000+50000) and 2 (5*10000); reserve 105000	OK
	4-1	Amended NAP upload	add installation 3 (4*20000); reserve 25000	OK
	4-2	Amended NAP upload	Inst 3 has amended allocation for 2012; reserve 15000	OK
Issuance	5-1	AAU issuance	issue 500000 AAU	OK
	5-2	EUA issuance	issue 265000 EUA	OK
Allowance allocation	5-3	Allowance allocation	2008: inst 1 - 15000; inst 2 - 10000	OK
	5-4	Allowance allocation	2009: inst 1 - 15000; inst 2 - 10000	OK
Internal transfer	6-1	Allowance Internal transfer (Party -> OHA)	From Party holding account to OHA (inst 1) 25000 EUA	OK
	6-2	Allowance internal transfer (OHA -> OHA)	From OHA (inst 1) to OHA (inst 2) 10000 EUA	OK
	6-3	Allowance internal transfer (OHA -> PHA)	From OHA (inst 2) to PHA 10000 EUA	OK
	6-4	Allowance internal transfer (PHA -> Party)	From PHA to Party holding account 10000 EUA	OK
	6-5	Allowance internal transfer (Party-> OHA)	From Party holding account to OHA (inst 2) 10000 EUA	OK
	6-6	EUA and AAU internal transfer (Party -> OHA)	From Party holding account to OHA (inst 2) 5000 EUA and 10000 AAU	OK
	6-7	EUA and AAU internal transfer (OHA -> PHA)	From OHA (inst 2) to PHA 5000 EUA and 10000 AAU	OK
	6-8	EUA and AAU internal transfer (PHA -> Party)	From PHA to Party holding account 5000 EUA and 10000 AAU	OK
External transfer	7-1	Allowance external transfer (Party -> YY)	From party holding account to registry YY: 10000 EUA	OK
	7-2	EUA and AAU external transfer (Party -> YY)	From party holding account to registry YY: 8000 EUA and 10000 AAU	skipped
	7-3	EUA and AAU external transfer (YY -> Party)	From registry YY to party holding account: 8000 EUA and 10000AAU	OK
Cancellation	8-1	Allowance cancellation	Cancel voluntarily 15000 allowances (inst 1)	OK
Account Management	9-1	Update OHA	The PAR is now SAR and vice-versa	OK
	9-2	Update OHA (SAR phone number and visibility)	Inst 2 - phone number changed; address and phone information not visible	OK
	9-3	Update OHA (Sar phone number and visibility)	Inst 2 - phone number changed; address and phone information visible again	OK
	9-4	Update permit number (inst 2)		
NAP upload	10-1	NAP upload for CP1	Inst 3: Delete; reserve: 105000	OK
Account closure	10-2	Account Closure		OK
Compliance	11-	Update verified emissions	For inst 1 - 9500; inst 2 - 10000	OK

Subject	Test case	Name	Description	Result
	1	(inst 1 and 2)		
	11-2	Surrendering	For inst 1 - 8500	OK
	11-4	Update verified emissions (inst 1 and 2)	For inst 1 - 9500; inst 2 - 9000	OK
	11-5	Upload compliance		OK
Account creation	12-1	Operator holding accounts creation	Inst 4	OK
NAP upload	12-2	NAP upload for CP1	Add installation 4: 4*15000; reserve: 45000	OK
Allowance allocation	12-4	Allowance allocation	Inst 4, 2009	OK
Retirement	13-1	Conversion of surrendered EUA to AAU	17500 surrendered allowances	OK
	13-2	EUA Retirement	17500 AAU	OK
	13-3	Conversion of none allocated allowances into AAUs	150000 allowances	skipped
	13-4	Retirement of AAUs	15000 AAU	skipped
	13-5	Retirement AAUs	6000 AAU	OK
Reconciliation	14-1	Positive reconciliation		OK
	14-2	Negative reconciliation		OK
	14-3	Manual intervention	Remove unit block from inst 2 to inst 1	OK
	14-4	Positive reconciliation		OK
NAP upload	15-1	Upload amended NAP	Reserve 225000	skipped
	15-2	Upload NAP	Reserve: 140000; inst 1 for 2010: 30000; for 2011 30000; for 2012 15000; inst 2 for 2009 until 2012: 25000	skipped
	15-3	NAP upload	Reserve: 125000	skipped

13.8 Response to Review Recommendations on the National Registry

Recommendation to make available public information in the registry website (Paragraphs 99 and 111 FCCC/ARR/2009/PRT)

Public information is now available through the national registry's website. (see item 11.4 Publicly Accessible Informationn).

Recommendation to include relevant test plans and tests reports (Paragraphs 102 and 111 FCCC/ARR/2009/PRT)

Information from internal tests and ETS testing is included in the item 13.7 Test results on registry software upgrade to CR v3.2.

Recommendation to improve the recovery of its services in the event of a disaster (Paragraphs 102 and 111 FCCC/ARR/2009/PRT)

The Party considered the recommendation to improve the recovery of its services in the event of a disaster. Please see item 13.6 Disaster management.

14 MINIMIZATION OF ADVERSE IMPACTS

This chapter concerns information on minimization of adverse impacts in accordance with Article 3, paragraph 14

Portugal's contribution to the minimisation of the adverse effects of climate change in other Parties, particularly developing countries, is carried out through a strong commitment to implementing the Convention and the Kyoto Protocol.

As such, the policies and measures implemented, adopted or foreseen in 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.

In some cases, such as measures pertaining to the diversification of primary energy sources (namely shifting to natural gas), there can simultaneously be positive effects on Portugal's emissions reduction and in the economy of some fossil fuel exporting countries.

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 equivalent	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
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	Ministério da Agricultura, Desenvolvimento Rural e Pescas
MAOT	Ministry of Environment and Land Use Planning	Ministério do Ambiente e Ordenamento do Território
MCF	Methane Conversion Factor	Factor de Conversão de Metano
MCOTA	Ministry of Urban Affairs, Land Use Planning and Environment	Ministério das Cidades, Ordenamento do Território e Ambiente
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	-
PM1	Particles with Aerodynamic Diameter smaller than 1 micrometer	Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro
PM10	Particles with Aerodynamic Diameter smaller than 10 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros
PM2.5	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 2010 Portuguese inventory estimates (1990-2008), the determination of key categories was conducted using the Tier 2 including LULUCF. A qualitative approach has been used in the case of emissions of PFCs from category 2F1, as this source is largely unknown and is quantified as potential emissions.

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:

$$\text{Trend Assessment with Uncertainty} = \text{Tier 1 Trend Assessment} \bullet \text{Relative category Uncertainty}$$
$$TU_{x,t} = T_{x,t} \bullet U_{x,t}$$

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 a qualitative approach, and resulted in the identification of 56 key categories.

Table A-1 presents a summary of identified key categories for 1990-2008 using Tier 2 analysis including LULUCF, and the criteria used (level, trend, qualitative) in the identification.

Three other tables are presented, Tables A-2.1 to A-2.3 for 1990 and 2008 inventory year's level assessment and trend assessment for 1990-2008.

Table A. 1 – Portuguese key categories (1990-2008) based on Tier 2 with LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identification	Comments on level assessment	2008 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	16346
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level	All years	8978
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1999, 2004, 2005, 2006, 2007, 2008	5153
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level	All years	3928
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level	All years	3864
6 A Municipal SWDL	SW Disposal on Land	CH ₄	✓	Level Trend	All years	3149
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level	All years	2958
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	2186
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	1944
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1793
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	All years	1768
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level	All years	1655
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level	1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	1412
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007	1392
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1265
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	✓	Level	All years	1108
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1070
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1993	1051
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	990
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	754
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	652
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2007, 2008	629
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2007, 2008	408
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level	2003, 2004, 2006, 2007, 2008	386
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	All years	378
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2005, 2006, 2007	360
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	✓	Level	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2006, 2007, 2008	354
1A 4 b Residential	Biomass	CH ₄	✓	Level Trend	All years	310
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	✓	Level Trend	All years	226
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	181
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	✓	Trend		135
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005,	126
3 D OTHER	Other Use of Chemicals	CO ₂	✓	Level	All years	102
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend	All years	102
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend	All years	65
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2006	63
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO ₂	✓	Level	All years	56
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	54
1B 2 b Natural gas	Gaseous Fuels	CO ₂	✓	Trend		53
2 F 2 Foam Blowing	Consumption	HFC	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008	45
1A 1a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level	All years	42
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	40
3 D OTHER	Other Use of Chemicals	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2004, 2005	34
1A 2 f Other	Biomass	N ₂ O	✓	Level	All years	27
1A 1a Public Electricity and Heat Production	Biomass	N ₂ O	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	20
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	✓	Level	2006, 2007, 2008	18
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		17
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	✓	Level Trend	2003, 2005	13
1A 1a Public Electricity and Heat Production	Other Fuels	N ₂ O	✓	Trend		11
2 F 8 Electrical Equipment	Consumption	SF ₆	✓	Qualitative		8
1A 1a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend	1992	5
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level Trend	All years	4
2 F 4 Aerosols	Consumption	HFC	✓	Qualitative		1
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	✓	Trend		-164
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-577
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-3837
Sub-total with LULUCF		All gases				65114
% of total with LULUCF		All gases				86.3
TOTAL EMISSIONS WITH LULUCF		All gases				75424

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	2098	2098	0.03	500.28	16.02	0.32	0.32
6 A 3 Industrial SWDL	Industrial Waste Disposal	CH ₄	1599	1599	0.02	149.82	3.66	0.07	0.39
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	156	156	0.00	1000.33	2.38	0.05	0.44
1 A 4 c Agriculture/ Forestry / Fishing	Liquid Fuels	N ₂ O	151	151	0.00	1000.05	2.30	0.05	0.49
4 Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	1323	1323	0.02	113.05	2.28	0.05	0.53
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	3355	3355	0.05	39.58	2.03	0.04	0.57
6 A Municipal SWDL	SW Disposal on Land	CH ₄	1433	1433	0.02	67.27	1.47	0.03	0.60
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1385	1385	0.02	60.90	1.29	0.03	0.63
1 A 4 b Residential	Biomass	N ₂ O	73	73	0.00	1001.80	1.11	0.02	0.65
1 A 3 b Road Transportation	All Fuels	CO ₂	9246	9246	0.14	7.07	1.00	0.02	0.67
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1386	1386	0.02	44.16	0.93	0.02	0.69
1 A 4 b Residential	Biomass	CH ₄	343	343	0.01	161.55	0.85	0.02	0.70
4 A ENTERIC FERMENTATION	Population size	CH ₄	2637	2637	0.04	20.90	0.84	0.02	0.72
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO ₂	51	51	0.00	1000.05	0.78	0.02	0.74
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	1056	0.02	48.28	0.78	0.02	0.75
3 D OTHER	Other Use of Chemicals	N ₂ O	99	99	0.00	500.00	0.75	0.02	0.77
3 D OTHER	Other Use of Chemicals	CO ₂	85	85	0.00	500.00	0.65	0.01	0.78
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7659	7659	0.12	5.10	0.60	0.01	0.79
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	1108	1108	0.02	34.61	0.59	0.01	0.80
1 A 2 f Other	Liquid Fuels	CO ₂	3375	3375	0.05	11.18	0.58	0.01	0.82
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	36	0.00	1000.00	0.55	0.01	0.83
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6301	6301	0.10	5.10	0.49	0.01	0.84
2 A 1 Cement Production	Production Quantities	CO ₂	3107	3107	0.05	10.10	0.48	0.01	0.85
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	3	0.00	10000.05	0.40	0.01	0.85
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-577	-577	0.01	45.01	0.40	0.01	0.86
1 A 3 a ii Domestic	Liquid Fuels	CO ₂	236	236	0.00	100.11	0.36	0.01	0.87
1 A 2 f Other	Solid Fuels	CO ₂	2103	2103	0.03	11.18	0.36	0.01	0.88
3 A PAINT APPLICATION	Paint application	CO ₂	86	86	0.00	262.39	0.35	0.01	0.88
1 A 2 f Other	Biomass	N ₂ O	21	21	0.00	1001.80	0.32	0.01	0.89
2 A 2 Lime Production	Production Quantities	CO ₂	178	178	0.00	105.34	0.29	0.01	0.90
1 A 4 c Agriculture/ Forestry / Fishing	Liquid Fuels	CO ₂	1660	1660	0.03	11.18	0.28	0.01	0.90
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	354	354	0.01	51.58	0.28	0.01	0.91
1 A 4 b Residential	Liquid Fuels	CO ₂	1621	1621	0.02	11.18	0.28	0.01	0.91
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	569	0.01	31.57	0.27	0.01	0.92
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	15	0.00	1000.00	0.23	0.00	0.92
1 A 3 d ii National navigation	Liquid Fuels	CO ₂	262	262	0.00	50.64	0.20	0.00	0.93
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	227	0.00	53.62	0.19	0.00	0.93
1 A 2 d Pulp, Paper and Print	Biomass	N ₂ O	11	11	0.00	1000.00	0.17	0.00	0.93
1 A 4 b Residential	Liquid Fuels	N ₂ O	11	11	0.00	1000.05	0.17	0.00	0.94
1 A 2 f Other	Liquid Fuels	N ₂ O	11	11	0.00	1000.05	0.17	0.00	0.94
1 A 1 b Petroleum refining	Liquid Fuels	CO ₂	1910	1910	0.03	5.10	0.15	0.00	0.94
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	820	820	0.01	11.18	0.14	0.00	0.95
1 A 1 b Petroleum refining	Liquid Fuels	N ₂ O	9	9	0.00	1000.00	0.14	0.00	0.95
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	228	228	0.00	39.58	0.14	0.00	0.95
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-164	-164	0.00	54.83	0.14	0.00	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	286	286	0.00	30.41	0.13	0.00	0.96
1 A 4 a Commercial/ Institutional	Liquid Fuels	CO ₂	744	744	0.01	11.18	0.13	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO ₂	1372	1372	0.02	5.83	0.12	0.00	0.96
2 A 7 Other	Production Quantities	CO ₂	64	64	0.00	113.66	0.11	0.00	0.96
1 B 1 a Coal Mining	Solid Fuels	CH ₄	66	66	0.00	100.12	0.10	0.00	0.97
2 B 5 Other	Production Quantities	CO ₂	65	65	0.00	100.50	0.10	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N ₂ O	6	6	0.00	1000.00	0.10	0.00	0.97
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	567	567	0.01	10.05	0.09	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N ₂ O	5	5	0.00	1001.80	0.08	0.00	0.97
1 B 2 a Oil	Liquid Fuels	CO ₂	105	105	0.00	50.16	0.08	0.00	0.97
1 B 2 a Oil	Liquid Fuels	CH ₄	51	51	0.00	100.08	0.08	0.00	0.98
1 A 2 f Other	Solid Fuels	N ₂ O	5	5	0.00	1000.05	0.07	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	743	743	0.01	5.83	0.07	0.00	0.98
1 A 3 b Road Transportation	All Fuels	N ₂ O	82	82	0.00	50.25	0.06	0.00	0.98
1 A 3 b Road Transportation	All Fuels	CH ₄	99	99	0.00	40.31	0.06	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	33	0.00	105.02	0.05	0.00	0.98
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	520	520	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	0.05	0.00	0.98
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	105	105	0.00	28.08	0.04	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH ₄	19	19	0.00	150.03	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	0.04	0.00	0.99
1 A 4 a Commercial/ Institutional	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.04	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
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	-25	-25	0.00	88.47	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
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	32	32	0.00	46.46	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
5 B 2 Land converted to Cropland	Emissions/Removals	N ₂ O	24	24	0.00	51.58	0.02	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO ₂	173	173	0.00	7.07	0.02	0.00	0.99
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry	CO ₂	12	12	0.00	100.00	0.02	0.00	1.00

Table A. 3 – Tier 2 Level assessment with LULUCF: 2008

Tier 2 Level Assessment (2008)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO ₂ eq.) 1990	Current year Estimate (kton CO ₂ eq.) 2008	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 Da AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	2098	1793	0.02	500.28	10.56	0.23	0.23
6 A 3 Industrial SWDL	Industrial Waste Disposal	CH ₄	1599	1768	0.02	149.82	3.12	0.07	0.30
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	156	226	0.00	1000.30	2.66	0.06	0.36
6 A Municipal SWDL	SW Disposal on Land	CH ₄	1433	3149	0.04	67.27	2.49	0.06	0.42
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	3355	-3837	0.05	39.58	1.79	0.04	0.45
1 A 3 b Road Transportation	All Fuels	CO ₂	9246	18346	0.22	7.07	1.53	0.03	0.49
1 B 2 d Other (Geothermal)	Energy Production	CO ₂	2	126	0.00	1000.05	1.49	0.03	0.52
4 Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	1323	1070	0.01	113.05	1.42	0.03	0.55
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	151	102	0.00	1000.05	1.20	0.03	0.58
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	990	0.01	99.29	1.16	0.03	0.60
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1385	1366	0.02	60.90	0.98	0.02	0.63
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1386	1655	0.02	43.88	0.86	0.02	0.65
1 A 4 b Residential	Biomass	N ₂ O	73	65	0.00	1001.80	0.77	0.02	0.66
4 A ENTERIC FERMENTATION	Population size	CH ₄	2637	2958	0.03	20.90	0.73	0.02	0.68
1 B 2 b Natural gas	Gaseous Fuels	CH ₄	0	408	0.00	150.33	0.72	0.02	0.69
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO ₂	51	56	0.00	1000.05	0.66	0.01	0.71
3 D OTHER	Other Use of Chemicals	CO ₂	85	102	0.00	500.00	0.60	0.01	0.72
1 A 4 b Residential	Biomass	CH ₄	343	310	0.00	161.55	0.59	0.01	0.74
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7659	8978	0.11	5.10	0.54	0.01	0.75
1 A 2 f Other	Liquid Fuels	CO ₂	3375	3864	0.05	11.18	0.51	0.01	0.76
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	4	0.00	10000.05	0.50	0.01	0.77
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	42	0.00	1000.00	0.50	0.01	0.78
2 A 1 Cement Production	Production Quantities	CO ₂	3107	4110	0.05	10.10	0.49	0.01	0.79
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	0	40	0.00	1000.00	0.47	0.01	0.80
2 A 2 Lime Production	Production Quantities	CO ₂	178	378	0.00	105.34	0.47	0.01	0.81
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	1108	1108	0.01	34.61	0.45	0.01	0.82
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	754	0.01	48.28	0.43	0.01	0.83
1 B 2 a Oil	Liquid Fuels	CO ₂	105	629	0.01	50.16	0.37	0.01	0.84
1 A 2 f Other	Biomass	N ₂ O	21	27	0.00	1001.80	0.32	0.01	0.85
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	0	5153	0.06	5.10	0.31	0.01	0.85
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-577	-577	0.01	45.01	0.31	0.01	0.86
1 A 2 f Other	Gaseous Fuels	CO ₂	0	2186	0.03	11.18	0.29	0.01	0.87
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	386	0.00	53.62	0.24	0.01	0.87
2 A 7 Other	Production Quantities	CO ₂	64	181	0.00	113.66	0.24	0.01	0.88
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	652	0.01	31.57	0.24	0.01	0.88
1 A 1 a Public Electricity and Heat Production	Biomass	N ₂ O	0	20	0.00	1000.00	0.24	0.01	0.89
2 F 2 Foam Blowing	Consumption	HFC	0	45	0.00	435.48	0.23	0.01	0.89
1 A 2 d Pulp, Paper and Print	Biomass	N ₂ O	11	18	0.00	1000.00	0.22	0.00	0.90
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	354	354	0.00	51.58	0.22	0.00	0.90
3 D OTHER	Other Use of Chemicals	N ₂ O	99	34	0.00	500.00	0.20	0.00	0.91
1 A 2 f Other	Gaseous Fuels	N ₂ O	0	17	0.00	1000.05	0.20	0.00	0.91
3 A PAINT APPLICATION	Paint application	CO ₂	86	63	0.00	262.39	0.19	0.00	0.92
1 A 4 b Residential	Liquid Fuels	CO ₂	1621	1412	0.02	11.18	0.19	0.00	0.92
1 A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	744	1392	0.02	11.18	0.18	0.00	0.92
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	135	0.00	105.02	0.17	0.00	0.93
1 A 1 b Petroleum refining	Liquid Fuels	CO ₂	1910	2624	0.03	5.10	0.16	0.00	0.93
1 A 3 b Road Transportation	All Fuels	N ₂ O	82	239	0.00	50.25	0.14	0.00	0.93
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	1660	1051	0.01	11.18	0.14	0.00	0.94
1 A 1 b Petroleum refining	Liquid Fuels	N ₂ O	9	11	0.00	1000.00	0.13	0.00	0.94
1 A 3 d ii National navigation	Liquid Fuels	CO ₂	262	213	0.00	50.64	0.13	0.00	0.94
1 A 1 a Public Electricity and Heat Production	Other Fuels	N ₂ O	0	11	0.00	1000.00	0.13	0.00	0.95
2 B 5 Other	Production Quantities	CO ₂	65	104	0.00	100.50	0.12	0.00	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	286	341	0.00	30.41	0.12	0.00	0.95
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6301	1944	0.02	5.10	0.12	0.00	0.95
1 A 2 f Other	Liquid Fuels	N ₂ O	11	10	0.00	1000.05	0.12	0.00	0.96
1 A 4 b Residential	Liquid Fuels	N ₂ O	11	10	0.00	1000.05	0.11	0.00	0.96
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-164	-164	0.00	54.83	0.11	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO ₂	1372	1384	0.02	5.83	0.10	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CO ₂	0	53	0.00	150.33	0.09	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N ₂ O	6	8	0.00	1000.00	0.09	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	820	600	0.01	11.18	0.08	0.00	0.97
1 B 2 a Oil	Liquid Fuels	CH ₄	51	61	0.00	100.08	0.07	0.00	0.97
1 A 4 b Residential	Gaseous Fuels	CO ₂	0	487	0.01	11.18	0.06	0.00	0.97
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	0	476	0.01	11.18	0.06	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N ₂ O	5	5	0.00	1001.80	0.06	0.00	0.97
1 A 4 a Commercial / Institutional	Liquid Fuels	N ₂ O	2	5	0.00	1000.05	0.06	0.00	0.98
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	5	0.00	1000.00	0.06	0.00	0.98
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	567	463	0.01	10.05	0.05	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	CH ₄	19	27	0.00	150.03	0.05	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	0	339	0.00	11.18	0.04	0.00	0.98
1 A 4 a Commercial / Institutional	Gaseous Fuels	N ₂ O	0	4	0.00	1000.05	0.04	0.00	0.98
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N ₂ O	0	4	0.00	1000.00	0.04	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	N ₂ O	0	3	0.00	1000.00	0.04	0.00	0.98
1 A 3 a ii Domestic	Liquid Fuels	N ₂ O	2	3	0.00	1000.00	0.04	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N ₂ O	0	3	0.00	1001.80	0.04	0.00	0.98
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	105	105	0.00	28.08	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	0	467	0.01	5.83	0.03	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N ₂ O	0	3	0.00	1000.05	0.03	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO ₂	49	51	0.00	50.09	0.03	0.00	0.99
1 A 2 c Chemicals	Gaseous Fuels	CO ₂	0	411	0.00	5.83	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	743	385	0.00	5.83	0.03	0.00	0.99
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	-25	-25	0.00	88.47	0.03	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH ₄	30	20	0.00	101.98	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N ₂ O	1	2	0.00	1000.00	0.02	0.00	0.99
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	520	327	0.00	6.05	0.02	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	CO ₂	236	360	0.00	5.00	0.02	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Other Fuels	CO ₂	0	350	0.00	5.10	0.02	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N ₂ O	22	17	0.00	101.98	0.02	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH ₄	0	11	0.00	150.33	0.02	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N ₂ O	2	2	0.00	1001.27	0.02	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH ₄	99	41	0.00	40.31	0.02	0.00	0.99
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	32	32	0.00	46.46	0.02	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH ₄	7	9	0.00	150.33	0.02	0.00	0.99
5 B 2 Land converted to Cropland	Emissions/Removals	N ₂ O	24	24	0.00	51.58	0.01	0.00	1.00

Table A. 4 – Tier 2 Trend assessment with LULUCF: 1990-2008

Tier 2 Trend Assessment (1990-2008)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Trend	Combined	Level	Share	Cumulative
			Estimate (kton CO ₂ eq.) 1990	Estimate (kton CO ₂ eq.) 2008	Assess.	Uncert. %	Uncert. %	Level %	Total
4 D a AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	2098	1793	0.01	500.28	3.85	0.19	0.19
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	3355	-3837	0.04	39.58	1.75	0.09	0.28
1 B 2 d Other (Geothermal)	Energy Production	CO ₂	2	126	0.00	1000.05	138	0.07	0.35
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	990	0.01	99.29	1.10	0.05	0.40
6 A Municipal SWDL	SW Disposal on Land	CH ₄	1433	3149	0.02	67.27	1.09	0.05	0.45
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	151	102	0.00	1000.05	0.85	0.04	0.50
1 B 2 b Natural gas	Gaseous Fuels	CH ₄	0	408	0.00	150.33	0.68	0.03	0.53
4 D b AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	1323	1070	0.01	113.05	0.62	0.03	0.56
1 A 3 b Road Transportation	All Fuels	CO ₂	9246	18346	0.08	7.07	0.58	0.03	0.59
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	156	226	0.00	1000.30	0.46	0.02	0.61
3 D OTHER	Other Use of Chemicals	N ₂ O	99	34	0.00	500.00	0.46	0.02	0.64
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	0	40	0.00	1000.00	0.45	0.02	0.66
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-577	-577	0.01	45.01	0.34	0.02	0.68
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6301	1944	0.06	5.10	0.31	0.02	0.69
1 A 2 f Other	Solid Fuels	CO ₂	2103	54	0.03	11.18	0.30	0.02	0.71
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	0	5153	0.06	5.10	0.29	0.01	0.72
1 B 2 a Oil	Liquid Fuels	CO ₂	105	629	0.01	50.16	0.28	0.01	0.73
1 A 2 f Other	Gaseous Fuels	CO ₂	0	2186	0.02	11.18	0.27	0.01	0.75
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	754	0.01	48.28	0.27	0.01	0.76
1 A 4 b Residential	Biomass	N ₂ O	73	65	0.00	1001.80	0.23	0.01	0.77
1 A 1 a Public Electricity and Heat Production	Biomass	N ₂ O	0	20	0.00	1000.00	0.23	0.01	0.78
2 F 2 Foam Blowing	Consumption	HFC	0	45	0.00	435.48	0.22	0.01	0.80
6 A 3 Industrial SWDL	Industrial Waste Disposal on	CH ₄	1599	1768	0.00	149.82	0.21	0.01	0.81
2 A 2 Lime Production	Production Quantities	CO ₂	178	378	0.00	105.34	0.20	0.01	0.82
1 A 2 f Other	Gaseous Fuels	N ₂ O	0	17	0.00	1000.05	0.19	0.01	0.82
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1385	1366	0.00	60.90	0.19	0.01	0.83
1 A 4 b Residential	Biomass	CH ₄	343	310	0.00	161.55	0.17	0.01	0.84
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	5	0.00	1000.00	0.15	0.01	0.85
2 A 7 Other	Production Quantities	CO ₂	64	181	0.00	113.66	0.13	0.01	0.86
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	4	0.00	1000.05	0.13	0.01	0.86
1 A 1 a Public Electricity and Heat Production	Other Fuels	N ₂ O	0	11	0.00	1000.00	0.12	0.01	0.87
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-164	-164	0.00	54.83	0.12	0.01	0.87
3 A PAINT APPLICATION	Paint application	CO ₂	86	63	0.00	262.39	0.12	0.01	0.88
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	1660	1051	0.01	11.18	0.11	0.01	0.89
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	228	13	0.00	39.58	0.11	0.01	0.89
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	135	0.00	105.02	0.11	0.01	0.90
1 B 2 b Natural gas	Gaseous Fuels	CO ₂	0	53	0.00	150.33	0.09	0.00	0.90
1 B 1 a Coal Mining	Solid Fuels	CH ₄	66	0	0.00	100.12	0.09	0.00	0.91
1 A 3 b Road Transportation	All Fuels	N ₂ O	82	239	0.00	50.25	0.08	0.00	0.91
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	108	108	0.00	34.61	0.08	0.00	0.91
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	386	0.00	53.62	0.07	0.00	0.92
1 A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	744	1392	0.01	11.18	0.06	0.00	0.92
1 A 4 b Residential	Liquid Fuels	CO ₂	1621	1412	0.01	11.18	0.06	0.00	0.92
1 A 4 b Residential	Gaseous Fuels	CO ₂	0	487	0.01	11.18	0.06	0.00	0.93
1 A 2 f Other	Solid Fuels	N ₂ O	5	0	0.00	1000.05	0.06	0.00	0.93
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	0	476	0.01	11.18	0.06	0.00	0.93
1 A 3 d ii National navigation	Liquid Fuels	CO ₂	262	213	0.00	50.64	0.05	0.00	0.94
1 A 2 d Pulp, Paper and Print	Biomass	N ₂ O	11	18	0.00	1000.00	0.05	0.00	0.94
2 A 1 Cement Production	Production Quantities	CO ₂	3107	4110	0.00	10.10	0.05	0.00	0.94
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO ₂	51	56	0.00	1000.05	0.05	0.00	0.94
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	820	600	0.00	11.18	0.05	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	0	339	0.00	11.18	0.04	0.00	0.95
1 A 4 a Commercial / Institutional	Gaseous Fuels	N ₂ O	0	4	0.00	1000.05	0.04	0.00	0.95
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N ₂ O	0	4	0.00	1000.00	0.04	0.00	0.95
1 A 4 b Residential	Liquid Fuels	N ₂ O	11	10	0.00	1000.05	0.04	0.00	0.95
4 A ENTERIC FERMENTATION	Population size	CH ₄	2637	2958	0.00	20.90	0.04	0.00	0.96
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	354	354	0.00	51.58	0.04	0.00	0.96
1 A 2 f Other	Liquid Fuels	N ₂ O	11	10	0.00	1000.05	0.04	0.00	0.96
1 A 2 c Chemicals	Gaseous Fuels	N ₂ O	0	3	0.00	1000.00	0.04	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N ₂ O	0	3	0.00	1001.80	0.03	0.00	0.96
1 A 2 a Iron and Steel	Solid Fuels	CO ₂	466	25	0.01	5.83	0.03	0.00	0.96
1 A 3 b Road Transportation	All Fuels	CH ₄	99	41	0.00	40.31	0.03	0.00	0.97
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	743	385	0.01	5.83	0.03	0.00	0.97
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	0	467	0.01	5.83	0.03	0.00	0.97
2 B 5 Other	Production Quantities	CO ₂	65	104	0.00	100.50	0.03	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N ₂ O	0	3	0.00	1000.05	0.03	0.00	0.97
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	-25	-25	0.00	88.47	0.03	0.00	0.97
1 A 2 f Other	Biomass	N ₂ O	21	27	0.00	1001.80	0.03	0.00	0.97
1 A 2 c Chemicals	Gaseous Fuels	CO ₂	0	411	0.00	5.83	0.03	0.00	0.98
1 A 4 a Commercial / Institutional	Liquid Fuels	N ₂ O	2	5	0.00	1000.05	0.02	0.00	0.98
2 B 2 Nitric Acid Production	Production Quantities	CO ₂	567	463	0.00	10.05	0.02	0.00	0.98
1 A 1 b Petroleum refining	Liquid Fuels	CO ₂	1910	2624	0.00	5.10	0.02	0.00	0.98
1 A 1 a Public Electricity and Heat Production	Other Fuels	CO ₂	0	350	0.00	5.10	0.02	0.00	0.98
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	520	327	0.00	6.05	0.02	0.00	0.98
4 F FIELD BURNING OF AGRICULTURAL WASTES	Gaseous Fuels	CH ₄	0	11	0.00	150.33	0.02	0.00	0.98
1 A 2 f Other	Residues Burning	CH ₄	30	20	0.00	101.98	0.02	0.00	0.98
1 A 2 f Other	Liquid Fuels	CO ₂	3375	3864	0.00	11.18	0.02	0.00	0.98
1 A 2 c Chemicals	Liquid Fuels	CO ₂	1372	1384	0.00	5.83	0.02	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N ₂ O	2	1	0.00	1000.00	0.01	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO ₂	85	102	0.00	500.00	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 A 2 f Other	Other Fuels	N ₂ O	0	1	0.00	1000.05	0.01	0.00	0.99
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	N ₂ O	23	1	0.00	39.58	0.01	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
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	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 3 c Railways	Liquid Fuels	CO ₂	173	79	0.00	7.07	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N ₂ O	22	17	0.00	101.98	0.01	0.00	0.99
1 A 2 a Iron and Steel	Liquid Fuels	CO ₂	154	47	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
1 A 3 d ii National navigation	Liquid Fuels	N ₂ O	2	2	0.00	1001.27	0.01	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	N ₂ O	2	3	0.00	1000.00	0.01	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH ₄	19	27	0.00	150.03	0.01	0.00	0.99
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	652	0.00	31.57	0.01	0.00	0.99
1 A 2 f Other	Solid Fuels	CH ₄	4	1	0.00	150.33	0.01	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy	Liquid Fuels	CO ₂	49	0	0.00	11.18	0.01	0.00	0.99
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1386	1655	0.00	43.88	0.01	0.00	0.99
1 A 2 f Other	Other Fuels	CO ₂	12	72	0.00	11.18	0.01	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO ₂	0	100	0.00	5.83	0.01	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	CO ₂	10	1	0.00	50.25	0.01	0.00	0.99
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	105	105	0.00	28.08	0.01	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7659	8978	0.00	5.10	0.00	0.00	1.00

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 judgement.

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 AP42¹⁶⁴;
- 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;

¹⁶⁴ 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 table¹⁶⁵

The uncertainty was estimated in a consistent way for all years from 1990 to 2008. However, the table presents information only for 2008 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 values¹⁶⁶. 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));

¹⁶⁵ Tables provided in excel annex

¹⁶⁶ 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)).

Table B. 1 – Tier 1 Uncertainty calculation and reporting (IPCC Good Practice Guidance and Uncertainty Management Table 6.1)

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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	CO ₂	6,301	1,944	15	30	35	0.13	-0.10	0.03	-0.49	0.23	0.56
	Public Electricity and Heat Production	S	1A1a	CO ₂	7,659	8,978	15	30	35	0.60	-0.01	0.15	-0.05	1.04	1.04
	Public Electricity and Heat Production	G	1A1a	CO ₂	0	5,153	15	30	35	0.34	0.08	0.08	0.42	0.60	0.73
	Public Electricity and Heat Production	O	1A1a	CO ₂	0	350	15	30	35	0.02	0.01	0.01	0.03	0.04	0.05
	Petroleum refining	L	1A1b	CO ₂	1,910	2,624	1	5	5	0.18	0.00	0.04	0.02	0.30	0.30
	Petroleum refining	G	1A1b	CO ₂	0	21	1	5	5	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid fuels and Other Energy Industries	L	1A1c	CO ₂	49	0	15	15	23	0.00	0.00	0.00	-0.01	0.00	0.01
	Manufacture of Solid fuels and Other Energy Industries	S	1A1c	CO ₂	25	0	17	25	33	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	L	1A2a	CO ₂	154	47	8	10	13	0.00	0.00	0.00	-0.01	0.01	0.01
	Iron and Steel	S	1A2a	CO ₂	466	25	8	10	13	0.00	-0.01	0.00	-0.05	0.00	0.05
	Iron and Steel	G	1A2a	CO ₂	0	100	8	10	13	0.01	0.00	0.00	0.01	0.01	0.01
	Iron and Steel	O	1A2a	CO ₂	3	1	8	10	13	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	CO ₂	1,372	1,384	8	10	13	0.11	-0.01	0.02	-0.03	0.16	0.16
	Chemicals	S	1A2c	CO ₂	44	61	8	10	13	0.01	0.00	0.00	0.00	0.01	0.01
	Chemicals	G	1A2c	CO ₂	0	411	8	10	13	0.04	0.01	0.01	0.03	0.05	0.06
	Chemicals	O	1A2c	CO ₂	63	64	8	10	13	0.01	0.00	0.00	0.00	0.01	0.01
	Pulp, Paper and Print	L	1A2d	CO ₂	743	385	8	10	13	0.03	-0.01	0.01	-0.04	0.04	0.06
	Pulp, Paper and Print	G	1A2d	CO ₂	0	467	8	10	13	0.04	0.01	0.01	0.04	0.05	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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Food Processing, Beverages and Tobacco	L	1A2e	CO ₂	820	600	10	5	11	0.09	-0.01	0.01	-0.03	0.07	0.08
	Food Processing, Beverages and Tobacco	S	1A2e	CO ₂	1	0	10	5	11	0.00	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	G	1A2e	CO ₂	0	339	10	5	11	0.05	0.01	0.01	0.03	0.04	0.05
	Other	L	1A2f	CO ₂	3,375	3,864	96	60	115	0.40	-0.01	0.06	-0.03	0.45	0.64
	Other	S	1A2f	CO ₂	2,103	54	96	60	115	0.00	-0.04	0.00	-0.21	0.01	0.21
	Other	G	1A2f	CO ₂	0	2,186	96	60	115	0.25	0.04	0.04	0.18	0.25	0.31
	Other	O	1A2f	CO ₂	12	72	96	60	115	0.01	0.00	0.00	0.00	0.01	0.01
	Civil Aviation. Domestic	L	1A3aii	CO ₂	236	360	0	20	20	0.02	0.00	0.01	0.01	0.04	0.04
	..International	L	1A3ai	CO ₂	1,453	2,590	0	20	20	0.17	0.01	0.04	0.06	0.30	0.31
	Road Transportation		1A3b	CO ₂	9,246	18,346	115	115	163	1.70	0.11	0.30	0.56	2.12	2.30
	Railways	S	1A3c	CO ₂	0	0	5	5	7	0.00	0.00	0.00	0.00	0.00	0.00
	Railways	L	1A3c	CO ₂	173	79	5	5	7	0.01	0.00	0.00	-0.01	0.01	0.01
	Navigation. Domestic	L	1A3dii	CO ₂	262	213	101	10	101	0.14	0.00	0.00	-0.01	0.02	0.03
	..International	L	1A3di	CO ₂	1,383	1,952	101	10	101	1.29	0.00	0.03	0.02	0.23	0.23
	Commercial / Institutional	L	1A4a	CO ₂	744	1,392	10	5	11	0.20	0.01	0.02	0.04	0.16	0.17
	Commercial / Institutional	G	1A4a	CO ₂	0	476	10	5	11	0.07	0.01	0.01	0.04	0.06	0.07
	Commercial / Institutional	B	1A4a	CO ₂	0	9	60	5	60	0.01	0.00	0.00	0.00	0.00	0.00
	Residential	L	1A4b	CO ₂	1,621	1,412	10	5	11	0.21	-0.01	0.02	-0.05	0.16	0.17
	Residential	G	1A4b	CO ₂	0	487	10	5	11	0.07	0.01	0.01	0.04	0.06	0.07
	Agriculture / Forestry / Fishing	L	1A4c	CO ₂	1,660	1,051	111	20	115	0.89	-0.02	0.02	-0.08	0.12	0.15
	Agriculture / Forestry / Fishing	G	1A4c	CO ₂	0	21	111	20	115	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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
Fugitive Emissions from Fuels	Agriculture / Forestry / Fishing	B	1A4c	CO2	0	1	261	20	262	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	L	1A5	CO2	95	85	25	15	29	0.01	0.00	0.00	0.00	0.01	0.01
	Other Combustion	S	1A5	CO2	8	0	25	15	29	0.00	0.00	0.00	0.00	0.00	0.00
	Solid fuels		1B1	CO2	9	0	18	300	308	0.00	0.00	0.00	-0.02	0.00	0.02
	Oil and natural gas		1B2	CO2	155	860	65	1,850	1,852	2.21	0.01	0.01	2.56	3.90	4.70
Industrial Processes	Mineral Products		2A	CO2	3,384	4,808	448	10,083	10,440	2.08	0.01	0.08	0.31	2.24	2.27
	Chemical Industry		2B	CO2	634	756	901	9,205	9,275	0.50	0.00	0.01	0.08	0.49	0.55
	Metal Production		2C	CO2	16	16	140	380	405	0.02	0.00	0.00	0.00	0.03	0.03
	Other Production		2D	CO2	0	0	1,210	1,000	2,115	0.00	0.00	0.00	0.00	0.00	0.00
	Solvent And Other Product Use				86	63	175	1,828	1,837	0.21	0.00	0.00	-0.19	0.38	0.49
Fuel Combustion	Paint Application		3A	CO2											
	Degreasing And Dry Cleaning		3B	CO2	7	5	110	0	110	0.00	0.00	0.00	0.00	0.00	0.00
	Chemical Products, Manufacture And Processing		3C	CO2	51	56	1,430	4,350	4,895	0.19	0.00	0.00	0.00	0.30	0.30
	Other		3D	CO2	85	102	2,035	576	2,291	0.32	0.00	0.00	-0.01	0.15	0.16
	Waste Incineration		6C	CO2	10	1	148	200	273	0.00	0.00	0.00	-0.01	0.00	0.01
	Public Electricity and Heat Production	L	1A1a	CH4	1	1	15	900	900	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	S	1A1a	CH4	1	1	15	900	900	0.00	0.00	0.00	0.00	0.00	0.01
	Public Electricity and Heat Production	G	1A1a	CH4	0	2	15	900	900	0.00	0.00	0.00	0.00	0.01	0.01

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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Public Electricity and Heat Production	B	1A1a	CH ₄	0	1	15	900	900	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	O	1A1a	CH ₄	0	0	15	900	900	0.00	0.00	0.00	0.00	0.00	0.00
	Petroleum refining	L	1A1b	CH ₄	2	2	1	150	150	0.00	0.00	0.00	0.00	0.01	0.01
	Petroleum refining	G	1A1b	CH ₄	0	0	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid fuels and Other Energy Industries	L	1A1c	CH ₄	0	0	15	450	450	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid fuels and Other Energy Industries	S	1A1c	CH ₄	0	0	17	750	750	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	L	1A2a	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	S	1A2a	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	G	1A2a	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	B	1A2a	CH ₄	0	0	63	300	312	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	O	1A2a	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	CH ₄	1	1	8	300	300	0.00	0.00	0.00	0.00	0.01	0.01
	Chemicals	S	1A2c	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	G	1A2c	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	B	1A2c	CH ₄	0	0	63	300	312	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	O	1A2c	CH ₄	0	0	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	L	1A2d	CH ₄	2	2	8	300	300	0.00	0.00	0.00	0.00	0.01	0.01
	Pulp, Paper and Print	G	1A2d	CH ₄	0	1	8	300	300	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	B	1A2d	CH ₄	19	27	63	300	312	0.05	0.00	0.00	0.01	0.09	0.09
	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

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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Food Processing, Beverages and Tobacco	S	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	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	7	9	96	1,800	1,803	0.02	0.00	0.00	0.00	0.03	0.05
	Other	S	1A2f	CH ₄	4	1	96	1,800	1,803	0.00	0.00	0.00	-0.01	0.00	0.01
	Other	G	1A2f	CH ₄	0	11	96	1,800	1,803	0.02	0.00	0.00	0.03	0.04	0.05
	Other	B	1A2f	CH ₄	2	4	606	1,800	1,916	0.01	0.00	0.00	0.00	0.01	0.02
	Other	O	1A2f	CH ₄	0	0	96	1,800	1,803	0.00	0.00	0.00	0.00	0.00	0.00
	Civil Aviation. Domestic	L	1A3aii	CH ₄	1	0	0	400	400	0.00	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3ai	CH ₄	3	2	0	400	400	0.00	0.00	0.00	0.00	0.00	0.00
	Road Transportation		1A3b	CH ₄	99	41	115	920	927	0.02	0.00	0.00	-0.05	0.04	0.08
	Railways	S	1A3c	CH ₄	0	0	5	40	40	0.00	0.00	0.00	0.00	0.00	0.00
	Railways	L	1A3c	CH ₄	0	0	5	40	40	0.00	0.00	0.00	0.00	0.00	0.00
	Navigation. Domestic	L	1A3dii	CH ₄	0	0	101	200	224	0.00	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3di	CH ₄	0	1	101	200	224	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	L	1A4a	CH ₄	1	2	10	150	150	0.00	0.00	0.00	0.00	0.01	0.01
	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	0	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	B	1A4b	CH ₄	343	310	60	150	162	0.65	0.00	0.01	-0.30	1.08	1.12

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 sensisitivity	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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
Fugitive Emissions from Fuels	Agriculture / Forestry / Fishing	L	1A4c	CH ₄	3	2	111	440	492	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	G	1A4c	CH ₄	0	0	111	440	492	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	B	1A4c	CH ₄	0	0	261	440	530	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	L	1A5	CH ₄	0	0	25	340	341	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	S	1A5	CH ₄	0	0	25	340	341	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Solid fuels		1B1	CH ₄	66	0	18	300	308	0.00	0.00	0.00	-0.14	0.00	0.14
	Oil and natural gas		1B2	CH ₄	51	469	65	1,250	1,262	0.88	0.01	0.01	1.00	1.56	1.88
Agriculture	Mineral Products		2A	CH ₄	1	2	448	75	473	0.00	0.00	0.00	0.00	0.00	0.00
	Chemical Industry		2B	CH ₄	8	10	901	9,200	9,274	0.01	0.00	0.00	0.00	0.02	0.02
	Enteric Fermentation		4A	CH ₄	2,637	2,958	3,641	510	3,859	1.10	-0.01	0.05	-0.12	1.39	1.42
	Manure Management		4B	CH ₄	1,385	1,366	3,023	1,448	3,896	1.58	-0.01	0.02	-0.60	2.71	2.85
Waste	Rice Cultivation		4C	CH ₄	227	386	393	282	513	0.27	0.00	0.01	0.07	0.36	0.36
	Field Burning Of Agricultural Wastes		4F	CH ₄	30	20	500	100	510	0.03	0.00	0.00	-0.01	0.01	0.01
	Urban Solid Waste Disposal On Land		6A	CH ₄	1,433	3,149	50	148	157	2.97	0.02	0.05	1.16	4.93	5.67
	Industrial Solid Waste Disposal On Land		6A	CH ₄	1,599	1,768	409	321	530	3.54	0.00	0.03	-0.61	2.83	3.65
	Industrial Wastewater		6B	CH ₄	1,386	1,655	25	36	44	0.95	0.00	0.03	-0.05	1.39	1.39
	Domestic and Commercial wastewater		6B	CH ₄	1,056	754	30	38	48	0.48	-0.01	0.01	-0.35	0.65	0.74
	Waste Incineration		6C	CH ₄	0	0	148	400	446	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	L	1A1a	N ₂ O	15	5	15	6,000	6,000	0.06	0.00	0.00	-0.24	0.11	0.27

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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Public Electricity and Heat Production	S	1A1a	N ₂ O	36	42	15	6,000	6,000	0.56	0.00	0.00	-0.05	0.98	0.98
	Public Electricity and Heat Production	G	1A1a	N ₂ O	0	40	15	6,000	6,000	0.52	0.00	0.00	0.66	0.93	1.14
	Public Electricity and Heat Production	B	1A1a	N ₂ O	0	20	15	6,000	6,000	0.27	0.00	0.00	0.33	0.47	0.57
	Public Electricity and Heat Production	O	1A1a	N ₂ O	0	11	15	6,000	6,000	0.14	0.00	0.00	0.18	0.25	0.30
	Petroleum refining	L	1A1b	N ₂ O	9	11	1	1,000	1,000	0.14	0.00	0.00	-0.01	0.26	0.26
	Petroleum refining	G	1A1b	N ₂ O	0	0	1	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid fuels and Other Energy Industries	L	1A1c	N ₂ O	0	0	15	3,000	3,000	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid fuels and Other Energy Industries	S	1A1c	N ₂ O	0	0	17	5,000	5,000	0.00	0.00	0.00	-0.01	0.00	0.01
	Iron and Steel	L	1A2a	N ₂ O	1	0	8	2,000	2,000	0.00	0.00	0.00	-0.01	0.00	0.01
	Iron and Steel	S	1A2a	N ₂ O	1	0	8	2,000	2,000	0.00	0.00	0.00	-0.02	0.00	0.02
	Iron and Steel	G	1A2a	N ₂ O	0	1	8	2,000	2,000	0.01	0.00	0.00	0.01	0.02	0.02
	Iron and Steel	B	1A2a	N ₂ O	0	0	63	2,000	2,002	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	O	1A2a	N ₂ O	0	0	8	2,000	2,000	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	N ₂ O	6	8	8	2,000	2,000	0.10	0.00	0.00	-0.01	0.18	0.19
	Chemicals	S	1A2c	N ₂ O	0	0	8	2,000	2,000	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	G	1A2c	N ₂ O	0	3	8	2,000	2,000	0.04	0.00	0.00	0.05	0.07	0.09
	Chemicals	B	1A2c	N ₂ O	1	2	63	2,000	2,002	0.03	0.00	0.00	0.00	0.05	0.05
	Chemicals	O	1A2c	N ₂ O	0	0	8	2,000	2,000	0.01	0.00	0.00	0.00	0.01	0.01
	Pulp, Paper and Print	L	1A2d	N ₂ O	2	1	8	2,000	2,000	0.01	0.00	0.00	-0.02	0.02	0.03
	Pulp, Paper and Print	G	1A2d	N ₂ O	0	4	8	2,000	2,000	0.05	0.00	0.00	0.06	0.08	0.10

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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
	Pulp, Paper and Print	B	1A2d	N ₂ O	11	18	63	2,000	2,002	0.24	0.00	0.00	0.07	0.42	0.43
	Food Processing, Beverages and Tobacco	L	1A2e	N ₂ O	2	2	10	1,000	1,000	0.02	0.00	0.00	-0.02	0.04	0.04
	Food Processing, Beverages and Tobacco	S	1A2e	N ₂ O	0	0	10	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	G	1A2e	N ₂ O	0	3	10	1,000	1,000	0.03	0.00	0.00	0.04	0.06	0.07
	Food Processing, Beverages and Tobacco	B	1A2e	N ₂ O	5	5	60	1,000	1,002	0.07	0.00	0.00	-0.02	0.12	0.12
	Other	L	1A2f	N ₂ O	11	10	96	12,000	12,000	0.13	0.00	0.00	-0.07	0.23	0.36
	Other	S	1A2f	N ₂ O	5	0	96	12,000	12,000	0.00	0.00	0.00	-0.09	0.00	0.09
	Other	G	1A2f	N ₂ O	0	17	96	12,000	12,000	0.22	0.00	0.00	0.28	0.39	0.48
	Other	B	1A2f	N ₂ O	21	27	606	12,000	12,018	0.36	0.00	0.00	0.02	0.63	0.65
	Other	O	1A2f	N ₂ O	0	1	96	12,000	12,000	0.01	0.00	0.00	0.02	0.03	0.03
	Civil Aviation. Domestic	L	1A3aii	N ₂ O	2	3	0	4,000	4,000	0.04	0.00	0.00	0.01	0.07	0.07
	..International	L	1A3ai	N ₂ O	13	23	0	4,000	4,000	0.30	0.00	0.00	0.11	0.53	0.54
	Road Transportation		1A3b	N ₂ O	82	239	115	1,150	1,156	0.16	0.00	0.00	0.11	0.28	0.31
	Railways	S	1A3c	N ₂ O	0	0	5	50	50	0.00	0.00	0.00	0.00	0.00	0.00
	Railways	L	1A3c	N ₂ O	11	5	5	50	50	0.00	0.00	0.00	-0.01	0.01	0.01
	Navigation. Domestic	L	1A3dii	N ₂ O	2	2	101	2,000	2,003	0.02	0.00	0.00	-0.02	0.04	0.04
	..International	L	1A3di	N ₂ O	11	16	101	2,000	2,003	0.21	0.00	0.00	0.03	0.36	0.37
	Commercial / Institutional	L	1A4a	N ₂ O	2	5	10	1,000	1,000	0.06	0.00	0.00	0.03	0.11	0.12
	Commercial / Institutional	G	1A4a	N ₂ O	0	4	10	1,000	1,000	0.05	0.00	0.00	0.06	0.09	0.10
	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	10	10	1,000	1,000	0.13	0.00	0.00	-0.07	0.23	0.24

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 e	Gg CO ₂ e	%	%	%	%	%	%	%	%	%
			A	B	C	D	E	F	G	H	I	J	K	L	M
LULUCF	Residential	B	1A4b	N ₂ O	73	65	60	1,000	1,002	0.86	0.00	0.00	-0.42	1.52	1.57
	Agriculture / Forestry / Fishing	L	1A4c	N ₂ O	151	102	111	2,100	2,147	0.15	0.00	0.00	-0.11	0.15	0.19
	Agriculture / Forestry / Fishing	G	1A4c	N ₂ O	0	0	111	2,100	2,147	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	B	1A4c	N ₂ O	0	3	261	2,100	2,177	0.01	0.00	0.00	0.00	0.01	0.01
	Other Combustion	L	1A5	N ₂ O	1	1	25	2,050	2,050	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	S	1A5	N ₂ O	0	0	25	2,050	2,050	0.00	0.00	0.00	0.00	0.00	0.00
	Chemical Industry		2B	N ₂ O	567	464	901	9,210	9,283	0.06	0.00	0.01	-0.04	0.11	0.11
	Other		3D	N ₂ O	99	34	2,035	200	2,158	0.23	0.00	0.00	0.00	0.00	0.00
	Manure Management		4B	N ₂ O	520	327	3,023	300	3,230	0.46	-0.01	0.01	-0.53	0.76	0.93
	Agricultural Soils		4D	N ₂ O	3,419	2,861	809	3,320	3,544	13.58	-0.02	0.05	-7.77	23.28	25.75
	Field Burning Of Agricultural Wastes		4F	N ₂ O	22	17	500	100	510	0.02	0.00	0.00	0.00	0.01	0.01
	Industrial Wastewater		6B	N ₂ O	156	226	25	1,000	1,000	2.96	0.00	0.00	0.51	5.23	5.25
	Domestic and Commercial wastewater		6B	N ₂ O	286	341	30	0	30	0.14	0.00	0.01	0.00	0.00	0.00
	Waste Incineration		6C	N ₂ O	0	0	148	400	446	0.00	0.00	0.00	0.00	0.00	0.00
	Changes In Forest And Other Woody Biomass Stocks		5A	CO ₂	168	-4,512	352	1,379	1,444	2.71	-0.08	-0.07	-3.84	-4.36	6.87
	Forest And Grassland Conversion		5B	CO ₂	190	190	491	928	1,155	0.55	0.00	0.00	-0.07	0.39	0.94
	CO ₂ Emissions And Removals From Soil		5D	CO ₂	105	105	419	811	1,016	0.11	0.00	0.00	-0.03	0.19	0.19
	Other		5E	CO ₂	1,114	1,114	418	829	1,020	1.14	0.00	0.02	-0.33	1.86	1.89
	Consumption Of Halocarbons and Sulphur Hexafluoride		2F	F G	59	1,050	867	3,443	3,685	1.81	0.02	0.02	2.05	3.05	3.68
Industrial Processes															

ANNEX C: Energy Balance Sheet for 2008

[illegible]

BALANÇO ENERGÉTICO		Gás Natural	Gás de Cidade	Gás de Coque	Gás de Alto Forno	Alcatrão	Gases Incombustíveis de Petroquímica	Hidrogénio	Gases e Outros Derivados	Hidroeletricidade e	Eólica e Geotérmica e Fot.	Termoelétricidade	Total de Electricidade	Calor	Resíduos Industriais	Lerhas e Resíduos Vegetais	Resíduos Sólidos Urbanos	Licores Sulfúricos	Outros Resíduos Renováveis	Bio gás	Biodiesel	Renováveis Sem Hídrica	TOTAL GERAL			
provisório tep		23	24	25	26	27	28	29	30 + 24 a 29	31	32	33	34 = 31 a 33	35	36	37	38	39	40	41	42	43 = 37 a 42	44 = 42 + 43 + 45 + 46 + 47 + 48 + 49			
2008		23	24	25	26	27	28	29	30 + 24 a 29	31	32	33	34 = 31 a 33	35	36	37	38	39	40	41	42	43 = 37 a 42	44 = 42 + 43 + 45 + 46 + 47 + 48 + 49			
IMPORTAÇÕES		1.	4 163 167										923 984										28 021 081			
PRODUÇÃO DOMÉSTICA		2.								627 456	514 882		1 142 338		41 030	1 985 559	182 765	789 311	34 793	22 799	149 003	3 164 230	4 347 588			
VARIAÇÃO DE "STOCKS"		3.	5 945																		- 837	- 837	97 178			
SAÍDAS		4.											112 918										3 836 162			
Exportações		4.1											112 918										2 719 245			
Transportes Marítimos Internacionais		4.2																					489 715			
Aviação Internacional		4.3																					627 202			
CONSUMO DE ENERGIA PRIMÁRIA		5.	4 157 222							627 456	514 882		1 953 404		41 030	1 985 559	182 765	789 311	34 793	22 799	132 206	3 147 433	34 435 338			
PARA NOVAS FORMAS DE ENERGIA		6.	2 997 143							627 456	514 882	-2 810 956	-2 810 996	-1 464 776	2 523	244 050	182 765	789 311			22 799	128 426	1 367 391	3 213 318		
Briquetes		6.1																								
Coque		6.2																								
Produtos de Petróleo		6.3																								
Gás de Cidade		6.4																								
Petroquímica		6.5						- 24 379		- 24 379											128 426	128 426	- 128 714			
Electricidade		6.6	1 970 751							627 456	514 882	-2 325 570	-2 325 570			61 957	182 765			19 729		264 451	2 829 906			
Cogeração		6.7	626 392					24 379		24 379					2 523	182 133		789 311		3 070		974 514	512 126			
Produção de Electricidade		6.7.1																					31 048			
(Central do Barreiro)		6.7.1.1																					9 740			
Refinação de Petróleo		6.7.2	28 206																				49 501			
Gás de Cidade		6.7.3																								
Agricultura		6.7.4	3 957																	329		329	2 325			
Alimentação e Bebidas		6.7.5	80 866																				30 288			
Textéis		6.7.6	59 985																				67 816			
Papel e Artigos de Papel		6.7.7	174 524																				232 400			
Químicas e Plásticos		6.7.8	113 462					24 379		24 379						164 763		789 311		1 328		955 402	31 210			
Cerâmicas		6.7.9	32 986																				10 443			
Vidro e Artigos de Vidro		6.7.10																					642			
Cimento		6.7.11																								
Metalurgias		6.7.12																								
Siderurgia		6.7.13																								
Vestuário, Calçado e Curtumes		6.7.14	1 982																				2 515			
Madeira e Artigos de Madeira		6.7.15														17 370						17 370	21 629			
Borracha		6.7.16																					615			
Metal-Electro-Mecânicas		6.7.17																								
Outras		6.7.18																								
Indústrias Extrativas		6.7.19	60 201																				7 887			
Serviços		6.7.20	34 163																				22 517			
CONSUMO DO SECTOR ENERGÉTICO		7.	110 345										605 301	270 736							3	3	1 466 752			
Consumo Próprio da Refinação		7.1	89 911										50 532	270 736									799 823			
Perdas da Refinação		7.2																					63 828			
Coque e outras não especificadas		7.3																								
Centrais Eléctricas		7.4											136 439										147 594			
Bombagem Hidroeléctrica		7.5											54 554										54 554			
Gás de Cidade		7.6																								
Extracção de Carvão, Petróleo e GN		7.7																					826			
Perdas de Transporte e Distribuição		7.8	21 434										362 576								3	3	385 717			
CONSUMO COMO MATÉRIA PRIMA		8.																					1 275 942			
DISPONÍVEL PARA CONSUMO FINAL		9.	1 449 734										4 139 099	1 194 040	38 507	1 741 469			34 793	3 777	1 789 039	16 479 427				
ACERTOS		10.	- 1 582										12								271	271	- 36 345			
CONSUMO FINAL		10.1	1 451 316										4 139 087	1 194 040	38 507	1 741 469			34 793	3 506	1 779 768	16 515 772				
AGRICULTURA E PISCAS		10.1.1	6 181										87 218	2 366							21	21	442 570			
Agricultura		10.1.1.1	6 128										87 218	2 366							21	21	374 263			
Piscas		10.1.2	53																				68 307			
INDÚSTRIAS EXTRATIVAS		10.2	7 172										49 882	30 944							4	4	154 411			
INDÚSTRIAS TRANSFORMADORAS		10.3	988 025										1 340 000	1 154 263	38 507	980 456		34 793		254	615 303	5 310 761				
Alimentação e Bebidas		10.3.1	79 874										152 856	70 540					1 589		89	94 487	538 210			
Textéis		10.3.2	115 728										103 010	50 203							1	55 663	343 189			
Papel e Artigos de Papel		10.3.3	47 337										222 110	775 888									1 086 465			
Químicas e Plásticos		10.3.4	81 125										200 188	217 645	20	36 716				56	36 774	766 048				
Cerâmicas		10.3.5	262 770										55 790	19 743	3 524	354 363							751 326			
Vidro e Artigos de Vidro		10.3.6	206 688										40 275	31									257 010			
Cimento		10.3.7	27 620										92 940		34 963				31 313				41 833	807 231		
Metalurgias		10.3.8	22 907										38 416										5 740	79 262		
Siderurgia		10.3.9	41 732										101 810											151 880		
Vestuário, Calçado e Curtumes		10.3.10	13 686										29 259	1 815										51 702		
Madeira e Artigos de Madeira		10.3.11	10 398										56 138	16 677		23 409								79 262		
Borracha		10.3.12	2 692										153 893	1 231										27 784		
Metal-Electro-Mecânicas		10.3.13	52 700										195 492											6 412	265 347	
Outras		10.3.14	2 848										32 847	510		836								23 859	40 783	
CONSTRUÇÃO E OBRAS PÚBLICAS		10.4	5 642										50 490											637 355		
TRANSPORTES		10.5	12 077										46 677											1 309	1 309	6 739 281
Aviação Nacional		10.5.1																							370 733	
Transportes Marítimos Nacionais		10.5.2																							192 077	
Caminho de Ferro		10.5.3											46 677												73 321	
Rodovias		10.5.5	12 077																						192 077	
SECTOR DOMÉSTICO		10.6	230 943										1 157 672			1 161 013								3 100 115		
SERVIÇOS		10.7	191 276										1 427 139	6 537											2 131 296	

ANNEX D: Standard Electronic Format Tables

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	3.52E+08	NO	NO	NO	NO	NO
Entity holding accounts	25799792	NO	NO	1245397	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	3.78E+08	NO	NO	1245397	NO	NO

Table 2 (a). Annual internal transactions

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Article 6 issuance and conversion												
Party-verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Article 3.3 and 3.4 issuance or cancellation												
3.3 Afforestation and reforestation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland management			NO				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired ICERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							NO	NO	NO	NO	NO	NO
Sub-total		NO	NO				NO	NO	NO	NO	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Retirement	27923069	NO	NO	1985373	NO	NO

Add registry

Delete registry

Table 2 (b). Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Transfers and acquisitions												
BE	NO	NO	NO	NO	NO	NO	27201	NO	NO	NO	NO	NO
CH	NO	NO	NO	721223	NO	NO	NO	NO	NO	117000	NO	NO
CZ	2607082	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
DE	3003316	NO	NO	1259	NO	NO	115691	NO	NO	49464	NO	NO
DK	12491009	NO	NO	134000	NO	NO	10953059	NO	NO	NO	NO	NO
ES	2065421	NO	NO	469029	NO	NO	7602846	NO	NO	NO	NO	NO
FR	930045	NO	NO	284000	NO	NO	6312292	NO	NO	15517	NO	NO
GB	4162000	NO	NO	712960	NO	NO	1462794	NO	NO	225000	NO	NO
IE	NO	NO	NO	NO	NO	NO	50000	NO	NO	NO	NO	NO
IT	131522	NO	NO	NO	NO	NO	21522	NO	NO	NO	NO	NO
LV	2000000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NL	629000	NO	NO	1304853	NO	NO	494410	NO	NO	198000	NO	NO
Sub-total	28019395	NO	NO	3627324	NO	NO	27039815	NO	NO	604981	NO	NO

Additional information

Independently verified ERUs								NO				
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Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	28019395	NO	NO	3627324	NO	NO	27039815	NO	NO	604981	NO	NO
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Table 3. Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Temporary CERs (tCERs)								
Expired in retirement and replacement accounts	NO							
Replacement of expired tCERs			NO	NO	NO	NO	NO	
Expired in holding accounts	NO							
Cancellation of tCERs expired in holding accounts	NO							
Long-term CERs (ICERs)								
Expired in retirement and replacement accounts		NO						
Replacement of expired ICERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of ICERs expired in holding accounts		NO						
Subject to replacement for reversal of storage		NO						
Replacement for reversal of storage			NO	NO	NO	NO		NO
Subject to replacement for non-submission of certification report		NO						
Replacement for non-submission of certification report			NO	NO	NO	NO		NO
Total			NO	NO	NO	NO	NO	NO

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	3.21E+08	NO	NO	NO	NO	NO
Entity holding accounts	29212224	NO	NO	2282367	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	NO	NO	NO
Retirement account	27923069	NO	NO	1985373	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	3.79E+08	NO	NO	4267740	NO	NO

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Issuance pursuant to Article 3.7 and 3.8	3.82E+08											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	3.82E+08	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	3503501	NO	NO	1533397	NO	NO	7917857	NO	NO	288000	NO	NO
Year 2 (2009)	28019395	NO	NO	3627324	NO	NO	27039815	NO	NO	604981	NO	NO
Year 3 (2010)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	31522896	NO	NO	5160721	NO	NO	34957672	NO	NO	892981	NO	NO
Total	4.13E+08	NO	NO	5.16E+06	NO	NO	3.50E+07	NO	NO	892981	NO	NO

Table 5 (b). Summary information on replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Previous CPs			NO	NO	NO	NO	NO	NO
Year 1 (2008)		NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)		NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)		NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)		NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO

Table 5 (c). Summary information on retirement

Year	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	27923069	NO	NO	1985373	NO	NO
Year 3 (2010)	NO	NO	NO	NO	NO	NO
Year 4 (2011)	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	27923069	NO	NO	1985373	NO	NO

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

Add transaction

Delete transaction

No corrective transaction

Table 6 (b). Memo item: Corrective transactions relating to replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

Add transaction

Delete transaction

No corrective transaction

Table 6 (c). Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

ANNEX E: Contribution of the Portuguese Geographic Institute for Portugal's reporting under Article 3, paragraphs 3 and 4, of the Kyoto Protocol, in the first year of the commitment period of the Protocol (2008)

ANNEX F: Carbon Stock Changes in Portuguese Forests

ANNEX G: Country specific data for grassland and cropland under specific management