

**PORTUGUESE NATIONAL INVENTORY REPORT
ON GREENHOUSE GASES, 1990 - 2006**

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

**Amadora
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Technical Reference

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ES.1 PREFACE

The Portuguese Environmental Agency (Agência Portuguesa do Ambiente)/ Ministry for the Environment, Land Use Planning and Regional Development (Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional), 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 Kyoto Protocol, 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.

This report constitutes the 2008 Portuguese NIR and refers to the inventory time series for the period 1990-2006.

The 2008 submission includes all recalculations that were performed since the submission of last year, taking into account the recommendations from the in-depth review of the Portuguese Initial Report, which took place from 21 to 26 May 2007. The recalculations resulted in the change to the final Portuguese Assign Amount.

Ministry for Environment, Land Use Planning and Regional
Development

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ES.2 EXECUTIVE SUMMARY

Background information on greenhouse gas inventories and climate change

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and to the Kyoto Protocol, Portugal is requested to provide each year an update of its inventory of emissions and removals of greenhouse gas not controlled by the Montreal Protocol, and supplementary information (Art. 7.1) of the KP, 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 2007 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 1990-2005.

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 2006, i.e., the inventory is internally consistent.

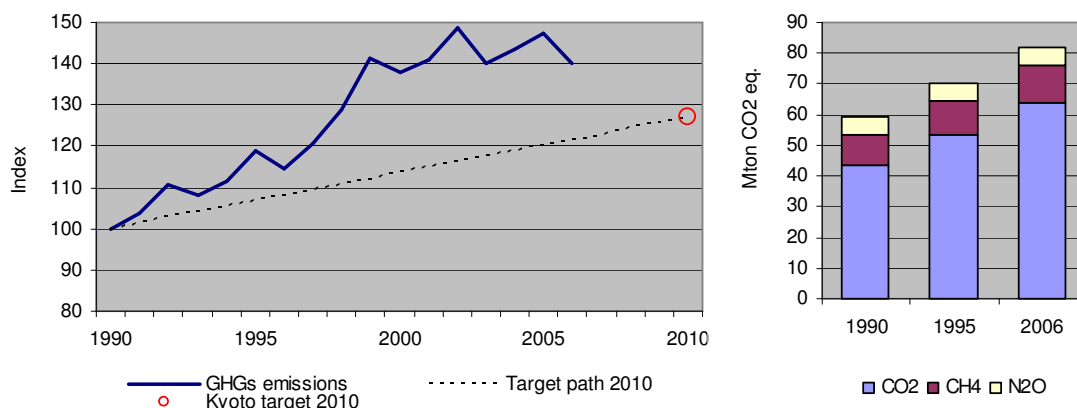
The report is structured according to the following source sectors: energy production and transformation, combustion in industry, domestic, agriculture, fisheries, institutional and commerce sectors, transportation (road, rail, maritime and air), industrial production and industrial and non industrial 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 2006, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated at about 82.7Mton CO₂eq., representing an increase of approximately 40 per cent compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27 per cent compared to

the 1990 level. Comparing the 1990-2006 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2006, 18 per cent above this target path (Figure ES. 1).

Figure ES. 1 – GHG emissions (without LULUCF)

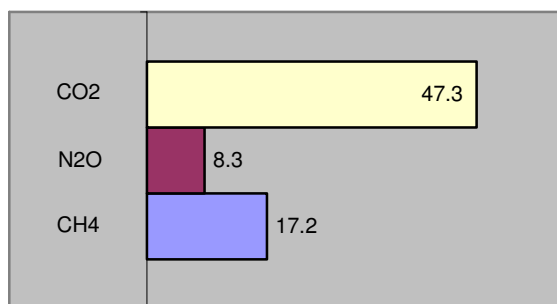


After a steady increase of the Portuguese emissions during the 90s, the growth of emissions thereafter has been more moderate and even appears to be a sort of stagnation in the more recent years. This situation is in part consequence of the implementation of some measures, such as the introduction of 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. However, the positive effect of these measures has been out weighted by the overall increase of energy consumption which relies in majority in fossil fuel sources. Furthermore, actual annual emissions shows significant variations in relation to the concomitant pronounced annual fluctuations of hydroelectric power generation directly related to annual variations in precipitation.

The principal source of GHGs in Portugal in 2006 is the energy sector. The largest gas emitted is CO₂ representing 77 per cent of total GHGs emissions expressed as global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for about 90 per cent of total CO₂ emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2006, 84 per cent of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas) whereas the renewable energy represents the remaining part, i.e. 16 per cent in average.

Figure ES. 2 illustrates the growth of GHG in the period 1990-2006. CO₂ is the gas having registered the biggest increase, 47 per cent¹.

Figure ES. 2– Increase of emissions by gas over the 1990-2006 period (percent)



The overall trend for direct GHG emissions in the 1990-2006 period is presented in Table ES. 1.



Bibliography



Key Categories



Uncertainty

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 2006: 1 per cent)

Table ES. 1 – GHG emissions and removals in Portugal by gas: 1990-2006

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	CO ₂ equivalent (Gg)																
CO ₂ emissions including net CO ₂ from LULUCF	44,810	45,491	47,536	45,568	45,685	49,133	44,906	47,953	52,003	59,028	57,284	58,932	62,653	69,967	62,310	65,209	59,730
CO ₂ emissions excluding net CO ₂ from LULUCF	43,444	45,271	49,389	47,982	49,200	53,157	50,286	53,532	58,216	64,695	63,412	64,694	68,855	64,159	66,208	68,447	63,993
CH ₄ emissions including CH ₄ from LULUCF	10,240	10,591	10,566	10,550	11,014	11,385	11,415	11,592	12,135	12,329	11,644	11,936	12,282	12,708	12,032	12,452	11,913
CH ₄ emissions excluding CH ₄ from LULUCF	10,103	10,374	10,497	10,509	10,988	11,234	11,362	11,572	12,035	12,275	11,525	11,858	12,170	12,213	11,934	12,236	11,846
N ₂ O emissions including N ₂ O from LULUCF	5,601	5,628	5,600	5,496	5,758	5,847	6,146	6,147	5,899	6,318	6,297	6,310	6,391	5,851	5,990	5,771	6,055
N ₂ O emissions excluding N ₂ O from LULUCF	5,561	5,580	5,566	5,466	5,729	5,806	6,114	6,119	5,863	6,286	6,258	6,276	6,354	5,774	5,954	5,723	6,021
HFCs	NA,NENO	NA,NENO	NA,NENO	NA,NENO	NA,NENO	53	74	108	149	210	307	393	496.69	607.42	684.26	785.26	850.86
PFCs	NA,NENO	NA,NENO	NA,NENO	NA,NENO	NA,NENO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
SF ₆	NA,NENO	NA,NENO	NA,NENO	NA,NENO	NA,NENO	6	7	7	8	8	8	9	10.24	11.52	13.26	13.71	15.50
Total (including LULUCF)	60,652	61,710	63,702	61,614	62,456	66,424	62,547	65,806	70,194	77,893	75,540	77,580	81,833	89,145	81,029	84,230	78,564
Total (excluding LULUCF)	59,109	61,225	65,452	63,957	65,917	70,255	67,843	71,337	76,270	83,475	81,512	83,230	87,885	82,765	84,793	87,205	82,728

NEA- not Aplicable; NE - not Estimated; NO - not occurring

Overview of source and sink category 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 present direct GHG emissions by sector for 1990 and 2006, respectively.

Throughout this report, the reference to “total emissions” is meant to refer to “total emissions without LULUCF on a carbon equivalent basis”.

Figure ES. 3 – GHG emissions in Portugal by sector: 1990

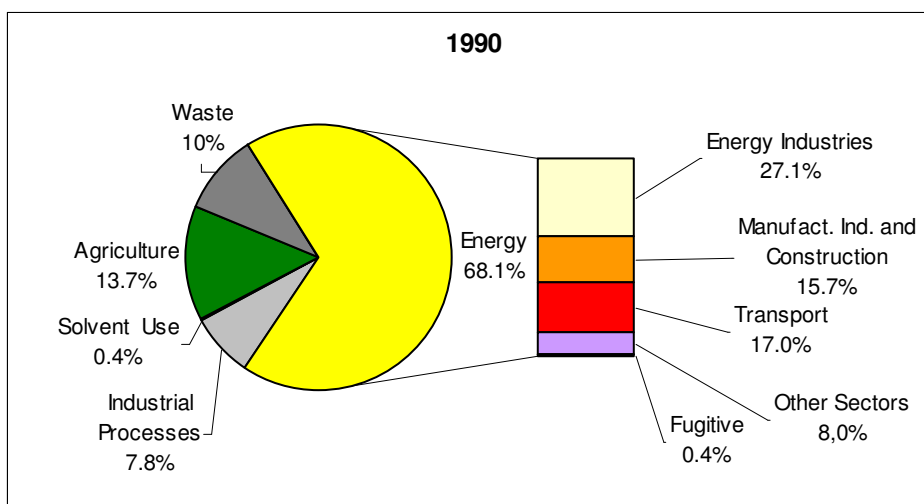
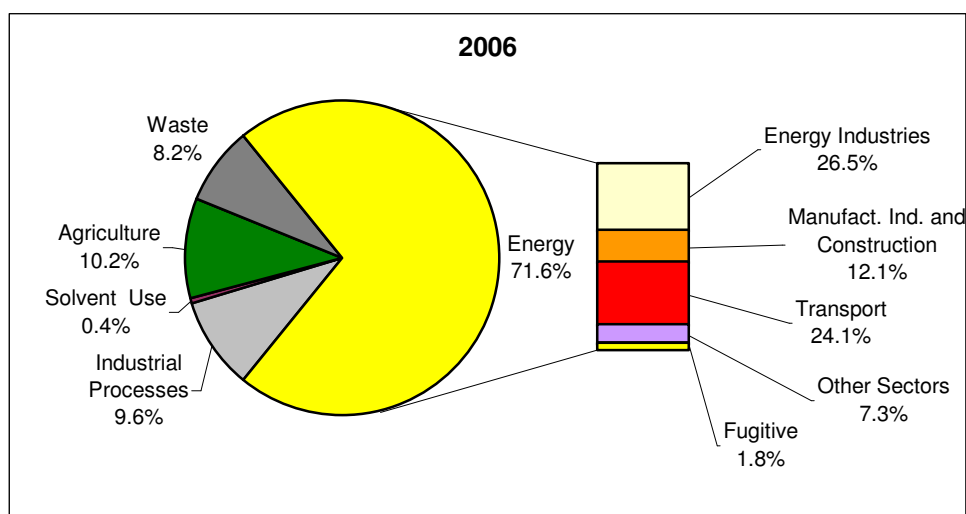


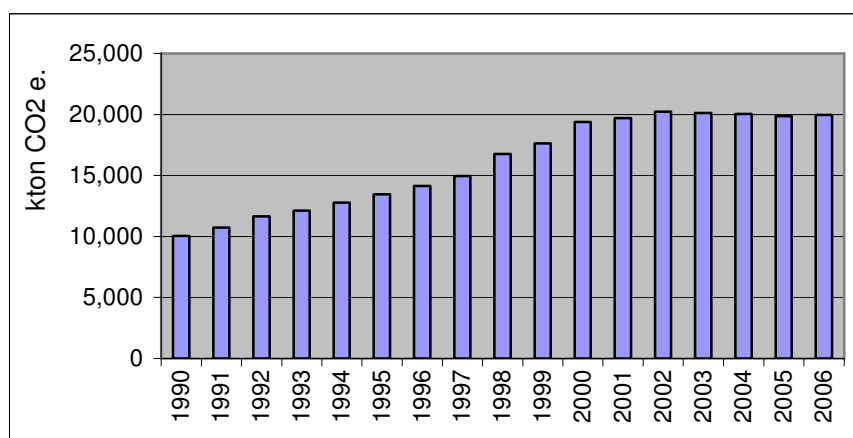
Figure ES. 4 – GHG emissions in Portugal by sector: 2006



Energy was by far the most important sector, accounting for 71.6 per cent of total emissions in 2006, and showing an increase of 47 per cent in the period 1990 through 2006. Energy industries and transport are the two most important sources representing respectively 26.5 per cent and 24.1 per cent of total emissions. This situation reflects the country heavy dependence on fossil fuels for electricity generation (which continues to grow following the continued increase of electricity demand) and transport sources.

Transportation sources, which are largely dominated by road traffic, are one of the sectors that are rising faster. In the period 1990-2006 these emissions increased 97.9 per cent, due to the steady growth of vehicle fleets and road travel, in association with the increase in family income and the strong investment in road infrastructure of the country, that was done 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, when the growth of transport emission has first stabilised and then even started to decline in most recent years.

Figure ES. 5 – Transport emissions (1990-2006)



Agriculture was the second most significant source of GHGs emissions (10.2 per cent of total emissions). Waste and industrial processes represented, respectively, 8.2 per cent and 9.2 per cent of Portuguese emissions in 2006, representing since 1990 a variation of approximately 14.7 per cent (waste) and 71.6 per cent (industrial processes). Solvent use represents less than 1 per cent 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 (1.5 Mt CO₂ eq.) to becoming a carbon sink in 1992 and the following years until 2002. The situation was again reverted in 2003 due to 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 1990-2006 period.

Table ES. 2 – GHG emissions and removals in Portugal by sector: 1990-2006

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	CO ₂ equivalent (Gg)																
1. Energy	40,262	42,072	46,408	45,018	45,628	48,959	46,397	49,020	53,361	60,569	59,080	60,340	64,268	59,785	61,328	63,916	59,244
2. Industrial Processes	4,611	4,584	4,352	4,204	5,009	5,809	5,575	6,277	6,543	6,269	6,190	6,766	7,236	7,203	7,535	7,725	7,911
3. Solvent and Other Product Use	220	234	243	236	253	256	275	285	290	285	290	304	312	318	325	332	339
4. Agriculture	8,088	8,195	8,052	7,933	8,159	8,174	8,514	8,415	8,414	8,534	8,797	8,653	8,689	8,070	8,340	8,081	8,434
5. Land-Use Change and Forestry ⁽⁷⁾	1,543	486	-1,750	-2,343	-3,461	-3,831	-5,296	-5,531	-6,076	-5,581	-5,972	-5,650	-6,052	6,381	-3,765	-2,975	-4,164
6. Waste	5,928	6,139	6,397	6,567	6,868	7,058	7,082	7,340	7,662	7,818	7,154	7,167	7,380	7,390	7,265	7,151	6,799
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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.

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

Table ES. 3– Indirect GHG and SO_x emissions: 1990-2006

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	% change 1990-05
	(Gg)																	
CO	892	906	939	906	878	862	843	810	796	770	755	706	694	679	670	642	631	-29.2
NO _x	245	259	278	267	266	276	269	269	278	288	285	287	295	272	274	274	249	1.8
NM VOC	304	311	318	307	312	311	312	313	312	303	297	299	301	302	303	301	301	-1.0
SO ₂	320	311	372	316	298	334	273	294	344	344	307	296	296	202	214	214	191	-40.4

In 2006, SO_x, CO and NMVOC emissions have decreased from 1990 levels: -40.4%, -29.2% and -1%, respectively. NO_x emissions have increased 1.8% (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 NMVOC emissions, respectively 40.9% and 16.8% of 2006 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. Transports represents the second most important source of CO emissions (40.3%) after Other sectors (commercial/institutional, residential and agriculture/ Forestry) which amounts for 40.7% of the 2006 totals.

Since the early 2000, NO_x emissions from transport has been presenting a decreasing tendency; and CO and NMVOC emissions recorded real reductions in the 1990-2006 period, respectively, -49.6% and -56%.

SO_x emissions are mainly generated in the energy industry sector (61.5% of total emissions in 2006) and combustion in manufacturing industries (18.7% of total emissions in 2006), 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. However the emissions variation in the period 1990-2006 shows a decrease in SO_x emissions in both sub-categories: manufacturing industries –55.8% and energy industries –41.6%. These tendencies 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.

CHAPTER: 1 INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

1.1.A 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, 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 emission 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.B 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. 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.C 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 United Nations Framework Convention on Climate Change (UNFCCC) on May 31, 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, adopted some years later in 1997, represents a deepening in the commitments inscribed in the Convention. The Protocol introduced legally binding commitments for developed countries to reduce their collective emissions of greenhouse gases by at least 5 per cent by the period 2008-12 (first commitment period of the Protocol), below their 1990 level.

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

The KP entered into force on 16 February 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 per cent 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.D History of national inventories

Air emission inventories in Portugal were only initiated in the late ninety-eighties/ early nineties 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 program. A major breakthrough occurred during the CORINAIR90 inventory realized during 1992 and 1993 by General-Directorate of Environment (DGA, renamed now IA). 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 and third communications was 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 (1990-2006), 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 (Pereira et al,2002) for the quantification of carbon sinks in Portugal, made under the development of PNAC and PTEN national programmes;

- Revision of the Energy Balances with comparison of information collected at IA (LCP Directive) and Statistical Information received at DGGE: 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 (IA/UE) for the determination of the Baseline Scenario under the CAFE program (IA,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 review (October 2005).
- UNFCCC in-depth review of the Initial Report in May 2007 which fixed the Assigned Amount for the first commitment period.

1.1.E National Assigned Amount

Following the proposed ERT revisions from the in-depth review of the Initial Report, the Assigned Amount was fixed by:

Proposed Assigned Amount = (1990 emissions [except f-gases] + f-gases emissions in 1995 + 1990 deforestation emissions) x 5 x 1.27 = 381 937 527 t CO₂ eq.

		(t CO ₂ e)
	1990 emissions [except f-gases]	59 108 797
+	1995 f-gases emissions	57 642
+	1990 emissions from deforestation	
	(Article 3.7 KP)	981 203
=		60 147 642
x	Commitment period (years)	5
x	Burden Sharing Agreement Target	1.27
=	Total	381 937 527

1.1.F 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 2006.

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 industrial and non industrial use of solvents, waste production (urban, industrial and hospitals solid wastes, and domestic and industrial waste water treatment), agriculture, animal husbandry emissions, as well as emissions and removals from forestry and land use change.

1.1.G 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 (CO₂ equivalents – CO₂ Eq.). 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

1.2.A National Inventory System

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 system is to prepare in a timely fashion 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 Responsible Body appointed is the Institute for the Environment (IA), being responsible for: 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;

The sectoral Focal Points work with IA in the preparation of INERPA, and are responsible for fostering intra and inter-sectoral cooperation to ensure a more efficient use of resources; and

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.

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 INIERPA

Sector of Activity	Focal Point	Involved Entities
³ National Statistics	National Statistics Institute	
⁴ Environment Statistics	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

1.3 Inventory Preparation Process

1.3.A Responsibility

The National Environmental Agency (Agência Nacional 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 Greenhouse Gas (GHGs) 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 (National Environment Agency)

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

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Telephone: +351 21 472 83 82

Fax: + 351 21 471 90 74

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1.3.B 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



Bibliography



Key Categories

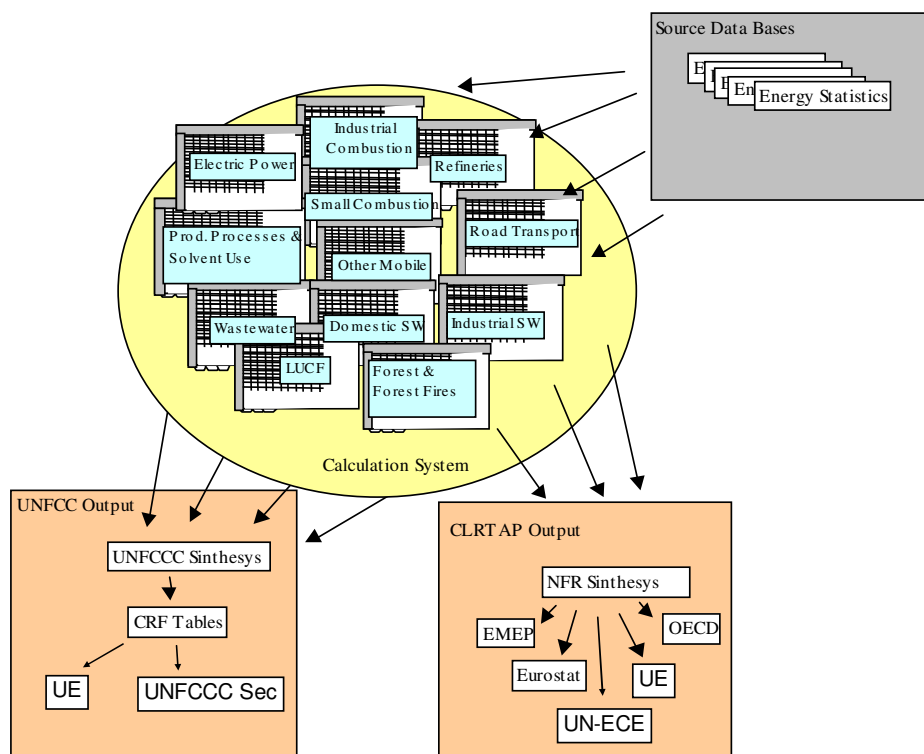


Uncertainty

³ InventAr, Estudos e Projectos Unip Lda

information and emission factors, and participates in the annual definition of priorities concerning the Methodological Development Programme (PDM). 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 below.

Figure 1.1 – Electronic System Structure of the estimation and reporting system



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 allow 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.

Annually reported data, e.g. CRF tables, are stored both in paper and magnetic format. IA plans to rebuild this informatics 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 2006 submission.

Table 1.3 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 1.3 – 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,D,OTH,PS	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	D	CR,OTH	CR,OTH	NA	NA						
1. Solid Fuels	NA	NA	NA	NA	NA	NA						
2. Oil and Natural Gas	D	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					NA	NA
B. Chemical Industry	D,T2	CS,PS	D	CR,OTH	D	CR,OTH					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	D	CR,CS,OTH			NA	NA						
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	D	D						
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,O	D	CR,D,OTH						
A. Solid Waste Disposal on Land	D	CS,D	D,T2	CS,D,OTH	D	CR,OTH						
B. Waste-water Handling	D		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 I.A)	NA	NA	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 1.4 gives an overview of the institutions and data sources providing data for the compilation of the Portuguese emission inventories.

Table 1.4 – 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 (DGGE): 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 • DGGE: energy balances
	CRF 1A3 – Transport	<ul style="list-style-type: none"> • DGGE: 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"> • DGGE: energy balances
CRF 1 B – Fugitive Emissions from Fuels		<ul style="list-style-type: none"> • DGGE: energy balances and statistical yearbooks • GALP
CRF 2 – Industrial Processes	CRF 2A – Mineral Products	<ul style="list-style-type: none"> • LPS, LCP • CIMPOR, SECIL • DGGE: 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"> • DGGE: energy balances • LCP • INE • Regional Air Inventories
	CRF 2C – Metal Production	<ul style="list-style-type: none"> • DGGE: energy balances • LCP • SN • INE • Regional Air Inventories
	CRF 2D – Other Production	<ul style="list-style-type: none"> • LCP • DGGE: 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"> • DGGE: energy balances • Gen-Dir of Enterprise (DGE) • INE
CRF 4 – Agriculture		<ul style="list-style-type: none"> • Ministry of Agriculture • General-Directorate for Forest Resources (DGRF) • INE: agriculture survey
CRF 5 – Land Use Change and Forestry		<ul style="list-style-type: none"> • DGRF • IGP • ISA
CRF 6 – Waste	CRF 6A – Solid Waste Disposal on Land	<ul style="list-style-type: none"> • National Institute for Waste (INR) • 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"> • INR • General Direction for Health/Ministry of Health • Data from Incineration Units

1.5 Brief description of key source categories

Key source analysis to the 2008 Portuguese inventory estimates (1990-2006) was conducted using Tier 2 approach with the LULUCF sector. Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2006 period.

The Tier 2 analysis with LULUCF resulted in the identification of 49 key categories, listed in the Table 1.5.

Table 1.5 – Summary overview of Portuguese key source categories (1990-2006) based on Tier 2 approach

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identification	Comments on level assessment	2006 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	8754
1A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level Trend	All years	1250
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1999, 2004, 2005, 2006	4226
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level	All years	3602
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level	1990, 1991, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	3581
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level	All years	3044
1A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2005	2784
6 A Municipal SWDL	SW Disposal on Land	CH ₄	✓	Level Trend	All years	2747
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level Trend	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	2005
4 D a AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1989
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	1990, 1991, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	1903
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level	All years	1762
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	All years	1476
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level Trend	All years	1249
4 D b AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1246
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1169
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	✓	Level Trend	All years	1108
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	All years	876
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006	800
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	699
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	✓	Level Trend	All years	580
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	587
1A 3 b Road Transportation	All Fuels	N ₂ O	✓	Trend		579
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	558
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	1990, 1991	539
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	All years	478
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level Trend	All years	436
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level	1990, 2002, 2003, 2004, 2005, 2006	360
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998, 2003	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	222
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	176
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO ₂	✓	Level Trend	All years	149
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend	1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	101
3 D OTHER	Other Use of Chemicals	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2003, 2004, 2005	80
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	70
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	✓	Level Trend	1991, 2003, 2005	67
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend	All years	66
1A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level Trend	All years	58
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	48
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	33
1A 2 f Other	Biomass	N ₂ O	✓	Level	All years	25
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	✓	Level	1992, 1993, 2004, 2006	18
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		15
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level Trend	All years	12
1A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend	1992	8
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	-5103
Sub-total with LULUCF		All gases				67264
% of total with LULUCF		All gases				82.1
TOTAL EMISSIONS WITH LULUCF		All gases				81937

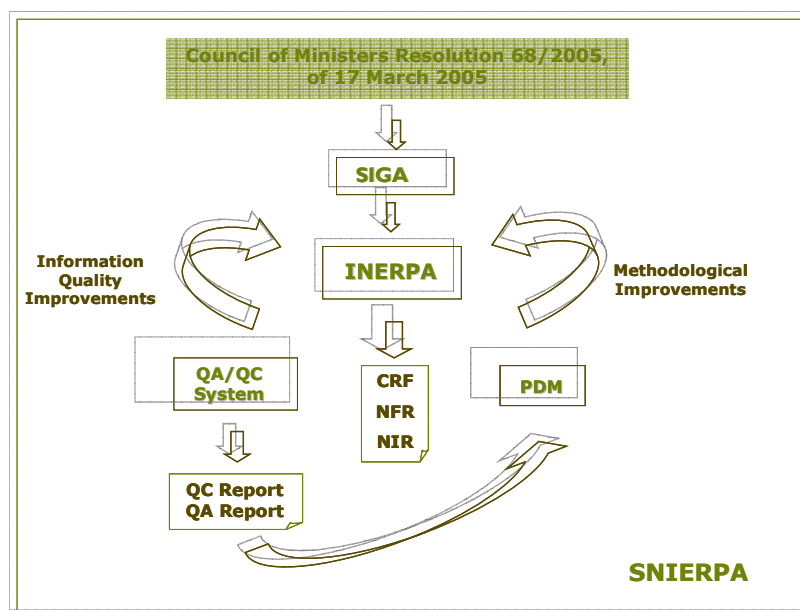
1.6 Information on QA/QC

A Plan for Quality Assurance/ Quality Control (QA/QC) has been developed. The Institute for the Environment is the national responsible entity for the Quality Assurance and Quality Control System of the inventory. The conceptualization of the system has been however done under an external consultancy with Ecoprogresso.

The QA/QC system is an integral part of the National System for the Inventory of Emission by Sources and Removal by Sinks of Air Pollutants (SNIERPA), which was created by the March, 17th Resolution of the Council of Ministers nr. 68/2005, and includes three technical instruments (Figure 1.2):

- Quality Control and Quality Assurance System (SCGQ)
- Methodological Development Programme (PDM)
- Integrated Management System (SIGA).

Figure 1.2 – SNIERPA 's main elements relations



The SCGQ is composed of 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 the 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 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 procedures, on the other hand, include technical verifications of emission factors, activity data, comparison of results among different approaches.

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 parameter 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 have been done under an external consultancy with INVENTAR.

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. A more detailed explanation of methodology is presented in Annex B. 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 2006. The results are presented in Table 1.6. The full range of emission possibilities, considering the confidence limit may be observable in

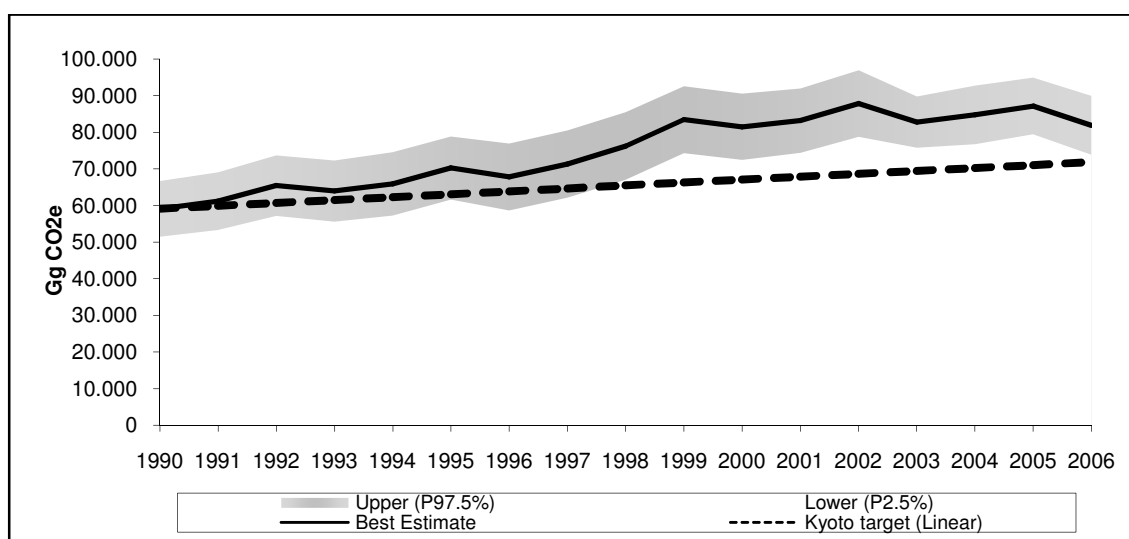
	CO ₂	CH ₄	N ₂ O	LULUCF	F Gas	Total
Year	Per cent					
1990	8.2	28.3	111.6	60.8	-	12.9
1991	7.8	28.0	112.2	287.0	-	12.8
1992	7.6	28.3	112.2	77.6	-	12.6
1993	7.5	26.4	115.4	62.7	-	13.1
1994	7.4	25.7	110.4	53.5	-	13.1
1995	6.8	25.4	105.5	62.0	80.8	12.3
1996	6.4	25.2	107.5	49.6	75.4	13.5
1997	6.2	25.3	107.0	47.6	71.9	12.9
1998	5.9	25.0	109.0	50.3	68.3	12.1
1999	5.6	24.9	102.0	49.1	59.9	10.9
2000	3.9	21.7	109.8	51.6	60.9	11.1
2001	4.0	22.9	105.2	50.1	65.7	10.6
2002	3.8	23.5	105.8	51.1	68.0	10.3
2003	4.2	23.6	98.9	41.7	66.3	8.5
2004	4.2	23.0	100.6	57.8	64.4	9.4
2005	4.2	24.0	98.1	78.3	65.8	8.9
2006	4.5	23.0	102.0	54.3	64.8	9.9

Figure 1.3. Total uncertainty vary along years from a minimum value of 12.9 per cent up to 9.9 per cent, from 1990 to 2006. The uncertainty in trend from 1990 to 2006 is 14.2 per cent. 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 1.6 – Uncertainty of the annual emission estimates, by gas and total uncertainty

Year	CO ₂	CH ₄	N ₂ O	LULUCF	F Gas	Total
	Per cent					
1990	8.2	28.3	111.6	60.8	-	12.9
1991	7.8	28.0	112.2	287.0	-	12.8
1992	7.6	28.3	112.2	77.6	-	12.6
1993	7.5	26.4	115.4	62.7	-	13.1
1994	7.4	25.7	110.4	53.5	-	13.1
1995	6.8	25.4	105.5	62.0	80.8	12.3
1996	6.4	25.2	107.5	49.6	75.4	13.5
1997	6.2	25.3	107.0	47.6	71.9	12.9
1998	5.9	25.0	109.0	50.3	68.3	12.1
1999	5.6	24.9	102.0	49.1	59.9	10.9
2000	3.9	21.7	109.8	51.6	60.9	11.1
2001	4.0	22.9	105.2	50.1	65.7	10.6
2002	3.8	23.5	105.8	51.1	68.0	10.3
2003	4.2	23.6	98.9	41.7	66.3	8.5
2004	4.2	23.0	100.6	57.8	64.4	9.4
2005	4.2	24.0	98.1	78.3	65.8	8.9
2006	4.5	23.0	102.0	54.3	64.8	9.9

Figure 1.3 – Trend of total GHG emissions without LULUCF and lower and upper estimates considering the 95% confidence interval



The application of a tier 2 methodology (Monte Carlo Techniques) is foreseen to be used in following submission, allowing the consideration of a more precise propagation method and the consideration of bias in Probability Density Functions.

1.8 Overview of the completeness

CRF Table 9 (Completeness) gives an overview of the level of completeness of the 2008 submitted inventories to the UNFCCC and EC. Additional information on this issue is given in the subchapters.

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

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

1.9 Future developments

Future improvements are defined under the Methodological Development Plan (PDM) which is settled each year in the context of the National Inventory System (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 PDM 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.

1.10 National Registry

1.10.A Registry administrator

The registry administration is performed by the Agência Portuguesa do Ambiente (APA).

Organization: Agência Portuguesa do Ambiente (APA)

Contact persons: Filomena Boavida / Ana Teresa Perez

Email: rpleadmin@apambiente.pt

Address: Rua da Murgueira 9/9^a, Apartado 7585, 2611 – 865 Amadora, PORTUGAL

1.10.B Registry Manager

APA has contracted eChiron to host and maintain the registry operation as well as to provide support to its users.

Organization: eChiron, Gestão de Aplicações de Software, S.A.

Contact persons: Rodrigo Proença de Oliveira

Email: rpleadmin@apambiente.pt

Address: Edifício Premium, Alameda Fernão Lopes, n.º16–10.º, 1495-190 Algés PORTUGAL

1.10.C Internet address

<https://rple.iambiente.pt/> (until May 2008)

<https://rple.pt/> (from May 2008 onwards)

1.10.D Current infrastructure of the Portuguese National Registry

Since October 1st 2007, the Portuguese Registry of GHG emissions and assigned amounts are supported by CR software, developed by Trasys for the European Commission and in use in several European countries. The CR software substituted the SERINGAS software which was in use since the start of the Portuguese Registry operation, in November 2005. From 2005 to 2007 two major SERINGAS versions were in production v2.7.2 and v2.9.5, added with several patches. Currently, the Portuguese registry is online with CR v1.1.4.

The current infra-structure includes two independent set of servers installed at different locations, both dedicated to support the Portuguese registry. Each location is supported by a different telecommunication operator (PT and Colt) and both are linked through a redundant Layer 2 Gigabit connection.

Each infra-structure set is composed by an application server, with Weblogic and the CR application, and a database server with Oracle 10g. The secondary set of servers serves as hot standby and a disaster recovery infrastructure.

The database servers are SUN V20z/1xCPU@2,2/4.0GB and run Oracle 10g over Linux. The applications servers are SUN V20Z 1xCPU@2,2/4.0GB and run Weblogic v8.1 SP6 over Windows 2003 Enterprise Edition.

eChiron, an IT company with a large experience in the environment domain, is responsible for the full operation of the registry, since its implementation. It hosts and manages the entire registry infrastructure, monitors its operation, evaluates and tests all software and provides support to the registry users and as well as to APA, as the registry administrator. In addition to several IT experts, a team of 4 people with special training on the registry regulation and protocols is responsible for the registry operation.

1.10.E Procedures to minimize discrepancies

The registry operation supported by the CR software has been tested by the EC and by Logica on behalf of the UNFCCC review team, who both evaluated how it conformed to technical standards for transactions between registries. The tests performed by the EC evaluated the performance of the registry when connected to the CITL. The tests performed by Logica evaluated the performance of the registry when connected to the ITL. The Portuguese technical team also maintains a fully operational test environment to test operational procedures or to test software upgrades and patches of CR, CITL and ITL. Further formal tests are planned for the summer of 2008 with the EC to evaluate the connection of the National Registry to CITL, though ITL, prior to the connection of all ETS registries to ITL.

A close cooperation between parties using CR (Portugal, Spain, Belgium, Luxembourg, Germany, Denmark and the EC) is maintained and any information regarding the software, namely possible bugs or performance issues, is quickly distributed and shared, as well as any available patch. The Portuguese Registry also benefits from the larger cooperation between all European national registries.

CR software includes a number of validations to minimize the discrepancies in the registry transactions and rules to terminate them whenever a discrepancy is identified. The operation of the registry is permanently monitored by the registry service team, in addition to the overall and continuous monitoring of the shared infrastructure and services managed by eChiron. Terminated transactions (uncompleted transactions) are swiftly investigated by the registry support team to identify the reason of the termination. The registry service team also routinely performs random checks of the database consistency and compares its results with information on the ETS, independent maintained by APA, namely regarding allowance allocation and surrendering and verified emission values.

All transactions performed on the Portuguese Registry are currently verified by CITL and will in the future be verified by ITL. Moreover, daily reconciliations are performed with CITL, a practice which will be maintained when the registry is connected to ITL.

It should be stressed that during the two and a half years period of operation of the registry no discrepancies have been found between the registry and the CITL. No complaint has also been reported by the registry users regarding a hypothetical discrepancy in their accounts.

A strict access control to the registry is maintained. The internet data centres, where the Portuguese Registry is housed enforce a strict control of physical access. All aspects of physical security are duly covered. The access to the datacentres is controlled by dedicated security staff.

The number of persons with administration privileges to the registry is kept to a minimum and all are under a strict confidentiality agreement. Written procedures are in place to ensure a common and tested way of dealing with all issues regarding the registry maintenance.

The Portuguese Registry interface is made available through https protocol. An SSL digital certificates provides authentication and encryption power for secure online transactions. The access to the Portuguese Registry is controlled by username and password. An account holder needs to sign an agreement with the Portuguese Registry to be granted access to the registry. By signing this contract, the account holder becomes aware of its obligations towards the registry, including the ones regarding security issues, and assumes the responsibility for fair use of the registry.

1.10.F Disaster management

The current infra-structure includes two independent set of servers installed at different locations, both dedicated to support the Portuguese registry. Each location is supported by a different telecommunication operator (PT and Colt) and both are linked through a redundant Layer 2 Gigabit connection.

Each infra-structure set is composed by an application server, with Weblogic and the CR application, and a database server with Oracle. The secondary set of servers serves as hot standby and a disaster recovery infrastructure.

In the event of failure in the primary infrastructure, the secondary infra-structure can provide the service if the internet connection of the main datacentre is maintained. If this internet connection becomes not operational for a long period (an extreme event given its redundancy and the fact that it is directly connected to the backbone of Portugal Telecom), a secondary a connection from the secondary datacentre can be implemented in a short period of time (this redundancy will only become available later in the year).

Routine daily backups are performed on the application servers and database servers (see description of this procedure in previous documents). In addition, the any data change in the primary database server is shipped to the secondary database server, making use of Oracle's DataGuard. A 5 minutes time interval is used in this procedure.

The backup procedure to an LTO3 tape library is run automatically and managed by a Veritas NetBackup Solution. Every morning a ticket in the eChiron service desk application is automatically opened and assigned to the Applications Group of eChiron Technology Management Department. The ticket is handled as any other ticket opened in the Service Desk application. A member of the Applications Group assumes the responsibility of this ticket and checks if the backup procedure has run without problems, before closing the ticket. The supervisor of the Applications Group makes sure that no ticket is left opened beyond a defined period. The service desk supervisor monitors all tickets opened in the application and is alerted is any unjustified delay occurs.

Security copies from the Portuguese registry are handled through the standard procedures of the company. Every month, each client service manager routinely selects a set of files and a database from its clients to be recovered. A ticket is opened in the Service Desk application to request such recovery. The Applications Group of eChiron Technology Management answers the requests and the ticket is closed when the client service manager verifies that the recovery was successful.

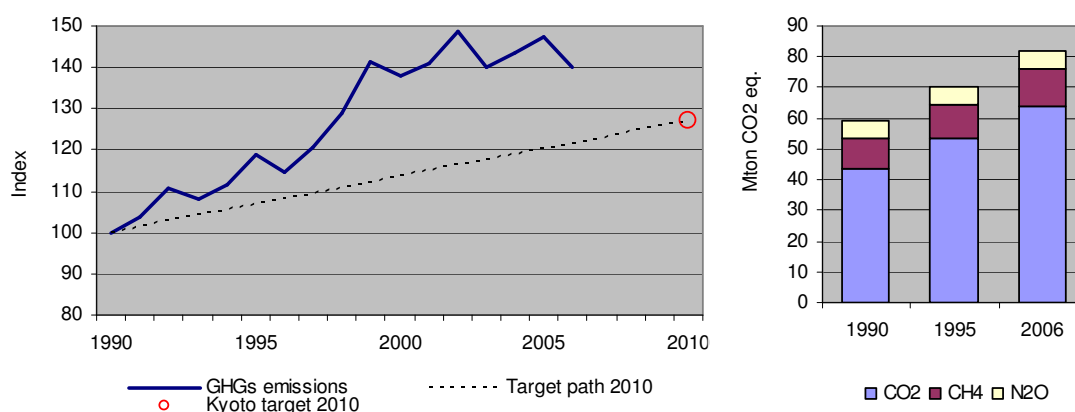
In addition to this internal verification, one must refer that eChiron clients often request the recovery of sets of files or the replication of databases. Since the backup procedures are the same for all clients, this provides an extra layer of confidence that the security copies are usable.

CHAPTER: 2 TRENDS IN PORTUGUESE GHG EMISSIONS

2.1 Trends of Total Emissions

In 2006, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated at about 82.7 Mton CO₂eq., representing an increase of approx. 40 per cent compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27 per cent compared to the 1990 level. Comparing the 1990-2006 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2006, 18 per cent above this target path.

Figure 2.1– GHG emissions (without LULUCF)

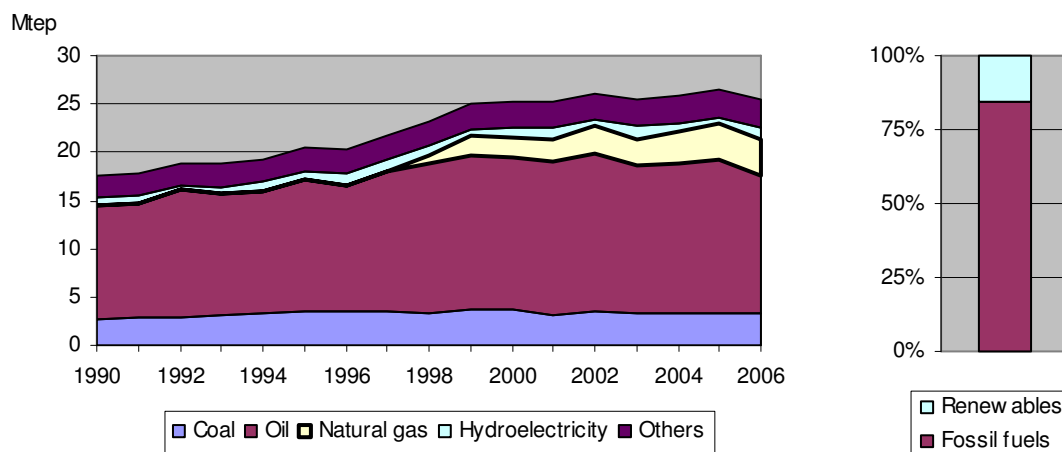


The principal source of GHGs in Portugal in 2006 is the energy sector. The largest gas emitted is CO₂ representing 77. per cent of total GHGs emissions expressed as global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for about 90 per cent of total CO₂ emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2006, 84 per cent of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas) whereas the renewable energy represents the remaining part, i.e. 16 per cent in average. (Figure 2.2)

The average annual emissions growth rate for the overall period 1990-2006 is about 2.5 per cent. However, as illustrated in Figure 2.1, there are roughly three different periods that can be identified in terms of the annual average rate evolution: from 1990 to 1995 3.8 per cent; from 1995 to 1999 4.7 per cent, and since 2000 a stagnation can be recognised (0.3 per cent increase).

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.

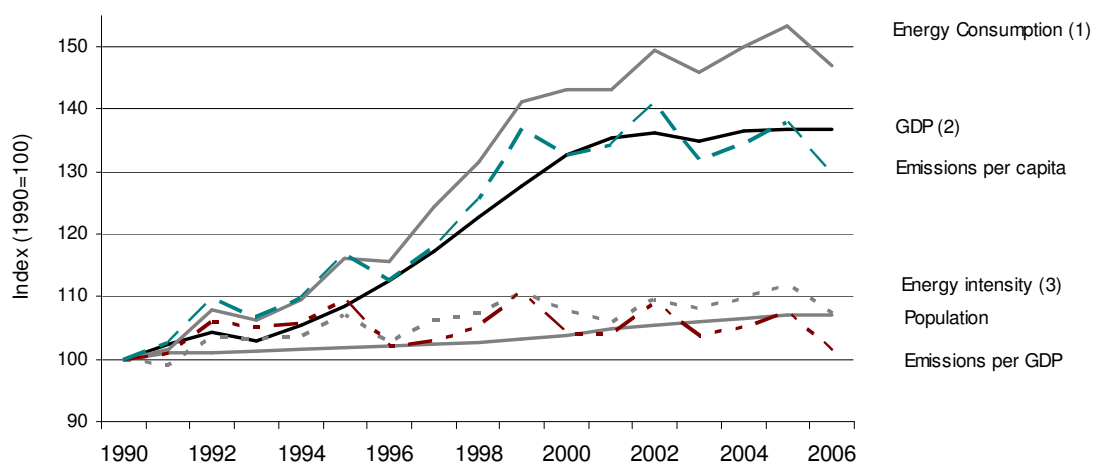
Figure 2.2 – Primary energy consumption



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.

During the 1990s Portugal experienced a rapid economic growth with an increase in GDP of about 36.9 per cent in the period 1990-2005, corresponding to an average annual increase of 2.5 per cent. The most rapid growth occurred from the years 1993 to 2000, where the average annual growth rate reached the 4.1 per cent. Since 2001, economic growth slowed considerably, contributing, at least partially, to the more moderate emissions growth registered in the most recent years.

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



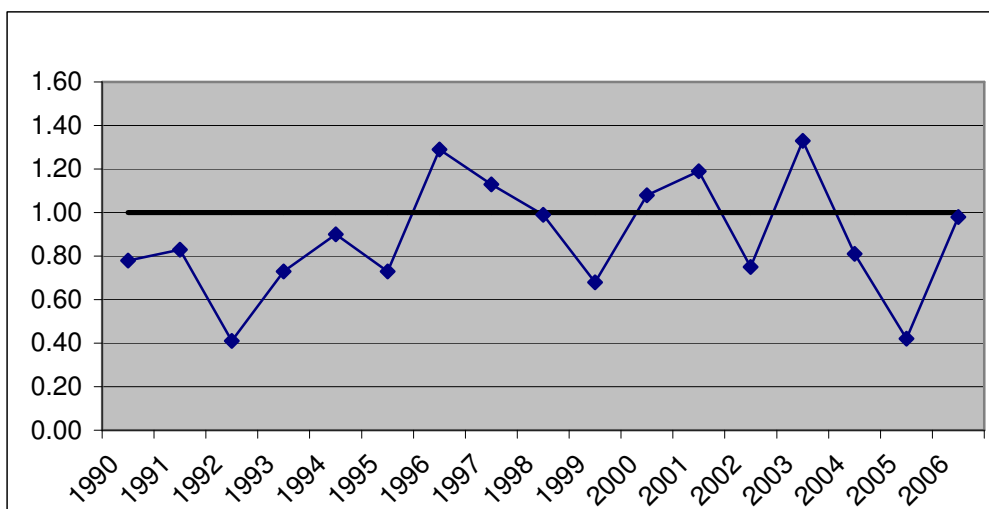
Notes:
(1) Primary Energy Consumption.
(2) 2000 prices.
(3) Energy Consumption per GDP.
Sources: INE, DGGE.

During the period analysed, the country has not achieved a clear decoupling of emission trends from economic growth. The slight decrease of carbon intensity (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 situation seems to ameliorate. In fact, the primary energy consumption seems to have stabilized since 2000, showing a slight increase in the 2000-2006 period. The energy intensity (primary energy consumption per GDP unit) starts to decline, registering a decrease of 0.6 per cent in the 2000-2006 period, and reflecting a positive energy efficiency trend in most recent years.

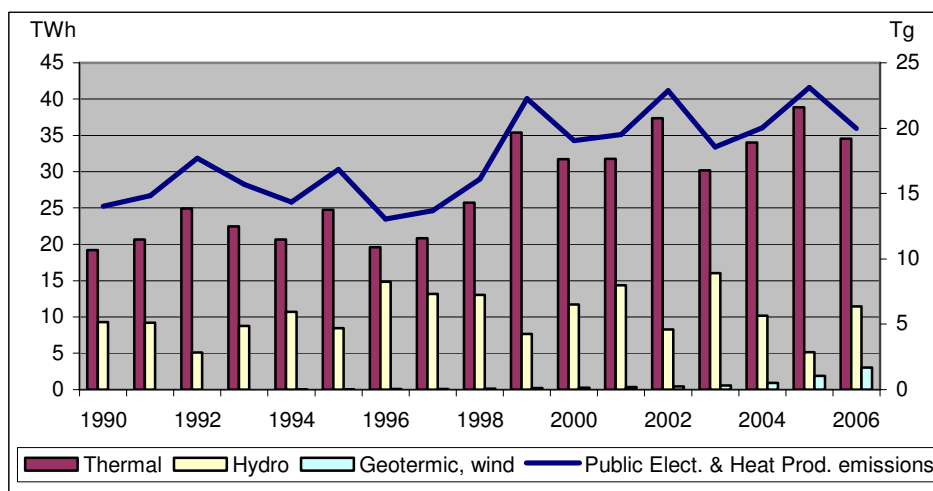
The level of emissions in the period analysed show significant inter-annual variations, which are related to the pronounced fluctuations of hydroelectric power generation, that is highly affected by annual variations in precipitation. Concerning recent years, year 2003 had a higher value of total annual water availability (hydraulic index (HI) of 1.33, meaning that it rained 33 per cent 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 year 2006 was a rainy year and high water availability (HI of 0.98) causing higher hydraulic production and again a decrease in emissions from this source category.

Figure 2.4 – Hydraulic Productivity Index



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

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



Source: DGGE.

2.2 Trends by Gas

Over the 1990-2006 period, all GHG emission levels grew (Figure 2.6). CO₂ is the gas having registered the biggest increase (47.1 Per cent). F-gases are excluded from the figure as they represent a small fraction of the emissions total (around 1 per cent in 2006).

Figure 2.6 – Increase of GHG emissions by gas over the 1990-2006 period

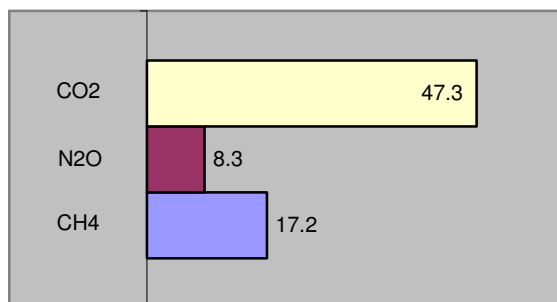


Figure 2.7 illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2006, being evident CO₂ as the primary GHG, accounting for about 77 per cent of Portuguese emissions on a carbon equivalent basis in 2006 (LULUCF excluded). The second most important gas is CH₄, followed by N₂O, representing, respectively, 14 per cent and 7 per cent of total emissions in 2006. Portugal has chosen 1995 as the base year for fluorinated gases. In 2006 these gases represented about 1 per cent 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”.

Figure 2.7 – GHG emissions by gas: 1990 and 2006

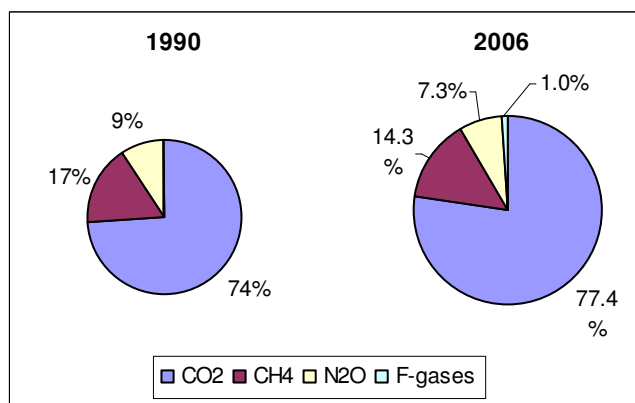


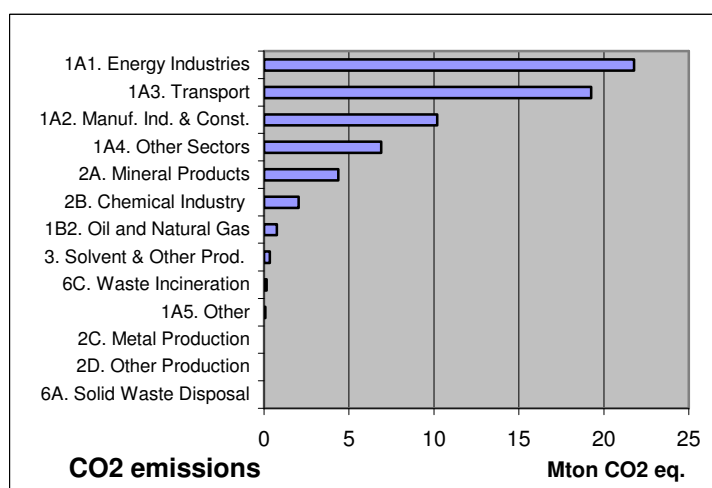
Table 2.1 – GHG emissions and removals in Portugal by gas: 1990-2006

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO ₂ equivalent (Gg)																	
CO ₂ emissions including net CO ₂ from LULUCF	44,810	45,491	47,536	45,568	45,685	49,133	44,906	47,953	52,003	59,028	57,284	58,932	62,653	69,967	62,310	65,209	59,730
CO ₂ emissions excluding net CO ₂ from LULUCF	43,444	45,271	49,389	47,982	49,200	53,157	50,286	53,532	58,216	64,695	63,412	64,694	68,855	64,159	66,208	68,447	63,993
CH ₄ emissions including CH ₄ from LULUCF	10,240	10,591	10,566	10,550	11,014	11,385	11,415	11,592	12,135	12,329	11,644	11,936	12,282	12,708	12,032	12,452	11,913
CH ₄ emissions excluding CH ₄ from LULUCF	10,103	10,374	10,497	10,509	10,988	11,234	11,362	11,572	12,035	12,275	11,525	11,858	12,170	12,213	11,934	12,236	11,846
N ₂ O emissions including N ₂ O from LULUCF	5,601	5,628	5,600	5,496	5,758	5,847	6,146	6,147	5,899	6,318	6,297	6,310	6,391	5,851	5,990	5,771	6,055
N ₂ O emissions excluding N ₂ O from LULUCF	5,561	5,580	5,566	5,466	5,729	5,806	6,114	6,119	5,863	6,286	6,258	6,276	6,354	5,774	5,954	5,723	6,021
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	53	74	108	149	210	307	393	496.69	607.42	684.26	785.26	850.86
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
SF ₆	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	6	7	7	8	8	8	9	10.24	11.52	13.26	13.71	15.50
Total (including LULUCF)	60,652	61,710	63,702	61,614	62,456	66,424	62,547	65,806	70,194	77,893	75,540	77,580	81833	89145	81029	84230	78564
Total (excluding LULUCF)	59,109	61,225	65,452	63,957	65,917	70,255	67,843	71,337	76,270	83,475	81,512	83,230	87885	82765	84793	87205	82728

NE - not Estimated; NO - not occurring

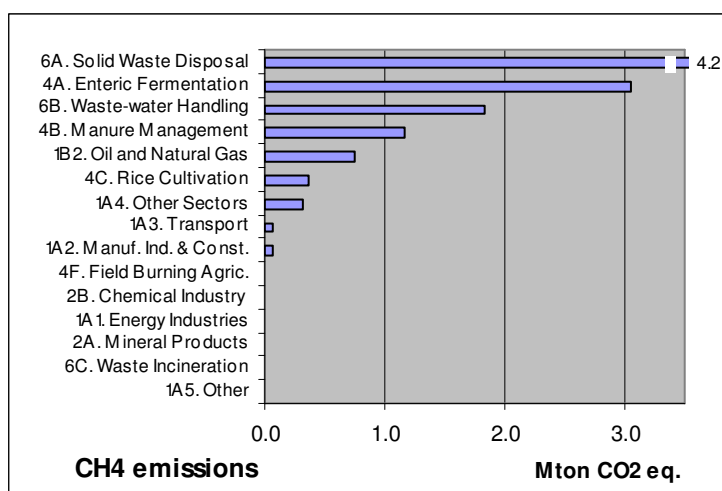
Next figures summarise the sources categories of emissions by gas (F-gases not presented).

Figure 2.8 – 2006 sources categories of CO₂



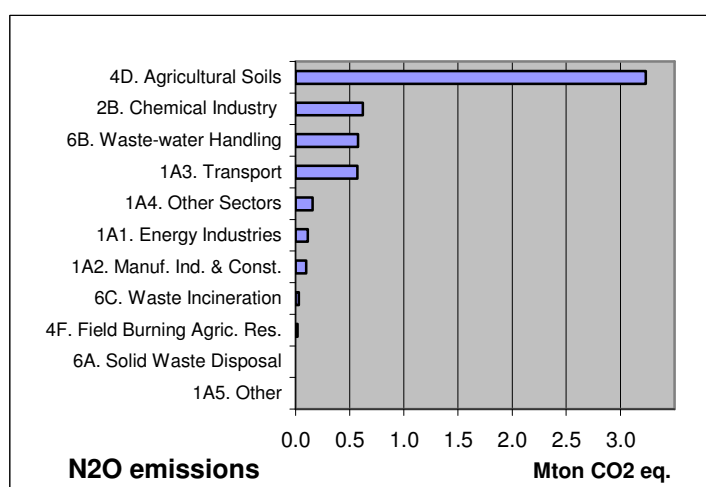
The largest GHG gas emitted is CO₂ which is mainly generated from fossil fuel combustion in energy-related activities (IPCC categories 1). Some other non-energy production processes such as cement production (included in category 2A), are also responsible for considerable quantities of CO₂ emissions.

Figure 2.9 – 2006 sources categories of CH₄



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 the distribution of natural gas and petroleum, biomass burning, and the incomplete fossil fuel combustion.

Figure 2.10 – 2006 sources categories of N₂O



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).

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, Land-Use Change and Forestry, and Waste. Emissions (Figure 2.11, Table 2.2) have risen for all these sectors. 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: 1990-2006

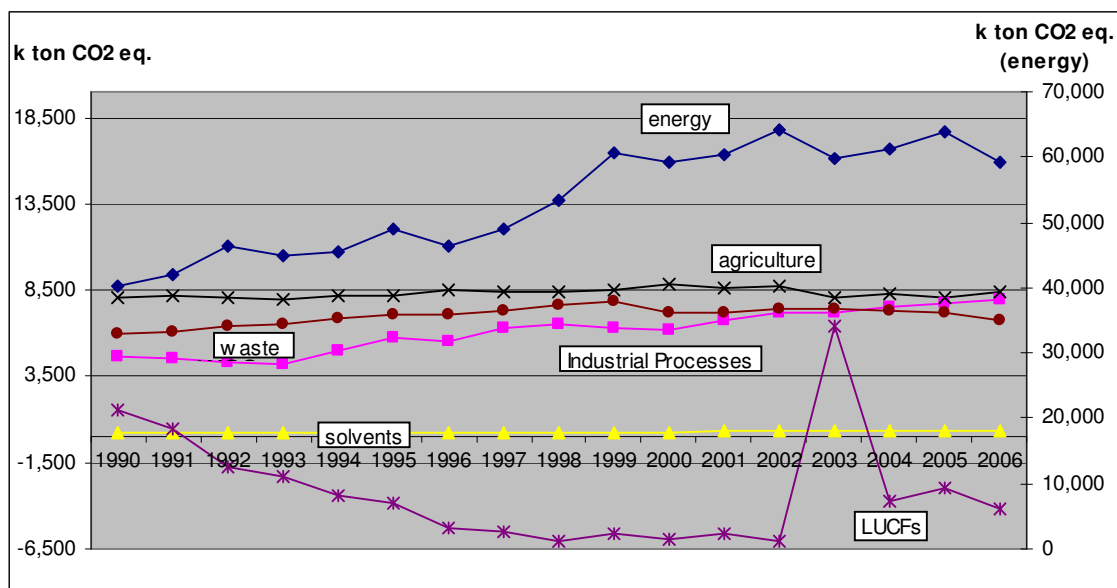


Figure 2.12 – GHGs emissions percentage change (1990-2006) by IPCC category (LULUCF excluded)

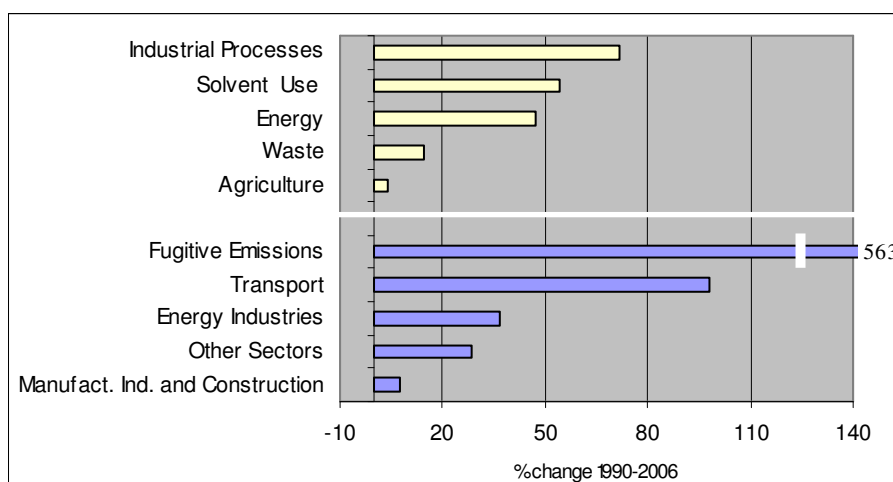


Table 2.2 – GHG emissions and removals by sector: 1990-2006

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	CO ₂ equivalent (Gg)																
1. Energy	40,262	42,072	46,408	45,018	45,628	48,959	46,397	49,020	53,361	60,569	59,080	60,340	64,268	59,785	61,328	63,916	59,244
2. Industrial Processes	4,611	4,584	4,352	4,204	5,009	5,809	5,575	6,277	6,543	6,269	6,190	6,766	7,236	7,203	7,535	7,725	7,911
3. Solvent and Other Product Use	220	234	243	236	253	256	275	285	290	285	290	304	312	318	325	332	339
4. Agriculture	8,088	8,195	8,052	7,933	8,159	8,174	8,514	8,415	8,414	8,534	8,797	8,653	8,689	8,070	8,340	8,081	8,434
5. Land-Use Change and Forestry ⁽⁷⁾	1,543	486	-1,750	-2,343	-3,461	-3,831	-5,296	-5,531	-6,076	-5,581	-5,972	-5,650	-6,052	6,381	-3,765	-2,975	-4,164
6. Waste	5,928	6,139	6,397	6,567	6,868	7,058	7,082	7,340	7,662	7,818	7,154	7,167	7,380	7,390	7,265	7,151	6,799
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Energy is by far the most important sector, accounting for 71.6 per cent of total emissions in 2006, and presenting an increase of 47 per cent over the 1990-2006 period. Energy industries and transport are the two most important sources representing respectively 26.5 per cent and

24.1 per cent of total emissions. Within the energy industries, public electricity and heat production represents alone 24.3 per cent of the total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation and transportation, which continues to grow due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the grow of mobility.

The total final energy consumption raised around 60 per cent between 1990 and 2006, and is related to the fact that the country has one of the lowest energy consumption per capita ratio in the EU (1.75 toe⁴ per capita in 2006). The situation seems to have stabilised in the more recent years, presenting a slight increase of 6% since 2000.

The sectoral evolution of energy consumption presented in the next figure, shows that the sectoral structure of the energy demand has been changing. The share of the industrial sector, which represented in 1990, 35 per cent of the final energy demand, decreased to 29 per cent in 2005. On the other hand, as previously mentioned, transports have been increasing importance, having raised from 31 per cent in 1990 to 38 per cent of the final energy consumption in 2006. The increase of energy consumption of this sector was 94 per cent from 1990 to 2006. Also, services is one of the sectors that are increasing the most, having registered a 186 per cent rise of energy consumption from 1990 to 2006. In 2006, this sector together with the domestic sector, represented 41 per cent of the share of the total energy consumed.



Bibliography



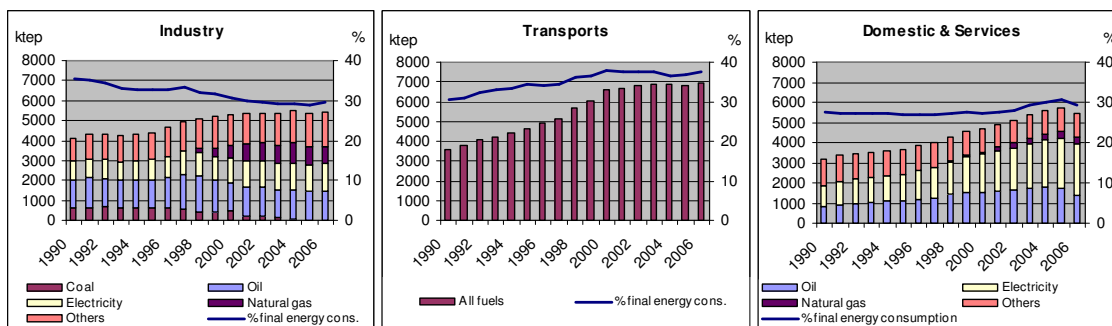
Key Categories



Uncertainty

⁴ Ton oil equivalent

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 are rising faster. The overall energy consumed for transportation is supplied by petroleum-based products, with nearly one third being gasoline (29 per cent in 2004). This fuel has been losing relatively importance since 1990, when the share was 40 per cent of the sectoral energy consumption. In the period 1990-2006 the emissions of transportation sources increased 98 per cent, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel, 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.

Still within the energy sector, other sectors, which include the residential and commercial activities, also registered a significant increase with almost 28 per cent rise in the 1990-2006 period. As previously mentioned this relates to the significant growth of these sectors with reflects on the energy consumed and emissions generated.

Agriculture was in the period analysed, the second most significant source of GHGs emissions but has been losing relatively importance: in 1990 it represented 13.7 per cent of total emissions; this percentage drop to 10 per cent in 2006. 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), and the decrease of fertilizer consumption.

Waste and industrial processes represented, respectively, 8.2 per cent and 9.6 per cent of Portuguese emissions in 2006, recording an increase of approximately 15 per cent (waste) and 72 per cent (industrial processes) since 1990. The growth of the industrial processes sector, whose emissions 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. Waste emissions registered a drop in 2006 which in part results from biogas recovery and burn in landfill sites. 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. Solvent use represents less than 1 per cent of total emissions, and is mainly related to NMVOC emissions⁵.

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 (1.5 Mt CO₂ eq.) to becoming a carbon sink in 1992 and the following years until 2002. The situation was again reverted in 2003 due to 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 SO_x emissions

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



Bibliography



Key Categories



Uncertainty

⁵ These are converted into ultimate carbon dioxide after being emitted to atmosphere.

Table ES. 4– Indirect GHG and SO_x emissions: 1990-2006

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	% change 1990-05
	(Gg)																	
CO	892	906	939	906	878	862	843	810	796	770	755	706	694	679	670	642	631	-29.2
NO _x	245	259	278	267	266	276	269	269	278	288	285	287	295	272	274	274	249	1.8
NM VOC	304	311	318	307	312	311	312	313	312	303	297	299	301	302	303	301	301	-1.0
SO ₂	320	311	372	316	298	334	273	294	344	344	307	296	296	202	214	214	191	-40.4

In 2006, SO_x, CO and NMVOC emissions have decreased from 1990 levels: -40.4%, -29.2% and -1%, respectively. NO_x emissions have increased 1.8% (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 NMVOC emissions, respectively 40.9% and 16.8% of 2006 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. Transports represents the second most important source of CO emissions (40.3%) after Other sectors (commercial/institutional, residential and agriculture/ Forestry) which amounts for 40.7% of the 2006 totals.

Since the early 2000, NO_x emissions from transport has been presenting a decreasing tendency; and CO and NMVOC emissions recorded real reductions in the 1990-2006 period, respectively, -49.6% and -56%.

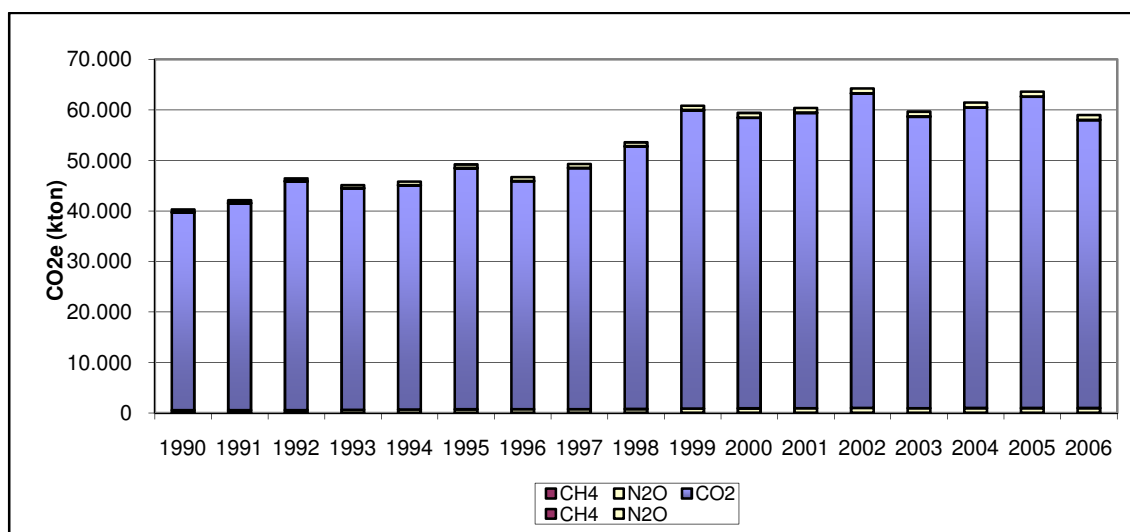
SO_x emissions are mainly generated in the energy industry sector (61.5% of total emissions in 2006) and combustion in manufacturing industries (18.7% of total emissions in 2006), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. However the emissions variation in the period 1990-2006 shows a decrease in SO_x emissions in both sub-categories: manufacturing industries -55.8% and energy industries -41.6%. These tendencies 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.

CHAPTER: 3 CHAPTER 3: ENERGY (CRF SECTOR 1)

3.1 3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting in 2006 for 70.7 per cent of total emissions of CO₂e excluded of LULUCF. Total emissions from this sector have increased 45.2 per cent from base year to last year, although the rise in emissions did not occur in a monotonous manner. Thus, the year with maximum emissions occurred in 2002, as may be seen in Figure 3.1. Also, after an 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 2006 emissions have even decreased by 2.2 per cent. This stagnation in emissions is concurrent with the existence of period of economic stagnation in Portugal, which may explain the situation.

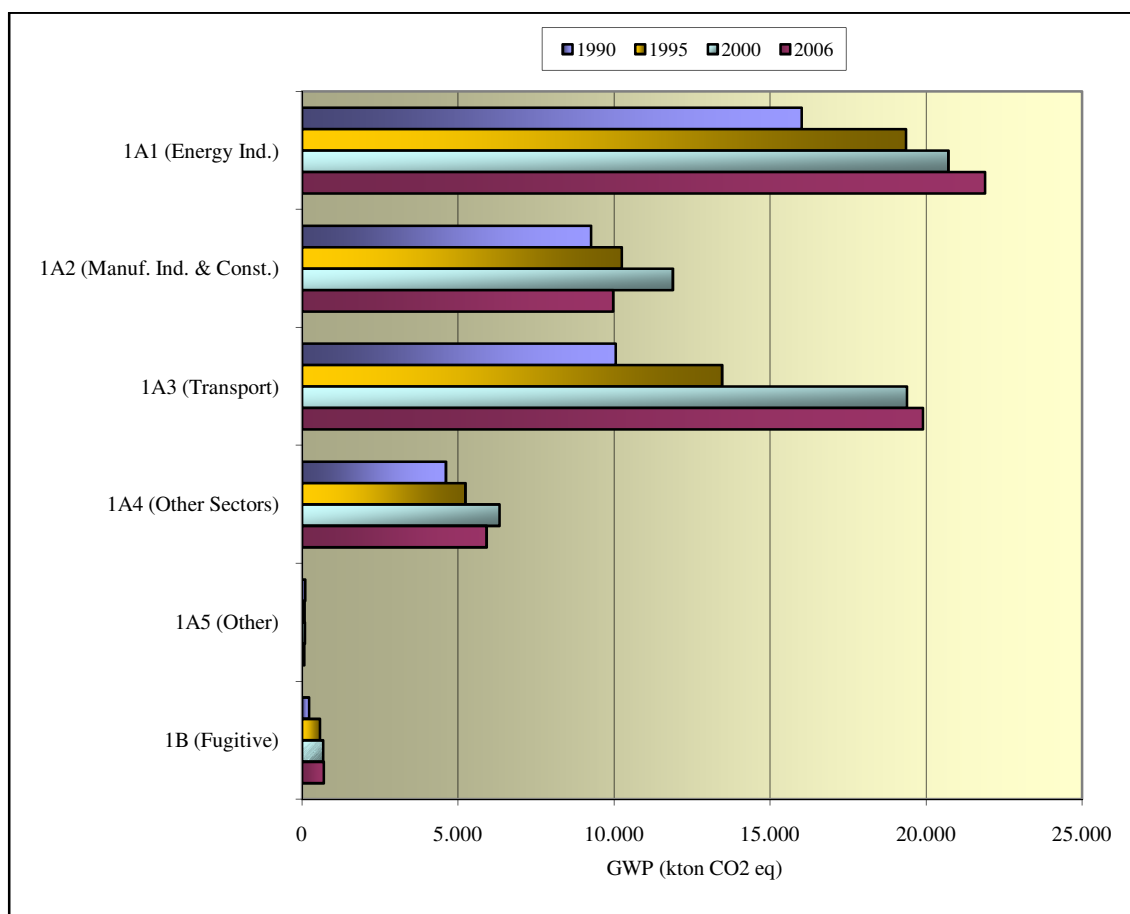
The relative importance of total CO₂e emissions from the Energy sector have increased, from 68.1 per cent in 1990 to 70.7 per cent in 2006. By far the most important gas emitted by this sector is CO₂, with 97.5 per cent of sector emissions expressed in CO₂ equivalent.

Figure 3.1 – Total CO₂ equivalent emissions from the Energy Sector (CRF Sector 1)⁶

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. In fact, it appears that it is the decrease in emissions in the Manufacturing Industry and Construction that is the main cause affecting the evolution of total emissions from energy after 2000.

⁶ Emissions of CH₄ and N₂O are comparatively very small and are not well visible in graph.

Figure 3.2 – Importance of CO₂e emissions from sub-sectors in Energy sector in selected years.



3.1.A Fuel Combustion Activities (CRF sector 1A)

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 per cent and 23.7 per cent of total GHG emissions excluding LULUCF in year 2006. 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 12.1 per cent of total emissions in 2006. GHG emissions from Refining of Petroleum Products is another relevant source with 3.2 per cent of total emissions for this sector. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 7.3 per cent of total sector emissions. Emissions for each sector in selected years are presented in Figure 3.3, and the full time trend in Figure 3.4.

Figure 3.3 – Total GHG emissions in source 1A, expressed as CO₂e, in 1990, 1995, 2000 and 2006

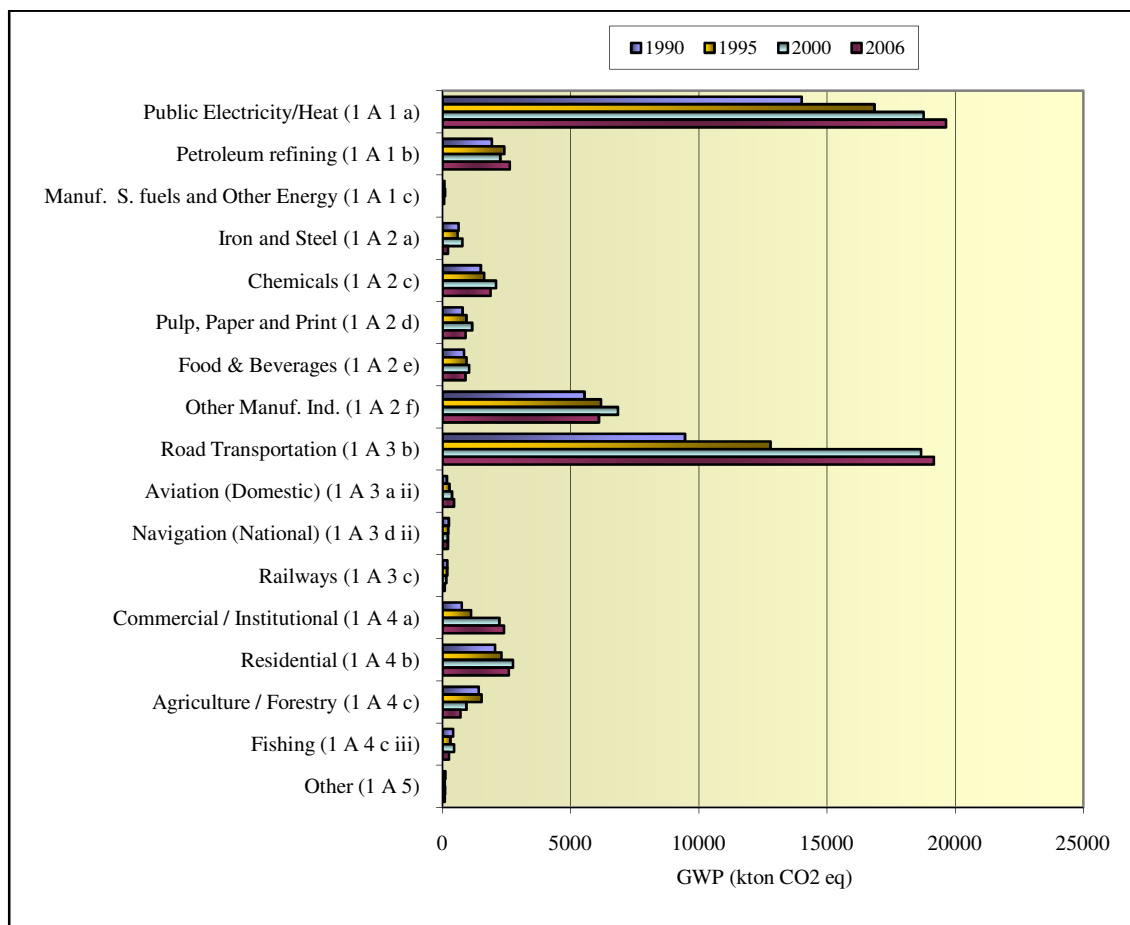
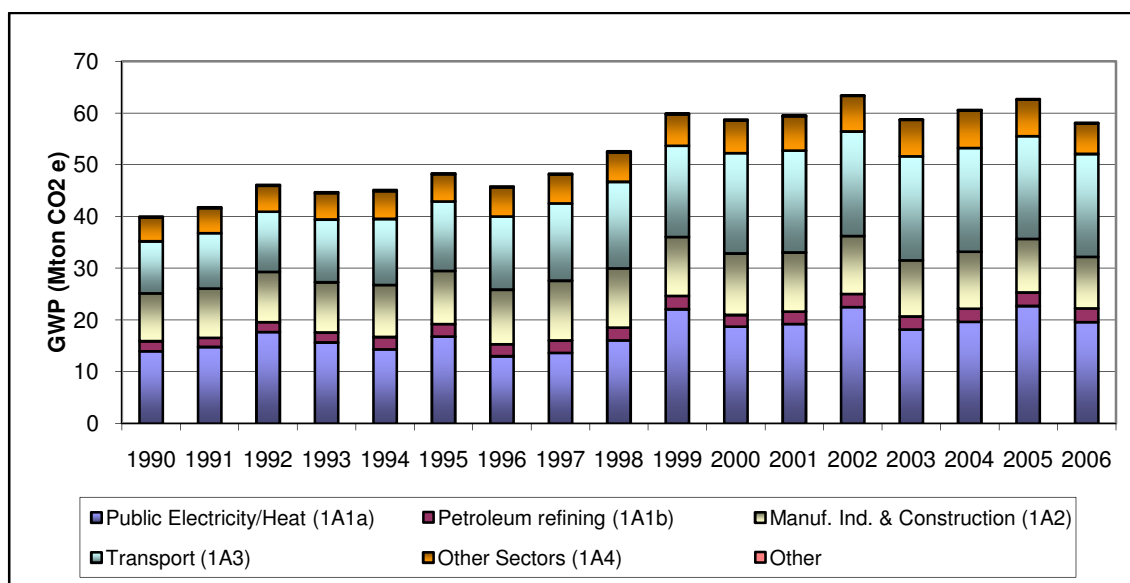


Figure 3.4 – Trend of total GHG emissions in source 1A, expressed as CO₂e, by sub-sector (1990-2006)



GHG emissions from this activity sector are almost fully dominated by direct CO₂ emissions, which represents about 97.6 per cent of GHG emissions in 2006. CH₄ and N₂O are minor sources, respectively 0.8 per cent and 1.7 per cent of total GHG emissions from the 1A sector in 2006.

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)⁷.

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 marine 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.



Bibliography



Key Categories



Uncertainty

⁷ 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.

3.1.B Fugitive Emissions from Fuels (CRF sector 1B)

Apart from fuel combustion emissions, the Energy sector includes also emission estimates from production, transmission, storage and distribution of fossil fuels. Generated gases from these sources are CO₂, NMCOV, 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 2006.

GHG emissions realized as CO₂ show a comparable contribution to CH₄, both responsible for 50 per cent in 2006. Emissions by gas are represented in Figure 3.6.

Figure 3.5 – Trend of total GHG emissions in source 1B, expressed as CO₂e, by sub-sector (1990-2006)

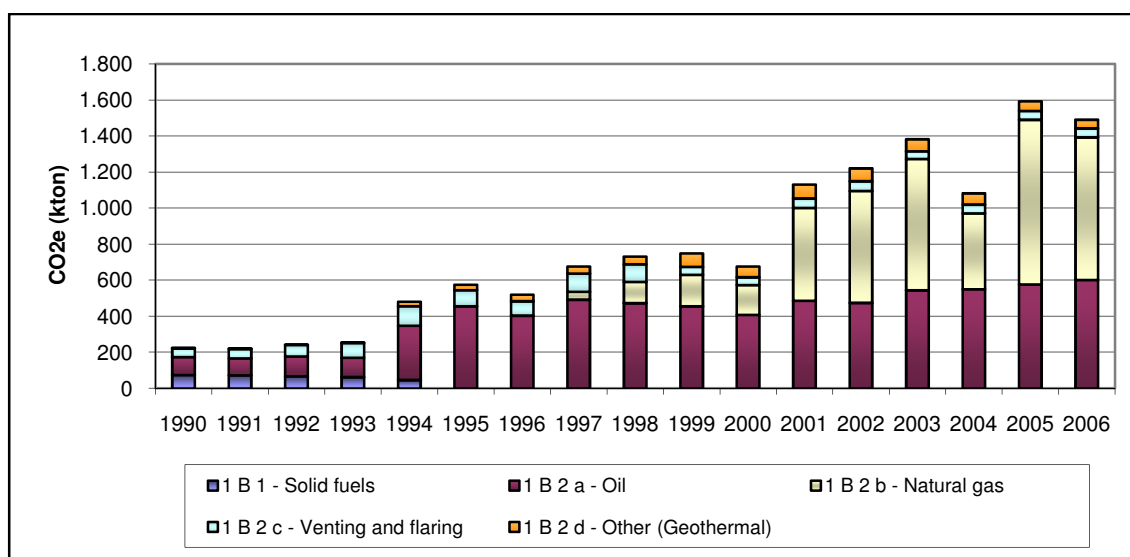
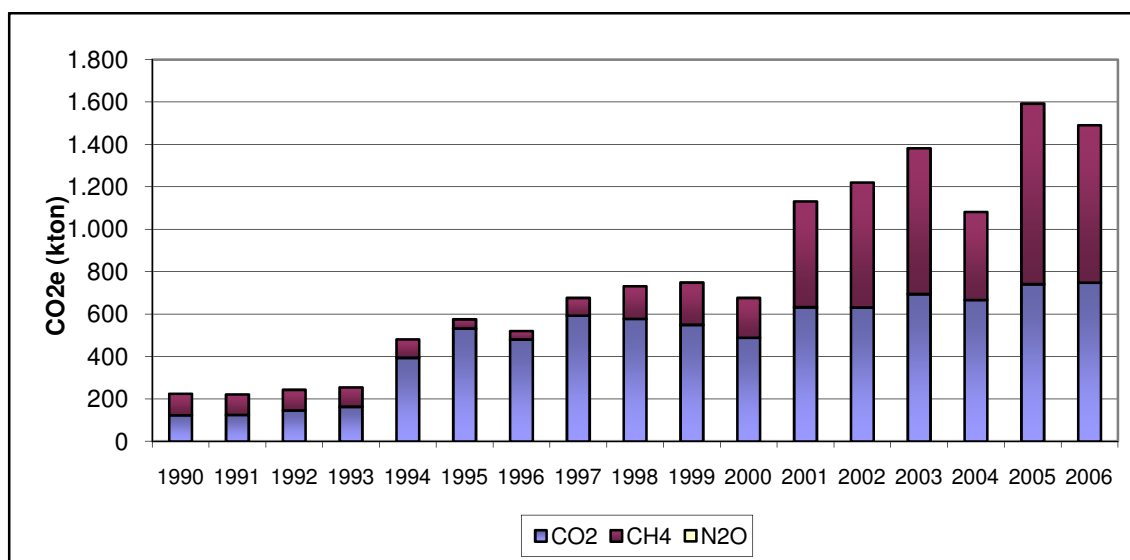


Figure 3.6 – Trend of total GHG emissions in source 1B, expressed as CO₂eq, by GHG (1990-2006)



3.2 3.2 Category sources

3.2.A 3.2.A. Energy Industries

3.2.A.1 3.2.A.1 PUBLIC ELECTRICITY AND HEAT PRODUCTION (CRF 1A1A)

OVERVIEW

Until 1950 electric energy production in Portugal was based in small power plant units using coal as energy source. In the nineteen-fifties increase in the demand for industry consumers cause 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 TER⁸ 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 producers⁹.



Bibliography



Key Categories



Uncertainty

⁸ TER – Termoelétrica do Carregado

⁹ 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-producer of electricity or heat, that also are agents producing or selling electricity or heat, but as a secondary activity and not as main business.

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

Large Point Source Energy Plants in Mainland Portugal

The number of Large Point Source Energy Plants (LPS-EP) in continental Portugal have increased from 6 units in 1990 to 12 units at present. Power plants and installed power are listed in Table 3.1 together with their main relevant characteristics.

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

Power Plant	Location	Start	Fuel***	Power MW _e	Treatment of gas effluents	Stack Height (m)	Comment
Tapada do Outeiro	Gondomar	1959	LIG& FO	150/100/47**	ESP	60 (3)	Lignite use stopped in 1997
Turbogas	Gondomar	1998	NG	990			Combined Cycle
Soporgen	Lavos	2001	NG	67	n.a.		Co-generation. Combined Cycle
Energin	Alhamdra	2002	NG	43.7	n.a.		Co-generation. Combined Cycle
Mortágua	Mortágua	1999	Wood wastes & NG	9	ESP		
Pêgo	Abrantes	1993	HC	615.2	ESP & Low NOx Burner	225 (1)	
Carregado	Alenquer	1968	FO & NG	710 (250*)	ESP	100 (3)	Natural Gas introduced in 1997
TER	Alenquer	2004	NG	1 176	-		Combined Cycle
Cariço	Sines	2006	NG	487			
Alto do Mira	Amadora	1975	GO	132	-	10-11	Gas turbine
Barreiro	Lavradio	1978	FO	56	-	104 (1)	Co-generation
Setúbal	Setúbal	1979	FO	946	ESP	200 (2)	
Sines	Sines	1985	HC	1 192	ESP & Low NOx burners (after 2000)	225 (2)	
Tunes	Silves	1973	GO	197	-	9-17	Gas Turbine

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

** This central is being de-activated. 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 were operating.

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

The two small gas turbine power plants included in the public service were: one near Lisbon to sustain peak power demands and another in Tunes, in the southern province of Algarve, 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 of 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 (*Turbogás/ 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, *Soporgene* 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.

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.

Table 3.2 - Electricity Power Plants in the Azores and Madeira

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

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 and was promoted after 1993. Some of these units, although working actually in close association with other industrial activities, are independent companies, in legal terms, and which main activity was 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.

METHODOLOGY

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" (GPG).

Emissions to atmosphere of CO₂ total emissions and of ultimate CO₂ from fossil origin were estimated from:

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

$$Fossil_{CO_2(y)} = \sum_u \sum_f [U_{CO_2(u,f,y)} * C_{Fossil(f)} * 10^{-2}]$$

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

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

EF_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 latter into CO₂ in the atmosphere or after deposition on soil. Emissions of CO₂ at stack exhaust (End-of-pipe emissions) may be estimated from final CO₂ emissions from:

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

where

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

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

CO - carbon monoxide emissions (ton);

CH₄ - Methane emissions (ton);

TPM - Total Particulate Matter emissions (ton);

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

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

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

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

where:

$\text{Emission}_{(u,f,y,p)}$ - Emission of pollutant p estimated from consumption of fuel f in power plant u in year y (ton);

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

$\text{EF}_{(u,f,y,p)}$ - Emission factor pollutant p, for fuel f consumed in power plant u in year y (g/GJ).

EMISSION FACTORS

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	$U_{\text{CO}_2}^{(i)}$ kg/GJ	$F_{\text{acox}}^{(i)}$ 0..1	Fossil _c %	$\text{CH}_4^{(i)}$ g/GJ	$\text{N}_2\text{O}^{(i)}$ g/GJ
Lignite	101.2	0.980	100	1.0	1.4
Hard Coal	⁽ⁱⁱⁱ⁾ 92.0	0.980	100	0.7	1.4
Fuel-oil	77.4	0.990	100	^(ii,iii) 0.7	0.6
Orimulsion	80.7	0.990	100	^(ii,iii) 0.7	0.6
Natural Gas	56.1	0.995	100	^(i,ii) 0.1 - 1.4	1.4
Biomass	109.6	1.000	0	15	⁽ⁱⁱ⁾ 4.3
Diesel (GT)	74.1	0.990	100	0.14	⁽ⁱⁱ⁾ 2.5
Diesel (Engine)	74.1	0.990	100	0.14	0.6

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

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 from Table 3.4 to **Erro! A origem da referência não foi encontrada.** for the public power plants belonging to the public system in Azores and Madeira, and from Table 3.5to **Erro! A origem da referência não foi encontrada.** for the non public co-generation self producers¹⁰.

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)

¹⁰ Power producers as main activity only.

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

ACTIVITY DATA

Activity data has different origins according to specific energy plants:

Large Point Source Energy Plants

Data on consumption of fuels by fuel type was available for all units and years until 1998 from the Large Combustion Plants (LCP) directive - which relies in direct information reported from the individual plant producer to the Environment Ministry - for all power plants except the two gas turbines. From 1999 onwards consumption of fuels for some units was also collected directly from energy plants under the Self-control program (*Programa Autocontrolo*)¹¹ or, from plant activity reports (EDP, 2000; EDP, 2001; EDP, 2002; EDP, 2003; EDP, 2004; EDP, 2005; EDP, 2006). Activity data for gas turbine units is from DGGE until 1997 and from industry reports (EDP, 2000; EDP, 2001; EDP, 2002; EDP, 2003; EDP, 2004; EDP, 2005; EDP, 2006) thereafter. Nevertheless, the consistency in time series is guaranteed considering that the same original source (Power plant companies) is ultimately used.

¹¹ The *Auto-controlo* program is a legal obligation for major emitters.

As a general rule power plant units report information about consumption in tons or cubic meters of gas together with the Low Heating Value ¹² 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	25.98 (24.51 - 27.23)MJ/kg
Fuel-oil	40.18 (39.42 - 41.15)MJ/kg
Orimulsion	28.00MJ/kg
Diesel oil	43.30MJ/kg
Natural Gas	38.22 (36.02 - 39.16)MJ/N m3
Biomass	7.8MJ/kg

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



Bibliography

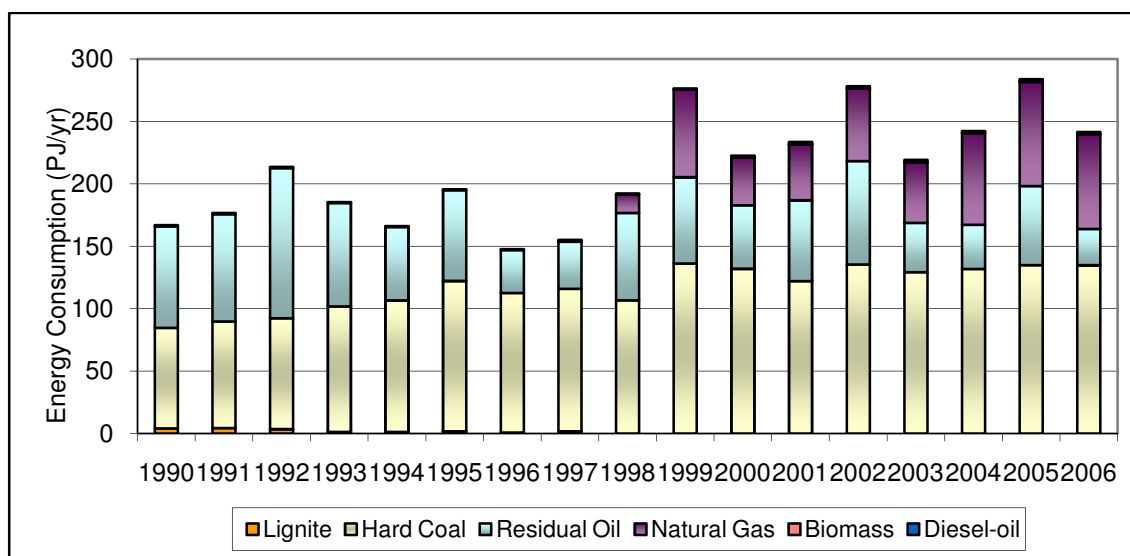


Key Categories



Uncertainty

¹² 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.

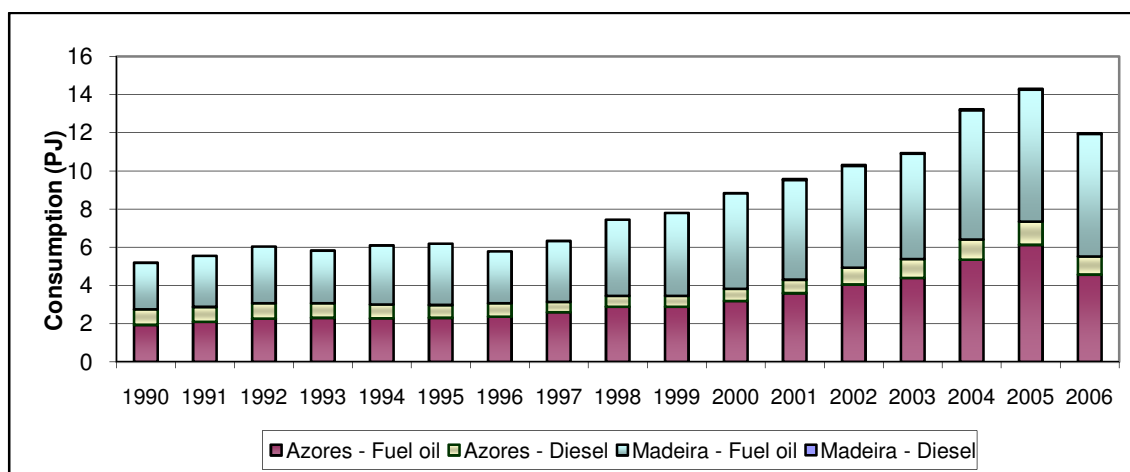
Figure 3.7 – Trends of fuel consumption per fuel type ¹³

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) and may be observed in the next figure. Figures from 2001 to 2003 were obtained from the reports made to the European Carbon Trading Scheme (UE-ETS). The values for 2004 to 2006 were estimated using total production of electricity in the islands and surrogate driver.

¹³ 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.

Figure 3.8 – Trends of fuel consumption in Azores and Madeira Archipelagos



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

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

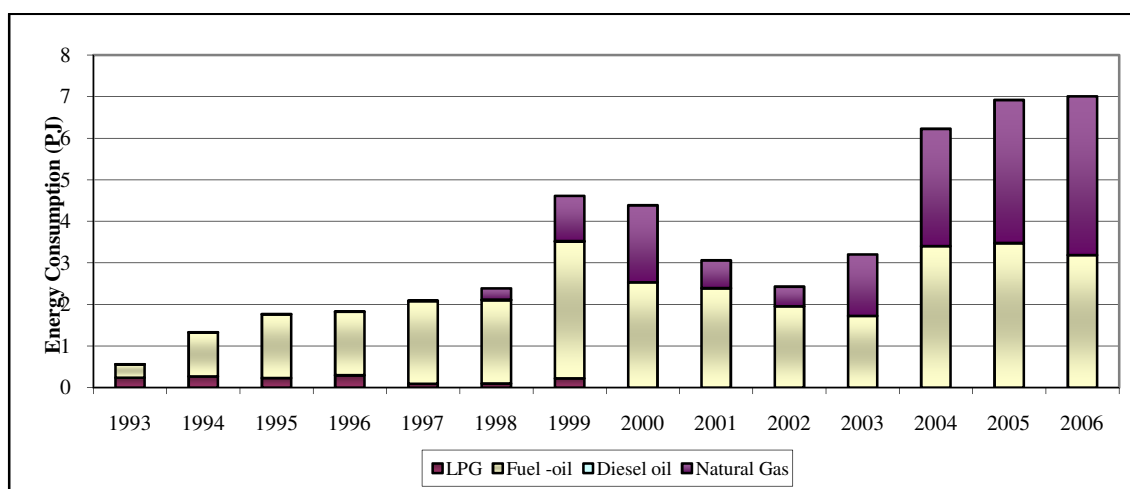
Table 3.7 - LHV per fuel type

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

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 DGGE and it is presented in Figure 3.9.

Figure 3.9 – Trends in consumption of fuels in non-public co-generation plants



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 (MJkg)
LPG	49.76
Fuel -oil	40.17
Diesel oil	43.30
Natural Gas	46.0

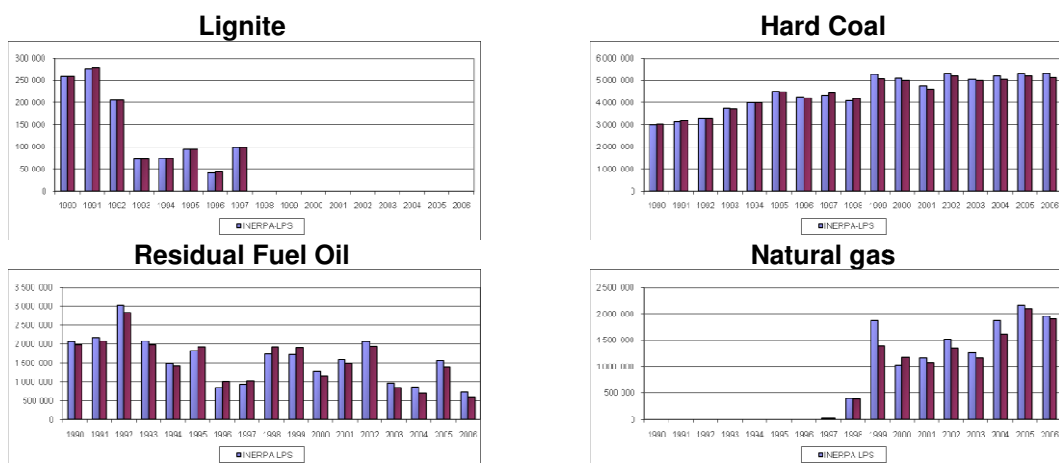
Comparison of LPS data vs. National Statistics

Consumption of fuel for electricity production in large units is also published in the Energy Balance of DGEG¹⁴. 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 next figure. Generally, there is an 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.

**Bibliography****Key Categories****Uncertainty**

¹⁴ Direcção-Geral de Energia e Geologia (General Directorate of Energy and Geology).

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



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

Since last submission, the use of plant specific data for the power plants in Azores and Madeira has decreased uncertainty, although not in a very significant value.

RECALCULATIONS

No major changes occurred in methodology, activity data and emission factors.

FURTHER IMPROVEMENTS

The main aim in emission estimate development that is expected is the more widespread use of plant specific emission factors, covering more pollutants and more plant units. 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. This efforts are in accordance with the goals that the EC¹⁵ has set to streamline data collection for the inventories and for the EU-ETS¹⁶.

In the same sense on-going efforts should be maintained for the compatibilization of data acquisition by IA and DGGE 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.



Bibliography



Key Categories



Uncertainty

¹⁵ European Commission.

¹⁶ European CO₂ trading scheme.

3.2.A.2 PETROLEUM REFINING (CRF 1A1B)

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.

METHODOLOGY

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

As explained in more detailed for 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:

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

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

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

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

Where

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

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

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

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 Table 3.9.

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

Fuel	Equipment	U _{CO2} ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1	Fossil _c %	CH ₄ ⁽ⁱⁱ⁾ 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)

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-oil¹⁷, fuel-gas, liquefied petroleum gases (LPG) and diesel oil.

The quantities of fuel consumption from 1990 to 2006 in boilers and furnaces were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in Figure 3.11 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.

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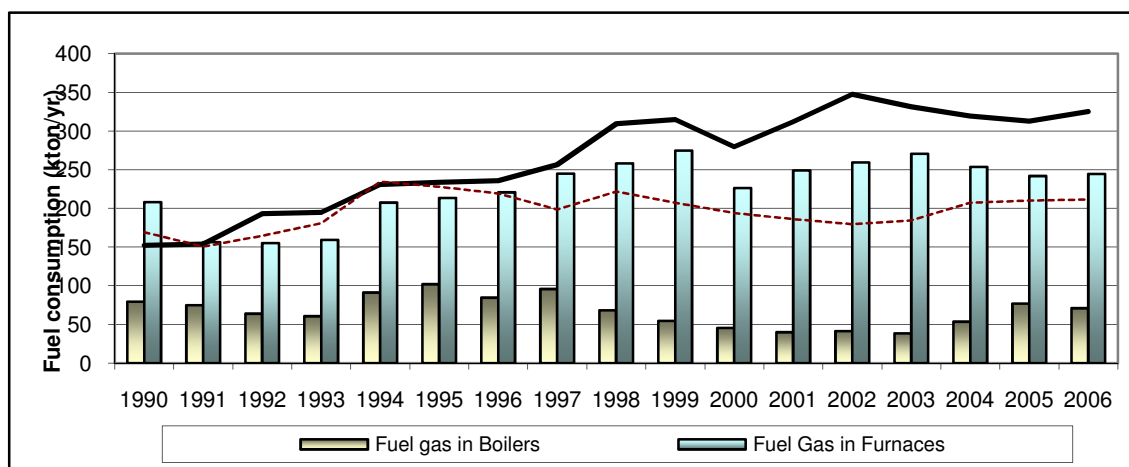
Key Categories

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Uncertainty

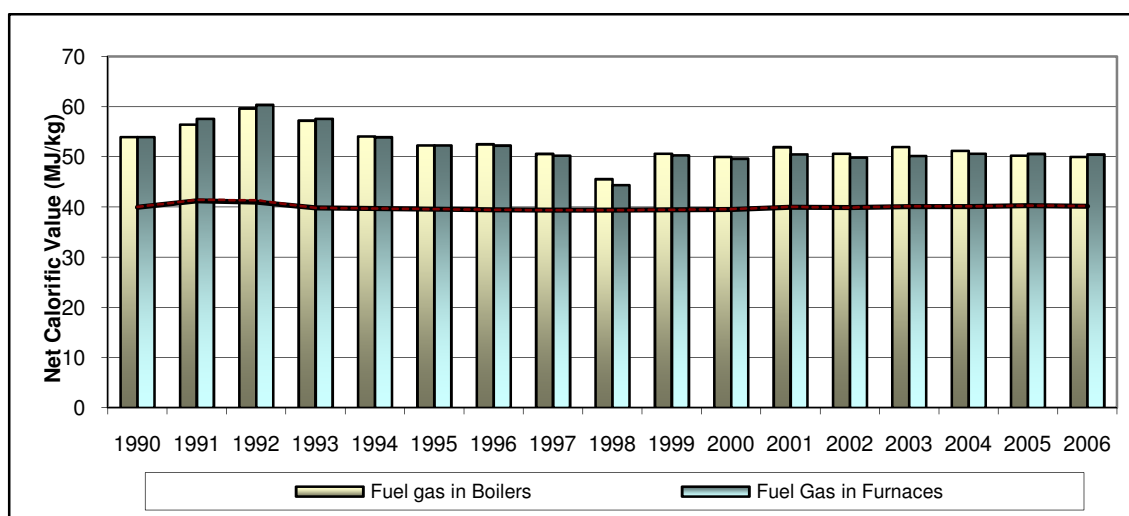
¹⁷ In strict terms this fuel is not traded and must not be named fuel-oil, to avoid confusion to traded fuel oil.

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.

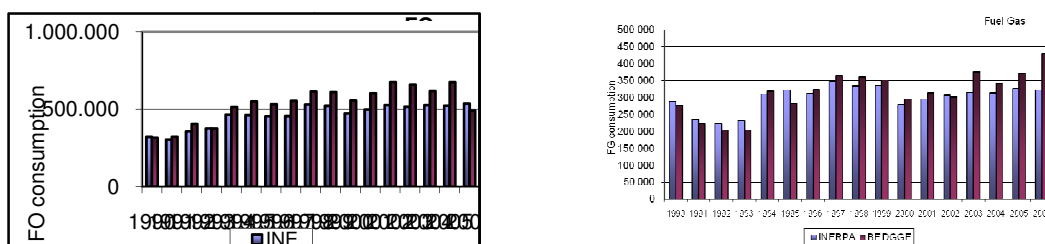
Figure 3.12 – Net Calorific Value (NCV) or Low Heating Value (LHV) expressed in MJ/ kg by type of equipment



Comparison of LPS data vs. National Statistics

In a similar mode that was done for large power plants, and explained before, total consumption in all units was compared between the data in the inventory (INERPA) and the Energy Balance (EB) – published by DGEG - 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.



UNCERTAINTY ASSESSMENT

The uncertainty value was established at 1 per cent, 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 per cent, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 per cent for CH₄ and 1000 per cent for N₂O.

RECALCULATIONS

No changes in methodology and emission factors were made for this source sector since last year's submission. However, some error was detected in the way that the quantities consumed in furnace were allocated per equipment from 1995 onwards. This error caused errors in total consumption in furnaces in the time-series from 1995 till 2004 and all annual values were revised.

3.2.A.3 OTHER ENERGY INDUSTRIES (CRF 1A1C)

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.

METHODOLOGY

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 other pollutants the following equation was applied to estimate emissions:

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

where

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

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

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

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 _{CO2} ⁽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 ₂ O ⁽ⁱ⁾	1.40	0.60	0.60	1.40	

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

ACTIVITY DATA

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 DGGE. 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 ;

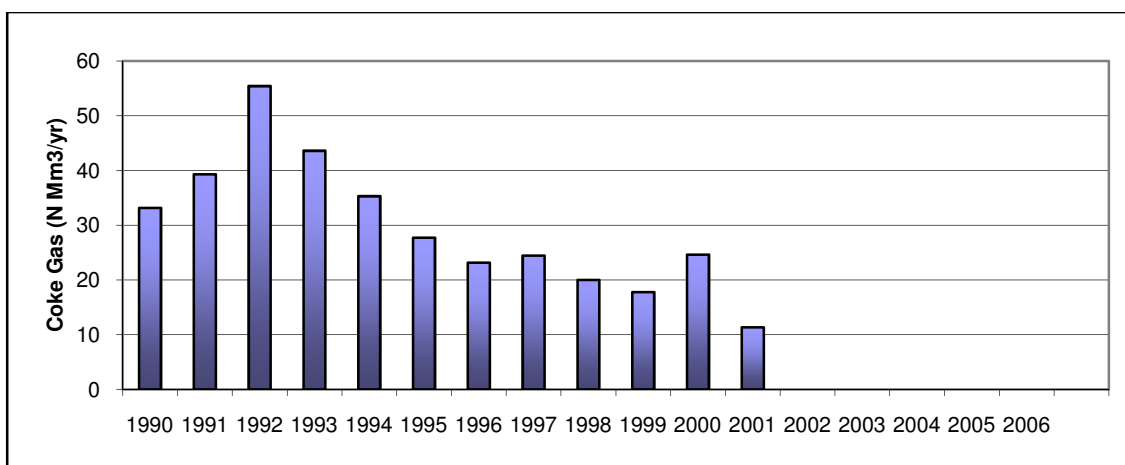
$\text{Coquerie}_{\text{CONS}}(91-94)$ - consumption of coke gas in the coquerie from 1990 till 1994;

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

$\text{TotalPlant}_{\text{CONS}}(y)$ - 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.

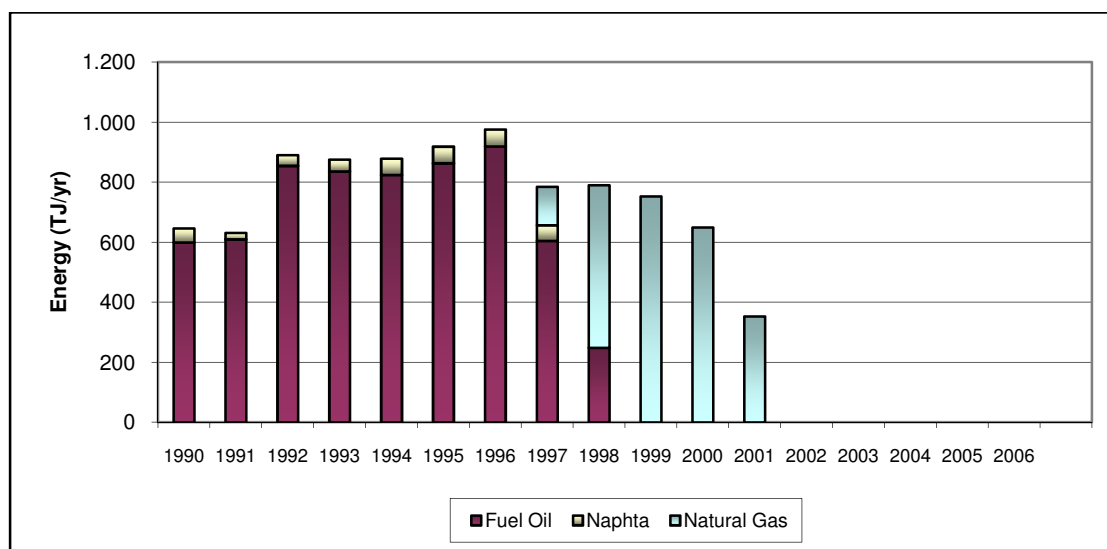
Figure 3.14 – Coke gas consumption in the coquerie: 1990-2006



City Gas Production

According to the energy balances from DGGE, this activity has used fuel oil, naphta and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001¹⁸. The available time series is presented in Figure 3.15.

Figure 3.15 – Consumption of fuels in co-generation in city gas production 1990-2006



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



Bibliography



Key Categories



Uncertainty

¹⁸ This activity uses also fuel gas, LPG, fueloil, naphta and natural gas as feedstocks. These quantities, separated in the energy balance, are not included in the inventory at this point but in use of city gas as fuel

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

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

UNCERTAINTY ASSESSMENT

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

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

RECALCULATIONS

No recalculations were done for this source sub-sector since the submission of last year.

3.2.A.4 MANUFACTURING INDUSTRIES AND CONSTRUCTION (CRF 1A2)

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 are 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 units¹⁹.

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. The following procedural scheme was used:

- 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;
- 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;
- 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

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Key Categories

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Uncertainty

¹⁹ Only when the co-generation activity is reported to 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).

emission factors are plant specific and obtained from information monitored at industrial plants. The remaining fuel use in this sector, that in cement production and in equipments other than kilns, is converted into emission using the general purpose emission factors (energy approach). Carbon dioxide originated from decarbonising of limestone and dolomite is quantified in production processes and reported in CRF sector 2A;

- Emissions of SO_x, NO_x, NMVOC, CH₄ and particulate materials 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;

- Emissions from glass production. Also for this sector emissions estimates from use of fuels in furnaces of sulphur oxides, nitrogen oxides, methane, carbon monoxide and particulate matter are estimated using production as activity data. 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 of materials, which are included in production process and reported in CRF sector 2;

- air emissions from sintering (SO_x, NO_x, NMVOC, CO and PM) and production of lime (SO_x, NO_x, CO, CO₂ and PM) in integrated iron and steel production are estimated using production as activity data. 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.

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:

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

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

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 the other GEE, methane and Nitrous Oxide, when the energy consumption approach is used the equation simplifies to:

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

where:

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

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

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

When in the production process occurs a close and intimate 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 licquor), 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).

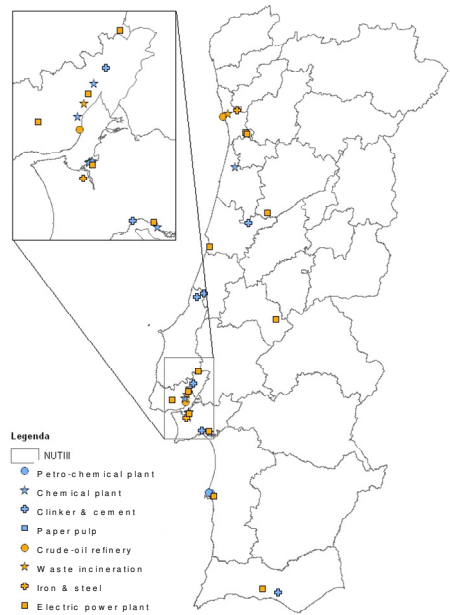
ACTIVITY DATA

Activity data comprehends consumption of fuels and industrial production rates.

Combustion Data

Data on fuel consumption for the Larger Point Sources (LPS) were obtained directly from Large Combustion Plants (LCP) submitted to APA under the provisions of the LCP Directive or from information received by IA from special surveys or from the EPER inventory. 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 Portugal²⁰



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:

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



Bibliography



Key Categories



Uncertainty

²⁰ This map includes also LPS that are accounted as process emissions (CRF 2).

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

Where,

$\text{Energy}_{\text{EB}(f,s,c)}$ – 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);

$\text{Cons}_{\text{LPS}(u,f,e)}$ – Reported consumption of fuel f consumed by LPS unit u in equipment e (ton/yr or Nkm³/yr);

$\text{Cons}_{\text{EB}(f,s)}$ – 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 Nkm³/yr);

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

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

$\text{Frac}_{\text{Equi}(s,f)}$ – fraction of consumption of fuel f in sector s that is used in equipment e (0..1);

$\text{LHV}_{\text{LPS}(u,f,e)}$ – Low Heating Value/ Net Calorific Value, reported by LPS unit u, for fuel f in combustion equipment e (MJ/kg or MJ/Nm³);

$\text{LHV}_{\text{EB}(f,s)}$ – Low Heating Value/ Net Calorific Value used by DGGE in the compilation of the Energy Balance for fuel f in activity sector s (tep/ton or tep/Nkm³);

$\text{LHV}_{\text{AREA}(f,s,e)}$ - 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/Nm³)²¹.



Bibliography



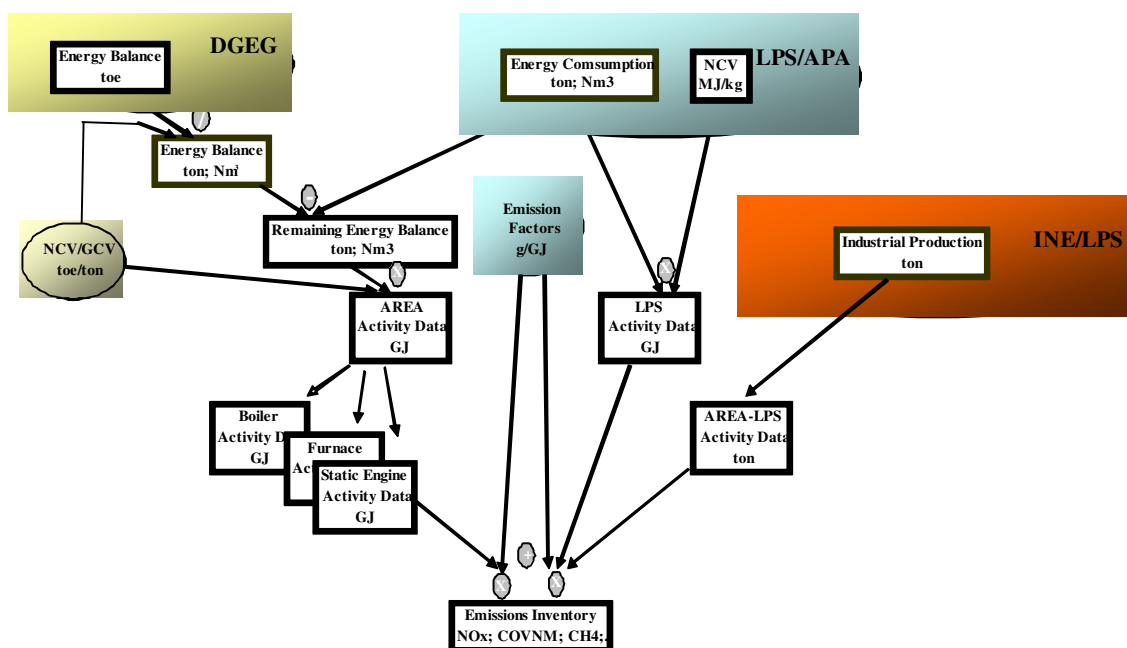
Key Categories



Uncertainty

²¹ In most cases similar values to Energy Balance are used

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 equipment combustion takes place, apart from division between co-generation and non co-generation. Thence 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.

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 2006 is presented in annex to the NIR.

Table 3.12 – 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
	Primary Energy Consumption		Textile		Chemical and Plastics
			Paper pulp and paper		Ceramic
Consumption in the Energy sector	Refineries (own consumption)		Chemical and Plastics		Glass
	Refineries (losses)		Ceramic		Cement
	Coquerie		Glass		Metalurgy
	Electric Power Plants		Cement		Iron and steel
	Hidropower pumping		Metalurgy		Cloth, shoes, leather
	City gas		Iron and steel		Wood
	Mining Industry		Cloth, shoes, leather		Rubber
	Transport and distribution (losses)		Wood		Equipment
Feedstocks			Rubber		Other Manufacturing Industries
Corrections			Equipment		Construction and Public Works
			Other Manufacturing Industries		National airplanes
			Extractive		National ships
			Services		Railways
					road
					Domestic
					Services

Table 3.13 – Structure of the Portuguese Energy Balance. Fuel categories

Coal	Imported coal	Non Energy Products	Lubricants
	National coal		Asphalts
	coal coke		Parafin
Oil	Intermediate refinery products		Solvents
	LPG		Propylene
	Gasoline	Electricity	Hydro-electricity
	Kerosene		Wind and Geothermal
	Jets		Thermo-electricity
	Diesel oil		
	Residual fuel oil		
	Naphtha		
	Petro coke		
Gases	Natural gas		
	City Gas		
	Coke oven gas		
	Blast Furnace gas		
	Petrochemical gas		
	Hydrogen		
Other	Tar		
	Wood and vegetable wastes		
	Solid Urban Waste		
	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 3.14 – 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&Steel
Iron and Steel Industry	Iron & 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

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.

Table 3.15 – 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
46.1-47.3	43.7	43.3	40.2-40.4	38.7	18.8	2.87	34.1	40.4	44.8

Table 3.16 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (1/2)

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	19 644	1 027 992	1 584 163

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

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

Table 3.18 – Fuel consumption in the Iron and Steel industry in Static Engines (GJ)

Year	Gasoline	Gas Oil
1990	1 673	22 985
1991	1 099	14 950
1992	1 727	16 393
1993	1 049	18 807
1994	1 805	16 258
1995	1 462	15 671
1996	2 251	17 333
1997	235	5 663
1998	141	6 792
1999	177	6 898
2000	151	7 796
2001	3 401	7 999
2002	164	9 581
2003	46	13 896
2004	0	16 344
2005	0	17 354
2006	0	19 644

The significant 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 2006

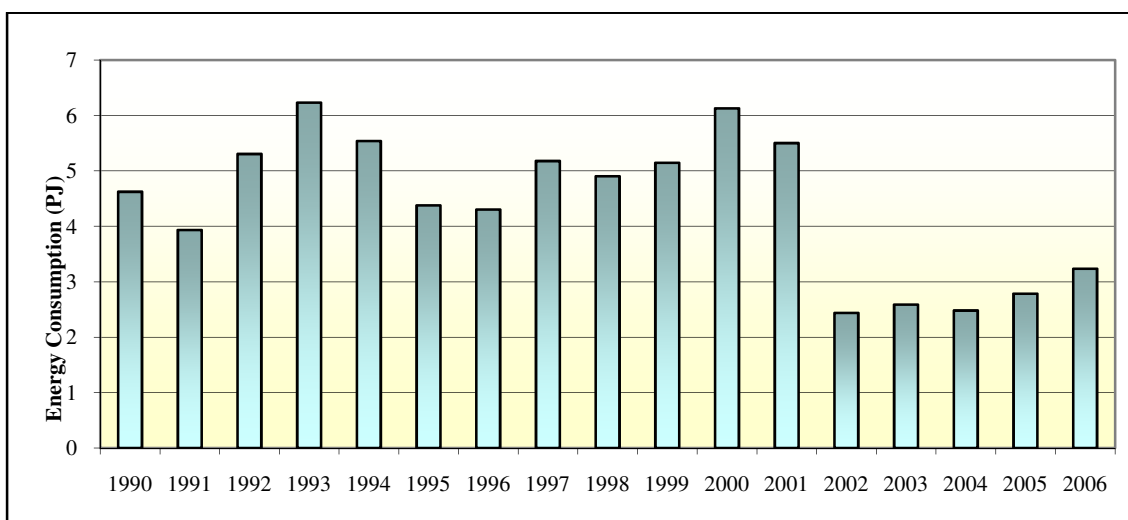


Figure 3.19 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2006

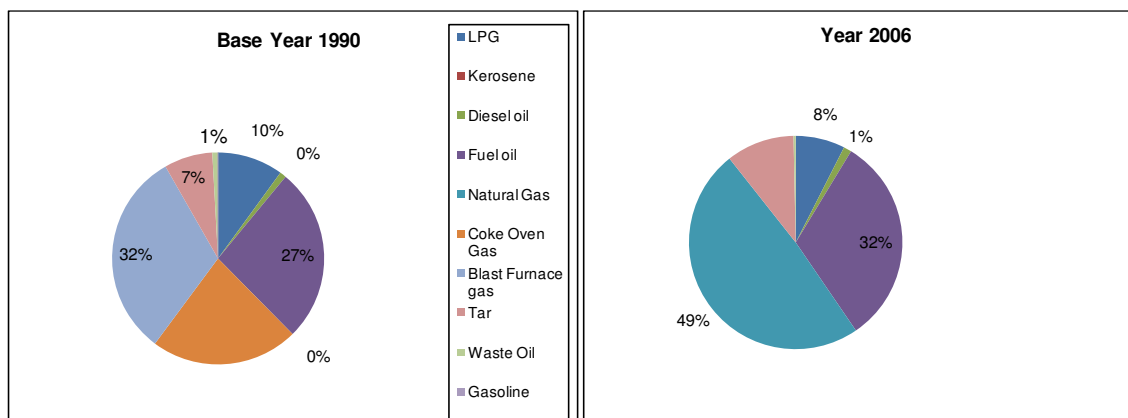


Table 3.19 – Low Heating Values/ Net Calorific Value (LHV/NCV) in Metallurgy Industry

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

Table 3.20 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Coal Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	132 885	381 367	525 854	372	14 478	1 162 634	0	142 678
1991	121 039	240 217	520 401	3	19 577	958 101	0	140 167
1992	30 883	240 167	596 416	0	19 777	1 059 136	0	138 033
1993	50 846	0	495 034	0	20 288	720 875	0	135 272
1994	6 192	0	526 065	0	22 378	554 304	0	135 314
1995	0	0	588 223	0	18 312	387 206	0	135 314
1996	0	0	634 504	0	32 207	479 883	0	143 515
1997	0	0	548 772	0	28 707	78 937	1 086	143 515
1998	0	0	491 977	544	28 159	75 028	31 177	143 818
1999	0	0	375 463	1 577	44 159	66 644	178 134	144 351
2000	0	0	241 731	7	43 857	81 157	441 236	143 515
2001	0	0	317 650	8	77 585	99 020	486 797	143 515
2002	0	0	340 485	0	70 917	68 489	510 836	143 515
2003	0	0	331 882	0	54 538	60 392	614 115	223 898
2004	0	0	325 001	0	56 557	67 776	585 376	227 897
2005	0	0	297 918	16	83 155	64 658	633 516	232 894
2006	0	0	286 025	0	68 891	68 828	663 806	235 900

Table 3.21 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil
1990	0	14 478
1991	254	19 577
1992	678	19 777
1993	3 602	20 288
1994	6 461	22 378
1995	7 119	18 312
1996	8 205	32 207
1997	8 404	28 707
1998	7 042	28 159
1999	3 189	44 159
2000	310	43 857
2001	10 972	77 585
2002	729	70 917
2003	807	54 538
2004	331	56 557
2005	349	83 155
2006	209	68 891

Emission 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 2006

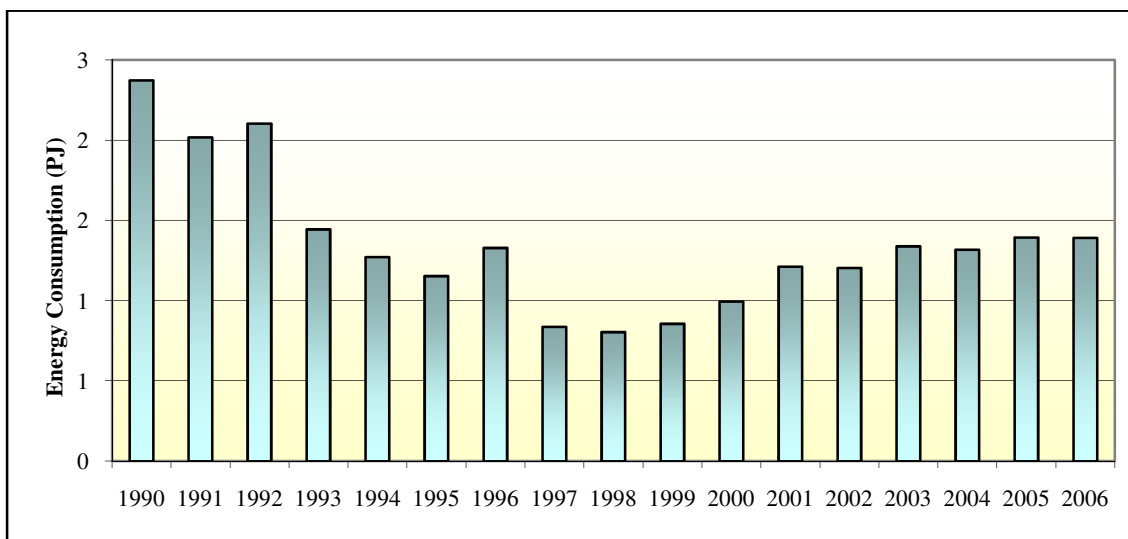


Figure 3.21 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2006

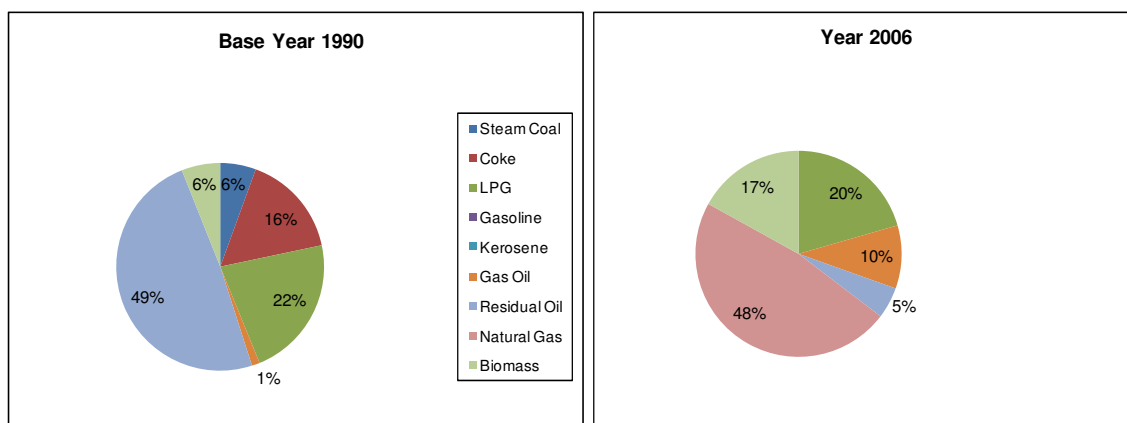


Table 3.22 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Chemical and Plastics Industry

	Coal	Coal Coke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil*	Natural Gas (MJ/Nm ³)	Biomass	Fuel Gas ²²	Flare Gas ²³
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

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



Bibliography



Key Categories



Uncertainty

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

²³ Several streams of intermediate gaseous products and tail gases that are used as energy source

Table 3.23 - Fuel consumption in Chemical and Plastics Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Coke	LPG	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas	Wood	Fuel Gas
1990	261 080	196 711	291 344	1 179	77 593	9 952 224	0	1 051 213	11 323 355
1991	198 665	276 550	127 766	515	122 788	11 674 756	0	1 032 803	9 037 651
1992	0	467 066	126 259	333	107 192	10 345 087	0	1 017 238	10 865 528
1993	0	427 538	223 054	118	99 230	7 774 578	0	996 904	10 235 002
1994	0	460 562	1 127 569	97	148 472	8 440 716	0	996 904	9 394 520
1995	0	491 903	1 608 177	54	166 877	10 479 504	0	996 904	10 383 010
1996	0	469 533	1 033 488	87	209 489	10 187 639	0	1 058 033	9 105 271
1997	0	404 607	872 311	9 752	166 805	10 746 350	0	1 058 033	11 603 903
1998	0	520 946	474 136	19 442	212 257	11 132 967	572 351	1 060 272	12 313 880
1999	0	520 946	419 501	45 537	211 827	11 173 745	1 674 434	1 343 390	12 666 161
2000	0	2 139 767	341 329	12 388	115 805	11 691 591	2 083 315	1 360 854	13 108 321
2001	0	576 452	584 584	5 889	173 599	11 254 082	2 362 443	1 360 837	9 090 262
2002	0	580 910	1 524 084	3 675	120 311	9 508 308	4 349 056	1 360 837	8 971 771
2003	313 321	283 250	789 047	3 091	99 524	8 033 235	6 347 178	1 414 358	10 145 726
2004	413 652	238 097	2 067 644	2 773	92 461	7 661 120	6 953 496	1 442 345	11 777 754
2005	482 261	135 654	1 182 681	2 359	97 943	7 791 007	5 736 630	1 471 332	12 946 207
2006	687 573	99 916	3 592 008	2 343	71 307	6 378 643	6 108 842	1 493 305	12 237 989

Table 3.24 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Fuel oil
1990	7 798	80 087	160 712
1991	24 195	128 919	274 906
1992	66 690	115 582	425 762
1993	67 416	105 718	588 618
1994	107 715	151 617	203 808
1995	165 896	172 985	379 018
1996	131 633	214 675	321 823
1997	190 721	172 202	334 966
1998	188 166	218 030	358 303
1999	161 516	219 722	489 977
2000	48 125	123 646	486 645
2001	72 064	179 854	378 123
2002	56 451	127 242	418 988
2003	47 912	106 543	424 255
2004	32 174	98 872	387 517
2005	12 341	104 787	413 694
2006	3 724	77 688	385 694

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

Year	Flare Gas
1990	859 031
1991	538 730
1992	574 865
1993	1 217 549
1994	1 223 447
1995	1 011 512
1996	858 870
1997	893 948
1998	956 229
1999	1 307 636
2000	1 298 744
2001	1 036 071
2002	1 148 041
2003	1 162 474
2004	1 061 809
2005	1 133 536
2006	1 056 813

Two industrial plants in this sector were treated as Large Point Sources in this source sector, representing a substantial component of total energy consumption, but for confidentiality constrains plant specific information can not be published individually. In the beginning of the period under analysis, fuel consumption²⁴ 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 was gained a relevant importance as the third energy source. An increasing trend in total energy consumption - although irregular - is verifiable in Figure 3.22.



Bibliography



Key Categories



Uncertainty

²⁴ 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 2006

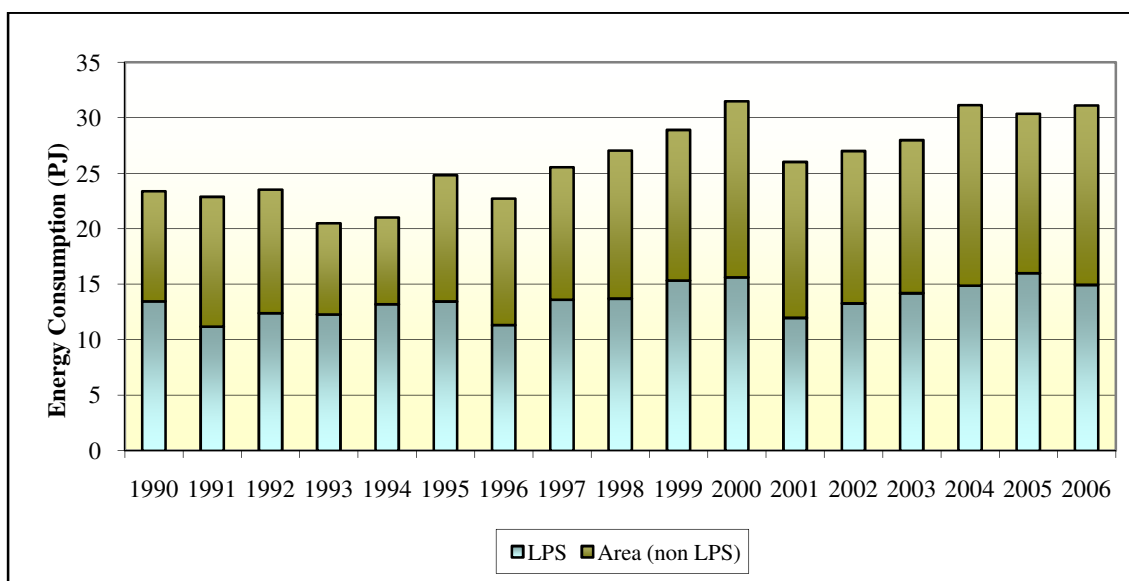


Figure 3.23 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2006

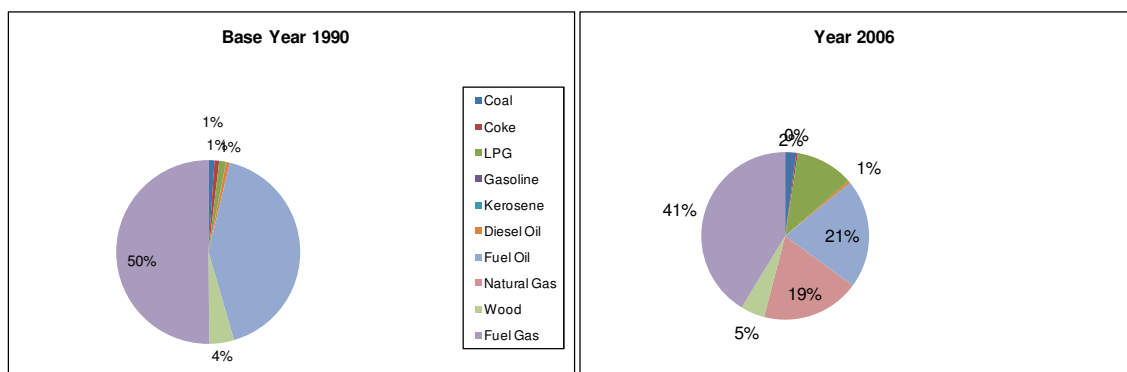


Table 3.26 – Low Heating Values / Net Calorific Values (LHV/NCV) in the Paper and Paper Pulp Industry (MJ/kg)

LPG	Gasoline	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas (MJ/Nm ³)	Wood & Wood Wastes	Liquor	Biogas	Other ²⁵
47.3	44.8	43.7	43.3	39.7-40.2	38.7	10.5-35.6	7.4-15.8	34.7	34.2-52.7

* includes biogas, Tall Oil, and NCG -non combustible gas



Bibliography



Key Categories



Uncertainty

²⁵ Tall Oil, non condensable gases and other sub-products

Table 3.27 - Fuel consumption in the Paper and Paper Pulp Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Liquors	Wood & Wood wastes	Other
1990	103 357	7	90 115	9 445 240	0	24 607 749	5 105 745	39 843
1991	190 436	51	78 814	10 256 575	0	28 333 851	5 982 805	353 670
1992	236 264	32	76 148	11 226 864	0	28 687 604	7 348 581	364 647
1993	199 374	7	70 927	11 614 769	0	27 141 730	8 660 247	350 407
1994	271 869	4	66 278	13 357 405	0	26 583 344	6 868 103	374 799
1995	282 906	23	72 499	11 179 480	0	27 204 795	7 656 588	378 662
1996	301 572	5	71 699	12 224 905	0	27 078 923	7 115 364	380 045
1997	325 960	6	80 280	12 487 985	0	30 006 253	7 684 886	381 443
1998	345 875	0	60 994	11 876 407	7 065	29 923 805	7 616 532	382 292
1999	265 142	0	59 581	12 024 106	305 186	30 849 031	8 180 982	382 096
2000	248 947	26	54 727	12 617 245	2 145 436	32 197 744	6 823 719	376 907
2001	240 115	109	79 587	9 755 170	4 342 236	31 438 403	6 221 961	439 571
2002	103 112	78	76 841	8 926 065	5 232 845	31 329 288	6 852 148	456 284
2003	99 442	79	77 100	7 886 163	5 976 615	28 908 734	5 909 725	472 998
2004	96 921	81	75 006	9 828 712	5 971 090	33 963 543	7 754 940	489 712
2005	92 341	55	81 243	5 721 305	7 461 323	32 512 974	7 609 998	615 973
2006	60 837	126	81 715	4 679 260	8 360 237	33 756 767	8 379 231	1 118 981

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal in the period (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 and natural gas - this last only recently - as auxiliary primary energy sources.

Table 3.28 - Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ)

Year	Gasoline	Diesel Oil	Biogas
1990	2 677	90 115	0
1991	6 335	78 814	0
1992	8 803	76 148	0
1993	4 832	70 927	0
1994	10 998	66 278	0
1995	6 133	72 499	0
1996	5 359	71 699	0
1997	9 478	80 280	0
1998	8 922	60 994	0
1999	7 697	59 581	0
2000	795	54 727	9 705
2001	24 295	79 587	17 804
2002	1 069	76 841	19 632
2003	1 282	77 100	19 056
2004	890	75 006	24 469
2005	910	81 243	28 895
2006	586	81 715	33 042

Figure 3.24 – Total Energy Consumption in the Paper and Paper Pulp Industry between 1990 and 2006

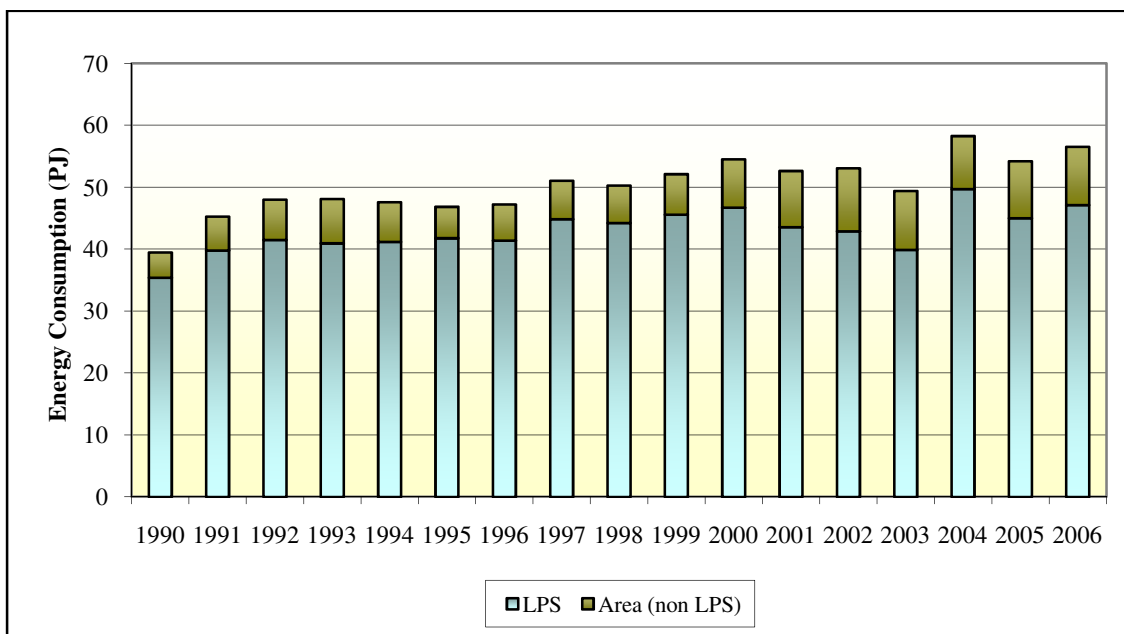


Figure 3.25 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2006

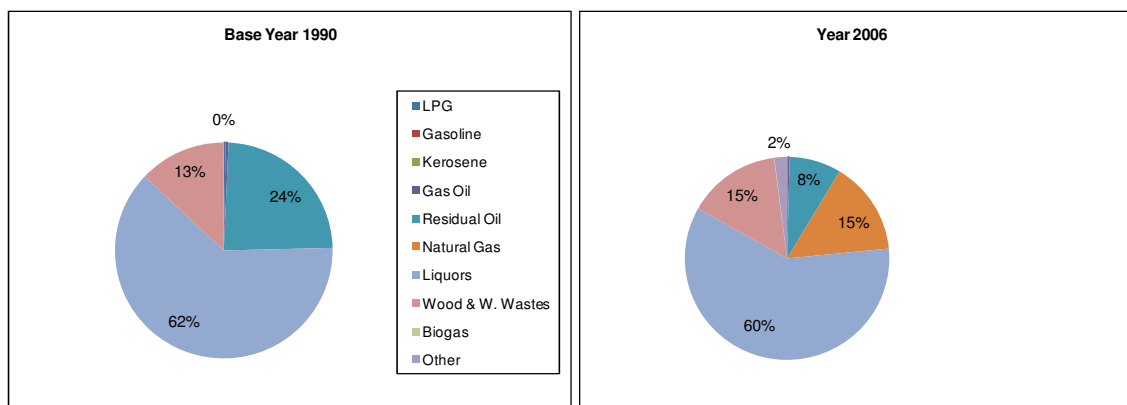


Table 3.29 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Food processing, Beverages and Tobacco Industries

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

Table 3.30 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas	Biomass
1990	12 408	905 695	13 310	545 296	8 896 746	0	3 981 464
1991	6 637	1 042 493	6 712	590 327	9 650 972	0	3 911 799
1992	432	1 146 947	7 581	682 889	9 552 680	0	3 852 887
1993	0	1 216 337	7 657	687 994	9 008 711	0	3 775 816
1994	0	1 362 783	6 219	728 047	8 940 015	0	3 775 858
1995	0	1 461 882	5 075	735 477	9 393 613	0	3 775 858
1996	0	1 625 730	2 129	798 171	9 397 656	0	4 006 695
1997	0	1 964 696	4 592	747 369	11 117 217	3 497	4 006 695
1998	0	1 942 985	5 537	719 673	11 353 423	355 065	4 015 170
1999	0	1 898 545	6 933	812 840	10 589 139	1 081 711	3 391 460
2000	0	1 698 723	1 728	668 841	9 378 846	1 625 761	3 435 549
2001	0	1 810 872	906	738 249	9 499 661	2 314 912	3 435 146
2002	0	1 702 062	801	650 188	9 548 553	3 467 625	3 435 146
2003	0	1 631 026	802	633 690	9 034 076	4 610 651	3 652 342
2004	0	1 437 151	741	677 596	6 539 384	4 440 777	3 642 346
2005	0	1 230 464	5	752 614	5 795 198	2 512 195	3 714 314
2006	0	1 117 280	0	668 849	6 979 540	3 091 801	3 769 289

Table 3.31 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Static Engines (GJ)

Year	Gasoline	Gas Oil
1990	17 576	545 296
1991	27 154	590 327
1992	68 216	682 889
1993	50 870	687 994
1994	103 895	728 047
1995	109 204	735 477
1996	118 030	798 171
1997	192 021	747 369
1998	174 508	719 673
1999	171 400	812 840
2000	117 866	668 841
2001	224 395	738 249
2002	101 308	650 188
2003	89 264	633 690
2004	73 129	677 596
2005	68 837	752 614
2006	53 808	668 849

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 2006

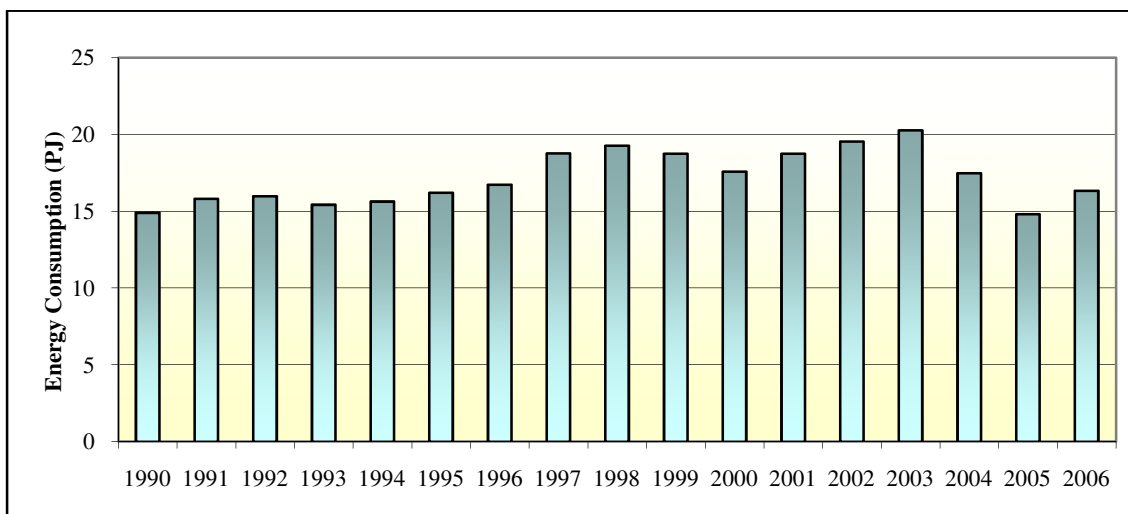


Figure 3.27 - Fuel consumption per fuel type in the Food processing, Beverages and Tobacco Industries in 1990 and 2006

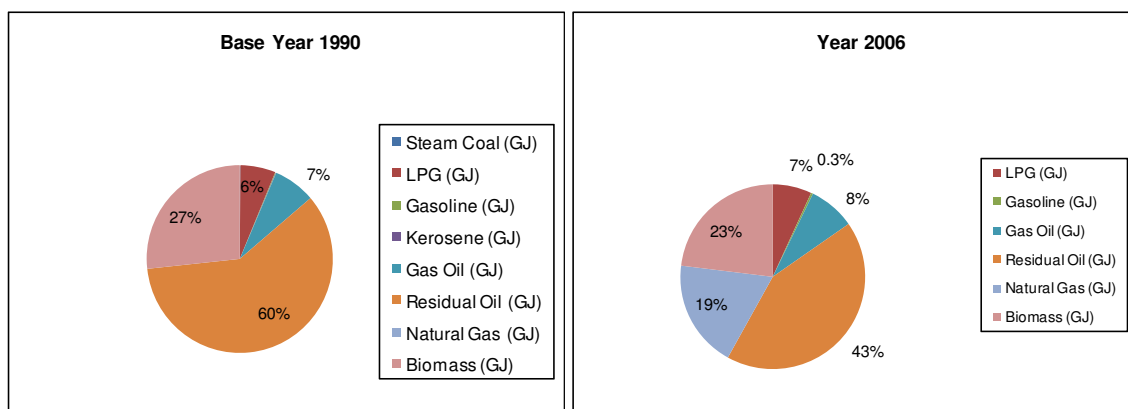


Table 3.32 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Textile Industry

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

Table 3.33 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	211 079	125	27 561	10 398 463	0	1 136 569
1991	260 039	113	28 133	8 869 912	0	1 116 695
1992	313 352	104	31 054	8 137 910	0	1 099 874
1993	308 947	65	31 611	7 368 260	0	1 077 866
1994	326 923	24	37 253	8 355 456	0	1 077 866
1995	375 672	4	37 309	8 873 230	0	1 077 866
1996	446 316	6	40 465	11 399 097	0	1 143 933
1997	554 583	180	50 824	14 710 345	0	1 143 933
1998	658 367	175	52 454	14 158 114	14 207	1 146 353
1999	714 187	8	51 536	11 696 369	565 827	2 033 077
2000	507 677	0	75 300	11 329 974	3 789 968	2 059 507
2001	450 357	0	67 930	9 257 887	5 583 570	2 059 498
2002	405 987	0	90 966	9 173 383	7 160 629	2 059 498
2003	394 399	0	100 352	7 734 712	8 183 262	2 140 028
2004	415 072	0	114 151	7 112 971	7 786 363	2 183 009
2005	362 382	4	108 604	7 290 657	7 586 130	2 225 989
2006	310 962	0	88 536	7 210 460	5 257 445	2 258 954

Table 3.34 – Fuel consumption in Textile Industry – Static Engines (GJ)

Year	Gasoline (GJ)	Gas Oil (GJ)
1990	4 313	27 561
1991	4 723	28 133
1992	12 058	31 054
1993	9 225	31 611
1994	18 616	37 253
1995	18 900	37 309
1996	19 241	40 465
1997	21 787	50 824
1998	22 716	52 454
1999	18 431	51 536
2000	66 347	75 300
2001	60 095	67 930
2002	59 015	90 966
2003	63 433	100 352
2004	50 081	114 151
2005	43 094	108 604
2006	37 699	88 536

Figure 3.28 – Total Energy Consumption in the Textile Industry between 1990 and 2006

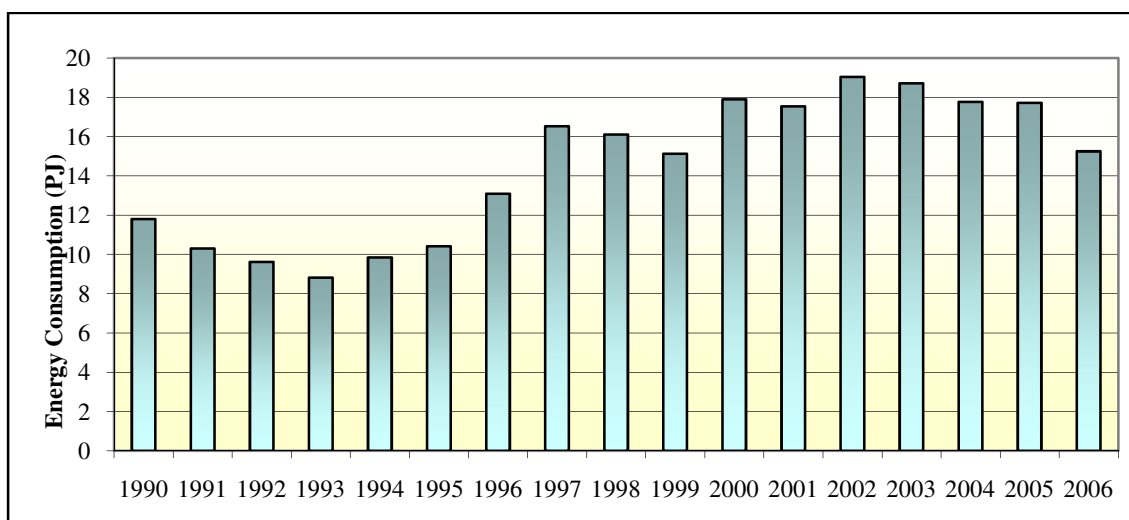


Figure 3.29 – Fuel consumption per fuel type in Textile Industry in 1990 and 2006

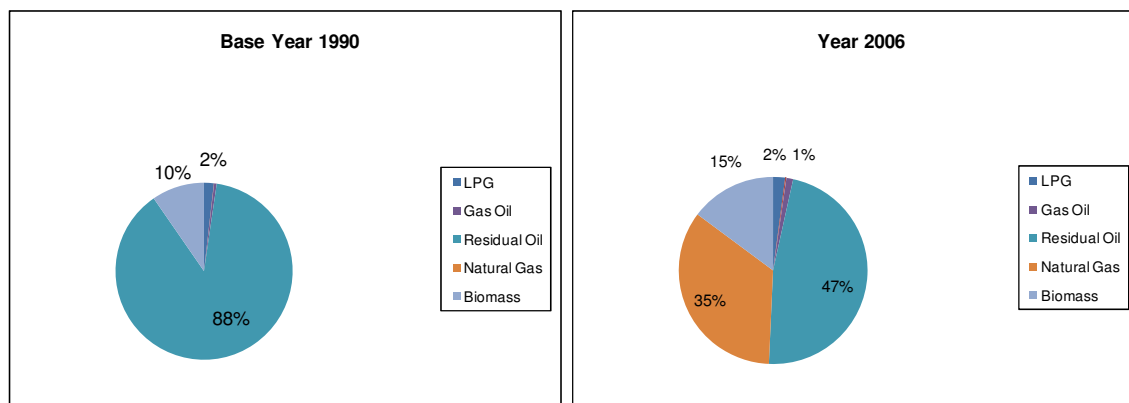


Table 3.35 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Ceramic Industry

	Steam Coal	Pet Coke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm3)	Biomass
LHV (MJ/kg)	29.3	31.0	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.36 - Fuel consumption in the Ceramic Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	6 552	0	6 146 949	28	128 005	3 299 724	0	12 476 234
1991	2 254	0	6 719 549	213	156 721	3 538 468	0	12 257 950
1992	0	0	7 323 141	4 320	157 274	3 340 715	0	12 073 347
1993	0	0	7 654 449	1 395	131 328	3 188 908	0	11 831 925
1994	0	0	8 221 720	109	133 500	3 286 663	0	11 831 883
1995	0	0	8 786 548	0	130 225	3 725 069	0	11 831 883
1996	0	0	9 077 042	1	135 835	3 920 669	0	12 556 485
1997	0	0	8 142 938	0	188 039	6 033 415	1 439 341	12 556 485
1998	0	0	4 497 803	0	199 550	5 880 619	6 583 568	12 583 047
1999	0	0	2 506 160	7	177 680	4 475 511	11 576 243	13 336 945
2000	0	0	1 409 302	347	181 120	3 752 353	14 214 380	13 510 325
2001	0	0	1 458 360	244	215 096	3 036 675	15 722 639	13 510 335
2002	0	0	1 119 759	256	171 336	2 073 502	16 527 884	13 510 335
2003	0	0	838 921	299	155 446	912 218	17 950 583	13 782 248
2004	0	552 404	690 903	193	157 661	825 504	15 820 660	14 059 122
2005	0	353 071	539 832	166	125 937	810 086	15 062 930	14 345 992
2006	0	0	439 247	209	99 874	549 498	14 511 785	14 562 887

Table 3.37 – Fuel consumption in the Ceramic Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil
1990	38 507	128 005
1991	41 454	156 721
1992	51 427	157 274
1993	50 694	131 328
1994	53 041	133 500
1995	48 814	130 225
1996	34 936	135 835
1997	30 024	188 039
1998	30 567	199 550
1999	20 668	177 680
2000	17 187	181 120
2001	17 677	215 096
2002	19 138	171 336
2003	21 409	155 446
2004	19 907	157 661
2005	435	125 937
2006	126	99 874

After the period 1990 until year 2001 when consumption of energy has increased steadily over the years, it is now observable a decline in total consumption in this sector. 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. In the last two years pet coke has start to be used as an alternative source of energy.

Figure 3.30 – Total Energy Consumption in the Ceramic Industry between 1990 and 2006

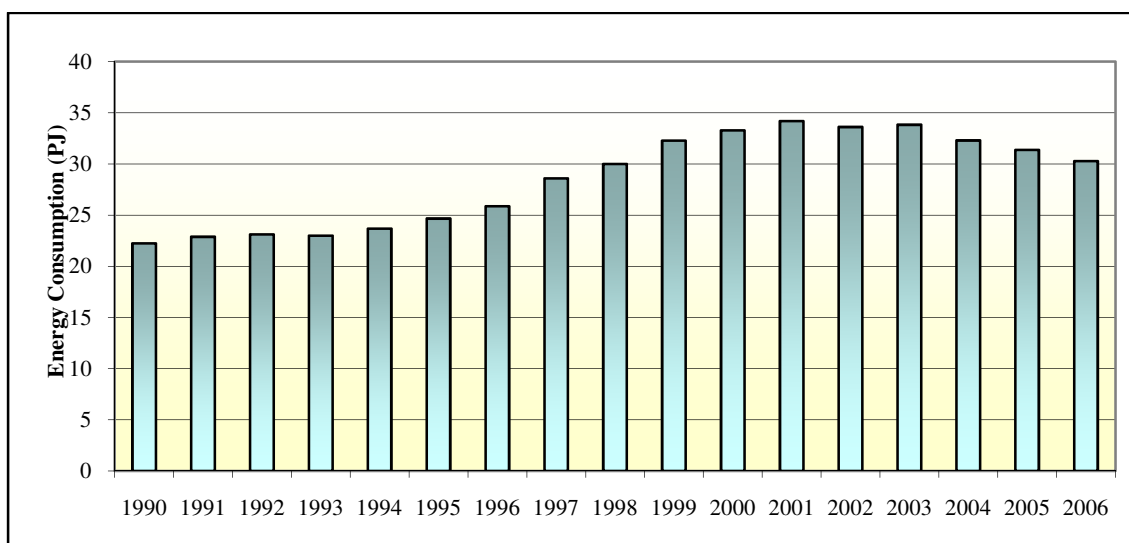


Figure 3.31 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2006

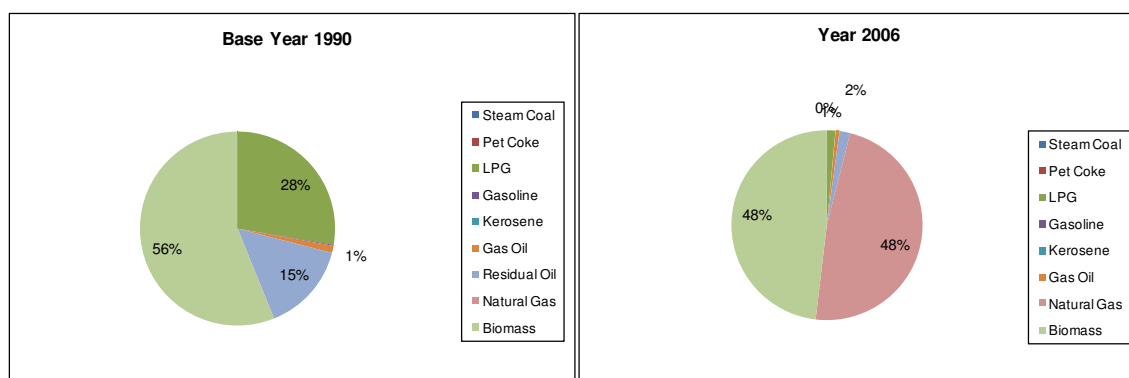


Table 3.38 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Glass Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.39 – Fuel consumption in the Glass Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	1 159 858	0	25 165	4 401 250	0	1 381
1991	1 247 925	0	23 607	5 440 438	0	1 339
1992	1 141 691	0	24 959	5 497 786	0	1 339
1993	1 132 445	0	16 936	6 016 685	0	1 297
1994	1 264 640	0	14 531	6 347 126	0	1 297
1995	1 380 459	0	21 312	6 492 308	0	1 297
1996	1 548 047	0	35 659	6 782 680	0	1 381
1997	1 732 774	0	29 326	7 563 906	29 108	1 381
1998	1 109 224	0	27 044	8 069 679	822 074	1 384
1999	566 874	0	31 071	5 588 831	2 913 173	1 381
2000	343 676	7	23 561	3 446 039	5 428 725	1 381
2001	240 621	0	35 074	3 055 480	6 218 824	1 381
2002	156 419	0	24 358	2 623 142	6 527 015	1 381
2003	134 267	0	25 980	1 989 232	7 422 992	1 381
2004	45 353	0	30 284	1 850 783	6 941 531	1 381
2005	20 868	0	19 269	1 733 688	6 865 351	1 381
2006	25 732	0	9 519	928 954	7 303 712	1 381

Table 3.40 – Fuel consumption in the Glass Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil
1990	3 998	25 165
1991	3 986	23 607
1992	5 226	24 959
1993	5 585	16 936
1994	4 930	14 531
1995	3 646	21 312
1996	3 814	35 659
1997	3 576	29 326
1998	4 313	27 044
1999	2 700	31 071
2000	1 030	23 561
2001	1 122	35 074
2002	283	24 358
2003	152	25 980
2004	171	30 284
2005	174	19 269
2006	126	9 519

The consumption of energy in this sector has suffered a stagnation in the most recent years after 1999. 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 2006

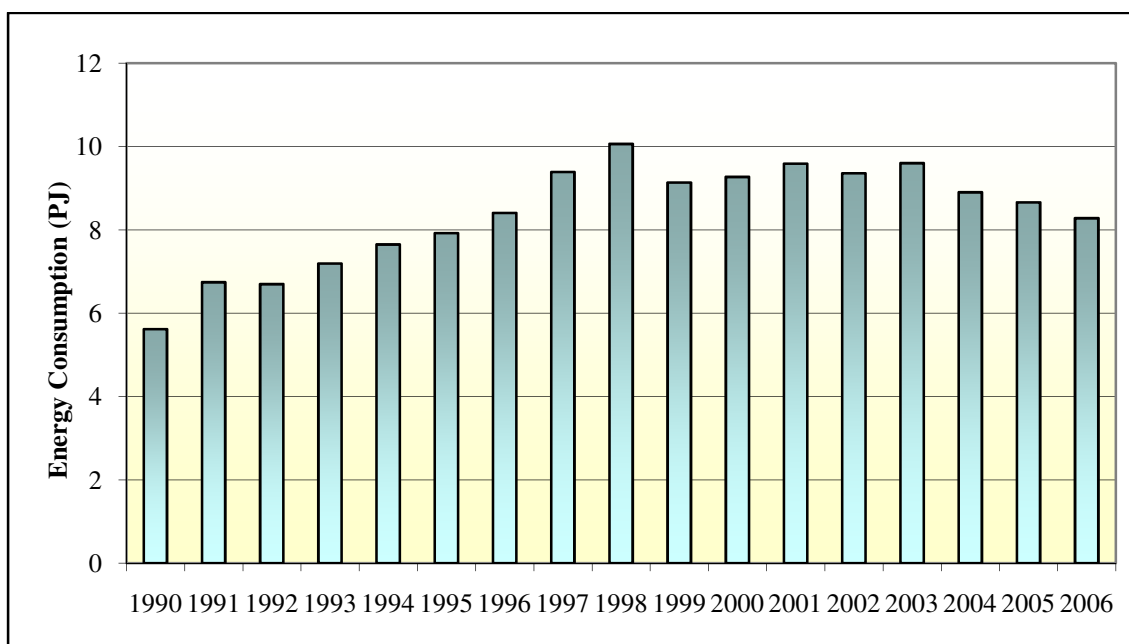


Figure 3.33 – Fuel consumption per fuel type in Glass Industry in 1990 and 2006

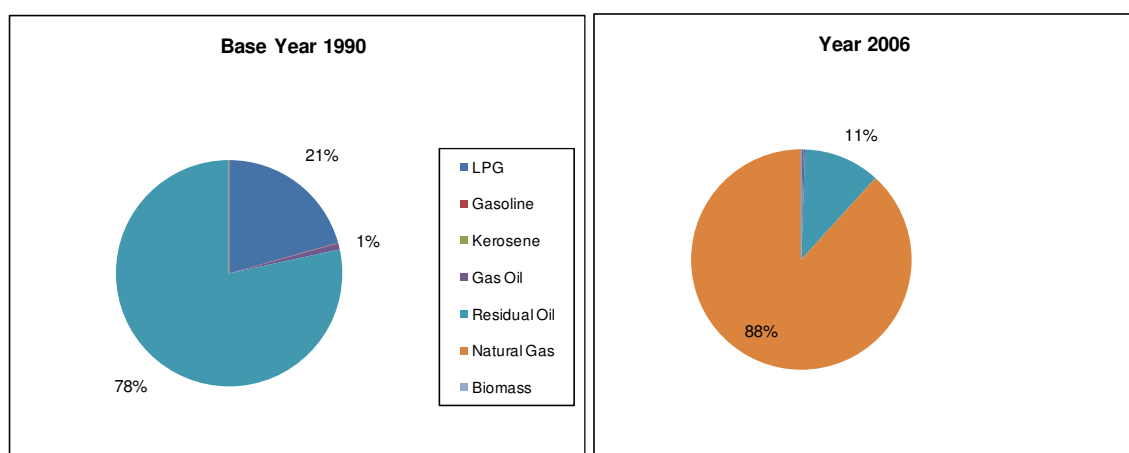


Table 3.41 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry (MJ/kg)

Steam Coal	Coke	Tires	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm3)	Biomass
26.2	27.0	23.9	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.42 – Fuel consumption in the Cement Industry – Boilers and Kilns (GJ)

Year	Steam Coal	Coke	Tires	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	20 688 254	488 593	199 591	29 728	28	312 509	1 034 949	0	256 820
1991	22 277 043	4 759	183 533	40 308	7	354 476	1 229 272	0	252 343
1992	20 782 282	426 362	57 455	67 886	46	363 364	1 002 711	0	248 536
1993	18 982 944	1 965 079	131 565	64 477	29	368 617	986 585	0	243 556
1994	20 713 811	916 712	101 263	62 105	22	352 902	1 138 851	0	243 556
1995	19 489 498	3 062 569	93 938	65 418	15	368 873	1 347 842	0	243 556
1996	18 773 198	3 101 757	161 271	72 327	2	388 015	1 393 357	0	258 577
1997	16 344 826	5 413 331	168 071	266 646	2	416 635	1 423 000	0	258 577
1998	11 752 914	7 788 250	150 582	214 585	0	238 463	1 276 636	66	259 124
1999	9 642 624	11 031 609	191 478	128 680	5	288 774	1 156 352	287	258 787
2000	12 276 213	8 987 620	182 149	176 138	0	321 067	1 011 793	67 487	258 996
2001	7 608 690	11 462 357	188 233	199 583	47 860	504 276	1 208 059	79 191	258 996
2002	7 631 971	14 725 540	204 458	166 823	6 220	638 213	963 815	175 691	258 996
2003	5 431 625	15 217 193	302 834	131 029	21 087	549 395	816 961	351 421	258 996
2004	5 431 625	15 217 193	302 834	103 298	0	501 854	763 274	528 346	258 996
2005	5 431 625	15 217 193	302 834	121 524	18	572 993	763 518	962 315	258 996
2006	5 431 625	15 217 193	302 834	68 075	42	471 464	260 235	1 009 424	258 996

Table 3.43 – Fuel consumption in the Cement Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil
1990	7 608	312 509
1991	6 285	354 476
1992	8 526	363 364
1993	6 748	368 617
1994	8 011	352 902
1995	10 978	368 873
1996	13 321	388 015
1997	11 577	416 635
1998	8 438	238 463
1999	6 077	288 774
2000	2 997	321 067
2001	9 076	504 276
2002	2 390	638 213
2003	1 955	549 395
2004	1 197	501 854
2005	249	572 993
2006	126	471 464

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 as energy source.

Figure 3.34 – Total Energy Consumption in the Cement Industry between 1990 and 2006

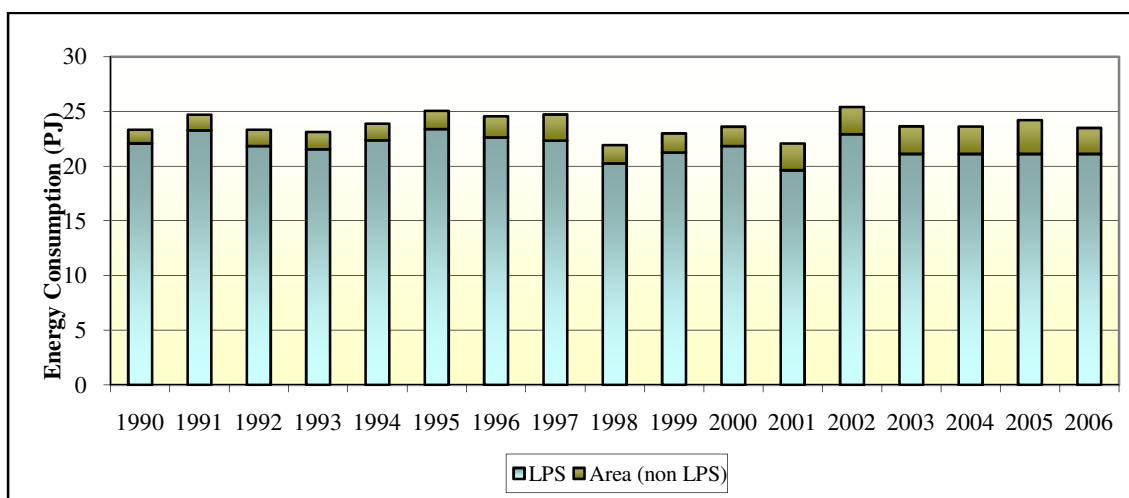


Figure 3.35 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2006

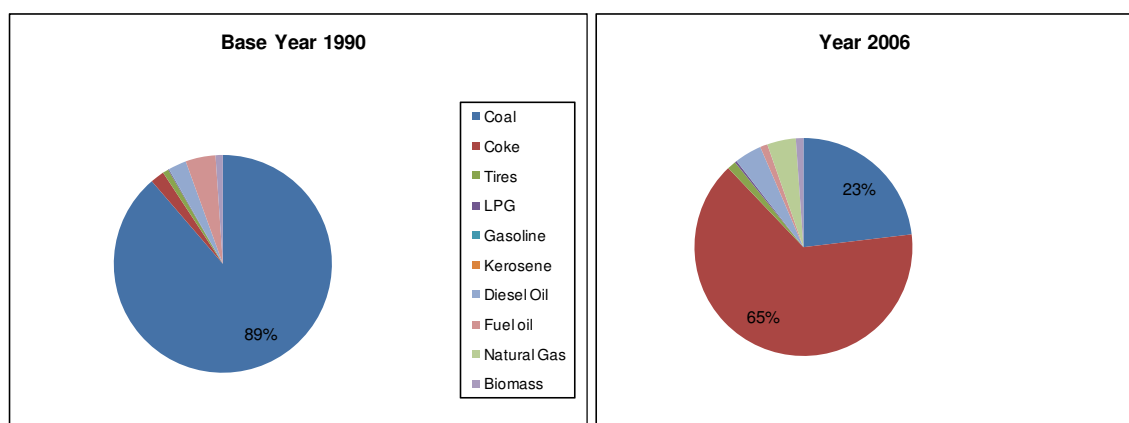


Table 3.44 – Low Heating Values/ Net Calorific Values (LHV/NCV) in clothing, shoes and leather Industries

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

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

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	56 700	28	27 647	765 605	0	279 958
1991	111 282	42	27 348	857 242	0	275 063
1992	162 079	35	25 753	1 391 289	0	270 921
1993	206 088	7	24 405	1 825 000	0	265 523
1994	221 966	0	25 331	1 335 613	0	265 481
1995	239 020	0	22 316	704 376	0	265 481
1996	305 465	0	24 033	791 071	0	281 590
1997	313 963	0	19 935	775 571	0	281 590
1998	329 960	0	20 217	714 440	7 916	282 186
1999	312 795	0	19 259	646 429	34 646	282 427
2000	225 900	0	15 069	349 856	152 751	282 636
2001	314 991	0	17 792	370 295	388 035	282 636
2002	297 297	0	14 765	466 138	266 962	282 636
2003	259 827	0	12 894	333 169	447 383	0
2004	241 927	0	11 749	323 514	487 088	0
2005	231 030	8	11 601	241 409	434 915	0
2006	212 594	0	8 347	244 812	463 940	0

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

Year	Gasoline	Gas Oil
1990	1 961	27 647
1991	2 750	27 348
1992	7 810	25 753
1993	7 113	24 405
1994	9 394	25 331
1995	8 662	22 316
1996	8 247	24 033
1997	7 984	19 935
1998	7 524	20 217
1999	6 185	19 259
2000	3 833	15 069
2001	13 192	17 792
2002	2 320	14 765
2003	1 362	12 894
2004	800	11 749
2005	464	11 601
2006	209	8 347

Figure 3.36 – Total Energy Consumption in the clothing, shoes and leather Industries between 1990 and 2006

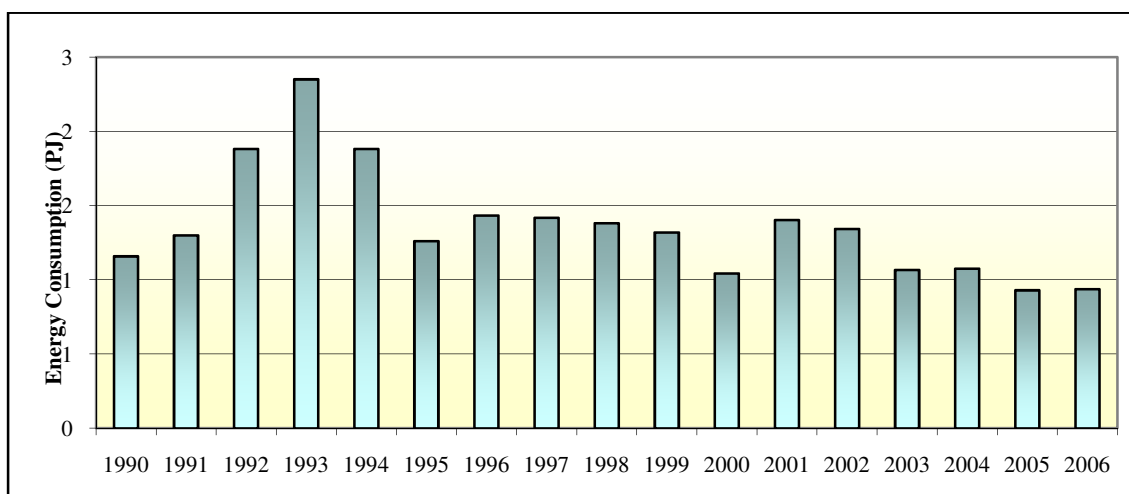


Figure 3.37 - Fuel consumption per fuel type in the clothing, shoes and leather Industries in 1990 and 2006

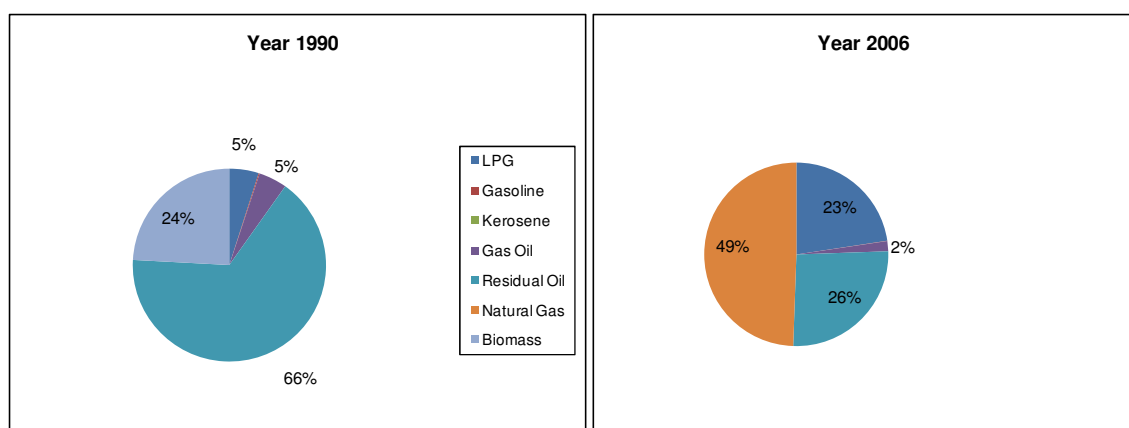


Table 3.47 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Wood Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

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

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	85 257	69	250 246	1 345 541	0	1 309 205
1991	100 153	57	246 290	1 275 845	0	1 286 318
1992	96 584	11	208 089	688 924	0	1 266 946
1993	110 646	22	179 398	1 074 773	0	1 241 590
1994	115 817	21	184 980	1 785 181	0	1 241 590
1995	115 223	0	192 129	3 034 466	0	1 241 590
1996	131 520	0	204 520	3 085 937	0	1 317 573
1997	330 118	1 912	479 619	2 897 581	0	1 317 573
1998	343 317	2 900	577 975	2 838 039	12	1 320 360
1999	378 236	74	497 917	2 842 876	35 845	895 593
2000	467 589	85	206 123	2 937 801	243 872	907 236
2001	444 713	81	255 226	1 741 058	315 564	903 766
2002	426 429	84	208 142	2 118 219	354 951	618 075
2003	381 836	73	202 161	1 998 170	452 243	1 637 257
2004	303 397	57	322 906	2 070 544	540 499	1 693 231
2005	260 445	1 126	215 491	1 997 453	625 009	1 632 259
2006	208 577	1 632	242 218	2 030 962	527 911	1 656 234

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

Year	Gasoline (GJ)	Gas Oil (GJ)
1990	792	250 246
1991	1 831	246 290
1992	3 552	208 089
1993	3 622	179 398
1994	9 242	184 980
1995	11 009	192 129
1996	11 948	204 520
1997	132 822	479 619
1998	169 127	577 975
1999	129 553	497 917
2000	4 047	206 123
2001	30 937	255 226
2002	3 231	208 142
2003	2 502	202 161
2004	1 594	322 906
2005	1 372	215 491
2006	418	242 218

Although total consumption of energy from combustion has increased from 1990 to 2005, 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 2006

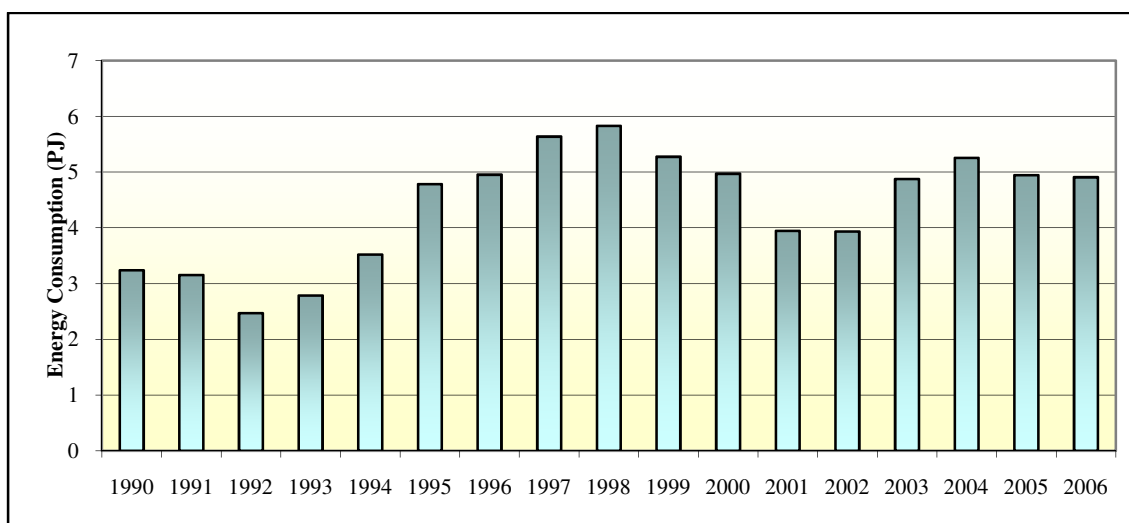


Figure 3.39 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2006

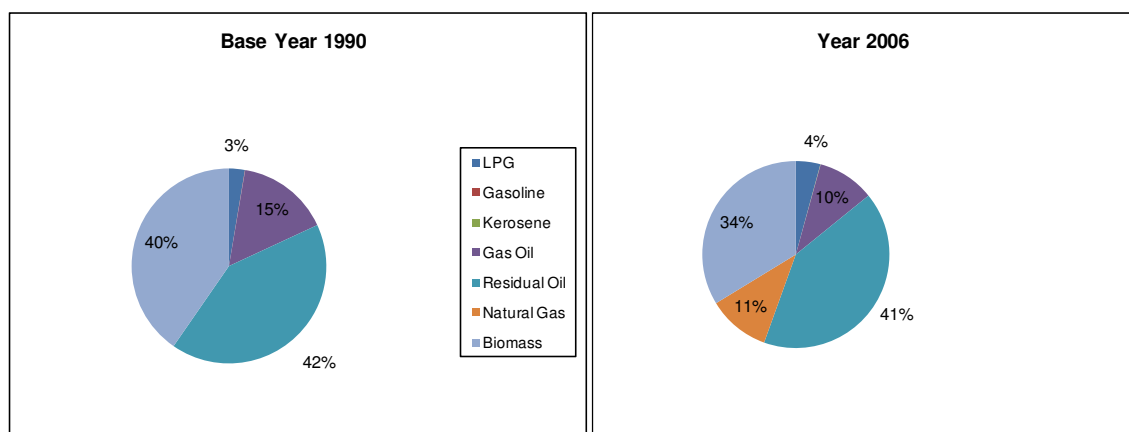


Table 3.50 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Rubber Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

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

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	27 671	240	5 478	571 116	0	46 820
1991	30 069	268	6 781	462 204	0	45 983
1992	28 308	223	13 604	344 038	0	45 314
1993	27 882	188	13 622	286 765	0	44 393
1994	30 736	118	14 576	262 449	0	44 393
1995	33 265	135	13 461	270 483	0	44 393
1996	39 185	168	14 008	268 019	0	47 280
1997	71 109	60	11 586	281 207	0	47 280
1998	27 993	28	11 869	307 506	373	47 380
1999	26 017	13	16 800	352 751	1 614	47 322
2000	28 093	48	29 560	379 685	35 797	47 280
2001	35 377	15	33 365	203 195	141 557	47 280
2002	29 338	0	29 323	87 426	278 541	47 280
2003	27 662	1	24 544	67 610	356 714	0
2004	19 790	0	25 387	50 847	413 590	0
2005	20 533	0	1 313	27 090	431 024	0
2006	17 448	0	272	17 448	496 401	0

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

Year	Gasoline	Gas Oil
1990	0	5 478
1991	0	6 781
1992	1 641	13 604
1993	2 359	13 622
1994	3 486	14 576
1995	4 725	13 461
1996	5 170	14 008
1997	7 280	11 586
1998	6 989	11 869
1999	20 478	16 800
2000	57 411	29 560
2001	53 084	33 365
2002	48 393	29 323
2003	43 541	24 544
2004	43 983	25 387
2005	48	1 313
2006	0	272

Figure 3.40 – Total Energy Consumption in the Rubber Industry between 1990 and 2006

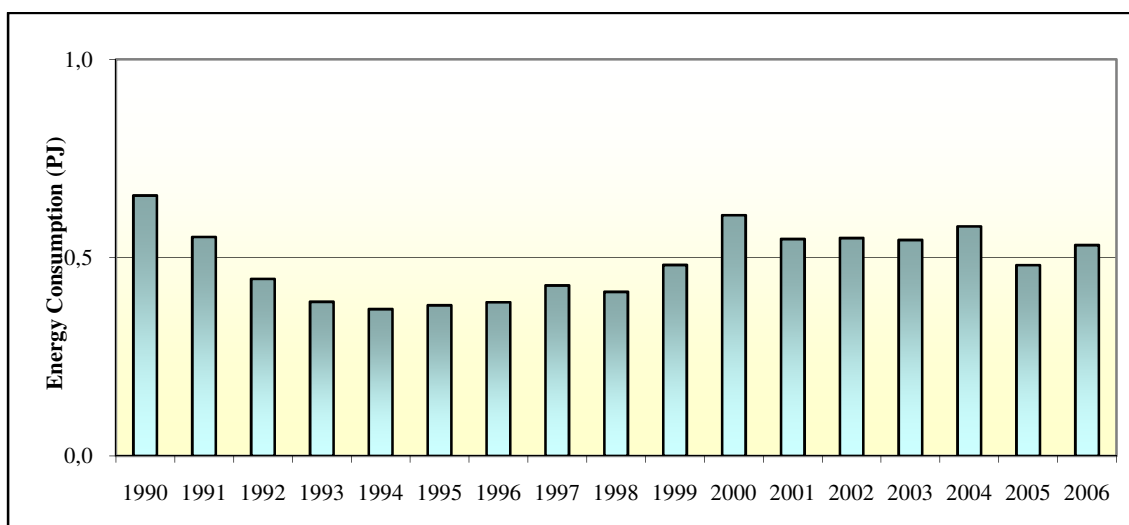


Figure 3.41 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2006

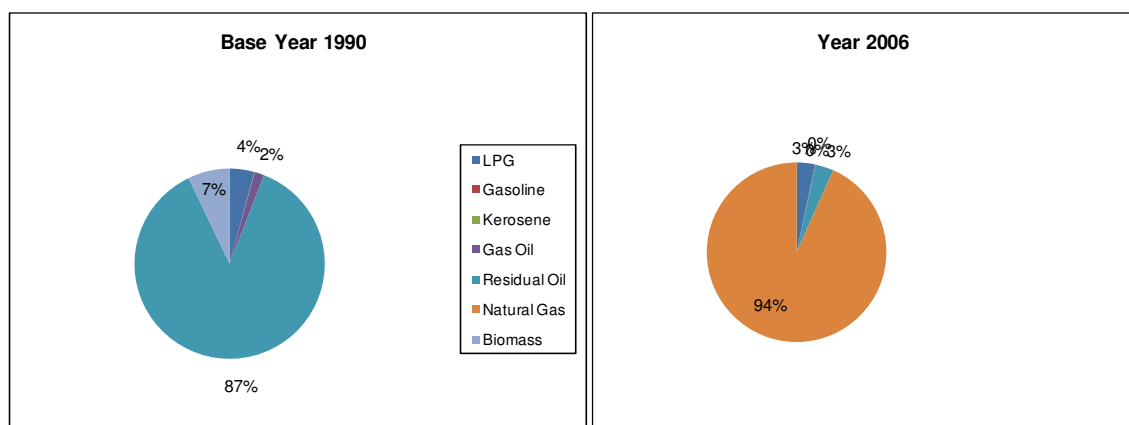


Table 3.53 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Manufacturing of Machines and Metallic Equipments Industry (GJ)

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

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

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	1 463 621	5 897	165 914	885 427	0	28 368
1991	1 512 383	2 696	163 350	814 743	0	27 866
1992	1 534 223	1 232	176 085	862 680	0	27 448
1993	1 512 254	429	159 784	535 701	0	26 904
1994	1 619 962	106	154 794	647 603	0	26 904
1995	1 605 495	77	210 767	508 242	0	26 904
1996	1 628 553	206	254 552	1 021 508	0	28 452
1997	2 370 280	208	217 276	727 924	167 933	28 452
1998	2 456 009	238	250 241	975 620	445 869	28 512
1999	2 268 829	377	238 777	650 999	730 723	15 993
2000	1 783 872	323	117 590	770 132	1 219 492	16 201
2001	1 674 634	136	175 163	494 440	1 606 199	16 192
2002	1 421 680	182	170 510	401 219	1 763 389	16 192
2003	1 330 280	110	151 271	331 183	2 133 290	16 992
2004	1 326 956	111	135 478	281 725	2 117 108	17 992
2005	1 292 911	296	142 399	215 389	2 180 384	16 992
2006	1 223 515	209	171 862	249 916	2 214 349	17 992

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

Year	Gasoline	Gas Oil
1990	43 694	165 914
1991	50 417	163 350
1992	84 252	176 085
1993	69 992	159 784
1994	95 095	154 794
1995	101 273	210 767
1996	165 257	254 552
1997	162 860	217 276
1998	157 108	250 241
1999	138 921	238 777
2000	45 657	117 590
2001	100 547	175 163
2002	49 713	170 510
2003	104 160	151 271
2004	20 182	135 478
2005	10 944	142 399
2006	37 406	171 862

Figure 3.42 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry between 1990 and 2006

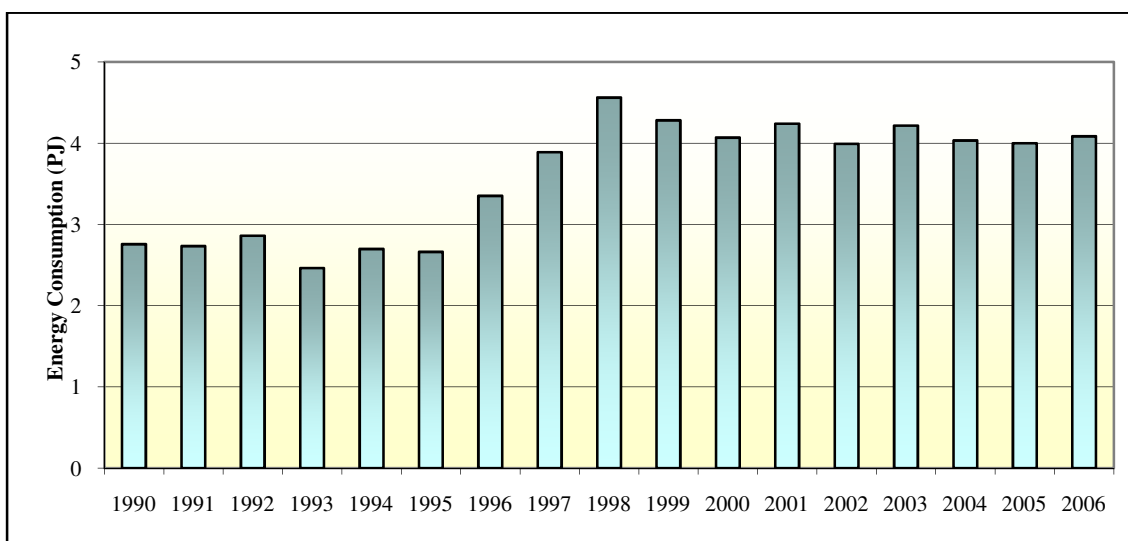


Figure 3.43 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2006

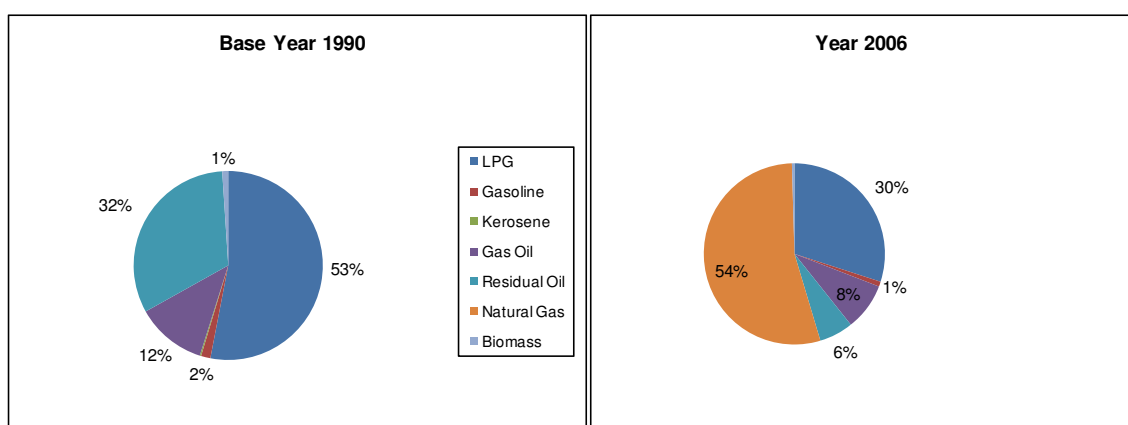


Table 3.56 – Low Heating Values/ Net Calorific Values (LHV/NCV) in other transformation industry

	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas (MJ/Nm3)	Biomass
LHV (MJ/kg)	17.2	47.3	44.8	43.7	43.3	40.2	15.7	38.7	12.6

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

Year	Lignite	LPG	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas	Biomass
1990	446	152 386	4 088	169 274	1 449 574	78	0	6 234
1991	206	203 448	3 982	219 224	1 386 088	2 746	0	6 109
1992	34	234 555	3 310	238 538	1 260 654	6 360	0	6 025
1993	463	340 825	2 197	363 460	938 562	64 686	0	5 900
1994	711	395 903	1 008	292 137	811 178	55 941	0	5 900
1995	0	430 781	37	180 548	168 320	55 690	0	5 900
1996	0	490 663	1 051	262 280	179 097	61 914	0	6 276
1997	0	114 667	0	20 021	331	72 929	0	6 276
1998	0	96 638	0	31 761	0	68 724	429	6 289
1999	0	128 737	0	27 403	0	60 544	18 688	6 276
2000	0	79 442	0	17 835	0	44 451	111 958	6 276
2001	0	49 970	30	24 944	0	6 056	148 858	6 276
2002	0	40 456	0	8 164	0	0	154 903	6 276
2003	0	33 267	0	7 449	0	0	209 904	33 985
2004	0	37 656	0	9 784	0	0	197 964	32 985
2005	0	33 747	0	8 018	0	0	203 814	34 984
2006	0	37 113	0	3 808	0	0	209 460	35 983

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

Year	Gasoline (GJ)	Gas Oil (GJ)
1990	307	169 274
1991	4 849	219 224
1992	221 092	238 538
1993	895 944	363 460
1994	503 491	292 137
1995	51 507	180 548
1996	88 067	262 280
1997	28 516	20 021
1998	32 759	31 761
1999	23 936	27 403
2000	2 620	17 835
2001	14 198	24 944
2002	3 592	8 164
2003	3 246	7 449
2004	3 020	9 784
2005	2 704	8 018
2006	1 046	3 808

Figure 3.44 – Total Energy Consumption in other transformation Industry between 1990 and 2006

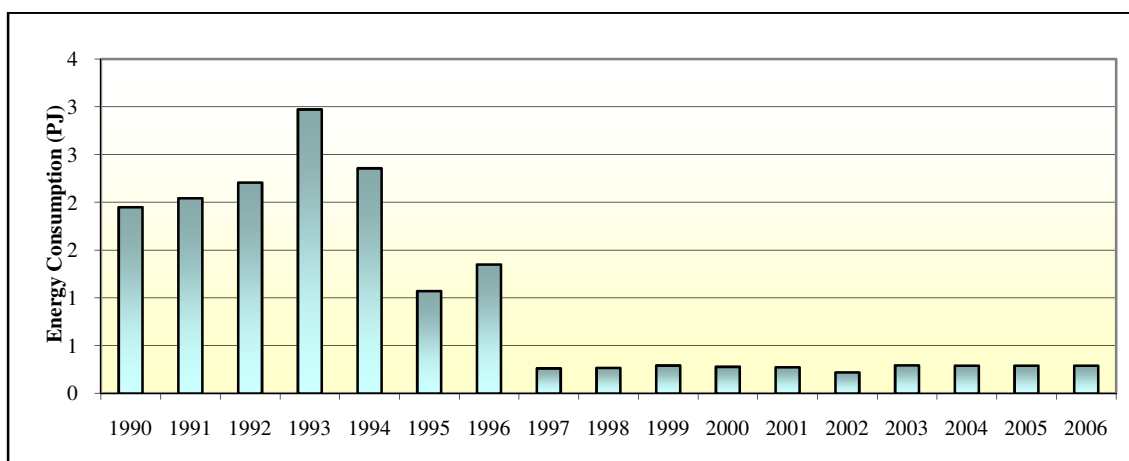


Figure 3.45 – Fuel consumption per fuel type in other transformation industry in 1990 and 2006

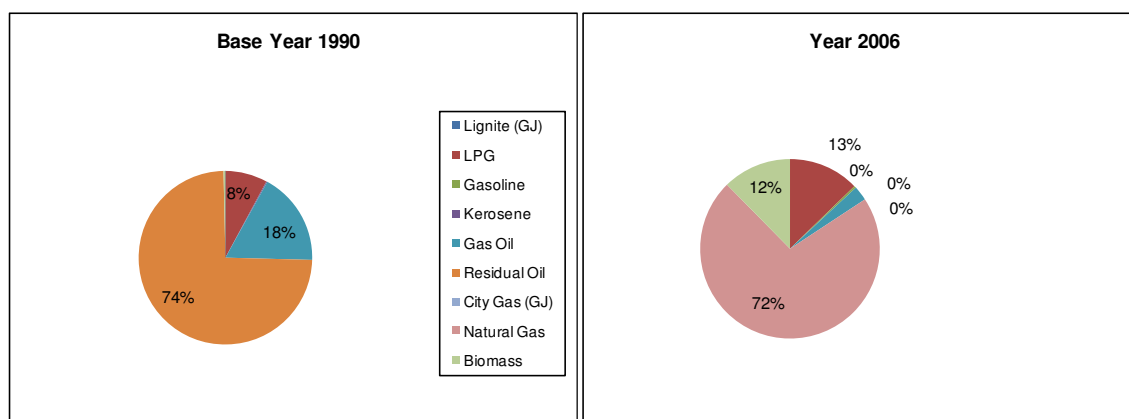


Table 3.59 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the extractive industry

	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/kg)
LHV (MJ/kg)	17.2	47.3	44.8	43.7	43.3	40.2	46.0

Table 3.60 – Fuel consumption in the extractive industry – Boilers and Furnaces

Year	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas
1990	75 290	0	1 929	484 511	110 565	0	2 402
1991	76 218	0	14	523 943	254 930	0	2 608
1992	74 950	18	1 274	598 314	156 191	0	1 904
1993	83 878	24	605	626 105	80 907	0	1 184
1994	100 845	8	625	469 123	49 864	0	412
1995	103 573	0	625	484 376	49 378	0	0
1996	124 108	0	202	583 210	52 824	0	0
1997	182 831	0	553	916 115	124 033	0	0
1998	199 683	0	520	816 776	103 756	0	0
1999	192 150	6	213	822 117	80 694	9 817	0
2000	172 033	29 133	0	1 034 421	95 513	13 539	0
2001	209 533	0	4	979 018	138 961	404 228	0
2002	138 743	7 376	0	924 267	110 817	52 009	0
2003	102 359	4 850	0	990 731	82 789	50 421	0
2004	65 690	2 992	0	988 134	0	778 833	0
2005	70 130	2 932	0	948 434	401 924	259 523	0
2006	71 755	2 552	0	888 948	129 980	250 030	0

Table 3.61– Fuel consumption in the extractive industry – Static Engines

Year	Gasoline (GJ)	Gas Oil (GJ)
1990	16 243	453 879
1991	15 821	492 320
1992	10 436	532 648
1993	8 638	530 086
1994	6 424	450 284
1995	2 036	482 069
1996	3 126	580 542
1997	5 729	912 961
1998	19 899	813 863
1999	30 243	820 769
2000	20 667	736 750
2001	82 104	979 018
2002	38 758	877 376
2003	25 136	876 411
2004	57 481	875 106
2005	22 453	857 781
2006	20 209	817 023

Figure 3.46 – Total Energy Consumption in the Extractive Industry between 1990 and 2006

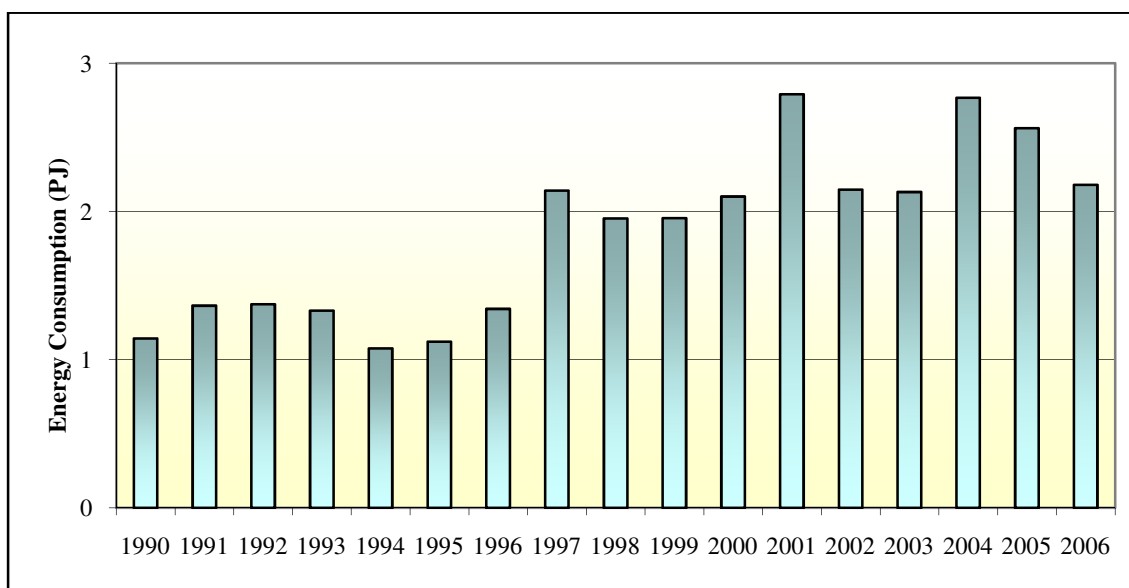


Figure 3.47– Fuel consumption per fuel type in the extractive industry in 1990 and 2006

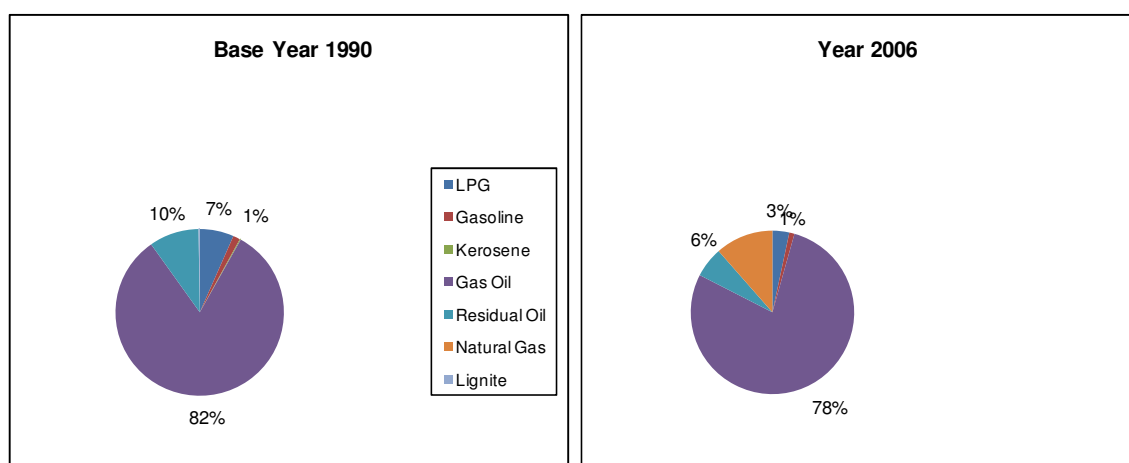


Table 3.62 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Construction and Building Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/kg)
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	46.0

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

Year	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas
1990	233 005	28 161	6 855	5 961 423	671 304	0
1991	206 098	54 264	333	6 751 708	884 706	0
1992	264 421	168 067	2 106	6 463 826	876 008	0
1993	462 221	217 517	2 772	6 589 927	1 775 969	0
1994	696 370	363 631	1 179	7 154 205	1 412 975	0
1995	912 385	455 546	640	7 705 986	1 763 816	0
1996	1 066 771	682 700	177	7 929 141	1 353 841	0
1997	646 260	380 360	1 796	8 255 251	1 892 148	0
1998	574 093	355 521	11 044	8 251 931	2 008 223	610
1999	578 294	301 584	228	8 116 581	1 429 069	2 718
2000	560 826	73 801	130	7 673 442	1 473 144	7 637
2001	843 368	396 140	389	9 525 562	1 637 796	286 481
2002	547 284	61 620	279	9 463 552	1 856 172	570 473
2003	495 233	57 695	104	8 773 984	1 295 338	823 671
2004	496 078	55 810	93	10 191 948	1 572 038	816 157
2005	423 557	68 579	184	9 286 778	1 724 975	804 870
2006	407 657	69 038	1 464	7 320 795	1 307 406	726 797

Figure 3.48 – Total Energy Consumption in the Construction and Building Industry between 1990 and 2006

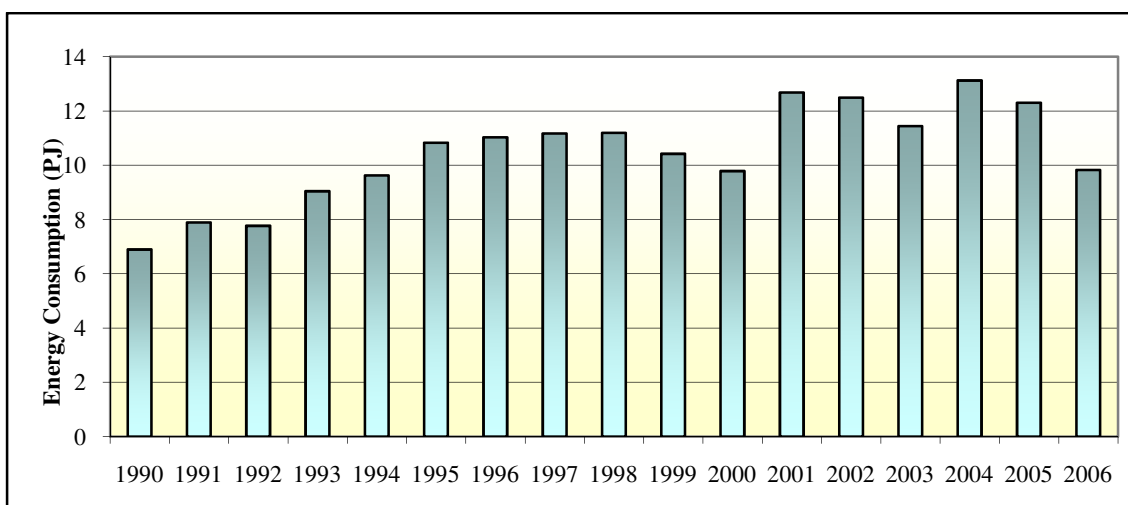
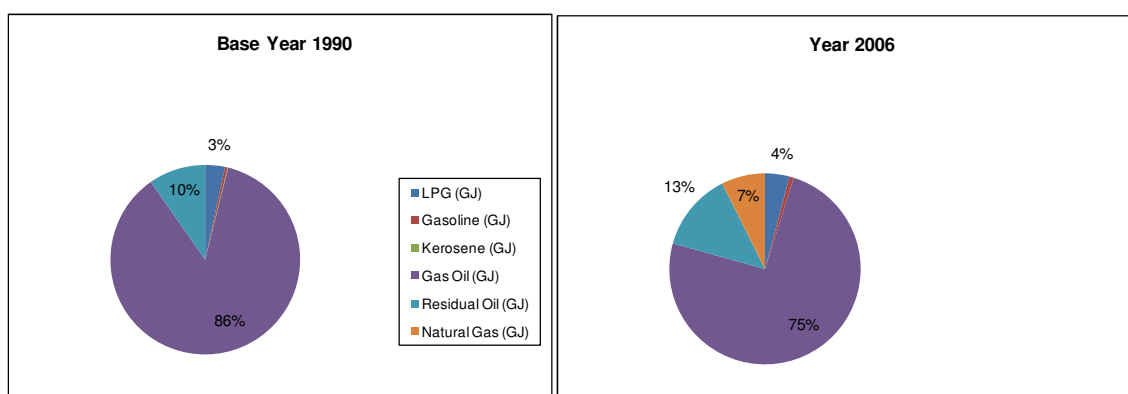


Figure 3.49 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2006

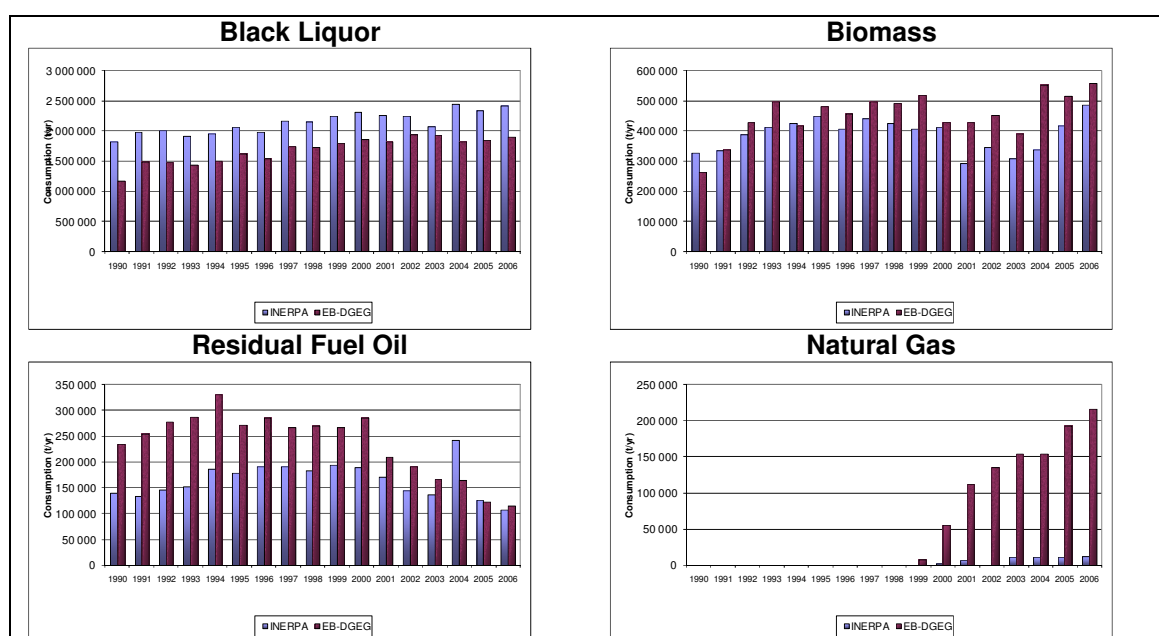


Comparison of LPS data vs. Energy Balance

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.

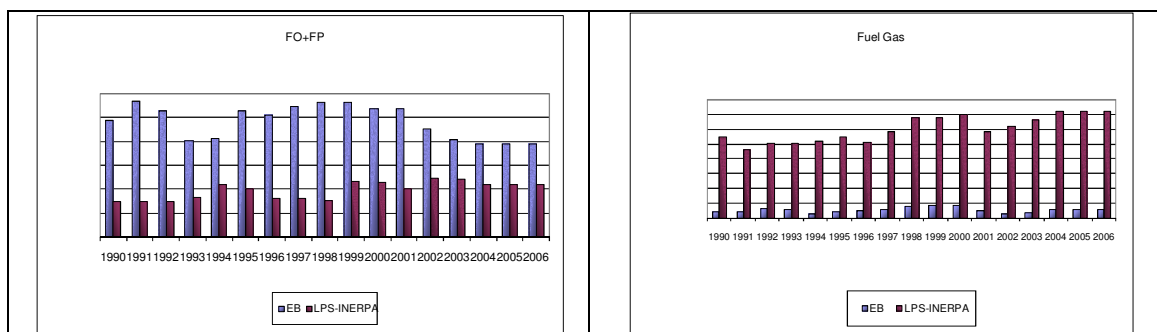
Before hand, to conclude by consistency between the two distinct datasets, the comparison should result in higher or equal consumption in the EB than in the inventory, because apart from specific fuels (black liquor in the paper and pulp industry, coke oven gas and blast furnace gas in the iron industry, 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”



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 (DGE,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.

Figure 3.51 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector “Chemical and Plastics”²⁶



For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil²⁷ is about 50 per cent 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.



Bibliography



Key Categories

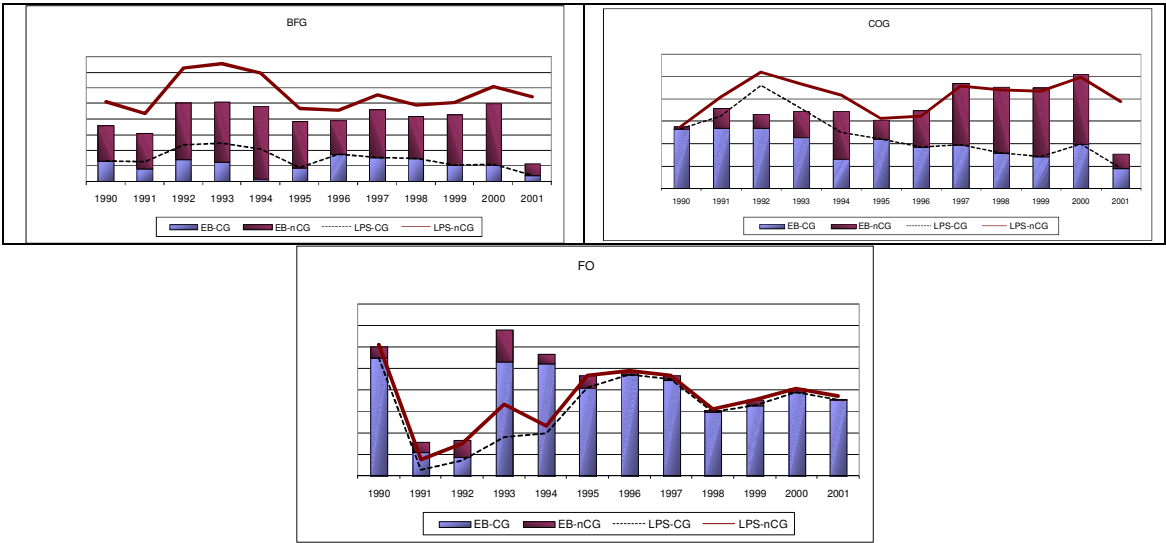


Uncertainty

²⁶ Units in the vertical axis are not indicated due to confidentiality issues.

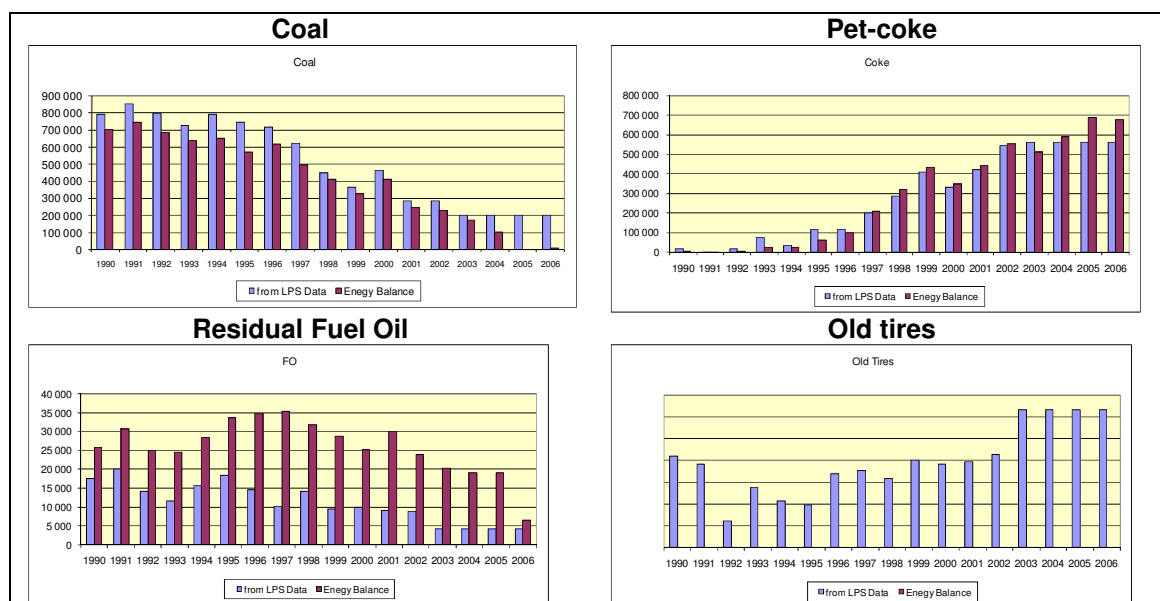
²⁷ This category includes residual fuel oil, a traded fuel, and fuel pyrolysis, a non-traded by product fuel, used inside the industrial unit that produces it.

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”²⁸



²⁸ Units in the vertical axis are not indicated due to confidentiality issues.

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



Concerning the cement industry, a acceptable coherence exists between both information sources, except for the fact that the consumption of old tires is not included in the energy balance, and for the need to review data of use of coal for the last couple of years in the inventory, that is showing some over-estimation of emissions.

In conclusion, the analysis indicate 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.

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.

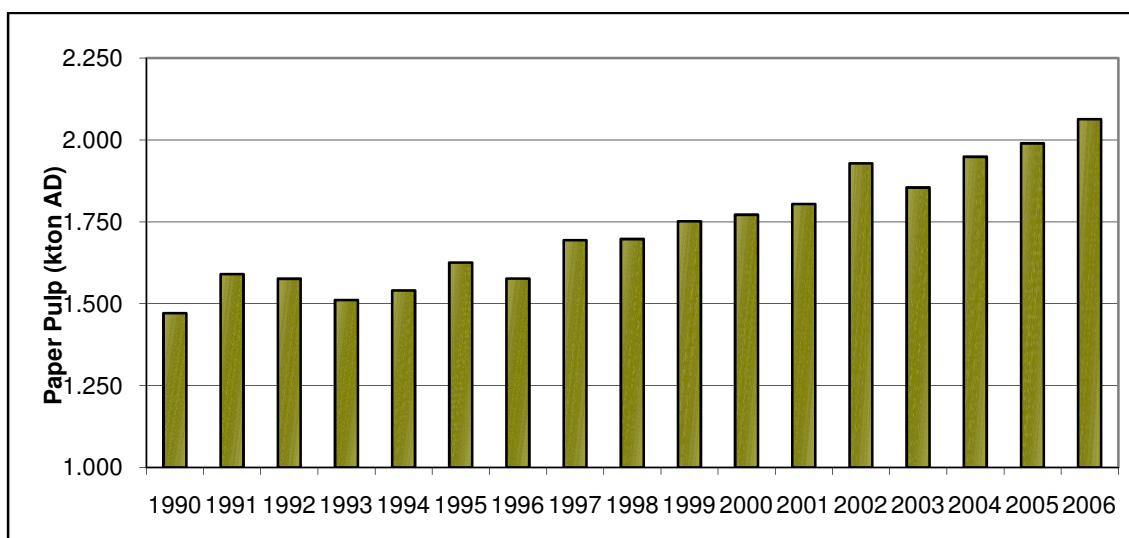
Total production of paper pulp is reported in Table 3.64. Production data for Kraft paper pulp from year 1990 to year 2000 was made available to IA directly from the six operating units, while data for 2001 till 2005 for the same units and the total time series of paper pulp by the acid sulphide process is from CELPA.

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

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

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
Pulp Production (kton)	1 698	1 752	1 772	1 805	1 929	1 855	1 949	1 990	2 064

Figure 3.54 – Total paper pulp production: Kraft and sulphide paper pulp (1990-2006)



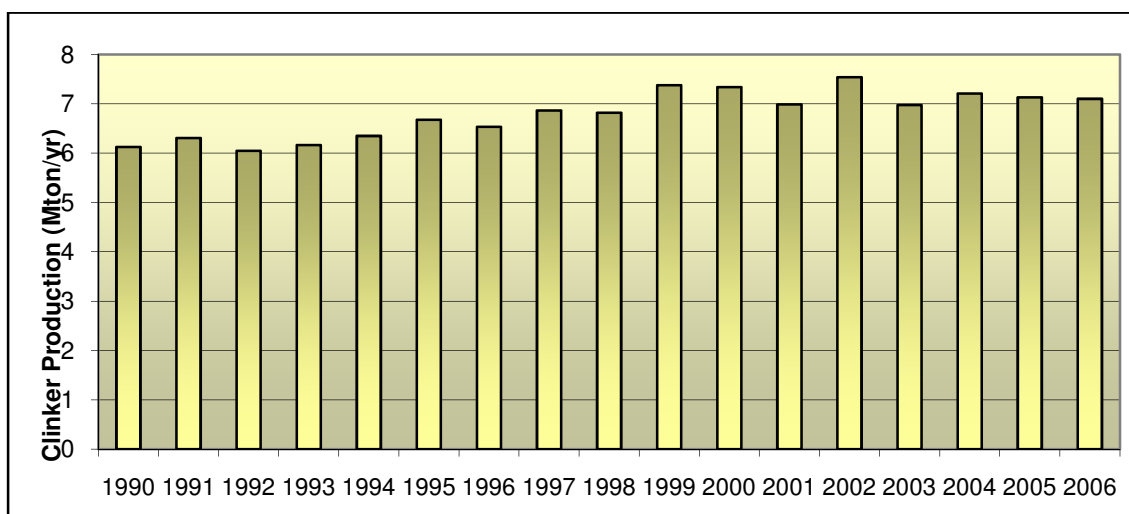
Production of clinker, presented in Table 3.65 and in Figure 3.55, results from data collected directly from the industrial plants until 2003. The production for 2004-2006 is the total clinker production reported in the National Statistical Database (INE), which was allocated to each specific plant unit according to the share in 2003.

Table 3.65 – Total clinker production (1990-2006)

Year	1990	1991	1992	1993	1994	1995	1996	1996
Clinker (kton)	6 128	6 311	6 050	6 165	6 352	6 679	6 535	6 870

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
Clinker (kton)	6 821	7 380	7 343	6 992	7 544	6 980	7 212	7 132	7 105

Figure 3.55 – Total clinker production (1990-2006)



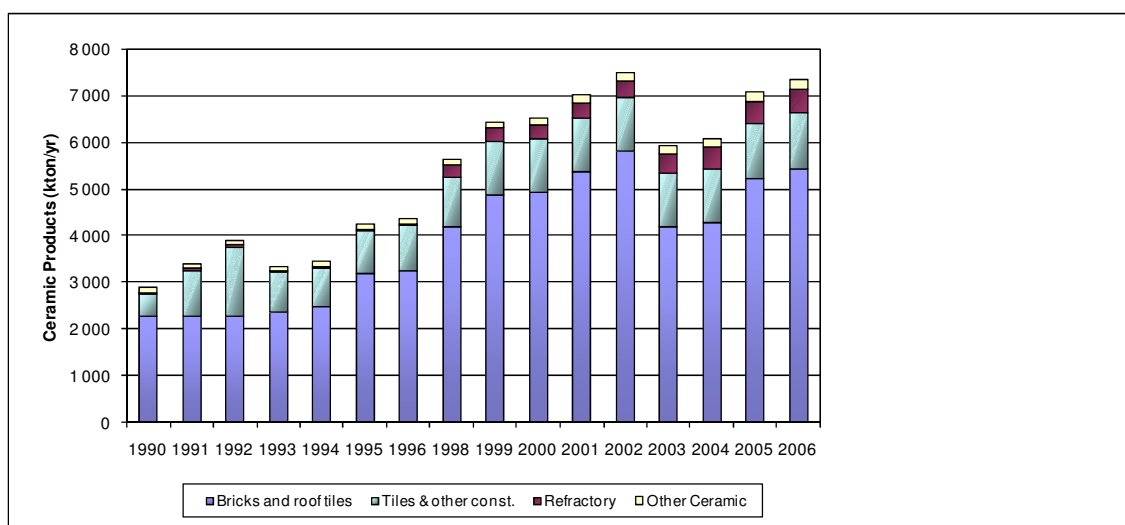
Data on annual manufacturing of ceramic products is available from 1990 to 2000 from INE statistical database. Values from 2001 to 2004 are provisional forecasts made by IA, in some cases relying also on data from the EU-ETS for 2002. Time series for total production may be seen in Table 3.66 and Figure 3.56, according to type of ceramic.

Table 3.66 – Ceramic Production according to type of ceramic (kton)

	1990	1991	1992	1993	1994	1995	1996	1997
Bricks & roof tiles	2 290	2 290	2 290	2 367	2 513	3 200	3 261	3 786
Tiles & other const	478	980	1 483	856	822	921	982	958
Refractory	31	42	53	40	32	32	37	225
Other ceramic	104	90	76	87	93	107	114	124

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bricks & roof tiles	4 203	4 874	4 932	5 376	5 820	4 220	4 284	5 248	5 459
Tiles & other const	1 077	1 170	1 170	1 163	1 156	1 148	1 174	1 170	1 182
Refractory	241	275	300	329	368	406	445	483	522
Other ceramic	135	141	143	158	167	176	184	193	202

Figure 3.56 – Ceramic Production according to type of ceramic (1990-2006)



The Production values for container glass, lead crystal glass and other glass are presented in Figure 3.57 and in Table 3.67, 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 3.57 - Glass production by glass type (excluding flat glass production)

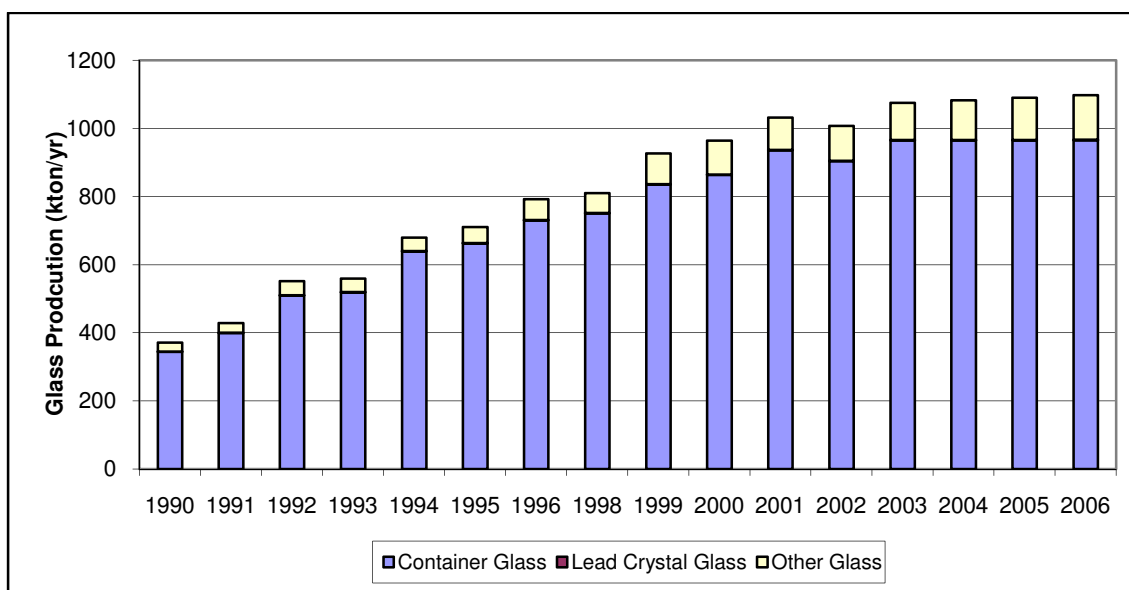


Table 3.67- Glass production by glass type (kton/yr) excluding flat glass production

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

Type of Glass	1998	1999	2000	2001	2002	2003	2004	2005	2006
Container Glass	751	835	864	936	904	965	965	965	965
Lead Crystal Glass	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.5
Other Glass	58	90	100	95	102	109	116	124	131

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

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 specific methodologies and emission factors available in the bibliography or either because country specific emission factors were developed from national studies and monitoring data. They are presented in the subsequent tables.

Table 3.68 – 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 ⁽ⁱⁱⁱ⁾ (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
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

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

Table 3.69 – 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 3.70 – 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, some of them obtained from direct measurements in Large Point Sources (LPS) or 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 Large Point Sources (LPS).

Table 3.71 – 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 3.72 – 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 3.73 – 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
				kg/GJ	% C fossil	Approach	EF	Unit	g/GJ
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 are presented in **Erro! A origem da referência não foi encontrada.** Most emission factors result from plant specific emission factors developed from monitoring at each installation, as reported to EPER exercise.

Table 3.74 – Emission Factors for clinker production units (LPS) using the Energy Approach ^(a)

Fuel		NAPFUE	CO ₂ (kg/GJ)	Oxidation Factor	N ₂ O (g/GJ)
Residual Oil	L	203	77.4	0.99	0.60
Coal	S	102	101.2	0.98	0.70
Petcoke	L	110	100.8	0.99	0.70
Tires	O	115	99.8	0.99	0.70

(a) – Only CO₂ from fuels and not including decarbonising limestone and dolomite rocks

Table 3.75 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Greenhouse Gases

Parameter	EF (kg/ton clinker)
CH ₄	0.001 - 0.257

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

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

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

Table 3.77 – Emission Factors for glass production using the Production Approach: SO_x and Indirect Precursor gases

Type of Glass	SO _x	NO _x	NMVOC	CO
	kg/ton glass			
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 3.78 – Emission Factors for glass production using the Production Approach: Greenhouse Gases

Type of Glass	CO ₂	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.

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 better data. Consequently, in concordance to what is proposed in IPCC (2000) but always assuming a conservative posture, the following rules were used to establish the uncertainty associated with activity data:

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

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

3.2.A.5 TRANSPORT (CRF 1A3)

ROAD TRANSPORTATION

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 19 169.6 kton CO₂ eq. in 2006 representing an increase of 102.7% when compared to 9 458.6 kton CO₂eq., estimated for 1990 (see Table 3.79 **Erro! A origem da referência não foi encontrada.**).

Emissions of N₂O have increased by a factor of 4.1 since 1990 due to the introduction of catalytic converters. Some authors suggested that in some cases N₂O emissions could increase by as much as a factor of 10 (Wade et al.. 1994; de Soete and Sharp. 1991; Dasch. 1992). 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 minimise NO_x and VOC emissions

Table 3.79 – Estimated emissions from road transport

Pollutant	Unit	1990	2006	Var (%)
CO2 Fossil	kt	9 249.4	18 541.2	100.5
CH4	t	3 418.7	2 613.8	-23.5
N2O	t	443.2	1 850.1	317.5
CO2 eq.	kt	9 458.6	19 169.6	102.7

Methodology

The inventory team has developed two emission calculation tools using Visual Basic programming language combined with Excel: one comprehending a model for road transport emission calculation – BURNN; together with a module to determine the national vehicle fleet – KAR. This last module estimates annual fleet from long-time series of vehicle sales and abatements.

BURNN model is compatible and based extensively in the methodology and emission factors from EMEP/CORINAIR Emission Inventory Guidebook which are based in COPERT 3 computer program. KAR and BURNN data flow is summarized in Figure 3.58 from where main following steps may be identified:

- Estimate national fleet per vehicle type²⁹ (KAR module output);
- Estimate kilometres driven per vehicle type, driving conditions and vehicle technology;
- Estimate fuel consumption per vehicle type, driving conditions and vehicle technology (bottom-up approach);
- Correct fuel consumption using bottom-up approach in conjunction with top-down approach;



Bibliography



Key Categories



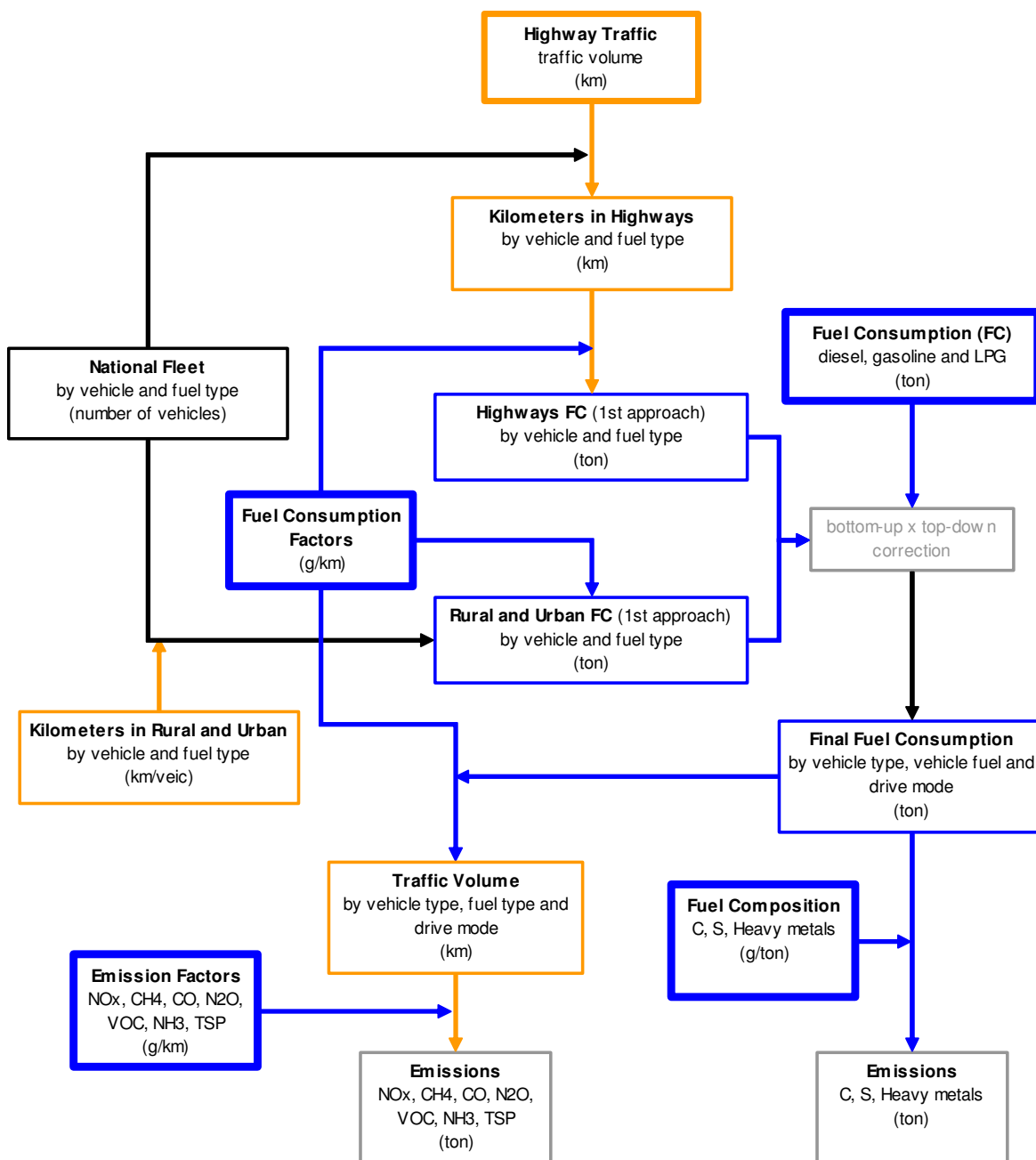
Uncertainty

²⁹ Vehicle type is disaggregated by vehicle category, age and fuel type. Vehicle technology is function of vehicle age (see Table 3.86).

- Emission factors, corrected for hot and cold-start emissions;
- Estimate emissions from kilometres travelled or fuel consumption.

These models were used to estimate emissions between 1990 and 2004. From 2005 to 2006 the emissions were estimated from averaged implied emission factors.

Figure 3.58 – General scheme of methodology applied for road transport emission estimate



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 ACAP³⁰ data and is valid for passenger cars, light duty vehicles and two wheelers and is summarized in the following couple equations:

$$T_{(c,a,f,y1)} = S_{(c,y2)} \times \left[1 - \frac{(0.0477 \times e^{(0.6003 \times A_{(y1-y2)})})}{100} \right]; A < 10$$

$$T_{(c,a,f,y1)} = S_{(c,y2)} \times \left[1 - \frac{(5.2721 \times A_{(y1-y2)} - 35.199)}{100} \right]; 10 \leq A \leq 20$$

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 heavy duty vehicles (HDV) fleet derives from ACAP data and is expressed in number of vehicles in moving fleet per year. Disaggregation of vehicle weight was also necessary in order to perform the calculation. Data on heavy duty vehicles sales in 2001 and 2002 was available from ACAP with adequate weight disaggregation as needed for calculation. The ratio per weight class was therefore adapted and applied to active fleet for all years of the emission estimation period (1990 to 2006). Fleet disaggregation by vehicle age was also performed according with fleet data available from ACAP for the years of 2000 and 2002, which is presented in Table 3.81.

**Bibliography****Key Categories****Uncertainty**

³⁰ Associação Aumóvel de Portugal

Table 3.80 – Percentage of heavy duty vehicles per weight class

Weight Class	Fleet (%)
< 7.5 t	11.5
7.5 – 16 t	68.3
16 – 32 t	20.2
> 32 t	-

Table 3.81 – Percentage of heavy duty vehicles by age

Age		Fleet (%)
From	To	
0	1	4.5
1	2	5.1
2	3	4.9
3	4	4.6
4	5	3.9
5	10	27.6
10	15	30.3
15	19	10.9
≥20		8.2

The same age pattern was assumed for all years in analysis.

All heavy duty vehicles were assumed to be equipped with diesel engines.

The number of buses and coaches was available from *Instituto Nacional de Estatística* (INE). Data was adapted in order to obtain the necessary disaggregation for calculation. The age pattern used for heavy duty vehicles was also assumed for buses and coaches.

Distance Travelled

Distance driven was established from INE and technical expertise taking also into account the amount of fuel sold each year. Distances travelled were estimated for two driving conditions: Urban; Long-distance (LD). Rural distance was later estimated by subtracting the activity measured in highways³¹ from the long-distance activity.

In Portugal a fraction of LDV is actually used exclusively for passenger transport purposes as regular passenger cars. For that reason distances driven by LDV were established for passenger and freight use.



Bibliography



Key Categories



Uncertainty

³¹ Highway measurements are provided by IEP

Table 3.82 – Input vehicle activity (km/veic).

Use	Class	Fuel	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998
Freight	HDV	GO	All	30 000	30 000	30 000	30 000	30 000	30 000	30 000	35 000	45 000
Freight	LDV	GO	All	24 000	24 000	24 000	24 000	24 000	24 000	24 000	24 000	24 000
Freight	LDV	LPG	All	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000
Pass.	Bus	CNG	Urban	-	-	-	-	-	-	-	-	-
Pass.	Bus	GO	Urban	53 211	52 006	50 800	49 594	48 389	47 183	47 353	47 523	47 693
Pass.	Coach	GO	LD	56 405	56 405	56 405	56 405	56 405	56 405	56 448	56 491	56 534
Pass.	Moped	Gasoline	Urban	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000
Pass.	Moto	Gasoline	All	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Pass.	PassCar	Gasoline	All	13 083	13 089	12 993	12 614	12 287	12 273	12 105	11 642	11 532
Pass.	PassCar	GO	All	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000
Pass.	LDV	GO	All	18 000	18 000	18 000	18 000	18 000	18 000	18 000	18 000	18 000
Pass.	PassCar	LPG	All	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000
Use	Class	Fuel	Mode	1999	2000	2001	2002	2003	2004	2005	2006	-
Freight	HDV	GO	All	45 000	55 000	55 000	55 000	55 000	57 576	53 667	52 994	
Freight	LDV	GO	All	24 000	24 000	24 000	24 000	24 000	24 000	24 000	24 000	
Freight	LDV	LPG	All	12 394	11 876	12 107	12 600	12 952	12 915	13 000	13 000	
Pass.	Bus	CNG	Urban	-	48 033	48 679	46 599	44 792	45 000	45 000	45 000	
Pass.	Bus	GO	Urban	47 863	48 033	48 679	46 599	44 792	45 000	45 000	45 000	
Pass.	Coach	GO	LD	56 577	56 620	57 107	59 079	57 957	56 800	56 800	56 800	
Pass.	Moped	Gasoline	Urban	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	
Pass.	Moto	Gasoline	All	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	
Pass.	PassCar	Gasoline	All	11 075	10 909	10 141	10 796	10 833	10 831	11 000	11 000	
Pass.	PassCar	GO	All	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000	
Pass.	LDV	GO	All	18 000	18 000	18 000	18 000	18 000	18 000	18 000	18 000	
Pass.	PassCar	LPG	All	12 394	11 876	12 107	12 600	12 952	12 915	13 000	13 000	

For some vehicle types distances travelled presented above were further disaggregated.

- Activity from HDV varies according with vehicle weight and driving mode;
- Activity from passenger cars and LDV used for passenger transportation varies according with vehicles age – newer vehicles tend to run more miles than older vehicles – in such a way that the average activity equals the value from Table 3.82.

Since information on age and distance driven is not available for national fleet an age distribution function was adapted from TRENDS data.

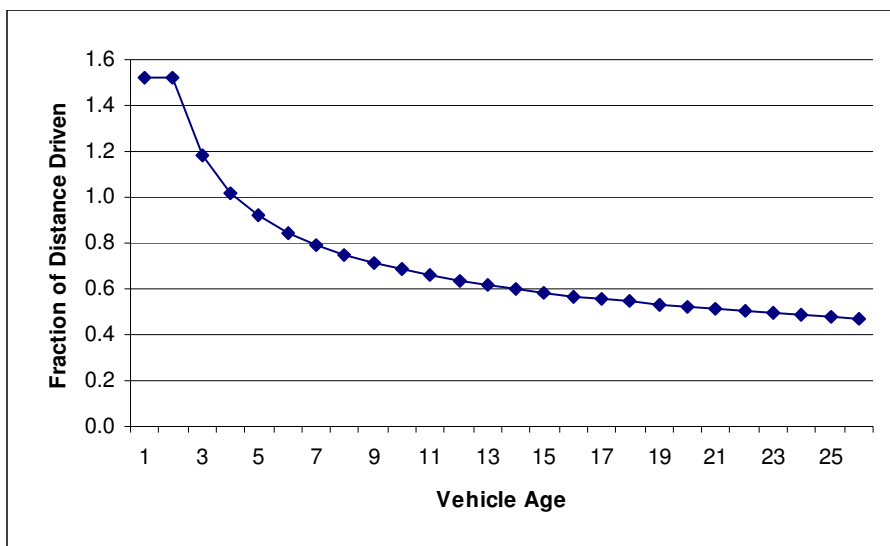


Figure 3.59 – Annual mileage fraction as a function of passenger vehicle age.

Vehicle activity, expressed in kilometres per vehicle, is multiplied by the number of vehicles to obtained the net vehicle activity.

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 vehicles type whereas vehicle fuel consumption and exhaust emissions such as CH₄ are strongly dependent on speed.

Table 3.83 – Assumed vehicle speeds by driving mode and vehicle type.

Driving Mode	Vehicle Type	Assumed Speed (km/h)	Data 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

Fuel consumption

Highway Fuel Consumption

Fuel consumption under highway driving mode was estimated for each fuel type according with the kilometres travelled in highways. Therefore:

$$Highway_{FC(f,y)} = \sum_c \sum_t [Highway_{Km(c,t,f,y)} \times FC_{(c,t,f,Hway)}] \times 10^{-6}$$

where,

$Highway_{FC(f,y)}$ = fuel consumption of fuel type f in highway driving mode by vehicles of all classes in year y (km/yr);

$Highway_{Km(c,t,f,y)}$ = total kilometres driven in highway net-road by vehicles of class c, with technology t, using fuel f in year y (km/yr);

$FC_{(c,t,f,Hway)}$ = EMEP/CORINAIR fuel consumption factor for vehicle type c, with technology t, using fuel f in highway driving mode (g/km);

c = vehicle class or type: light passenger, LDV, HDV, etc;

t = vehicle technology: PRE-ECE, ECE, Euro I, Euro II, etc;

f = fuel type (gasoline, diesel or LPG);

y = civil year.

Individual fuel consumption for each vehicle type was estimated from:

$$Highway_{FC(c,t,f,y)} = Highway_{Km(c,t,f,y)} \times FC_{(c,t,f,Hway)} \times 10^{-6}$$

Urban and Rural Fuel Consumption

Fuel consumption under urban and rural driving modes was estimated simply by subtracting fuel consumption estimated for highway traffic from total fuel sales, at national level:

$$Urban_{FC(f,y)} + Rural_{FC(f,y)} = Total_{FC(f,y)} - Highway_{FC(f,y)}$$

where:

$Urban_{FC(f,y)}$, $Rural_{FC(f,y)}$ = total fuel consumption of fuel type f, under urban and rural driving conditions in year y (t);

$Highway_{FC(f,y)}$ = fuel consumption of fuel type f in highway driving condition by vehicles of all classes in year y (t);

$Total_{FC(f,y)}$ = total national fuel consumption of fuel type f in year y (t).

However, this fuel is aggregated being necessary to distinguish it by vehicle type. Therefore, individual fuel use under rural and urban driving conditions was finally determined from the number of vehicles, kilometres driven in urban and rural modes and, fuel consumption factors for all vehicle categories:

$$Rural_{1stFC(c,t,f,y)} = T_{class(c,t,f,y)} \times Km_{rural(c,f,y)} \times FC_{(c,t,f,s)} \times 10^6$$

$$Urban_{1stFC(c,t,f,y)} = T_{class(c,t,f,y)} \times Km_{urban(c,f,y)} \times FC_{(c,t,f,s)} \times 10^6$$

where,

$Rural_{1stFC(c,t,f,y)}$, $Urban_{1stFC(c,t,f,y)}$ = first approach fuel consumption in rural and urban areas made by vehicles of class c, with technology t, using fuel f in year y (t);

$T_{class(c,t,f,y)}$ = number of vehicles of class c, with technology t, using fuel f in year y;

$Km_{rural(c,f,y)}$, $Km_{urban(c,f,y)}$ = rural and urban kilometres driven per vehicle of class c, using fuel f in year y (km/vehicle);

$FC_{(c,t,f,s)}$ = fuel consumption factor for vehicles of class c, with technology t, using fuel f, at speed s (g/km).

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 *Direcção-Geral de Geologia e Energia* (DGGE). Urban and rural fuel consumption estimates were corrected with the following factor for car type c, technology t, fuel f, driving mode d and year y.

$$Correc_{Factor(f,y)} = \frac{[Total_{FC(f,y)} - Highway_{FC(f,y)}]}{\sum_c \sum_t [Rural_{1stFC(c,t,f,y)} + Urban_{1stFC(c,t,f,y)}]}$$

Correction factors are later applied to the first approach fuel consumption under rural and urban driving conditions in the following manner:

$$Urban_{FC(f,y)} = Correc_{Factor(f,y)} \times \sum_c \sum_t [Urban_{1stFC(c,t,f,y)}]$$

$$Rural_{FC(f,y)} = Correc_{Factor(f,y)} \times \sum_c \sum_t [Rural_{1stFC(c,t,f,y)}]$$

This correction guarantees that emission estimates are in accordance with 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).

Adjustment of Distances Travelled

Ultimate activity, in kilometres, is estimated according with total corrected fuel consumption in the following manner:

$$Km_{urban(c,t,f,y)} = \frac{[Urban_{FC(c,t,f,y)} \times 10^6]}{FC_{(c,t,f,s)}}$$

$$Km_{rural(c,t,f,y)} = \frac{[Rural_{FC(c,t,f,y)} \times 10^6]}{FC_{(c,t,f,s)}}$$

$$Km_{total(c,t,f,y)} = Km_{highway(c,t,f,y)} + Km_{urban(c,t,f,y)} + Km_{rural(c,t,f,y)}$$

Where,

$Km_{total(c,t,f,y)}$, $Km_{highway(c,t,f,y)}$, $Km_{urban(c,t,f,y)}$, $Km_{rural(c,t,f,y)}$ = total driven distance under all driving modes estimated for vehicles of class c, with technology t, using fuel f in year y (km);

$Urban_{FC(c,t,f,y)}$, $Rural_{FC(c,t,f,y)}$ = total fuel consumption allocated to vehicles of class c, equipped with technology t, using fuel type f, under urban and rural driving conditions in year y (t);

$FC_{(c,t,f,s)}$ = fuel consumption factor for vehicles of class c, with technology t, using fuel f, at speed s (g/km).

Table 3.84 – Vehicle activity after adjustments (km/vehicle).

Vehicle Class	Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998
PassCar	Gasoline	13 226	13 089	12 988	12 415	11 749	11 356	10 837	10 133	9 832
Moped	Gasoline	5 029	4 997	4 983	4 972	4 956	4 940	4 886	4 845	4 801
Moto_2t	Gasoline	4 021	3 998	3 988	3 980	3 968	3 957	3 917	3 888	3 855
Moto_4t	Gasoline	4 021	3 998	3 988	3 980	3 968	3 957	3 917	3 888	3 855
PassCar	GO	13 490	13 539	13 978	13 594	13 994	14 298	14 135	14 292	14 922
LDV	GO	21 919	20 501	19 992	18 751	18 778	19 212	19 011	18 932	19 345
HDV	GO	30 389	28 978	28 731	27 424	27 790	28 863	29 047	34 062	44 966
Bus	GO	53 951	50 036	48 365	44 780	44 291	45 098	45 513	45 953	47 650
Coach	GO	57 160	54 383	53 870	51 265	51 959	54 100	54 466	54 842	56 489
PassCar	LPG	36	73	102	99	95	215	1 245	10 743	11 517
LDV	LPG	31	64	91	92	93	219	1 303	11 564	12 721
Bus	CNG									
Vehicle Class	Fuel	1999	2000	2001	2002	2003	2004	2005	2006	-
PassCar	Gasoline	9 339	9 019	8 162	8 455	8 163	7 864	7 467	7 463	
Moped	Gasoline	4 779	4 738	4 678	4 673	4 650	4 644	4 376	4 494	
Moto_2t	Gasoline	3 839	3 809	3 766	3 764	3 748	3 745	3 553	3 639	
Moto_4t	Gasoline	3 839	3 809	3 766	3 764	3 748	3 745	3 553	3 639	
PassCar	GO	15 302	15 413	15 186	14 504	14 129	13 709	13 516	12 976	
LDV	GO	19 413	19 365	19 429	18 909	18 561	17 798	17 395	16 715	
HDV	GO	45 473	55 795	56 499	55 837	55 608	56 744	52 006	49 596	
Bus	GO	48 479	48 867	50 292	47 467	45 401	44 211	43 308	41 494	
Coach	GO	57 199	57 442	58 675	59 992	58 605	55 982	55 021	53 105	
PassCar	LPG	13 418	12 175	11 765	11 645	11 455	10 830	12 043	12 092	
LDV	LPG	15 217	14 214	14 156	14 406	14 547	14 048	15 726	15 714	
Bus	CNG		19 563	77 663	74 918	96 222	77 157	86 712	78 829	

Emission Factors

Emissions factors were determined from the available set of algorithms reported in EMEP/CORINAIR, 2002, which results from a compilation for the CORINAIR85 and CORINAIR90 programs and updated with results from the MEET project and the COST319 action.

Ultimate CO₂ emission factors were established considering CORINAIR/EMEP Emission Inventory Guidebook equation:

$$EF_{CO_2(f)} = \frac{44.011}{(12.011 + 1.008 \times R_{H/C})}$$

Where

$EF_{CO_2(f)}$ = emission factor for fuel type f;

$R_{H/C}$ = the ratio of hydrogen to carbon atoms in the fuel. Values for this ratio and the resulting CO_2 emission factor are presented in Table 3.85.

Table 3.85 - $R_{H/C}$ ratio and CO_2 emission factor (Source: EMEP/CORINAIR)

Fuel	$R_{H/C}$	EF_{CO_2} (t CO_2 /t fuel)
Diesel-oil	2.00	3.14
Petrol	1.80	3.18
LPG	3.00	2.93
CNG	3.66	2.80

European technology standards were determined according with the vehicle built year as present in Table 3.86.

The average trip length, which determines the cold engine emissions, was set at 10 km (L_{trip}), which results in an annual β factor of 0.305. It was considered, according to EMEP recommendations, to set w (fraction of trips finished with cold or warm engine) equal to β .

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

Table 3.86 – 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	...
Light Duty Vehicles	Conv	...	1991
	Euro I	1992	1997
	Euro II	1998	2001
	Euro III	2002	2006
	Euro IV	2006	...
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	...

Implied Emission Factors

The implied emission factors are estimated by dividing the estimated emissions by the energy consumption. The yearly variation reflects the increase of the diesel to gasoline fuel consumption ratio.

Table 3.87 – Road transportation emission factors (kg/GJ)

Vehicle	Pollutant	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998
Passenger Cars	CO2	L Gas	kg/GJ	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06
Motorcycles	CO2	L Gas	kg/GJ	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06
Passenger Cars	CO2	L DiesO	kg/GJ	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41
LDV	CO2	L DiesO	kg/GJ	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41
HV	CO2	L DiesO	kg/GJ	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41
Passenger Cars	CO2	L LPG	kg/GJ	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87
LDV	CO2	L LPG	kg/GJ	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87

HV	CO2	G CNG	kg/GJ									
Passenger Cars	CH4	L Gas	kg/GJ	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Motorcycles	CH4	L Gas	kg/GJ	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Passenger Cars	CH4	L DiesO	kg/GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LDV	CH4	L DiesO	kg/GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HV	CH4	L DiesO	kg/GJ	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Passenger Cars	CH4	L LPG	kg/GJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LDV	CH4	L LPG	kg/GJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
HV	CH4	G CNG	kg/GJ									
Passenger Cars	N2O	L Gas	kg/GJ	0.002	0.002	0.002	0.003	0.005	0.006	0.007	0.007	0.008
Motorcycles	N2O	L Gas	kg/GJ	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Passenger Cars	N2O	L DiesO	kg/GJ	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
LDV	N2O	L DiesO	kg/GJ	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006
HV	N2O	L DiesO	kg/GJ	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Passenger Cars	N2O	L LPG	kg/GJ	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005	0.005
LDV	N2O	L LPG	kg/GJ	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
HV	N2O	G CNG	kg/GJ									

Vehicle	Pollutant	Fuel	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007
Passenger Cars	CO2	L Gas	kg/GJ	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06
Motorcycles	CO2	L Gas	kg/GJ	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06	71.06
Passenger Cars	CO2	L DiesO	kg/GJ	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41
LDV	CO2	L DiesO	kg/GJ	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41
HV	CO2	L DiesO	kg/GJ	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41	72.41
Passenger Cars	CO2	L LPG	kg/GJ	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87
LDV	CO2	L LPG	kg/GJ	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87	61.87
HV	CO2	G CNG	kg/GJ		60.98	60.98	60.98	60.98	60.98	60.98	60.98	60.98
Passenger Cars	CH4	L Gas	kg/GJ	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Motorcycles	CH4	L Gas	kg/GJ	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.21
Passenger Cars	CH4	L DiesO	kg/GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LDV	CH4	L DiesO	kg/GJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HV	CH4	L DiesO	kg/GJ	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Passenger Cars	CH4	L LPG	kg/GJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LDV	CH4	L LPG	kg/GJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
HV	CH4	G CNG	kg/GJ		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Passenger Cars	N2O	L Gas	kg/GJ	0.008	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.010
Motorcycles	N2O	L Gas	kg/GJ	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Passenger Cars	N2O	L DiesO	kg/GJ	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
LDV	N2O	L DiesO	kg/GJ	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
HV	N2O	L DiesO	kg/GJ	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Passenger Cars	N2O	L LPG	kg/GJ	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
LDV	N2O	L LPG	kg/GJ	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005
HV	N2O	G CNG	kg/GJ		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Activity Data*Vehicle Fleet*

The following table shows the number of vehicles between 1990 and 2004 was based in data available from ACAP, DGV, ISP and INE. The fleet pattern used in year 2005 and 2006 was the same as for year 2004.

Table 3.88 – Vehicle fleet synthesis: 1990-2004

Class	1990	1991	1992	1993	1994	1995	1996	1997
PassCar	1 617 301	1 803 057	2 040 104	2 244 022	2 440 575	2 601 137	2 777 808	2 949 859
Moped	834 704	797 888	761 098	724 308	687 518	650 728	613 938	577 148
LDV	487 999	525 957	572 755	623 126	690 150	726 289	776 444	839 842
HDV	102 986	112 008	119 002	130 988	131 976	134 004	142 012	138 996
Moto (4 str)	30 082	36 556	48 360	60 398	67 470	72 722	76 622	82 264
Moto (2 str)	5 850	7 124	9 412	11 752	13 130	14 144	14 924	16 016
Coach	5 434	5 876	6 318	6 760	7 202	7 644	7 592	7 540
Bus	2 366	2 548	2 756	2 938	3 146	3 328	3 640	3 952
Total	3 086 722	3 291 014	3 559 805	3 804 292	4 041 167	4 209 996	4 412 980	4 615 617

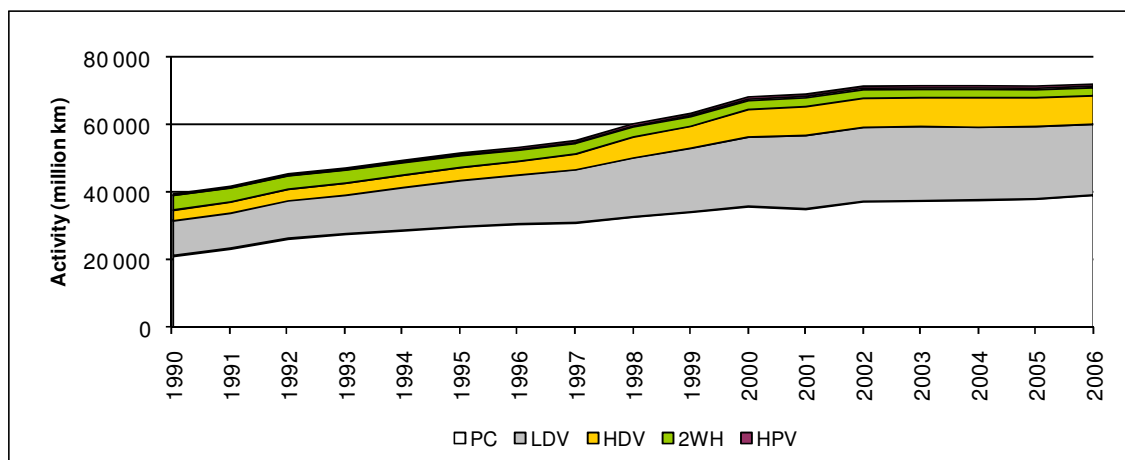
Class	1998	1999	2000	2001	2002	2003	2004	2005
PassCar	3 158 069	3 391 592	3 614 172	3 798 957	3 948 644	4 061 448	4 178 005	-
Moped	540 358	503 568	466 778	448 214	429 676	423 592	422 214	-
LDV	911 323	981 486	1 067 323	1 128 354	1 166 993	1 192 487	1 216 950	-
HDV	140 010	145 002	148 980	153 972	158 002	156 104	157 586	-
Moto (4 str)	89 440	98 306	105 794	112 034	114 972	114 478	117 572	-
Moto (2 str)	17 420	19 136	20 592	21 814	22 386	22 282	22 880	-
Coach	7 488	7 436	7 358	6 526	5 902	7 202	7 228	-
Bus	4 264	4 576	4 966	5 512	5 408	5 330	5 356	-
Total	4 868 372	5 151 102	5 435 963	5 675 383	5 851 983	5 982 923	6 127 791	-

The growth of gasoline passenger cars has decreased over the last years. It was observed a decrease in the number of this type of vehicles while diesel passenger cars have increased. After an initial growth, LPG fuelled vehicles have stabilised as a small percentage of passenger cars. The number of mopeds is decreasing according to data from ISP.

Distances Travelled

Total road traffic activity has increased 80.9% since 1990.

Figure 3.60 – Kilometers travelled by vehicle type: passenger cars (PC); light duty vehicles (LDV); heavy duty vehicles (HDV), two wheelers (2WH) and heavy passenger vehicles (HPV)



Fuel Consumption

Fuel consumption from road transport sector is available for the years from 1990 to 2005 from the revised energy balances from DGGE. Fuel consumption in 2006 was set as equal to 2005 since no further information was available at time. Total consumption of petrol, diesel-oil and LPG are shown in Table 3.89. LPG and CNG represent only a small fraction of the total fuel consumption.

Table 3.89 – Fuel consumption from road transport sector (ton).

Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998
Diesel	1 576 543	1 637 417	1 739 180	1 791 854	1 932 608	2 074 530	2 230 750	2 470 851	2 947 856
Gasoline	1 351 651	1 486 804	1 660 449	1 749 492	1 796 122	1 852 198	1 900 644	1 889 283	1 954 485
LPG	20	53	93	104	111	273	1 704	16 405	18 748
CNG	0	0	0	0	0	0	0	0	0

Fuel Type	1999	2000	2001	2002	2003	2004	2005	2006	2007
Diesel	3 185 774	3 695 451	3 909 184	3 961 191	3 996 395	4 052 241	4 096 654	4 096 654	-
Gasoline	1 977 545	2 015 378	1 898 390	1 992 870	1 932 283	1 855 988	1 759 447	1 759 447	-
LPG	22 601	21 149	20 508	20 092	19 401	17 872	19 829	19 829	-
CNG	0	690	4 565	7 045	10 180	9 070	10 193	10 193	-

Original data in DGE energy balances were in tonnes of oil equivalent and they were converted to mass units by the following IPC default Low Heat Values (LHV).

Table 3.90 – Low Heat Values (LHV) in Road Transportation

Fuel	toe/ton	MJ/kg
Diesel oil	1.035	43.31
Petrol	1.070	44.80
LPG	1.160	47.31

CNG	1.031	45.97
-----	-------	-------

Fuel consumption was also estimated from the fuel consumption factors given from EMEP/CORINAIR Emission Inventory Guidebook. The bottom-up versus top-down correction factor was derived from the differences between estimated and real fuel consumption as explain in sector Methodology - Fuel consumption.

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%.

RAILWAYS

Overview

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

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 Carbon Dioxide emissions (kg CO₂/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);

$EF_{(f,p)}$ - Quantity of pollutant p emitted from fuel f (kg/ton);

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

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

	Coal	Coke	Diesel-oil	Fuel-oil
LHV ^(a)	29.3	28.0	43.3	40.2
CH ₄	0.22 ^(iv)			
U _{CO2}	3 168 ^(v)			
FAC _{OX} ^(b)	0.980	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;

Activity Data

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2003 from the energy balance produced by General-Directorate of Geology and Energy (DGGE). 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 3.61.



Bibliography



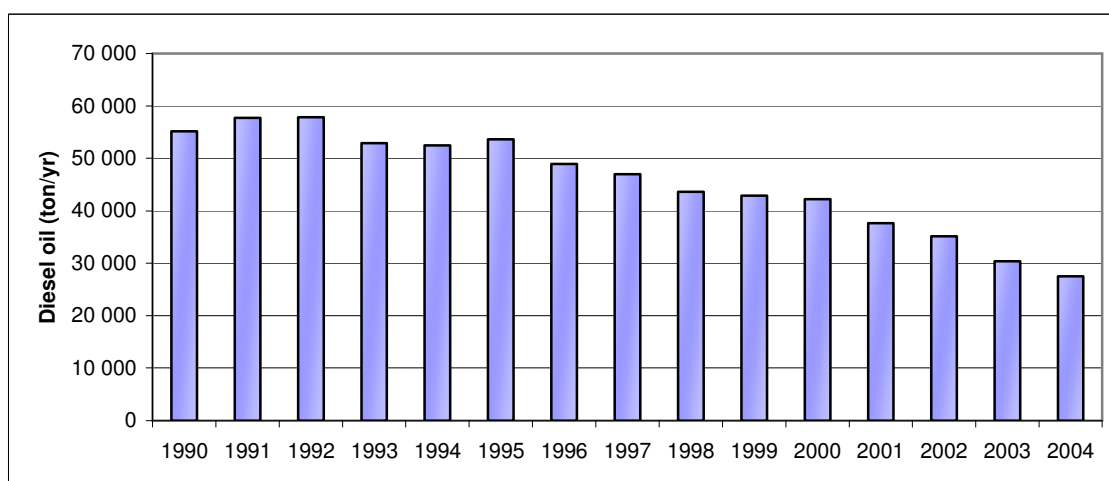
Key Categories



Uncertainty

³² Gas oil represents no less than 99.9% of total annual use of combustible energy.

Figure 3.61 - Consumption of diesel oil in the railway transport sector: 1990-2004



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.

AVIATION

Overview

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

Emissions estimates differentiate between two different components:

- 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.

Two different fuel types are usually distinguished in aircraft activity: jet fuel (JP) and aviation gasoline (AG). Jet fuel is used mostly in large commercial aircraft. Aviation gasoline is used in piston engine aircrafts.

Separate 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 3.92 – IPCC criteria for distinction of bunker aviation emissions in domestic and international

Criteria	Domestic	International
Depart and Arrive in Same Country	Yes	No
Depart from one country and arrive in another	No	Yes
Depart in one country, stop in the same country without dropping or picking up any passengers or freight, then depart again to arrive in another country	No	Yes
Depart in one country, stop in the same country and drop or pick passengers or freight, then depart finally arriving in another country	Domestic Stage	Intern. Stage
Depart in one country, stop in the same country, only pick up more passengers or freight and then depart finally arriving in another country	No	Yes
Depart in one country with a destination in another country, and makes an intermediate stop in the destination country where no passengers or cargo are loaded	No	Yes

Source: IPCC (2000)

However, the Portuguese inventory presently can not fully achieve this level of detail and separation is done exclusively according to the location of departing and arriving airport, being domestic if they are both in national territory.

Portuguese territorial area comprehends, in what concerns definition of domestic, mainland continental area and the autonomous regions of Azores and Madeira islands³³.

Disaggregation of emission is presently at the level expressed in Figure 3.62 below.



Bibliography



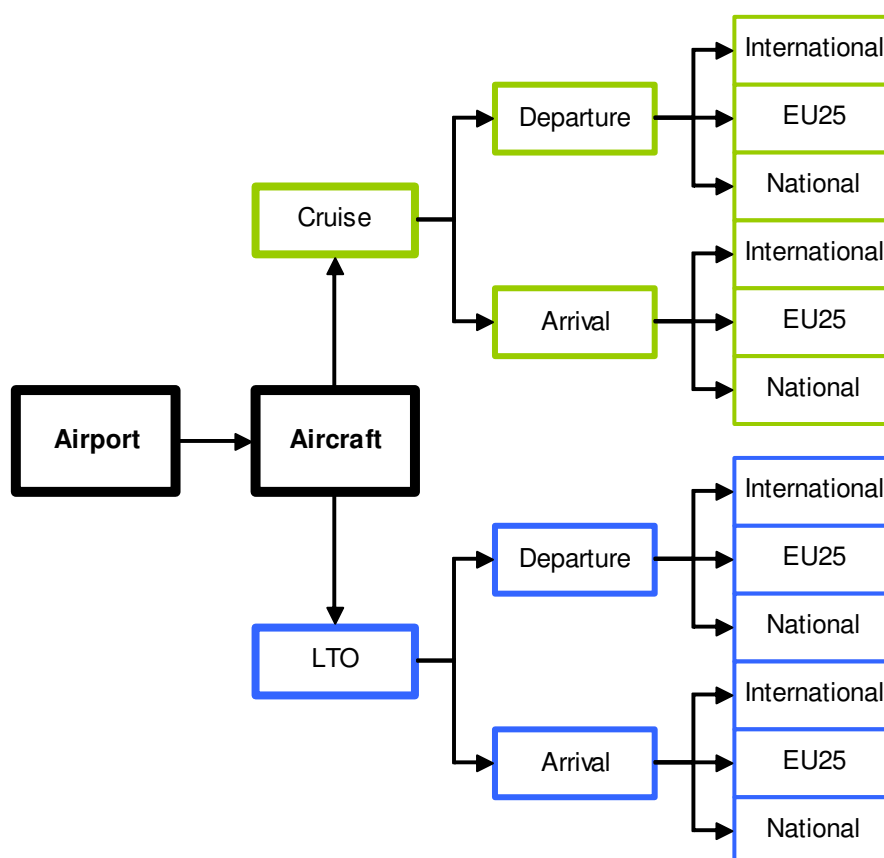
Key Categories



Uncertainty

³³ The inventory did not consider as domestic, however, movements to Macau city in China until 2000, when this territory was considered Chinese territory under Portuguese administration.

Figure 3.62 – Available disaggregation of total aviation emissions



Methodology

The methodology that is used in the inventory is coherent with good practices and is equivalent to the Tier2b approach which is applied at the level of individual aircraft types. Emissions are calculated separately for:

- (1) LTO and cruise;
- (2) Fuel type: jet fuel and aviation gasoline;
- (3) Origin-Destiny in relation to territorial space of airport: domestic, EU25 and international flights;
- (4) Movement type: arrival and departure
- (5) Aircraft type.

Landing/Take-off

The general approach to estimate emissions during Landing/Take-off is:

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

where

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

$Emission_{Arrival(p,d,a,s,y)}$, $Emission_{Departure(p,d,a,s,y)}$ – 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);

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

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

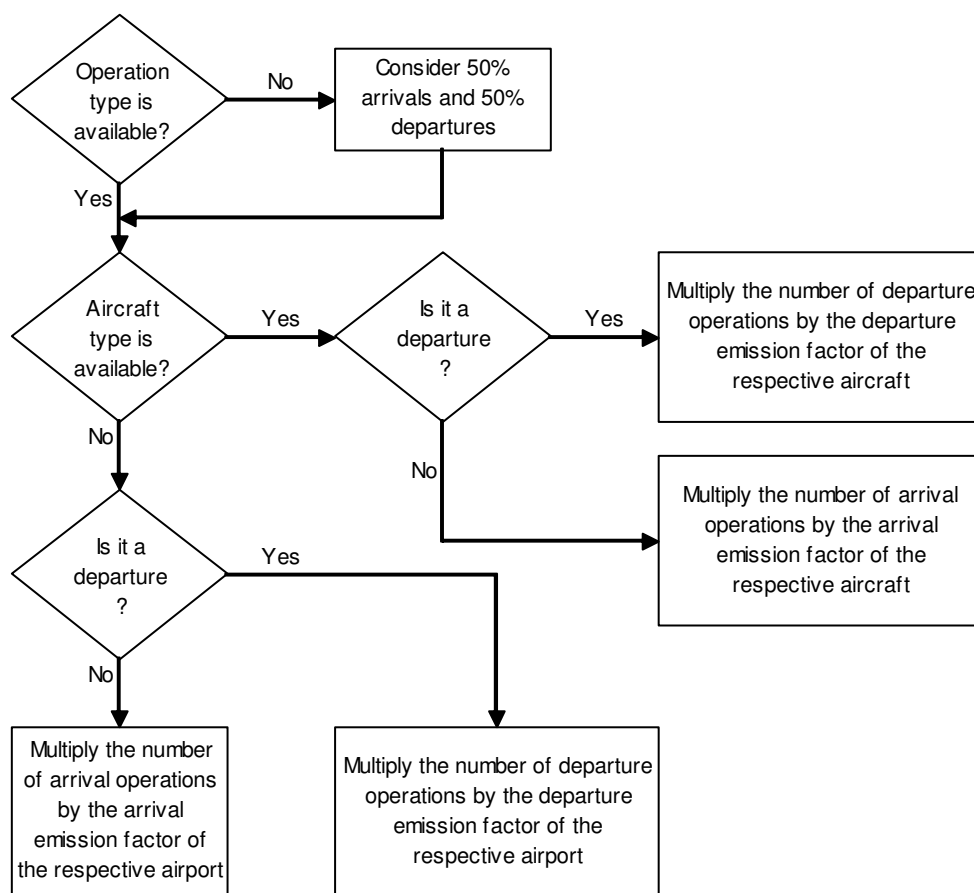
$EF_{Departure(p,s)}$ – Sum of taxi-out, take-off and climb emission factor for pollutant p and aircraft s (kg/movement);

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

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

Figure 3.63 outlines the process whereby LTO emissions are estimated.

Figure 3.63 – Decision tree for LTO emission calculation



Cruise

Domestic cruise emissions are estimated based on aircraft movement data. The approach relies on a origin and destiny matrix crossed with time table information. Emission factors are given for each aircraft type and for a specific flight time. International cruise emissions are estimated from fuel consumption. The international fuel consumption is estimated by subtracting the LTO and the domestic cruise fuel from the total fuel sales.

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

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);

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

$\text{EF}_{\text{cruise}(p,d,a,s,t,y)}$ – Emission factor for pollutant p specific for flight with origin/destiny 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.

Emission Factors*LTO*

Aircraft Based LTO Emission Factors

Emissions factors for LTO were set for each aircraft type according to information from FAEED database which contains emission factors for each operation condition: idle, take off, climb out and approach conditions. Emissions factors for arrival and departure were then set from the time in mode 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 3.93 - Emissions factors for most common aircraft movements in national airports³⁴ (kg/movement).

IATA Code	Departure		Arrival	
	FC	CH ₄	FC	CH ₄
100	520	0.1	217	<0.1
310	1 109	0.3	463	0.1
320	579	<0.1	241	<0.1
321	694	0.1	283	<0.1
330	1 373	0.3	564	0.1
340	1 359	0.3	551	0.1
727	893	0.3	370	0.1
737	629	0.2	264	0.1
747	2 520	3.4	1 053	1.4
757	904	0.1	380	<0.1
767	1 216	0.3	510	0.1
72F	902	0.4	375	0.2
75F	953	0.1	411	<0.1
ABF	1 196	0.5	481	0.2
ARJ	402	0.1	168	<0.1
ATR	794	0.1	334	<0.1
BE1	64	0.5	34	0.2
BET	64	0.5	34	0.2
CCJ	76	<0.1	60	<0.1
CNA	7	<0.1	4	<0.1
CNJ	37	0.1	32	0.1
DH8	794	0.1	334	<0.1
DHT	51	0.2	27	0.1
F27	176	0.3	87	0.1
GRJ	173	<0.1	141	<0.1

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Bibliography

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Key Categories

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 Av. da Liberdade 126, 1200-088 Lisboa

Uncertainty

³⁴ The complete list of aircraft LTO emission factors can be found in annex.

H25	42	<0.1	34	<0.1
LOH	134	0.6	173	0.6
LRJ	42	<0.1	34	<0.1
M80	700	0.1	296	0.1
S20	134	0.6	173	0.6
SH6	64	0.5	34	0.2
SWM	129	0.1	61	<0.1

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, available in annex, was used mainly in movements from 1990 to 1999 since this was the period for which information on aircraft characteristics was scarce.

Cruise

Aircraft Based Cruise Emission Factors

Cruise emission factors were estimated from EMEP/CORINAR detailed methodology.

Cruise emission factors are given for typical cruise distances. This information was used to derive equations relating distances with emissions for representative aircrafts³⁵. Using aircraft speeds it was possible to estimate cruise fuel consumption and emissions for a given flight time.



Bibliography



Key Categories



Uncertainty

³⁵ Correspondence between representative aircraft and other aircraft types was obtained from EMEP/CORINAIR Emission Inventory Guidebook.

Table 3.94 – Aircraft cruise speeds.

Aircraft	Speed (km/h)	Aircraft	Speed (km/h)
D28	241	ARJ	720
PAG	273	146	767
DHT	297	DFL	780
DH6	298	M80	813
EMB	326	D9S	820
SH6	400	ERJ	833
DH7	400	320	840
J31	426	310	850
DH8	440	757	850
AN6	450	737	852
ATR	450	767	854
SWM	450	330	860
F50	454	100	861
SF3	467	340	880
F27	480	B11	885
ATP	491	DC9	885
BE1	495	TU5	900
BET	558	777	905
LOH	571	747	907
CNJ	644	D10	908
F28	678	727	917

Source: www.airliners.net

Table 3.95 gives representative aircraft cruise consumption and emission factors for one hour cruise flight.

Table 3.95 – Aircraft cruise emission factors for one hour cruise flight (kg/1hour).

Aircraft	FC	CH ₄
De Havilland Canada DHC-6	90	0.01
Embraer EMB.110	154	<0.01
Gates Learjet	191	-
Fairchild (Swearingen) SA26	195	0.01
BAe Jetstream 31	226	0.01
Beechcraft 1900	250	0.25
Shorts SD.360	333	0.14
Saab SF340A/B	356	0.09
Embraer RJ135	414	0.01
De Havilland Canada DHC-7	422	0.04
Fokker F-27	461	0.51
Fokker 50	547	-
Antonov AN-26	661	2.03
Fokker F-28	1 724	0.34
Lockheed L-182	2 081	0.13
BAe 146	2 123	0.08
Fokker 100	2 289	0.09
BAe 111	2 324	0.05
Airbus A319	2 543	0.04
Airbus A320	2 543	0.04
Boeing 737-200	2 584	0.21
Boeing 737-500	2 584	0.21
McDonnell Douglas DC-9	2 792	0.17
McDonnell Douglas M81-88	3 107	0.16
Boeing 757	3 488	0.35
Airbus 310	3 947	0.07
Boeing 727-300	4 163	0.24
Boeing 727-100	4 163	0.24
Boeing 727-200	4 163	0.24
Boeing 767	4 653	0.13
McDonnell Douglas DC-8	4 653	0.13
Airbus A330	5 676	0.59
Airbus A340	6 295	2.03
Boeing 777	7 237	1.94
McDonnell Douglas DC-10	7 831	2.27
Boeing 747	10 546	0.82

Airport Based Cruise Emission Factors

Specific airport cruise emission factors were needed for movements where information about the aircraft type was not available. Therefore weighted averaged cruise emission factors were estimated from the fleet composition for each airport, year and origin/destiny, considering that preferably aircraft types are used according with the flight length.

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

Fuel dependent emission factors

Fuel dependent emission factors were set for CO₂, N₂O, SO_x and heavy metals.

Table 3.96 – Fuel dependent emission factors.

Pollutant	AG	JP
LHV (MJ/kg)	44.77	44.56
CO ₂ (kg/ton)	3 117	3 117
N ₂ O (kg/ton)	0.04	0.04

Source: IPCC, 1997

Activity Data*Flight movements in Airports*

The determinant 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 2006 was provided by the *Instituto Nacional de Aviação Civil* (INAC). This database is being improved and new airports were connected along the process.

Table 3.97 – LTO per airport

Airport Name	Airport Code	1990	1995	2000	2005	2006
Lisboa	LIS	30 862	34 932	56 073	64 515	68 005
Porto	OPO	11 574	13 348	23 277	23 415	24 498
Faro	FAO	11 252	13 067	18 243	18 936	21 094
Cascais	XXC	na	na	na	19 961	22 097
Funchal	FNC	6 475	9 460	12 037	13 658	12 664
Terceira	TER	3 801	4 049	4 501	4 683	4 805
Ponta Delgada	PDL	2 954	3 382	4 134	6 001	5 776
Porto Santo	PXO	2 403	4 243	3 774	3 650	2 697
Horta	HOR	1 237	1 542	1 756	2 394	2 244
Santa Maria	SMA	634	893	1 552	1 338	1 346
Vila Real	VRL	na	na	na	na	863
Bragança	BGC	na	na	na	na	463
Flores	FLW	281	357	552	714	653
Pico	PIX	na	na	na	707	738
São Jorge	SJZ	na	na	na	599	566
Graciosa	GRW	na	na	na	439	417
Corvo	CVU	na	na	na	283	289
Total		71 473	85 271	125 898	161 290	169 209

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 in determining the aircraft fleet composition between 1990 and 1999 for each of the national airports in order to determine airport representative arrival and departure emission factors.

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 3.64 – Decision tree for distinction between domestic and international emissions.

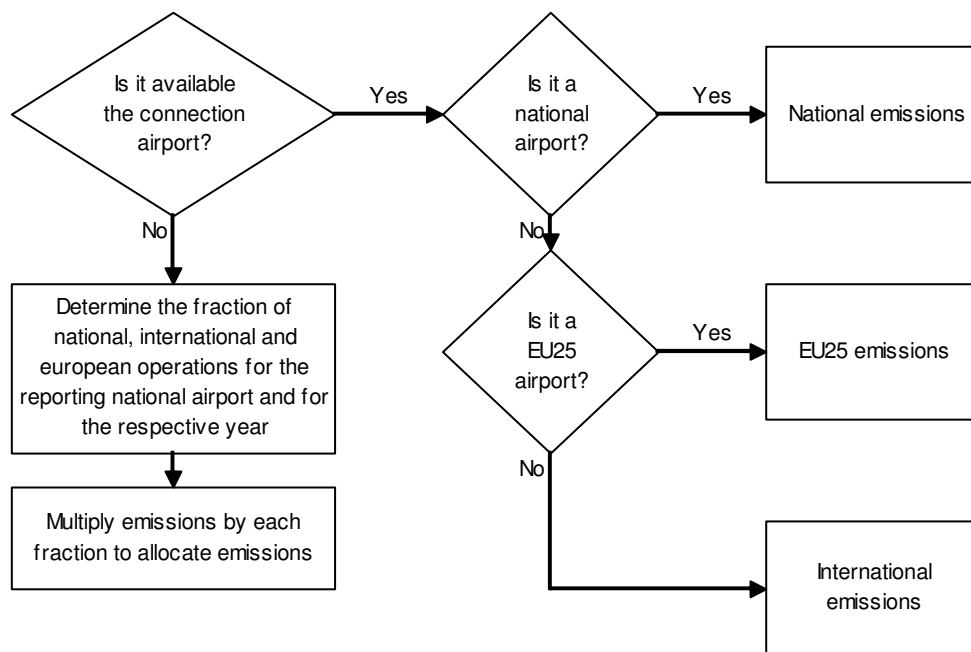
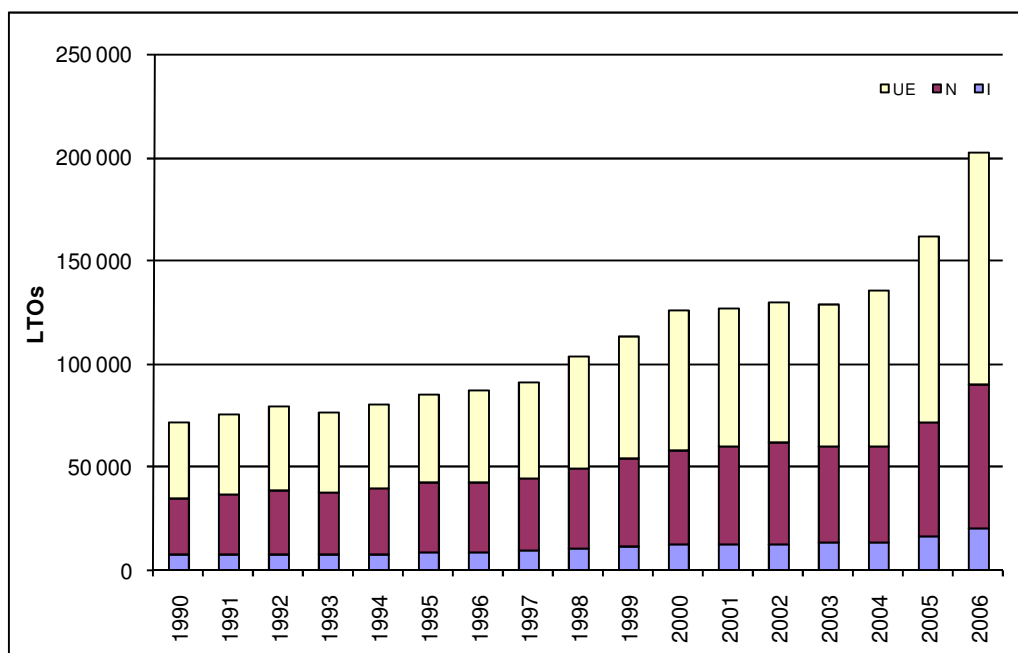


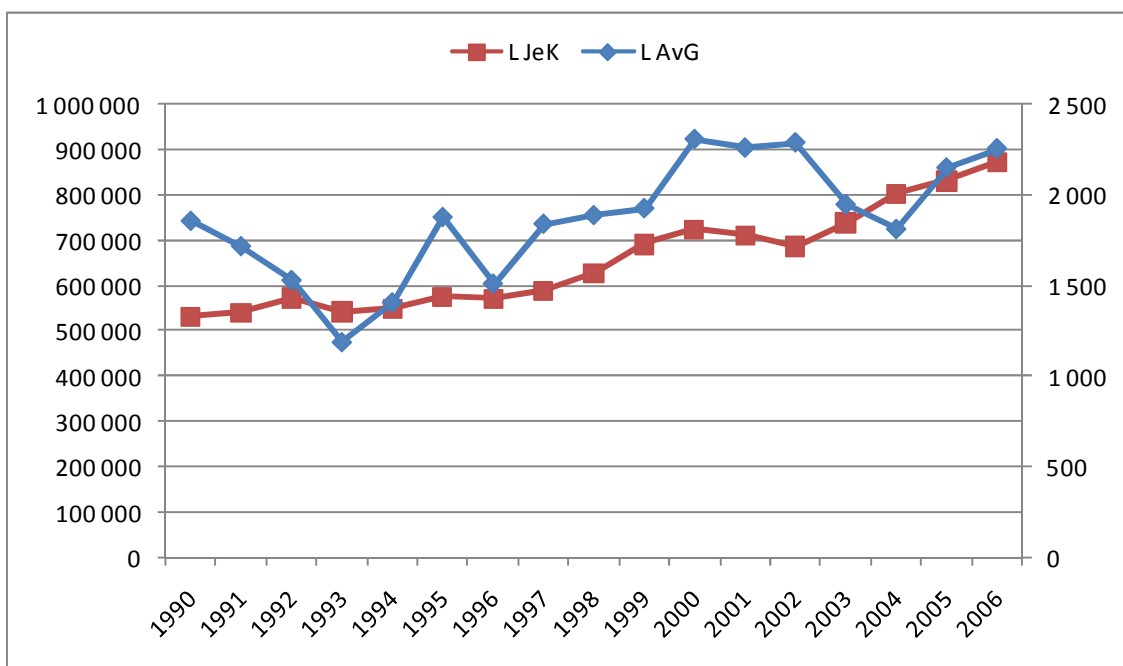
Figure 3.65 – Domestic (N), EU25 (UE) and international (I) LTOs



Fuel Consumption

Fuel consumption is available from fuel sales statistics from DGGE. 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 3.66 – Fuel consumption of aviation gasoline (L AvG) and jet fuel (L JeK) (values in ton)



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 3.98 – Aviation activity level uncertainty.

Source	Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997
All	Uglobal	%	83%	82%	84%	87%	87%	82%	72%	72%
Cruise	Ucruise	%	129%	129%	129%	129%	129%	121%	99%	99%
LTO	Ulto	%	100%	100%	100%	100%	100%	100%	100%	100%
Movements	Umovements	%	5%	5%	5%	5%	5%	5%	5%	5%
Fligh Time	Utime	%	84%	84%	84%	84%	84%	70%	9%	9%
Cruise FC	Ucruise_fc	%	98%	98%	98%	98%	98%	98%	98%	98%
LTO FC	Ulto_fc	%	100%	100%	100%	100%	100%	100%	100%	100%

Source	Parameter	Unit	1998	1999	2000	2001	2002	2003	2004
All	Uglobal	%	72%	72%	37%	37%	38%	38%	38%
Cruise	Ucruise	%	99%	99%	49%	49%	49%	50%	50%
LTO	Ulto	%	100%	100%	48%	48%	48%	49%	49%
Movements	Umovements	%	5%	5%	5%	5%	5%	5%	5%
Fligh Time	Utime	%	9%	9%	9%	9%	9%	9%	9%
Cruise FC	Ucruise_fc	%	98%	98%	48%	48%	48%	49%	49%
LTO FC	Ulto_fc	%	100%	100%	48%	48%	48%	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.

WATER BORNE NAVIGATION

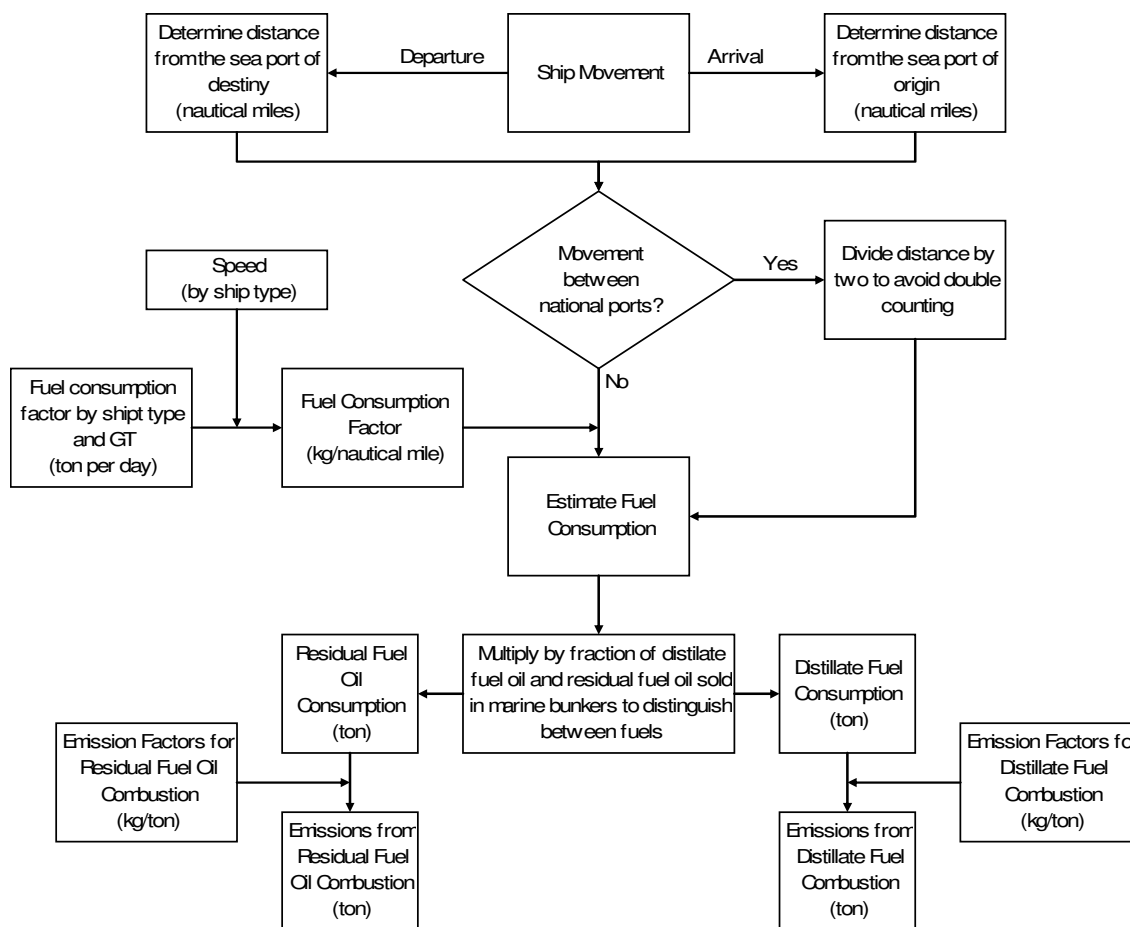
Overview

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

Methodology

Emissions from navigation were calculated according to the EMEP/CORINAIR methodology, an improved tier 1 methodology. First fuel consumption is calculated based on ship movements between ports then emissions are estimated from the fuel use. Domestic and international traffic is not fully according with IPCC Good Practices since there is no complete information on passenger and freight. The domestic/international classification was based in the origin and destiny country (see Table 3.92). The general approach could be described as follows:

Figure 3.67 – Generic methodology flowchart.



Emission Factors

Emission factors were obtained from EMEP CORINAIR guidebook except for CO₂ which was obtained from IPCC.

Table 3.99 – Emission factors for navigation

Pollutant	Unit	Gas-oil	Residual fuel oil
LHV	MJ/kg	40.170	43.310
CO ₂	ton/TJ	74.067	77.367
NO _x	kg/tonne fuel	72.000	72.000
SO _x	kg/tonne fuel	⁽¹⁾ 4.000 ⁽²⁾ 2.000	53.400
CO	kg/tonne fuel	7.400	7.400
NMVOC	kg/tonne fuel	2.400	2.400
CH ₄	kg/tonne fuel	0.050	0.050
N ₂ O	kg/tonne fuel	0.080	0.080

⁽¹⁾ Until year 2000, inclusive;

⁽²⁾ After year 2000

Source: EMEP/CORINAIR, IPCC

In order to estimate fuel consumption for use with emission factors from Table 3.99 default consumption factors suggested by EMEP/CORINAIR were used.

Table 3.100 – Consumption factors

Ship Type	Consumption at fuel power (tonne/day) ^(a)
Solid bulk	$20.186 + 0.00049 \times \text{gt}$
Liquid bulk	$14.685 + 0.00079 \times \text{gt}$
General cargo	$9.8197 + 0.00143 \times \text{gt}$
Container	$8.0552 + 0.00235 \times \text{gt}$
Passenger/Ro-Ro/Cargo	$12.834 + 0.00156 \times \text{gt}$
Passenger	$16.904 + 0.00198 \times \text{gt}$
High speed ferry	$39.483 + 0.00972 \times \text{gt}$
Inland cargo	$9.8197 + 0.00143 \times \text{gt}$
Sail ships	$0.4268 + 0.00100 \times \text{gt}$
Tugs	$5.6511 + 0.01048 \times \text{gt}$
Fishing	$1.9387 + 0.00448 \times \text{gt}$
Other ships	$9.7126 + 0.00091 \times \text{gt}$
All ships	$16.263 + 0.001 \times \text{gt}$

Legend:

gt – gross tonnage

^(a) – a factor of 0.8 was applied to obtain consumption for cruise.

Source: EMEP/CORINAIR

Activity Data

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 2004. The number of movements and the distances travelled for the period 1991-1994 and 1996-1999 were estimated according with a trend line 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 movements

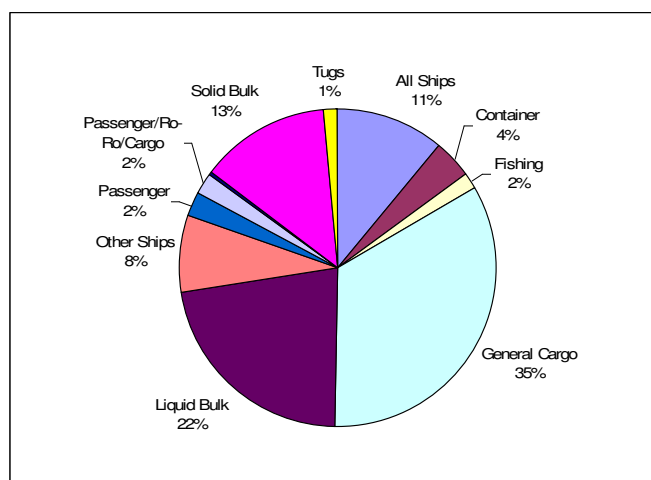
Sea Port	Sea Port Code	Unit	1990	1995	2000	2004
Aveiro	PTAVE	docks	876	1 098	1 009	1 053
Canical	PTCNL	docks	76	76	76	94
Faro	PTFAO	docks	163	163	163	36
Figueira da Foz	PTFDF	docks	315	297	307	292
Funchal	PTFNC	docks	1 063	1 063	1 063	1 022
Leixões	PTLEI	docks	2 742	2 896	3 050	2 815
Lisboa	PTLIS	docks	5 586	4 993	3 869	3 473
Ponta Delgada	PTPDL	docks	1 080	1 080	1 080	1 067
Portimão	PTPRM	docks	34	34	37	56
Porto Santo	PTPXO	docks	402	402	402	398
Setúbal	PTSET	docks	1 453	1 453	1 699	1 669
Sines	PTSIE	docks	1 038	979	808	927
Viana do Castelo	PTVDC	docks	254	293	49	73

Note: each dock reports two movements: one from the origin port to the national reporting sea port; and the other from the reporting national sea port to the destiny

Ship Fleet

The fleet is composed mainly by general cargo ships. The fleet from Figure 3.68 refers to all ships that docked in national seaports between 1990 and 2004 irrespective of domestic or international movements.

Figure 3.68 – Ship fleet.



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 – Fuel consumption (ton)

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998
L ResO	Domestic	55 672	55 462	55 092	54 537	54 187	50 883	53 722	56 099	57 783
L ResO	International	350 197	348 798	346 565	278 711	250 123	238 643	251 261	253 606	261 639

L GasD	Domestic	21 028	20 948	20 809	20 599	20 467	19 219	20 292	21 189	21 825
L GasD	International	103 729	100 756	100 998	98 106	92 087	119 664	125 964	113 907	108 174

Fuel	Region	1999	2000	2001	2002	2003	2004	2005	2006	-
L ResO	Domestic	52 321	46 937	45 355	47 503	47 829	48 939	42 217	45 578	
L ResO	International	362 525	426 526	284 415	317 164	394 213	478 426	412 708	445 567	
L GasD	Domestic	19 762	17 729	17 131	17 942	18 065	18 485	18 758	18 622	
L GasD	International	120 699	105 702	85 712	75 354	90 747	88 270	89 576	88 923	

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 3.103. Specific tug fuel consumption factors were supplied by IPTM.

Table 3.103 – 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 (Table).

Table 3.104 – 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.

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:

$$U_{global} = \sqrt{U_{movements}^2 + U_{distance}^2 + U_{FC}^2}$$

Movements 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 through the travelling time between seaports. For the same OD its 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 3.105.

Table 3.105 – Navigation activity level uncertainty.

Source	Parameter	Value
All	Uglobal	51%
Movements	Umovements	5%
Distance Travelled	Udistance	16%
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%.

OTHER MOBILE SOURCES

Overview

There is no much information allowing the estimation of emissions from off-road vehicles and machines, mainly because they are not individualized in the energy balances from DGGE. The only exception are 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.

JET FUEL FOR MILITARY OPERATIONS

These emissions are to be reported under category 1 A 5 b (Other Mobile).

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 militar 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 an LHV of 44.59 MJ/kg as reported in Table 1-3 from Reference Manual, IPCC, 1996.

Table 106 - Activity Data

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

Parameter	Unit	1999	2000	2001	2002	2003	2004	2005	2006	-
Energy	TJ	1127	1338	1338	939	749	570	1025	1075	-

The emission factors used to estimate emissions are IPCC default emission factors. CO₂ emission factor was obtained from:

$$EF_{CO_2}[t/TJ] = EF_C[t/TJ] \times 44/12[tCO_2/tC] \times \text{Carbon Oxidised Fraction}$$

$$EF_{CO_2}[t/TJ] = 19.5 \times 44/12 \times 0.99$$

$$EF_{CO_2}[t/TJ] = 70.79$$

The carbon emission factor (EF_C) and the carbon oxidised fraction are from IPCC Reference Manual, 1996.

Table 107 - 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

Agriculture

Overview

Due to typical operation in vast land areas, agriculture and Forestry activities are heavily dependent on machines and off-road vehicles: agricultural and forest 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 a 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.

Methodology

Emissions to atmosphere of ultimate CO₂ from fossil origin were estimated from CO₂ total emissions by:

$$Fossil_{CO_2(y)} = \sum_f [EF_{CO_2} * Fa_{CO_2} * Cons_{Fuel(y)} * LHV] * 10^{-5}$$

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:

$$Emission_{(p,y)} = EF_{(p)} * Cons_{Fuel(y)} * 10^{-3}$$

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).

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), except the emission factor for Particulate Matter, set from the EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002).

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

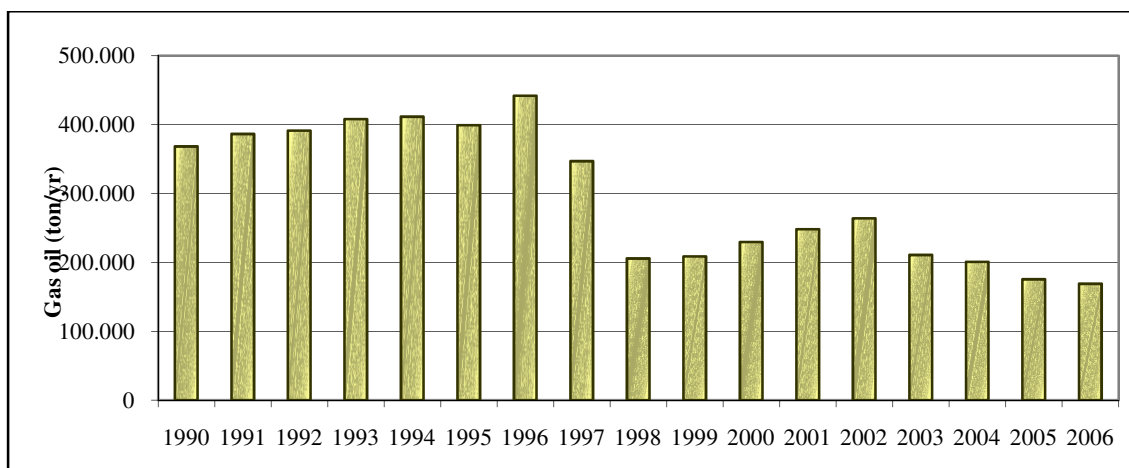
Parameter	EF	Unit
LHV	43.3	MJ/kg
SOx	0.3	%
NOx	56.9	g/kg
NM VOC	8.4	
CH4	0.3	
CO	20.7	
U CO2	3 136	
Fac_{OX}	0.990	0..1
N2O	1.3	g/kg
NH3	0.007	
PM	5.87	
As	0.05	
Cr	0.05	g/ton
Cu	1.7	
Ni	0.07	
Se	0.01	
Zn	1	

Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to 2006 from General-Directorate of Geology and Energy (DGEG) in the energy balance. Although there is no

clear specification, in 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. Quantities that were consumed are presented in Figure 3.69.

Figure 3.69 - Consumption of gas-oil in machines and other off-road vehicles (1990-2006)



Uncertainty Assessment

The time trend of diesel oil consumption in this activity shows a sharp and unexpected decrease between 1996 and 1998. Although future developments are expected to correct this situation, in this year the uncertainty in activity data was set as the maximum inter-annual variation, 80 per cent. Concerning emission factors, because there is no specific information for this activity in the GPG, the same uncertainty values that were used for road transportation were used to estimate uncertainty from off-road emissions of CO₂, CH₄ and N₂O.

Fishing Vessels

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 can not be individualised from road traffic consumption.

Methodology

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

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

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).

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 was used to chose 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. Particulate matter emission factors are from Lloyd's register (1995) and EMEP/CORINAIR (EEA,2002), and are function of type of fuel. Emission factors are presented in next table.

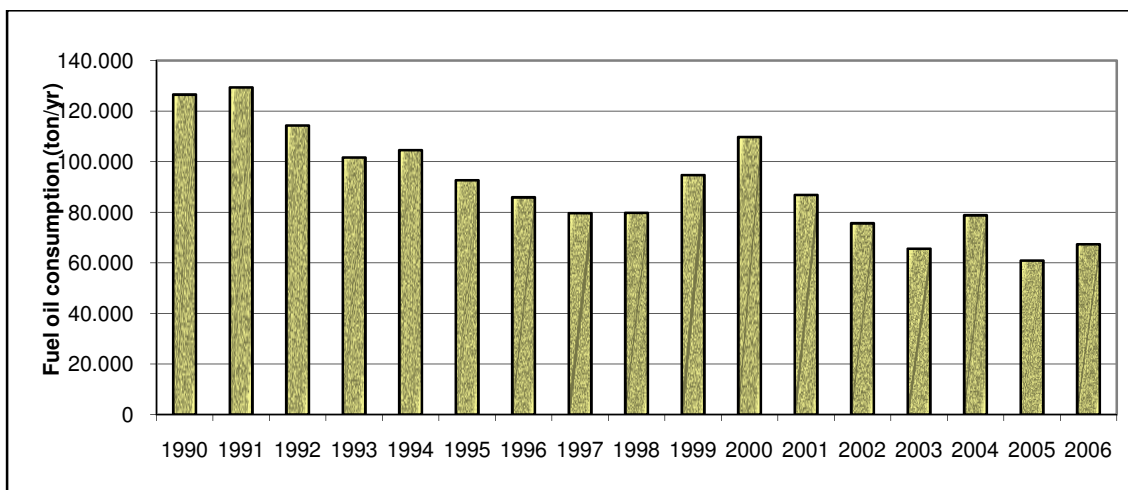
Table 3.109 – Emission factors for Water Borne Navigation and Fishing Vessels

EF	Units	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries
		Gas-oil		Fuel-oil	
LHV	MJ/kg	43.31		40.17	
SO _x	%	0.3		3	
NO _x	g/kg	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
EF _{CO2}	kg/GJ	74.07		77.37	
C _{Fossil}	%	100			
Fac _{OX}	0..1	0.99			
N ₂ O	g/kg	0.08			
PM	g/kg	1.2		7.6	
As	g/ton	0.05		0.5	
Cd	g/ton	0.01		0.03	
Cr	g/ton	0.04		0.2	
Cu	g/ton	0.05		0.5	
Hg	g/ton	0.05		0.02	
Ni	g/ton	0.07		30	
Pb	g/ton	0.2		1.3	
Se	g/ton	0.2		0.4	
Zn	g/ton	0.5		0.9	

Activity Data

Total fuel consumption in fishing activities is also available from the energy balance in energy units (toe). Because information from DGGE does not separate energy consumption in ships and in inland static equipments, it was assumed that the totality of diesel oil, 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 figure³⁶.

Figure 3.70 – Consumption of fuel oil in fishing bunkers (1990-2006)



Additional information in DGGE annual reports, available only until 2001, allow the division³⁷ of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea

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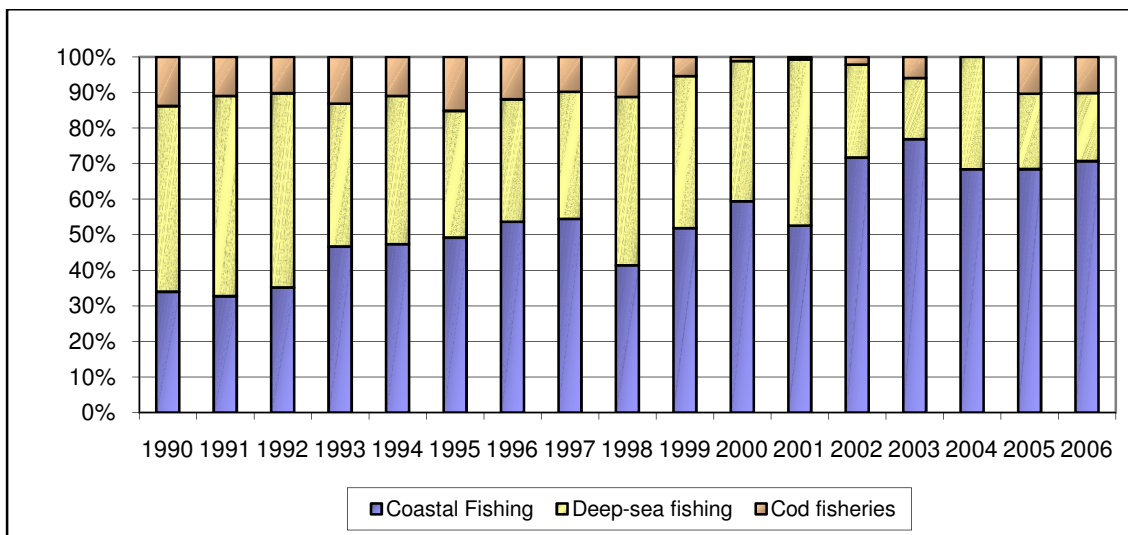
Uncertainty

³⁶ Use of diesel oil and fuel oil is insignificant, always less than 2.5% of gas oil consumption.

³⁷ 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

fishing and (3) Cod-fish fishing vessels³⁸. Percentage for each type of fisheries is presented in next figure.

Figure 3.71 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries (1990-2006)



Uncertainty Assessment

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



Bibliography



Key Categories



Uncertainty

³⁸ 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 per cent and 1000 per cent.

ANNEXES

Aviation

Annex Table 1 – Airport based LTO emission factors (kg/movement)

Airport	Parameter	Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
LIS	FC	Arrival	372	350	331	321	308	304	299	292	288	274
OPO	FC	Arrival	322	310	297	300	284	294	285	267	250	220
FAO	FC	Arrival	317	327	319	317	324	322	327	313	317	307
SMA	FC	Arrival	321	369	403	404	396	368	357	356	370	355
PDL	FC	Arrival	239	351	342	342	308	360	301	307	329	341
HOR	FC	Arrival	126	323	307	293	322	264	323	323	323	327
FLW	FC	Arrival	87	334	249	237	334	334	334	334	334	334
FNC	FC	Arrival	239	351	342	342	308	360	301	307	329	341
PXO	FC	Arrival	107	329	278	265	328	299	328	329	328	330
TER	FC	Arrival	151	336	299	291	321	319	319	321	329	334
LIS	CO	Arrival	6.63	5.39	4.90	4.98	4.35	3.95	3.78	3.66	3.71	3.18
OPO	CO	Arrival	5.33	4.39	4.30	4.49	4.31	4.31	4.12	3.74	3.52	3.29
FAO	CO	Arrival	4.79	4.14	4.07	4.16	4.47	4.07	4.27	3.96	4.25	3.85
SMA	CO	Arrival	11.37	4.50	5.35	5.23	4.86	3.80	4.38	3.79	4.22	3.75
PDL	CO	Arrival	6.65	3.84	3.95	3.81	3.79	4.12	3.56	3.56	4.00	3.80
HOR	CO	Arrival	5.01	3.27	3.79	3.06	3.27	3.50	3.27	3.27	3.27	3.26
FLW	CO	Arrival	5.43	3.23	5.90	2.56	3.23	3.23	3.23	3.23	3.23	3.23
FNC	CO	Arrival	6.65	3.84	3.95	3.81	3.79	4.12	3.56	3.56	4.00	3.80
PXO	CO	Arrival	5.22	3.25	4.84	2.81	3.25	3.36	3.25	3.25	3.25	3.25
TER	CO	Arrival	5.70	3.45	4.55	3.14	3.43	3.62	3.35	3.35	3.50	3.43
LIS	NOx	Arrival	2.35	2.29	2.17	2.01	1.95	1.96	1.93	1.90	1.97	1.95
OPO	NOx	Arrival	1.92	1.97	1.81	1.77	1.62	1.70	1.64	1.50	1.52	1.20
FAO	NOx	Arrival	1.91	2.10	2.02	1.96	2.05	2.05	2.10	2.01	2.03	1.96
SMA	NOx	Arrival	1.97	2.92	3.14	3.08	3.05	2.79	2.76	2.75	2.91	2.86
PDL	NOx	Arrival	1.37	2.75	2.64	2.64	2.38	2.82	2.31	2.38	2.57	2.61
HOR	NOx	Arrival	0.38	2.55	2.42	2.31	2.54	1.48	2.54	2.55	2.55	2.61
FLW	NOx	Arrival	0.07	2.74	2.02	1.92	2.74	2.74	2.74	2.74	2.74	2.74
FNC	NOx	Arrival	1.37	2.75	2.64	2.64	2.38	2.82	2.31	2.38	2.57	2.61
PXO	NOx	Arrival	0.23	2.65	2.22	2.11	2.64	2.11	2.64	2.65	2.64	2.67
TER	NOx	Arrival	0.61	2.68	2.36	2.29	2.55	2.35	2.53	2.56	2.62	2.65
LIS	PM	Arrival	3.99	3.76	3.57	3.45	3.31	3.27	3.21	3.14	3.11	2.96
OPO	PM	Arrival	3.45	3.34	3.19	3.21	3.04	3.14	3.05	2.85	2.69	2.35
FAO	PM	Arrival	3.40	3.52	3.43	3.41	3.49	3.46	3.52	3.37	3.42	3.30
SMA	PM	Arrival	3.44	4.02	4.38	4.39	4.31	4.00	3.89	3.87	4.03	3.87
PDL	PM	Arrival	2.56	3.82	3.72	3.72	3.34	3.92	3.27	3.34	3.58	3.71
HOR	PM	Arrival	1.33	3.52	3.34	3.19	3.51	2.81	3.51	3.52	3.52	3.56
FLW	PM	Arrival	0.91	3.65	2.72	2.58	3.65	3.65	3.65	3.65	3.65	3.65
FNC	PM	Arrival	2.56	3.82	3.72	3.72	3.34	3.92	3.27	3.34	3.58	3.71
PXO	PM	Arrival	1.12	3.58	3.03	2.89	3.58	3.23	3.58	3.58	3.58	3.60
TER	PM	Arrival	1.60	3.66	3.26	3.17	3.50	3.46	3.47	3.50	3.58	3.64
LIS	NMVOG	Arrival	2.35	1.58	1.40	1.49	1.13	0.81	0.72	0.69	0.71	0.56
OPO	NMVOG	Arrival	1.58	0.96	0.90	0.99	0.95	0.88	0.78	0.68	0.72	0.64
FAO	NMVOG	Arrival	1.20	0.92	0.88	0.91	1.15	0.87	0.97	0.92	1.01	0.84
SMA	NMVOG	Arrival	5.58	1.04	1.50	1.42	1.16	0.65	1.10	0.69	0.92	0.61
PDL	NMVOG	Arrival	2.20	0.62	0.60	0.66	0.77	0.80	0.61	0.58	0.74	0.64

HOR	NM VOC	Arrival	0.94	0.36	0.34	0.39	0.36	0.63	0.36	0.36	0.36	0.34
FLW	NM VOC	Arrival	1.02	0.31	0.25	0.41	0.31	0.31	0.31	0.31	0.31	0.31
FNC	NM VOC	Arrival	2.20	0.62	0.60	0.66	0.77	0.80	0.61	0.58	0.74	0.64
PXO	NM VOC	Arrival	0.98	0.33	0.30	0.40	0.33	0.47	0.33	0.33	0.33	0.32
TER	NM VOC	Arrival	1.39	0.43	0.40	0.48	0.48	0.58	0.43	0.41	0.47	0.43
LIS	CH ₄	Arrival	0.26	0.18	0.16	0.17	0.13	0.09	0.08	0.08	0.08	0.06
OPO	CH ₄	Arrival	0.18	0.11	0.10	0.11	0.11	0.10	0.09	0.08	0.08	0.07
FAO	CH ₄	Arrival	0.13	0.10	0.10	0.10	0.13	0.10	0.11	0.10	0.11	0.09
SMA	CH ₄	Arrival	0.62	0.12	0.17	0.16	0.13	0.07	0.12	0.08	0.10	0.07
PDL	CH ₄	Arrival	0.24	0.07	0.07	0.07	0.09	0.09	0.07	0.06	0.08	0.07
HOR	CH ₄	Arrival	0.10	0.04	0.04	0.04	0.04	0.07	0.04	0.04	0.04	0.04
FLW	CH ₄	Arrival	0.11	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03
FNC	CH ₄	Arrival	0.24	0.07	0.07	0.07	0.09	0.09	0.07	0.06	0.08	0.07
PXO	CH ₄	Arrival	0.11	0.04	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.04
TER	CH ₄	Arrival	0.15	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.05	0.05
LIS	FC	Departure	889	835	791	767	736	727	715	698	688	656
OPO	FC	Departure	771	741	711	718	679	703	681	637	597	522
FAO	FC	Departure	756	781	761	758	774	768	782	747	757	731
SMA	FC	Departure	746	879	960	963	944	875	848	845	880	843
PDL	FC	Departure	556	836	814	815	727	857	710	726	782	812
HOR	FC	Departure	275	769	730	696	767	629	767	769	768	776
FLW	FC	Departure	176	794	590	559	794	794	794	794	794	794
FNC	FC	Departure	556	836	814	815	727	857	710	726	782	812
PXO	FC	Departure	226	781	660	628	780	711	780	781	781	785
TER	FC	Departure	336	800	711	690	762	760	757	763	781	794
LIS	CO	Departure	14.90	12.13	11.08	11.21	9.84	9.10	8.75	8.46	8.64	7.41
OPO	CO	Departure	12.00	10.05	9.88	10.29	9.76	9.89	9.46	8.55	8.05	7.41
FAO	CO	Departure	10.83	9.42	9.30	9.49	10.20	9.35	9.79	9.02	9.77	8.82
SMA	CO	Departure	24.30	10.40	12.35	12.16	11.40	8.95	9.90	8.80	9.77	8.76
PDL	CO	Departure	14.29	9.01	9.22	8.90	8.33	9.62	7.86	7.95	9.10	8.84
HOR	CO	Departure	10.28	7.65	8.82	7.09	7.65	7.84	7.65	7.65	7.65	7.64
FLW	CO	Departure	10.97	7.62	13.61	5.88	7.62	7.62	7.62	7.62	7.62	7.62
FNC	CO	Departure	14.29	9.01	9.22	8.90	8.33	9.62	7.86	7.95	9.10	8.84
PXO	CO	Departure	10.63	7.63	11.21	6.49	7.63	7.73	7.63	7.63	7.63	7.63
TER	CO	Departure	11.85	8.09	10.55	7.29	7.87	8.36	7.71	7.74	8.12	8.03
LIS	NO _x	Departure	13.22	12.37	11.60	10.82	10.29	10.20	10.00	9.74	10.20	10.14
OPO	NO _x	Departure	10.11	10.25	9.51	9.41	8.40	8.83	8.52	7.58	7.58	5.96
FAO	NO _x	Departure	10.11	10.86	10.49	10.42	11.32	11.14	11.47	10.95	11.29	10.94
SMA	NO _x	Departure	11.86	15.48	17.49	18.00	17.42	16.31	15.56	15.49	16.02	14.93
PDL	NO _x	Departure	7.31	13.94	13.39	13.42	12.18	14.59	11.72	12.01	13.16	13.25
HOR	NO _x	Departure	1.69	12.60	11.94	11.34	12.52	6.40	12.53	12.62	12.58	12.94
FLW	NO _x	Departure	0.35	13.70	10.09	9.44	13.70	13.70	13.70	13.70	13.70	13.70
FNC	NO _x	Departure	7.31	13.94	13.39	13.42	12.18	14.59	11.72	12.01	13.16	13.25
PXO	NO _x	Departure	1.02	13.15	11.02	10.39	13.11	10.05	13.12	13.16	13.14	13.32
TER	NO _x	Departure	3.12	13.42	11.81	11.40	12.80	11.56	12.65	12.78	13.15	13.30
LIS	PM	Departure	8.21	7.73	7.32	7.08	6.80	6.72	6.61	6.45	6.37	6.08
OPO	PM	Departure	7.11	6.87	6.57	6.63	6.26	6.49	6.28	5.88	5.51	4.81
FAO	PM	Departure	6.98	7.23	7.04	7.01	7.16	7.10	7.23	6.90	7.00	6.76
SMA	PM	Departure	6.88	8.24	8.97	8.99	8.82	8.18	7.92	7.90	8.24	7.91
PDL	PM	Departure	5.12	7.83	7.61	7.62	6.80	8.02	6.64	6.79	7.31	7.59
HOR	PM	Departure	2.51	7.21	6.85	6.53	7.19	5.79	7.19	7.21	7.20	7.29
FLW	PM	Departure	1.58	7.46	5.55	5.25	7.46	7.46	7.46	7.46	7.46	7.46

FNC	PM	Departure	5.12	7.83	7.61	7.62	6.80	8.02	6.64	6.79	7.31	7.59
PXO	PM	Departure	2.04	7.34	6.20	5.89	7.33	6.62	7.33	7.34	7.33	7.37
TER	PM	Departure	3.07	7.50	6.67	6.47	7.15	7.09	7.10	7.16	7.32	7.45
LIS	NMVOG	Departure	5.77	3.82	3.39	3.61	2.71	1.95	1.73	1.67	1.73	1.36
OPO	NMVOG	Departure	3.88	2.32	2.17	2.38	2.28	2.13	1.86	1.62	1.75	1.54
FAO	NMVOG	Departure	2.95	2.22	2.10	2.19	2.77	2.08	2.32	2.19	2.44	2.03
SMA	NMVOG	Departure	14.32	2.53	3.68	3.48	2.84	1.58	2.59	1.64	2.23	1.48
PDL	NMVOG	Departure	5.72	1.51	1.48	1.60	1.70	1.95	1.31	1.25	1.70	1.56
HOR	NMVOG	Departure	2.54	0.86	0.84	0.94	0.86	1.49	0.86	0.85	0.86	0.82
FLW	NMVOG	Departure	2.84	0.74	0.70	1.02	0.74	0.74	0.74	0.74	0.74	0.74
FNC	NMVOG	Departure	5.72	1.51	1.48	1.60	1.70	1.95	1.31	1.25	1.70	1.56
PXO	NMVOG	Departure	2.69	0.80	0.77	0.98	0.80	1.12	0.80	0.80	0.80	0.78
TER	NMVOG	Departure	3.70	1.04	1.01	1.19	1.10	1.40	0.97	0.95	1.10	1.04
LIS	CH4	Departure	0.64	0.42	0.38	0.40	0.30	0.22	0.19	0.19	0.19	0.15
OPO	CH4	Departure	0.43	0.26	0.24	0.26	0.25	0.24	0.21	0.18	0.19	0.17
FAO	CH4	Departure	0.33	0.25	0.23	0.24	0.31	0.23	0.26	0.24	0.27	0.23
SMA	CH4	Departure	1.59	0.28	0.41	0.39	0.32	0.18	0.29	0.18	0.25	0.16
PDL	CH4	Departure	0.64	0.17	0.16	0.18	0.19	0.22	0.15	0.14	0.19	0.17
HOR	CH4	Departure	0.28	0.10	0.09	0.10	0.10	0.17	0.10	0.09	0.10	0.09
FLW	CH4	Departure	0.32	0.08	0.08	0.11	0.08	0.08	0.08	0.08	0.08	0.08
FNC	CH4	Departure	0.64	0.17	0.16	0.18	0.19	0.22	0.15	0.14	0.19	0.17
PXO	CH4	Departure	0.30	0.09	0.09	0.11	0.09	0.12	0.09	0.09	0.09	0.09
TER	CH4	Departure	0.41	0.12	0.11	0.13	0.12	0.16	0.11	0.11	0.12	0.12

Annex Table 2 – Airport based cruise emission factors (kg/hr)

Airport	Parameter	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
FAO	CH4	I	0.29	0.30	0.27	0.26	0.29	0.19	0.28	0.25	0.18	0.13
FAO	CH4	N	0.28	0.11	0.11	0.15	0.15	0.14	0.13	0.13	0.12	0.12
FAO	CH4	UE	0.26	0.25	0.24	0.25	0.26	0.22	0.23	0.20	0.20	0.20
FAO	CO	I	7.23	6.97	6.51	5.98	5.94	4.99	5.75	5.42	5.01	4.10
FAO	CO	N	11.83	4.70	4.58	4.51	4.51	4.29	4.19	4.15	4.00	3.82
FAO	CO	UE	6.43	5.97	5.78	5.74	5.54	5.28	5.37	5.01	4.89	4.78
FAO	FC	I	4 036	3 956	3 762	3 411	3 661	3 454	3 529	3 385	3 491	3 073
FAO	FC	N	2 213	1 926	1 980	2 515	2 790	2 839	2 618	2 519	2 823	2 731
FAO	FC	UE	3 082	3 051	2 980	2 966	2 993	2 938	2 957	2 777	2 748	2 713
FAO	NMVOC	I	2.63	2.66	2.45	2.36	2.64	1.68	2.54	2.21	1.65	1.21
FAO	NMVOC	N	2.48	1.02	1.02	1.35	1.39	1.24	1.16	1.13	1.11	1.04
FAO	NMVOC	UE	2.34	2.28	2.19	2.29	2.34	1.99	2.10	1.83	1.78	1.78
FAO	NOx	I	53.18	53.61	51.81	48.70	56.28	51.10	53.44	51.35	54.57	46.74
FAO	NOx	N	23.81	21.38	21.82	28.25	33.55	34.96	33.12	32.37	37.01	36.59
FAO	NOx	UE	35.83	36.37	35.60	36.63	39.03	37.54	38.15	35.74	35.91	36.18
FLW	CH4	I	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	CH4	N	0.51	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	CH4	UE	0.51	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	CO	I	27.76	3.86	1.59	1.52	1.54	1.58	1.58	1.59	1.65	1.65
FLW	CO	N	27.76	3.86	3.81	2.65	2.98	3.36	3.32	3.41	3.56	3.57
FLW	CO	UE	27.76	3.86	2.28	1.63	1.76	1.99	1.96	2.05	2.27	2.30
FLW	FC	I	461	403	193	191	194	198	197	199	203	204
FLW	FC	N	461	403	295	283	324	357	354	362	375	376
FLW	FC	UE	461	403	209	191	213	235	232	240	260	262
FLW	NMVOC	I	4.61	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	NMVOC	N	4.61	0.00	0.16	0.01	0.00	0.00	0.00	0.00	0.00	0.00
FLW	NMVOC	UE	4.61	0.00	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00
FLW	NOx	I	0.58	3.37	1.81	1.78	1.83	1.85	1.85	1.86	1.90	1.90
FLW	NOx	N	0.58	3.37	2.39	2.38	2.78	3.03	3.01	3.07	3.17	3.17
FLW	NOx	UE	0.58	3.37	1.85	1.70	1.97	2.13	2.10	2.16	2.31	2.33
FNC	CH4	I	0.22	0.14	0.14	0.09	0.12	0.15	0.15	0.24	0.45	0.17
FNC	CH4	N	0.45	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
FNC	CH4	UE	0.28	0.17	0.17	0.14	0.12	0.17	0.14	0.14	0.16	0.19
FNC	CO	I	6.98	4.61	4.66	3.47	4.07	4.57	4.17	5.04	7.44	5.09
FNC	CO	N	23.75	3.91	4.01	3.70	3.59	3.91	3.61	3.64	3.71	3.97
FNC	CO	UE	11.14	5.12	5.26	4.51	4.08	4.92	4.25	4.30	4.56	5.32
FNC	FC	I	4 194	3 752	3 397	2 252	3 082	3 719	3 261	3 444	4 158	3 693
FNC	FC	N	1 019	784	747	738	770	881	796	793	876	759
FNC	FC	UE	2 610	2 594	2 561	2 165	1 997	2 658	2 124	2 144	2 316	2 598
FNC	NMVOC	I	1.96	1.24	1.23	0.82	1.12	1.38	1.33	2.20	4.08	1.56
FNC	NMVOC	N	4.07	0.13	0.15	0.14	0.14	0.17	0.15	0.15	0.20	0.17
FNC	NMVOC	UE	2.54	1.49	1.52	1.30	1.12	1.52	1.27	1.29	1.41	1.70
FNC	NOx	I	60.60	55.84	49.14	32.97	47.39	58.27	49.63	52.36	66.71	55.00
FNC	NOx	N	9.38	9.00	8.39	8.38	9.15	10.70	9.34	9.29	10.69	8.33
FNC	NOx	UE	28.73	31.46	30.52	26.01	25.41	35.29	26.91	26.93	30.32	30.54
HOR	CH4	I	0.32	0.10	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
HOR	CH4	N	0.50	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01
HOR	CH4	UE	0.33	0.14	0.11	0.10	0.10	0.13	0.10	0.11	0.11	0.08
HOR	CO	I	13.65	4.62	2.30	2.19	1.96	1.81	2.04	2.11	2.12	2.15

HOR	CO	N	26.56	3.92	4.10	3.58	3.69	2.49	3.73	3.76	3.76	3.67
HOR	CO	UE	14.30	4.97	4.48	3.89	3.91	3.91	4.04	4.11	4.14	3.54
HOR	FC	I	1 807	1 412	456	468	375	373	406	426	436	1 061
HOR	FC	N	575	472	446	429	451	782	454	452	455	517
HOR	FC	UE	1 745	1 881	1 458	1 376	1 379	1 634	1 442	1 454	1 481	1 399
HOR	NMVOC	I	2.88	0.87	0.20	0.21	0.13	0.14	0.15	0.17	0.17	0.20
HOR	NMVOC	N	4.47	0.06	0.11	0.06	0.06	0.46	0.06	0.05	0.06	0.05
HOR	NMVOC	UE	2.96	1.27	1.00	0.91	0.90	1.13	0.94	0.95	0.97	0.68
HOR	NOx	I	15.28	12.80	4.17	4.32	3.47	3.47	3.74	3.92	4.01	14.90
HOR	NOx	N	1.83	4.01	3.75	3.64	3.86	7.22	3.89	3.86	3.88	5.12
HOR	NOx	UE	14.60	17.19	13.28	12.62	12.63	15.04	13.20	13.30	13.55	15.28
LIS	CH4	I	0.36	0.30	0.27	0.24	0.23	0.47	0.50	0.54	0.47	0.43
LIS	CH4	N	0.23	0.10	0.12	0.14	0.14	0.14	0.13	0.14	0.12	0.09
LIS	CH4	UE	0.28	0.23	0.20	0.19	0.18	0.19	0.17	0.17	0.14	0.12
LIS	CO	I	8.01	7.31	6.87	6.20	5.98	7.95	8.23	9.05	7.99	7.43
LIS	CO	N	8.34	4.37	4.41	4.39	4.41	4.52	4.13	4.18	4.15	3.54
LIS	CO	UE	6.42	5.72	5.23	5.08	4.95	4.96	4.82	4.74	4.14	3.66
LIS	FC	I	4 483	4 350	4 248	3 797	3 842	4 103	4 099	4 408	4 283	4 019
LIS	FC	N	2 651	2 004	2 342	2 796	2 836	2 766	2 686	2 681	2 801	2 607
LIS	FC	UE	3 189	2 987	2 860	2 790	2 787	2 792	2 748	2 678	2 415	2 379
LIS	NMVOC	I	3.25	2.67	2.41	2.17	2.07	4.25	4.47	4.86	4.26	3.90
LIS	NMVOC	N	2.04	0.89	1.06	1.29	1.27	1.30	1.20	1.22	1.10	0.83
LIS	NMVOC	UE	2.50	2.05	1.76	1.72	1.63	1.68	1.55	1.53	1.30	1.06
LIS	NOx	I	69.81	66.36	64.97	55.46	55.80	60.22	59.70	65.99	64.19	59.56
LIS	NOx	N	33.32	24.45	29.08	34.43	34.93	33.65	32.72	32.68	36.62	36.12
LIS	NOx	UE	38.91	34.83	33.20	31.84	32.11	32.68	31.76	31.47	29.49	31.35
OPO	CH4	I	0.38	0.25	0.19	0.17	0.19	0.19	0.32	0.28	0.23	0.21
OPO	CH4	N	0.20	0.07	0.10	0.12	0.15	0.14	0.12	0.12	0.12	0.09
OPO	CH4	UE	0.28	0.20	0.17	0.18	0.19	0.19	0.19	0.15	0.12	0.11
OPO	CO	I	7.43	6.21	5.42	4.97	5.11	5.35	6.24	6.24	5.64	4.77
OPO	CO	N	7.55	4.12	4.13	4.12	5.26	4.74	3.89	4.01	3.91	3.47
OPO	CO	UE	6.17	5.20	4.78	4.83	5.05	5.12	4.97	4.52	3.78	3.54
OPO	FC	I	3 918	3 745	3 630	3 465	3 276	3 546	3 471	3 437	3 511	3 042
OPO	FC	N	2 384	1 568	2 103	2 684	2 558	2 626	2 528	2 489	2 681	2 420
OPO	FC	UE	3 011	2 735	2 664	2 708	2 702	2 765	2 733	2 471	2 096	2 040
OPO	NMVOC	I	3.46	2.28	1.71	1.55	1.75	1.73	2.92	2.55	2.09	1.87
OPO	NMVOC	N	1.84	0.64	0.87	1.11	1.34	1.22	1.06	1.11	1.04	0.82
OPO	NMVOC	UE	2.51	1.81	1.53	1.58	1.70	1.72	1.71	1.34	1.08	0.95
OPO	NOx	I	56.13	52.83	51.30	49.00	45.45	48.35	48.95	46.72	48.73	43.54
OPO	NOx	N	25.97	16.75	23.00	30.71	28.30	28.96	28.56	27.27	31.85	30.43
OPO	NOx	UE	34.34	29.26	28.32	29.36	28.90	29.58	29.96	25.49	22.16	22.63
PDL	CH4	I	0.22	0.14	0.14	0.09	0.12	0.15	0.15	0.24	0.45	0.17
PDL	CH4	N	0.45	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PDL	CH4	UE	0.28	0.17	0.17	0.14	0.12	0.17	0.14	0.14	0.16	0.19
PDL	CO	I	6.98	4.61	4.66	3.47	4.07	4.57	4.17	5.04	7.44	5.09
PDL	CO	N	23.75	3.91	4.01	3.70	3.59	3.91	3.61	3.64	3.71	3.97
PDL	CO	UE	11.14	5.12	5.26	4.51	4.08	4.92	4.25	4.30	4.56	5.32
PDL	FC	I	4 194	3 752	3 397	2 252	3 082	3 719	3 261	3 444	4 158	3 693
PDL	FC	N	1 019	784	747	738	770	881	796	793	876	759
PDL	FC	UE	2 610	2 594	2 561	2 165	1 997	2 658	2 124	2 144	2 316	2 598
PDL	NMVOC	I	1.96	1.24	1.23	0.82	1.12	1.38	1.33	2.20	4.08	1.56
PDL	NMVOC	N	4.07	0.13	0.15	0.14	0.14	0.17	0.15	0.15	0.20	0.17

PDL	NMVOC	UE	2.54	1.49	1.52	1.30	1.12	1.52	1.27	1.29	1.41	1.70
PDL	NOx	I	60.60	55.84	49.14	32.97	47.39	58.27	49.63	52.36	66.71	55.00
PDL	NOx	N	9.38	9.00	8.39	8.38	9.15	10.70	9.34	9.29	10.69	8.33
PDL	NOx	UE	28.73	31.46	30.52	26.01	25.41	35.29	26.91	26.93	30.32	30.54
PXO	CH4	I	0.42	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
PXO	CH4	N	0.50	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00
PXO	CH4	UE	0.42	0.07	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.04
PXO	CO	I	20.70	4.24	1.95	1.86	1.75	1.70	1.81	1.85	1.88	1.90
PXO	CO	N	27.16	3.89	3.95	3.11	3.34	2.92	3.52	3.58	3.66	3.62
PXO	CO	UE	21.03	4.42	3.38	2.76	2.83	2.95	3.00	3.08	3.21	2.92
PXO	FC	I	1 134	907	325	329	285	285	302	312	320	632
PXO	FC	N	518	437	371	356	387	569	404	407	415	447
PXO	FC	UE	1 103	1 142	834	783	796	934	837	847	870	830
PXO	NMVOC	I	3.74	0.43	0.11	0.11	0.07	0.07	0.08	0.08	0.09	0.10
PXO	NMVOC	N	4.54	0.03	0.13	0.03	0.03	0.23	0.03	0.03	0.03	0.03
PXO	NMVOC	UE	3.78	0.63	0.54	0.46	0.45	0.56	0.47	0.47	0.49	0.34
PXO	NOx	I	7.93	8.09	2.99	3.05	2.65	2.66	2.80	2.89	2.95	8.40
PXO	NOx	N	1.21	3.69	3.07	3.01	3.32	5.13	3.45	3.46	3.53	4.15
PXO	NOx	UE	7.59	10.28	7.56	7.16	7.30	8.58	7.65	7.73	7.93	8.81
SMA	CH4	I	0.60	0.44	0.29	0.28	0.22	0.33	0.35	0.34	0.32	0.24
SMA	CH4	N	0.52	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.00
SMA	CH4	UE	0.75	0.34	0.26	0.29	0.28	0.32	0.27	0.29	0.27	0.17
SMA	CO	I	11.11	8.63	6.66	6.25	5.31	6.94	7.62	7.03	7.86	7.66
SMA	CO	N	26.52	3.94	4.00	3.97	3.83	3.97	3.90	3.91	3.97	3.91
SMA	CO	UE	15.97	7.12	6.02	5.79	5.58	5.92	5.59	5.68	5.95	5.55
SMA	FC	I	5 428	4 582	4 478	4 098	3 345	3 892	4 239	3 837	4 341	4 134
SMA	FC	N	821	530	873	928	810	520	557	486	513	446
SMA	FC	UE	4 062	2 888	3 337	3 320	3 056	3 279	2 882	3 020	3 018	2 388
SMA	NMVOC	I	5.38	3.93	2.61	2.49	2.02	2.99	3.17	3.08	2.92	2.20
SMA	NMVOC	N	4.64	0.08	0.20	0.23	0.17	0.10	0.13	0.08	0.09	0.04
SMA	NMVOC	UE	6.72	3.06	2.36	2.60	2.55	2.85	2.39	2.61	2.40	1.56
SMA	NOx	I	90.06	75.55	73.94	68.69	54.17	65.90	72.01	66.42	70.84	62.41
SMA	NOx	N	7.50	5.55	11.23	12.24	10.26	5.51	6.24	4.95	5.39	4.16
SMA	NOx	UE	67.52	44.56	55.17	57.73	52.33	58.34	50.10	53.69	52.07	38.15
TER	CH4	I	0.22	0.14	0.14	0.09	0.12	0.15	0.15	0.24	0.45	0.17
TER	CH4	N	0.45	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
TER	CH4	UE	0.28	0.17	0.17	0.14	0.12	0.17	0.14	0.14	0.16	0.19
TER	CO	I	6.98	4.61	4.66	3.47	4.07	4.57	4.17	5.04	7.44	5.09
TER	CO	N	23.75	3.91	4.01	3.70	3.59	3.91	3.61	3.64	3.71	3.97
TER	CO	UE	11.14	5.12	5.26	4.51	4.08	4.92	4.25	4.30	4.56	5.32
TER	FC	I	4 194	3 752	3 397	2 252	3 082	3 719	3 261	3 444	4 158	3 693
TER	FC	N	1 019	784	747	738	770	881	796	793	876	759
TER	FC	UE	2 610	2 594	2 561	2 165	1 997	2 658	2 124	2 144	2 316	2 598
TER	NMVOC	I	1.96	1.24	1.23	0.82	1.12	1.38	1.33	2.20	4.08	1.56
TER	NMVOC	N	4.07	0.13	0.15	0.14	0.14	0.17	0.15	0.15	0.20	0.17
TER	NMVOC	UE	2.54	1.49	1.52	1.30	1.12	1.52	1.27	1.29	1.41	1.70
TER	NOx	I	60.60	55.84	49.14	32.97	47.39	58.27	49.63	52.36	66.71	55.00
TER	NOx	N	9.38	9.00	8.39	8.38	9.15	10.70	9.34	9.29	10.69	8.33
TER	NOx	UE	28.73	31.46	30.52	26.01	25.41	35.29	26.91	26.93	30.32	30.54

Annex Table 3 – LTO share for domestic (N), EU (UE) and international (I) flights

Airport Code	Distinc.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
LIS	I	15.7%	15.7%	15.7%	15.7%	15.7%	15.7%	16.1%	15.6%	15.6%	16.3%	16.7%	16.0%	15.9%	17.0%	16.2%
LIS	N	26.6%	26.6%	26.6%	26.6%	26.6%	26.6%	26.8%	26.8%	26.4%	27.4%	24.7%	25.8%	25.4%	23.8%	22.6%
LIS	UE	57.6%	57.6%	57.6%	57.6%	57.6%	57.6%	57.2%	57.6%	58.0%	56.3%	58.6%	58.3%	58.6%	59.1%	61.1%
OPO	I	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%	13.7%	11.7%	10.1%	7.0%	6.6%	8.9%	9.2%	7.7%	7.9%
OPO	N	26.5%	26.5%	26.5%	26.5%	26.5%	26.5%	25.4%	26.6%	27.1%	30.0%	25.3%	24.4%	26.1%	27.8%	24.2%
OPO	UE	61.9%	61.9%	61.9%	61.9%	61.9%	61.9%	60.8%	61.7%	62.8%	63.1%	68.2%	66.7%	64.7%	64.4%	67.9%
FAO	I	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.5%	3.5%	4.1%	3.4%	4.8%	4.0%	3.7%	3.7%	3.6%
FAO	N	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%	10.8%	13.3%	12.3%	12.3%	14.7%	14.5%	17.2%	14.4%	11.4%
FAO	UE	84.1%	84.1%	84.1%	84.1%	84.1%	84.1%	85.7%	83.1%	83.6%	84.2%	80.4%	81.5%	79.1%	81.9%	85.1%
FNC	I	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.8%	1.7%	1.7%	1.6%	1.4%	1.1%	1.4%	1.3%	1.5%
FNC	N	66.9%	66.9%	66.9%	66.9%	66.9%	66.9%	65.8%	67.5%	67.4%	67.2%	67.5%	71.1%	70.8%	65.5%	59.5%
FNC	UE	31.4%	31.4%	31.4%	31.4%	31.4%	31.4%	32.4%	30.8%	30.9%	31.2%	31.1%	27.7%	27.8%	33.2%	39.0%
PDL	I	6.2%	6.2%	6.2%	6.2%	6.2%	6.2%	5.7%	6.7%	6.0%	5.8%	1.2%	5.5%	5.4%	6.1%	6.2%
PDL	N	92.6%	92.6%	92.6%	92.6%	92.6%	92.6%	92.9%	92.0%	92.9%	94.1%	98.1%	91.0%	90.5%	90.4%	89.2%
PDL	UE	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%	1.4%	1.4%	1.1%	0.1%	0.7%	3.5%	4.1%	3.5%	4.6%
HOR	I	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.2%	0.3%	0.1%
HOR	N	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.7%	99.5%	99.8%
HOR	UE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.2%	0.1%
SMA	I	18.3%	18.3%	18.3%	18.3%	18.3%	18.3%	18.1%	19.6%	17.1%	11.1%	32.8%	32.8%	29.1%	28.1%	16.0%
SMA	N	66.1%	66.1%	66.1%	66.1%	66.1%	66.1%	67.1%	63.0%	68.4%	80.1%	48.5%	48.0%	55.1%	56.9%	74.2%
SMA	UE	15.6%	15.6%	15.6%	15.6%	15.6%	15.6%	14.8%	17.4%	14.5%	8.8%	18.7%	19.2%	15.8%	15.0%	9.8%
PXO	I	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	1.3%	0.8%	0.5%	0.9%	0.7%	0.1%	0.1%	0.2%	0.1%
PXO	N	92.5%	92.5%	92.5%	92.5%	92.5%	92.5%	91.9%	91.8%	94.1%	94.7%	96.1%	98.9%	99.1%	98.9%	99.2%
PXO	UE	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.8%	7.4%	5.4%	4.3%	3.2%	1.0%	0.8%	0.9%	0.7%
FLW	I	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.2%	0.2%	0.2%	0.0%
FLW	N	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.8%	99.7%	99.8%	100.0%
FLW	UE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
TER	I	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%	3.2%	4.0%	3.1%	7.4%	7.7%	2.6%	2.0%	0.8%	1.0%
TER	N	95.8%	95.8%	95.8%	95.8%	95.8%	95.8%	96.4%	95.4%	95.7%	91.7%	91.2%	96.5%	97.5%	98.4%	98.9%
TER	UE	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.4%	0.6%	1.2%	0.9%	1.1%	0.9%	0.4%	0.7%	0.1%

3.2.A.6 OTHER SECTORS (CRF 1A4)

OVERVIEW

The sources covered in this chapter refer to those emissions resulting from combustion in such activities such as residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) sources. All emissions resulting from combustion equipments, either 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 nevertheless discussed in chapter 3.2.A.5.

METHODOLOGY

Emissions were estimated from fuel/energy consumption using either mass balance (CO₂) or emission factors, according to the pollutant, and using a IPCC Tier 2 methodology.

For Carbon Dioxide (CO₂), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO_2(s,f)} = 44/12 * EF_{C(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

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

where,

$U_{CO_2(s,f)}$ - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

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

EF_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 pollutants use the following basic formula (Energy Approach):

$$Emi_{(p,s)} = \sum_t [EF_{(f,s,t,y,p)} * Activity_{(f,s,t,p)}] * 10^{-3}$$

where:

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

$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO₂ in kg/GJ);

Activity_(f,s,t) - Energy Consumption of fuel f in sub-sector s and in equipment/technology t (GJ).

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)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997
Residual Oil	L	203	63 530	62 097	55 535	51 459	66 691	42 565	43 312	40 271
Diesel/Gas Oil	L	204	158 214	210 819	285 505	205 027	190 282	200 936	132 606	91 896
Kerosene	L	206	793 373	753 052	626 060	530 505	513 747	355 816	415 879	728 302
Motor Gasoline	L	208	6 185	7 785	5 900	5 649	6 252	9 577	13 749	14 898
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
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
Natural Gas	G	301	0	0	0	0	0	0	0	31 980
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
Charcoal	B	112	749 950	738 791	727 632	716 473	705 314	694 155	682 996	671 837

Fuel	1998	1999	2000	2001	2002	2003	2004	2005	2006
Residual Oil	10 915	3 880	2 594	0	0	0	0	0	0
Diesel/Gas Oil	105 979	144 221	90 426	82 408	120 300	380 121	666 824	599 849	1 439 707
Kerosene	761 508	705 271	365 327	194 406	147 838	89 780	88 601	50 087	30 795
Motor Gasoline	14 691	6 077	772	93	24 848	36 159	37 346	57	84
LPG	30 788 636	32 600 574	33 436 221	30 740 137	30 729 805	29 733 968	29 234 481	28 536 176	26 357 931
City Gas	2 106 088	2 039 388	1 212 913	156 763	0	0	0	0	0
Natural Gas	361 961	1 360 508	2 883 241	4 450 418	5 568 369	6 640 771	6 880 762	7 581 594	7 688 057
Wood	47 907 950	47 280 335	47 071 130	47 280 335	47 280 335	48 127 150	48 477 991	48 727 878	48 577 950
Charcoal	660 678	649 519	638 360	627 201	616 042	604 883	593 724	582 565	571 406

Figure 3.72 – Total Energy Consumption in fuels in the residential sector between 1990 and 2006

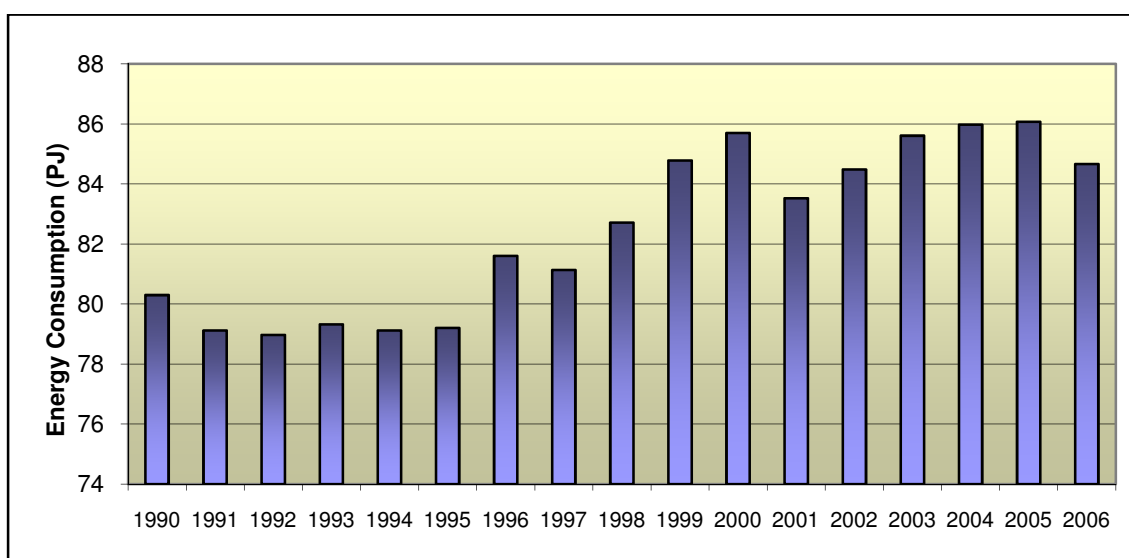


Figure 3.73 – Consumption of energy in fuels in the residential sector in 1990 and 2006

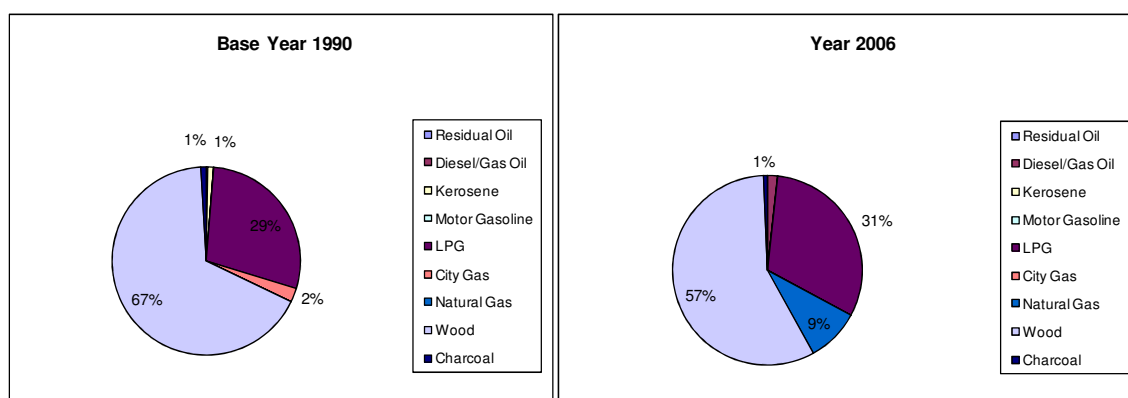


Table 3.111 - Fuels consumed in the commercial, services and institutional sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997
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
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
Kerosene	L	206	74 874	33 376	64 163	73 739	24 495	13 459	12 677	25 053
Motor Gasoline	L	208	579 235	638 264	617 276	604 690	1 035 873	1 174 153	1 418 403	2 592 133
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
City Gas	L	308	504 399	556 773	528 075	643 808	647 871	732 803	785 507	777 866
Natural Gas	G	301	0	0	0	0	0	0	0	14 258
Biogas	B	309	0	0	0	0	0	0	0	0

Fuel	1998	1999	2000	2001	2002	2003	2004	2005	2006
Residual Oil	2 836 712	3 438 705	3 312 313	3 447 019	3 532 016	2 905 392	3 150 365	3 180 779	3 538 745
Diesel/Gas Oil	16 708 519	18 339 696	18 379 823	21 943 150	24 179 733	29 752 522	33 040 833	33 332 904	19 059 665
Kerosene	27 126	17 190	6 133	7 568	9 489	7 340	7 211	6 330	8 201
Motor Gasoline	3 260 397	3 216 908	2 215 997	2 852 911	2 485 291	2 362 703	2 424 946	1 636 075	1 025 272
LPG	3 904 492	4 121 761	4 297 205	5 068 917	4 978 362	5 147 243	5 270 092	4 678 785	4 233 872
City Gas	908 944	1 044 085	732 238	69 195	0	0	0	0	0
Natural Gas	509 290	1 438 849	2 330 208	3 651 585	4 653 783	5 932 664	5 954 088	5 862 928	6 633 482
Biogas	0	49 772	101 885	54 356	60 473	48 419	100 729	135 455	128 462

Figure 3.74 – Total Energy Consumption in fuels in the commercial/services/institutional sector between 1990 and 2005

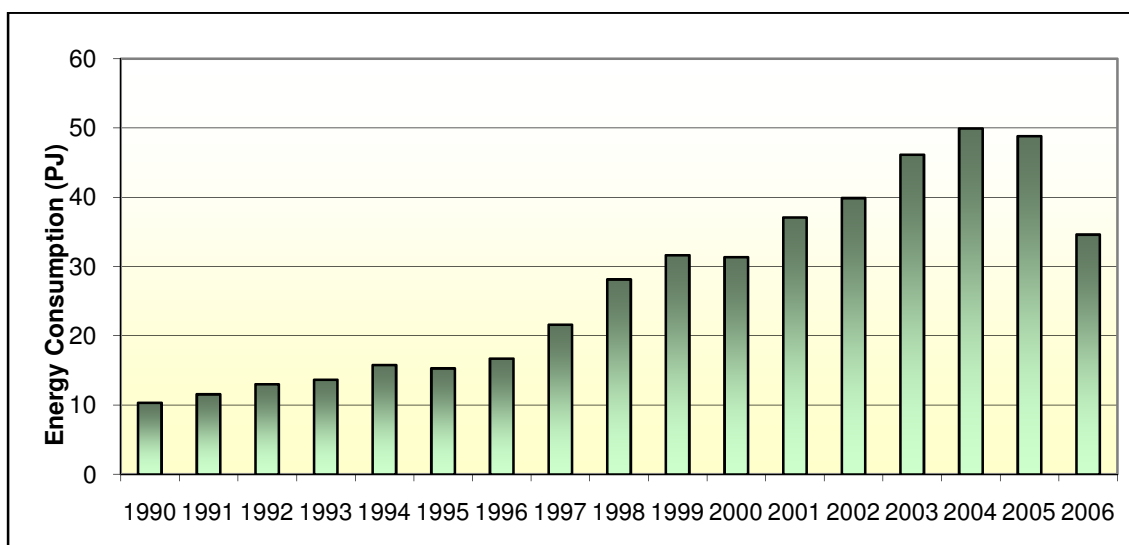


Figure 3.75 – Consumption of energy in fuels in the commercial/services/institutional sector in 1990 and 2006

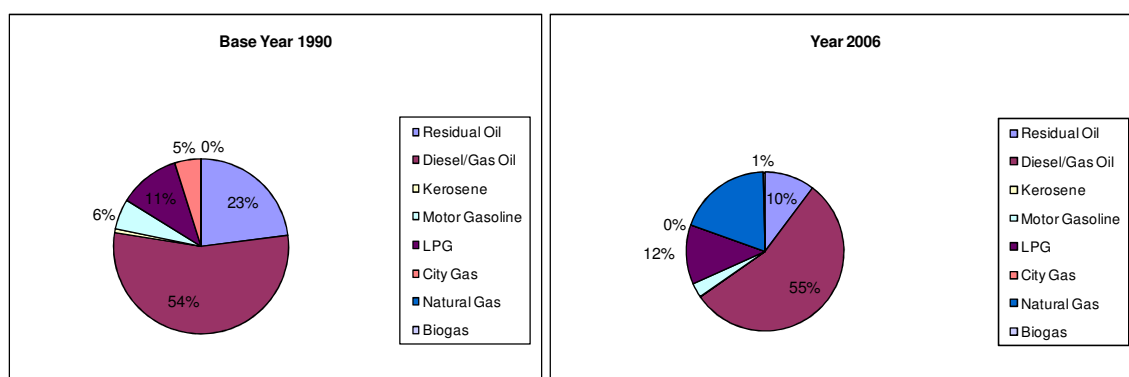


Table 3.112 - Fuels consumed in agriculture and forestry sector (GJ) (excluding mobile sources)

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

Fuel	1998	1999	2000	2001	2002	2003	2004	2005	2006
Residual Oil	475 768	678 844	891 798	802 636	1 210 609	1 086 402	758 390	870 746	611 164
Kerosene	493 714	24 152	44 370	47 054	50 254	47 209	48 886	54 548	56 402
Motor Gasoline	174 300	159 631	42 694	119 459	106 749	116 899	117 357	208 416	153 389
LPG	713 407	674 208	496 566	672 831	639 244	532 167	523 118	540 883	493 640
Natural Gas	32	158	4 423	192 700	257 274	276 779	266 981	258 053	156 364
Biogas	0	0	9 294	7 773	5 939	6 344	11 122	29 039	26 946

Figure 3.76 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources) between 1990 and 2006

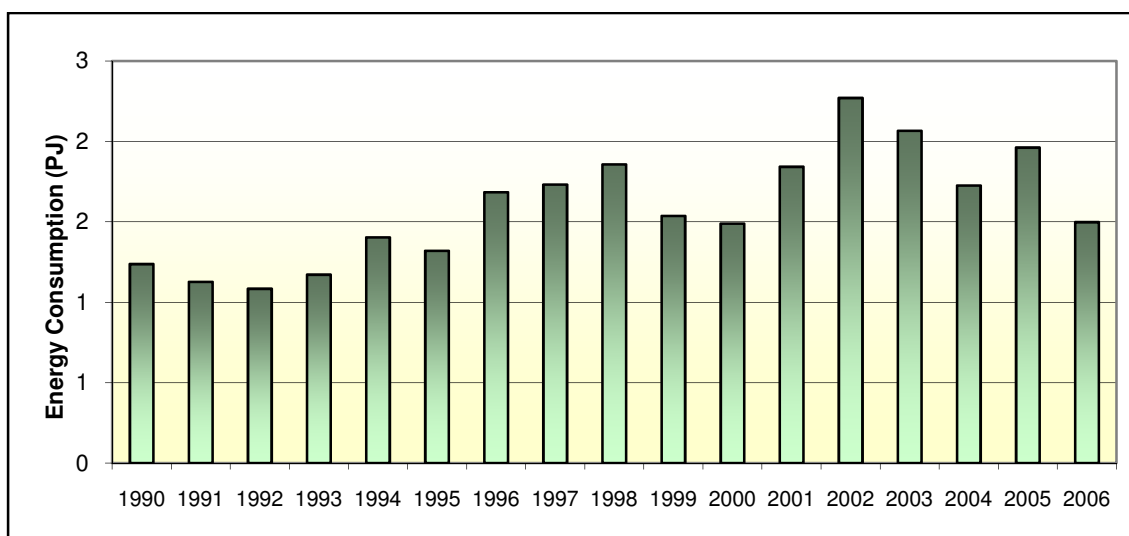


Figure 3.77 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2006

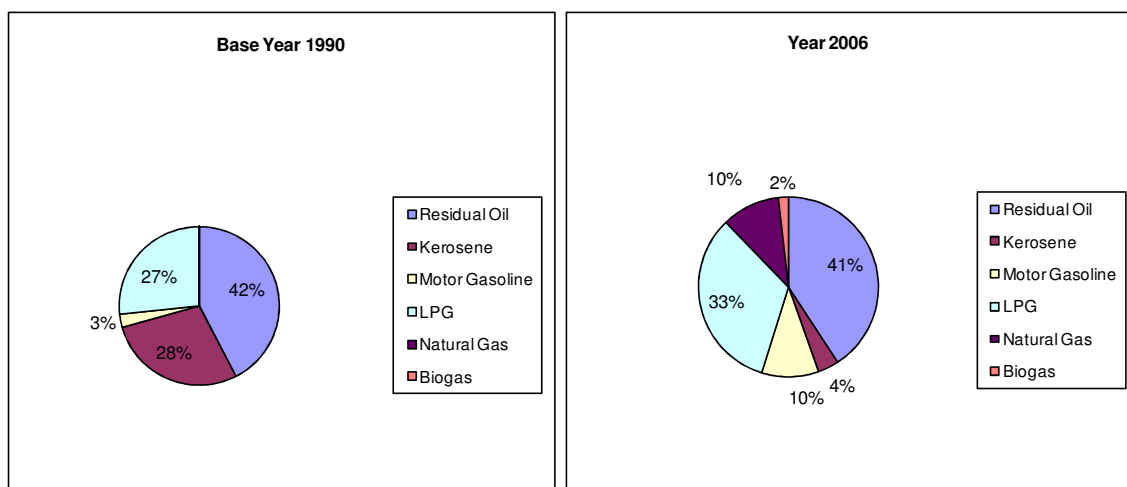
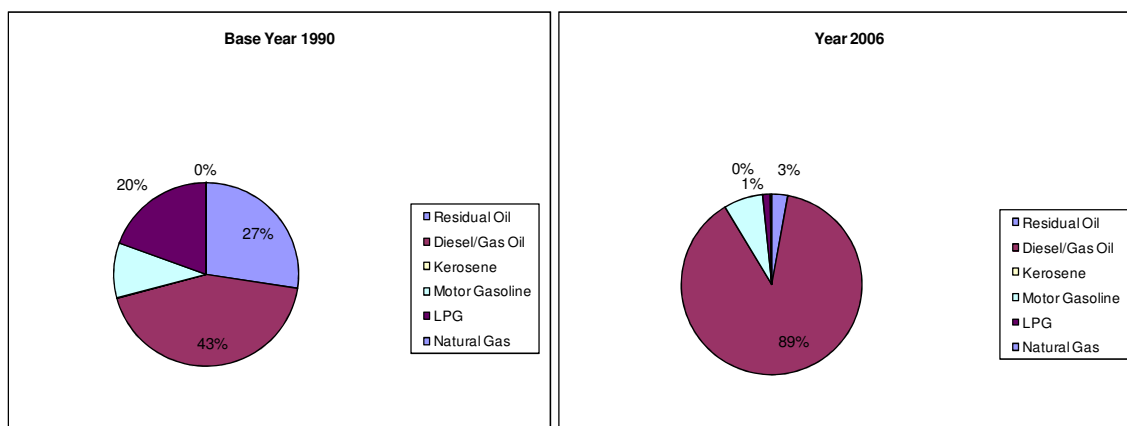


Table 3.113 - Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997
Residual Oil	L	203	4 002	5 397	7 454	9 101	5 353	11 778	4 994	8 782
Diesel/Gas Oil	L	204	6 346	460	1 018	17	1 003	16 980	1 595	150 903
Kerosene	L	206	7	0	7	7	0	0	0	0
Motor Gasoline	L	208	1 405	0	214	85	277	706	985	727
LPG	L	303	2 845	5 789	4 074	1 498	2 146	0	110	3 900
Natural Gas	G	301	0	0	0	0	0	0	0	0

Fuel	1998	1999	2000	2001	2002	2003	2004	2005	2006
Residual Oil	6 225	49 567	6 469	18 044	28 112	25 325	0	0	13 013
Diesel/Gas Oil	539 112	769 712	1 000 313	2 114 053	1 553 975	1 220 053	1 396 791	1 078 906	399 797
Kerosene	2 651	74 915	10 073	94	47	47	319	15	0
Motor Gasoline	4 038	61 546	278 979	286 123	280 695	278 521	260 737	29 899	31 799
LPG	2 529	8 429	20 796	32 627	21 126	20 695	91 236	5 899	5 983
Natural gas	0	0	0	0	0	0	0	0	1 248

Figure 3.78 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2006



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 (USEPA,1996; 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
Residual Oil	L	203	40.17	77.4	0.990	100	5.1
Diesel/Gas Oil	L	204	43.31	74.1	0.990	100	5.0
Kerosene	L	206	43.72	71.9	0.990	100	5.0
Motor Gasoline	L	208	44.77	69.3	0.990	100	9.9
LPG	L	303	47.28	63.1	0.995	100	1.5
City Gas	L	308	15.69	60.0	0.995	100	1.5
Natural Gas	G	301	45.97	56.1	0.995	100	2.5
Wood	B	111	12.55	109.6	1.000	0	300
Charcoal	B	112	25.10	109.6	1.000	0	300

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

UNCERTAINTY ASSESSMENT

The uncertainty in activity data was established from the knowledge of the way that activity data information was collected in the inventory but nevertheless trying as much as possible to make an assessment consistent to what is proposed in the GPG. Therefore, for fuel consumption except biomass, uncertainty was set at 10 per cent. For biomass fuels, considering that the quantification error is higher, namely due to lack of clarification of the actual moisture content in which biomass is reported, the uncertainty was assumed to be 60 per cent.

The uncertainty of CO₂ emission factors was assumed to be 5 per cent for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N₂O were set respectively at 150 per cent and an order of magnitude.

3.2.B Fugitive Emissions from Fossil Fuels (CRF 1B)

3.2.B.1 FUGITIVE EMISSIONS FROM SOLID FUELS (CRF 1B1)

COAL MINING AND HANDLING

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 *Peirão* and *S. Pedro da Cova* - no estimates are included in the inventory.

Emissions from fuel combustion for coal extraction are included under category 1A1c1, and discussed in chapter 3.2.A.3.

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:

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

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).

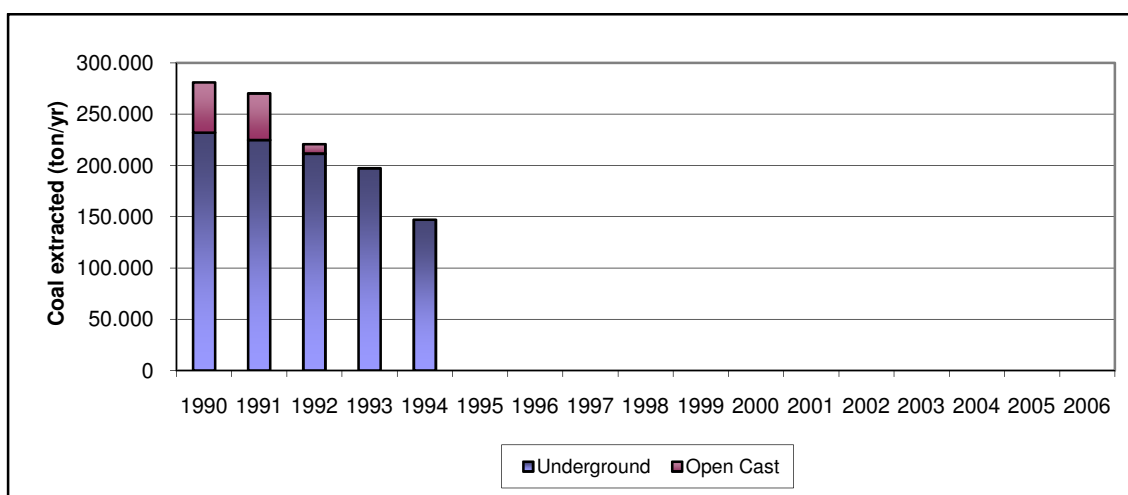
Table 3.116– Emission Factors for coal extraction and processing

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

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 General-Directorate of Geology and Energy (DGGE).

Figure 3.79 – Quantities of coal extracted from mines in Portugal (1990-2006)



Uncertainty Assessment

A value of 5 per cent 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 per cent for underground mines and 200 per cent 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.

Recalculations

No recalculations of emissions were made on this source sector.

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.B.2 FUGITIVE EMISSIONS FROM OIL PRODUCTION AND REFINING (CRF 1B2A)

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 : (1) flaring and venting in oil refining; (2) 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.

TRANSPORT OF CRUDE/ MARINE TERMINALS

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.

Methodology

Emissions of methane and non-methane volatile organic compounds (NMVOC) where estimated from:

$$\text{Emission} = \text{Crude}_{\text{InFlow}} * \text{EF} * 10^{-6}$$

where

Emission - of methane or NMVOC (ton/yr);

$\text{Crude}_{\text{InFlow}}$ - is total crude oil received at each refinery plant for processing (ton/yr);

EF - emission factor for methane or NMVOC (g/ton crude oil).

Emissions of VOC will ultimately be oxidized in atmosphere and contribute to ultimate carbon dioxide, which estimates are also included in the inventory. Emissions of ultimate carbon dioxide result from conversion of carbon in NMVOC and CH₄:

$$\text{Emi}_{\text{CO}_2\text{U}} = 44/12 * (\text{Emi}_{\text{NMVOC}} * 0.85 + \text{Emi}_{\text{CH}_4} * 12/16)$$

Emission Factors

Emission factors for NMVOC and CH₄ are those reported in next table and where set from CONCAWE, US-EPA (AP-42) and IPCC96.

Table 3.117 – Emission Factors for marine terminals and crude oil transportation

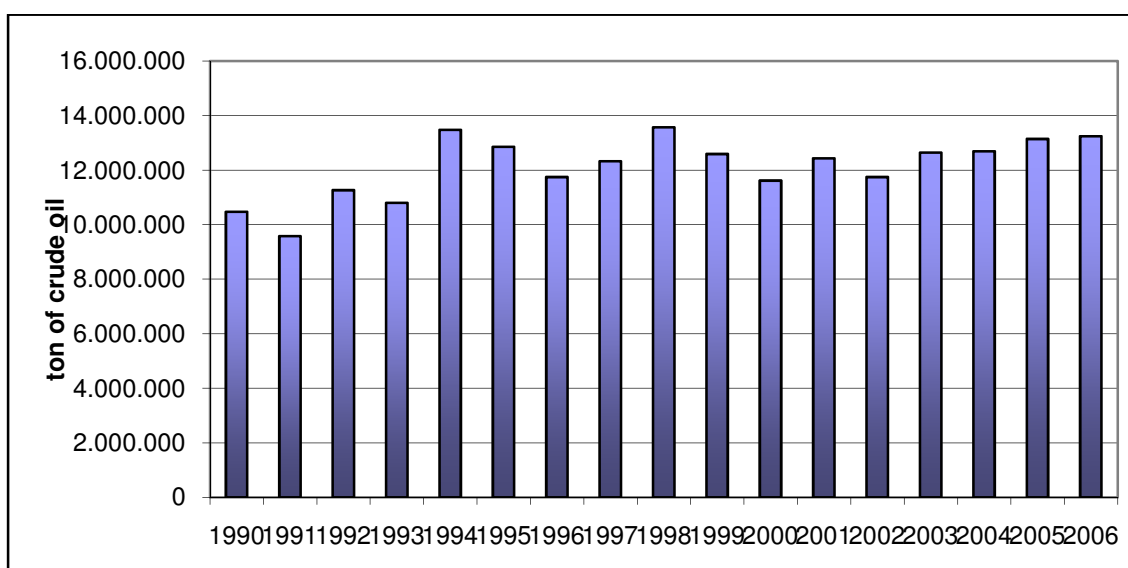
Component	Emission Factor (g/ton crude oil)
NMVOC	300
CH ₄	60 (2500 kg CH ₄ /PJ ^(a))
Ultimate CO ₂	1 100

(a) Norwegian SPCA (1992b) in IPCC (1997)

Activity data

Quantity of crude oil entered into the Portuguese refining system is available from annual publications from General-Directorate of Geology and Energy (DGGE), with detailed information on the crude received at each individual refinery, and have increased unsteadily since 1990, as may be seen in next figure. Total use of crude in 2006 is 26 per cent higher than the quantity used in year 1990, although there were some oscillations in intermediate years.

Figure 3.80 – Total consumption of crude oil: 1990-2006



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 DGGE. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO₂ emissions, was considered to be 50 per cent, 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 per cent, 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.

Recalculations

No modifications were done for emission estimates for this sub-source.

REFINING AND STORAGE

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: (1) Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular height into smaller ones, including visbreaking; (2) Polymerisation of small molecules combined in bigger molecules with different characteristics. Alkylation has similar objectives and (3) chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing;
- Treatment processes. Operations which include hydrodesulfurization, hydrotreating, chemical sweetening, acid gas removal, deasphaltating and desalting, that are used to remove impurities, the most important is sulphur;

- Blending of individual fractions and intermediate products to obtain final commercial products with characteristics as desired.

Emissions of storage of crude oil and other materials, intermediate products and final products are also included in this source sector as they are fugitive emissions occurring as part of the refining process. Because emissions from organic liquids in storage occur both from the evaporative loss of the liquid as well as from changes in the liquid level, the emission sources vary significantly with tank design. Six basic tank designs are usually used for organic liquid storage vessels: fixed roof (vertical and horizontal), external floating roof, domed external (or covered) floating roof, internal floating roof, variable vapor space, and pressure (low and high).

NM VOC and methane emissions may also result from “normal” leaks³⁹ scattered trough the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NM VOC emissions resulting from non-condensable fraction at the steam ejectors or vacuum pumps of the Vacuum distillation. Emissions in flares are discussed in “Venting and Flaring in Oil Industry” below.

Use of some catalytic converters, such as Fluid Catalytic Cracking and Platforming units, are used to convert heavy oils into lighter products, by action of heat, pressure and catalysts. Fluidized-bed Catalytic Cracking (FCC) use finely divided catalysts suspended in a riser with hot vapour from the fresh feed. Catalytic processes result in operations emissions, when the coke that is deposited in the catalytic bed over time has to be burned in the regenerator equipment. Emissions from catalyst regeneration are also included in this source category.

Finally sulphur oxide is emitted to the atmosphere when sulphur that is present in the tail gas of the refining process is not recovered in the Claus units and transformed into elemental sulphur, either because the normal recovery efficiency is actually not hundredth percent by design, or because the Claus unit was not at all operating and the sulphur flux had to oxidized to SO₂ in the tail gas incinerator before being released to atmosphere

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Uncertainty

³⁹ Sometimes only these emissions are referred as fugitive emissions from refineries.

Methodology

Storage and Tanks

GALP, the company operating all refineries in Portugal, made annually estimates of emissions from storage in the tanks existing inside the refineries. The estimates, relying on the TANKS4.0 model, are available from 2002 till 2005.. This detailed information lead to the establishing of plant specific emission factors, and its evolution, for 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 activity⁴⁰.

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

Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations where estimated from:

$$\text{Emission}_{(p,r)} = \text{ActivityRate} * \text{EF}_{(p,r)} * 10^{-6}$$

where

Emission (p,r) - annual emissions of pollutant p occurring from refining operation r (ton/yr);

ActivityRate - is a suitable activity indicator, specific of each pollutant and refining operation (ton/yr);

EF (p,r)- emission factor for a particular pollutant p and a specific refining operation (g/ton).



Bibliography



Key Categories



Uncertainty

⁴⁰ This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

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.

Ultimate Carbon Dioxide 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:

$$U_{CO_2} = 44/12 * (0.85 * NMVOC + 12/16 * CH_4 + 12/28 * CO) * 10^{-3}$$

Emission Factors

Storage/ Tanks

For the year 2002, 2003, 2004 and 2005, GALP, the single petroleum refinery operator in Portugal, in collaboration with the Institute for the Environment, performed a detailed inventory of NMVOC emissions from tanks in Oporto and Sines refineries using TANKS 4.0 (USEPA,1990).

TANKS4.0 program 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 seals⁴¹.

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 **Erro! A origem da referência não foi encontrada..**



Bibliography



Key Categories



Uncertainty

⁴¹ This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

Table 3.118 – 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	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	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 3.119 – 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 throughput⁴² in each refinery, are presented in next table. After 2005 the emission factors were forecasted.

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⁴² Crude oil input added to input of other materials.

Table 3.120 – 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

Fugitive Emissions

The following emission factors (kg/ton) 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 3.121 – Emission Factors for fugitive emissions of NMVOC in operation processes in petroleum refineries

Pollutant	EF
	Kg NMVOC/ ton crude
NMVOV	0.9
CH ₄	0.1

Recovery of Catalysts

From information collected from the refinery at Sines (quantities of coke burnt in FCC unit during 2002 and monitoring data for NO_x, SO_x and particulate matter) 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 3.122 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

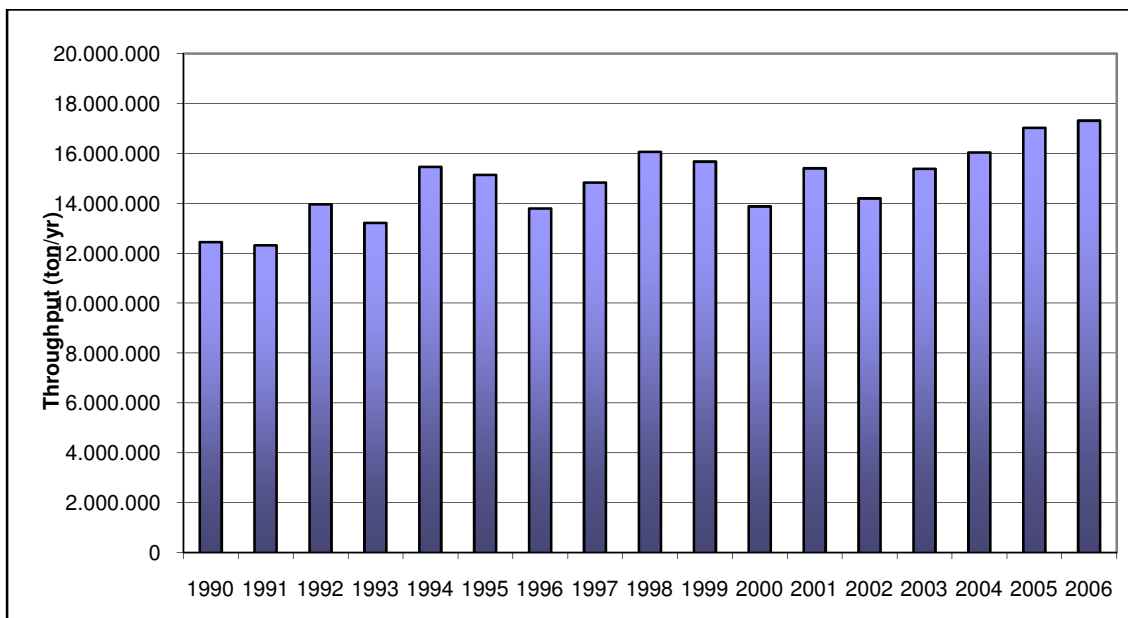
Parameter	Emission Factor
	kg/ton coke
UCO ₂	3 373

Activity data

The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed and it was already presented in “Transport of Crude” (Figure 3.80).

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 Figure 3.81.

Figure 3.81 – Total throughput entered in Lisbon, Oporto and Sines refineries: 1990-2006



Source: Petrogal

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 1990-2006 period. Total coke burning was obtained from the industrial units and it is considered confidential data.

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 DGGE (which is based also in information surveyed from the industrial plants). Therefore a low uncertainty of 3 per cent may be assumed for this sub-source in a similar mode to other LPS combustion data.

Uncertainty of emission factors for NMVOC⁴³ were set as 50 per cent, 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%)

RECALCULATIONS

No modifications were made to this source sector.

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.

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Uncertainty

⁴³ The uncertainty of NMVOC was considered to be the uncertainty of CO₂ emission factor.

DISTRIBUTION OF OIL PRODUCTS

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.

Methodology

Emissions of NMVOC, in tonnes per year, are estimated from the application of emission factors (EF in g/ton) to total quantities mobilized (Activity Rate in ton/yr):

$$\text{Emission}_{\text{NMVOC}} = \text{EF} * \text{ActivityRate} * 10^{-6}$$

The specific activity data/ Indicator to which the emission factor is multiplied differs with emission source:

Emission	Activity Rate Indicator
Terminal Dispatch Station	Total Gasoline/Petrol Output from Refinery to internal market and exportation
Transport and Depots	Total Gasoline/Petrol Output from Refinery to internal market and exportation
Service Stations	Total Gasoline/Petrol Output from Refinery to internal market

Ultimate carbon dioxide emissions, also in ton/yr, are calculated assuming that emitted VOC have on average 85% of carbon:

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

Emission Factors

Emission Factors for NMVOC, corresponding to those proposed in the simpler methodology of EMEP/CORINAIR, which result from CONCAWE studies, are reported in next table.

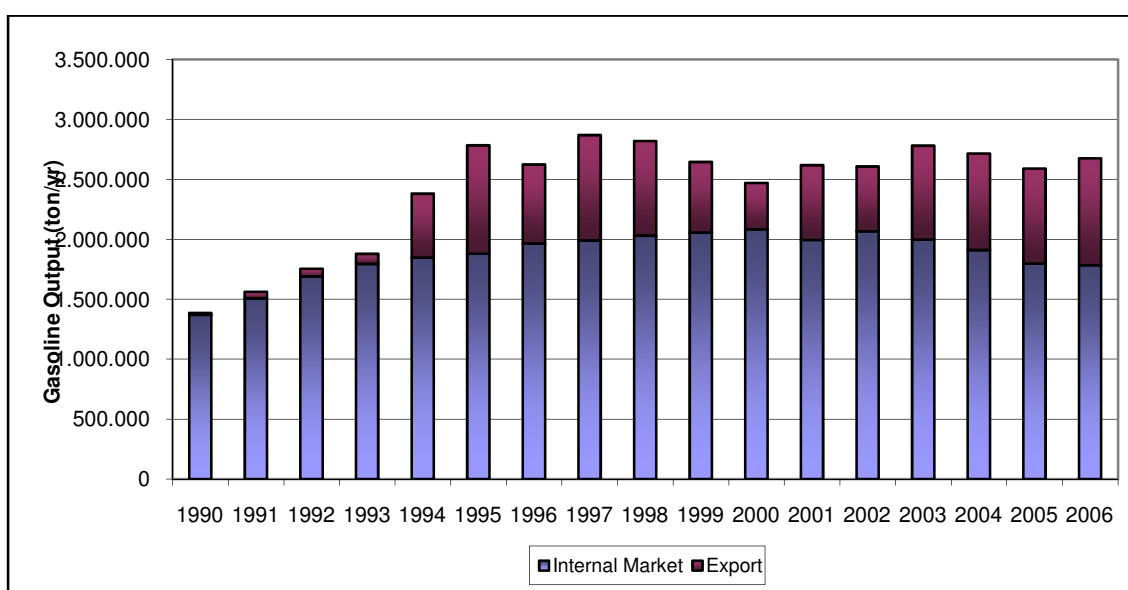
Table 3.123 – Emission Factors

Sub-source category	Emission Factor (g /ton)
Refinery Dispatch Station	310
Transport and Depots	740
Service Stations	2 880

Activity data

Activity data, in accordance to what was already defined in the methodology, for the years 1990 to 2002 is from the annual publications from the General-Directorate of Geology and Energy (DGGE). Total gasoline output for internal market and exportation is presented in the Figure 3.82. It is noticeable the decrease in total sales since 2003.

Figure 3.82 – Gasoline consumption in the internal market and gasoline exportation



Recalculations

No changes were made for this source sector since last submission.

Further Improvements

The efforts that the refineries are doing together with APA, in order to ameliorate emission estimates of this source category. After the application of validation procedures, will be used for the improvement in the inventory methodologies and emission factors for the coming years.

VENTING AND FLARING IN OIL INDUSTRY

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.

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).

Emission Factors

Emission factors for all pollutants except SO_x where set from US-EPA (1991). Emission factor for SO_x is from (USEPA;1985 in EMEP/CORINAIR 3r ed).

Feed density was assumed as of 0.85 kg/L.

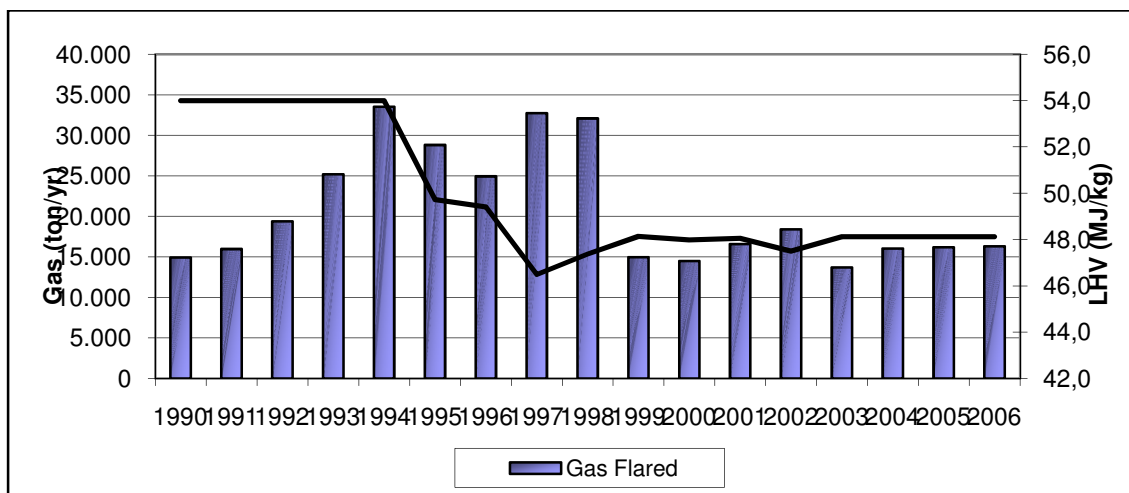
Table 3.124 – Emission Factors for flaring in refineries

Pollutant	EF (g/GJ)
CO ₂ (kg/GJ)	60
COVNM	12
CH ₄	15
CO	70

Activity data

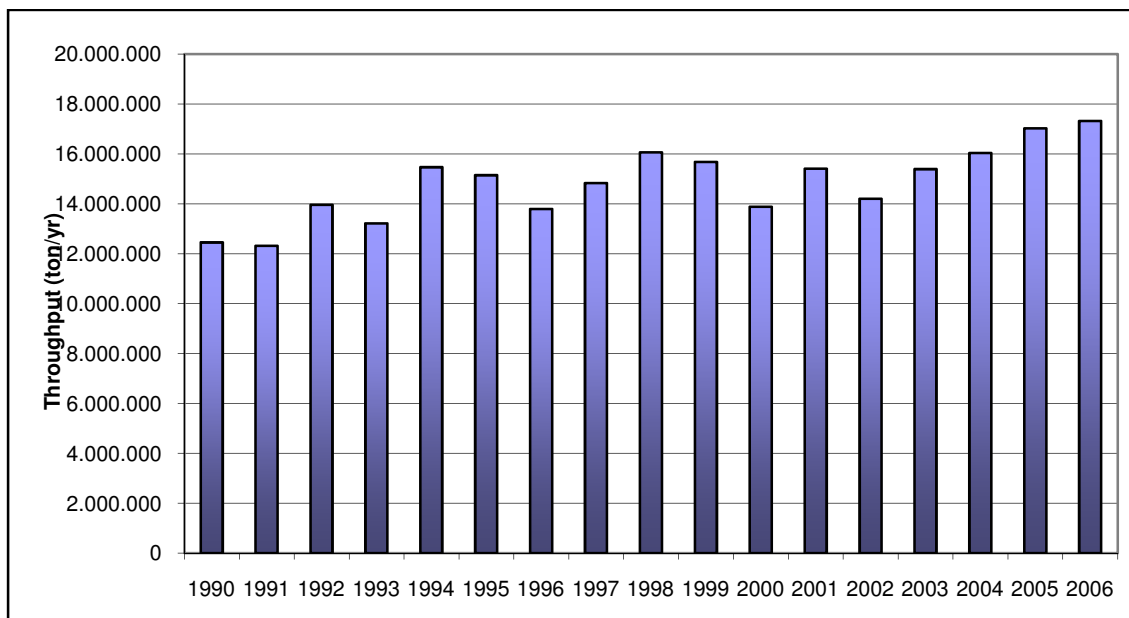
Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL and it is presented in Figure 3.83.

Figure 3.83 – Total consumption of flare gas in Portuguese refineries and Low Heating Value: (1990-2006)



Total throughput (feed) entered in refinery units is available from annual energy publications of (DGGE), and is again presented in Figure 3.84.

Figure 3.84– Total throughput entered in Lisbon, Oporto and Sines refineries (1990-2006)



Uncertainty Assessment

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

Recalculations

No recalculations were done for this emission source.

3.2.B.3 FUGITIVE EMISSIONS FROM NATURAL GAS (CRF 1B2B)

Overview

There is no production of natural gas in Portugal. The use of natural gas in Portugal was initiated only in 1997 (DGGE). 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 the gas is imported and received through shipping transport from Algeria and Nigeria as Liquefied Natural Gas (LNG). There are also no major processing operations in Portugal.

Natural gas pipelines may be classified in two different sub-groups:

- Transmission lines. Operating at high pressure, are used to transport natural gas in bulk over large distances till distribution centres;
- Distribution networks. Comprehend the network of extensive pipelines that convey natural gas to the end-user. They tend to work on lower pressure and with smaller diameter lines. There are distribution networks of natural gas distributing for industrial consumers, services and domestic users.

The gas received from Algeria in ships is re-gasified in a plant in Sines, in southern Portugal.

Methane emissions from natural gas result mostly from leaks of unmodified natural gas, in pipes or in the plant. Although these losses happen as result of maintenance operations or abnormal accident situations (pressure surges due to failure of equipment that controls pressure), they occurs also constantly as result of normal operations of the system in operation valves or in chronic leaks due to seal failure, flawed valves, small cracks and holes in the lines or reservoirs.

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 DGGE. 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:

$$\begin{aligned} \text{Emi}_{\text{CH}_4} &= \text{Pipeline}_{\text{Lenght}} * \text{EF}_{\text{CH}_4} \\ \text{Emi}_{\text{CO}_2\text{direct}} &= \text{Pipeline}_{\text{Lenght}} * \text{EF}_{\text{CO}_2\text{direct}} \\ \text{Emi}_{\text{CO}_2} &= \text{Emi}_{\text{CH}_4} * 44/16 + \text{Emi}_{\text{CO}_2\text{direct}} \end{aligned}$$

Where,

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

$\text{Emi}_{\text{CO}_2\text{direct}}$ – Direct emissions of CO₂ from leakages, t/yr;

Emi_{CO_2} – Total emissions of CO₂, including conversion of carbon in methane and other gases in atmosphere, t/yr;

EF_{CH_4} , $\text{EF}_{\text{CO}_2\text{direct}}$ – Emission factors, t/km;

$\text{Pipeline}_{\text{Lenght}}$ – 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 processes⁴⁴ as activity data:

$$\begin{aligned} \text{Emi}_{\text{CH}_4} &= \text{Import}_{\text{NG}} * \text{EF}_{\text{CH}_4} / 100 \\ \text{Emi}_{\text{CO}_2\text{direct}} &= \text{Import}_{\text{NG}} * \text{EF}_{\text{CO}_2\text{direct}} \\ \text{Emi}_{\text{CO}_2} &= \text{Emi}_{\text{CH}_4} * 44/16 + \text{Emi}_{\text{CO}_2\text{direct}} \end{aligned}$$

Where,

EF_{CH_4} , $\text{EF}_{\text{CO}_2\text{direct}}$ – Emission factors, per cent;



Bibliography



Key Categories



Uncertainty

⁴⁴ Equals imports in Portugal

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}):

$$\text{Emi}_{\text{DIST}} = \text{Emi}_{\text{TOTAL}} - \text{Emi}_{\text{TRANS}} - \text{Emi}_{\text{GAS}}$$

EMISSION FACTORS

The emission factors are based on the IPCC Good Practice (IPCC,2000), and are reported in Table 3.125.

Table 3.125 – Net Calorific Value and Emission Factor for fugitive emissions from natural gas

-	Transmission (t/km) [#]	NGL Plant (%) ^{\$}
CH4	2.5	0.05
CO2	0.016	0.00032

- IPCC (2000), table 2.16

\$ - IPCC (2000), table 2.18, assuming same CO2/CH4 ratio in transmission

The implicit emission factor from emissions from distribution was calculated in the end. It corresponds to the annual loss of about 1.1 per cent of the natural gas consumed in the distributive systems.

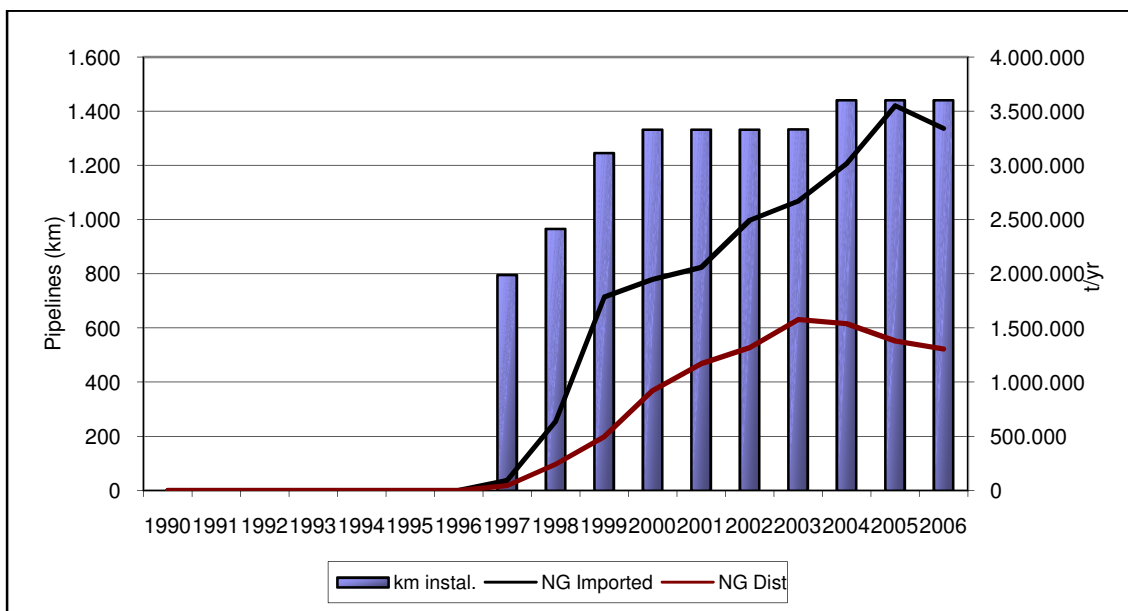
ACTIVITY DATA

According to the above explained methodology, activity data comprehends:

- extension of pipelines for transmission. Total extension of pipelines in kilometres was estimated from the date at which each major pipeline start operation, and its extension. These data was received via DGGE from TRANSGAS;
- importation of natural gas, obtained from the DGGE'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 3.85 – Activity data used to estimate GHG emissions from Natural gas transmission, distribution and transformation (1990-2006)



UNCERTAINTY ANALYSIS

The uncertainty in activity data was considered to be 5 per cent, the value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in CH₄ emission factor, considering a low quality inventory, was assumed to be 150 per cent, and the same value was considered for CO₂ emissions which were determined simply from simple conversion of emissions in methane form.

RECALCULATIONS

No changes were made for this source sector since last year's submission.

FURTHER IMPROVEMENTS

Efforts are being done with DGEG⁴⁵ and the major Portuguese company responsible for gross transport of natural gas⁴⁶, in order to increase the tier level of the methodology. Results and changes in estimates are expected in the coming years.

3.2.B.4 OTHER FUGITIVE EMISSIONS (GEOTHERMAL ELECTRICITY PRODUCTION) (CRF 1B2D)

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, missions 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.

Emissions of fugitive emissions from geothermal electricity production are therefore reported in category 1B2d (Other fugitive emissions from oil and natural gas).



Bibliography



Key Categories



Uncertainty

⁴⁵ Direcção Geral de Energia e Geologia/ General Directorate of Energy and Geology

⁴⁶ TRANSGAS

METHODOLOGY

From 1994 till, in Azores, the Regional Authority of Economy (Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia) performed own estimates of carbon dioxide 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 is from General-Directorate of Geology and Energy (DGGE), and using the emission factors estimated for the 1994-1999 period.

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 Azores⁴⁷. These results were used to estimate an average emission factor applied to the whole period.



Bibliography



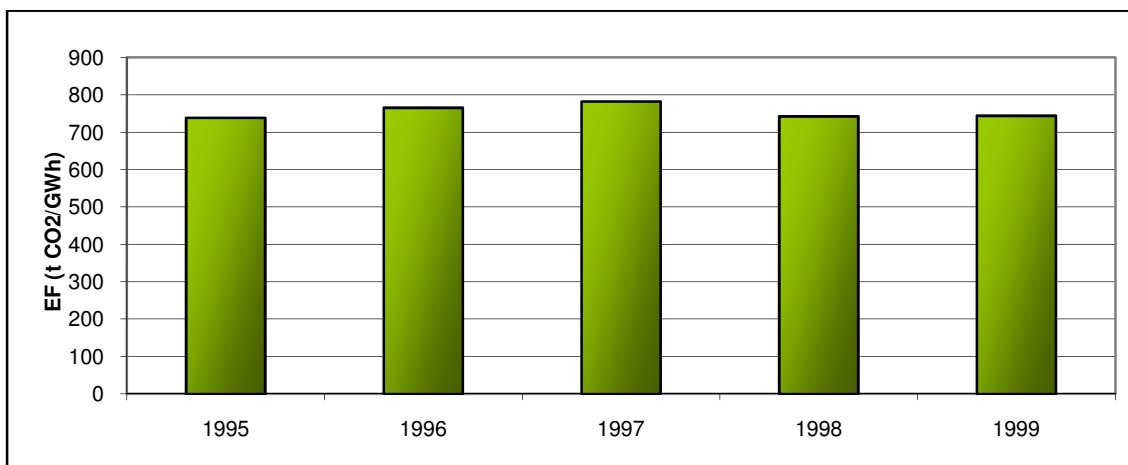
Key Categories



Uncertainty

⁴⁷ 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)

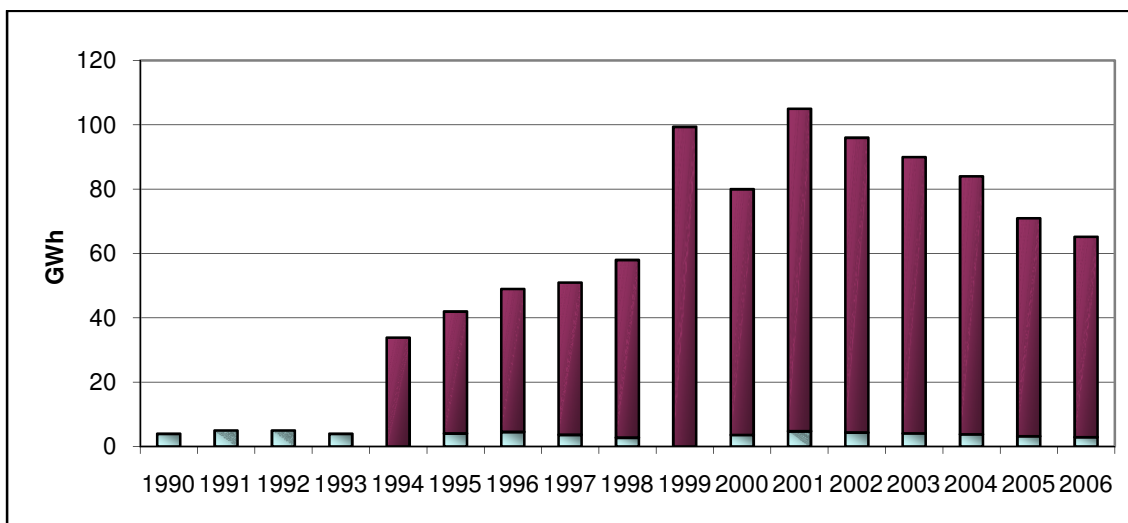


For the other power plant, Pico Vermelho, the regional authority provides estimates that indicate a common emission factor of 500 ton CO₂/GWh.

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 1990-2006. 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 (1990-2006)



UNCERTAINTY ANALYSIS

The uncertainty of the activity data is 10 per cent 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.

RECALCULATIONS

Comparing to the IIR under Kyoto Protocol, the activity data time series was revised for the period 1994-2004 using statistical information from DGGE.

The trend of the EF for one plant, Ribeira Grande, was revised since last submission, although that change is not affecting the estimates for base year.

FURTHER IMPROVEMENTS

Under the Methodology Development Plan efforts are being done together with the regional government of Azores islands, to improve the knowledge of this activity and resulting emissions.

3.3 Recalculations

Changes in sectoral overall GHG emissions, expressed in CO₂ equivalent, since last submission were not very significant in the energy sector, as may be seen in Figure 3.88, both in what concerns base year (1990) and year 2005. Overall emissions were reduced in 1990 for methane while have increased for carbon dioxide and N₂O.

Figure 3.88 – Differences between 2007 and 2008 submissions (CO₂, CH₄ and N₂O)

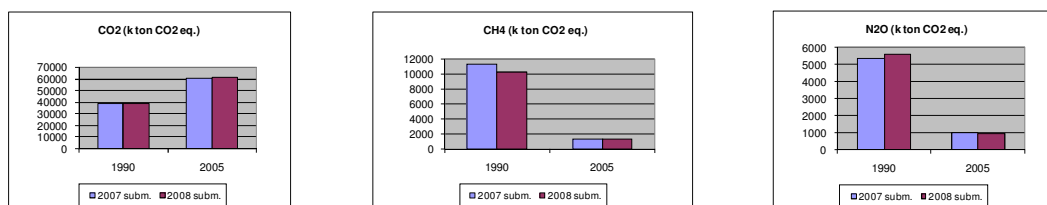


Table 3.126 – Recalculations (differences between 2007 to 2008 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)
	CO ₂ equivalent (Gg)		(%)	CO ₂ equivalent (Gg)		(%)	CO ₂ equivalent (Gg)		(%)
1990									
1. Energy	39 087.11	39 179.34	0.24	11 363.69	10 240.48	-9.88	5 379.82	5 601.39	4.12
1.A. Fuel Combustion Activities	38 963.28	39 055.50	0.24	565.12	564.70	-0.07	505.17	518.11	2.56
1.A.1. Energy Industries	15 944.40	15 944.40	0.00	463.91	463.49	-0.09	505.17	518.11	2.56
1.A.2. Manufacturing Industries and Construction	9 157.88	9 154.95	-0.03	4.33	4.33	0.00	61.04	61.04	0.00
1.A.3. Transport	9 827.74	9 827.74	0.00	38.03	38.03	0.00	67.25	67.25	0.00
1.A.4. Other Sectors	4 025.13	4 025.13	0.00	73.09	72.66	-0.59	139.95	152.06	8.66
1.A.5. Other	8.13	103.28	1 171.03	348.30	348.30	0.00	236.92	236.92	0.00
1.B. Fugitive Emissions from Fuels	123.83	123.83	0.00	0.15	0.17	9.33	0.02	0.85	4 582.96
1.B.1. Solid fuel	8.65	8.65	0.00	101.21	101.21	0.00	NE,NO	NE,NO	
1.B.2. Oil and Natural Gas	115.19	115.19	0.00	66.02	66.02	0.00	NO	NO	
2005									
1. Energy	60 861.28	61 671.38	1.33	1 284.93	1 292.46	0.59	981.39	952.59	-2.94
1.A. Fuel Combustion Activities	60 156.48	60 929.63	1.29	433.22	440.75	1.74	981.39	952.59	-2.94
1.A.1. Energy Industries	23 761.68	24 824.48	4.47	7.20	7.44	3.26	111.99	120.18	7.32
1.A.2. Manufacturing Industries and Construction	10 515.04	10 216.91	-2.84	57.67	58.35	1.17	95.09	94.45	-0.68
1.A.3. Transport	19 292.97	19 228.76	-0.33	50.51	57.11	13.06	612.16	574.87	-6.09
1.A.4. Other Sectors	6 586.79	6 586.93	0.00	317.84	317.84	0.00	162.16	162.46	0.19
1.A.5. Other	NO	72.56		NO	0.01		NO	0.64	
1.B. Fugitive Emissions from Fuels	704.80	741.75	5.24	851.71	851.71	0.00	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	704.80	741.75	5.24	851.71	851.71	0.00	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).

3.3.A Cross-cutting issues

The in-country review of submission 2006 under the UNFCCC and of the IIR under the Kyoto Protocol, that took place in Lisbon in 2007, caused some changes in the energy sector, namely:

- Recently, under the efforts made by the Portuguese General Directorate of Energy and Geology (DGEG) for the European Carbon Trading Scheme (EU-ETS), and using data from the industrial plant, the EF was revised downward, from 99.8 kg CO₂/GJ to 85 kg CO₂/GJ. According to DGEG the new value represent better the characteristics of this fuel;
- The in-country review detected that emissions from military fuel use were not included in the inventory, although the Energy Balance reports consumption of liquid fuels, city gas and natural fo military use under Services. Following the recommendation from the ERT, emissions from military fuel use (jet fuel) were estimated. All the jet fuel for military operations was considered to be domestic, in accordance with the IPCC Guidelines, since there is no information available regarding the origins and destinies of air movements by the army air-fleet. These emissions are now reported under category 1 A 5 b (Other Mobile);
- Inclusion for the first time for 2006 of emissions from the use of biodiesel in road transportation;
- correction of the values of LHV for gasoline and diesel oil toward default IPCC values for the road transport;
- correction of the H/C ratio for the estimate of the EF from combustion of natural gas in road vehicles;
- top-down calibration for the aviation and navigation sectors, in order to achieve consistency with the Energy Balance, and in accordance with the IPCC Guidelines;
- correction of a programming error detected in the calculation of CH₄ emissions from aviation.

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 Methodological Development Plan for the implementation of the National System, which is being made with direct contact with the main intervenients of the energy sector, and in close collaboration of the

inventory team from IA. 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 Carbon Market 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, NO_x and PM) from monitoring data collected from the *Autocontrolo* program and CO₂ emission factors for information collected under carbon market;

3.5 Reference Approach

3.5.A 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”⁴⁸ 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)



Bibliography



Key Categories



Uncertainty

⁴⁸ 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.B 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.B.1 FUEL CONSUMPTION

Apparent consumption was estimated from the National Energy Balances produced by the General Directorate of Energy and Geology (DGGE) 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.B.2 ENERGY CONSUMPTION

The Portuguese National Balance reports consumption in energy units (toe⁴⁹), apparent consumption needs only to be converted to TJ using the multiplier 41.868 GJ/toe.

3.5.B.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 3.127.



Bibliography



Key Categories



Uncertainty

⁴⁹ Ton of oil equivalent

Table 3.127 – Carbon content of fuels and Oxidation Factor used in the Reference Approach

Fuel			C content (t C/TJ)	Fac _{ox} 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.B.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 is reported in Table 3.128.

Table 3.128 – Reference Approach. Carbon Emission Factor and Fraction of carbon stored

Fuel	C content (t C/TJ)	FacOX 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.C Actual Carbon Dioxide Emissions

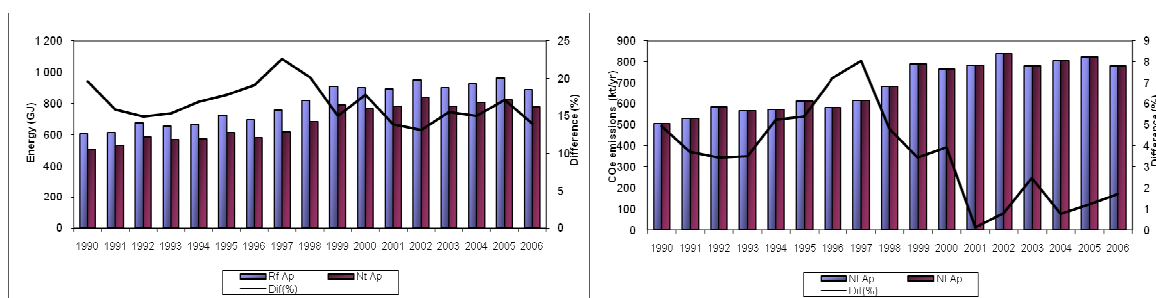
Estimated simply from:

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

3.5.D 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



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 is in

not following the IPCC guidelines, and cause 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 DGGE and the Institute for the Environment in order to improve consistency between the different approaches. This positive situation is less visible when comparing energy data.

3.5.E 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.

CHAPTER: 4 : INDUSTRIAL PROCESSES (CRF SECTOR 2)

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 production⁵⁰. 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 Report⁵¹.

In terms of total GHG, emissions from the industrial production sector have increased from about 4.6 Mton CO₂e in 1990 to 7.9 Mton CO₂e in 2006, as may be seen from Figure 4.1, i.e. emissions estimated for 2006 are about 71.6 per cent higher than the emissions estimated for 1990⁵², making this sector one with of the highest increase in the period. The majority of

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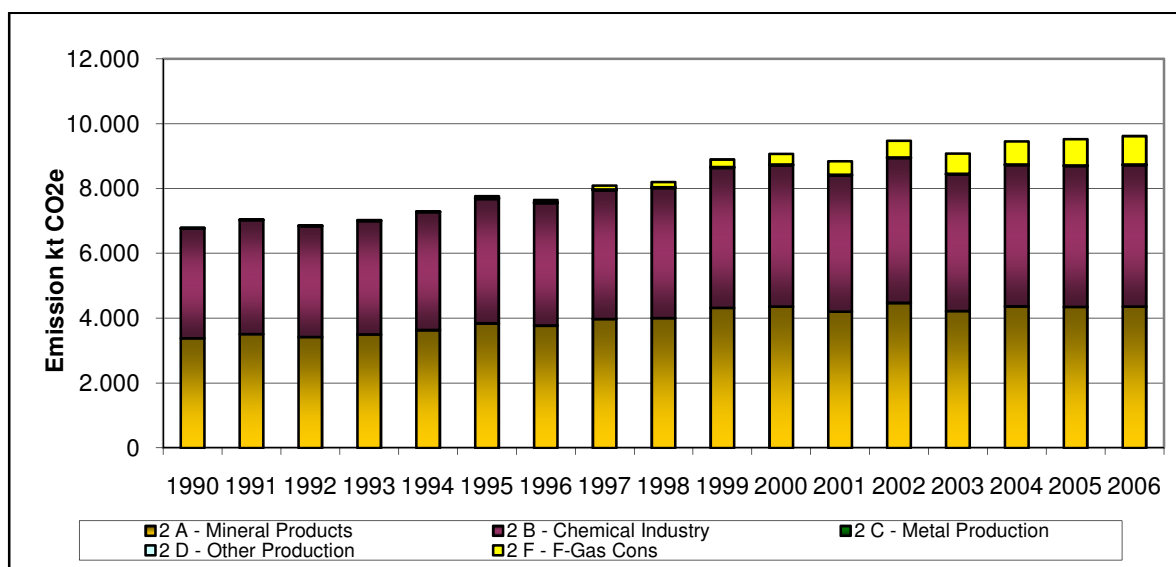
⁵⁰ Emissions of combustion are considered in this sector if they are considered a production process and not as a way to obtain energy, even if the energy is used directly in the production process such as in a furnace. Emissions from combustion processes in industry with the sole aim of obtaining energy (boilers, furnaces, engines) are included in Energy sector.

⁵¹ 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>.

⁵² Base year for F-gases is however 1995.

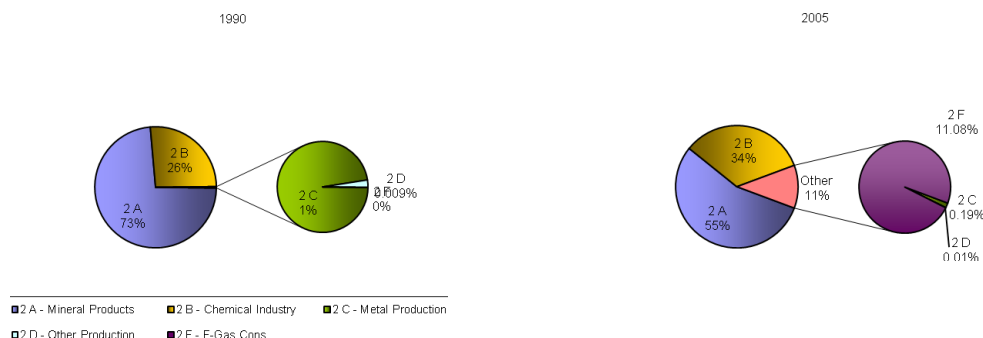
emissions, expressed in CO₂ equivalent (GWP), are associated with mineral industry, responsible for 73.2 per cent of total emissions from this sector in 1990, and 55.1 per cent of total emissions from this sector in 2006, as may be seen in Figure 4.2. In second place of importance are the emissions from the chemical industry, which have increased from 26.2 per cent of emissions from this sector in 1990 toward 33.6 per cent of emissions in 2006. The remaining sub-source sectors (2C, 2D and 2F⁵³) have a lower importance in the beginning years, but they became more relevant toward the end of the period, when they amount to 11.3 per cent of emissions. This increase occurs mostly because of sub-category 2F, consumption of Halocarbons and SF₆, which represents in 2006 about 11.1 per cent of total GHG emissions from this source sector, and shows a fast grow over years.

Figure 4.1 – Total GHG emissions from Industrial Processes per source sub-sector (1990-2006)



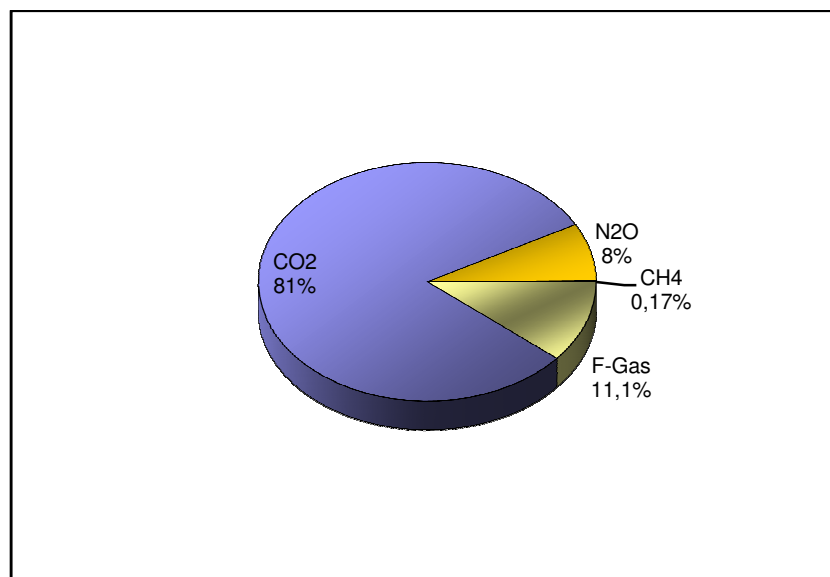
⁵³ No emissions were allocated to sub-category 2G – Other. Emissions for category. Sector 2 F - Production of Halocarbons and SF₆ does not occur in Portugal.

Figure 4.2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2006



The great major part of green-house gas emissions are realized directly as CO₂; while N₂O represents a smaller proportion of emissions and methane emissions are a non relevant part, as may be seen in Figure 4.3 for year 2006. 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 green-house gas in 2005



Recalculations

Recalculations in this submission result mostly from the recommendations made during the review of submission 2006 and Initial Inventory Report under Kyoto Protocol, that took place last year. Detailed explanation of the recalculations made will be presented for each category, and in broad terms they resulted from:

- Correction of double counting and calculation errors in category 2C1, Iron and steel production;
- Revision of the methodologies in some sub-categories of 2F, Consumption of Halocarbons and Sulphur Hexafluoride.

The change in the estimates made for the base year result solely from the corrections of errors found for Metal Production.

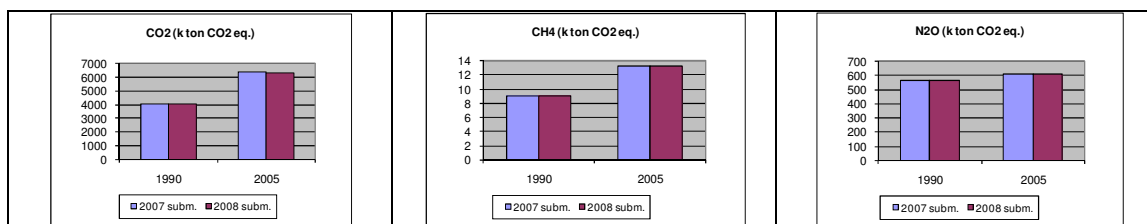
Figure 4.4 - Differences between 2007 and 2008 submissions for CO₂, CH₄ and N₂O emissions

Table 4.1 - Recalculations (differences between 2007 and 2008 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2			CH4			N2O		
	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)
	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)
1990									
2. Industrial Processes	4 034.96	4 035.28	0.01	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	15.73	16.06	2.07	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	
2005									
2. Industrial Processes	6 341.52	6 300.77	-0.64	13.29	13.29	0.00	612.09	612.09	0.00
2.A. Mineral Products	4 390.46	4 349.70	-0.93	1.83	1.83	0.00	NO	NO	
2.B. Chemical Industry	1 935.67	1 935.67	0.00	11.46	11.46	0.00	612.09	612.09	0.00
2.C. Metal Production	14.96	14.96	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 = $100\% \times [(LS-PS)/PS]$, where LS = Latest submission and PS = Previous submission.

Category Sources

Mineral Industry (CRF 2A)

CEMENT PRODUCTION (CRF 2A1)

OVERVIEW

During the 1990-2005 period there were six cement production plants operating in Portugal, mostly dedicated to Portland cement production⁵⁴ 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-calciners⁵⁵. The importance of clinker production for each one of the six plants is presented in Table 4.2, from where it is evident that production of clinker and CO₂ decarbonising emissions are dominated by three plant units.

Table 4.2 - Main Characteristics of Cement Production Plants in Portugal

Unit	Nut III	Average % of total Clinker Production			
		1990	1995	2000	2004-2006
Souzelas	RC122	26	26	25	26
Maceira	RC123	13	12	11	13
Pataias	RC123	4	4	6	4
Alhamdra	RC132	24	25	25	30
Outão	RC133	26	25	24	18
Loulé	RC150	7	7	8	8

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⁵⁴ 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.

⁵⁵ One calciner is a false pre-calciner.

Portland cement is broadly a mixture of clinker and gypsum with some minor additives. Cement production is in essence a pyro-processing operation on calcium carbonate, aluminium-siliceous and iron-oxide materials to form a mixture of calcium silicates, aluminates and aluminoferrites that forms a binder with water.

Carbon dioxide emissions from cement production process result from the conversion of CaCO_3 and MgCO_3 , the main constituents of limestone, to lime (CaO) and MgO , while leaving CO_2 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 CO_2 , 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 CO_2 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. CO_2 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.

METHODOLOGY

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

$$\text{Emi}_{\text{CO}_2 (y)} = \text{EF}_{\text{Clinker}} * \text{Prod}_{\text{CLINKER} (y)} * \text{CKD} * 10^{-6}$$

where

$\text{Emi}_{\text{CO}_2 (y)}$ - emissions of CO_2 from cement production, originated from carbon in mineral constituent materials (kton/yr);

$\text{EF}_{\text{Clinker}}$ - emission factor (kg/ton clinker);

$\text{Prod}_{\text{CLINKER} (y)}$ - 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).

EMISSION FACTORS

The CO_2 emission factor was estimated according to the following formula, equivalent to the GPG equation 3.3:

$$\text{EF}_{\text{Clinker}} = 44.01 / 56.08 * \text{Ratio}_{\text{CaO}}$$

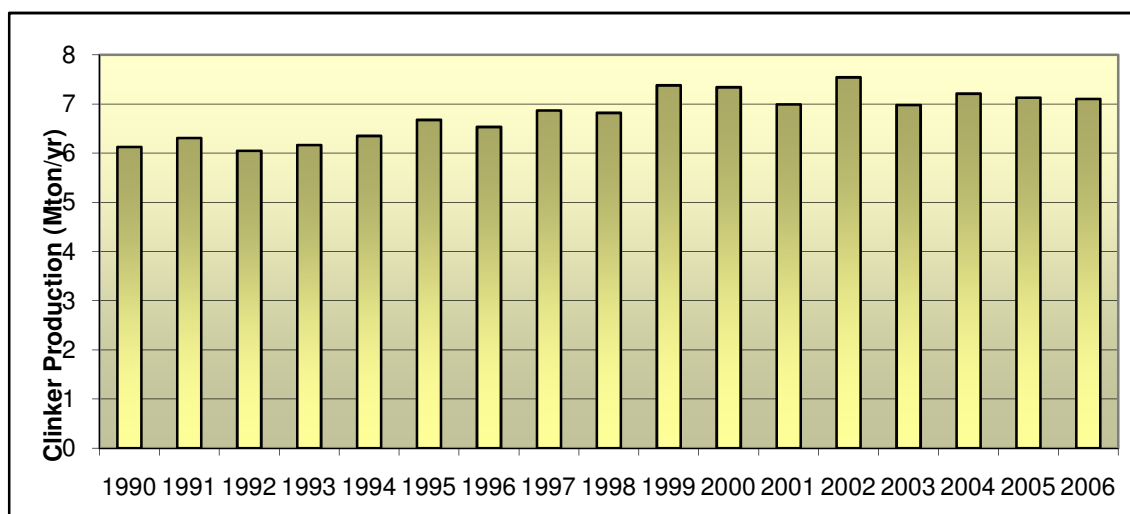
where $\text{Ratio}_{\text{CaO}}$ is the Calcium oxide (lime) content of clinker (kg CaO / kg clinker). The default IPCC CaO fraction in clinker was considered in the inventory (64.6%). Final emission factor is therefore 0.507 ton CO_2 / ton clinker.

ACTIVITY DATA

Clinker production, for all the years from 1990 to 2003, was received directly from each industrial plant, and the correspondent time series may be observed in next figure. For 2004 only total production of clinker in Portugal is available. Total clinker production for 1990-2003 as reported in the National Statistical Database from INE is fully consistent with the sum of the information received from each individual plant.

The values for 2005 and 2006 are still provisional figures forecasted using the time-series from 1990-2004. It is evident an increase from 1990 till 1999 and a stagnation thereafter.

Figure 4.5 – Total Production of cement clinker in Portugal (1990-2006)



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:

$$EF_{\text{Clinker}} = 0.785 * \text{Ratio}_{\text{CaO}} + 1.092 * \text{Ratio}_{\text{MgO}}$$

The emission factors would therefore change from 0.507 ton CO₂/ton clinker to 0.525 ton CO₂/ton clinker, resulting in an increase of emissions of 3.55 %⁵⁶. The CKD correction factor to 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.

UNCERTAINTY ASSESSMENT

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

RECALCULATIONS

No changes occurred for this sector apart from update of the clinker production value for 2005. No modifications were done in what concerns methodology and emission factors.

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;

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⁵⁶ Assuming CaO fraction in clinker of 64.5% and MgO 2%, the default value set by GHP Protocol (WBCSD/WRI).

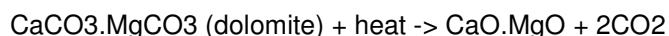
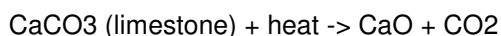
some raw materials, such as carbonate shales, have a very large range of possible carbonate content; and some carbon content materials are only used as fillers and will not result in emissions.

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.

LIME PRODUCTION (CRF 2A2)

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 reconversion of the hydroxide to CaCO₃ (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.

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).

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 CO₂ during production of pure high calcium quicklime (kg/kg);

$SR_{CaO.MgO}$ - stoichiometric ratio between CaO.MgO (50:50) and CO₂ during production of pure Dolomite lime (kg/kg);

$Content_{CaO}$ – Content of CaO in high calcium lime as in final product (kg/kg)⁵⁷;

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

$Content_{H_2O}$ – 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 4.3 – Parameters used to derive the Emission Factors for Lime Production

Lime	Dol_{Lime} (%)	$Content_{CaO}$	$Content_{CaO.MgO}$	$Content_{H_2O}$ (%)	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 ($SR_{CaO.MgO}$).

⁵⁷ These 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.

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.

ACTIVITY DATA

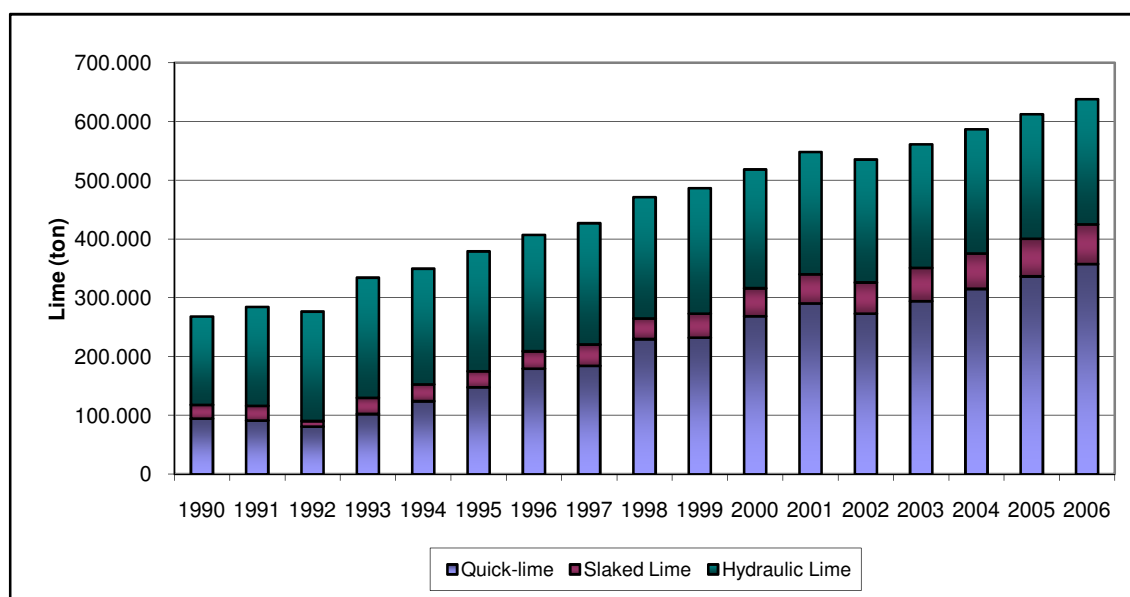
Production of lime products in industrial plants solely dedicated to this activity is available for the period 1989-2000 from National Statistics (INE): for the period 1989-1991 from IAIT industrial survey, and for 1992-2000 from the IAPI industrial survey. In order to avoid double counting of decarbonisation (calcination), only lime sold was quantified but not lime produced for internal consumption in unit plant. Production values for 2001-2006 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 plan 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 1992-2000 from the IAPI industrial survey.

The time-series of Lime production per lime type is presented in Figure 4.6, from where it is clear the pattern of production increase (138 per cent from 1990 to 2006), 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 (1990-2006)



UNCERTAINTY ASSESSMENT

According to the GP the uncertainty associated with the carbon dioxide emission factor for lime production is 15 per cent for hydraulic lime and 2 per cent 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 per cent.

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 per cent was therefore used in the uncertainty analysis.

RECALCULATIONS

No modification was made in emission estimates for this source sector.

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 slacked 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 lime⁵⁸ 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 can not 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.



Bibliography



Key Categories



Uncertainty

⁵⁸ 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.

LIMESTONE, DOLOMITE AND CARBONATE USE (CRF 2A3)

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 consumption⁵⁹ 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.



Bibliography



Key Categories



Uncertainty

⁵⁹ Determined from composition of Blast Furnace Gas given by 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-CO₂ 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.

METHODOLOGY

CO₂ emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of CO₂ that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

$$Emi_{CO_2 (y)} = 44/12 * Mat_{Carb (m,y)} * C_{content (m)} * 10^{-3}$$

where

Emi_{CO₂ (y)} - emission of carbon dioxide in year y (kton/yr);

Mat_{Carb (m,y)} - consumption of carbonate containing material m in year y (ton/yr);

C_{content (m)} - carbon content of material m consumed in year y (ton C/ton).

EMISSION FACTORS

Carbon content of materials consumed in Portugal was set from molecular stoichiometry⁶⁰:



Bibliography



Key Categories



Uncertainty

⁶⁰ It was assumed that limestone was totally pure, which causes over-estimated emissions.

Table 4.4 - Carbon content of carbonate materials

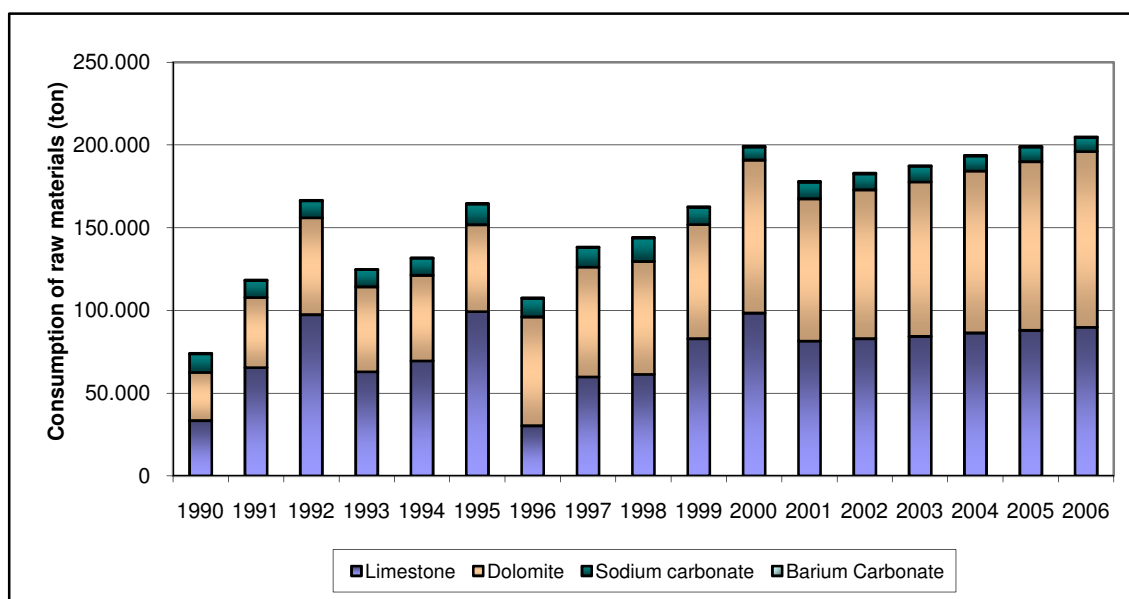
Material	Ccontent
Sodium Carbonate	0.42
Barium Carbonate	0.22
Limestone*	0.44
Dolomite #	0.48
Magnesium Carbonate	0.52
Coal (Electrodes) to be removed	3.67

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

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 2000 and thereafter forecasted. Final total consumption of carbonaceous materials is presented in Figure 4.7 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 177 per cent since year 1990.

Figure 4.7 - Consumption of carbonate materials in industry (1990-2006)



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 per cent), 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.

RECALCULATIONS

No modification was made in emission estimates for this source sector.

FURTHER IMPROVEMENTS

More efforts to obtain necessary statistical information or alternative methodologies will be envisaged to estimate emissions from carbonate use in the production of synthetic fertilizers (nitrates of calcium and magnesium and ammonium nitrate with calcium and magnesium).

ROAD PAVING WITH ASPHALT (CRF 2A6)**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^o-160^o)⁶¹. Cold mix plants also involve mixing aggregate materials with an asphalt binder, but now the binder is an asphalt emulsion or is a cutback cement, and this process takes place at much lower temperature (40-60^o).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers⁶². Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphta (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12% 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



Bibliography



Key Categories



Uncertainty

⁶¹ That are needed to fluidize the asphalt cement.

⁶² And also a solvent in several emulsion types.

pollutants are also emitted but they result mostly from combustion of fuels and are considered in chapter Energy (1A2)⁶³. Emission estimates for hot-mix are only made here for pollutants COVNM 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 activity⁶⁴.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible⁶⁵.

It was still not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation or asphalt roofing, and therefore all emissions from production of asphalts – except emissions from fuel combustion – are included in this source category.

METHODOLOGY

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100 per cent composed of VOC (USEPA,2001) and that emitted VOC have on average 85 per cent of carbon⁶⁶:

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



Bibliography



Key Categories



Uncertainty

⁶³ To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

⁶⁴ It is not possible to distinguish fuel combustion in hot mix production activity.

⁶⁵ 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.

⁶⁶ Normal carbon content for medium linear simple hydrocarbons.

Different methodologies were used to estimate emissions of NMVOC during asphalt application or from asphalt production.

Application of Asphalt Concretes and Liquefied Asphalts

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA,1997; USEPA,2001):

$$Emi_{NMVOC(y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Emi_{NMVOC(y)}$ - Emissions of NMVOC from asphalt application during year y (ton/yr);

$Binder_{(y)}$ – Total quantity of asphalt binder used in road paving during year y (ton/yr);

SLV_{Fac} - Fraction of distillate (solvent) in asphalt (m^3/m^3);

d_{SLV} - density of solvent added to liquefied asphalt (kg/l);

d_{BIN} - density of bitumen binder mixture (kg/l);

$Cure_{FC}$ - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

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);

$Hotmix_{Batch(y)}$ 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.

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 4.5 - 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 4.6 - 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

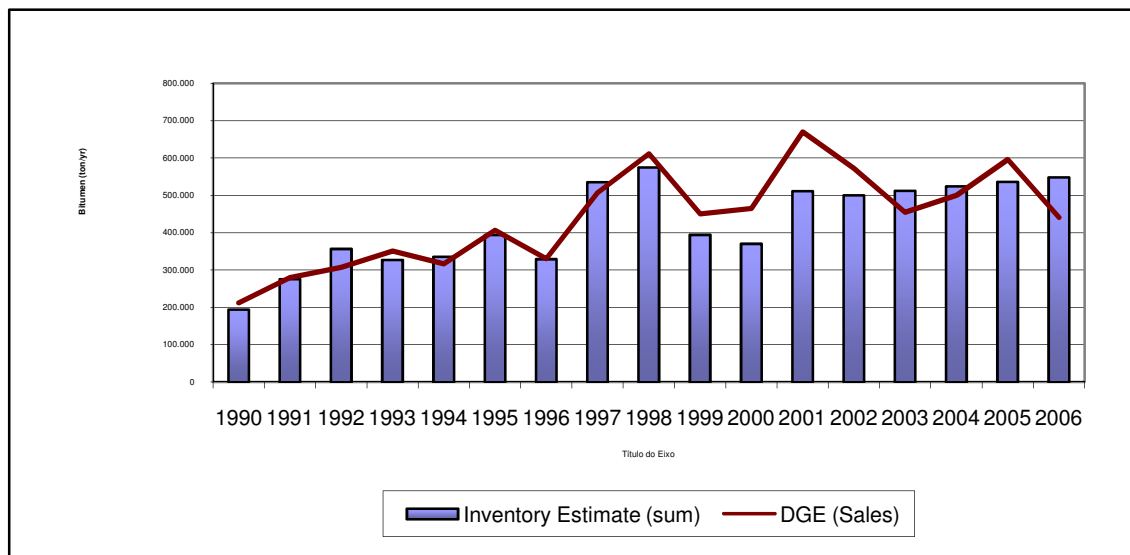
Source: USEPA (2000)

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 Geology and Energy

(DGGE) based on surveys⁶⁷, and it is presented in Figure 4.8. Although this time series was not used in the inventory, it is nevertheless used for the verification that the estimates made for each asphalt materials, which are subsequently explained, are coherent with total sale statistics.

Figure 4.8 - Total consumption of bitumen in the construction sector according to sales from DGGE and sum of values of asphalt used, according to the inventory (1990-2006)



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 Table 4.7 and Figure 4.9. 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

⁶⁷ Original data from DGE is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGE

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 per cent in 1996. Data for Hot mix concrete asphalt production is from EAPA for 1991-2001 and forecasted for the remaining years. Bitumen in hot mix asphalt was estimated considering that it equals 5 per cent 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 DGGE, match the sum of individual estimates, and both values agree reasonably well as may be seen from Figure 4.8 above. Total production of Hot mix concrete asphalts is presented in Figure 4.9.

Table 4.7 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (ton)

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

Asphalt	1999	2000	2001	2002	2003	2004	2005	2006
Cutback	162	576	824	501	340	0	0	0
Emulsified	95 000	86 000	107 000	116 000	116 000	116 000	116 000	116 000

Figure 4.9 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (1990-2006)

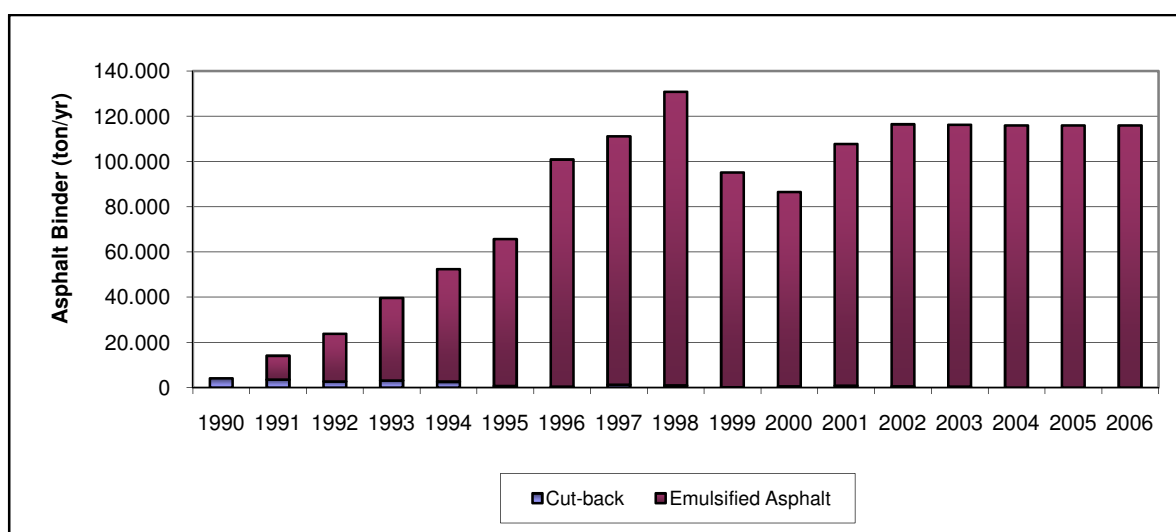
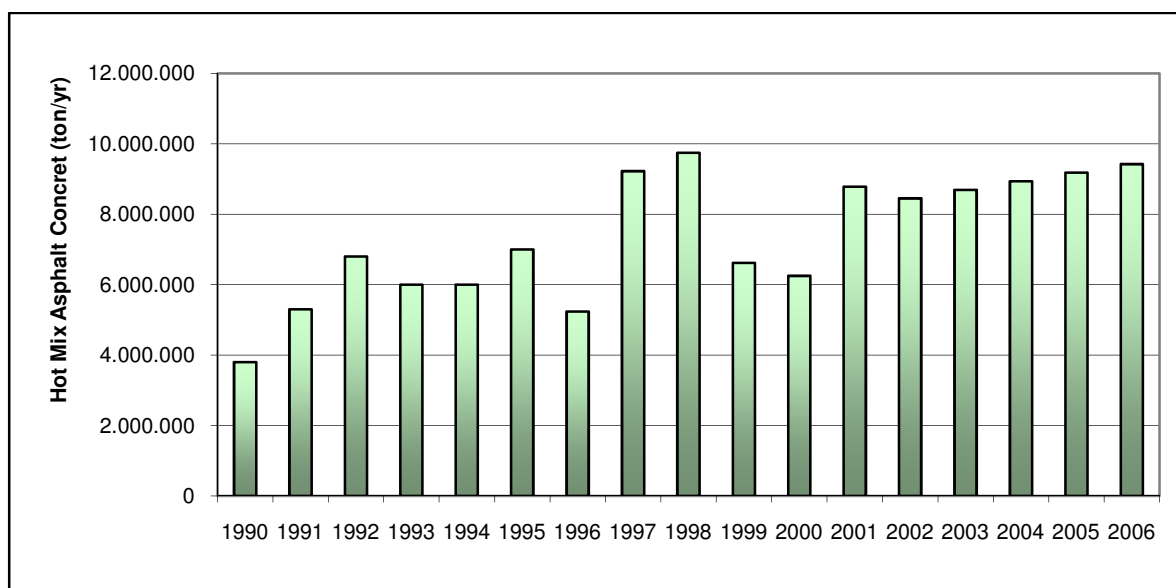


Figure 4.10 – Total Production of Hot Mix Asphalt (1990-2006)



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 per cent continuous equipment and 54 per cent batch, which is an expert guess (PTEN,2002).

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 per cent.

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.

RECALCULATIONS

No modification was made in emission estimates for this source sector.

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 year 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.

GLASS PRODUCTION (CRF 2A7)

OVERVIEW

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. It is made submitting this 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 here⁶⁸.

METHODOLOGY

Carbon dioxide emissions from glass production were estimated from:

$$\text{Emission}_{\text{CO2}(t,y)} = \text{EF}_{\text{CO2}(t)} * \text{ActivityRate}_{(t,y)} * 10^{-3}$$

where

$\text{Emission}_{\text{CO2}(t,y)}$ - 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);

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Key Categories

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Uncertainty

⁶⁸ They were not used to derive the country specific emission factors for instance.

EF_{CO2(t)} - emission factor from production of glass of type t (kg/ton)

EMISSION FACTORS

The following emission factors were considered:

Table 4.8 - 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.

ACTIVITY DATA

Some problems with the use of statistical information from INE were detected, mainly because not all products are reported in weight, but instead are measured in area-units (m²) or number of produced pieces. Because the available emission factors are expressed on weight basis, an effort was made to build time series in common weight units, converting production estimates from INE databases and also making use of information collected directly from industrial plants. The following assumptions were made:

- Flat glass. Presently there is only one industrial unit producing flat glass in Portugal. Activity data was set for 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 (m²) but was not used because conversion to weight units would lead to high uncertainties. Production value for 2002 to 2006 were forecasted by IA;
- 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 umbers 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 2004-2006 was estimated by IA 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 2001-2006. 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 4.9 – 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 Figure 4.11. 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)

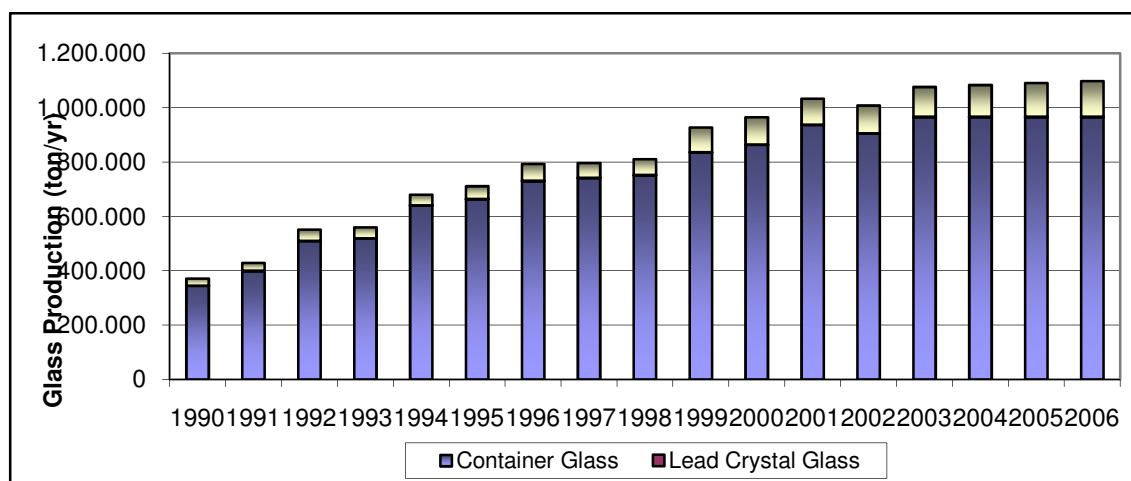


Table 4.10 - Glass production by glass type (excluding flat glass)

Type of 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

Type of Glass	1999	2000	2001	2002	2003	2004	2005	2006
Container Glass	835 451	863 502	936 471	904 433	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
Other Glass	90 141	100 059	94 912	102 081	109 251	116 421	123 591	130 760

UNCERTAINTY ASSESSMENT

A 100 per cent 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 per cent.

RECALCULATIONS

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

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.

Chemical Industry (CRF 2B)

AMMONIA PRODUCTION (CRF 2B1)

OVERVIEW

Presently only one fertilizer industrial plant manufactures ammonia in Portugal, using Vacuum Residual Fuel Oil (VRF) and 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.

METHODOLOGY

Carbon dioxide emissions were estimated from feedstock consumption using the following formulation:

$$\text{Emi}_{\text{CO}_2(y)} = 44/12 * \text{Feedstock}_{(y)} * C_{\text{Feed}(y)} * 10^{-5}$$

where

Emi_{CO₂(y)} - Emission of carbon dioxide (kton/yr);

FeedStock_(y) - Annual consumption of feedstock (ton/yr)

$C_{\text{Feed}(y)}$ - Carbon content of feedstock (%).

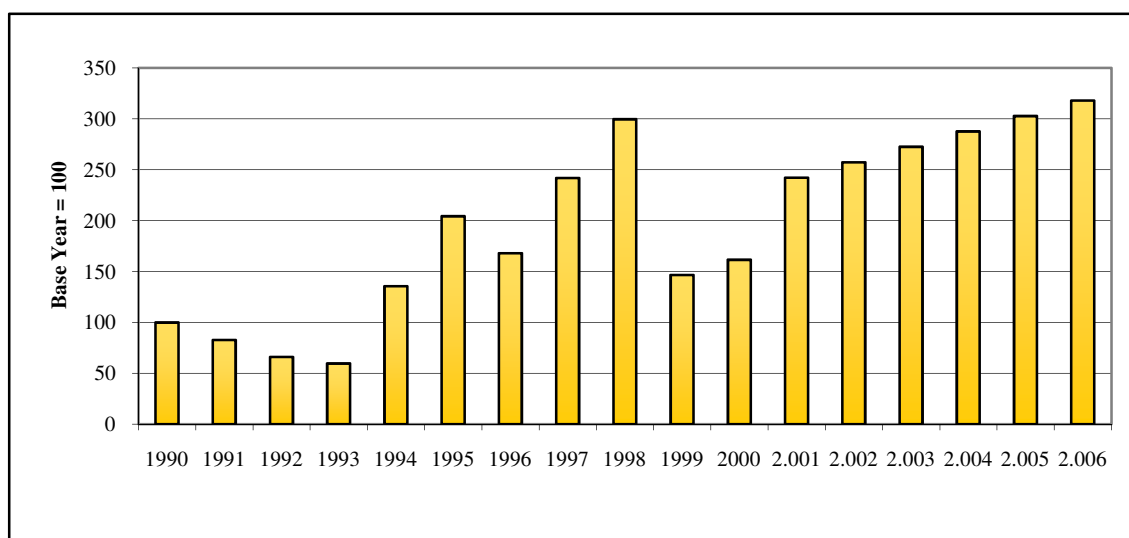
EMISSION FACTORS

The EF for CO₂ was determined assuming that the percent of carbon in VFR is 86 per cent, according to information received from the industrial unit. Thus the EF expressed in kg CO₂/ton NH₃ is 3.2.

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 quantity of ammonia produced in the period may be however depicted in Figure 4.12, 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 (1990-2006)



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 1990-2000, 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 after 2001 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 a 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.

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 conservativeness⁶⁹. The final uncertainty value for activity data was set as 31 per cent.

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

RECALCULATIONS

No changes were made in inventory estimates for this source sector either in methodology, emission factors or activity data.

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.



Bibliography



Key Categories



Uncertainty

⁶⁹ A further doubling was used to convert from standard deviation to 95% confidence interval.

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.

NITRIC ACID (CRF 2B2)

OVERVIEW

Only three industrial plants did produced nitric acid in Portugal between 1990 and 2004, 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.

METHODOLOGY

For all pollutants emissions are estimated using the following equation:

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

where

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

ActivityRate_(y) – production of Nitric Acid in year y (ton/yr);

EF_(p) - emission factor for pollutant p (kg/ ton)

EMISSION FACTORS

The emission factors that were used are presented in Table 4.11, with a short explanation of their origin. All emissions were estimated using monitoring data for industrial plants in Portugal and used for the overall production.

In Portugal there are still no units equipped for reducing nitrous oxide emissions.

Table 4.11 – Emission Factors for emission estimate for Nitric Acid Production

Pollutant	EF kg/ton HNO ₃
N ₂ O	7.52 ^(a)

(a) From plant specific monitoring data at one
(of a total of three industrial plants)

ACTIVITY DATA

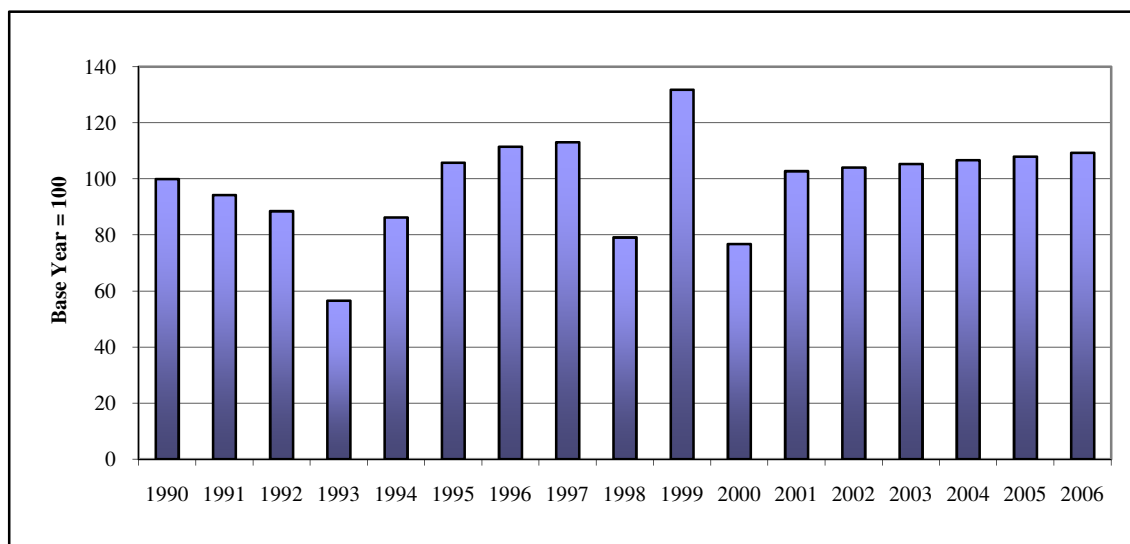
The activity data that was used to estimate emissions from this sub-source sector is subjected to confidentiality constraints due to the limited number of existing production units and may not

be presented here in actual figures, but only in relation to production in 1990 (trends). The sources of information that were used to establish activity data time series are discussed below in Figure 4.13, 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 2000, total national production of Nitric Acid was set from INE statistical database (IAP survey);
- For 1989-1991 statistical information of Nitric Acid Production is available from the IAIT survey;
- After 2001 the time series was provisionally estimated by a simple linear forecast.

Figure 4.13 - Trend in Nitric Acid production (1990-2006)



UNCERTAINTY ANALYSIS

The uncertainty value for activity data is 3per cent, 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 per cent 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.

RECALCULATIONS

Emission estimates for this source did not suffer modifications in either in methodology, emission factors or activity data.

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.

ORGANIC CHEMICAL INDUSTRY

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 sector⁷⁰:

- Vinyl Chloride Monomer (VCM);
- Low Density Poly-ethylene (LDPE);
- Poly Vinyl Chloride (PVC);
- Poly propylene (PP);
- Poly styrene (PS);
- Formaldehyde;
- Explosives.

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



Bibliography



Key Categories



Uncertainty

⁷⁰ 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

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);

EMISSION FACTORS

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994⁷¹. Emissions estimated for this period were used to determine plant-specific process emission factors that were used to estimate emissions for all time series from 1990 to 2001 and using

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Key Categories

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Uncertainty

⁷¹ Unpublished.

ethylene production as activity rate indicator⁷². Emissions from flares and flue gas combustor were included in the emission factors.

Table 4.12 – Emission Factors for determination of process emissions in Borealis (kg/ton)

Fábrica	NM VOC	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 4.13 – 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)
COVNM	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

⁷² This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Emission factors for the Phthalic Anhydride Plant are from US-EPA (1983) and are presented in table 4.8:

Table 4.14 - Emission Factors for the production of Phthalic Anhydride

Pollutant	kg/ton
COVNM	1.2
CO	151

Source: USEPA (1983)

ACTIVITY DATA

Activity data used to estimate emissions may not be reported in NIR, due to confidentiality issues that result from the limited number of units concerned for each individual compound.

For BOREALIS Petrochemical Plant in Sines - produced quantities are available from 1990 to 1997 and were forecasted thereafter. Production of carbon black and explosives is available from 1990 to 2000 from INE Statistical Database (IAIT and IAPI surveys).

Statistical information for all emissions sources other than Sines industrial Plants were obtained from the National Statistical Institute (INE).

UNCERTAINTY ASSESSMENT

The uncertainty of activity data received from Large Point Sources was set as 10 per cent. 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 per cent and 20 per cent 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 per cent for Large Point Sources⁷³.

RECALCULATIONS

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

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 relies 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:

- Update of activity data from 1991 to 2004;
- 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;



Bibliography



Key Categories



Uncertainty

⁷³ The uncertainty of emission factors refers to uncertainty of NMVOC determination. Uncertainty for conversion from NMVOC to CO₂ is comparatively irrelevant.

- 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.

Metal Production (CRF 2C)

IRON AND STEEL PRODUCTION (CRF 2C1)

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 can not 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 mater 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.

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.

EMISSION FACTORS

Emissions factors for production process where 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 4.15 - Emission Factors for Iron and Steel Production

	Coke Oven	Sintering	Blast Furnace	BOF	EAF
Pollutant	(kg/ton coke)	(kg/ton sinter)	(kg/ton steel)	(kg ton/steel)	(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.

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 Figure 4.14. The following sources of information were used to establish activity data time series:

- coke production is available from DGGE (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 (IA 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 plant⁷⁴ as surrogate data⁷⁵, 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.

Production of total steel and intermediate products as they are presently considered may be seen in next figure. Details about specific products and origin by furnace technology (BOF and EAF) can not be reported due to confidentiality constrains.



Bibliography



Key Categories

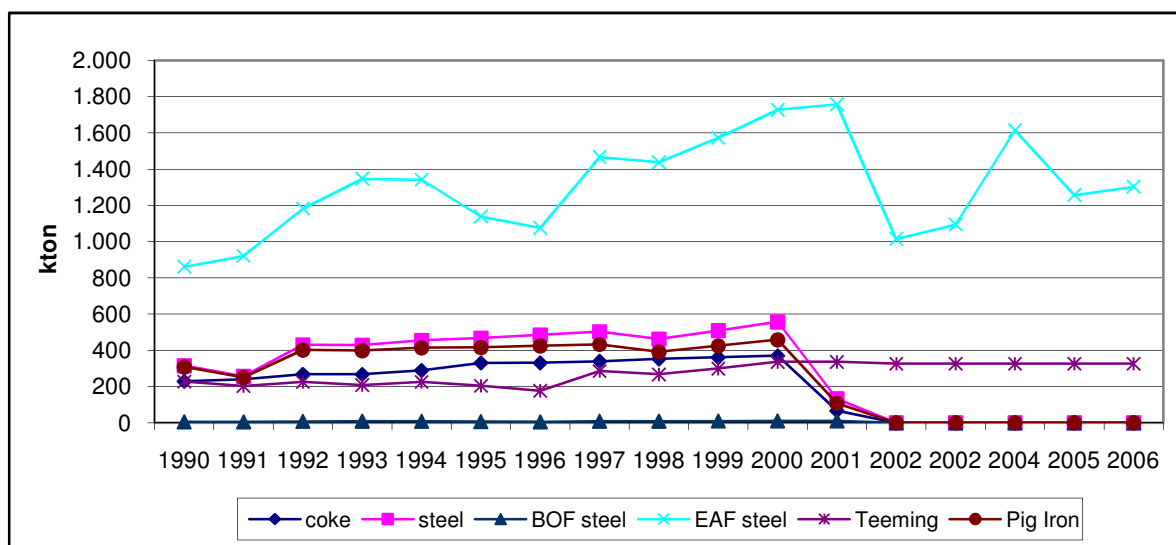


Uncertainty

⁷⁴ Power plant that is part of the iron and steel plant

⁷⁵ They may result not from iron produced at this industrial plant

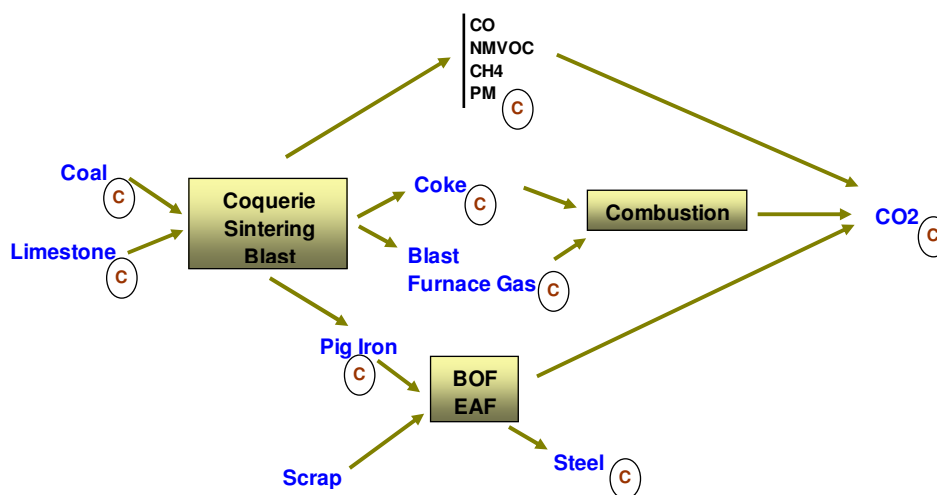
Figure 4.14 - Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2006)



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 from coal = coal consumption * 29.9 (GJ/ton) * 96.1 kg (CO₂/ton)

C in limestone = lime consumption * 0.75 kg CO₂/kg lime (High Ca)

2. Bottom-up

CO₂ emissions estimated from:

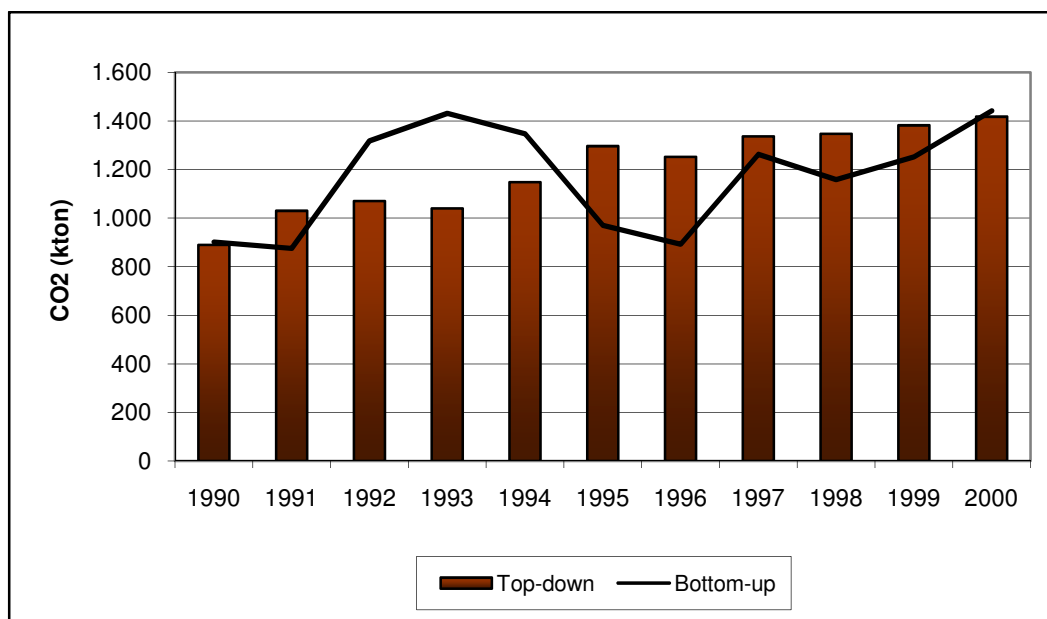
- Consumption of derivative gases: COG and BFG

CO₂ from fuel use = Consumption (Nm³/yr) * LHV * EF

- Process emissions (not including other fuels)
 - Coke Oven leakage, etc
 - Blast Furnace leakages, etc
 - BOF
 - EAF (not including consumption of electrodes)
- Other Carbon items
 - 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



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 carbon market (EU-ETS). In the intermediate period information had to be collected from statistical information from National Statistical Institute (INE), General Directorate of Geology and Energy (DGGE) 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 an uncertainty of 25 per cent in the carbon content of both raw materials and final steel and additional 5 per cent in the quantity of reducing agent for EAF.

RECALCULATIONS

Three errors were detected in the inventory concerning GHG emission estimates made for the production of Iron and Steel.

- the activity data used to estimate emissions from BOF and EAF from one unit was by mistake made equal to coke production;

- the EF for BOF was estimated from change in carbon content in steel, but there was no conversion of carbon to CO₂;

- Final CO₂ emissions from BOF and EAF were estimated from consumption of carbon (decrease of carbon in steel in BOF and consumption of electrodes in EAF), but CO emissions (estimated using EF in kg/t steel) were added, after conversion to CO₂, causing double counting of emissions. Considering that there are no other sources of carbon in BOF and EAF the carbon released as CO is originated from carbon in steel (BOF) and in electrodes (EAF).

The errors in activity data were corrected for all years after the review process for submission 2006 under UNFCCC and IIR under the Kyoto Protocol. The following table shows the change in EF.

Table 4.16 - Proposed revision of EF for BOF and EAF

Category	Pollutant	EF (kg/t steel)	
		IIR	Sub 2008
BOF	CO	69.0	69.0
BOF	CO ₂	22.5	82.5
BOF	CO ₂ Total	130.9	82.5
EAF	CO	9.0	9.0
EAF	CO ₂	14.2	14.2
EAF	CO ₂ Total	28.3	14.2

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 mater are still not included in the inventory.

FERROALLOYS PRODUCTION (CRF 2C2)

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.

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)

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).

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.

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 per cent while uncertainty in emission factor was estimated from the range of emission factors proposed in IPCC (1997) i.e. 0 – 6.5.

RECALCULATIONS

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

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.

ALUMINIUM PRODUCTION (CRF 2C3)

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.

Other Production (CRF 2D)

WOOD CHIPBOARD PRODUCTION

OVERVIEW

Chipboard manufacturing involves solvent emission but it included in this source sector.

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

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

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

EF_{NMVOC} - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents and these have fossil origin contributing to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$\text{Emi}_{\text{CO}_2} = 44 / 12 * 0.85 * \text{Emi}_{\text{NMVOC}}$$

EMISSION FACTORS

Emission factor is 0.9 kg/ton, from Corinair90 Default Emission Factor Handbook.

ACTIVITY DATA

Information about activity data for this sector is still scarce and limited to 1990, from National Statistics Institute (INE). In 1990 571 kilo-tons of chipboard were produced in Portugal.

RECALCULATIONS

No changes have been made since last submission.

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 these 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.

4.1.A Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2F)

4.1.A.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)⁷⁶ are the most important among those compounds. CFC and HCFC are already under control and being phased out under the Montreal Protocol, as consequence of their role as Ozone Depleting Substances (ODS). Therefore, under the United Nations Convention on Climate Change it was decided to consider in the GHG inventory those substances not included in the Montreal Protocol: HFC, PFC and SF₆.

Some emission sources are still not included in the inventory:

- Aerosols. According to information from industry importers (Carreira, 2002) fluorine gases have not been used as aerosol propellants produced in Portugal. Instead Portugal has been using R12 (CFC), hydrocarbons (butane and propane) and even N₂O. The presence of fluorine gases incorporated in imported aerosols is unknown because F gases are not reported explicitly at customs services and consequent emission cannot be estimated;
- Solvents. According from information from national importers in Portugal there is no reference of the use of HFC as solvents, but only of HCFC (Carreira, 2002). Use of HFC as a solvent represents probably a minor source in global terms;

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:



Bibliography



Key Categories



Uncertainty

⁷⁶ 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.

- 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)

4.1.A.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 filled⁷⁷;
- 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.



Bibliography



Key Categories

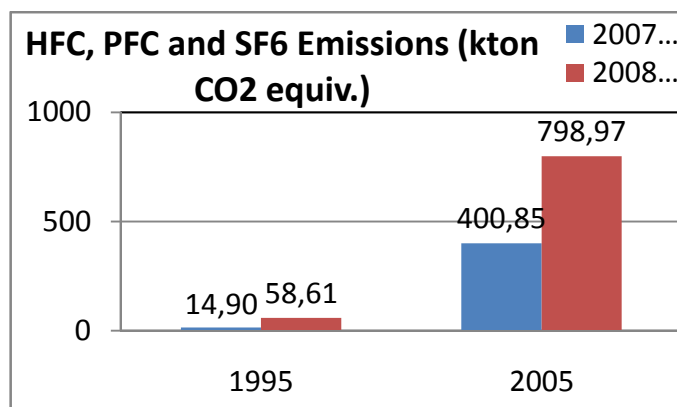


Uncertainty

⁷⁷ Assembly emissions could include also emissions during refilling but no data was available to make this distinction

4.1.A.3 RECALCULATIONS

Following the recommendations of the in-country review and as result of the work being made under the Methodology Development Plan, Halocarbons and Sulphur Hexafluoride emissions have suffered expressive changes since last submission.



Some changes were made in the Domestic Refrigeration subsector. Since 2001, there is no information on assembled units from INE IAPI Survey. Previously data was forecasted using information from previous years; Currently, the assembled units in the period 2001-2006 are estimated using Gross Domestic Product trends.

A survey was made in the Commercial Refrigeration subsector, with the support of “Turismo de Portugal, ip” and “AHP – Associação da Hotelaria de Portugal”. This survey made possible the characterization of the refrigeration equipments used in Hotels, Hostels, Boarding Houses and Camping Parks.

During the review a correction on the discrimination of the number of hypermarkets by dimension was made. The differences are reflected in the emission values.

There is a new and corrected time series on the number of refrigeration transport registered vehicles. There are no methodological changes and emission values reflect only the change on the activity data.

In the Industrial Air Conditioning subsector, activity data was revised using a study from Professor Luís Roriz (UTL-IST) and emission values obtained are higher for all time series.

A new activity data time serie was built in the Metered Dose Inhalers subsector, based on a survey with the support of “Infarmed” and Pharmaceutical Laboratories. Information on the number of sold inhalers and on the % of propellent (F-gas) used in each MDI was collected.

New time series on activity data were built in the Electrical Equipment subsector, based on data provided by “EDP Distribuição”, “EDP Produção”, “REN”, “Tejoenergia” and “Turbogás”. Emission values reflect both changes in activity data and in estimate methodology.

4.1.A.4 FURTHER IMPROVEMENT

It is expected that emission estimates will improve as a consequence of the inclusion of non quantified sources and the upgrade of methodologies and parameters for the already quantified sources. The main aspects that will be subjected to future improvements include:

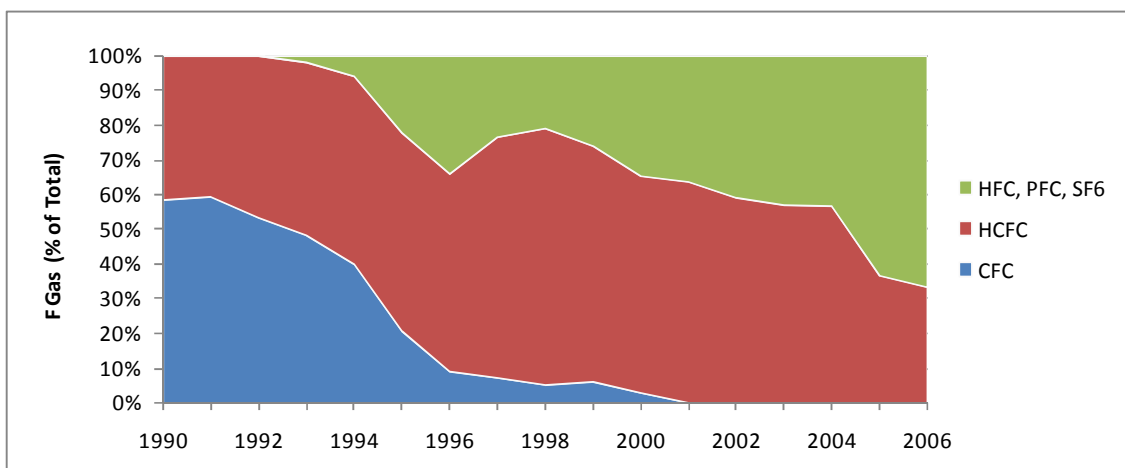
- It is known that SF6 was used in Portugal as a tracer in scientific studies, even in the development of air emission methodologies (VOC from forest). But the quantities used in this activity remain unknown;

- The consideration of refilling of refrigeration equipments should be better addressed in the inventory;
- Emissions from certain source sectors rely in less accurate activity data, which was estimated from surrogate data and assumptions. Efforts will be made to reduce uncertainty on activity data and parameters.

4.1.A.5 IMPORTERS DATA

The share of each F-gas used in the assembling of refrigeration equipments was estimated for each year relying on importation data from the major national importers and suppliers of assembled units. Although data from importers does not cover the totality of national market, it was assumed to represent 60% (value agreed upon with importers) 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 substituting HCFC imports. The share of imports of each gas can be seen in the following figure.

Figure 4.17 - Percentage of imported fluorinated gases (F-Gases) in Portugal by gas type (1990-2006)



Source: Importers

Figure 4.18 – Imported amounts of pure HFC, PFC, SF6 and Blends containing HFC and PFC (1990-2006)

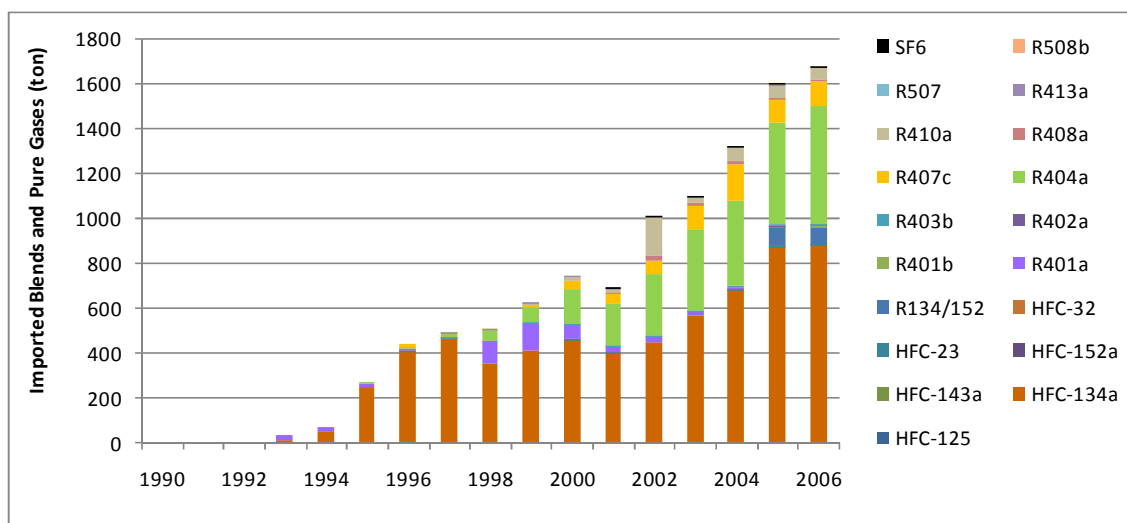


Figure 4.19 – Percentual Distribution of pure HFC, PFC, SF6 and Blends containing HFC and PFC

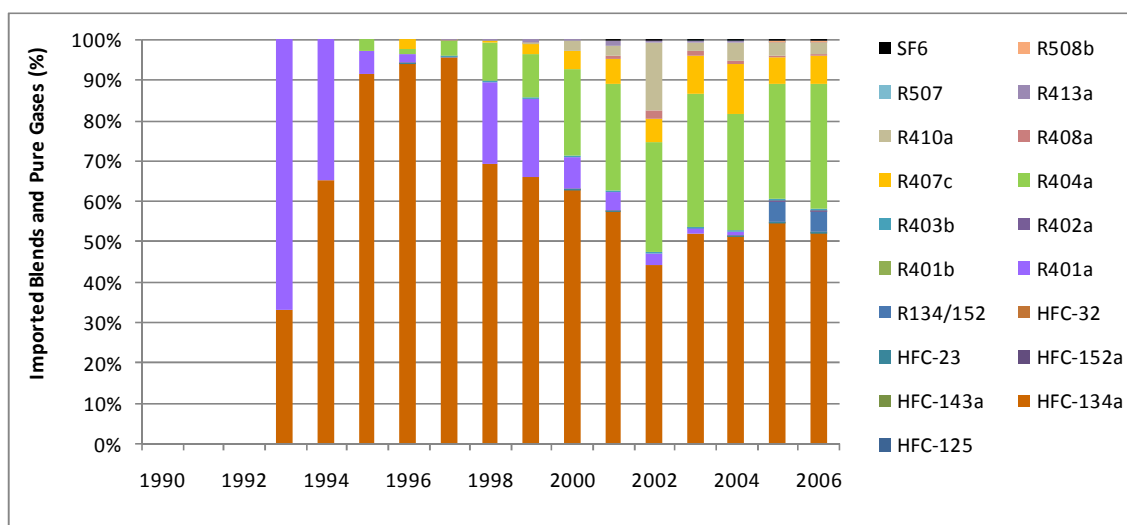


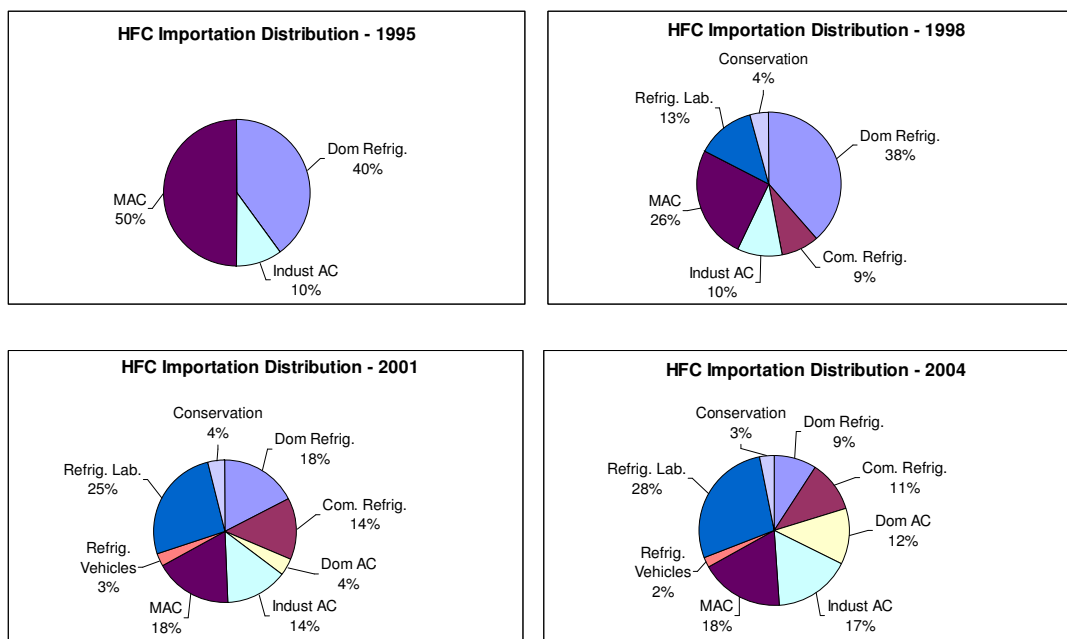
Table 4.17 – Constitution of each blend

Blend Name	Gases in the Blend	% of each gas
R-134/R152	HFC-134a	87%
	HFC-152a	13%
R-401a	HCFC-22	53%
	HCFC-124	34%
R-401b	HFC-152a	13%
	HCFC-22	61%
R-401b	HCFC-124	28%
	HFC-152a	11%
R-402a	HFC-125	60%
	HCFC-22	38%
R-402a	HC-290 (propane)	2%
	HCFC-22	75%
R-403a	PFC-218	20%
	HC-290 (propane)	5%
R-404a	HFC-143a	52%
	HFC-125	44%
R-404a	HFC-134a	4%
	HFC-134a	52%
R-407c	HFC-125	25%
	HFC-32	23%

Blend Name	Gases in the Blend	% of each gas
R-408a	HCFC-22	47%
	HFC-143a	46%
R-408a	HFC-125	7%
	HCFC-22	60%
R-409a	HCFC-124	25%
	HCFC-142b	15%
R-410a	HFC-32	50%
	HFC-125	50%
R-413a	HFC-134a	88%
	PFC-218	9%
R-413a	HC-600a (iso-butane)	3%
	CFC-115	51%
R-502	HCFC-22	49%
	HFC-125	50%
R-507	HFC-143a	50%
	HFC-125	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 (1990-2006)



Source: Importers

4.1.A.6 DOMESTIC REFRIGERATION

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.

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 4.18 - 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*.

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 based on 1991 and 2001 Census values.

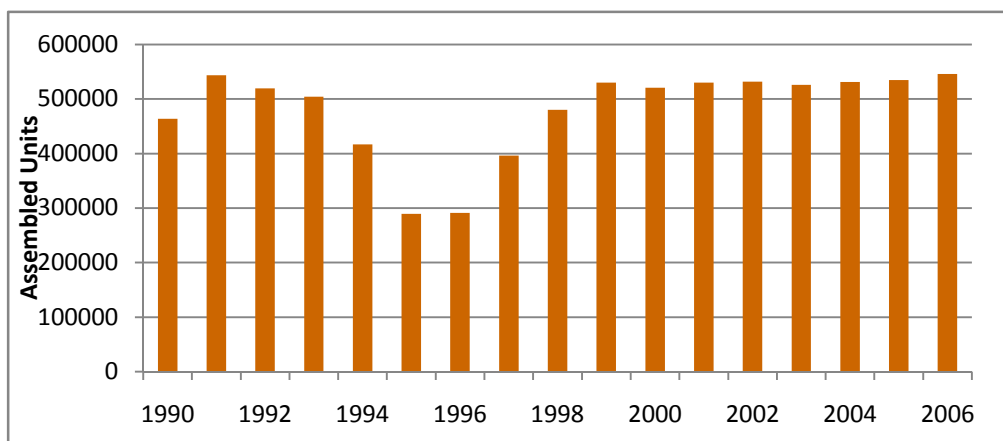
Table 4.19 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000	2006
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 the period 2001 - 2006 were forecasted by APA.

Figure 4.21 – Number of assembled refrigeration units (1990-2006)



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.

OTHER RELEVANT DATA AND PARAMETERS

According to data from Importers, 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 equipment⁷⁸. Prior to 1993 no F-gas was used in the assembling of

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Uncertainty

⁷⁸ In consequence no emissions of HFC from disposal are estimated for the reported period.

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.

RECALCULATIONS

No recalculations were made in this subsector.

UNCERTAINTY ASSESSMENT

An uncertainty of 10 per cent was considered for the number of assembled units each year, and 15 per cent 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 per cent was assumed. Uncertainty values for emission factors, or F gas liberation, incorporate the uncertainty in initial charge, emission factors and also a component for time of discharge – expressing the uncertainty in lifetime. Each individual value was determined from the range of default emission factors in GPG, except the uncertainty in initial charge that was established from the maximum range obtained from expert guess from the direct (bulk) importers of fluoride gases in Portugal. Individual uncertainty values are presented in next table.

Table 4.20 – 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 per cent).

4.1.A.7 COMMERCIAL REFRIGERATION

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

$$\text{Oper}_{\text{Emi}(t)} = \text{Equip}_{\text{Stock}(t)} * \text{Initial}_{\text{Charge}(t)} * (x/100)$$

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 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

$$\text{Ass}_{\text{Emi}(t,j)} = \text{Ass}_{\text{Emi}(t)} * \text{F-gas}_{\% (j,t)}$$

Operation/ Lifetime

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

Disposal

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

where

$\text{Ass}_{\text{Emi}(t)}$, $\text{Oper}_{\text{Emi}(t)}$, $\text{Disp}_{\text{Emi}(t)}$ - 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.

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 4.21 - 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).

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 DGE (Enterprise and Industry 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 4.22 - 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 4.23 - 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 4.24 - 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 4.25 – 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

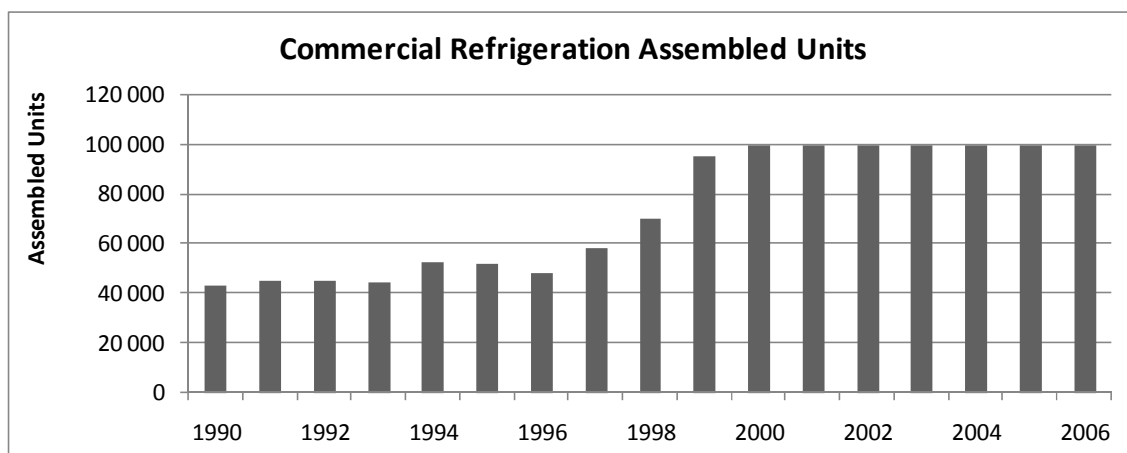
Source: Hypermarket Company

Table 4.26 – Number of installations using F-Gas as Refrigeration Fluid

Category		Number of Units using F-gas as Refrigeration Fluid											
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Positive Temperature	Big	0	0	0	0	4	7	9	11	14	15	17	18
	Medium	0	0	0	0	17	27	42	49	53	62	88	98
	Small	0	0	0	0	34	85	128	161	178	192	224	224
Negative Temperature	Big	0	0	0	0	0	3	5	7	10	11	13	14
	Medium	0	0	0	0	0	10	25	32	36	45	71	81
	Small	0	0	0	0	0	51	94	127	144	158	190	190

Data on the assemble of commercial and industrial refrigeration units from the new Industrial Survey (IAPI) 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 after 2001 was forecasted by APA, and those 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 (1990-2006)



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).

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.

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 per cent or overestimated by 200 per cent. 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 per cent uncertainty for stock and 75 per cent 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 per cent 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 mixture⁷⁹, 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 per cent). Apart from the great effort placed in a better knowledge of the stocks, the main cause of the decrease of 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 4.27 – 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



Bibliography



Key Categories



Uncertainty

⁷⁹ This factor was not considered in the 2006 submission. It represents the change in final CO₂ equivalent values given the possible range in the gas composition that is used in the final mixture.

4.1.A.8 TRANSPORT REFRIGERATION

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 emissions⁸⁰ 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

$$\text{Disp}_{\text{Emi (t)}} = \text{Equip}_{\text{Disposal (t)}} * \text{Initial}_{\text{Charge (t-lifetime)}} * (y/100) * (1-z/100)$$

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:

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Key Categories

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Uncertainty

⁸⁰ Assembly emissions are not estimated and they are included in the assembling of other refrigeration equipments

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 F-gas emissions at year t from during Operation (Oper) and Disposal (Disp);

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

$\text{Equip}_{\text{Stock}(t)}$ - 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 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.

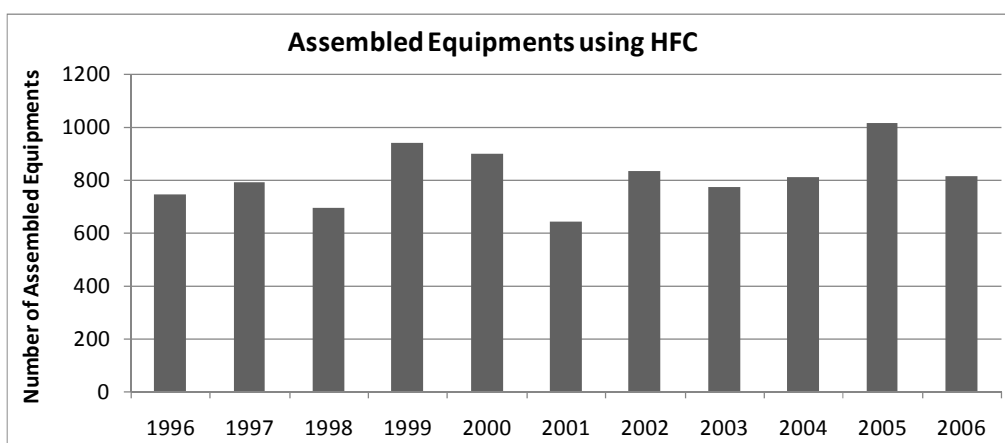
EMISSION FACTORS

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.

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.

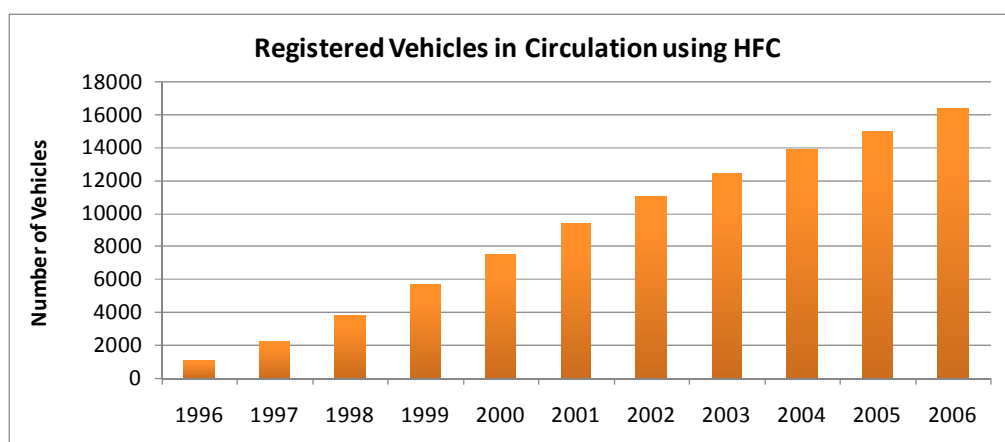
Figure 4.23 – Number of Equipments produced in Portugal (1990-2006)



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 (1990-2006)



Source: DGV – National Entity responsible for road traffic

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).

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 per cent (new units), 20 per cent (stock) and up to 50 per cent (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 4.28 – 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

4.1.A.9 DOMESTIC STATIONARY AIR CONDITIONING

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

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

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;

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.

EMISSION FACTORS

Lifetime emission factor was set as 3 per cent 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).

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 2006, was adopted by the inventory. According to IAIT, 50 821 and 63 108 units were assembled, respectively, in 1990 and 1991⁸¹.

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).



Bibliography



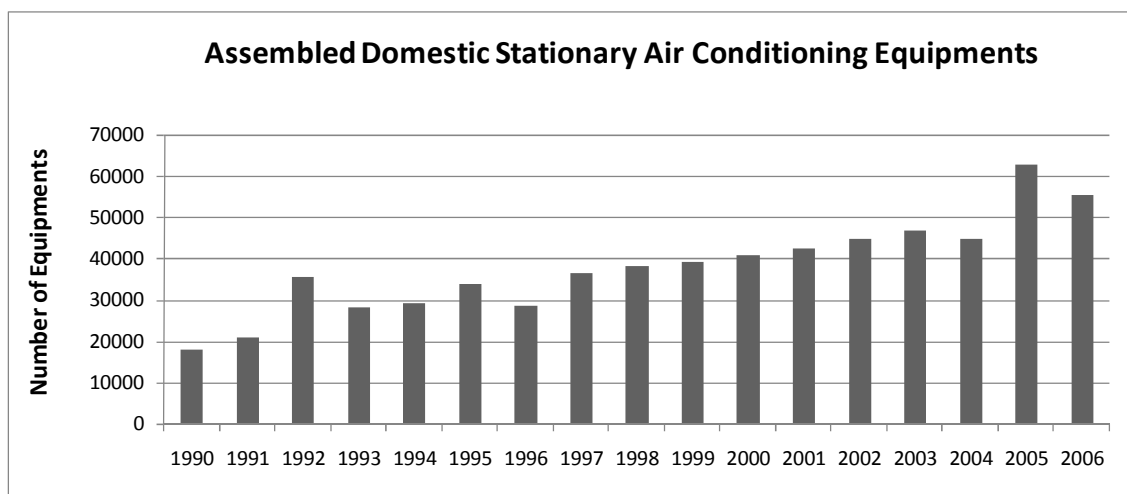
Key Categories



Uncertainty

⁸¹ Due to difference in magnitude order these values from IAIT are not shown in the graph

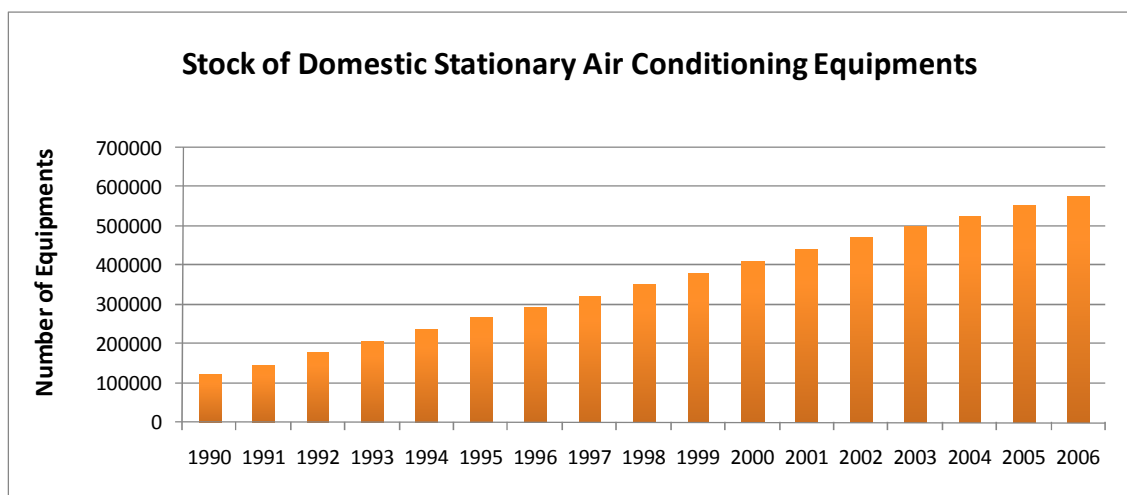
Figure 4.25 - Number of Domestic Stationary Air Conditioning Equipments assembled in Portugal in the period 1990-2006



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 (1990-2006)



Source: Prof. Luís Roriz (IST-UTL – Technical Superior Institute)

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).

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 per cent was assumed. Regarding stock in existence, an uncertainty of 30 per cent was considered, and a higher value of 75 per cent 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 last year, 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 4.29 – 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

4.1.A.10 INDUSTRIAL STATIONARY AIR CONDITIONING

METHODOLOGY

The methodology used for Industrial Refrigeration Air Conditioning is the same as for Domestic Refrigeration Air Conditioning (see 4.1.A.9).

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 per cent of initial charge per year, corresponding to the average value from the proposed range in IPCC GPG table 3.22, was considered.

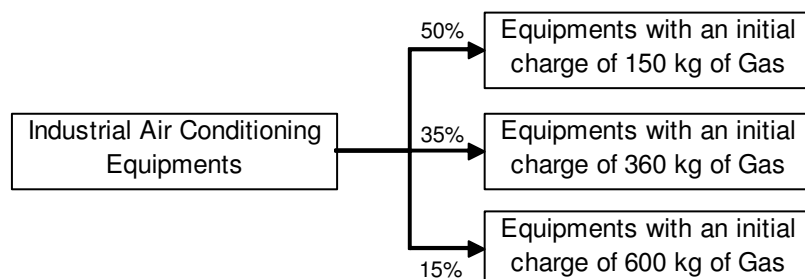
It was assumed a recovery of the gas of 10% (data from importers) at the end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90% (IPCC 1996 Revised Guidelines). It was assumed a lifetime of 15 years for the equipments (values suggested by manufacturers and importers).

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 4.28), from 1990 to 2006, was considered in the inventory.

Figure 4.28 – Number of Industrial Stationary Air Conditioning Equipments Assembled in Portugal using F-gases in the period 1990-2006

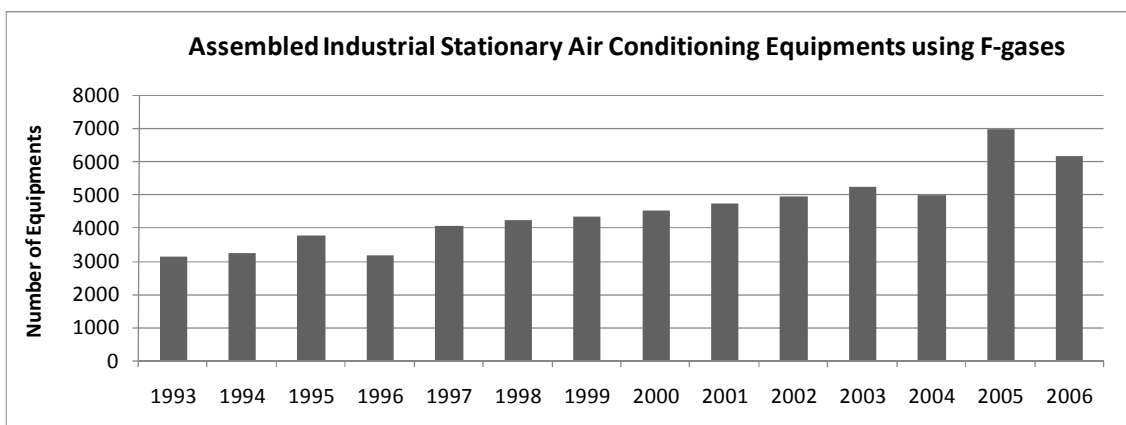
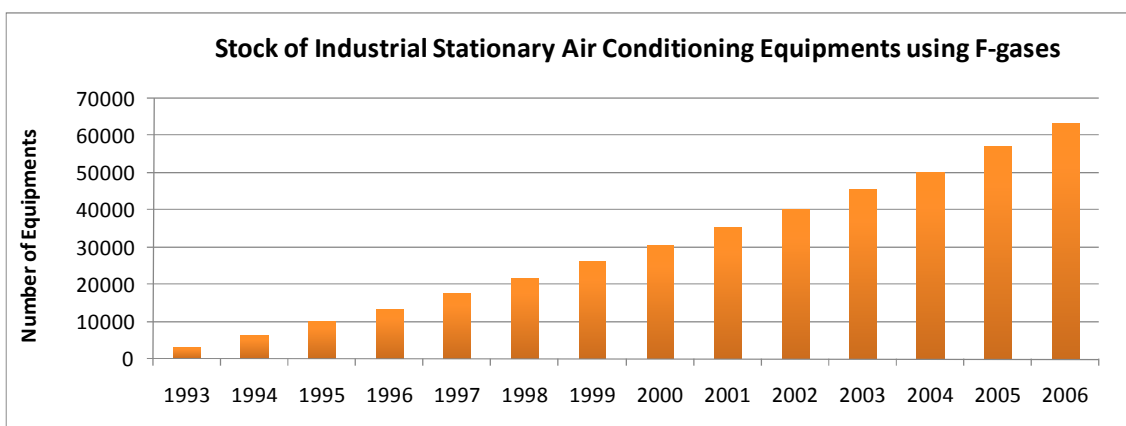


Figure 4.29 – Annual Stock of Industrial Stationary Air Conditioning Equipments in Portugal (1990-2006) using F-gases



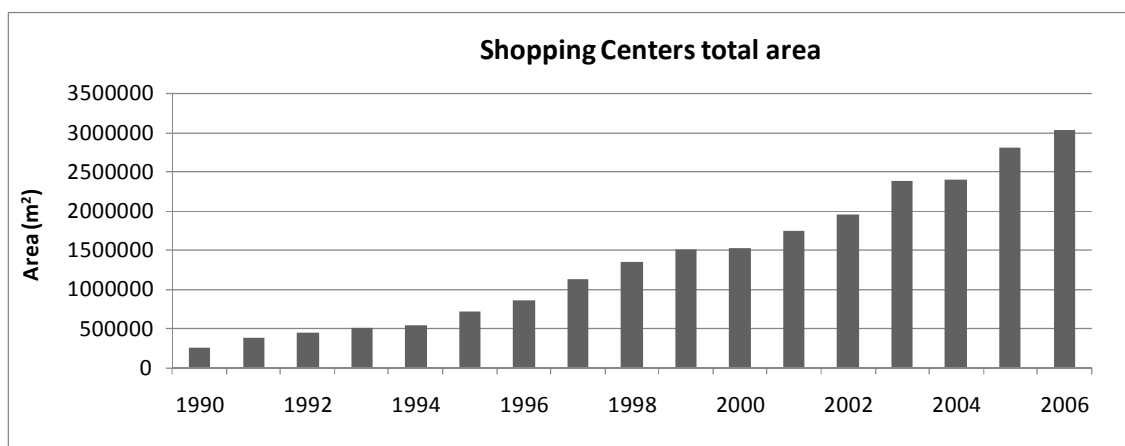
Data on the Temporal Distribution by type of gas was obtained from importers.

AIR CONDITIONING EQUIPMENTS FROM SHOPPING CENTERS

When considering shopping centers with centralised 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). Figure 4.30 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.

UNCERTAINTY ASSESSMENT

The uncertainty assessment is explained in the chapter describing Domestic Stationary Air Conditioning (4.1.A.9).

4.1.A.11 MOBILE AIR CONDITIONING

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.

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).

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 (1995-2006)

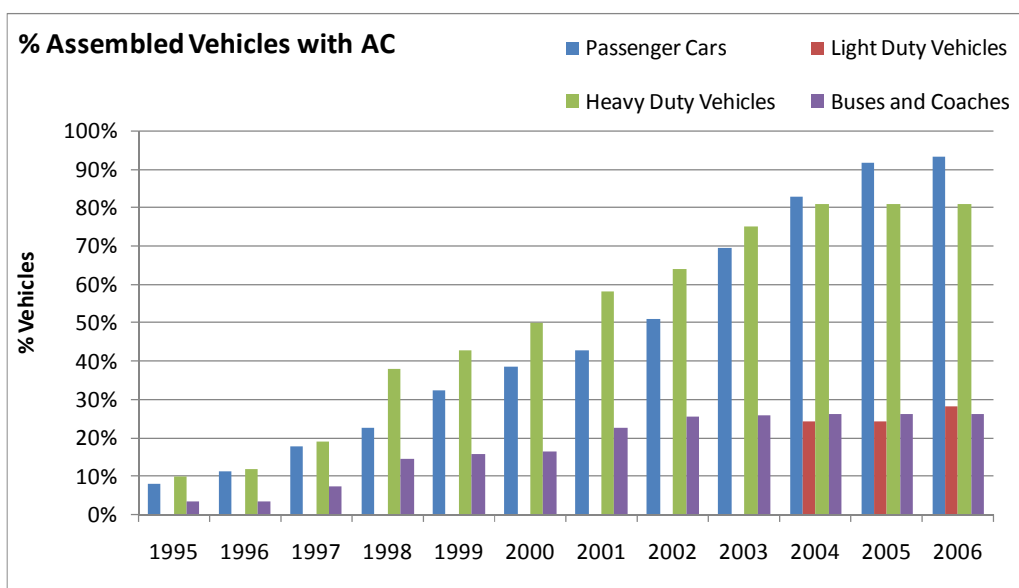
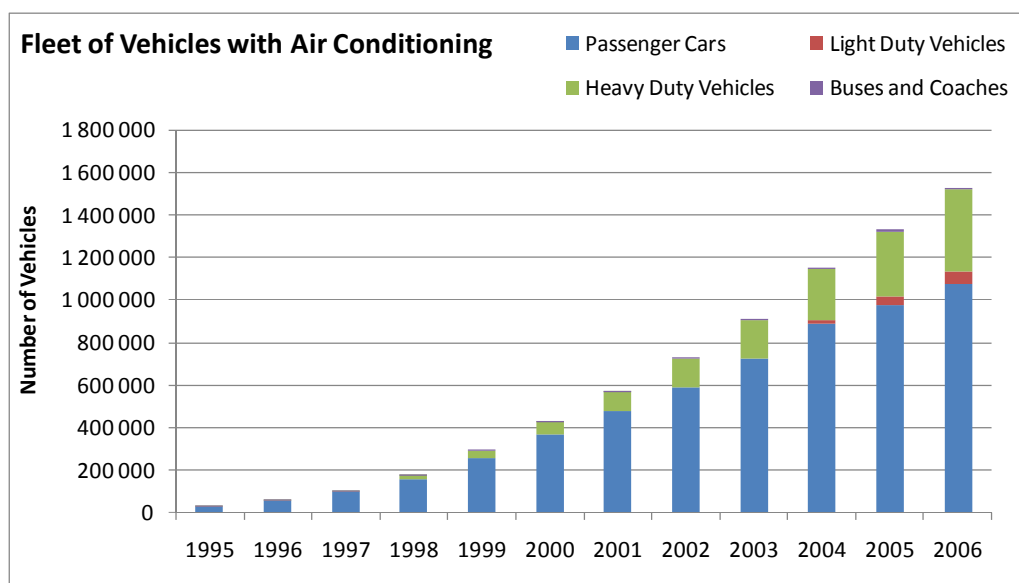


Figure 4.32 – Fleet of Vehicles equipped with AC systems (1995-2006)



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 quantity of initial charge considered was 1.05-1.5 kg/MAC unit and 4-20 kg/MAC unit, on the crew room and on passenger rooms, respectively.

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 per cent 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 4.30 – 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

4.1.A.12 FOAM BLOWING

OVERVIEW

Fluorinated gases are nowadays used as blowing agents in the manufacture of foams that are used as insulating, cushioning and packaging materials.

The foams blowing agent is eventually ventilated to the atmosphere, but at a rate dependent on the type of foam and its structure. Open cell foams emit virtually all blowing agent at the time of

manufacture. Closed-cell foams emit the HFC blowing agent during their lifetime at three distinct phases:

- Foam Manufacturing emissions, occurring during the first year at the location where the foam is manufactured;
- Annual losses, occurring where the foam is applied, result from the slow release of the blowing agent trapped inside the foam.
- Disposal. Emissions occurring when foam is removed and destroyed. The remaining gas in cells is emitted to atmosphere.

Activity data on the use of HFC in foam manufacturing in Portugal is available, allowing the estimation of manufacturing emissions. Annual losses are, however, harder to estimate because it is not known neither the quantity of closed-cells imported that were manufactured with F gases, nor the quantities of foams that were exported with HFC. Nonetheless, assumptions are based on expert judgements.

In Portugal, there is production of Polystyrene closed-cell foams and Polyurethane open-cell foams, associated to the use of HFC-134a and HFC-152a as blowing agents.

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.

$$F_{GasEmi(t)} = F_{GasinFoam(t)} * (x/100)$$

$$F_{GasinFoam(t,j)} = \sum_{y=t-Lifetime}^{t-Lifetime} [Fill_{GasConsumption(y)} * HFC\%(j,y)]$$

Where:

$F_{GasEmi(t,j)}$ - gas emission at year t of fluorine gas j;

$F_{GasConsumption(t)}$ - Total F gas consumption at year t used in closed-cell manufacturing;

$HFC\%(j,t)$ - Percentage of Fluorine gas J used at year t in closed-cell manufacturing;

$F_{GasinFoam(t,j)}$ - quantity of F gas j in closed-cell existing in the country at year t⁸²;

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 larger⁸³ than the time between the first use of HFC and 2006.



Bibliography



Key Categories



Uncertainty

⁸² For the time being the stock is restricted to foam filled in Portugal;

⁸³ Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

EMISSION FACTORS

Due to unavailability of country-specific information, default emission factors from GPG (table 3.17) shown in the following table were used:

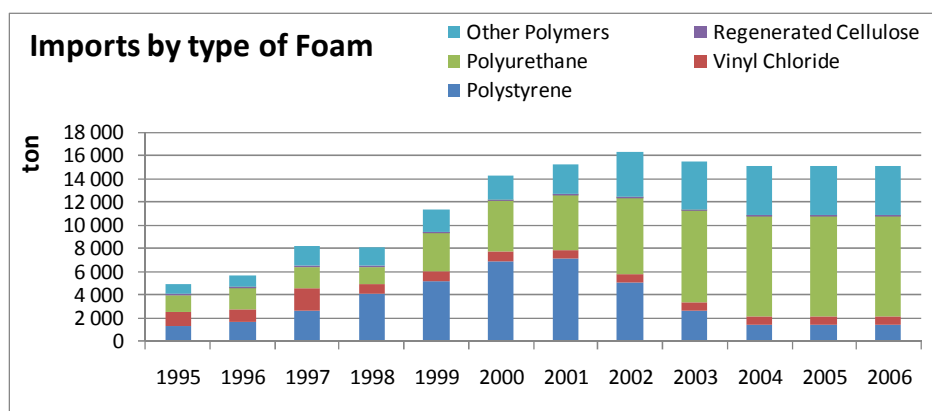
Table 4.31 - Emission Factors to estimate F gas emissions from foam losses

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

ACTIVITY DATA

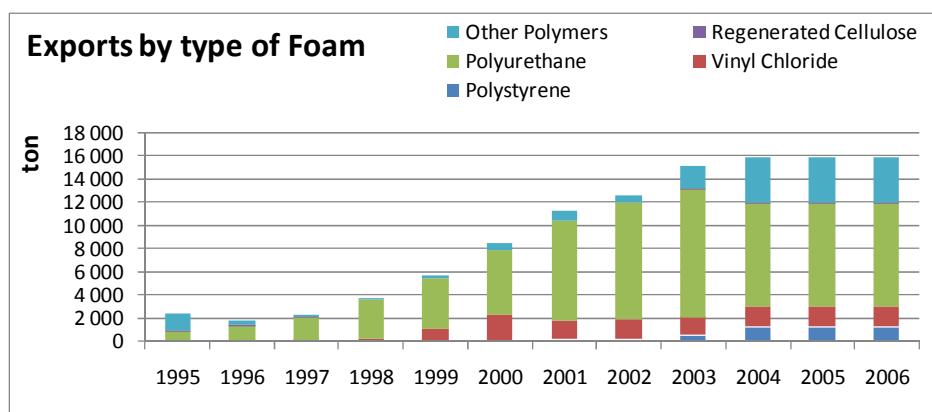
Data on amounts of imported and exported foams (see Figure 4.33 and Figure 4.34) by type of product were obtained from DGE (General Directorate for the Enterprise) and data on produced amounts of foam were provided by DGE and manufacturers.

Figure 4.33 – Imports by type of Foam (1995-2006)



Source: DGE (General Directorate for the Enterprise)

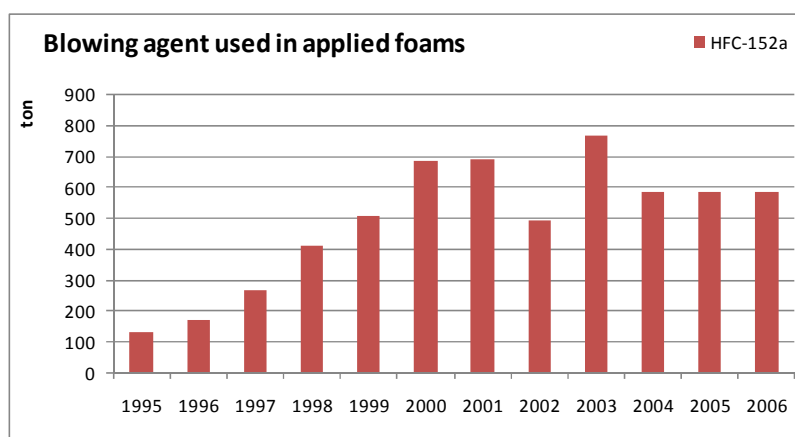
Figure 4.34 – Exports by type of Foam (1995-2006)



Source: DGE (General Directorate for the Enterprise)

It was only considered that the use of F-gases as foam blowing agents in foams produced in Portugal was only 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 2006, is presented in Figure 4.35.

Figure 4.35 – Amount of blowing agents used in Applied Foams in Portugal (ton/yr)



UNCERTAINTY ASSESSMENT

Improvements in the uncertainty assessment have occurred for this sector since last year's submission. According to recommendations of GPG for country-specific top-down information, the uncertainty in fill gas consumption was maintained at 50 per cent, but the establishment of a better foam stock time series allowed the reduction of uncertainty in operation from one order of magnitude to 100 per cent.

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 4.32 – 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

4.1.A.13 METERED DOSE INHALERS

OVERVIEW

Fluorinated gases are used as propellents in pressurized solutions (metered dose inhalers) in the treatment of asthma.

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.

$$\text{Emi}_{\text{HFCt}} = [\Sigma(\text{Sold MDI}_{t-1} * K_{t-1}) + \Sigma(\text{Sold MDI}_t * K_t)] / 2 * 10^{-6}$$

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

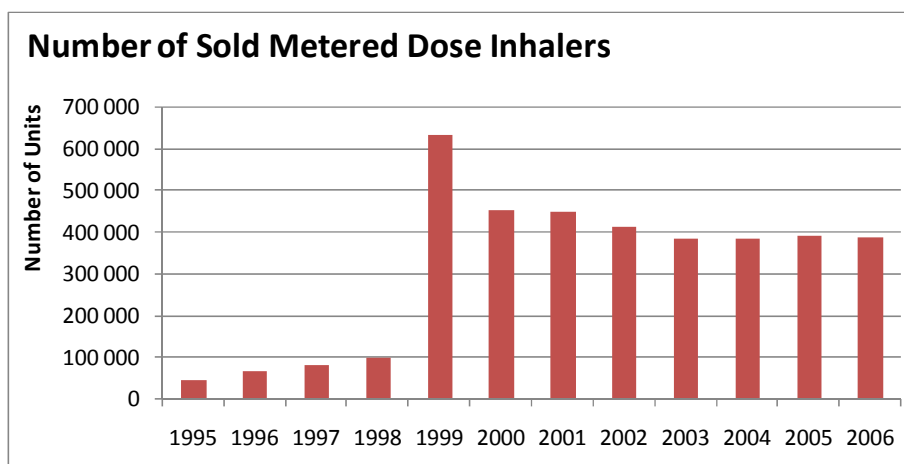
EMISSION FACTORS

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.

ACTIVITY DATA

Last year, a survey on inhalers was conducted with the support of “Infarmed” and pharmaceutical laboratories. Information was gathered on the amounts of sold inhalers charged with F-gases in the period 1995-2006. 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

FURTHER IMPROVEMENTS

More detailed information should be provided by manufacturers in the future, in order to obtain a better characterization of the inhalers market, specially to address the observed leap between inhalers sold at year 1998 and at year 1999.

UNCERTAINTY ANALYSIS

The uncertainty in MDI was assumed as 80 per cent, due to yearly changes.

4.1.A.14 FIRE PROTECTION

OVERVIEW

The most used equipments for fire protection in Portugal are the streaming (portable) ones. They contain HFC-23 and HFC-227ea gases.

METHODOLOGY

A Tier 2 comparable Top-Down approach from the IPCC Good Practice Guidance was considered.

$$\text{Emissions} = F\text{-gas}_{a.s.} - (F\text{-gas}_{n.e.} - F\text{-gas}_{r.e.})$$

Where:

$F\text{-gas}_{a.s.}$ – F-gas annual sales (ton)

$F\text{-gas}_{n.e.}$ – F-gas used to charge new fire protection equipments (ton)

$F\text{-gas}_{r.e.}$ – F-gas used to charge retiring fire protection equipments (ton)

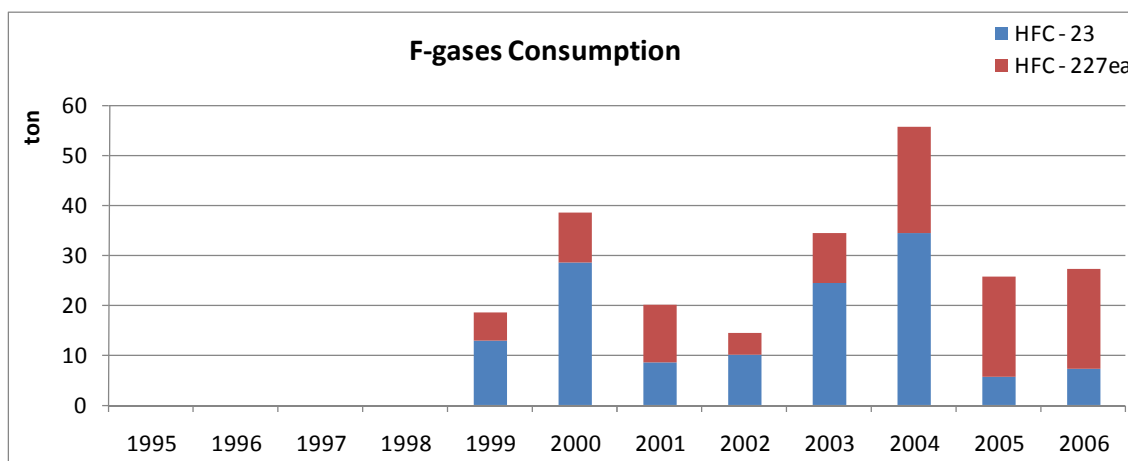
EMISSION FACTORS

It was assumed y equal to 99.99% and z equal to 99%. Annually, 4% of the existing equipments are dismissed.

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 Figure 4.37). 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 2005 and 2006 there is a decrease in consumption values associated to a market saturation.

Figure 4.37 – HFC consumption on Fire Extinguishing Equipments by type of gas (ton)



UNCERTAINTY ASSESSMENT

The uncertainty from fire protection equipment data was assumed as 20 per cent, given that only one company is importing these type 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 per cent. The final uncertainty value was set at 64 per cent.

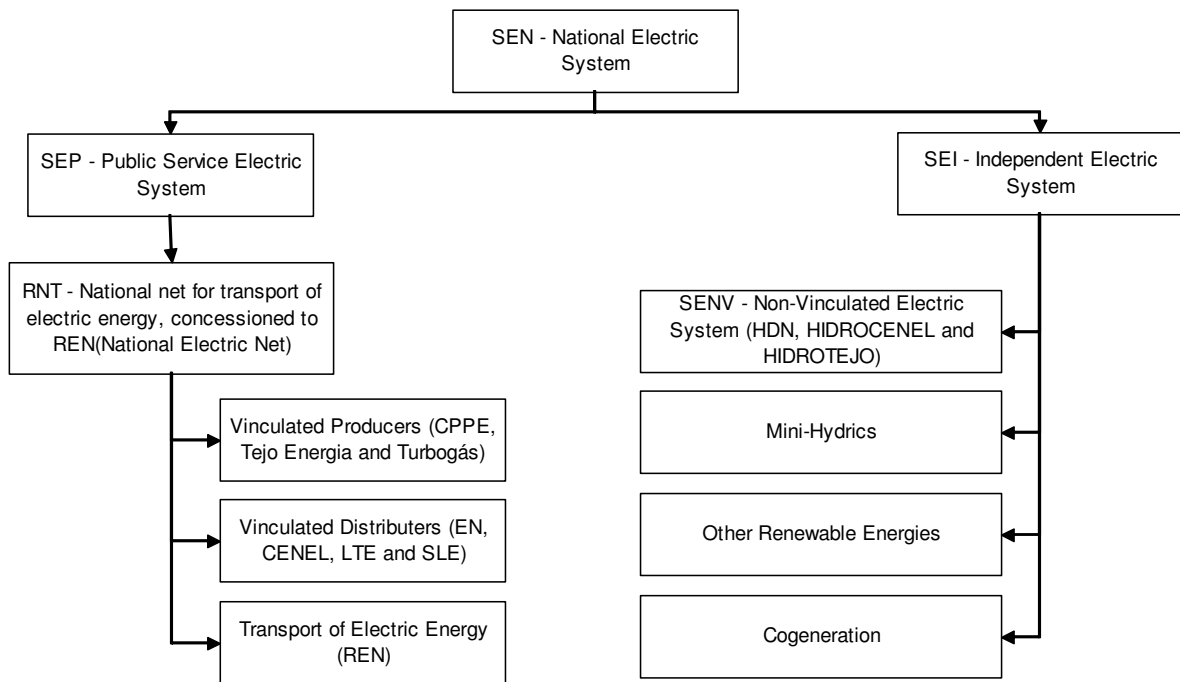
4.1.A.15 ELECTRIC EQUIPMENT

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



Source: REN – Rede Eléctrica Nacional (www.ren.pt)

METHODOLOGY

There are different estimates methodologies for:

- REN;
- EDP Distribuição, EDP Produção, Tejoenergia and Turbogás.

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.

$$n_i = \frac{P_i \cdot V}{R \cdot T_i} \cdot \frac{1}{Z_i}$$

$$n_f = \frac{P_f \cdot V}{R \cdot T_f} \cdot \frac{1}{Z_f}$$

$$m = (n_f - n_i) \cdot M$$

where:

T_i and P_i	- Measured Temperature and Pressure at the beginning of reposition of lost SF ₆ ;
T_f and P_f	- Measured Temperature and Pressure at the end of reposition of lost SF ₆ ;
R	- Gases Constant;
V	- Compartment volume filled with SF ₆ inside the equipment;
Z_i	- Compressibility Factor at Pressure P_i and Temperature T_i ;
Z_f	- Compressibility Factor at Pressure P_f and Temperature T_f ;
n_i	- Mole number of SF ₆ at pressure P_i and T_i before the reposition of gas;
n_f	- Mole number of SF ₆ at pressure P_f and T_f after the reposition of gas;
M	- SF ₆ molecular mass;
m	- SF ₆ 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.

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.

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.

EMISSION FACTORS

There are different emission factors for:

- REN;
- EDP Distribuição;
- EDP Produção;
- Tejoenergia;
- Turbogás.

REN

The database on SF₆ repositions by equipment was available for the period 2003-2006. For the period 1995-2002, an average of the estimated loss (0.38%) for the period 2003-2006 was considered.

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”;

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 2000-2006. 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.

Tejoenergia and Turbogás

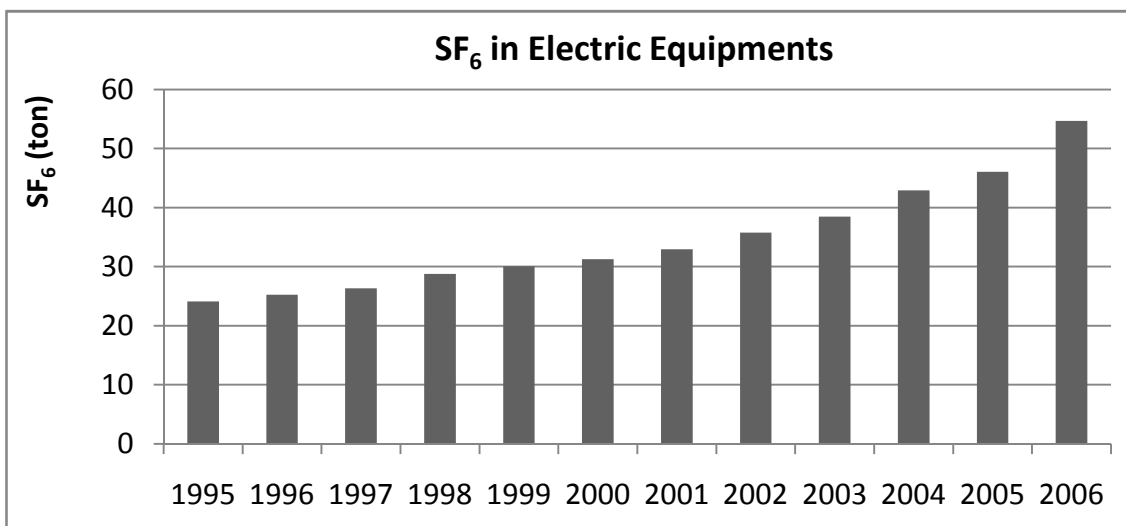
It is assumed by “Tejoenergia” and “Turbogás” expert judgment that all equipments are “Closed Pressure” and that the emission factor is 2.6%/year as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”.

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 Figure 4.40).

Table 4.33 – 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 (1995-2006)

UNCERTAINTY ASSESSMENT

The uncertainty of 15 per cent 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 per cent.

FURTHER IMPROVEMENTS

Further improvements should be addressed by EDP Distribuição in order to obtain better quality activity data.

CHAPTER: 5 : SOLVENT AND OTHER PRODUCT USE (CRF 3)

5.1 Overview

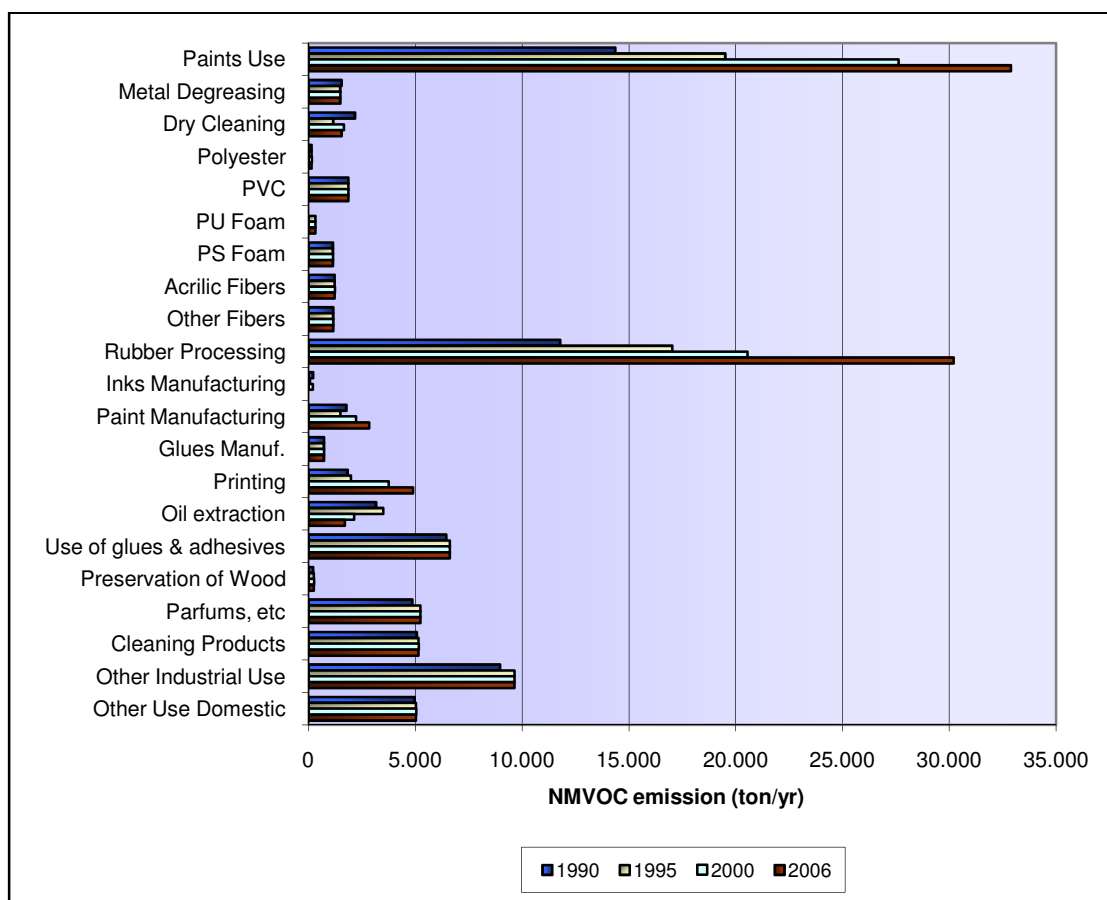
Solvents and related compounds are a significant source of emissions of non-methane volatile organic compounds (NMVOC). It is the conversion, in the atmosphere, of the organic compounds with fossil origin to carbon dioxide that is contributing to emissions of greenhouse gases.

Although emissions of N₂O should also be included in this source, if resulting from use of this compound as component in specific applications, estimate for these sources are still under work. 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.

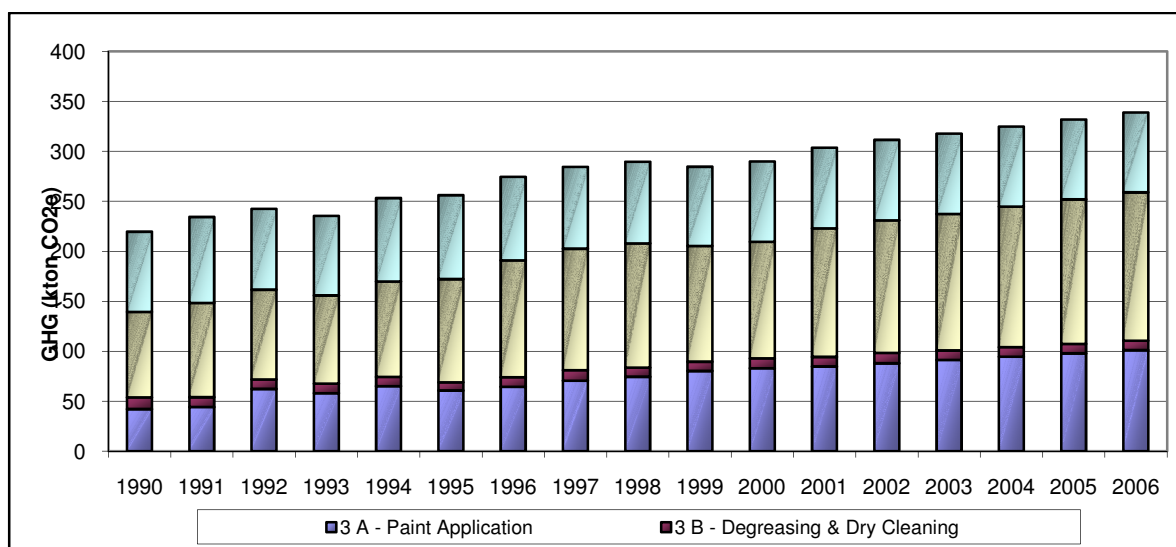
The dominant sources of NMVOC from this sector in Portugal during the period 1990-2004 were Paint Application, Chemical Products Manufacture and Processing and other solvent use, while Degreasing and Dry Cleaning also contribute to emissions at a smaller scale. This may be seen in Figure 5.1, where the importance of emissions of NMVOC is shown in detail for years 1990, 1995, 2000 and 2006. From there it is evident the prevalence of emissions from paint use, rubber processing and other use of solvent products, and the substantial increase in emissions that was observable for use of paints and rubber processing.

Figure 5.1 - NMVOC emissions from Solvent Use per individual source category in 1990, 1995, 2000 and 2006



Total GHG emissions from this source sector have increased steadily in the period from 1990 to 2006, from 220 kton of CO₂ in 1990 (which is only 0.51 per cent of total CO₂ emissions or 0.36 per cent of total GWP CO₂e) to 339 kton CO₂ eq. in 2006 (0.43 per cent of total GHG emissions in CO₂e), which represents an increase of 54.3 per cent. All emissions, quantified as carbon dioxide, are presented in Figure 5.2 per sub-source sector.

Figure 5.2 - GHG emissions from Solvent Use per source sub-sector (1990-2006)



Recalculations

No major changes were made for this source sector (Figure 5.3).

Figure 5.3 - Differences between 2007 and 2008 submissions for CO₂ emissions from solvent use

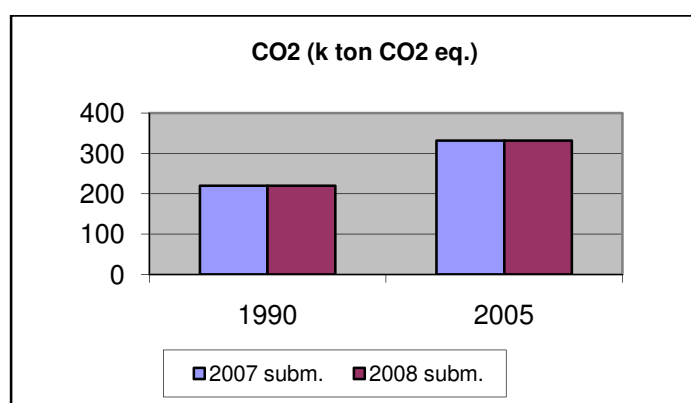


Table 5.1 - Recalculations of emissions from solvent use: differences between 2007 and 2008 submissions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)
	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)
1990									
3. Solvent and Other Product Use	219.71	219.71	0.00				NE,NO	NE,NO	
2005									
3. Solvent and Other Product Use	332.09	332.09	0.00				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).

General Methodological Issues

NMVOC emissions estimates must be converted in CO₂ emissions whenever the carbon that is present in organic compounds has fossil fuel origin (originated from feed-stocks 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.

Therefore, in general terms in except for the cases where a specific methodology is presented, emission of ultimate CO₂ were calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory as CO₂e.

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

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

Category Sectors

Paint Application (CRF 3A)

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 appearance⁸⁴ – 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 5.2.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, however, because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

METHODOLOGY

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from use/application of coating substances during year y (ton/yr);



Bibliography



Key Categories



Uncertainty

⁸⁴ 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.

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).

EMISSION FACTOR

Emission factors for NMVOC were made equal to solvent content of paints, which were established as expert guess from information collected from two of the biggest paint sellers in Portugal⁸⁵.

Table 5.2 - Solvent content of paints consumed in Portugal

Paint Type	Resin/ polymer	Solvent (%)
Water Based	Acrilic & Vinyl	1.5
	Alkyd & Other	1.5
Solvent Based	Acrilic & Vinyl	90
	Acrylic & Vinyl low solvent content	47
	Polyester	39
	Alkyd, celulosic & Other	51
Oil Paints, Powder Paints		0
Other Paints		29

These specific emission factors were applied to the total consumption of paint, irrespective of the application where it is used, and average emission factors were hence determined for water

⁸⁵ Information from CIN and DYRUP. Original detailed information was given in ranges of solvent content and other paint classes and it can not be published due to confidential constraints. Choice of representative solvent content and correspondence of paint classes was done at IA

based paint, solvent based paint and other paints. The resulting emission factors, that were in fact used to estimate emissions for each economic activity, are presented in next table.

Table 5.3 – Average NMVOC emission factors from use of Paints

Paint Type	NMVOC EF
	(kg/ton Paint)
Water Based	1.5
Solvent Based	51
Oil and Powder Paints	0
Other Paints	29

there are small annual variations, although smaller than 1 kg/ton

ACTIVITY DATA

For most activities in Portugal there is no available and reliable statistical information concerning the use of paints. 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:

$$\text{Total}_{\text{Cons}(y,p)} = \text{Production}_{(y,p)} + \text{Imports}_{(y,p)} - \text{Exports}_{(y,p)}$$

where:

$\text{Total}_{\text{Cons}(y)}$ - Consumed paint and varnish of type p in year y (ton/yr);

$\text{Production}_{(y,p)}$ - National Produced paint and varnish of type p in year y (ton/yr);

$\text{Imports}_{(y,p)}$ - Imported paint and varnish of type p in year y (ton/yr);

Exports_(y,p) - Exported paint and varnish of type p in year y (ton/yr).

The most detailed level desegregation per paint type that was possible to achieve was dependent, however on the fact that the statistical classes available for production data were dissimilar from the classes that are used for external trade. Annual production of paints by paint type⁸⁶, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 5.4 and Table 5.5.

Table 5.4 – Paint Production in Portugal by Paint Type in ton/yr (1990-1997)

Type	Polimer	1990	1991	1992	1993	1994	1995	1996	1997
Water	Acrylic & Vinyl	0	0	76 811	64 714	72 375	66 924	80 693	89 371
	Alkyd & Other	0	0	32	22	20	17	14	3
	Other	78 380	81 619	211	118	98	102	1 181	1 397
Solvent	Acrylic & Vinyl	0	0	248	48	23	76	134	136
	Acrylic & Vinyl Low solvent content	0	0	0	0	0	63	439	743
	Alkydic	0	0	13 013	10 622	10 946	10 956	12 941	12 984
	Celulosic	7 579	7 215	5 663	5 552	5 242	3 679	4 343	4 367
	Polyester	0	0	2 155	1 688	1 315	890	1 810	1 849
	Other	13 981	13 367	10 937	8 659	8 639	9 865	12 028	13 171
Oil		14 789	13 800	318	364	353	392	430	423
Powder		2 069	2 542	2 896	2 889	3 269	3 747	3 618	3 843
Other		1 164	1 357	37	2 181	2 133	2 363	2	68

Source: INE;
included as other

⁸⁶ No distinction is made of end use (Wood industry, construction industry, etc) neither is made according to paint being paint, varnish, primers, enamels or lacquers, which differentiation is available at original databases

Table 5.5 – Paint Production in Portugal by Paint Type in ton/yr (1998-2006)

Type	Polymer	1998	1999	2000	2001	2002	2003	2004	2005	2006
Water	Acrylic & Vinyl	103 585	99 909	102 718	108 629	113 530	118 431	123 333	128 234	133 135
	Alkyd & Other	0	41	0	6	4	2	0	0	0
	Other	1 639	671	1 883	1 872	2 084	2 296	2 508	2 720	2 933
Solvent	Acrylic & Vinyl	562	535	546	572	635	698	761	825	888
	Acrylic & Vinyl Low solvent content	2 089	2 476	2 335	2 707	3 068	3 428	3 789	4 149	4 509
	Alkydic	12 131	11 050	13 269	12 549	12 661	12 772	12 884	12 996	13 108
	Celulosic	4 401	3 971	3 144	3 167	2 903	2 640	2 376	2 112	1 849
	Polyester	2 873	3 620	4 247	3 792	4 096	4 400	4 704	5 008	5 312
	Other	13 515	14 840	12 953	14 928	15 589	16 250	16 911	17 572	18 233
Oil		539	556	588	612	647	681	715	750	750
Powder		4 706	5 846	5 759	6 004	6 392	6 781	7 169	7 557	7 557
Other		364	310	399	399	399	399	399	399	399

Source: INE;
included as other

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 5.6 and Table 5.7, respectively for imports and exports.

Table 5.6 –Import of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Water	Acrylic & Vinyl	538	957	1 705	907	2 760	3 411	3 262	2 696	3 081	2 240	1 983
	Alkyd & Other	1 204	1 731	1 789	2 151	3 357	6 493	7 924	8 661	9 066	8 751	10 104
Solvent	Acrylic & Vinyl	78	78	80	102	1 365	440	568	424	359	462	383
	Acrylic & Vinyl Low solvent	1 036	920	970	3 007	4 129	4 597	5 948	4 526	6 339	5 331	6 031
	Polyester	890	1 302	1 695	2 298	3 010	3 560	3 274	4 235	4 956	5 059	6 301
	Alkyd, celulosic & other	3 813	5 098	5 523	5 509	7 169	6 345	6 638	8 165	7 796	9 966	10 229
Oil		91	141	326	199	148	223	216	264	291	234	157
Other		31	111	123	257	48	15	17	11	24	186	247

Source: INE;

Table 5.7 –Export of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Water	Acrylic & Vinyl	387	519	858	424	519	103	435	492	183	419	503
	Alkyd & Other	783	963	1 206	980	1 439	2 020	1 717	2 547	2 082	3 396	4 649
Solvent	Acrylic & Vinyl	0	1	3	2	1	1	1	2	3	0	4
	Acrylic & Vinyl Low solvent	2 084	2 289	1 659	1 579	1 399	806	1 343	1 126	1 606	1 089	856
	Polyester	908	1 085	761	705	2 658	3 228	5 342	4 439	8 464	7 055	6 755
	Alkyd, celulosic & other	499	395	663	840	808	1 707	3 538	2 829	1 972	1 482	794
Oil		91	516	341	523	610	468	157	213	140	316	91
Other		31	158	32	113	275	242	107	266	39	45	90

Source: INE;

Thus, total consumption of paints was calculated from 1990 and 2000, and the resultant time series is presented in Table 5.8, Table 5.9 and in Figure 5.4. Values for 2001 to 2006 were forecasted by APA from the available time series of paint consumption.

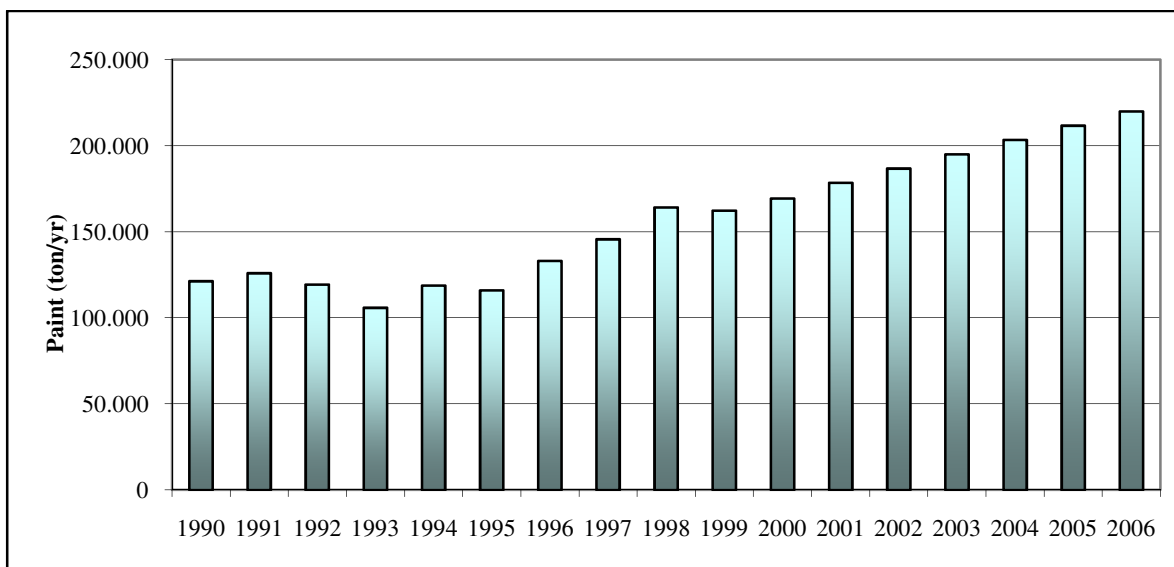
Table 5.8 –Estimated total consumption of Paints in Portugal by Paint Type (1990-1997)

Type	Polimer	1990	1991	1992	1993	1994	1995	1996	1997
Water	Acrylic & Vinyl	151	438	77 658	65 196	74 616	70 233	83 520	91 575
	Alkyd & Other	78 800	82 388	826	1 311	2 036	4 593	7 401	7 514
Solvent	Acrylic & Vinyl	78	77	326	149	1 388	514	701	558
	Acrylic & Vinyl Low solvent	0	0	0	1 428	2 730	3 853	5 043	4 142
	Polyester	0	217	3 090	3 280	1 667	1 222	0	1 646
	Alkyd, celulosic & other	24 873	25 286	34 473	29 503	31 187	29 138	32 412	35 857
Oil		14 363	13 601	122	0	33	457	433	547
Powder		2 069	2 542	2 896	2 889	3 269	3 747	3 618	3 843
Other		1 037	1 436	48	2 164	1 939	2 271	0	39
Total		121 371	984	119 438	920	118 866	116 029	133 129	145 721

Table 5.9 –Estimated total consumption of Paints in Portugal by Paint Type (1998-2006)

Type	Polimer	1998	1999	2000	2001	2002	2003	2004	2005	2006
Water	Acrylic & Vinyl	106 483	101 730	104 198	111 204	116 218	121 232	126 246	131 260	136 274
	Alkyd & Other	8 624	6 067	7 337	9 780	10 720	11 660	12 600	13 540	14 481
Solvent	Acrylic & Vinyl	918	996	925	1 057	1 124	1 191	1 259	1 326	1 394
	Acrylic & Vinyl Low solvent	6 821	6 718	7 510	8 781	9 688	10 594	11 500	12 407	13 313
	Polyester	0	1 624	3 794	1 392	1 307	1 223	1 139	1 054	970
	Alkyd, celulosic & other	35 871	38 345	38 801	38 948	39 946	40 945	41 944	42 943	43 941
Oil		514	699	554	780	861	942	1 024	1 105	1 105
Powder		4 706	5 846	5 759	6 004	6 392	6 781	7 169	7 557	7 557
Other		343	406	576	576	576	576	576	576	576
Total		164 281	162 433	169 453	178 521	186 833	195 145	203 457	211 768	211 768

Figure 5.4 - Total consumption of Paints in Portugal (1990-2006)



Total consumption of paint was also 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 5.10 and Table 5.11. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction⁸⁷, as well as all use of oil and powder paints.

⁸⁷ No further desagregation by this uses is possible from available statistical information

Table 5.10 - Paint and varnish consumption in industrial activities (1990-1997)

Activity	Tipo de Tinta	1990	1991	1992	1993	1994	1995	1996	1997
Wood	Water	15	13	97	182	266	681	783	887
Plastic, cables		8	19	1 026	2 033	3 040	2 449	2 881	230
Glass and Ceramics		31	33	22	11	0	0	0	0
Metalic Equipment and furniture		0	0	0	0	0	0	0	0
Vehicles		0	0	0	0	0	0	0	0
Other machinery		35	33	22	11	0	2	46	53
Domestic, Services and Construction		78 862	82 728	77 317	64 271	73 347	71 694	87 211	97 920
Wood	Solvent	0	0	0	0	0	0	0	0
Plastic, cables		0	0	0	0	0	0	0	0
Glass and Ceramics		0	0	0	0	0	0	0	0
Metalic Equipment and furniture		838	996	664	332	0	0	1	1
Vehicles		1 581	1 242	836	430	24	28	630	690
Other machinery		476	444	1 936	3 428	4 920	5	12	11
		22 056	22 898	34 453	30 170	32 029	34 695	37 514	41 501
Domestic, Services and Construction	Oil	14 363	13 601	122	0	33	457	433	547
	Powder	2 069	2 542	2 896	2 889	3 269	3 747	3 618	3 843
	Other Paints	1 037	1 436	48	2 164	1 939	2 271	0	39

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by APA

Table 5.11 - Paint and varnish consumption in industrial activities (1998-2006)

Activity	1998	1999	2000	2001	2002	2003	2004	2005	2006
Wood	794	887	1 047	1 205	1 321	1 436	1 551	1 666	1 781
Plastic, cables	337	597	625	1 180	1 176	1 172	1 168	1 164	1 160
Glass and Ceramics	64	61	161	82	90	98	106	114	122
Metalic Equipment and furniture	0	0	0	0	0	0	0	0	0
Vehicles	0	0	0	0	0	0	0	0	0
Other machinery	84	92	93	89	97	104	112	119	127
Domestic, Services and Construction	113	106	109	124	130	130	135 910	141 737	147 564
	828	161	609	118 428	255	082			
Wood	0	0	0	0	0	0	0	0	0
Plastic, cables	0	0	0	0	0	0	0	0	0
Glass and Ceramics	0	0	0	0	0	0	0	0	0
Metalic Equipment and furniture	3	36	34	34	34	34	34	34	34
Vehicles	735	685	1 874	799	800	800	801	801	802
Other machinery	16	16	23	23	23	23	23	23	23
	42 857	46 946	49 099	49 321	51 209	53 096	54 984	56 872	58 759
Domestic, Services and Construction	514	699	554	780	861	942	1 024	1 105	1 186
	4 706	5 846	5 759	6 004	6 392	6 781	7 169	7 557	7 945
	343	406	576	576	576	576	576	576	576

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by APA

UNCERTAINTY ASSESSMENT

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 per cent and the error for solvent based paints is 67 per cent. The overall uncertainty value for CO₂/NMVOC emission factor is therefore calculated to be 261 per cent for all uses of paint.

There is a great uncertainty associated with the activity data due to the fact that was estimated at IA from production data and importation and exportation. An overall uncertainty value of 30 per cent may be assumed.

RECALCULATIONS

No substantial modifications have been made in emission estimates from this source sector since last year's submission.

FURTHER IMPROVEMENTS

In future, particularly after 2007, emissions factors must take account of the procedures set in each economic sector for the reduction of NMVOC emissions from paint use, including the control of the solvent content of paint and varnishes. In fact nowadays some control measures and low solvent content paints are already being applied in some economic activities - for instance in the car building industry – but no comprehensive information allows introduction of this level of detail in emission estimates. Therefore, efforts will be done in order that more detailed information from these sectors is collected and incorporated in the emission inventory.

Degreasing and dry cleaning (CRF 3B)

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, rubber⁸⁸, 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.

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



Bibliography



Key Categories



Uncertainty

⁸⁸ Emissions from degreasing in this industry are included under rubber processing

consumption of solvents in an economic activity is used to replenish the quantity of solvent that was lost, then annual NMVOC emissions may be estimated from the annual consumption of solvent. This methodology overcomes the need of being aware of the portion of solvent that is recovered.

In the case of the dry-cleaning activity it was assumed that either the solvent is lost directly to atmosphere, or if it is conveyed to water or retained in clothes, but it will eventually reach atmosphere by evaporation.

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several sources (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

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 5.12, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

Table 5.12 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	1992-2006
Metal Degreasing	1 552	1 415	1 484

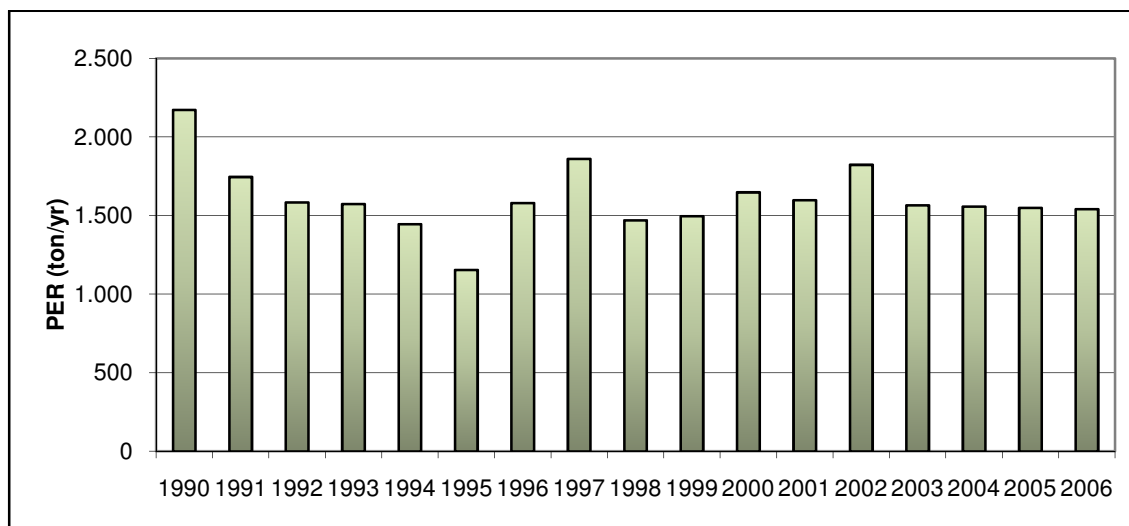
Source:IAIT industrial survey (INE)

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)⁸⁹ imported to

⁸⁹ 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.

Portugal is used in dry-cleaning⁹⁰ activity and that all PER that is 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 Figure 5.5.

Figure 5.5 – Annual importation/ consumption of PER (Tetra-chloro-ethylene) in Portugal (ton/yr) 1990-2006



Source: INE (1990-2002); Forecast by APA thereafter



Bibliography



Key Categories



Uncertainty

⁹⁰ There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

UNCERTAINTY ASSESSMENT

The time trend of activity data for metal degreasing is very incomplete and an uncertainty of 100 per cent 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 per cent was used (USEPA). The uncertainty of emissions from both sectors are fully considered under activity data.

RECALCULATIONS

No changes were made in emission estimates from this source sector since last submission.

FURTHER IMPROVEMENTS

A better knowledge of this sector should be achieved, namely to verify if other solvents are also used and in which quantities. Alternative methodologies, based on washed cloths and type of cleaning equipment should be also done, and results compared to the estimates that are now reported.

Chemical products, manufacture and processing (CRF 3C)

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.

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)

A. 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 non-methane volatile organic compounds 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.

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.

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 5.13 – Emission factors of NMVOC from Polymer Processing

Material	Polymer	NMVOC
Synthetic Fibers	Rayon	0 ^(a)
	Poliamides	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)

UNCERTAINTY ASSESSMENT

The uncertainty in activity data was considered high, 100 per cent, expressing the reduced number of available years. Although an uncertainty of 50 per cent 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.

B. RUBBER PROCESSING

METHODOLOGY

Assuming that all solvents consumed during rubber processing evaporate, NMVOC emission will be equal to the amount of solvents used. This procedure could be used to estimate emissions for years 1990 and 1991. However, because statistical data on solvent consumption

in this sector is not available beyond year 1992, NMVOC emissions had to be estimated from quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = \text{Solvent (y)} = \sum_p [S_{Fac(p)} * Proc_{RUBBER(p,y)}] * 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from rubber processing (ton/yr);

Solvent (y) – Total solvent use in rubber processing (ton/yr);

$S_{Fac(p)}$ – Quantity of solvent used to produce product p, either in kg/unit or kg/ton;

$Prod_{RUBBER(p,y)}$ – Production of rubber product p in year y. Units vary according to product either number/yr to ton/yr.

EMISSION FACTORS

The emission factor, or solvent use factor, that was used to estimate solvent consumption after 1992 was derived from the statistical information available from IAIT for this sector for years 1989 to 1991, which is reproduced in Table 5.14. From the several materials that were consumed in this activity only Benzene and Gasoline were considered solvents and prone to evaporation.

Table 5.14 – Statistical information used to establish solvent use factors in the rubber processing industry, in Portugal

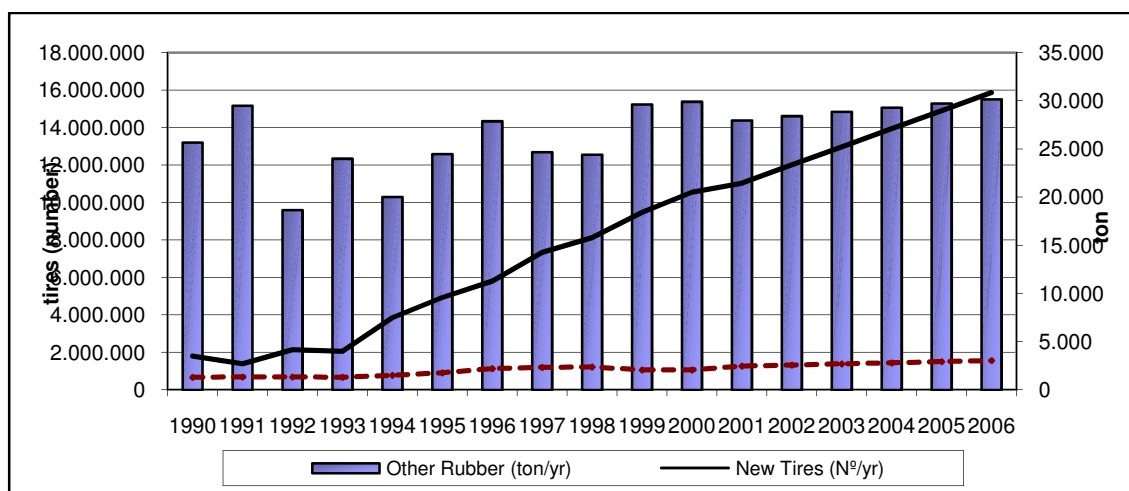
Product	Unit	1989	1990	1991	SFac
New Tires	nº	4 201			
Reconstructed Tires		941	1 796 201	1 378 575	
Other rubber products	ton	969 972	663 772	689 342	
		19 272	25 687	29 502	
New Tires	ton of solvent	615	312	155	
Reconstructed Tires		11 579	11 180	12 851	
Other rubber products		766	285	244	
New Tires	kg/Tire	0.146	0.174	0.112	0.143
Reconstructed Tires		12	17	19	18
Other rubber products	kg/ton	40	11	8	10

Source: Production and use of solvent from INE – IAIT industrial survey.

ACTIVITY DATA

Production data of rubber artefacts, including tires and tire reconstruction, was available from the IAIT and IAPI industrial surveys from INE. The aggregated values, collected from original INE's database, are reported in Figure 5.6.

Figure 5.6 - Processed rubber products in Portugal (1990-2006)



Source: INE (1990-2000); APA's forecasts thereafter

UNCERTAINTY ASSESSMENT

The uncertainty in activity data seems comparatively small and a value of was used. There is however a great uncertainty in the country-specific emission factors, particularly the high levels of consumption of solvent for each tyre reconstructed. Consequently an order of magnitude was attributed to uncertainty of emission factors.

RECALCULATIONS

No modifications were made in this source sector since last submission.

PAINTS MANUFACTURING

ACTIVITY DATA

Production of paints and varnish in Portugal was already presented in chapter 5.2 – Paint Application.

EMISSION FACTORS

The USEPA (1983) emission factor was used - 15 kg for each tone of paint or varnish manufactured, that includes emissions during cleaning of installations and applies to production of all coating materials. This emission factor was applied to the total value of paint and varnish produced in Portugal irrespective of type.

UNCERTAINTY ASSESSMENT

An uncertainty of 10 per cent 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 per cent.

RECALCULATIONS

No modifications were made in this source sector since last submission.

D. INKS MANUFACTURING

ACTIVITY DATA

Statistical data of annual production of inks in Portugal is available from IAIT and IAPI industrial surveys (INE), for years 1990 through 2000. Linear forecast values were considered for subsequent years. Production of inks is presented in Table 5.15 and Table 5.16 by ink type.

Table 5.15 – Production of inks in Portugal, by type of ink (ton/yr) (1990-1997)

Ink	1990	1991	1992	1993	1994	1995	1996	1997
Lithographic	1 122	1 064	135	45	69	60	448	272
Newspaper ink	318	185	0	0	0	0	0	0
Rotogravure	654	406	0	0	0	0	0	0
Flexography	880	999	119	119	907	1 084	2 025	1 928
Serigraphy	31	26	0	0	0	0	0	0
Drying by physical reaction	482	462	0	0	0	0	0	0
Other	40	51	99	47	50	22	109	17
Total	3 528	3 193	353	212	1 027	1 166	2 582	2 216

Source: INE (1990-2000); Forecast by APA (2001-2006)

Table 5.16 – Production of inks in Portugal, by type of ink (ton/yr) (1997-2006)

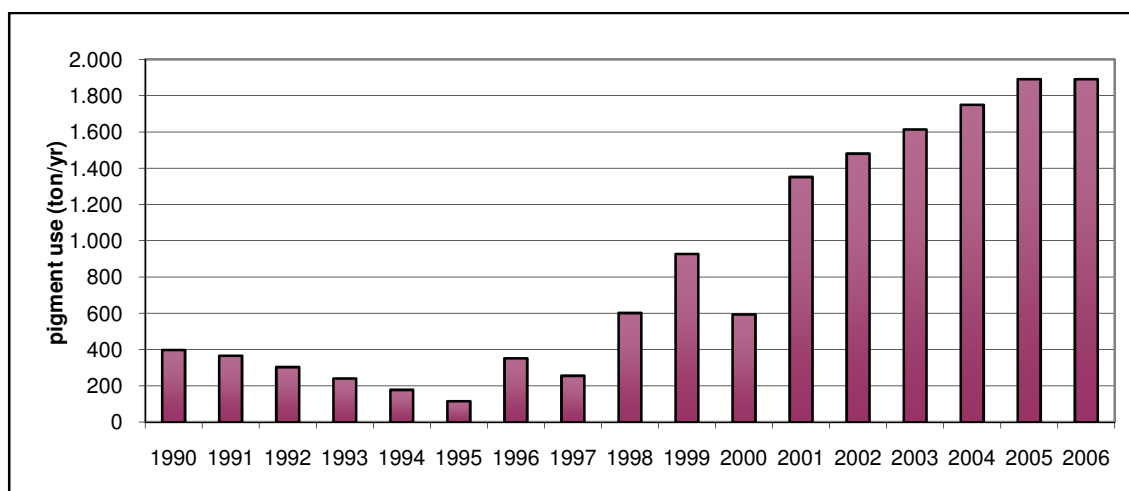
Ink	1998	1999	2000	2001	2002	2003	2004	2005	2006
Lithographic	266	213	175	175	175	175	175	175	175
Newspaper ink	0	0	0	0	0	0	0	0	0
Rotogravure	0	0	0	0	0	0	0	0	0
Flexography	2 039	1 663	3 008	2 640	2 857	3 073	3 289	3 506	3 506
Serigraphy	0	0	1	1	1	1	1	1	1
Drying by physical reaction	0	0	0	0	0	0	0	0	0
Other	11	0	82	82	82	82	82	82	82
Total	2 316	1 875	3 266	2 899	3 115	3 331	3 548	3 764	3 764

Source: INE (1990-2000); Forecast by APA (2001-2006)

IRON ONLY

Use of pigments in ink production was also available from INE's database. Total pigment consumption is presented in Figure 5.7.

Figure 5.7 – Total pigment consumed in ink manufacturing in Portugal from 1990 to 2006



Source: INE

EMISSION FACTORS

The NMVOC emission factor that was used, 60 kg for each tone of ink manufactured, refers to vehicle coking and applies to general ink type, is from USEPA (1983).

Particulate emissions during ink manufacturing were also estimated using an emission factor of 1 kg/ton pigment used (USEPA,1983).

UNCERTAINTY ASSESSMENT

An uncertainty of 10 per cent was considered for the activity data. In the original document the emission factors are reported to have a E rate quality, which translated in uncertainty value represents 1000 per cent.

RECALCULATIONS

No modifications were made in this source sector since last submission.

E. GLUES MANUFACTURING

ACTIVITY DATA

Production of glues and adhesives in Portugal is available in Portugal for years 1990 and 1991 from INE. Average values were considered for subsequent years. Production of glues and adhesives is reported in chapter 5.5.

EMISSION FACTORS

The CORINAIR emission factor was adopted - 20 kg for each tone of glues and adhesives manufactured, which is applied to all kind of glues and adhesives, with or without solvents in their composition, and includes the cleaning of industrial installations.

UNCERTAINTY ASSESSMENT

An uncertainty of 100 per cent was considered for the activity data, considering the lack of information, only available to some restricted years, to build a reliable time-series.

A high uncertainty in the emission factor lead, in similarity to what was done for inks manufacturing, to the choice of a uncertainty value of 1000 per cent.

RECALCULATIONS

No modifications were made in this source sector since last submission.

Other use of solvents and related activities (CRF 3D)

OVERVIEW

In this chapter are included emission calculations for different activities, such as:

- 1) printing;
- 2) edible and non edible oil extraction;
- 3) use of glue and adhesives;
- 4) preservation of wood;
- 5) other solvents use;
- 6) use of perfume;
- 7) use of waxes and polishing products;
- 8) use of soaps and detergents.

A. PRINTING

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).

METHODOLOGY

$$Emi_{NMVOC(a,p,y)} = \sum_p \sum_t \sum_i [EF_{(i)} * INK_{CONS(p,i,t,y)}] * 10^{-3}$$

Where

$E_{iNMVOC(y)}$ – NMVOC emissions resulting from printing activities during year y (ton/yr);

$Ink_{CONS(p,i,t,y)}$ – Use of ink i for printing product p using technology t during year y (ton coater/yr);

$EF_{(p)}$ – Emission Factor (solvent content) of ink i (kg/ton).

EMISSION FACTORS

NMVOC emission factors reflect solvent content of ink, assuming that all solvents contribute to volatile organic compounds, and that control equipment for emissions are not widespread and representative. Solvent content of ink are from USEPA (1981) and are presented in Table 5.17⁹¹.

Table 5.17 – Solvent content and emission factors used in Printing Industry (kg/ton ink consumed)

Product	Technology	Solvent Content ok ink (%)	density of solvent (kg/l)	EF kg/ton ink
Newspaper	Web Offset Lithography	5	0.74	37
	Letterpress	0		0
Books	Web Offset Lithography	40		297
Publications	Rotogravure	75		557
Packaging	Flexography	75		557
Artifacts	Flexography	75		557
Other		-		334

Source: USEPA (1981)



Bibliography



Key Categories



Uncertainty

⁹¹ USEPA (1981) differentiates emissions during printing from those remaining in product. In the Portuguese inventory all solvents are assumed to emit NMVOC

ACTIVITY DATA

Consumption of inks in printing industry according to printing product is available from IAPI industrial survey, for years 1995 to 2000, from the INE's statistical database, which is summarized in Table 5.18.

Table 5.18 – Consumption of inks in industry by press product (ton/yr)

Industry	Product	1995	1996	1997	1998	1999	2000
Press	Newspaper	908	662	566	514	568	567
	Books	105	139	171	256	191	146
	Magazines & Other	19	24	16	57	109	146
	Packaging	1 062	1 228	1 280	1 234	1 350	1 646
	Other	2 513	3 113	3 312	3 548	3 822	4 003
Textile industry		0	0	0	0	0	58
Other	Artefacts	766	1 522	1 685	1 877	1 965	2 330

Source: IAPI, INE

Original data allows that total consumption of inks – but not its type – be divided by printing products. Data printing activities in other economic activities – metallic industry, plastic industry, ceramic and - is also included. Some assumptions were made concerning what technology was used for each press product, i.e.:

- newspapers are printed using web letterpress or web offset lithography, according to national sales of ink;
- books printing uses lithography;
- Magazines and other publications use rotogravure;
- Packages and metallic, plastic and other artefacts use flexography;
- serigraphy technology is used in textile processes.

For years in the period from 1990 to 1994, consumption of inks had to be estimated from national production and external trade, which is presented in Table 5.19, and according to:

$$\text{Total}_{\text{Cons}(y)} = \text{Production}_{(y)} + \text{Imports}_{(y)} - \text{Exports}_{(y)}$$

where:

$\text{Total}_{\text{Cons}(y)}$ - Total consumption of inks in year y (ton/yr);

$\text{Production}_{(y,p)}$ - National Produced inks in year y (ton/yr);

$\text{Imports}_{(y,p)}$ - Imported inks in year y (ton/yr);

$\text{Exports}_{(y,p)}$ - Exported quantity of inks in year y (ton/yr).

Because external trade classifies inks in a single class, the more detailed desegregation of inks, available for production of inks (Chapter 5.2.3), could not be used, and only total ink

consumption could be assessed. The same proportion of technologies/products in 1995 was used to separate total inks consumption for the years between 1990 and 1994.

Table 5.19 - Production and External Trade of inks in 1990-1994 (ton)

Year	1990	1991	1992	1993	1994
National Production	3 528	3 193	353	212	1 027
Importation	1 481	1 745	2 705	2 720	3 051
Exportation	65	71	58	34	35
Consumption	4 944	4 868	3 000	2 898	4 044

Source: INE

Final consumption of inks per technology type is synthesized in Table 5.20 and Table 5.21. Values for 2001 to 2005 are forecasts made by APA from the previous time series.

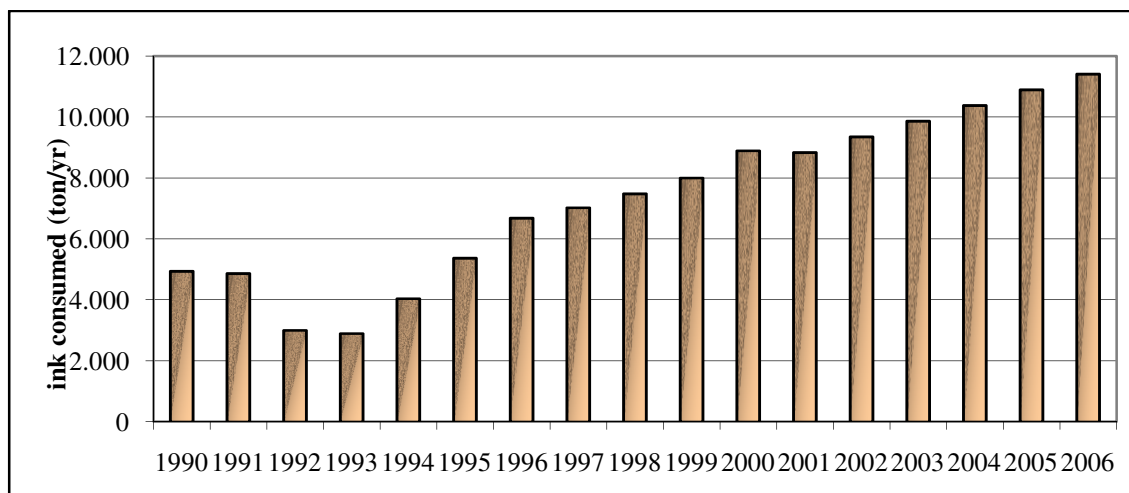
Table 5.20 – Consumption of inks by printing technology and press product (1990-1997)

Technology	Product	1990	1991	1992	1993	1994	1995	1996	1997
Web Offset Lithography	Newspaper	701	691	426	411	574	762	548	467
Letterpress		3	3	2	2	3	4	5	3
Web Offset Lithography	Books	100	98	60	58	81	108	141	174
Rotogravure	Publications	18	18	11	11	15	20	24	16
Flexography	Packages	1 008	993	612	591	825	1 095	1 250	1 299
Flexography	Artifacts	727	716	441	426	595	790	1 550	1 710
Serigraphy	Fabric	0	0	0	0	0	0	0	0
Total		2 386	2 350	1 448	1 399	1 952	2 593	3 170	3 361

Table 5.21 – Consumption of inks by printing technology and press product (1998-2006)

Technology	Product	1998	1999	2000	2001	2002	2003	2004	2005	2006
Web Offset Lithography	Newspaper	422	466	465	430	412	394	376	358	339
Letterpress		11	21	27	20	22	24	26	28	30
Web Offset Lithography	Books	259	193	147	211	225	239	252	266	280
Rotogravure	Publications	58	110	147	105	115	126	137	147	158
Flexography	Packages	1 249	1 364	1 661	1 550	1 627	1 704	1 782	1 859	1 936
Flexography	Artifacts	1 899	1 986	2 351	2 350	2 541	2 733	2 925	3 117	3 308
Serigraphy	Fabric	0	0	59	21	24	27	29	32	35
Total		3 589	3 864	4 039	4 153	4 388	4 623	4 858	5 094	5 094

Figure 5.8 – Total inks consumption in Portugal (1990-2006)



UNCERTAINTY ASSESSMENT

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 per cent 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 per cent was considered, in conservative way.

RECALCULATIONS

No modifications were made to estimates of this source sector.

FURTHER IMPROVEMENTS

Although this source sector has suffered extensive modifications, efforts must continue in order to ameliorate emission estimates for this sub-source category. Key aspects are the improvement in consistency in the activity data time series and a better knowledge of printing processes that are used for each press product.

B. EDIBLE AND NON EDIBLE OIL EXTRACTION

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 olives⁹². 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.

Particulate matter is emitted as result of grain handling, cracking, dehulling and drying processes.

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:



Bibliography



Key Categories



Uncertainty

⁹² Classified as virgin olive oil

$$Emi_{NMVOC}(y) = MakeUp_{Solvents}(y)$$

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 85.71 percent of the mass emissions of NMVOC is carbon⁹³ 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.

$$U_{CO_2} = 44/12 * NMVOC * 0.8571$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

II ONLY

Particulate matter emissions are estimated from consumption of grain:

$$Emi_{PM}(y) = EF * Cons_{GRAIN}(y) * 10^{-3}$$

⁹³ Hexane chemical formula

where:

$Emi_{PM}(y)$ - Emissions of PM (ton/yr);

$Cons_{GRAIN}(y)$ - annual consumption of grain in the production of edible and non-edible oil industry (ton/yr);

EF – Emission factor (g/ton).

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 5.22, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole 1990-2004 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.

Table 5.22 – 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	
sum		207 150	201 569	220 672	
Edible	Solvent Use (ton)	2 328	1 763	1 697	
non-edible		1 394	1 257	1 408	
sum		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
sum		18.0	15.0	14.1	15.7

The emission factor for Particulate Material, 1.34 g/kg grain handled is from (USEPA,1995).

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 2001-2006 was forecasted by APA from previous years. All annual values are reported in Table 5.23, together with olive oil production, although that product does not cause NMVOC emissions. Total grain processed is also reported in Table 5.23 and Table 5.24. Total extraction of edible and non-edible oil is also shown in Figure 5.9.

Table 5.23 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1990-1997)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997
Olive Oil Production	10 253	9 883	8 368	16 948	25 269	27 691	36 404	31 839
Oil refining	201 569	220 672	184 406	161 998	222 430	223 330	208 116	174 686
Grain processed	672 382	668 734	662 759	691 625	791 687	1 042 605	969 983	982 574

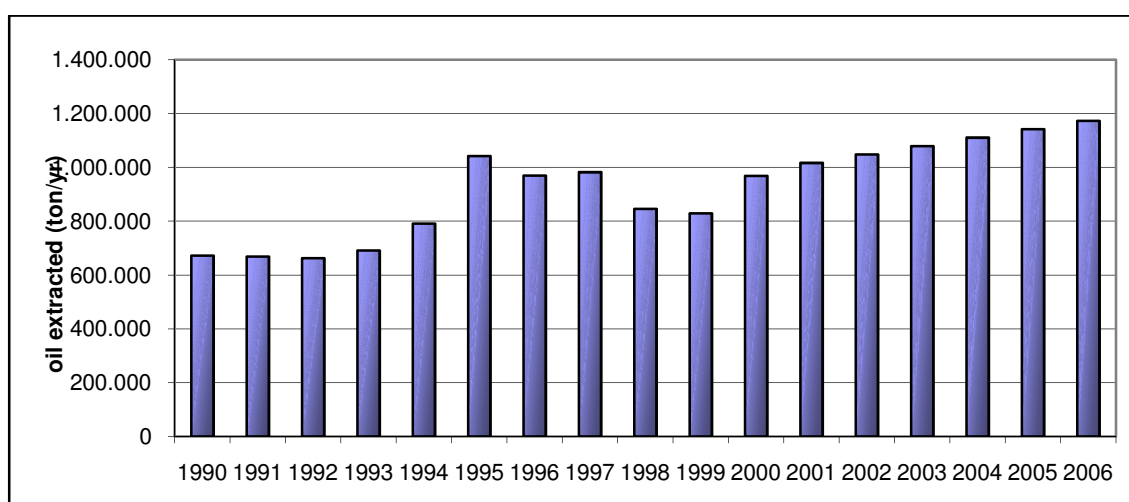
Source: National Statistics Institute (INE)

Table 5.24 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1998-2006)

Parameter	1998	1999	2000	2001	2002	2003	2004	2005	2006
Olive Oil Production	41 190	46 673	41 912	38 796	NA	NA	NA	NA	NA
Oil refining	168 580	122 263	136 230	142 748	135 869	128 989	122 110	115 230	108 351
Grain processed	846 161	829 526	968 898	1 017 147	1 048 385	1 079 623	1 110 861	1 142 098	1 173 336

Source: National Statistics Institute (INE)

Figure 5.9 – Total edible and non-edible oil extraction in Portugal (ton/yr)



UNCERTAINTY ANALYSIS

The activity data time trend is reasonably complete and an uncertainty of 10 per cent was considered. The uncertainty of NMVOC/CO₂ emission factor was established by comparison of the emission factors determined from the several available years: 26 per cent.

RECALCULATIONS

No modifications were made to estimates of emissions from this source since last submission.

C. GLUES AND ADHESIVES

METHODOLOGY

$$\text{NMVOC} = \text{Cons}_{\text{Nat}} \times \text{FE}_{\text{Nat}} + \text{Imp} \times \text{FE}_{\text{imp}}$$

where:

NMVOG = Global emissions of NMVOG (ton)

Cons_{Nat} = Consumption of Glues and Adhesives produced in Portugal (ton)

FE_{Nat} = Emission factor for Glues and Adhesives produced in Portugal (kg NMVOG/ton Ink)

Imp = Importation of Glues and Adhesives (ton)

FE_{imp} = Emission factor associated to 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 Produced Glues and Adhesives (ton)

Exp = Exported Glues and Adhesives (ton)

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 5.25 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5.26). 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 5.25 - 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 5.26 - 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 NMVOG emission.

ACTIVITY DATA

Table 5.27 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	1992 - 2006
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)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

D. WOOD PRESERVATION

OVERVIEW

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts and building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

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.

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.

ACTIVITY DATA

Table 5.28 - Wood preservation products consumption (ton)

Year	1990	1991	1992 - 2006
Wood Preservation products Consumption (ton)	2 083	2 900	2 491

Source: National Statistics Institute (INE)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

E. PERFUMES AND COSMETICS USE

METHODOLOGY

Perfumes, personal hygiene and cosmetic products. 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)

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:

$FE_{\text{Prod+use}}$ = 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 5.29 - Calculated emission factor (kg/ton).

1989	1990	1991	Average
162	170	184	172

ACTIVITY DATA

Table 5.30 - Activity data associated to Perfumes Use (ton)

Year	1990	1991	1992-2006
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)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

F. WAXES AND POLISHING PRODUCTS

METHODOLOGY

The Methodology is similar to the one that was used for Perfume Use.

EMISSION FACTORS

The national emission factor, obtained in the same mode, was (kg/ton):

Table 5.31 – Emission factors

1989	1990	1991	Average
525	299	293	372

ACTIVITY DATA

Table 5.32- Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2006
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)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

G. SOAPS AND DETERGENTS

METHODOLOGY

The Methodology is similar to the one that was used for Perfume Use.

EMISSION FACTORS

The national emission factor (kg/ton), obtained in the same mode kg/ton is:

Table 5.33 – Emission factors

1990	1991	Average
2	2	2

ACTIVITY DATA

Table 5.34 - Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2006
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)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

H. 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.

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.

ACTIVITY DATA

Industrial production of ethanol is presented in Table 5.35, which may be considered, neglecting foreign trades, equal to the consumption of alcohol. Industrial consumption of alcohol in 1989 is shown in Table 5.36 by use. Statistical data is from INE in both cases.

Table 5.35 - Industrial production of ethanol (ton).

1989	1990	1991
7 754	9 941	8 027

Table 5.36 - 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 5.37 and foreign trades values in Table 5.38. Statistical information is from the National Statistical Institute (INE).

Table 5.37- Rosin derivatives production (ton).

1989	1990	1991
13 362	12 145	11 299

Table 5.38 - Foreign trades of rosin derivatives (ton).

<i>Imports (ton)</i>		<i>Exports (ton)</i>	
1990	1991	1990	1991
722	700	11 558	13 692

I. OTHER USES OF SYNTHETIC SOLVENTS FROM FOSSIL FUELS

METHODOLOGY

NMVOC = 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:

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

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

ACTIVITY DATA

Table 5.39 - Synthetic solvents consumption in other industries (ton)

Year	1990	1991	1992 - 2006
Solvents (ton)	3 885	4 014	3 950

Source: General Directorate of Energy (DGGE)

UNCERTAINTY ASSESSMENT

Activity data is very scarce and doubtful and the overall uncertainty was assumed to be 1000 per cent.

RECALCULATIONS

No recalculations were made for this source sector.

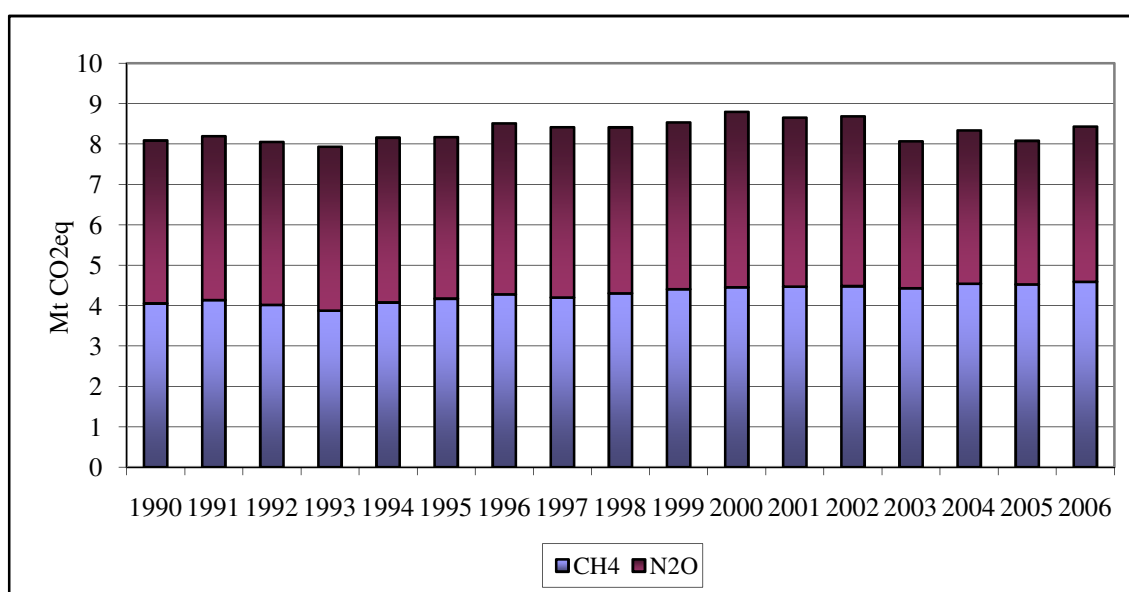
CHAPTER 1 AGRICULTURE (CRF 4)

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).

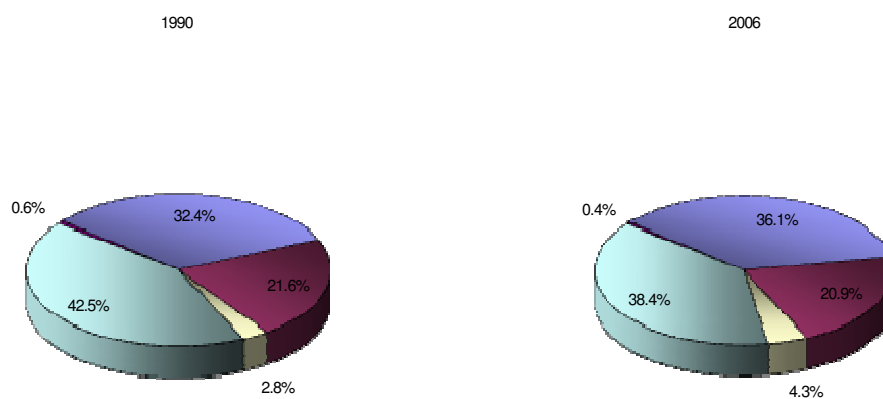
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 13.7 per cent in 1990 to 10.2 per cent in 2006. Nevertheless this uncovers the existence of an absolute increase in emissions such that emissions from agriculture in 2006 are 4.3 per cent higher than emissions from agriculture in 1990: 8.1 Mton of CO₂eq in 1990 and 8.4 Mton CO₂eq in 2006 (Figure 1.1). Total GHG emissions show an approximately equal share of methane and nitrous oxide emissions: in 2005 methane emissions were about 51.8 per cent of total GHG emissions from agriculture.

Figure 1.1 – Total Greenhouse Gas Emissions from Agriculture. Trends by GHG



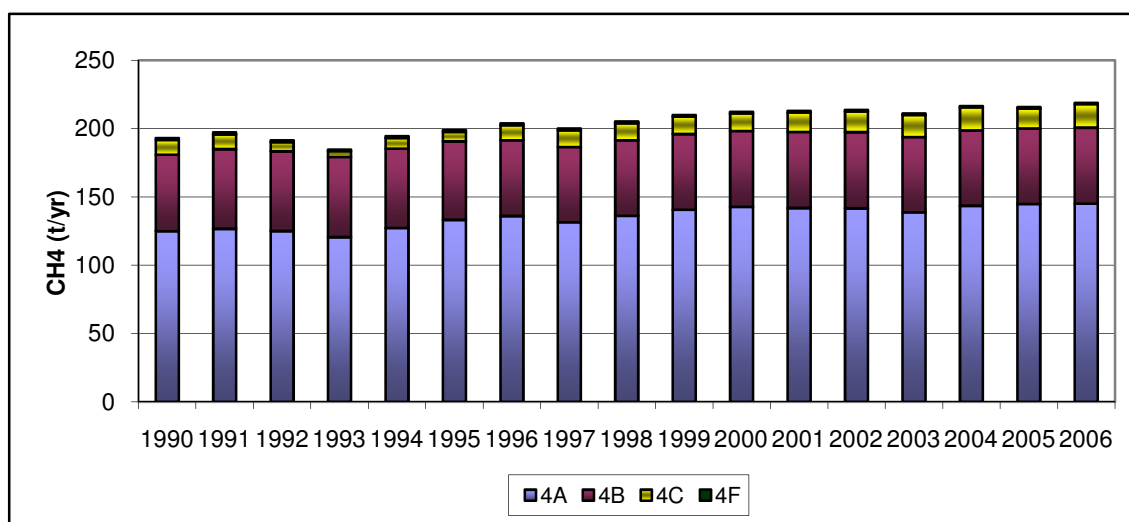
The majority of emissions from agriculture are the result of only 3 sub-source sectors. Agriculture Soils emissions is the prevalent followed from methane emissions from Enteric Fermentation and total emissions from Manure Management (Figure 1.2).

Figure 1.2 - Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2006



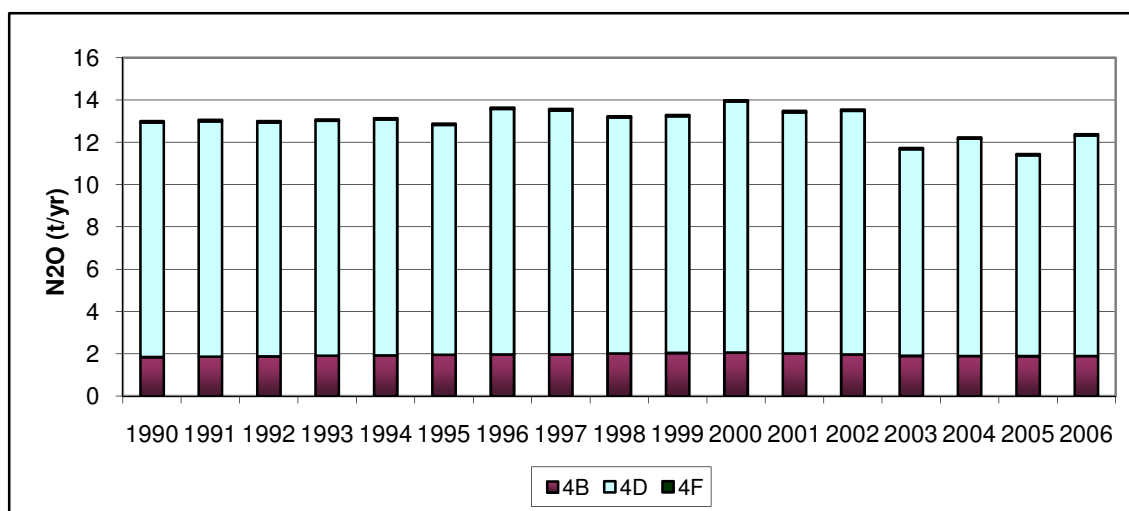
Emissions of CH₄ from agriculture have increased 13.3 per cent from 1990 to 2006 (Figure 1.3). Enteric Fermentation was responsible, in 2006, for 66.1 per cent of the sectoral emissions and Manure Management accounted for 27.5 per cent of the sectoral emissions in the same year. The remaining 6.4 per cent of emissions result mostly from rice cultivation, with only a very small contribution from field burning of residues, only 0.6 per cent of total emissions in the same the most recent year.

Figure 1.3 - Methane emissions from agriculture



Following an opposite trend, N₂O emissions have decreased by -4.8 per cent from 1990 to 2006 (Figure 1.4). 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 2006 were associated with direct and indirect emissions from agricultural soils (84.5 per cent), manure management is responsible for 15.0 per cent of emissions, while the small remaining fraction results from field burning of agricultural residues (0.5 per cent).

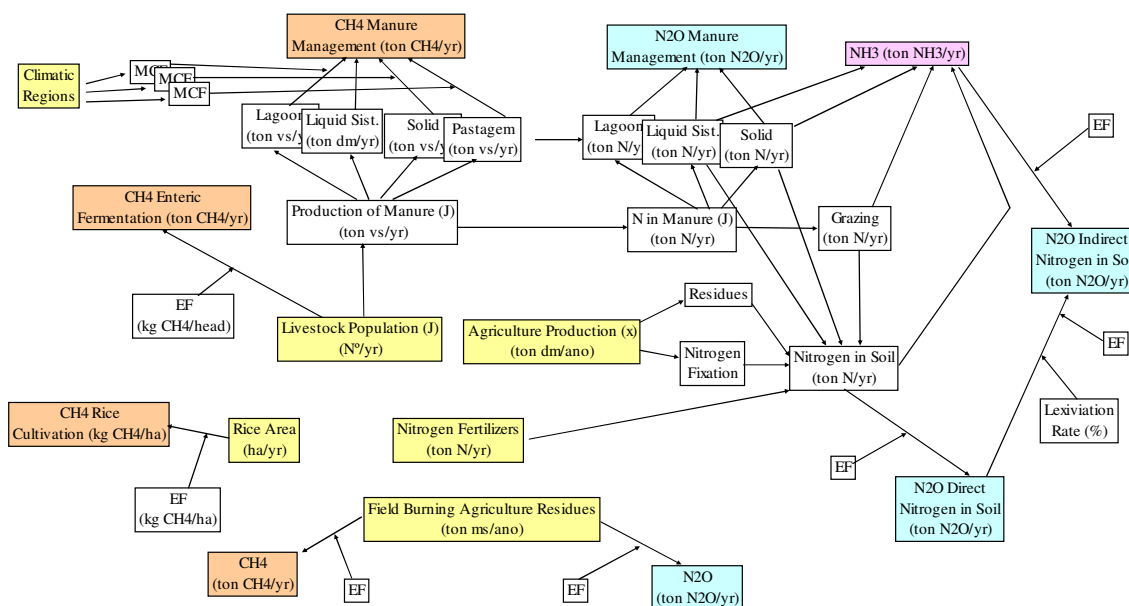
Figure 1.4 - Nitrous Oxide emissions from Agriculture



Emissions were estimated following as far as possible the methodology recommended by IPCC (1996 Revised IPCC Guidelines and Good Practice Guidebook) and were done in a consistent

way: the same activity data is used and balanced for all source categories. A general overview of methodology is presented in Figure 1.5.

Figure 1.5 - Overview of Methodology



This integration of calculus means that changes in methodology are done also in a consistent and coherent way among the several source sectors. Improvements in methodology in each source sector are reflected in changes in other related sources.

Recalculations

Changes in GHG emission estimates for this sector were the result of the in-country review of the 2006 Inventory Submission under UNFCCC and of the Informative Inventory Report under the Kyoto Protocol, which took place in 2007. Detailed explanation of changes will be presented in the description of each sub-category, the following list showing only the main overview:

- Revision of the Nitrogen Excretion Ratios for sheep;
- Revision of the CH₄ EF for rice cultivation. EF is now set using the original study referenced in IPCC(2000) and incorporating the effect of organic amendments;
- Revision of the time series of the cultivated area in rice paddies that is subjected to burning of stubbles;
- Reporting of emissions of N₂O from nitrogen in swine effluents from anaerobic lagoons as indirect emissions from leaching and run-off;
- Revision of activity data and volatilization rates for synthetic fertilizer use for years where statistical information was not available. Forecasting functions were replaced by average value in the known period;
- Correction of errors in activity data for some permanent crops (grape production). This change caused revision of activity data and estimates for the all time series of source categories 4.D (N₂O) and 4.A (CH₄ and N₂O).

Figure 1.6 - Differences between submission 2007 and submission 2008 for CH₄ and N₂O emissions from agriculture

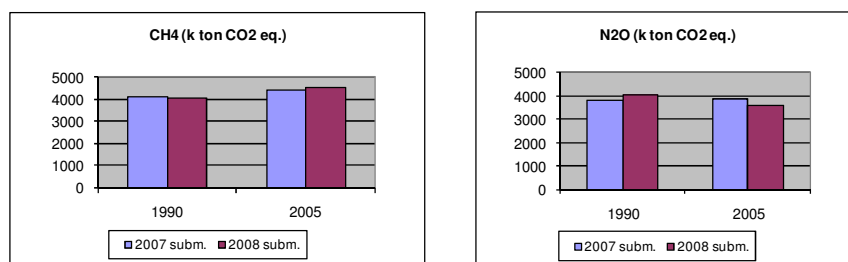


Table 1.1 – Recalculations. Differences between submission 2007 and submission 2008 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2			CH4			N2O		
	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)	2007 subm.	2008 subm.	Difference(1)
	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)
1990									
4. Agriculture				4 070.88	4 054.76	-0.40	3 796.93	4 033.58	6.23
4.A. Enteric Fermentation				2 621.76	2 621.88	0.00			
4.B. Manure Management				1 175.65	1 175.66	0.00	563.37	575.15	2.09
4.C. Rice Cultivation				255.71	226.76	-11.32			
4.D. Agricultural Soils				NE,NO	NE,NO		3 215.90	3 436.64	6.86
4.E. Prescribed Burning of Savannas				NO	NO		NO	NO	
4.F. Field Burning of Agricultural Residues				17.76	30.46	71.52	17.66	21.80	23.40
4.G. Other				NO	NO		NO	NO	
2005									
4. Agriculture				4 379.00	4 527.84	3.40	3 864.81	3 553.33	-8.06
4.A. Enteric Fermentation				3 037.74	3 040.16	0.08			
4.B. Manure Management				1 159.29	1 159.32	0.00	577.69	589.77	2.09
4.C. Rice Cultivation				165.85	309.34	86.52			
4.D. Agricultural Soils ⁽²⁾				NE,NO	NE,NO		3 271.06	2 947.20	-9.90
4.E. Prescribed Burning of Savannas				NO	NO		NO	NO	
4.F. Field Burning of Agricultural Residues				16.12	19.01	17.94	16.05	16.36	1.90
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.

Source categories

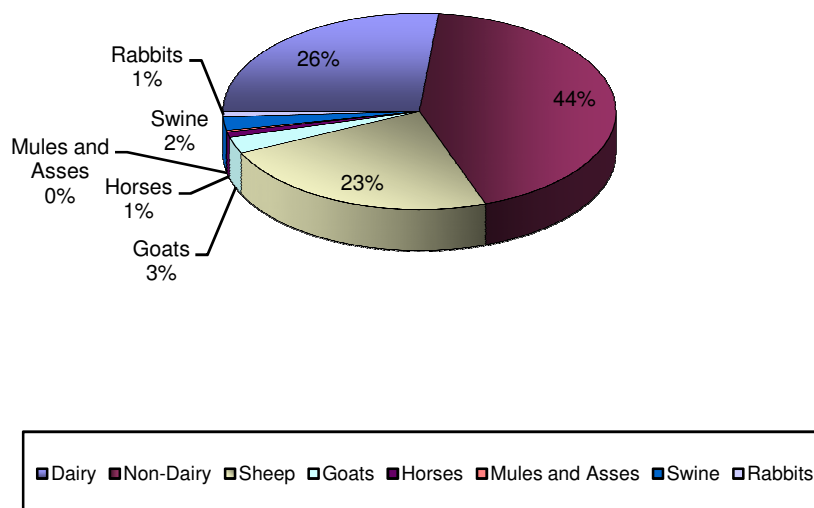
CH₄ Emissions from Enteric Fermentation in Domestic Livestock (CRF 4A)

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 1.7. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents, according to different years, 26 to 30 per cent of total CH₄ emissions from Enteric Fermentation, while non-dairy cattle represents about 39 to 44 per cent of total CH₄ from enteric fermentation. Together, in 2006 cattle was responsible for about 70 per cent of total CH₄ emissions from enteric fermentation.

Figure 1.7 - Relative Importance of emissions of CH₄ from Enteric Fermentation per each animal specie in 2006



Sheep is also an important source of methane, for which emissions have oscillated between 21 and 23 per cent of total CH₄ from Enteric Fermentation. Emissions from goats were 2.5 to 4.4 per cent of total enteric fermentation and swine represented 2.2 to 3.0 per cent of emissions. Total emissions of methane for all other species varied between 2.4 and 2.0 per cent in the period and have a lesser importance.

METHODOLOGY

Emissions were estimated for each animal type⁹⁴ 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).

$$Emi_{CH_4 (y)} = \sum_i [EF_{(i,y)} * N_{(i,y)}]$$

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.

EMISSION FACTORS

Emission factors may be seen in Table 1.2, 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.



Bibliography



Key Categories



Uncertainty

⁹⁴ 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 1.2 - 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

DETERMINATION OF TIER 2 EMISSION FACTORS

Following the recommendations from previous review processes, a tier 2 analysis was seek 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.

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 CH₄/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 production⁹⁵, both of which are published by the National Statistical Institute (INE). The calculated milk yield and the corresponding emission factor are shown in Figure 1.8. 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 unfavourable climacteric conditions such as droughts, as can be seen in the temporary decreases in 1993, 2003 and 2004, and recover periods thereafter.



Bibliography



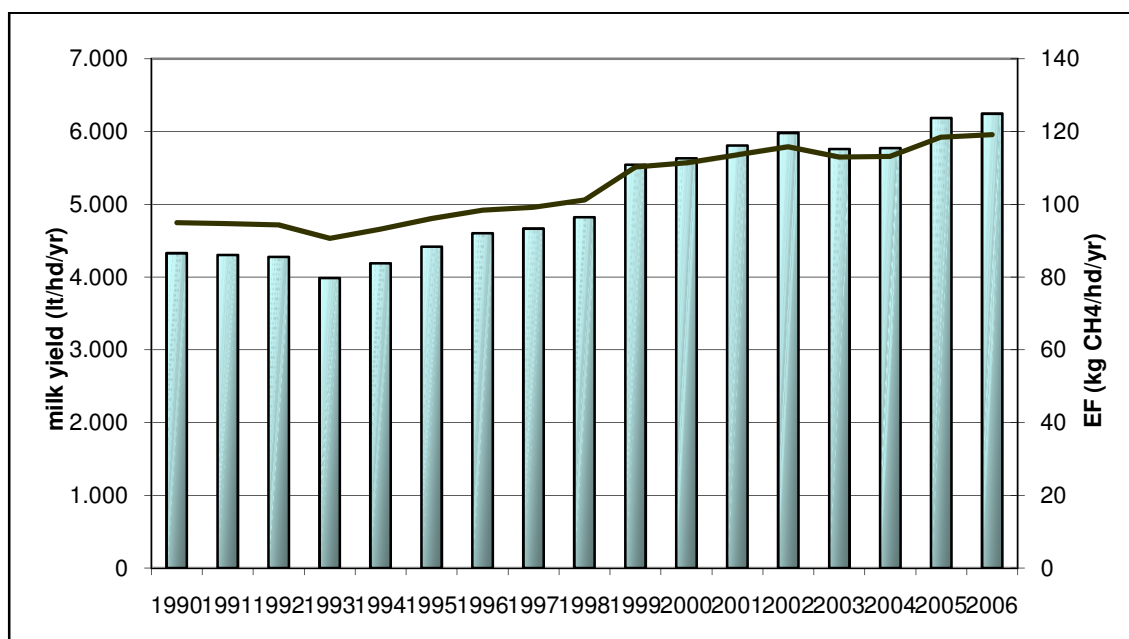
Key Categories



Uncertainty

⁹⁵ The same time series used in the inventory but not averaged over 3 years.

Figure 1.8 – Annual production of milk yield per dairy cow in Portugal (bars) and the estimated emission factor of CH₄ from Enteric Fermentation (line)



Assuming a constant methane conversion rate of 0.6 per cent (default IPCC) and an energy density of the feed of 18.45 MJ/kg, the corresponding Feed Intake (FI) per day, was estimated to have increased from 13 kg dm/hd/day in 1990 to 16 kg dm/hd/day, in 2006. This trend in increase in the feed intake was used, in a consistent way, in the determination of the annual manure production per cow, in the determination of CH₄ emissions from Manure Management (see more adequate explanation in chapter 6.3.B).

Non-dairy cattle

The Ministry of Agriculture compiled in 1998, and updated recently (GPPAA,2004), information from the eighteen breeders associations existing in Portugal, this database comprehending the number of registered producers, number of animals, age at weaning, age at slaughter, use as working animal, territorial range and biometric parameters such as weight at birth, at 7 months and at adult age. Thirteen breeds have national origin and four are imported breeds. The number of registered animals represents about 20 per cent of total reproductive animals. Some animals in the remaining livestock population are the result of cross-breeding and are not registered, but it was assumed that they attain the average characteristics of the progenitors.

The calculation was made individually for each sub-category, determined from the available statistical information:

<1 yr	Beef Calfs
	Calfs, Males for Replacements
	Calfs, Females for Replacements
1-2 yr	Males
	Beef Females
	Females for Replacement
>2 yr	Steers
	Heifers for Beef
	Heifers for Replacements
	non-dairy cows

Feed intake estimates for each cattle sub-category was estimated using the energy model of the IPCC Good Practices (IPCC,2000), which is briefly presented here. First, net energy is determined from:

$$\begin{aligned} NE_m &= CF_i * (Weight)^{0.75} \\ NE_a &= C_a * NE_m \\ NE_w &= 0.10 * W_{hour} \\ NE_g &= 4.18 * \{0.0635 * [0.891 * (Weight * 0.96) * (478/(C_g * MW))]^{0.75} * (WG * 0.92)^{1.097}\} \\ NE_l &= milk_{Yield} * (1.47 + 0.40 * Fat) \\ NE_p &= C_{pregnancy} * NE_m \end{aligned}$$

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 range⁹⁶. The difference between traditional animals on pasture and range depends on the type of terrain, being assumed the range situation for breeds mostly existing in the south plains (“Montados”) and pasture in small grazing plots (“Prados” and “Lameiros”) in central and northern continental Portugal and in the islands.

Given that the database did not have detailed information for all age classes a model had to be derived for each breed from information at birth, 7 months and adult weight. The model, based



Bibliography



Key Categories

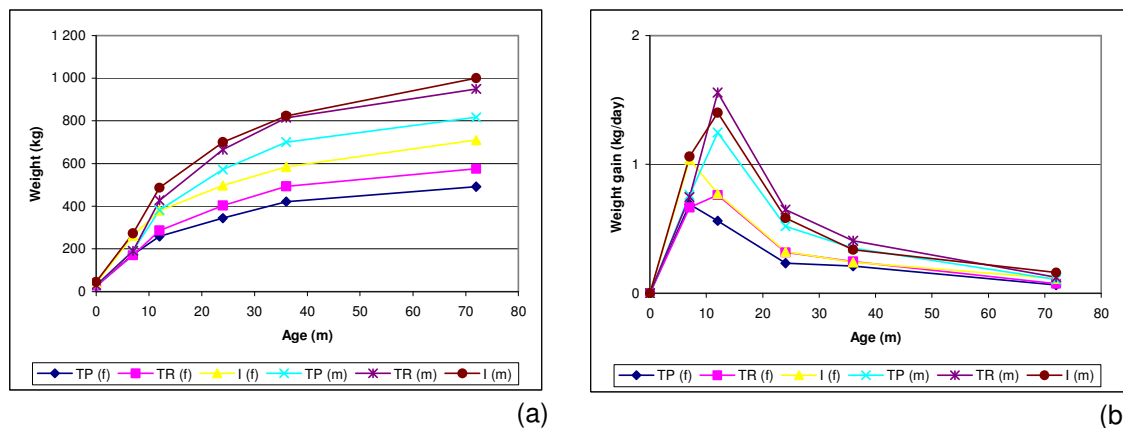


Uncertainty

⁹⁶ 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.

on information collected from other countries (Jarrige, 1988), considers the following evolution pattern.

Figure 1.9 – 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 factor⁹⁷. The average values of the parameters and the average values of the values calculated are presented in Table 1.3 though Table 1.6.



Bibliography



Key Categories



Uncertainty

⁹⁷ 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 1.3 – 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	NE _m (MJ/day)	Ca	NE _a (MJ/day)	Cg	NE _g (MJ/day)
Beef calves (<1 yr)	212	0.948	0.322	17.8	0.177	2.8	0.9	8.6
Calves, Males Rep. (<1 yr)	230	1.139	0.322	19.0	0.177	3.2	1.0	8.9
Calves, 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

Table 1.4 – 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 1.5 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of Mature Weight (MW).

MW	kg
Male	930
Female	600

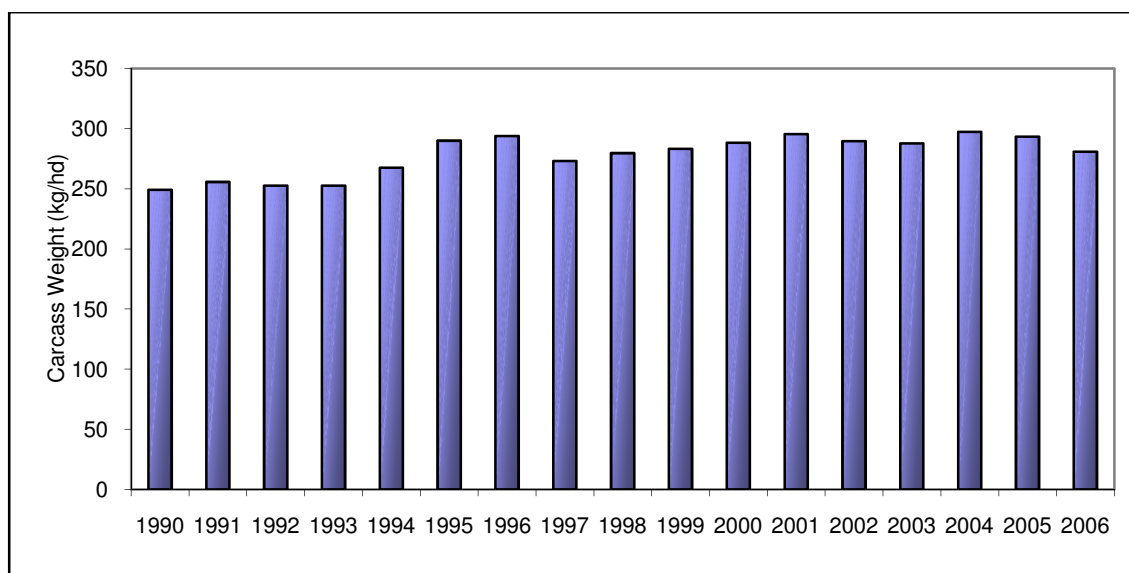
Table 1.6 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Ym) and Emission Factor of CH₄ emissions from Enteric Fermentation for non-dairy cattle. Weighted averages from individual breeds.

sub-class	NE (MJ/day)	NE _{ma} /DE	NE _{ga} /DE	DE (%)	GE (MJ/day)	FI (kg dm/day)	Y _m	FE CH ₄ (g/hd/yr)
Beef calves (<1 yr)	29.2	0.514	0.308	65	105	5.7	0.06	35
Calfs, Males for Rep. (<1 yr)	31.1	0.514	0.308	65	111	6.0	0.06	44
Calfs, 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 1.10, 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 that CH₄ emission factors per animal are in 2005 about 13 per cent higher than the corresponding values in 2006.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 1.10 – Average carcass weight at slaughtering. Total Cattle.



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Sheep and Goats

The same database from the Ministry of Agriculture that was referenced previously for non dairy cattle, includes also information for the twelve⁹⁸ native Portuguese breeds of sheep and the five native Portuguese breeds of goats⁹⁹. Three imported breeds of sheep¹⁰⁰ 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:

$$\begin{aligned} NE_m &= CF_i * (Weight)^{0.75} \\ NE_a &= C_a * Weight \\ NE_g &= \{WG_{Lamb} * [a + b * BW]\} \\ NE_l &= milk_{Yield} * EV_{milk} / 365 \\ NE_p &= C_{pregnancy} * NE_m \\ NE_{wool} &= Wool_{Prod} * EV_{wool} / 365 \end{aligned}$$

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:

⁹⁸ 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.

⁹⁹ Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

¹⁰⁰ Assaf, Ile de France and Merino Precoces.

$$\begin{aligned}
 NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\
 NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\
 GE &= \{[(NE_m + NE_a + NE_l + NE_p)/(NE_{ma}/DE)] + [(NE_g + NE_{wool}) / (NE_{ga}/DE)]\} / (DE/100) \\
 FI &= GE / ED
 \end{aligned}$$

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 * 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;

$C_{\text{pregnancy}}$ = 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 1.7 – 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	-	-	-	-
$C_{\text{pregnancy}}$	-	0.075	-	-	0.066	-
NE_p (MJ/day)	-	0.32	-	-	0.20	-

Table 1.8 – 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

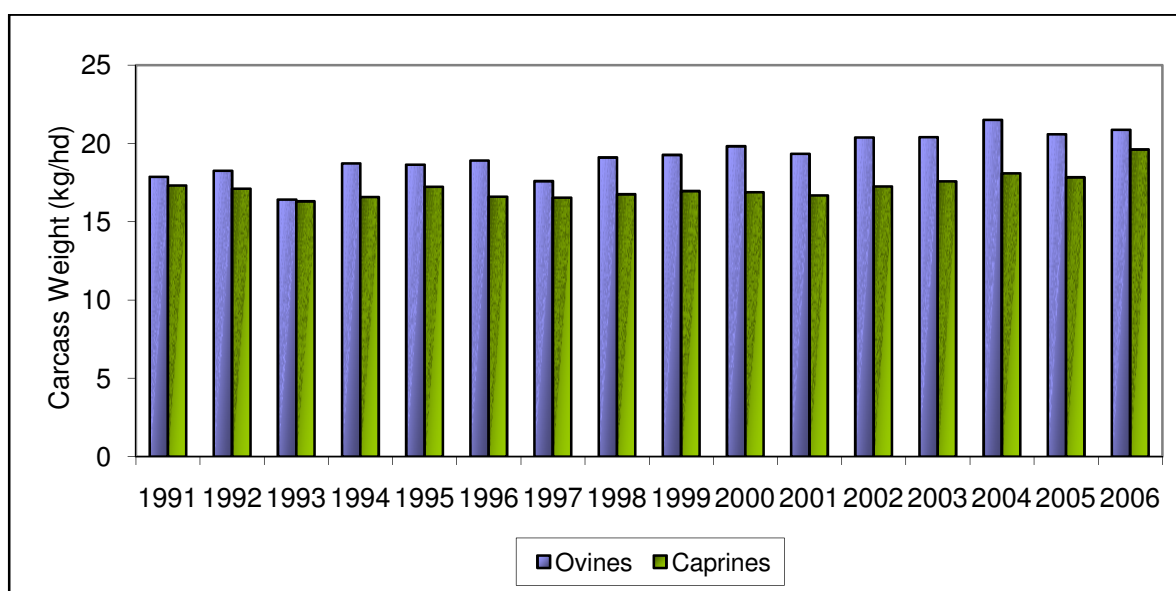
Table 1.9 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Ym) and Emission Factor of CH₄ emissions from Enteric Fermentation for sheep and goats. Weighted averages of individual breeds.

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 1.11, 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 that CH₄ emission factors for ovine per animal are in 2006 about 9 per cent higher 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 1.11 – Average carcass weight at slaughtering. Total sheep and total goats.



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

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 1.10.

Table 1.10 – 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 (r2 - 0.998)
Fattening Pigs (80-110 kg)	95	41.3	72.6	2.24		
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

Poultry¹⁰¹

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):



Bibliography



Key Categories



Uncertainty

¹⁰¹ 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

$$GE = \text{Feed}_{ME} / (EM/GE / 100)$$

Where,

GE – gross energy, MJ/day;

Feed_{ME} – Recommended metabolic energy ingestion, MJ/day;

EM/GE - Metabolisability, metabolic energy expressed as a percentage of gross energy, per cent.

Table 1.11 – 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

ACTIVITY DATA

Periodic census to agriculture¹⁰² and animal husbandry activities are realized by the National Statistical Institute. In accordance with the requirements of FAO and UE the census are realized



Bibliography



Key Categories



Uncertainty

¹⁰² Referred in Portuguese as Recenseamento Geral da Agricultura (RGA)

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.

Period agriculture censuses 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 per cent.

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 2004 for cattle, swine, sheep, goats, horses, mules and donkeys, disaggregated per region¹⁰³, age and sex. The number of rabbits, hens, broilers, turkeys, ducks, geese and guinea-fowl, is only available for 1999 – from the national agriculture census that is done every ten years - and extrapolations were done for the other years using surrogate indicators of trend. The following procedures were made to estimate the full time series:

- The number of hens for industrial egg production and for production of chicks was available from the Regional Agriculture Statistics (INE) from 1990 to 2000. The census

¹⁰³ 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.

made in 1999 (RGA99 from INE) found a substantially higher number of hens, 95 per cent higher than the values reported in the Regional Agriculture Statistics, reflecting the consideration, in the RGA99 census only, of animal in small farms. The original number of hens was corrected by the ratio of total hens in RGA99 and total hens from Regional Statistics. The values after 2001 are provisional and estimated using total number of eggs produced as surrogate data;

- Broilers: two different situations were considered: animals risen in industrial poultry farms and in small agricultural farms. The total number of animals in 1999 was obtained from the agriculture census (RGA99). The number of animals in small farms at that same year was estimated by difference of total numbers from the total number of available broiler places in industrial exploitations (about 24 per cent of total population), which is also statistical information from INE, and assumed constant in the period 1990-2004. The remaining part, industrial broilers, were extrapolated for years other than 1999, using annual slaughtered animals as surrogate driver;

- Also for 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;

- Rabbits. Number of breeding females was available for 1999, from the RGA99 census. The number of animals for the full time series was estimated using total tons of slaughtered animals as surrogate driver. This procedure may result in an increasing trend more accentuated than in reality, because animals in small farms are expected to have less tendency to increase its numbers;

- 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.

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 to 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 models¹⁰⁴ for both species, Figure 1.12, using the weight at slaughter that was determined from the information in the Regional Statistics (INE), which values are presented in Figure 1.13. Resultant average ages vary from 107 to 113 days for sheep and 73 to 102 days for kids.



Bibliography



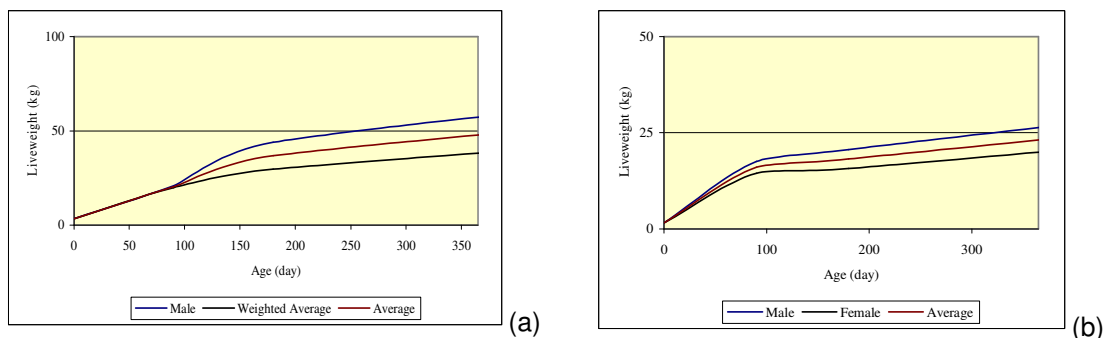
Key Categories



Uncertainty

¹⁰⁴ Model set from the information on the breeds existent in Portugal, complemented by information in Jarrige (1988) concerning growth pattern.

Figure 1.12 – 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 1.14 for two subsequent years (GPPAA,2004). The importance of the periods of Christmas and Easter is evident. From this data, the population of lambs and kids was estimated for the beginning of each month (day 1), considering that at that moment were alive all animals killed in that same month and in the subsequent months according to the average age when young animals are killed. The ratio of population of young animals in the first of December (reference data for RGA99) to the average annual population, estimated to be 1.17 for sheep and 1.89 for goats, was used to estimate lamb and kids population in the moment of the RGA. The number of animals remaining from the total ovine and caprine numbers after subtraction of number of females (ewes and does) and the number of youngsters (lambs and kids) is reported as “Other Ovines” and “Other Caprines”. These animals are mostly adult males, but also young animals that are kept to reproductive functions and are not slaughtered.

Figure 1.13 – Average carcass weight at slaughtering. Lambs and Kids.

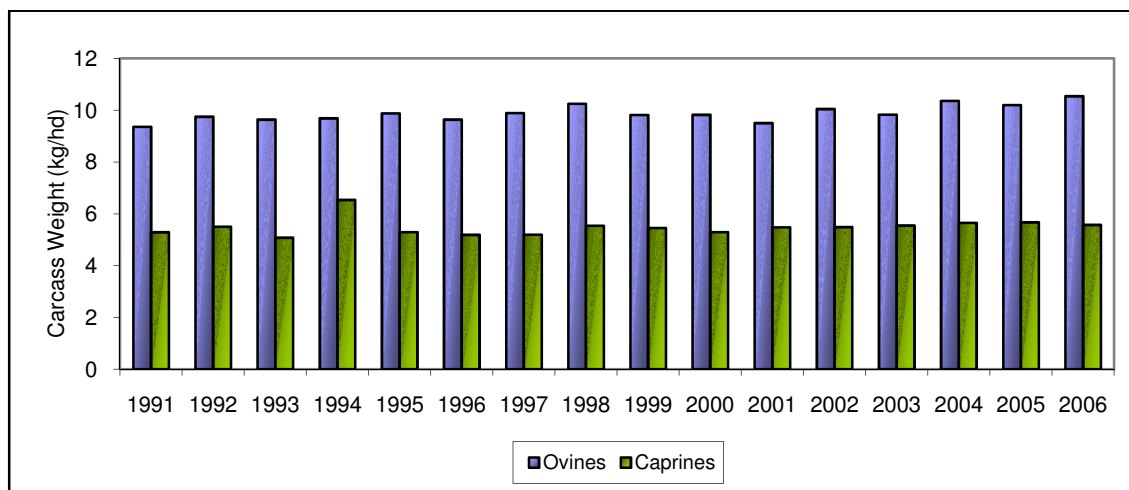


Figure 1.14 – Number of slaughtered young animals in each month for the years 2001 and 2002

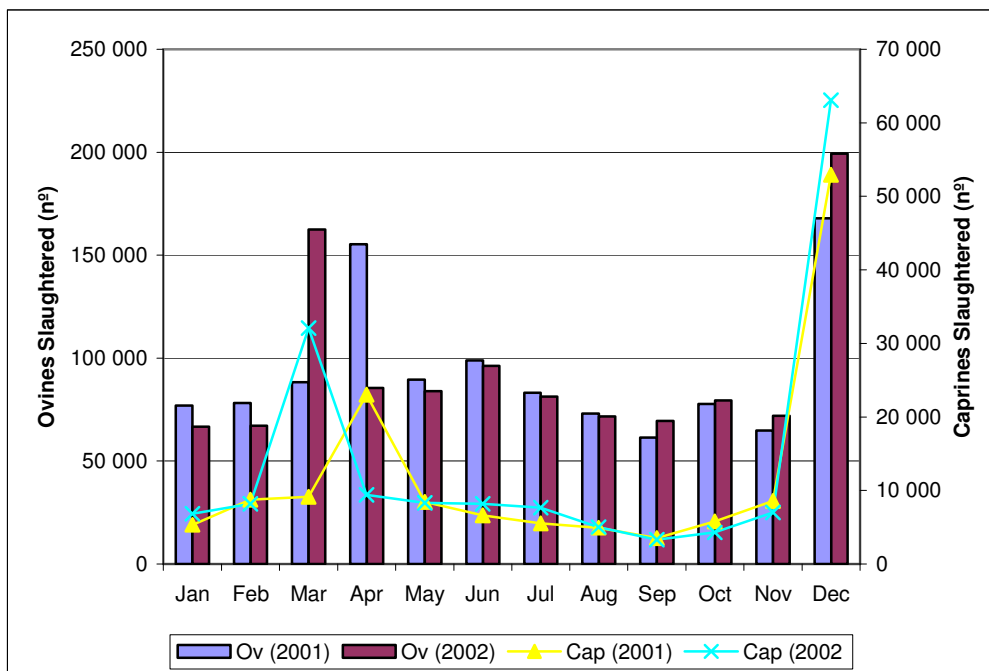


Table 1.12 - Livestock Numbers (Thousands): 1990-1997

Animal	sub-class	1990	1991	1992	1993	1994	1995	1996	1997
Dairy-Cattle	Dairy cows	394	388	381	383	382	383	380	379
non-dairy cattle	Beef calves (<1 yr)	46	52	53	53	58	60	64	64
	Calfs M.Rep. (<1 yr)	186	185	182	176	167	162	155	151
	Calfs F Rep. (<1 yr)	177	178	178	174	164	158	152	152
	Males 1-2 yrs	112	114	114	108	103	103	105	101
	Beef Fem. 1-2 yrs	18	19	20	22	22	22	24	24
	Females rep. 1-2 yrs	111	115	112	109	106	109	112	109
	Steers (>2 yrs)	38	38	36	37	35	33	33	31
	Heifers Beef (>2 yrs)	4	5	7	9	10	10	9	9
	Heifers rep. (>2 yrs)	45	46	45	48	50	52	51	50
	non-dairy cows	242	245	238	241	252	273	296	316
Swine	Piglets (<20 kg)	727	756	756	750	735	726	703	701
	Fatt. Pigs (20-50 kg)	662	675	660	671	668	660	633	631
	Fatt. Pigs (50-80 kg)	537	558	557	553	542	530	505	496
	Fatt. Pigs (80-110 kg)	209	217	216	214	203	194	179	177
	Fatt. Pigs (> 110 kg)	42	43	44	44	43	43	40	39
	Boars (>50 kg)	26	28	27	28	28	26	24	23
	Sows, pregnant	210	219	218	220	216	211	204	204
	Sows, non-pregnant	124	131	135	136	134	132	127	128
Ovines	Ewes	2 211	2 251	2 257	2 268	2 303	2 339	2 376	2 368
	Other Ovines	395	398	402	420	430	433	414	401
	Lambs	592	610	606	578	565	568	592	598
Caprines	Does	600	581	556	538	528	517	509	498
	Other Caprines	44	42	41	39	39	38	37	36
	kids	102	102	96	92	89	82	77	72
Equides	Horses	33	38	40	42	44	48	52	54
	Asses and Mules.	118	116	114	114	109	103	96	90
Poultry	Hens, reproductive	1 876	1 953	1 935	2 061	2 179	2 712	2 978	3 069
	Hens eggs	4 133	4 598	4 966	5 715	6 000	6 347	6 290	6 678
	Broilers	20 095	20 437	21 190	21 972	22 840	23 179	23 769	24 519
	Turkeys	603	623	643	693	757	827	886	937
	Ducks, Geese and Guinea Fowl	804	804	804	804	804	804	804	804
Other	Rabbits	274	275	276	286	307	328	344	342

Table 1.13 - Livestock Numbers (Thousands): 1997-2006

Animal	sub-class	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dairy-Cattle	Dairy cows	375	369	361	350	344	336	336	330	323
non-dairy cattle	Beef calves (<1 yr)	65	66	67	72	72	70	73	79	85
	Calves M.Rep. (<1 yr)	149	149	149	149	150	155	153	148	140
	Calves F Rep. (<1 yr)	155	165	171	173	172	169	168	164	161
	Males 1-2 yrs	95	86	82	80	78	79	78	79	76
	Beef Fem. 1-2 yrs	24	20	17	15	15	15	16	17	16
	Females rep. 1-2 yrs	108	116	126	133	133	130	132	131	135
	Steers (>2 yrs)	31	29	27	25	23	22	22	24	27
	Heifers Beef (>2 yrs)	9	7	5	4	5	5	5	6	5
	Heifers rep. (>2 yrs)	52	60	67	67	60	55	57	60	62
	non-dairy cows	332	338	342	345	351	360	371	385	399
Swine	Piglets (<20 kg)	695	691	685	684	686	678	676	681	690
	Fatt. Pigs (20-50 kg)	633	623	610	596	589	575	567	570	573
	Fatt. Pigs (50-80 kg)	492	498	501	502	494	483	481	474	466
	Fatt. Pigs (80-110 kg)	174	176	176	190	205	216	221	222	229
	Fatt. Pigs (> 110 kg)	38	38	39	43	43	42	39	40	42
	Boars (>50 kg)	23	22	21	20	20	18	17	15	14
	Sows, pregnant	202	201	199	206	210	213	209	208	207
	Sows, non-pregnant	127	127	126	118	111	102	103	104	106
Ovines	Ewes	2 367	2 388	2 417	2 403	2 350	2 304	2 297	2 319	2 303
	Other Ovines	431	430	422	352	303	301	374	450	535
	Lambs	604	615	639	674	725	702	669	621	616
Caprines	Does	485	472	461	441	419	393	383	381	381
	Other Caprines	35	34	34	32	31	29	28	28	28
	kids	73	73	66	76	83	85	73	65	65
Equides	Horses	56	57	58	59	59	58	61	64	69
	Asses and Mules.	82	75	69	63	57	51	47	43	39

Poultry	Hens, reproductive	2 919	2 733	2 806	2 824	2 968	3 044	3 191	3 383	3 490
	Hens eggs	7 866	8 960	9 591	9 532	9 484	9 728	10 197	10 404	9 828
	Broilers	25 902	26 636	26 999	26 511	26 056	24 603	23 934	23 631	23 906
	Turkeys	1 069	1 180	1 283	1 288	1 285	1 150	1 068	1 020	1 093
	Ducks, Geese and Guinea Fowl	804	804	804	804	804	804	804	804	804
Other	Rabbits	346	346	356	359	363	363	363	363	363

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 trends¹⁰⁵.

Livestock numbers¹⁰⁶ 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 National Statistics.



Bibliography



Key Categories



Uncertainty

¹⁰⁵ Reports available at (<http://www.min-agricultura.pt/mediateca>)

¹⁰⁶ Annual values, not 3 year averages.

Figure 1.15 – 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 turkeys¹⁰⁷ 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

Bibliography



Key Categories



Uncertainty



¹⁰⁷ While poultry numbers do not affect emissions of CH₄ from Enteric Fermentation they are discussed here to simplify NIR presentation.

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 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 annex¹⁰⁸, 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.”

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 absence of statistic numbers for poultry, 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.

¹⁰⁸ In the original document to the UNFCCC only.

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-series¹⁰⁹ was used as an indicator of the uncertainty of livestock numbers, and they are presented in table Table 1.14.

Table 1.14 - 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	272
Hens	64
Broilers	41
Turkeys	771
Other	771

The uncertainty of the emission factor was assumed to be 20 per cent for all animals where tier 2 was used and 50 per cent when tier 1 emission factors were used, in accordance with the Good Practice Guidebook (IPCC, 2000).

¹⁰⁹ The comparison was done without 3 year averages were calculated.

RECALCULATIONS

No substantial changes were made to this source category apart from the update of time series to 2006 and the correction of small errors in calculation that have resulted in very small changes in annual emissions.

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.

CH₄ Emissions from Manure Management (CRF 4B)

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 category¹¹⁰.

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.



Bibliography



Key Categories

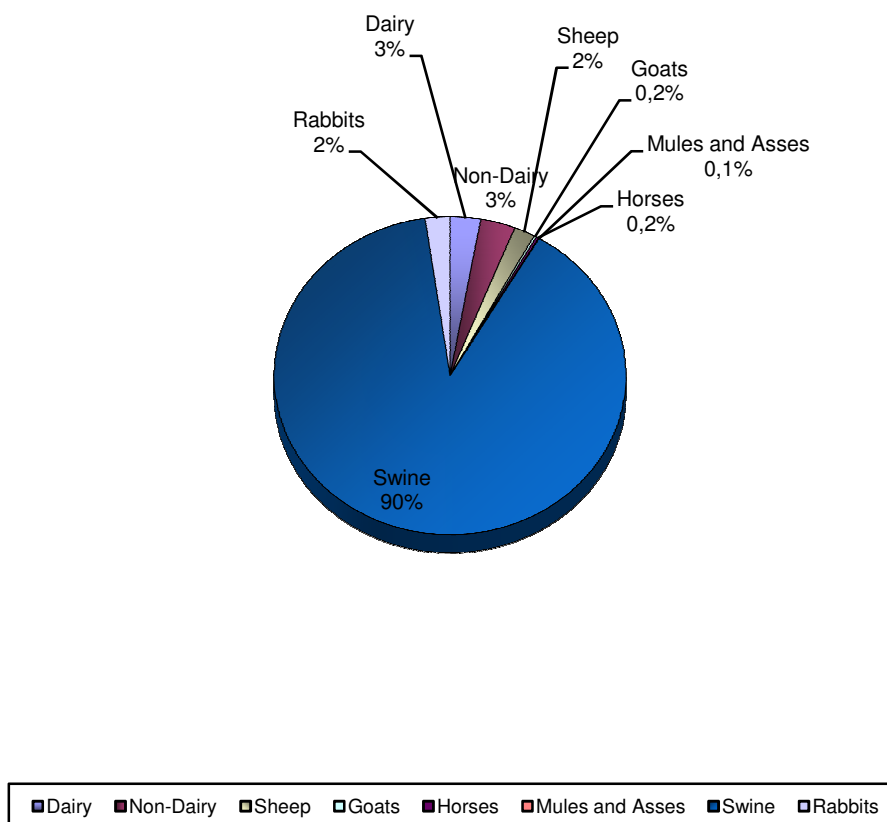


Uncertainty

¹¹⁰ 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.

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 90 per cent of emissions in 2006, as may be seen in Figure 1.16, and according to the Good Practice rule of thumb this specie is the only significant source.

Figure 1.16 - Relative Importance of emissions of CH₄ from Enteric Fermentation per each animal specie in 2006



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.

$$Emi_{CH_4} = \sum_i \sum_k [EF_{(i,k)} * N_{(i,k)}]$$

where, for each specie:

Emi_{CH_4} = methane emissions from manure management, kg CH₄/year;

$EF_{(i,k)}$ = emission factor for the specific population of animal type i, living in climate region k, kg/head/year;

$N_{(i,k)}$ = total number of animals of type i, living in climate region k, head.

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. $0.67 \text{ kg}/m^3$ 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 $18.45 \text{ MJ}/\text{kg-dm}$;

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 1.15 – Parameters used in the estimate of Volatile Excretion per animal

Animal Class	sub-class	DE (MJ/kg)	Ash (%)	B _o (m ³ /kg VS)
Dairy-Cattle	Dairy Cows	60	8	0.24
non-dairy cattle	Calfs (<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 guess¹¹¹, 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

¹¹¹ Information received from Dr. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005.

evolution between year 1990 and the target year of 2010 was assumed, Table 1.17. The new structure replaces the former expert guess used in the inventory, and also available from the Agriculture Ministry (Seixas et al, 2000), being assumed that it represents better the Portuguese situation.

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 1.16 and also in Figure 1.17. 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;
- 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 is still the prevalent method of treatment for wastes from other cattle;
- 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 1.16 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990

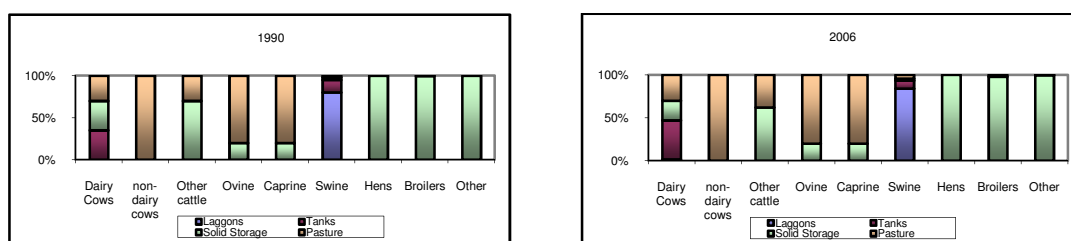
Animal Type	Laggons	Tanks	Solid Storage	Pasture	Total
Dairy Cows		35	35	30	100
non-dairy cows				100	100
Other cattle			70	30	100
Ovine			20	80	100
Caprine			20	80	100
Swine	80	15	3	2	100
Hens			100		100
Broilers			99.9	0.1	100
Turkeys			100		100
Ducks			100		100
Rabbits			100		100

Table 1.17 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type.

Animal Type	Laggons	Tanks	Solid Storage	Pasture
Dairy Cows	0.1	0.65	-0.75	
non-dairy cows				
Other cattle			-0.5	0.5
Ovine				
Caprine				
Swine	0.25	-0.35	-0.05	0.15
Hens				
Broilers			-0.12	0.12
Turkeys			-0.005	0.005
Ducks				
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 1.17 - Percentage of manure handled by each Manure Management System, by animal type in 1990 and 2006



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 unit¹¹² 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 1.18. 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 RGA99¹¹³. 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 area percentage, and always assuming an homogeneous distribution of animals in the *Concelho* territorial area. Animal numbers were summed at each Administrative Region (Região)¹¹⁴ for all *Concelhos*, and a percentage 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.



Bibliography



Key Categories



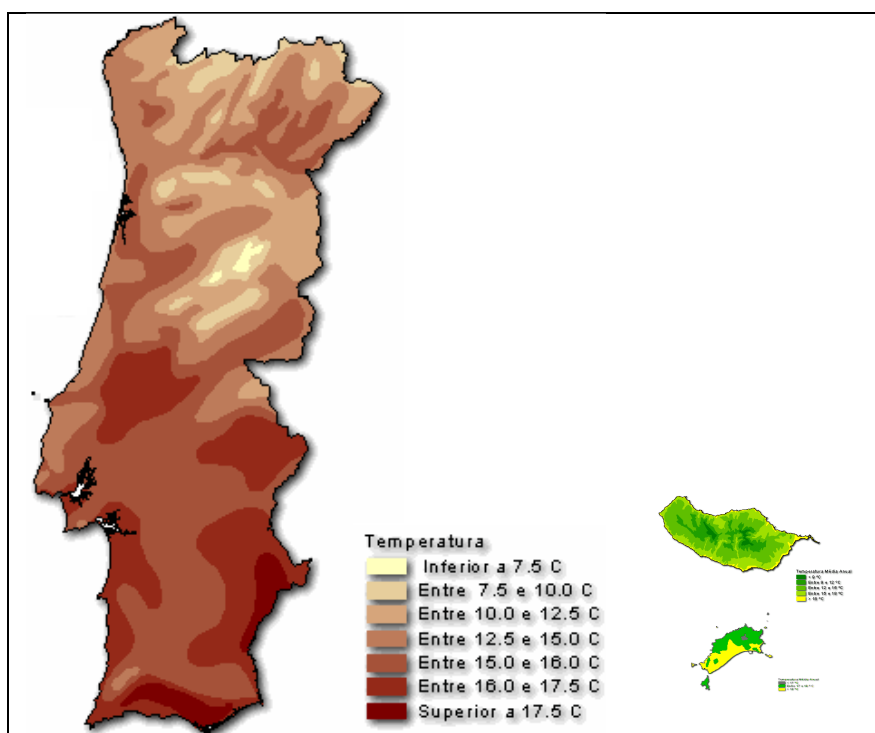
Uncertainty

¹¹² 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.

¹¹³ Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

¹¹⁴ 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 1.18 – 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 2006, obtained in accordance with the above explained procedure, is presented in Table 1.19.

Table 1.18 – Percentage of livestock population living in climate cool regions in Portugal in years 1990 and 2005.

Animal Type	1990	2006
Dairy Cows	48	43
Other Cattle	43	26
Sheep	29	31
Goats	50	52
Horses	34	36
Mules and Asses	58	69
Swine	22	20
Poultry	43	44
Other	65	65

Finally, the Methane Conversion Factors are the defaults for temperate regions of Western Europe and developed countries:

Table 1.19 - Methane Conversion Factors (MCF), per cent, for determination of CH₄ emissions from Manage

MMS	Temperature	cool
Laggons	45	39
Tanks	0	0
Solid Storage	1.5	1
Pasture	1.5	1

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.

UNCERTAINTY ASSESSMENT

Livestock numbers are considered to be the activity data of this source category and the uncertainty values were equal to uncertainty values discussed for CH₄ emissions from Enteric Fermentation, as explained in the previous chapter.

No recommendations exist in the Good Practice Handbook concerning the uncertainty levels associated with emission factors, and they were set in the following mode:

- total uncertainty in the emission factor was determined calculating the propagation of error in accordance with the equation that was used for the determination of the Emission Factors and incorporating an additional factor for the consideration of errors in climate region determination;
- uncertainty for the quantity excreted, VS parameter, was set at 20 per cent, considering the use of an enhanced livestock characterization, similar to that used in the derivation of the emission factor of CH₄ from Enteric Fermentation;

- the uncertainty of the allocation of manure for each Manure Management System (MMS) was determined comparing the share patterns that were used in Seixas et al (1999) with the new revised patterns¹¹⁵. This error was combined with the error associated with the MCF parameter: the uncertainty was assumed to be 100 per cent for Anaerobic Lagoons, given the possible range in the IPCC defaults (IPCC,2000), and Liquid Storage, in this case considering not only the range of IPCC defaults but also the uncertainty in the time period during which the manure is stored; for solid storage and pasture, the uncertainty values of 50 per cent reflect the variation of this parameter;
- the error associated with the parameters B_0 is specie dependent and was establish from the range of possible values in the IPCC, for developed and developing nations. Uncertainty values vary from 10 per cent for horses up to 22 per cent for dairy cows. The uncertainty of the biogas density was assumed not to be determinant of the overall uncertainty value;
- from observation of the climate maps it is evident that, from the particular conditions that affect Portuguese climate, small annual variations in average air temperatures and also mapping techniques could exert a profound modification in the percentage of livestock numbers that are classified as either cool or temperate. Territorial units under each climate class could easily change as much as 30 per cent in either direction, value that was assumed as representative of uncertainty for this factor.

The individual uncertainty values are presented in next table.



Bibliography



Key Categories



Uncertainty

¹¹⁵ 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.

Table 1.20 – 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
Equides	48	20	10.6	30	61

RECALCULATIONS

No recalculations were made for this source sector, except the small corrections in errors, in a consistent mode to what was done for CH₄ emissions from Enteric Fermentation and N₂O emissions from Manure Management and Agricultural soils (Manure as fertilizer and Pasture).

FURTHER IMPROVEMENTS

No improvements are expected for this source sector in the near future, except the amelioration and better documentation of activity data and parameters. The implementation of IPPC revised guidelines 2006 is expected only for the second commitment period of the Kyoto Protocol.

CH₄ Emissions from Rice Cultivation (CRF 4C)

OVERVIEW

Methane production is enhanced in rice cultivation areas (rice paddies) due to the prevalence of anaerobic conditions which result from flooding and high levels of organic material in soil surface. The methane that is formed in soil underwater escapes to atmosphere as greenhouse gas emission, as visible bobbles or through transport inside plant stems.

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:

$$E_{\text{RiceCH}_4(y)} = EF * \text{Rice}_{\text{Area}(y)} * 10^{-2}$$

where

$E_{\text{RiceCH}_4(y)}$ - Emission from rice production estimated for year y (ton/yr);

EF - Final emission factor, seasonally integrated and adjusted for management practices (g/m²/yr);

$\text{Rice}_{\text{Area}(y)}$ - Area under rice cultivation in year y (ha).

EMISSION FACTORS

According to GPG formulation, the final value for the emission factor results from the multiplication of several factors:

$$EF = E_{fc} * SF_w * SF_o * SF_s$$

where

EF - Final emission factor, seasonally integrated and adjusted for management practices (g/m²/yr);

E_{fc} - Seasonally integrated emission factor for continuously flooded fields without organic amendments (g/m²/yr);

SF_w - Scaling factor for water management regime and ecosystem hydrologic conditions;

SF_o - Scaling factor reflecting organic amendments (rice straw, manure, compost, wastes), because easily decomposable carbon increase methane formation;

SF_s - Scaling factor for soil type.

The default E_{fc} proposed in GPG (20 g/m²/yr) was not used, but replaced by a regional specific E_{fc} that was determined by reference to Schutz et al (1989)¹¹⁶. Considering the information in

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Key Categories

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Uncertainty

¹¹⁶ 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.

tables in the original document¹¹⁷, the E_{fc} more adjusted to the Portuguese conditions is 31.9 g/m²/yr. This value is slightly lower than the value that is proposed by IPCC96 in table 4-13 for Italy (36 g/m²/yr).

Rice culture in Portugal is almost homogeneous, in what concerns hydrologic management regime and characterized by cultivation being done under irrigated continuous flooded areas, where water regime is controlled by human activity (water diversion, irrigation and dikes). Rice fields are in standing water throughout all rice growing season and are only dried for harvest. All areas under rice cultivation are situated close to river banks almost at sea level. Accordingly the parameter SF_w was set as 1.0.

The time series of the quantity of residues that were burnt or plowed into soil before next crop season, was revised (SF_o was assumed to be 1 in the previous submissions) following the information received from the agriculture experts from the Portuguese Ministry of Agriculture:

- Traditionally, stubbles and straw were burnt between crops;
- The use of rice straw as fodder or bedding is not significant, and is not removed from field;
- 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 Protection¹¹⁸ are used;
- The area subjected to “Techniques of Integrated Production and Protection” occupied about 50 per cent of rice paddies in 2004. Today the area burnt occupies only about 30-40 per cent of total area;



Bibliography



Key Categories



Uncertainty

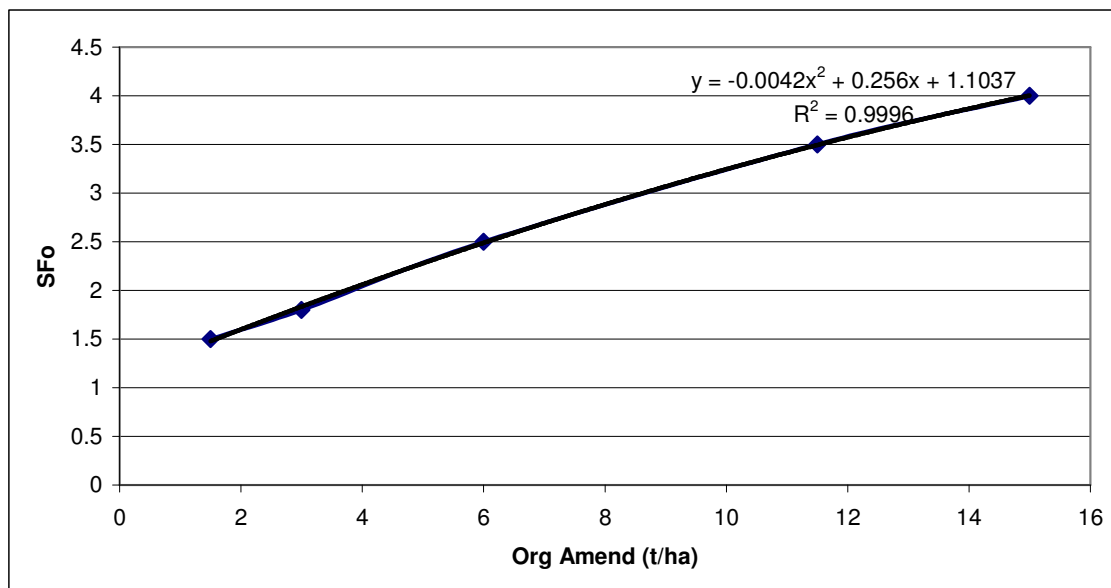
¹¹⁷Table 1 - Average Seasonal CH₄ Emission Rates from Unfertilized Rice Paddies (pg 16 409); Table 2 - CH₄ Emission Rates Measured on fields which received Mineral or Organic Fertilizer Applications (pg 16 411); Table 3 - CH₄ Emission Rates in Rice Paddies Fertilized with both organic and Mineral Fertilizers (pg 16 414).

¹¹⁸ “modos de protecção e produção integrada” in the original in Portuguese.

- It may be assumed that, in 1990, 100 per cent of rice paddies were burnt and no organic amendments were added to soil. In 2004 the area subjected to burning was reduced to only about 40 per cent.

Total quantity of residues per hectare were estimated from rice production and assuming a residue/crop ratio (1.4) and a dry matter content (85 per cent) (table 4.16 IPCC's GP). Using this information SF₀, the scaling factor for organic amendments, was determined using the data in table 4.21 of the GPG¹¹⁹. The following regression was set from the original table.

Figure 1.19 – Relation between SF₀ and the quantity of organic amendments added to soil.

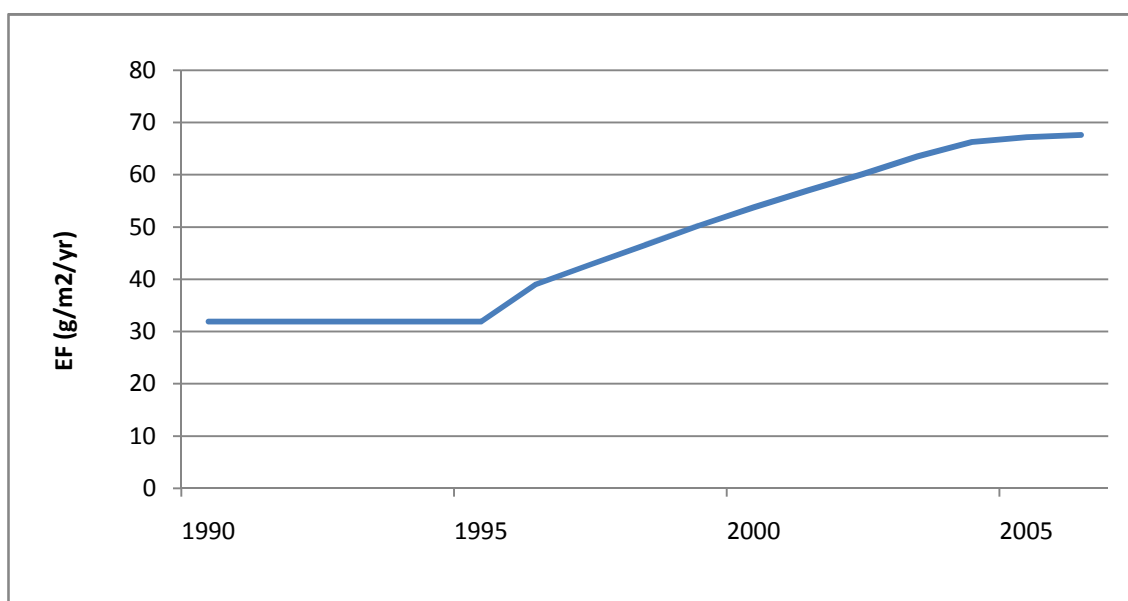


¹¹⁹ The available data in Schutz et al (1989) could not be used to estimate this factor in accordance with EF₀.

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.

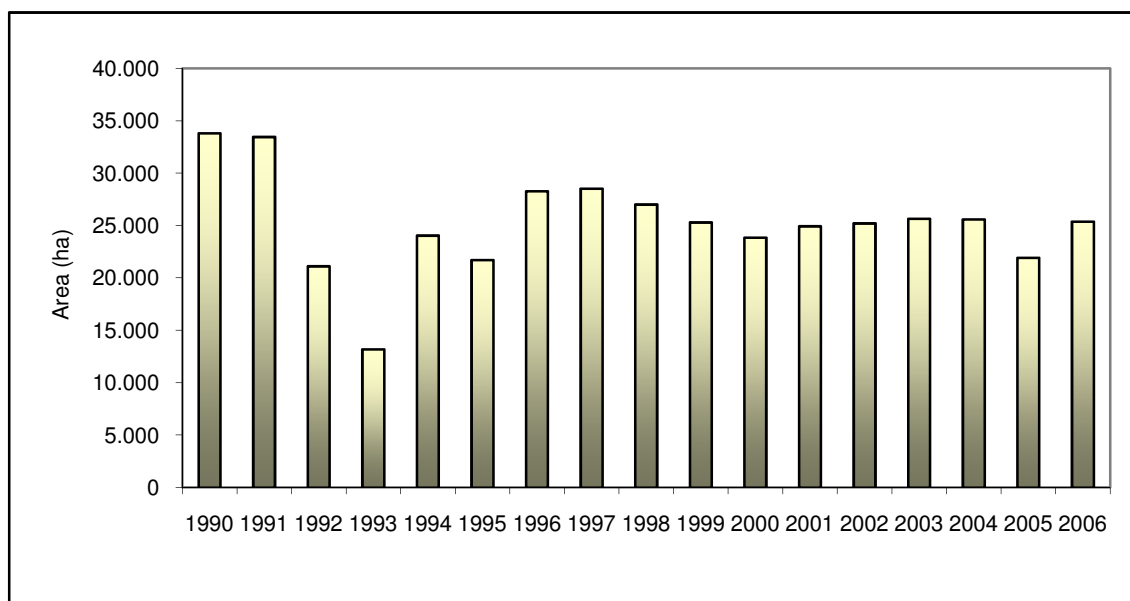
Figure 1.20 – Emission Factor EF used to estimate CH₄ emissions from rice paddies in Portugal.



ACTIVITY DATA

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 1.21. 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 1.21 – Area under rice cultivation in Portugal (1990-2006)



Relevant characteristics of rice cultivated areas, such as water management regime, organic amendments and soil type are included already in emission factor setting.

UNCERTAINTY ASSESSMENT

The uncertainty in the adjusted seasonally integrated emission factor was considered to be 40 per cent, according to the range proposed in table 4.22 of the GPG. For activity data, the standard deviation of inter-annual area under rice cultivation was considered, also 40 per cent.

RECALCULATIONS

The substantial change in methodology followed the recommendations made during the in-country review of the 2006 Inventory Submission under UNFCCC and of the Informative Inventory Report under the Kyoto Protocol, which took place in 2007.

Overall, according to the changes made, CH₄ emissions from rice fields, were decreased in 1990, by 11 per cent when in comparison to submission 2006, whereas emissions have increased substantially in more recent years following the increased use of straw and stubble as organic amendments.

New estimates of GHG from burning of residues in rice paddies were made, in order to maintain the coherence in the inventory. Changes were made in the per cent of area burnt. The quantity of residues burnt was also revised, making consistent with the quantity of crop residues that were used to estimate N₂O emissions in agricultural soils.

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.

N₂O Emissions from Manure Management (CRF 4B)

OVERVIEW

Part of the Nitrogen that is in manure, either in faeces or urine, is emitted as N₂O during management or during storage of manure, before application to soil, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen.

Emissions of N₂O that occur after manure is deposited in soil, either as a way for disposal or as a fertilizer process, are reported in the category N₂O from agricultural soils and are discussed later. Following the UNFCCC reporting guidelines, emissions of N₂O from dung and urine that are deposited directly into soil during grazing, pasture and in paddocks, are also included in category N₂O from agricultural soils.

In a short description, this is a biological based process where emission of N₂O from manure require the previous oxidation of organic nitrogen in ammonia form, which results from bacterial mineralization of organic nitrogen, into nitrites and nitrates (nitrification, a biological process mediated by bacteria such as Nitrobacter and Nitrosomomas) in an aerobic environment and thereafter the reduction of this compounds in an anaerobic environment (the denitrification process where nitrate is converted to N₂ and nitrous oxide). Although there is no extensive information concerning the factors that affect this process it is believed that N₂O emissions increase with aeration, at least to finalize the process, and hence increase under opposite conditions that determine methane emissions from solid storage or deposition during grazing and dry lot, which means that are lesser emissions in fully anaerobic systems like liquid systems and anaerobic lagoons.

In terms of the importance of each Manure Management System, observable in Figure 1.22, the great majority of emissions result from solid storage and dry-lot, totalizing on average in the 1990-2006 period 97.5 per cent of total N₂O emissions from Manure Management. The rest comprehends 1.3 per cent of emissions from anaerobic lagoons and 1.2 per cent of total emissions from liquid systems. In terms of origin by animal type¹²⁰, emissions are dominated by



Bibliography



Key Categories

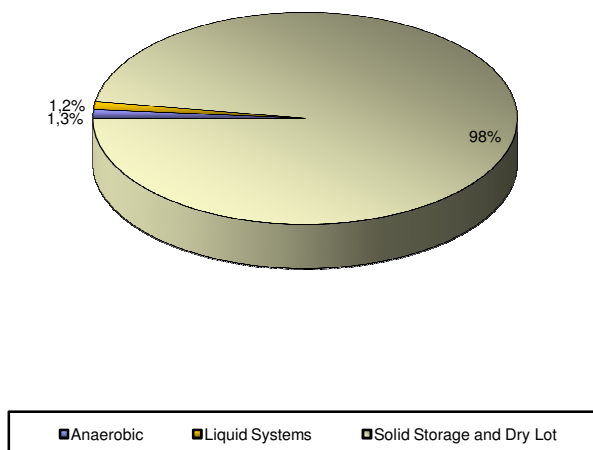


Uncertainty

¹²⁰ 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.

poultry, non dairy cattle and dairy cattle, which together comprehend about 78.3 per cent of total emissions, as may be seen in Figure 1.23 for the year 2006. Emissions from poultry were the most significant source with 47.7 per cent of emissions in 2006¹²¹ while, non-dairy cattle (18.8 per cent in 2005) and dairy cattle (11.8 per cent) are also important sources.

Figure 1.22 – Distribution of total N₂O emissions from Manure Management per System in year 2006



Bibliography



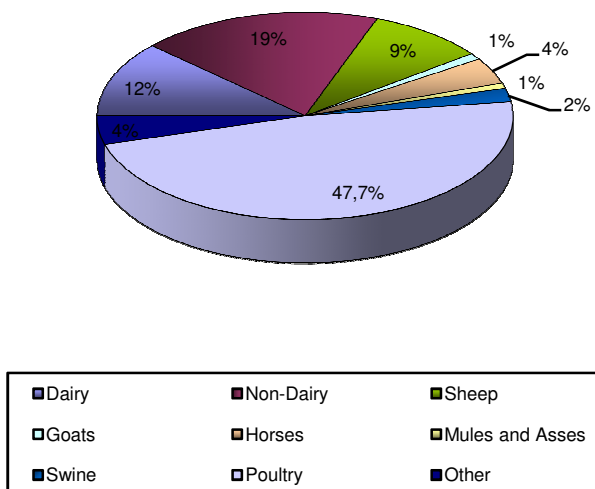
Key Categories



Uncertainty

¹²¹ 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 1.23 – Distribution of total N₂O emissions from Manure Management per animal specie as origin of manure in year 2006



METHODOLOGY

Emissions of N₂O from manure for each Manure Management Systems were estimated from the following formula:

$$EN2O_{(s)} = 44/28 * \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)}$$

where,

EN2O_(s) - N₂O emissions from manure in Manure Management System S;

S - Manure Management System;

i - Animal/species category of livestock;

N_(i) - Number (head) of individuals from livestock category i in the country;

Nex_(i) - Annual country average N excretion per head of animal species/category i;

MS_(i,s) - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s;

EF3_(s) - N₂O emission factor for Manure Management System s (kg N₂O-N/kg N).

This formulation follows the one proposed in GPG (equation 4.18).

The following Manure Management Systems were considered for the calculation of total N₂O emissions from manure management, in accordance with the expert information received from the Ministry of Agriculture (MADRAP). The following table presents the original classes from the MADRAP and the correspondent classes in CRF table 4.D.

Table 1.21 – 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 N₂O soil emissions from manure deposited in soil during grazing (Pasture Range and Paddock). However, emissions from this activity are further discussed in the sub-chapter (6.2.5) “Direct Nitrous Oxide Emissions from agricultural soils”.

Parameters $N_{(i)}$, $N_{ex(i)}$ and $MS_{(i,s)}$ will be discussed under “activity data” and $EF3_{(s)}$ will be discussed as “emission factor”.

EMISSION FACTORS

N₂O emission factors are presented in next table for all MMS (although the uses of daily spread, use for fuel and other systems are not considered in the Portuguese inventory). These emission factors are the default IPCC96 emission factors (table 4-22 which were maintained in GPG table 4.12) because there are no country-specific emission factors.

Table 1.22 – N₂O from Manure Management: Emission factors per Manure Management System

MMS	EF3 (kg N ₂ O-N/kg N)
Water Treatment Plant: Anaerobic Lagoon	0.001
Liquid Systems: Tank, Open Pit	0.001
Solid Storage and drylot	0.02
Pasture Range and Paddock	0.02

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 Agriculture¹²². 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.



Bibliography



Key Categories



Uncertainty

¹²² Dr^a Fátima Calouro, director of the Laboratório Químico Agrícola Rebelo da Silva in Lisbon. This laboratory was created in 1886. Performs research in the area of fertilizer use and improvement, soil and plant analysis and fertilizer recommendations.

The nitrogen excretion rates proposed by the Ministry of Agriculture reflect the monitoring results obtained in the Laboratory Rebelo da Silva, complement with international sources such as Ryser et al. (1994) and data submitted by other countries. These rates were considered to be more representative of the national conditions than those that were formerly submitted, until submission 2005, and which were set (Seixas et al, 2000) from information received from the Agriculture Ministry.

The following section presents the detailed calculation that was used to establish the country/specific nitrogen ratios for swine and sheep. This information was delivered, on demand, to the ERT team that was responsible for the review of Submission 2006 under the UNFCCC and the IIR under the Kyoto Protocol. Similar calculations were performed for other species.

SWINE AND SHEEP

LQARS¹²³ laboratory has extensive collection of data about composition of manure. The following table presents main results available for swine and sheep.

Table 1.23 – Results of analysis of Manure Composition (Source: LQARS)

Specie	Stat	Water	Dry Mater	N Total	
		% w/w	% dm w/w	% w/w	% dm
Swine*	Avg	89.2	10.9	0.49	10.3
	Stdv	12.9	-	0.17	-
Sheep #	Avg	69.6	30.4	0.65	2.34
	Stdv	7.0	-	-	1.19

* Fattening pigs # - Manure collected in stall

The concentration of Nitrogen in Manure was multiplied by the amount of fresh manure that is produced per day and per animal. Special care was given to ensure that the conditions at which

¹²³ Laboratório Química Agrícola Rebelo da Silva, Lisbon, Portugal

analysis were made match the assumptions behind volume rates - namely consistency in water content.

- For swine, typical annual volume of fresh manure varies between 1 and 2 m³/yr depending on management conditions (existence of bedding, etc). These volumes are related to nitrogen content in accordance with an inverse relation. Considering a density liquid manure of 1.0155, the production rate is 1.52 t/hd/yr (1.02-2.03 t/hd/yr);
- For sheep, the production rate, also obtained from (MADRP,1997), is 2.5 t fresh manure per head and per year for 22 per cent dry mater content. When this value is converted to the dry mater content that was obtained in manure analysis (30.4 per cent), the actual manure generation rate is 1.7 t/hd/yr.

For swine, total nitrogen excretion was estimated simply from:

$$\text{Nex (kg N/yr)} = \text{Manure Production (t/yr)} * \text{N content (\% wt)} * 1000/100$$

Nitrogen excretion ratios for fattening pigs are in the range 4.99 to 9.97 kg N/hd/yr. Final values were corrected for other animal classes according to size and feed intake.

For sheep, because there is typically a significant quantity of bedding (usually straw), and to avoid double counting of nitrogen in straw that was already accounted in N₂O emissions from crop residues, this quantity has to be estimated and subtracted.

Total Nitrogen in Manure was therefore estimated in a similar procedure that was used for swine, and the average Nitrogen excretion rate is therefore 10.9 kg N/yr. The quantity of straw in manure is not available. However, it may be estimated comparing the quantity of dry matter that is estimated in Manure:

$$581 \text{ kg dm/hd/yr} = \text{Manure Production (kg/hd/yr)} * \text{dm content (\%)} / 100 = 1.67 * 30.28 \%$$

With the quantity of dry matter that the energy balance - in the inventory - estimated to be in manure, 179 kg dm/hd/yr¹²⁴. The difference, 581 - 179 = 329 kg dm/hd/yr, may be explained by the straw.

Nitrogen content of straw is 0.51 per cent (average value for crop residues) and the nitrogen content of straw was estimated as:

$$\text{Bedding (kg dm/hd/yr)} * \text{N content (\% dm)} = 329 * 0.0051 = 1.7 \text{ kg N/hd/yr}$$

Final Nitrogen excretion ratio is thereafter 9.2 kg N/hd/yr. For lambs, the excretion ratio is 30 per cent of an adult, 2.8 kg N/hd/yr.

OTHER ANIMALS

For some few animal types, for which excretion rates were not provided by this information source, the rates were estimated from data on animal feed, ingestion of nitrogen (Crude Protein converted in nitrogen) and the use of the retention rates proposed in the GP (IPCC,2000). The nitrogen rates that were used per animal type are presented in next table, together with the default nitrogen excretion rates from IPCC for Western Europe (table 4-20 of IPCC96).

FINAL N_{EXC} AND NITROGEN EXCRETION

There is an acceptable agreement between country-specific values and IPCC defaults for all species other than sheep, goats and equines. Albeit the nitrogen excretion rate for sheep appearing now too low, when in comparison to IPCC default (9.2 against 20), it has similarities to those used by other parties.

¹²⁴ Calculated from VS and including 8 per cent of ash

Table 1.24 – N excretion rate per head and by animal species/category (Nex)

Animal Class	Animal type	Nex (kg N/hd/yr)			
		Sub 2008	Sub 06-07	Sub 2005	IPCC Default
Dairy-cattle	Dairy Cows	87.6	87.6	108.07	100
non dairy cattle	Beef calves (<1 yr)	26.3	26.3	54.03	70
	Calfs, Males for Rep. (<1 yr)				
	Calfs, Females for Rep. (<1 yr)				
	Males 1-2 yrs	52.6	52.6		
	Beef Fem. 1-2 yrs				
	Females for R. 1-2 yrs				
	Steers (>2 yrs)	61.3	61.3		
	Heifers for Beef (>2 yrs)	70.1	70.1		
	Heifers for Rep. (>2 yrs)				
	non-dairy cows	61.3	61.3		
Swine	Piglets (<20 kg)	2.0	2.0	14.89	20
	Fat. Pigs (20-50 kg)	7.0	7.0		
	Fat Pigs (50-80 kg)	10.0	10.0		
	Fat Pigs (80-110 kg)				
	Fat Pigs (> 110 kg)				
	Boars (>50 kg)	17.5	17.5	29.78	
	Sows, pregnant				
	Sows, non-pregnant				
Ovine	Ewes	9.2	7.0	6.9	
	Other Ovines				
	Lambs	2.8	2.1		
Caprine	Does	7.0	7.0	4.93	25
	Other Caprines				
	kids	2.1	2.1		
Equides	Horses	60.0	60.0	54.03	
	Asses, Mules and hynies	22.0	22.0		
Poultry	Hens Reproductive	0.6	0.6	1.58	0.6
	Hens eggs				
	Broilers	0.8	0.8	0.74	
	Turkeys	1.8	1.8	3.29	
	Ducks, Geese and Guinea Fowl	0.9	0.9	1.58	
Other	Rabbits	7.4	7.4	1.5	25

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to year 2005, is presented in Table 1.25 and Table 1.26.

Table 1.25 – Total Nitrogen in Manure produced by livestock in Portugal 1990-1998 (ton N/yr)

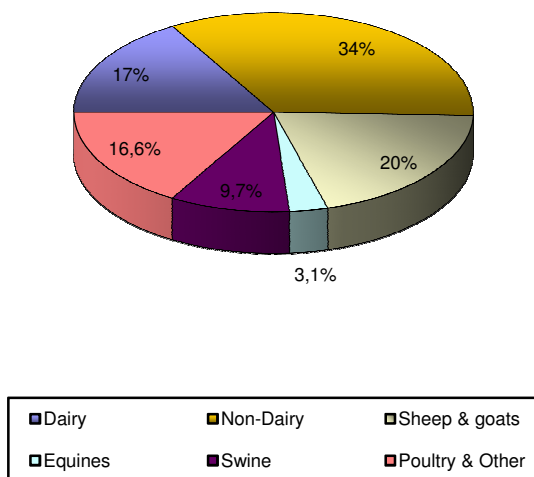
Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998
Dairy	30 365	29 878	29 338	29 492	29 415	29 492	29 236	29 184	28 876
Non-Dairy	41 751	42 639	42 042	42 008	42 019	43 266	44 571	45 312	46 091
Sheep	25 015	25 458	25 541	25 720	26 099	26 450	26 681	26 504	26 787
Goats	4 625	4 489	4 288	4 152	4 069	3 975	3 906	3 811	3 718
Horses	1 831	2 108	2 215	2 331	2 471	2 650	2 876	3 032	3 144
Mules and Asses	2 411	2 376	2 332	2 319	2 220	2 110	1 953	1 828	1 681
Swine	15 897	16 512	16 449	16 531	16 220	15 881	15 183	15 079	14 980
Poultry	16 325	16 814	17 464	18 414	19 218	19 929	20 470	21 220	22 725
Other	1 579	1 584	1 596	1 651	1 772	1 894	1 988	1 977	1 996
Total	139 800	141 858	141 265	142 617	143 502	145 647	146 862	147 947	149 998

Table 1.26 – Total Nitrogen in Manure produced by livestock in Portugal 1999-2006 (ton N/yr)

Animal Type	1999	2000	2001	2002	2003	2004	2005	2006	1999
Dairy	28 382	27 810	26 929	26 521	25 848	25 847	25 389	24 863	28 382
Non-Dairy	46 831	47 634	47 961	47 775	47 876	48 690	49 998	50 956	46 831
Sheep	26 990	27 240	26 578	25 804	25 313	25 817	26 566	27 172	26 990
Goats	3 628	3 529	3 402	3 253	3 070	2 968	2 937	2 941	3 628
Horses	3 197	3 234	3 259	3 259	3 231	3 378	3 584	3 848	3 197
Mules and Asses	1 538	1 405	1 281	1 159	1 036	950	872	802	1 538
Swine	14 955	14 854	14 904	14 881	14 692	14 593	14 542	14 590	14 955
Poultry	23 747	24 438	24 135	23 904	22 988	22 757	22 662	22 753	23 747
Other	1 998	2 054	2 072	2 093	2 093	2 093	2 093	2 093	1 998
Total	151 267	152 198	150 520	148 649	146 146	147 093	148 642	150 018	151 267

The major contributors to total nitrogen from livestock in Portugal in 2006 were non-dairy cattle and sheep, as may be seen in Figure 1.24.

Figure 1.24 – Origin of nitrogen in manure from livestock production in Portugal in 2004, 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 Management¹²⁵.



Bibliography



Key Categories



Uncertainty

¹²⁵ 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.

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), 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 N_2O emissions from manure are larger than if the default MMS from IPCC was applied.

For pigs, the fact that IPCC assumes most manure managed is Liquid systems, while national information considers Anaerobic Lagoons is not much relevant because the default EF_3 is the same for both 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. Overall emissions estimated using country specific data results in lower values than those that would result from the utilization of IPCC defaults.

For sheep and goats, there is a different percentage of animals in closed systems and in Pasture, but that does not affect significantly total N_2O estimates - because EF_3 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 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.

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 CH_4 emissions from enteric fermentation. The uncertainty in N-excretion rate was set at 37.5 per cent, considering an intermediate situation between the uncertainty values recommended by GPG for default N-excretion rates (50 per cent) and the lower uncertainty when country-specific values are based on accurate national statistics (25 per cent). Uncertainty in MMS share was determined as the maximum difference in total excretion for each MMS considering the allocation per MMS used in previous submissions (Seixas et al, 1999) and the new revised share of MMS, and the values vary from about 1 per cent for anaerobic lagoons and liquid systems to around 10 per cent for solid systems and pasture. The overall uncertainty values range from 37.5 per cent to 39 per cent, which is lower than the value considered in last year's submission (52 per cent) and reflects the improvements made in the methodology and determination of parameters.

The uncertainty in N_2O emission factors was set in accordance with the maximum values proposed in table 4.12 of the Good Practice Handbook (IPCC,2000), 100 per cent for all MMS.

RECALCULATIONS

Following the recommendation, by the ERT team that was responsible for the review of Submission 2006 under the UNFCCC and the IIR under the Kyoto Protocol, the nitrogen excretion ratio for sheep was increased slightly, from 7 to 9.2 kgN/hd/yr for adults and 2.1 to 2.8 kg N/hd/yr for lambs.

FURTHER IMPROVEMENTS

Presently the nitrogen excretion rates are fixed in time. Efforts will be made to add time evolution.

Direct N₂O Emissions from Agricultural Soil (CRF 4D1)

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:

- application of synthetic fertilisers;
- application of animal manure;
- animal manure (droppings) deposited directly by animals on pasture, range and paddock;
- nitrogen fixation by N-fixing crops (leguminous plants);
- nitrogen input from incorporation of crop residues into soils.

Most effort was placed to made estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources: N₂O, CH₄ and NH₃.

The inventory of N₂O from Direct Soil Emissions from Agricultural Soils is almost complete, except the non inclusion of estimates for N₂O from the application of sewage sludge, due to the unavailability of data. However, this sources 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.

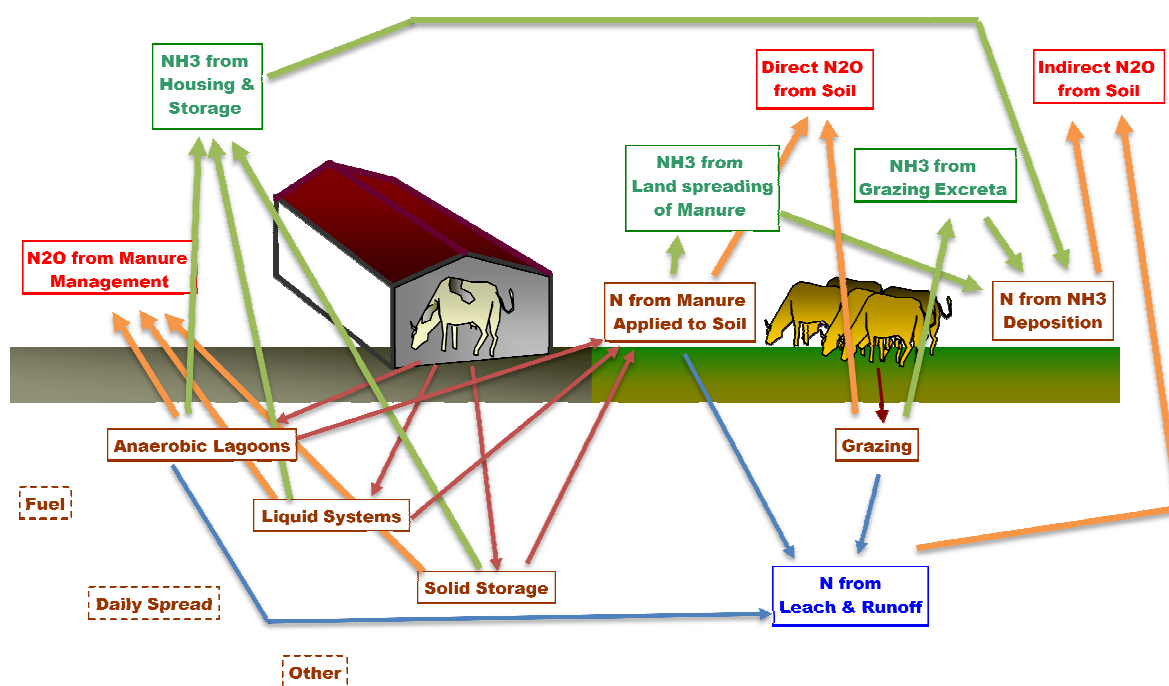
It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

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.

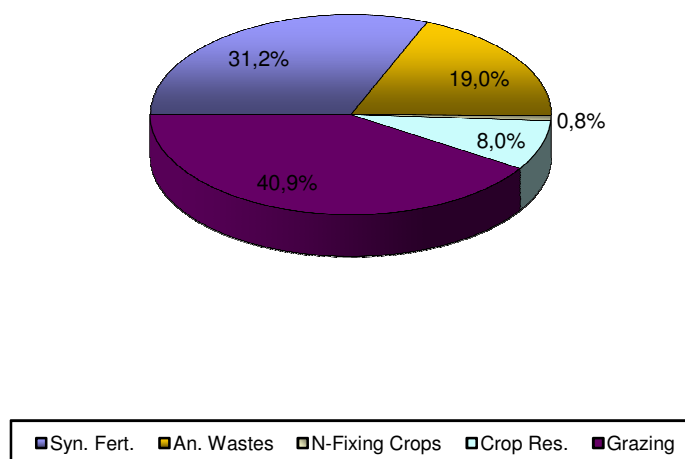
The following figure synthesizes the livestock system in what concerns nitrogen fluxes and direct and indirect N_2O emissions.

Figure 1.25 – Nitrogen fluxes from livestock system



The comparative importance of the several sub-source activities is shown in Figure 1.26, from where it is evident the major contribution from direct deposition (Grazing 40.9 per cent) and synthetic fertilizers (Sin. Fert with 31.2 per cent) which may be considered significant sources in accordance with the IPCC rule of thumb. Manure used as fertilizer is also an important source, responsible for 19.9 per cent of emissions.

Figure 1.26– Contribution of the various sub-sources to total N₂O emissions from Direct agricultural soil emissions in 2006



METHODOLOGY

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 soil¹²⁶.

Final N₂O emissions are estimated with a formulation derived from equation 4.20 of GPG:

$$EN2O_{Direct} = 44/28 * (FSN + FAM + FBN + FCR) * EF_1$$

where:

EN2O_{Direct} - Annual emission of N₂O

FSN - Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilises as NH₃

FAM - Annual amount of animal manure nitrogen intentionally applied to soils adjusted to account for the amount that volatilises 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)



Bibliography



Key Categories



Uncertainty

¹²⁶ However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

FSN, the annual amount of synthetic fertilizer nitrogen applied to soil after adjusting to account for the amount that volatilises, is estimated from:

$$FSN = N_{Fert} * (1 - \text{Frac}_{GASF})$$

where,

N_{Fert} - total amount of nitrogen in synthetic fertilizers consumed annually

Frac_{GASF} - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH_3 or NO_x

The amount of nitrogen in animal manure that is used as fertilizer (FAM) was estimated from total nitrogen excreted from livestock that is applied to agricultural soils and after subtraction of nitrogen that was volatilised in housing, manure storage and after deposition in soil as fertilizer. The following equation applies:

$$FAM = \sum_i \{ N_{(i)} * N_{ex(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * (1 - EF_{NH3SD(i)}) \}$$

where

FAM - total amount of nitrogen in manure from Manure Management System that is applied to soil as fertilizer;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$N_{ex(i)}$ - 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:

$$FBN = \sum_i \{ \text{Crop}_{BF(i)} * (1 + \text{Res}_{BF}/\text{Crop}_{BF(i)}) * \text{Frac}_{DM(i)} * \text{Frac}_{NCRBF(i)} \}$$

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.

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.

1.1.A.1 EMISSION FACTORS

EF_1 , the emission factor relating N input to soil with N_2O emissions, was set equal to the IPCC default value of 0.0125 kg N_2O -N/kg N input (table 4.17 of GPG and table 4.18 of IPCC96)¹²⁷.

The emission factor of N_2O for Pasture, Range and Paddock (EF_3) was set at 0.02 kg N_2O -N/kg N which is the default IPCC96 emission factor (table 4-22) that is also maintained in GPG (table 4.12).

1.1.A.2 ACTIVITY DATA

The estimated quantities of nitrogen added to agricultural soils from each specific source are shown in Table 1.27 and Table 1.28 below and the percent contribution of each one in year 2004 is also represented graphically in Figure 1.27.

For the last year in the inventory (2006) the majority (36.8 per cent) of nitrogen added to soil has resulted from the application of synthetic fertilizers, followed by nitrogen in manure as direct

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Key Categories

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Uncertainty

¹²⁷ Which is the same as stating that 1.25% of nitrogen input to soil is emitted as N_2O

droppings during grazing in Pasture (30.0 per cent) and as manure applied to agricultural soil as fertilizer (22.4 per cent) and . Smaller quantities came from nitrogen returning to soil as crop residues (9.5 per cent) and from nitrogen fixed by leguminous plants (1.0 per cent). Total nitrogen added to agricultural soils in Portugal has increased slightly along years up to 2002, but after 2003 successive years with severe droughts caused a sharp decline in the use of fertilizers. Therefore, total nitrogen added to soil was in 2006 about 8.5 per cent lower than what it was applied in 1990, although for the year 2002, application of nitrogen was 2.7 per cent higher than in base year.

Table 1.27 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1990-1998¹²⁸

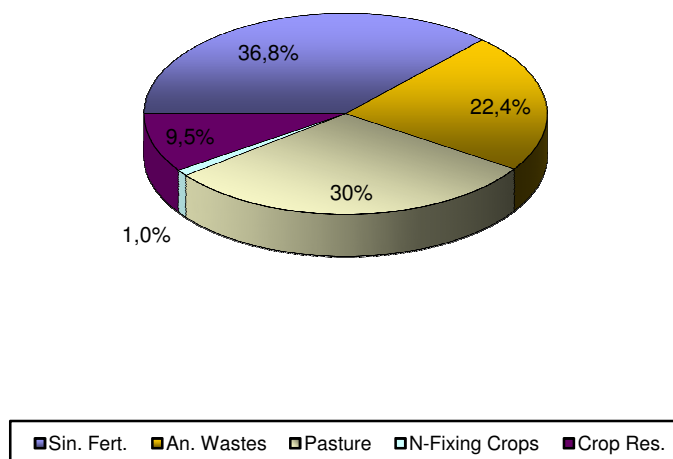
ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998
Synthetic Fertilizer	149 856	149 856	149 939	151 322	149 721	137 628	158 325	153 963	140 850
Animal Manure	56 440	57 306	57 331	58 244	58 533	59 074	59 018	59 153	59 927
Pasture Range	67 899	68 793	68 168	68 363	68 937	70 460	71 856	72 772	73 863
Fixed by Crops	5 032	4 701	4 272	3 906	3 740	3 780	3 667	3 411	3 045
Crop Residues	26 568	25 212	23 526	23 420	24 288	25 955	25 547	26 121	26 335
Total	305 796	305 868	303 237	305 256	305 219	296 896	318 413	315 420	304 020

¹²⁸ 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

Table 1.28 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1999-2006

ton N/yr	1999	2000	2001	2002	2003	2004	2005	2006
Synthetic Fertilizer	139 979	160 265	148 504	154 529	103 834	118 648	93 175	120 224
Animal Manure	60 349	60 628	59 628	58 640	56 918	56 746	56 720	56 751
Pasture Range	74 593	75 177	74 702	74 022	73 663	74 845	76 457	77 810
Fixed by Crops	2 840	2 672	2 646	2 611	2 625	2 553	2 523	2 484
Crop Residues	26 612	25 828	24 858	24 131	25 018	24 153	24 028	22 645
Total	304 374	324 570	310 337	313 933	262 058	276 946	252 903	279 915

Figure 1.27 – Sources of direct input of Nitrogen to agricultural soil in 2005



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 Silva¹²⁹



Bibliography



Key Categories



Uncertainty

¹²⁹ Laboratório Químico Agrícola Rebelo da Silva is a public laboratory, under the Ministry of Agriculture, and proceeds to soil, plant and fertilizer analysis.

and ADP¹³⁰, 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 census¹³¹. Data of Imports and Exports is also from INE. The available time series is presented in 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.

Figure 1.28.

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.



Bibliography



Key Categories

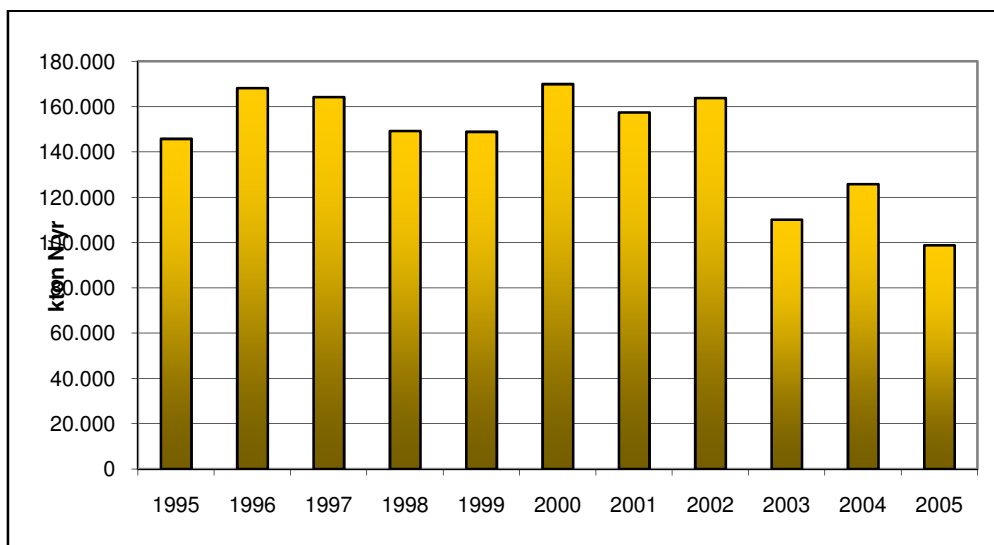


Uncertainty

¹³⁰ ADP, Adubos de Portugal, S.A., is the main producer of fertilizers in Portugal, and responsible for about 75% of fertilizer sales (INE,2004)

¹³¹ Annual census made to the Manufacturing Industry, by INE.

Figure 1.28 - Use of Nitrogen Fertilizers in Portugal according to INE for the period 1995 to 2005 (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 2004 - 2005 lead to the revision of the time series¹³². The value for 2006 was also forecast using the same approach.

The line that was obtained, Figure 1.29, shows an increasing trend until 2002, being the value in that last year 3.1 per cent higher than the value reported for 1990, with a sharp decrease for the next year. In the period where the time series is available from INE, the annual application of nitrogen fertilizers decreased by 32.3 per cent, from 1995 till 2005.



Bibliography



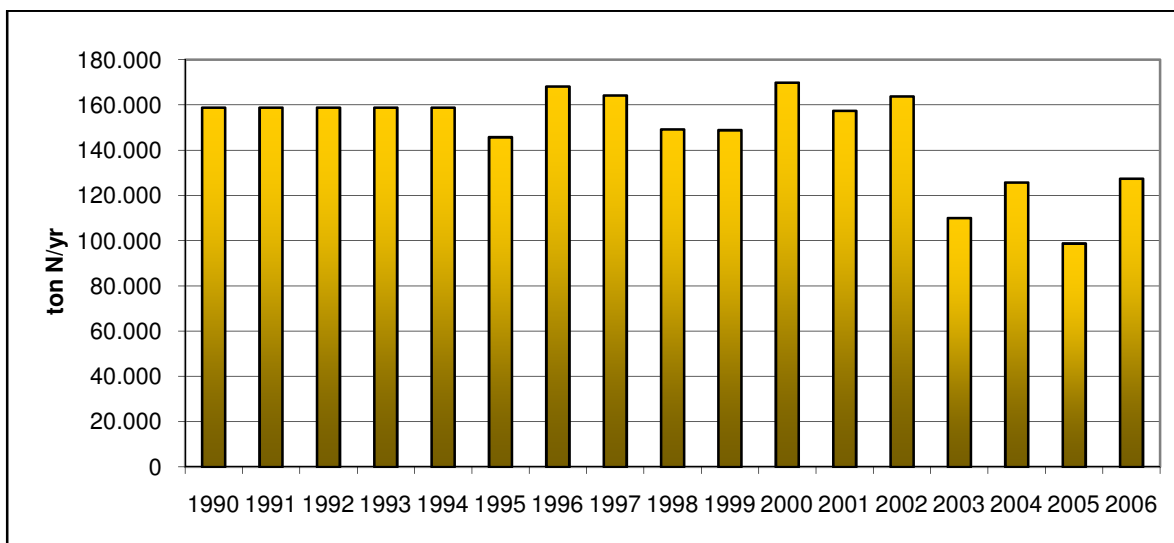
Key Categories



Uncertainty

¹³² But not of the back-casting model, and the estimate for base year was not revised.

Figure 1.29 - Use of Nitrogen Fertilizers in Portugal, estimated from INE data and using a simple average value for 1990-1994 (ton N/yr)

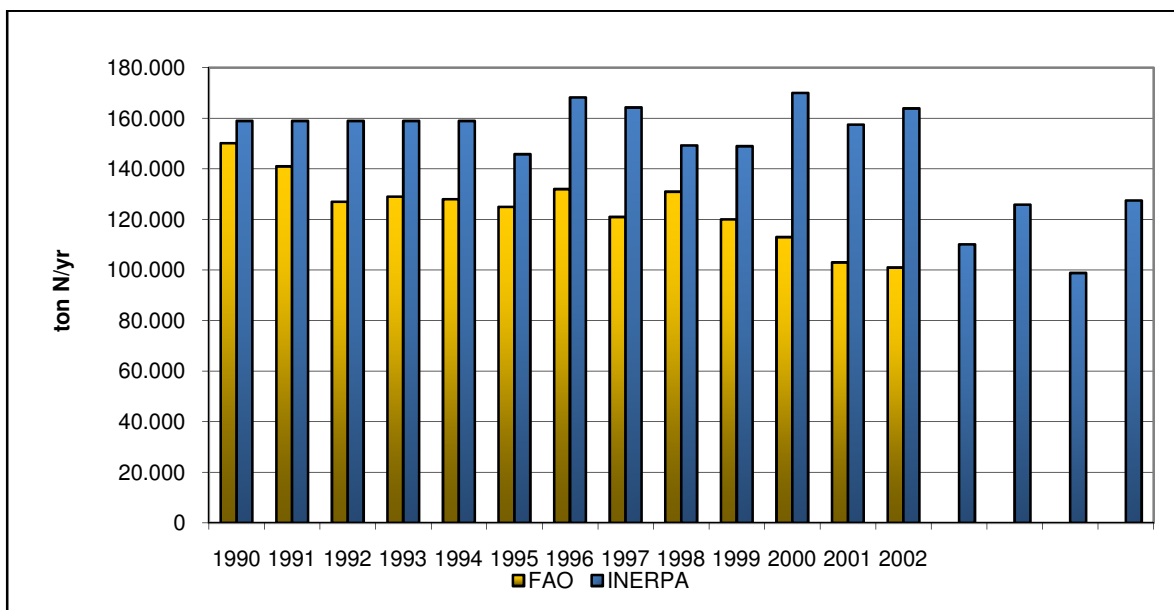


Losses of nitrogen from volatilisation of NH_3 and NO_x were estimated using a time variable and country-specific fraction $\text{Frac}_{\text{GASF}}$, which varies between 0.053 and 0.064 kg $\text{NH}_3\text{-N/kg N}$, and which are almost half the default value from table 4-19 of IPCC96 (0.1 kg $\text{NH}_3\text{-N/kg N}$). 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 Agriculture (Chapter 6.2.8).

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. a overall reduction of about 33 per cent. This series, presented in **Erro! A origem da referência não foi encontrada.**, 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 yea, although the values in this series appear to be over-estimating the rate of decrease of synthetic fertilizers in Portugal.

Figure 1.30 - Use of Nitrogen Fertilizers in Portugal according to FAO, and comparison to time-series in the inventory (ton N/yr)



ANIMAL MANURE

The quantity of nitrogen in manure that is applied to soil as fertilizer resulting in N_2O emissions was estimated from the same data that was used to estimate nitrogen excreted in N_2O from Manure Management and assuming that all the manure that is treated under Solid Storage or liquid systems is used as soil fertilizer, i.e. $MSSD_{(i,s)}$ equals 1 only for Solid Storage and Liquid Systems. Concerning the other Manure Management System, Anaerobic Lagoons, 80 per cent of effluent is added to soil as fertilizer¹³³, in accordance with a characterization study made in

Bibliography

Key Categories

Uncertainty

¹³³ 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 per cent are rejected directly to the water system.

Portugal (Bicudo & Albuquerque, 1995; LNEC, 1996; GPPAA,2001)¹³⁴. As explained before, under CH₄ and N₂O emissions from Manure Management, no other Manure Management Systems exist in Portugal. Quantities applied each year were also presented in **Erro! A origem da referência não foi encontrada.** and Table 1.28 above, where is shown that manure is the third major source of nitrogen applied to soil. Ammonia volatilisation factors, EF_{NH3(i,s)} and EF_{NH3SD}, are presented and discussed in more detail in chapter NH3 Emissions from Agriculture (Chapter 6.2.8) and they result from EMEP/UNECE Guidebook 3rd ed (table 3A in chapter B1050). These volatilisation fractions depend only on animal class and not on the specific Manure Management System.

Table 1.29 – Emission factors used for calculation of NH3 volatilisation emissions from land spreading of manure as fertilizer

Animal Type	Losses after land spreading (kg NH3-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 1.30 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%.



Bibliography



Key Categories



Uncertainty

¹³⁴ According to the same studies the remaining 20 per cent wastewater flow and nitrogen is rejected directly to water systems. This fraction is included in the determination of N₂O indirect emissions from agricultural soils.

Table 1.30 – Emission factors used for calculation of NH₃ 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 $Frac_{GASM}$ that is different and slightly 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). The resultant implied $Frac_{GASM}$ oscillates between 0.22 to 0.23 kg N-NH₃ + N-NO_x/ kg of N excreted¹³⁵.

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 desegregation: Agricultural Zone (ZA - Zona Agrária) and for 1999 the data was collected at an even thinner desegregation: 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.

¹³⁵ The rates presented in previous tables are expressed in kg N-NH₃ + N-NO_x/ kg of N deposited in soil.

The data series for crops that was considered in the inventory, at National level, is presented in Table 1.31 and Table 1.32 for leguminous crops and Table 1.33 to Table 1.36 for non leguminous crops. For each year a three year average centered in the reporting year was used¹³⁶. It must be stressed that not only pulses and beans were included in nitrogen fixing crops but all leguminous crops, but 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 1.31 – Annual (three year average) production of Leguminous Crops (metric tons) (1/2)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998
Peanut ⁽¹⁾ after 1995	29	32	29	26	20	17	20	23	27
Broad Beans ⁽¹⁾ 95-96	15 486	15 402	15 285	15 182	14 766	15 050	12 776	10 417	7 390
Broad Beans, green	32 000	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
Chick-Peas	3 563	3 081	2 583	2 101	1 937	1 899	1 815	1 810	1 478
Lupins	48	43	35	37	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
Carobs ⁽¹⁾	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
Total	133 236	126 850	120 292	114 949	118 377	123 646	123 886	113 917	102 114

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

¹³⁶ 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 1.32 - Annual (three year average) production of Leguminous Crops (metric tons) (2/2)

Crop	1999	2000	2001	2002	2003	2004	2005	2006
Peanut ⁽¹⁾ after 1995	25	25	25	25	25	25	25	25
Broad Beans	7 533	6 902	7 108	6 703	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
Beans	7 456	6 157	5 883	5 478	5 073	4 242	3 892	3 611
Chick-Peas	1 198	968	1 012	1 167	1 318	1 135	995	626
Lupins	34	34	34	34	34	34	34	34
Peas Green ⁽¹⁾	6 947	6 974	7 000	7 000	7 000	7 000	7 000	7 000
Carobs ⁽¹⁾	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green ⁽¹⁾	21 002	18 107	16 679	16 833	16 563	16 563	16 563	16 563
Total	94 195	89 166	87 742	87 240	87 553	86 539	86 049	85 399

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 1.33 - Annual Production of non-leguminous Crops (metric tons) (1/4)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998
Wheat	510 519	425 761	467 499	415 445	414 741	409 403	364 982	295 345	277 452
Triticale	61 983	61 350	67 167	74 463	70 552	63 141	47 680	37 354	29 787
Maize	666 832	666 596	667 567	685 982	698 177	738 450	789 109	877 874	926 044
Barley	95 691	88 545	95 201	85 904	82 590	73 074	50 600	41 648	28 096
Rye	98 612	82 120	72 195	66 673	55 594	51 326	43 625	42 367	42 930
Oats	91 718	64 436	65 868	66 907	71 084	65 778	54 137	44 496	57 578
Rice Paddy	156 939	145 418	116 394	103 482	108 432	142 842	153 658	166 064	159 204
Sunflower	46 954	48 644	43 418	45 355	37 061	34 806	30 466	34 319	27 399
Hops	194	112	68	45	88	129	131	107	72
Tomatoes	714 563	657 940	552 343	612 691	742 308	877 383	848 629	931 862	963 897
Tobacco	5 072	4 901	4 108	3 855	4 059	5 283	5 665	6 310	6 170
Tea ⁽¹⁾ until 2002	170	127	73	43	48	62	57	37	25
Chicory ⁽¹⁾	2 203	2 533	2 761	3 035	2 855	2 644	2 391	2 290	2 342
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
Sugar Beet	12 225	14 627	21 051	33 769	46 346	46 492	79 635	123 188	280 829
Yams ⁽¹⁾ after 1994	1 294	1 438	1 369	1 314	1 182	1 176	1 535	1 770	2 091
Sugar Cane ⁽¹⁾ after 1991	3 760	3 878	3 996	4 000	4 000	4 000	4 000	4 000	4 000
Sweet Potatoes ⁽¹⁾	27 000	26 667	28 000	27 333	26 333	23 667	22 667	22 000	22 000
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
Sorghum for Forage ⁽¹⁾	331 667	363 333	361 667	356 667	341 667	346 667	360 000	360 000	360 000
Roots Fodder ⁽¹⁾	378 333	383 333	388 333	393 333	386 667	395 000	401 667	418 333	420 000
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
Pumpkins ⁽¹⁾	4 200	4 200	4 033	3 867	6 600	9 700	12 600	12 600	12 167
Lettuce ⁽¹⁾ until 1996	32 000	32 000	34 667	40 000	49 267	56 367	62 761	74 069	84 876
Garlic ⁽¹⁾	1 667	1 667	1 533	1 467	1 467	1 467	1 433	1 400	1 400
Eggplants ⁽¹⁾	6 667	6 667	6 100	5 833	5 833	5 833	5 667	5 500	5 500
Onions ⁽¹⁾ until 1996	57 200	57 200	68 133	82 400	101 933	107 900	109 540	104 479	108 760
Carrots ⁽¹⁾ until 1996	82 667	83 000	83 000	83 000	97 700	128 133	139 062	144 900	144 646
Cauliflower ⁽¹⁾ until 1996	19 667	20 000	20 000	20 000	23 300	26 700	29 441	29 823	31 140
Cabbages ⁽¹⁾ until 1996	166 667	166 667	153 333	146 667	150 000	150 000	195 705	248 032	316 469
Spinach ⁽¹⁾	16 667	16 667	15 333	14 667	14 667	14 667	14 333	14 000	14 000
Watermelons ⁽²⁾ until 1996	64 385	43 959	32 427	22 478	24 772	26 355	35 514	45 463	55 412
Melons ⁽²⁾ until 1996	127 281	109 970	91 754	73 780	80 667	85 122	95 546	109 307	127 281
Cucumbers ⁽¹⁾	8 333	8 333	7 667	7 333	7 333	7 333	7 167	7 000	7 000
Chillies ⁽²⁾ until 1996	51 662	48 786	45 088	44 346	49 506	52 461	50 178	50 920	51 662
Mushrooms ⁽¹⁾	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000

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

Table 1.34 - Annual Production of non-leguminous Crops (metric tons) (2/4)

Crop	1999	2000	2001	2002	2003	2004	2005	2006
Wheat	285 933	286 823	307 120	238 743	285 168	174 673	208 014	165 580
Triticale	30 216	29 849	27 295	17 622	17 779	12 062	21 666	24 169
Maize	930 023	905 264	859 531	833 755	794 677	699 263	604 481	512 017
Barley	30 613	26 075	22 982	15 208	19 759	21 842	52 687	65 911
Rye	44 851	42 086	34 980	28 481	29 505	24 655	23 604	21 775
Oats	80 278	83 605	70 852	46 394	53 934	41 829	57 855	56 124
Rice Paddy	152 012	146 731	144 816	146 546	147 654	139 079	138 877	133 688
Sunflower	27 928	23 242	24 443	20 926	17 690	11 443	6 809	3 256
Hops	52	51	50	48	42	35	35	35
Tomatoes	996 516	937 512	889 848	891 044	987 509	1 060 059	1 089 729	1 034 128
Tobacco	6 267	5 895	5 834	5 700	5 565	5 280	4 163	3 566
Tea ⁽¹⁾	26	27	27	57	89	118	79	56
Chicory ⁽¹⁾	2 220	2 633	2 967	3 033	2 767	2 500	2 607	2 660
Potatoes	874 442	795 252	739 309	737 055	762 294	691 709	650 159	590 355
Sugar Beet	384 902	415 982	462 161	469 632	584 857	571 863	517 160	462 459
Yams ⁽¹⁾ after 1994	2 100	2 100	2 100	2 100	2 100	2 100	2 100	2 100
Sugar Cane ⁽¹⁾ after 1991	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Sweet Potatoes ⁽¹⁾	22 000	22 000	22 000	22 000	22 000	22 000	22 000	22 000
Maize for Forage ⁽¹⁾	5 000 000	5 000 000	5 000 000	5 000 000	5 000 000	5 016 667	5 020 000	5 030 000
Sorghum for Forage ⁽¹⁾	360 000	360 000	360 000	360 000	360 000	363 333	364 000	366 000
Roots Fodder ⁽¹⁾	420 000	420 000	420 000	420 000	420 000	423 333	424 000	426 000
Forage ⁽¹⁾	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 216 667	7 220 000	7 230 000
Pumpkins ⁽¹⁾	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000
Lettuce	79 469	66 190	54 680	57 424	59 192	59 192	59 192	59 192
Garlic ⁽¹⁾	1 400	1 400	1 400	1 400	1 400	1 400	1 400	1 400
Eggplants ⁽¹⁾	5 500	5 500	5 500	5 500	5 500	5 500	5 500	5 500
Onions	85 286	62 362	34 474	35 335	37 079	37 079	37 079	37 079
Carrots	123 294	90 898	49 775	49 255	50 170	50 170	50 170	50 170
Cauliflower	26 201	20 378	14 715	15 966	17 161	17 161	17 161	17 161
Cabbages	268 789	209 110	153 837	165 642	179 489	179 489	179 489	179 489
Spinach ⁽¹⁾	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000
Watermelons	43 959	32 427	22 478	24 772	26 355	26 355	26 355	26 355
Melons	109 970	91 754	73 780	80 667	85 122	85 122	85 122	85 122
Cucumbers ⁽¹⁾	7 000	7 000	7 000	7 000	7 000	7 000	7 000	7 000
Chillies	48 786	45 088	44 346	49 506	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

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 1.35 - Annual Production of non-leguminous Crops (metric tons) (3/4)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998
Quinces	4 567	4 067	3 560	3 793	3 148	2 647	1 916	1 819	1 990
Loquat	1 528	1 594	1 527	1 622	1 606	1 666	1 552	1 388	1 142
Pomegranate	1 803	1 803	1 770	1 737	1 667	1 636	1 422	1 142	743
Pineapples ⁽¹⁾ after 1992	1 476	1 760	1 927	2 093	2 000	2 000	2 000	2 000	2 000
Bananas ⁽¹⁾ after 1993	43 648	41 156	38 300	37 667	35 000	32 667	31 667	31 667	33 333
Peach	90 123	94 948	97 090	95 860	90 813	85 731	83 124	71 005	69 346
Apples	270 551	275 635	269 502	252 390	237 011	234 541	259 108	234 168	246 816
Kiwi	3 406	5 863	8 403	9 808	9 412	9 554	9 960	8 711	8 822
Pears	93 580	96 660	97 790	110 070	104 094	108 363	127 956	140 384	147 176
Sour Cherries	642	682	713	677	630	606	444	268	110
Fig	15 100	14 683	13 583	10 809	8 330	6 656	5 548	4 700	3 952
Kaki	4 650	4 633	4 460	4 393	3 633	2 785	1 582	994	1 240
Apricots	4 543	4 610	4 480	4 695	4 812	4 956	4 904	4 507	4 956
Cherry	11 795	13 333	13 940	13 291	11 425	10 892	10 841	9 044	10 786
Plum	16 332	16 639	15 935	16 747	17 162	17 757	17 812	16 743	16 975
Avocados ⁽¹⁾	20 967	20 333	18 667	16 233	14 100	13 000	13 000	13 000	13 000
Strawberries ⁽¹⁾	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Raspberries ⁽¹⁾	100	100	100	100	100	100	100	100	100
Berries nes ⁽¹⁾	100	133	133	133	100	100	100	100	100
Tangerine	25 125	25 623	26 741	29 525	32 194	34 769	34 906	35 814	39 763
Lemon	10 117	10 438	10 518	10 791	10 906	10 402	9 981	9 301	9 864
Orange	169 155	174 974	173 802	179 825	190 173	191 883	199 290	219 960	231 015
Pomelo	4 950	5 267	5 550	5 909	6 320	6 769	6 863	6 868	5 816
Grapefruit	832	800	760	852	924	996	964	880	657
Walnut	5 610	5 283	4 508	3 550	3 105	3 053	3 245	3 331	3 740
Chestnuts	19 052	17 358	15 266	17 174	19 602	23 316	24 956	26 981	28 880
Hazelnuts	1 993	1 900	1 690	1 435	1 116	976	865	802	752
Almonds	50 377	48 375	47 548	38 783	31 320	26 406	31 049	31 464	33 263
Olives (Oil)	302 638	246 248	266 260	200 115	256 993	269 537	298 497	269 950	285 190
Olives (fruit)	21 400	19 900	16 821	12 491	9 823	9 156	9 248	9 275	10 160
Wine grapes ⁽¹⁾	1 285 581	1 285 582	997 133	826 044	834 841	1 036 179	1 015 820	818 094	733 423
Grapes	52 752	54 418	52 867	52 112	53 445	55 401	58 131	52 392	52 370

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 1.36 - Annual Production of non-leguminous Crops (metric tons) (4/4)

Crop	1999	2000	2001	2002	2003	2004	2005	2006
Quinces	2 110	2 203	2 090	2 061	2 068	2 077	2 077	2 077
Loquat	948	888	903	885	869	851	851	851
Pomegranate	527	411	411	403	395	387	387	387
Pineapples ⁽¹⁾ after 1993	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Bananas ⁽¹⁾ after 1992	35 000	35 000	33 333	30 000	30 000	30 000	30 000	30 000
Peach	62 671	53 891	50 153	47 930	56 357	52 706	50 393	49 569
Apples	227 159	261 999	263 940	284 190	288 425	272 292	258 732	249 447
Kiwi	8 315	9 148	9 237	9 774	10 859	10 903	11 386	11 646
Pears	131 057	138 305	136 302	118 911	134 175	135 819	164 145	152 434
Sour Cherries	95	91	64	42	42	42	42	42
Fig	3 840	3 790	3 632	3 634	3 594	3 056	2 940	2 661
Kaki	1 799	2 591	2 810	3 030	3 162	3 229	3 229	3 229
Apricots	5 148	4 742	4 242	3 907	4 614	4 670	4 802	4 823
Cherry	9 506	12 123	13 201	15 368	16 758	15 299	15 774	15 587
Plum	16 214	15 108	14 478	14 893	16 544	16 526	17 484	18 023
Avocados ⁽¹⁾	13 000	13 000	13 000	13 000	13 000	13 000	13 000	13 000
Strawberries ⁽¹⁾	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Raspberries ⁽¹⁾	100	100	100	100	100	100	100	100
Berries nes ⁽¹⁾	100	100	100	100	100	100	100	100
Tangerine	42 052	44 924	48 097	53 997	58 428	59 061	58 774	58 352
Lemon	10 516	11 260	11 447	12 019	12 328	12 546	11 810	11 551
Orange	245 725	229 659	251 633	258 756	268 176	248 276	234 123	226 026
Pomelo	4 788	3 774	4 021	4 150	4 207	3 941	3 459	3 200
Grapefruit	471	306	287	265	262	242	252	250
Walnut	3 880	4 322	4 323	4 530	4 570	4 426	4 392	4 305
Chestnuts	31 200	30 135	30 273	30 257	31 901	28 933	28 140	26 684
Hazelnuts	668	641	614	596	572	493	441	411
Almonds	28 821	25 804	24 539	23 470	22 873	17 246	13 432	13 172
Olives (Oil)	237 880	235 516	199 086	221 014	248 407	278 115	300 699	300 699
Olives (fruit)	9 253	10 947	10 952	12 199	11 453	10 227	10 161	9 530
Wine grapes ⁽¹⁾	763 925	940 712	893 026	890 074	874 674	911 015	936 462	932 535
Grapes	49 675	53 888	54 641	54 338	55 405	52 397	52 421	50 789

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

The Nitrogen fixed by crops was estimated from the ratio of residue to crop product mass ($Res_{BF}/Crop_{BF}$), the fraction of dry matter in product ($Frac_{DM}$) and the fraction of dry biomass in the whole plant that is nitrogen ($Frac_{NCRBF}$). 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 1.37

Table 1.37 – Parameters considered for determination of N fixed by nitrogen fixing plants

Crop	Res_{BF}/Crop_{BF}	Frac_{DM} (%)	Frac_{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 1.37). 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 1.38 - 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.

UNCERTAINTY ASSESSMENT

The Good Practice Guidebook presents no information concerning the uncertainty in activity data, and therefore, the values were set in the following mode:

Synthetic Fertilizers: Apart from the time series of the total quantity of nitrogen applied in synthetic fertilizers from INE, that was considered as activity data for the period 1995-2000, other estimates are available or were made for the inventory for the same time period: PNAC studies (Seixas et al, 1999), FAO statistical database and the estimates of nitrogen necessity using the Good Practice Use of Fertilizers (MA,2000). Comparing the values of nitrogen in synthetic fertilizers from these independent data sources between 1995 and 2000 a maximum uncertainty value of 17 per cent was obtained. This value represents a good reduction in uncertainty since last submission, when the uncertainty amounted to 66 per cent;

For nitrogen in animal manure applied to soil and animal production the same uncertainty value that was used for activity data in N₂O from Manure Management was used and increased, in the case of animal manure applied to soil, by 100 per cent due to the uncertainty in the percentage of manure that ends up in soil;

An uncertainty error of 25 per cent in crop production was considered in accordance with GPG considerations about overall error for the all source sector;

Errors due to determination of nitrogen volatilization are difficult to access because of the interconnections with indirect emissions, and were quantified only in source category Indirect N₂O emissions from Agricultural Soils.

GPG presents a possible variation from one-fifth to 5 times the default emission factor of 1.25 per cent. From that range an uncertainty of 500 per cent was assumed in uncertainty analysis for nitrogen applied as synthetic fertilizers, manure, crop residues and nitrogen fixed by n-fixing crops. Considering that in the cases of nitrogen added to soil from n-fixing crops and crop residues, an additional 100 per cent uncertainty was added to take into account errors in the determination of nitrogen content of crops and residues from production. In the case of animal production a lower uncertainty of 100 per cent was used, following table 4.12 of the GPG.

RECALCULATIONS

No modifications were made for this source category except the update of statistical information for more recent years (2004-2005), and the revision of time series for grape production were an error was detected in submission 2006 and in the IIR report, and in accordance with the recommendations from the ERT.

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 IA 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.

Indirect N₂O Emissions from Agriculture (CRF 4D2)

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 the atmospheric system - after volatilisation as ammonia or nitrogen oxides and intermediate transformation in nitric acid and ammonium salts in particulate or aerosol form- or in the soil-water system - after leaching and/or runoff as ammonia, nitrite, nitrate or light organic compounds.

Actually N_2O indirect emissions result from the same microbial process associated to nitrification and denitrification that causes direct emissions. The only difference results from the fact that direct emissions occur solely in agricultural soils whether indirect emissions will occur in whenever conditions are adequate: in agricultural soils, non agricultural soils and even aquatic, Benthic and wetland systems.

Also, all NO_x and NH_3 emissions from other emissions sources may settle in soil and water and result in similar N_2O emissions. However, estimates of indirect emissions from these sources are not included in the portuguese inventory.

Indirect emissions of N_2O from ammonia and NO_x volatilisation were estimated from ammonia volatilised whether actual indirect N_2O emissions occurred in the Portuguese territory or not. In the case of N_2O indirect emissions from leaching and runoff the geographical characteristics of the territory - where there are no water basins discharging to other countries - cause that all indirect emissions will occur still on the national territory or nearby ocean waters¹³⁷.

As may be seen from Figure 1.36, where the percent importance of each sub-source is represented for year 2006, indirect emissions from runoff and leaching from synthetic fertilizers, animal manure applied to soil and direct droppings during grazing are significant sources.



Bibliography



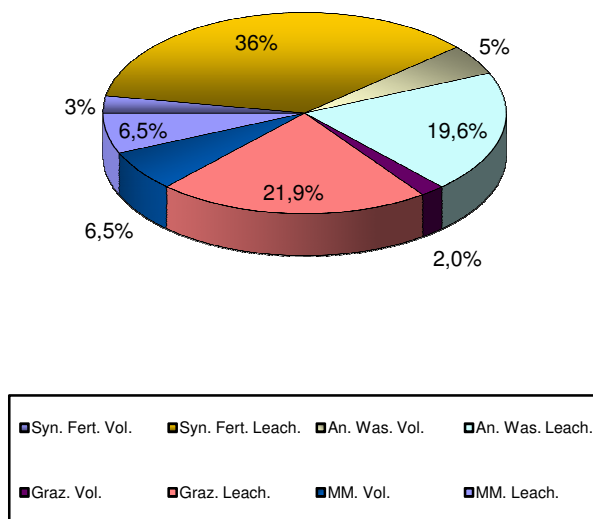
Key Categories



Uncertainty

¹³⁷ In fact, part of indirect N_2O emissions from leaching and runoff from agriculture activities in Spain will occur most probably in Portuguese territory. These emissions are not included however in the Portuguese inventory.

Figure 1.31 – Relative importance of Indirect emissions of N₂O from agriculture in year 2006



METHODOLOGY

Different methodologies were used to estimate emissions for:

VOLATILIZATION

$N_2O_{(G)}$, Indirect N_2O emissions from atmospheric deposition of nitrogen that has volatilised as NO_x and ammonia from nitrogen used in agriculture as an external input¹³⁸, either synthetic or in animal manure. The following equation, that is similar to GPG Tier1a equation, was utilized for N_2O emissions from volatilisation:

$$N_2O_{(G)} = 44/28 * (SF_NVol + MMS_NVol + AM_NVol + GR_NVol) * EF_4$$

where

SF_NVol - Total volatilisation, as ammonia or nitrogen oxides, of the nitrogen from synthetic fertilizers applied to soil (ton NH_3 -N+ NO_x -N/yr);

MMS_NVol - Volatilisation of nitrogen from manure in Manure Management Systems (emissions in housing and outside storage) (ton NH_3 -N+ NO_x -N/yr);

AM_NVol - Volatilisation of nitrogen from manure applied to soil as fertilizer (ton NH_3 -N+ NO_x -N/yr);

GR_NVol - Volatilisation of nitrogen from animal excreta deposited in soil during grazing in pasture range and paddock (ton NH_3 -N+ NO_x -N/yr);

EF_4 - Emission factor for N_2O emissions from atmospheric deposition of nitrogen on soil and water surfaces (kg N_2O -N/kg NH_3 -N+kg NO_x -N).

Methodologies for the estimation of ammonia from synthetic fertilizers, manure and animal excreta are explained in chapter NH_3 Emissions from agriculture (6.2.8). It was assumed that volatilisation emissions occurs predominantly in ammonia form.



Bibliography



Key Categories



Uncertainty

¹³⁸ No indirect N_2O emissions are estimated from nitrogen leached or removed in runoff from nitrogen fixation by leguminous plants or from nitrogen in crop residues.

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):

$$N_{2O(L)} = 44/28 * (N_{Fert} + N_{AM} + N_{GR}) * \text{Frac}_{LEACH} * EF_5$$

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:

$$N_{AM} = \sum_i \{ N_{(i)} * N_{ex(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] \}$$

N_(i) - Number (head) of individuals from livestock category i in the country;

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;

N_{GR} - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture;

Frac_{LEACH} - Fraction of N input that is lost through leaching and runoff

EF₅ - Emission factor for leaching/runoff (Kg N₂O / kg NH₃-N + NO_x-N)

Until submission 2007, 80 per cent of the effluent from anaerobic lagoons is used as soil fertilizer whereas the remaining 20 per cent is discharged to the water system. However, during the review of the 2006 inventory 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 drylots, 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

$$N_{leaching-MMS} = \sum_S \left[\sum_T \left[\left(N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)} \right) \cdot \left(\frac{Frac_{leachMS}}{100} \right)_{(T,S)} \right] \right]$$

EQUATION 10.29
INDIRECT N₂O EMISSIONS DUE TO LEACHING FROM MANURE MANAGEMENT

$$N_2O_{L(mm)} = (N_{leaching-MMS} \cdot EF_5) \cdot \frac{44}{28}$$

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

$$N_{MMS_Avb} = \sum_S \left\{ \sum_T \left[\frac{\left(N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)} \right) \cdot \left(1 - \frac{Frac_{LeachMS}}{100} \right)}{\left[N_{(T)} \cdot MS_{(T,S)} \cdot N_{beddingMS} \right]} \right] \right\}$$

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 per cent fraction of nitrogen fertilizer. This procedure reflects in the best way what is happening in the environment. Nevertheless, the final value will not be consistent with the activity data reported as F_{SN} (Nitrogen added to soil as synthetic fertilizer), F_{aw} (Nitrogen added to soil as animal manure) and Nitrogen deposited into soil during grazing and pasture. Also the reported Frac_{LEACH} in table 4Ds2 will no longer reflect the actual leaching and run-off rate that is applied to the nitrogen added on soil. With the agreement of ERT, the methodology that was chosen is simply to estimate emissions using the default emission factor for Indirect emissions from Leaching and Run-off (EF₅), 0.025 kg N-N₂O/kg N-leached, applied to the quantity of nitrogen discharged¹³⁹. 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 system¹⁴⁰;

EF₅ – Emission factor for leaching/runoff (Kg N₂O / kg NH₃-N + NO_x-N)

¹³⁹ Total contribution, not assuming volatilization or leaching rates.

¹⁴⁰ MSSW in the case of Anaerobic Lagoons is equal to 1-MSSD.

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 1.39 – 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.

ACTIVITY DATA

Emissions of N₂O from atmospheric deposition of nitrogen compounds that were volatilised consider 4 components: SF_NVol; MMS_NVol; AM_NVol and GR_NVol, that are presented in Table 1.40 and Table 1.41 and which contribution of sub-sources in year 2006 is presented in Figure 1.32. Nitrogen from NH₃ volatilisation from Manure Management Systems was the major contributor to indirect emissions with about 39 per cent of total deposition in 2006. The following most important components are nitrogen in manure applied to soil as fertilizer (26 per cent) and nitrogen volatilised from synthetic fertilizers (35 per cent). Nitrogen in droppings during grazing is a less important source with 22.6 per cent of total contribution in 2006. Total ammonia emissions and deposition have decreased about 1.3 per cent from base year to last year in the inventory.

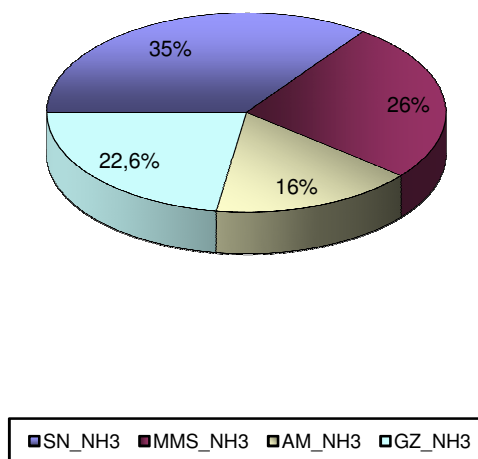
Table 1.40 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1990-1998)

ton NH ₃ /yr	1990	1991	1992	1993	1994	1995	1996	1997	1998
SF_NVol	9 089	9 089	9 006	7 623	9 224	8 187	9 904	10 325	8 453
MMS_NVol	16 905	17 215	17 267	17 591	17 700	17 866	17 821	17 910	18 225
AM_NVol	12 931	13 119	13 123	13 341	13 402	13 524	13 500	13 538	13 730
GR_NVol	4 463	4 523	4 475	4 487	4 522	4 633	4 738	4 817	4 896
Total	43 387	43 945	43 871	43 043	44 847	44 210	45 963	46 591	45 303

Table 1.41 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1999-2006)

ton NH ₃ /yr	1998	1999	2000	2001	2002	2003	2004	2005	2006
SF_NVol	8 965	9 744	9 007	9 372	6 298	7 196	5 651	7 292	8 965
MMS_NVol	18 421	18 547	18 291	18 042	17 526	17 443	17 399	17 389	18 421
AM_NVol	13 840	13 913	13 694	13 482	13 083	13 024	12 987	12 961	13 840
GR_NVol	4 948	4 987	4 974	4 948	4 941	5 021	5 125	5 211	4 948
Total	46 173	47 192	45 965	45 845	41 847	42 684	41 162	42 853	46 173

Figure 1.32 – Percent importance of nitrogen added to soil from volatilization of ammonia applied to agricultural soils, by emission source/component (2006)



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 oxide¹⁴¹.

The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in tables Table 1.42 and Table 1.43 and in Figure 1.33, for each component that is considered in lixiviation/runoff estimate: FSN, FAM, FGR and direct discharge

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Key Categories

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agência portuguesa do ambiente
ministério do ambiente, do ordenamento do território e do desenvolvimento regional

Uncertainty

¹⁴¹ Which explains the fact that in CRF table 4Ds2, the “implicit” $Frac_{LEACH}$ is a little higher than the default.

to the water system. Nitrogen added to soil in synthetic fertilizers is the major lixiviation/runoff source. From 1990 to 2005 nitrogen deposited into soil has decreased by 7 per cent.

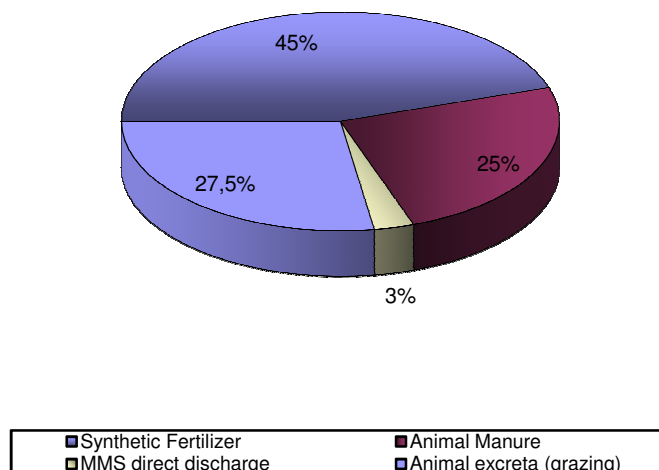
Table 1.42 – Nitrogen Lost from soil from lixiviation and runoff (1990-1998)

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998
Synthetic Fertilizer	47 684	47 684	47 684	47 684	47 684	43 745	50 469	49 286	44 791
Animal Manure	20 811	21 128	21 136	21 476	21 580	21 779	21 755	21 808	22 097
MMS direct discharge	2 529	2 640	2 642	2 668	2 631	2 589	2 488	2 483	2 478
Animal excreta (grazing)	20 370	20 638	20 450	20 509	20 681	21 138	21 557	21 832	22 159
Total	91 394	92 089	91 913	92 336	92 576	89 251	96 269	95 408	91 525

Table 1.43 – Nitrogen Lost from soil from lixiviation and runoff (1999-2006)

ton N/yr	1999	2000	2001	2002	2003	2004	2005	2006
Synthetic Fertilizer	44 683	51 003	47 253	49 170	33 040	37 753	29 648	38 255
Animal Manure	22 257	22 363	21 996	21 637	21 000	20 931	20 912	20 914
MMS direct discharge	2 485	2 479	2 497	2 504	2 482	2 477	2 479	2 496
Animal excreta (grazing)	22 378	22 553	22 410	22 207	22 099	22 454	22 937	23 343
Total	91 803	98 397	94 157	95 518	78 621	83 615	75 976	85 008

Figure 1.33 – percent importance of sub-sources of Nitrogen Lost from soil from lixiviation and runoff in 2006



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 per cent.

RECALCULATIONS

Changes in emission estimates of N₂O Indirect emissions resulted only from the inclusion of emission estimates from nitrogen added to the water system directly as discharge. This addition of emissions followed the recommendations from the review of the 2006 inventory under UNFCCC and the IIR under the Kyoto Protocol.

Indirectly, emissions suffered also changes resulting from the revision of the nitrogen excretion rate of sheep and from the review of the quantity of synthetic fertilizers added to soil as fertilizers for some years, according to what was discussed in previous chapters.

FURTHER IMPROVEMENTS

No major modifications are expected for this source sector.

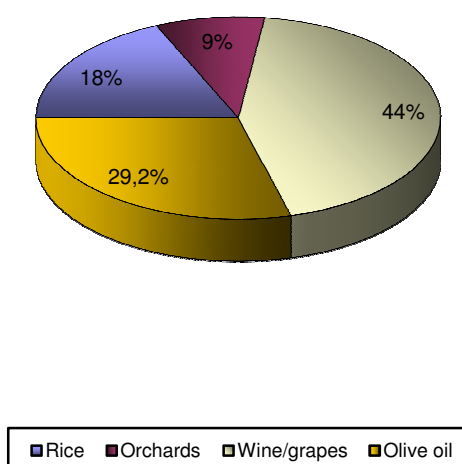
Field Burning of Agriculture Residues (CRF 4F)

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 1.34), burning of residues from vineyards and olive oil are the most significant sources of this non-key source.

Figure 1.34 – Importance of GHG emissions from field burning of agriculture residues by crop in 2006



METHODOLOGY

Emissions of in-site burning of agriculture residues were estimated from the following equation:

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

where

$\text{Emission}_{(p,crop,y)}$ - Emission estimate of pollutant p from field burning of residues from a specific crop in year y (ton/year);

$\text{Crop}_{\text{BURN}(crop,y)}$ - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{EF}_{(p,crop)}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm).

Other methodology formulations could be used that would result in equal results. However activity data definition in dry matter terms was chosen in order that emission factors would be expressed in the same units that are presented in Implied Emission Factors (IEF) of table 4.F of CRF format. Consequently part of methodology that is in fact used to determine emissions, is included in emission factor determination and part also in activity data determination and they are subsequently described in the appropriate chapters. But for all relevant aspects, the methodology that it is used, follow the same methodology proposed in IPCC96 except for the fact that residue biomass is not estimated from crop production but from residue production quantities by cultivated area.

EMISSION FACTORS

Except for NMVOC and Particulate Matter, emission factors for each specific pollutant are estimated from different equations whether they are carbon containing pollutants (CO_2 , CH_4 and CO) or nitrogen containing pollutants (NO_x and N_2O). This methodology - after IPCC96 - assumes that some fixed part of carbon and nitrogen that are submitted to burning are emitted as specific compounds.

For carbon containing pollutants the equation is:

$$\text{EF}_{(pol,crop)} = \text{CFraction}_{(Crop)} * \text{Frac}_{\text{RESOXI}(crop)} * \text{ER}_{(crop,pol)} * \text{MWC}_{(Pol)}$$

For nitrogen containing compounds the equation is:

$$\text{EF}_{(pol,crop)} = \text{CFraction}_{(Crop)} * \text{Frac}_{\text{RESOXI}(crop)} * \text{NC}_{\text{Ratio}(crop)} * \text{ER}_{(crop,pol)} * \text{MWC}_{(Pol)}$$

where

$\text{EF}_{(pol,crop)}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$\text{CFraction}_{(Crop)}$ - Ratio of carbon content in dry biomass matter (kg C/kg dm);

$\text{Frac}_{\text{RESOXI}(crop)}$ - Fraction or ratio of carbon that it is oxidized during the active burning period (kg C/kg C);

$\text{NC}_{\text{Ratio}(crop)}$ - Ratio of nitrogen to carbon in crop residue (kg N/kg C);

$ER_{(crop,pol)}$ - Emission ratio, the fraction of total carbon/nitrogen content that it is emitted as pollutant pol (kg C/kg C or kg N/kg N);

$MWC_{(Pol)}$ - Stechiometric correction fraction to convert emissions in carbon/nitrogen units to total molecular weight emissions (kg/kg C or kg/kg N respectively for carbon compounds or nitrogen compounds).

The parameters used to establish emission factors for each crop are presented in next table.

Table 1.44 – Parameters used for determination of emission factors for field burning of agricultural residues

Crop	C _{fraction}	Frac _{RESOXI}	NC _{Ratio}
Rice	0.6	0.9	0.04
Orchards	0.6	0.9	0.05
Wine/Grapes	0.6	0.9	0.04
Olive oil	0.6	0.9	0.04

The pollutant specific emission ratios that were used follow the IPCC default emission ratios proposed in table 4-17 of IPCC96 and which were still not updated in GPG (Annex 4.A.2).

Table 1.45 – 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 and Particulate Matter are those proposed by AP-42 (USEPA,1992), which are reproduced in Table 1.46, together with final emission factors for all other pollutants and all crops.

Table 1.46 – Final emission factors for field burning of agricultural residues by pollutant and crop

Crop	CH ₄	N ₂ O	NO _x	CO	NMVOC	TSP	PM ₁₀ -PM ₁
Rice	2.1	0.14	5	44.2	15.6	15.6	100%
Fresh Fruits	0.4	0.04	1.3	9.1	2.0	2.2	100%
Citrines	0.4	0.04	1.3	9.1	4.0	2.4	100%
Dry fruits	0.4	0.04	1.3	9.1	2.4	2.4	100%
Wine/grapes	1.8	0.12	4.3	37.8	7.5	7.5	100%
Olive oil	0.7	0.04	1.6	14.2	2.6	2.3	100%

ACTIVITY DATA

According to expert information from the Ministry of Agriculture (Seixas et al, 2000) only vegetal residues from wine, olive oil cultivation and orchards¹⁴² 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 established 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 each 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;

¹⁴² Comprehending fresh fruit, citrines and dry fruits (nuts)

- 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 Protection¹⁴³ are used;
- The area subjected to “Techniques of Integrated Production and Protection” occupied about 50 per cent of rice paddies in 2004. Today the area burnt occupies only about 30-40 per cent of total area;
- It may be assumed that, in 1990, 100 per cent of rice paddies were burnt and no organic amendments were added to soil. In 2004 the area subjected to burning was reduced to only about 40 per cent.

Activity data in suitable units is estimated from:

$$\text{Crop}_{\text{BURN (crop,y)}} = \text{Crop}_{\text{AREA(crop,y)}} * \text{Resid}_{\text{PROD (crop)}} * \text{Dm}_{\text{Content(crop)}} * \text{Frac}_{\text{RESBURN (crop)}} * 10^{-7}$$

where

$\text{Crop}_{\text{BURN (crop,y)}}$ - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{Crop}_{\text{AREA (crop,y)}}$ - Cultivated area for each specific crop in year y (ha/yr);

$\text{Resid}_{\text{PROD (crop)}}$ - Quantity of residue generated from each unit cultivation area of crop y expressed in live weight (kg/ha);

$\text{Dm}_{\text{Content(crop)}}$ - Dry matter content of crop residues (% dm/live weight);



Bibliography



Key Categories



Uncertainty

¹⁴³ “modos de protecção e produção integrada” in the original in Portuguese.

$Frac_{RESBURN(crop)}$ - Fraction of total residues from a specific crop that are burnt in site (%).

Parameters $Resid_{PROD}$, $Dm_{Content}$ and $Frac_{RESBURN}$ are the same considered in (Seixas et al, 2000) and are presented in Table 1.47. Final activity data expressed in crop area dry matter content may be seen in Table 1.47 and Table 1.48, and in Table 1.49.

Table 1.47 – Parameters used for the estimation of the quantity of burnt crop residues

Crop	$Resid_{PROD}$ kg live weight/ha	$Frac_{RESBURN}$ %	$DMContent$ %
Rice	3 900	50	30
Orchards	800	30	50
Wine/Grapes	2 500	40	50
Olive oil	375	100	50

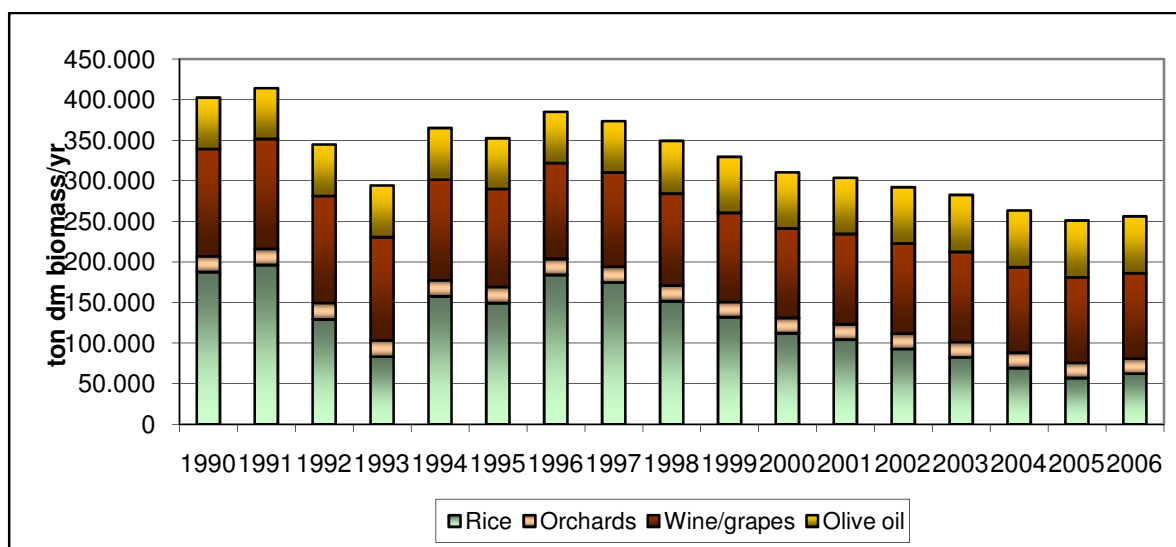
Table 1.48 – Estimated quantities of burnt crop area per crop (ha) (1990-1998)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998
Rice	33 824	33 466	21 118	13 200	24 051	21 726	28 278	28 540	27 020
Orchards	164 147	166 120	168 101	166 838	165 690	164 748	163 842	162 336	161 382
Wine/grapes	264 359	271 160	264 062	254 528	247 615	241 964	236 654	232 226	226 497
Olive oil	337 189	333 757	338 947	340 579	340 672	333 144	336 621	338 414	347 271
Total	799 519	804 503	792 228	775 145	778 028	761 582	765 395	761 516	762 169

Table 1.49 – Estimated quantities of burnt crop area per crop (ha) (1999-2006)

Crop	1999	2000	2001	2002	2003	2004	2005	2006
Rice	25 307	23 859	24 936	25 216	25 657	25 587	21 938	25 392
Orchards	157 122	157 698	157 909	157 985	158 152	158 362	157 152	154 925
Wine/grapes	219 444	220 356	222 569	222 620	222 446	210 486	210 464	210 371
Olive oil	368 974	369 162	369 314	369 858	374 154	374 154	374 154	374 154
Total	770 847	771 075	774 728	775 679	780 409	768 589	763 708	764 842

Figure 1.35 – Estimated total quantities of burnt crop residues per crop (1990-2006)



UNCERTAINTY ASSESSMENT

The uncertainty in activity data is higher than the error associated with crop area determination, because there is a higher uncertainty in the percentage of crop areas that are subjected to burning and in which crops field burning is practiced. An uncertainty value of 100 per cent was therefore considered.

The uncertainty range in emission factors was set at 20 per cent in accordance with recommendations from GPG (IPCC,2000).

RECALCULATIONS

Emission estimates for these two source categories were changed after the review process of inventory submission 2006 and the IIR under the Kyoto Protocol, in order to maintain consistency to the changes made to the estimates of CH₄ from rice fields. The new time series of areas burnt have decrease substantially since 1990.

FURTHER IMPROVEMENTS

Associated with agriculture activities, the burning of hedge rows and some infestants 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.

NH₃ Emissions from Volatilization of Fertilizers

METHODOLOGY

Although emissions of ammonia from nitrogen was already discussed in several chapters, it is explained again here for inventory clarification.

Ammonia volatilisation from the application of synthetic fertilizers (SN_NH₃) is calculated using the following formula:

$$SN_NH3 = N_{Fert} * Frac_{GASF}$$

where,

N_{Fert} - total amount of nitrogen in synthetic fertilizers consumed annually

$Frac_{GASF}$ - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH_3 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_NH_3) are not differentiated and are estimated according to equation:

$$MMS_NH3 = \sum_i [N_{(i)} * Nex_{(i)} * (1 - MS_{GRAZ(i)}) * EF_{NH3(i)}]$$

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:

$$AM_NH3 = \sum_t \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

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;

$EF_{NH3SD(t)}$ - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

Emissions from volatilisation of nitrogen added to soil during grazing (GZ_NH3) was estimated by:

$$GZ_NH3 = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * EF_{NH3(i)}]$$

where:

i - Animal/species category of livestock;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock;

$EF_{NH3(i)}$ - Fraction of nitrogen excreted from livestock category i during grazing that is lost to atmosphere as ammonia.

Ammonia emissions from agriculture also result from field burning of residues as it was already presented in chapter 6.2.7.

EMISSION FACTORS

AMMONIA VOLATILIZATION FROM SYNTHETIC FERTILIZERS

The volatilization ratio from synthetic fertilizers, $Frac_{GASF}$, was determined from an estimate of the share of nitrogen synthetic fertilizers used in Portugal based on statistical information from INE on import, export and national production of each individual nitrogen fertilizer. Albeit some deficiencies still found in the basic information data, it was considered this volatilization ratio to be more suitable to represent the national conditions than to use the default IPCC approach that is recognized to be too high and not representative of the national conditions of fertilization, particularly when the results of the inventory are being used to discuss capes under the European Emissions Ceiling (NEC). The following approach was used:

- Data information concerning national production of nitrogen synthetic fertilizers was available from INE from 1992 till 2000, from the IAPI industrial survey and using PRODCOM product classification. This statistical information has confidential constraints and may not be published in the present report;
- Statistical information about foreign trade is available also from INE concerning importation and exportation of nitrogen fertilizers. Products are classified according to NC codes. The same confidential constraints apply to this data;

- annual consumption of nitrogen fertilizers per fertilizer type was hence estimated by IA for the years from 1992 to 2000, using the following equation¹⁴⁴. In Figure 1.36 the share of consumption of each nitrogen fertilizer, as estimated by IA, is presented as an average situation in the 1992-2000 period, where it may be seen that Calcium Ammonium Nitrate is the main fertilizer in use and urea, the fertilizer more prone to nitrogen volatilization, represented about 17 per cent of nitrogen added as fertilizer to soils.

$$\text{Consumption}_{(f)} = \text{Production}_{(f)} + \text{Import}_{(f)} - \text{Export}_{(f)}$$

where,

Consumption_(f) – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

Production_(f) – Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

Import_(f) – Annual importation in Portugal of nitrogen fertilizer f (ton N/yr);

Export_(f) – Annual exportation in Portugal of nitrogen fertilizer f (ton N/yr);



Bibliography



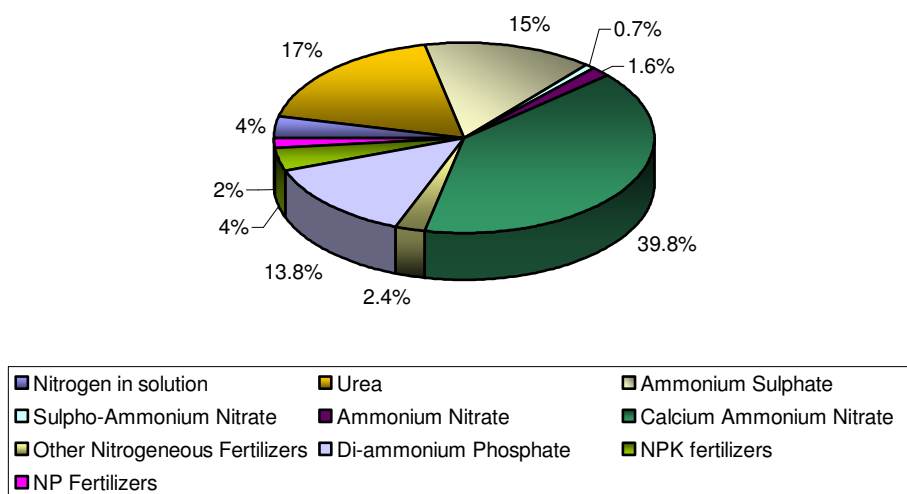
Key Categories



Uncertainty

¹⁴⁴ This estimates are only preliminary guesses and are being revised together with INE and the Ministry of Agriculture.

Figure 1.36 – Relative Importance of the use of various nitrogen fertilizers in Portugal, as estimated by IA form production and foreign trade



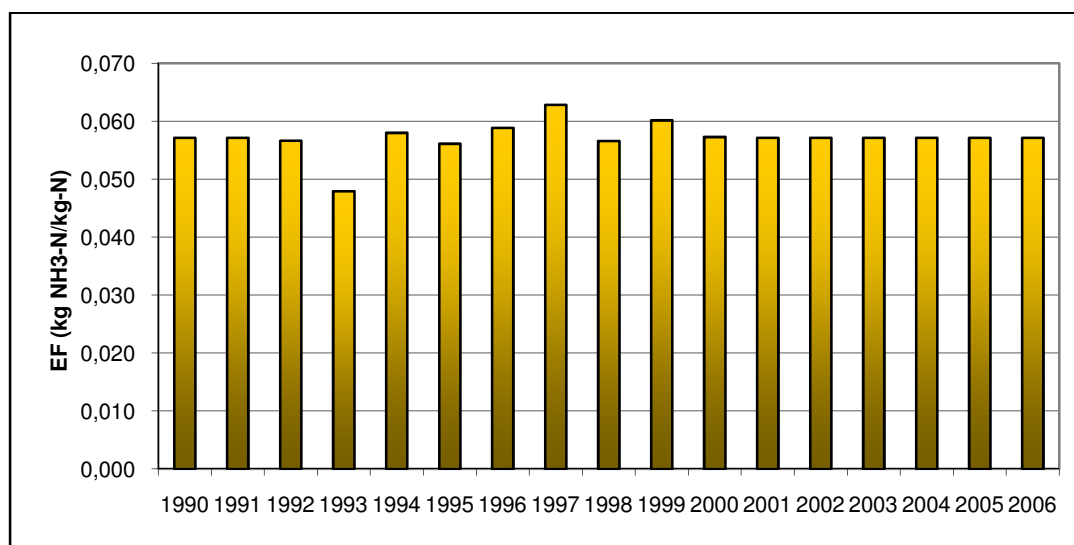
- product specific volatilization rates from EMEP/CORINAIR (EEA,2003) were used for each nitrogen fertilizer type according to Table 1.50.

Table 1.50 – Volatilization rates for each nitrogen fertilizer (Source: EMEP/CORINAIR file B1010vs4 - Revision of 3rd ed in Jan2003)

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

- 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 2001-2006. The final volatilization rates appear in Figure 1.37.

Figure 1.37 – Final volatilization rate of ammonia from the application of synthetic fertilizer in agricultural soils



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 nitrous Oxide Emissions from Agricultural Soils and are present again in Table 1.51. These emission factors result from EMEP/UNECE 3rd edition in annex A of chapter B1050 and version 4.0 of chapter B1010 and are not dependent on the Manure Management System that is used. Final emission factors per animal class are presented in next table.

Table 1.51 - 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	Total
Dairy Cows	0.17	0.17	0.08	0.42
Other Cattle	0.17	0.17	0.08	0.42
Sheep	0.10	0.07	0.04	0.21
Goats	0.10	0.07	0.04	0.21
Swine	0.22	0.16	0.08	0.38
Equines	0.12	0.07	0.08	0.27
Poultry	0.22	0.16	-	0.38
Hens	0.23	0.15	-	0.39
Rabbits	0.22	0.16	-	0.38

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).

ACTIVITY DATA

The quantity of nitrogen that is subjected to volatilisation is presented in Table 1.52 and Table 1.53 and Figure 1.38.

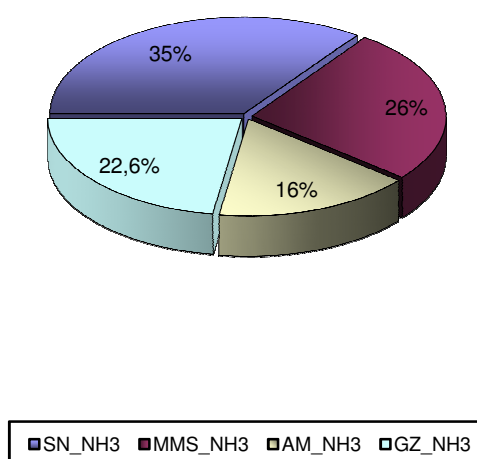
Table 1.52 – Nitrogen subjected to volatilization from each emission source/component (1990-1997)

Source	ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997
Synthetic Fertilizers	SN_NH3	149 856	149 856	149 939	151 322	149 721	137 628	158 325	153 963
M.M.S.	MMS_NH3	88 805	90 280	90 364	91 845	92 265	93 052	92 827	93 085
Animal Manure	AM_NH3	56 440	57 306	57 331	58 244	58 533	59 074	59 018	59 153
Grazing/ Pasture	GZ_NH3	67 899	68 793	68 168	68 363	68 937	70 460	71 856	72 772
Total		363 000	366 236	365 803	369 775	369 456	360 215	382 027	378 974

Table 1.53 – Nitrogen subjected to volatilization from each emission source/component (1997-2005)

ton N/yr	1998	1999	2000	2001	2002	2003	2004	2005	2006
SN_NH3	140 850	139 979	160 265	148 504	154 529	103 834	118 648	93 175	120 224
MMS_NH3	94 361	95 095	95 568	94 110	92 669	90 009	89 690	89 584	89 597
AM_NH3	59 927	60 349	60 628	59 628	58 640	56 918	56 746	56 720	56 751
GZ_NH3	73 863	74 593	75 177	74 702	74 022	73 663	74 845	76 457	77 810
Total	369 002	370 016	391 638	376 943	379 860	324 424	339 929	315 936	344 382

Figure 1.38 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation in 2006



RECALCULATIONS

The major change is the replacement of the forecast method to estimate volatilization rates for the years for which no data is available (1990-91; 2001-2006). This change was done following the recommendations from the ERT that reviewed submission 2006 under UNFCCC and the IIR under Kyoto Protocol.

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.

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.

CHAPTER: 6 LAND USE, LAND USE CHANGE AND FORESTRY (LULUCF) (CRF 5)

6.1 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 as far as possible.

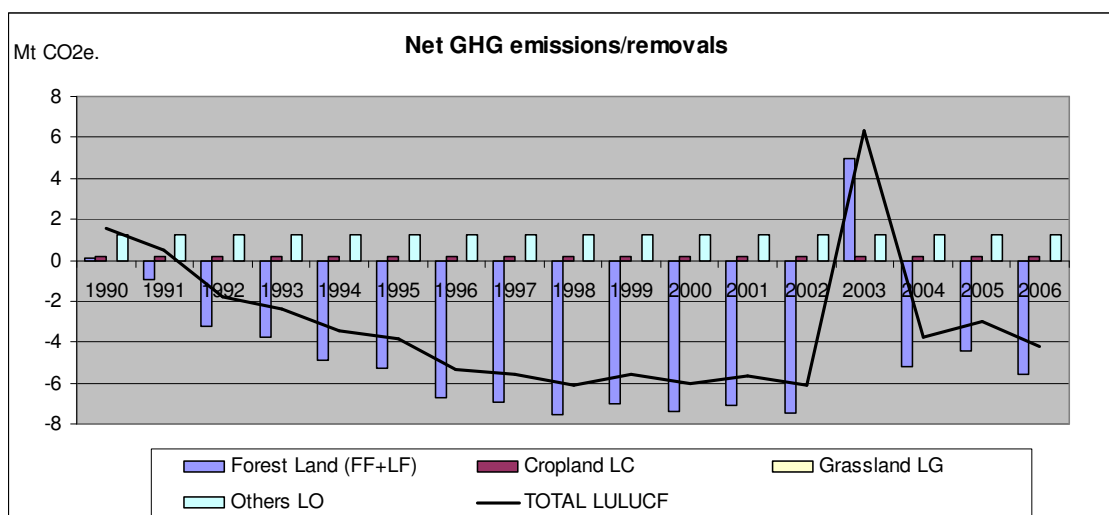
The six GPG LULUCF categories are: Forest Land (5A), Cropland (5B), Grassland (5C), Wetlands (5D), Settlements (5E) and Other Land (5F). Although according to the reporting guidelines these categories should be reported individually, it was considered more transparent and consistent to report common considerations under the same chapter – Land Use Conversion. Therefore, only Forest Land Remaining Forest (FF) is reported separately, while for the others only a reference to the Land Use Conversion sub-chapter is made.

Carbon stock changes in the 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 among 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 previous chapter Agriculture. In fact statistical information does not distinguish fertilizer use in forest and agricultural areas. N₂O emissions from enhanced mineralization of soil organic matter associated with land-use conversion to cropland are also estimated.

According to the last estimates, the sector shifted from a net emitter in 1990 to a sink in 2006, and was responsible for the sequestration of 4.2 Mt of CO₂ e. in 2006.

Figure 6.1 –Net Annual CO₂ Change from LULUCF (Mt CO₂e.) 1990-2006



6.2 Source categories

6.2.A 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. 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).

6.2.A.1 FOREST LAND REMAINING FOREST LAND (FF)

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:

$$\Delta CFF = (\Delta CFF_{LB} + \Delta CFF_{DOM} + \Delta CFF_{Soils})$$

where:

ΔCFF - annual change in carbon stocks from forest land remaining forest land, t C yr⁻¹;

ΔCFF_{LB} - annual change in carbon stocks in living biomass (includes above and belowground biomass) in forest land remaining forest land, t C yr⁻¹;

ΔCFF_{DOM} - annual change in carbon stocks in dead organic matter (includes dead wood and litter) in forest land remaining forest land, t C yr⁻¹;

ΔCFF_{Soils} - annual change in carbon stocks in soils in forest land remaining forest land, t C yr⁻¹.

As ΔCFF_{DOM} and ΔCFF_{Soils} were assumed as zero, the equation simplifies to:

$$\Delta CFF = \Delta CFF_{LB}$$

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:

ΔCFF_G - annual increase in carbon stocks due to biomass growth, t C yr⁻¹

ΔCFF_L - annual decrease in carbon stocks due to biomass loss, t C yr⁻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 (default = 0.5), t C (t d.m.)⁻¹.

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 appropriate to increments

The **average annual aboveground biomass increment** was calculated as follows:

$$G_W = IV \cdot ConvF$$

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;

ConvF = volume stem conversion factor into biomass above ground, t d.m. m⁻³.

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 management 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 (DGGE data).

Annual carbon losses due to commercial fellings

The equation used to estimate annual carbon losses due to commercial fellings is:

$$L_{\text{fellings}} = H_{\text{adjust}} \cdot \text{ConvF} \cdot \text{CF}$$

where:

L_{fellings} - annual carbon losses due to commercial fellings, t C yr⁻¹;

H_{adjust} - adjusted annual volume of commercial fellings, roundwood, m³ yr⁻¹;

ConvF - volume stem conversion factor into biomass above ground, t d.m. m⁻³;

CF - carbon fraction of dry matter (default = 0.5), t C (t d.m.)⁻¹.

$$H_{\text{adjust}} = H \cdot \text{EF}$$

H - annual volume of commercial fellings, roundwood, m³ yr⁻¹;

EF - expansion factor to account for the whole tree volume (softwood = 1.24; hardwood = 1.2)

For the estimation of biomass loss from commercial fellings, the IPCC default was assumed: 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).

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. In the event of a disturbance, the generic IPCC proposed method assumes the complete destruction of forest biomass, considering “stand-replacing” disturbances only.

This approach is however different from reality as not all forest biomass is destroyed during a fire. To consider non-stand replacing disturbances, the proportion of pre-disturbance biomass that is not affected by the disturbance was used in the calculus.

The annual carbon loss in living biomass resulting from wildfires was estimated as follows:

$$L_{\text{Wildfires}} = \sum A_{\text{disturbance}} \cdot B_W \cdot (1 - f_{\text{BL}}) \cdot (1 - f_{\text{BB}}) \cdot CF$$

where:

$A_{\text{disturbance}}$ - forest areas affected by wildfires, ha yr⁻¹

B_W - average above ground biomass stock of forest areas, t d.m. ha⁻¹

f_{BL} - fraction of biomass left to decay in forest (transferred to dead organic matter)

f_{BB} - fraction of biomass not affected by the disturbance

CF - carbon fraction of dry matter, t C (t d.m.)⁻¹

The biomass stock (B_W) includes the above ground biomass for forest trees, undergrowth cover (only for non-CO₂ emissions), and biomass from litter existing in forest land.

The fraction of biomass left to decay in forest (f_{BL}) is not considered (set as 0), assuming that all biomass lost is accounted under commercial harvest or that the species regenerate after the disturbance.

To avoid double counting, the calculation of annual carbon loss in tree above ground biomass was estimated, in previous submissions, assuming that all above ground biomass from burnt trees was removed through harvesting as salvaged wood volumes. The most recent UNFCCC review reports raised, however, the issue of the potential underestimation of CO₂ emissions from forest fires. In reality, due to scarcity of information (e.g. the per cent of salvaged volumes within harvest), it is difficult to determine exactly which part of salvaged wood are considered in the harvest volumes, or if part of the burnt trees are not removed from the burnt forest, which would generate emissions from dead wood, non-harvested fallen logs, and snags remaining in the forest. Despite the efforts developed by the inventory team, it was still not possible for this submission to have an assessment of the proportion of the harvested wood coming from burnt areas, or estimates about the fraction of burnt trees that are not removed after a fire. In the absence of this information, the calculation of annual tree carbon loss in above ground biomass considered two situations:

- 1) For pinus pinaster and eucalyptus, the two representative species in terms of industrial wood consumption, it was assumed that the affected trees are harvested as

salvaged wood and used in the industry, and are considered included in the harvest volumes. This approach was based on the premise that these quantities were largely used in industry, and were considered to be fully included in the harvest volumes which refer to wood consumption. However, if the extent of the volumes burnt exceed by large the industrial wood consumption, then the whole amount of the burnt volume are accounted in the estimates, which is the case of the year 2003 for coniferous species.

2) For the other species, the calculation of annual carbon loss in above ground biomass, refer to the fraction of biomass that is affected by the disturbance, based in the assumptions described below, and on the supposition that other 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 fraction of the tree biomass affected by the wildfires ($1 - f_{BB}$) was estimated based on the following assumptions (PNAC **xpto**):

50 per cent of the trees in a burnt area are affected by fires;

10 per cent of the total biomass of the affected trees, corresponding to the fine parts of the trees (branches and leaves), is consumed;

80 per cent of the fine materials burn.

In what refers to the undergrowth cover, it was considered that 80 per cent of shrub and bush biomass undergrowth is combusted in average during a fire (Botelho et al.1994 e Fernandes et al. 2000). For the litter part it was assumed that in average 63 per cent of the biomass burns (Botelho et al.1994 e Fernandes et al. 2000a).

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.

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.

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.

NON-CO2 GREENHOUSE GAS EMISSIONS

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 ($L_{\text{Wildfires}}$).

The carbon trace gas emissions (CH_4 , CO and NMVOC) are calculated using direct ratios to total carbon. To estimate nitrogen trace gas releases (N_2O 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 N_2O and NO_x are then calculated multiplying the total N released by the N_2O and NO_x emissions ratios to the total N released.

Emissions ratios:

<p>IPCC 1996 - CH_4: 0.012; CO: 0.06; N_2O: 0.007; NO_x: 0.121</p> <p>AP-42 - COVNM: 0.0068</p>
--

Emissions estimation:

<p>Emissions $\text{CH}_4 = L_{\text{Wildfires}} * \text{emission ratio} * 16/12$</p> <p>Emissions COVNM (expressed as CH_4) = $L_{\text{Wildfires}} * \text{emission ratio} * 16/12$</p> <p>Emissions CO = $L_{\text{Wildfires}} * \text{emission ratio} * 28/12$</p> <p>Emissions $\text{N}_2\text{O} = L_{\text{Wildfires}} * \text{ratio N/C (0.01)} * \text{emission ratio} * 44/28$</p>

$$\text{Emissions NOx} = L_{\text{Wildfires}} * \text{ratio N/C (0.01)} * \text{emission ratio} * 46/14$$

ACTIVITY DATA AND PARAMETERS

AREA OF FOREST LAND

Data for forest area are largely based on data from periodic forest surveys: National Forestry Inventories (NFI) conducted by the General Direction for Forestry Resources/Ministry of Agriculture, Rural Development and Fisheries (Direcção Geral dos Recursos Florestais (DGRF)/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 (1995¹⁴⁵) and the NFI 2005/06. Forest area data for 1990 is based on 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 refer to 2005.

Forest definition used by DGRF 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.

¹⁴⁵ 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, 3^a revisão 1995-98.

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.

Table 6.1 – Forest area from National Forest Inventories (1000 ha)

	1982 (NFI 2nd rev.)	1990 (DGF estimates)	1995 (NFI 3rd rev.)	2005/6 (IFN 2005/06)
<i>Pinus pinaster</i>	1217	1069	976	711
<i>other softwood</i>	104	104	105	98
<i>Eucalyptus</i>	366	554	672	647
<i>Quercus suber</i>	662	693	713	737
<i>Quercus ilex</i>	464	462	462	388
<i>other Quercus</i>	109	123	131	118
<i>Castanea sativa</i>	30	37	41	28
<i>other hardwood</i>	89	98	102	97
Other woody biomass	-	-	-	18
Plantations	-	-	-	296
Pure, dominant mixed and young stands	3041	3140	3201	3137
Burnt forest land	-	-	79	213
Clear-cut areas	-	-	28	41
Other wooded land	-	-	41	21
TOTAL	3041	3140	3349	3412

Note: Other woody biomass and other wooded land were not considered in the estimates.

Sources:

1982, 1995 and 2005/06: data refer to National Forestry Inventory (2007 data).

1990: estimates from DGRF (Direcção Geral dos Recursos Florestais).

Forest land area used in the calculations have been revised in order to consider young plantations, clear-cuts and damaged (burnt) areas (i.e. temporally unstocked areas), that were not included in the forest area considered in previous submissions. The distribution of the areas according to the species was based on plantation data (forestry plans), and on the relative percentage of each species to the total pure and dominant areas (burnt areas).

Table 6.2 – Revised Forest area (1000 ha)

	1990	1995	2005/6
<i>Pinus pinaster</i>	1096	1000	792
<i>other softwood</i>	107	108	159
<i>Eucalyptus</i>	597	716	766
<i>Quercus suber</i>	711	730	910
<i>Quercus ilex</i>	474	473	449
<i>other Quercus</i>	126	134	126
<i>Castanea sativa</i>	38	42	30
<i>other hardwood</i>	100	105	140
TOTAL (including burnt and clear-cut areas)	3249	3308	3373

Note: 1990 total include 1995 data for burnt forest and clear-cut areas.

Source: APA estimates.

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.

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:

$$FF_{ni} = FF_{n-1i} + ((LF - FL) / 14 \text{ years} * plant_{ni} / \Sigma plant_n)$$

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 forestly 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 forestly areas by forest type in the year n;

$plant_{ni}$ - plantations (new forest areas) in year n for forest type i;

$\Sigma plant_n$ - total of plantation area in year n.

The product CLC-Changes are based on data for 1985/86/87 and 2000. For the calculation of the annual cover changes it was considered a period of 14 years (1986 being the intermediate year for the first cartography), assuming a constant land use change during the 14 years. A better description of this statistical information source is provided in the chapter 6.1.

Table 6.3 – 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
<i>Pinus pinaster</i>	1064	1049	1034	1019	1004	989	989	988	988	987	987	941	895	849	803	757	757
<i>other softwood</i>	84	84	84	84	84	83	85	87	88	90	91	101	111	120	130	139	139
<i>Eucalyptus</i>	558	584	610	637	663	689	690	692	693	694	695	709	723	738	752	766	766
<i>Quercus suber</i>	679	678	677	676	675	674	677	680	683	686	690	719	749	779	809	839	839
<i>Quercus ilex</i>	470	467	464	461	458	455	455	456	457	458	458	455	452	448	445	442	442
<i>other Quercus</i>	126	128	129	131	133	134	134	134	134	134	133	132	130	129	127	126	126
<i>Castanea sativa</i>	38	39	39	40	41	42	42	41	41	41	41	39	37	35	32	30	30
<i>other hardwood</i>	76	78	81	84	86	89	90	91	92	93	94	99	104	110	115	120	120
Total Forest remaining Forest Land	3095	3107	3119	3131	3142	3154	3161	3169	3176	3183	3190	3196	3202	3208	3214	3220	3220
Land converted to Forest Land	154																
Forest land converted to other uses	56																
TOTAL FOREST	3249	3261	3272	3284	3296	3308	3315	3322	3329	3337	3344	3350	3355	3361	3367	3373	3373

Sources: APA estimates based on National Forest Inventories (NFI), CLC-Changes cartography and data on plantations.

Data concerning plantations) refer in majority to public forestry plans. Data sources are: DGRF, IFADAP (PAF, Reg 797, PDF, Reg 2080, Modelo 47, Projecto Florestal Português do Banco Mundial, Fundo Fomento Florestal). For eucalyptus, afforestation refers to the private sector.

Table 6.4 – 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: DGRF, 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 sequester 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 refer to m³ of roundwood over bark per ha and per year. This requires the use of coefficients for the conversion of stem volumes into biomass above and below ground. The parameters used results from a study performed by a Portuguese University under a contract with the APA for the development of PNAC. National values for these parameters are presented in the table below.

The IPCC default value for the carbon fraction of dry matter (0.5) was used.

Table 6.5 – Parameters used in the calculations of forest increment

	Growth Rates (m3/ha/yr)	Volume stem conversion factor into		Root-shoot ratio
		above ground biomass (t ms/m3)	total biomass	
Pinus pinaster	5.6	0.78	1.03	0.320
Pinus pinea	5.6	0.84	1.11	0.320
other softwood	5.0	1.44	1.90	0.320
Eucalyptus	9.5	0.7	0.87	0.249
Quercus suber	0.5	0.57	0.82	0.430
Quercus ilex	0.5	0.57	0.82	0.430
other Quercus	0.5	0.57	0.82	0.430
Castanea sativa	5.0	0.56	0.80	0.430
other hardwood	2.9	0.57	0.82	0.430

Sources:

Growth rates: DGRF.

Above ground biomass: PNAC July 2003 - Santos Pereira et al, "Quantificação dos sumidouros terrestres de carbono em Portugal Continental", Julho 2002, ISA, UTL.

Root-Shoot ratio: LULUCF GPG, Table 3A.1.8; excepting Eucalyptus (Soares and Tomé, 2004).

BIOMASS LOSS

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, and consequently is not consider 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 (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 6.6 – Volumes of harvested wood (1000 m3 over bark) (1990-2006)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	4,608	4,608	4,608	4,608
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	7,363	7,363	7,363	7,363
Total	14,139	13,564	12,884	12,796	12,312	11,750	11,267	11,267	10,712	11,227	10,831	11,145	10,830	11,972	11,972	11,972	11,972

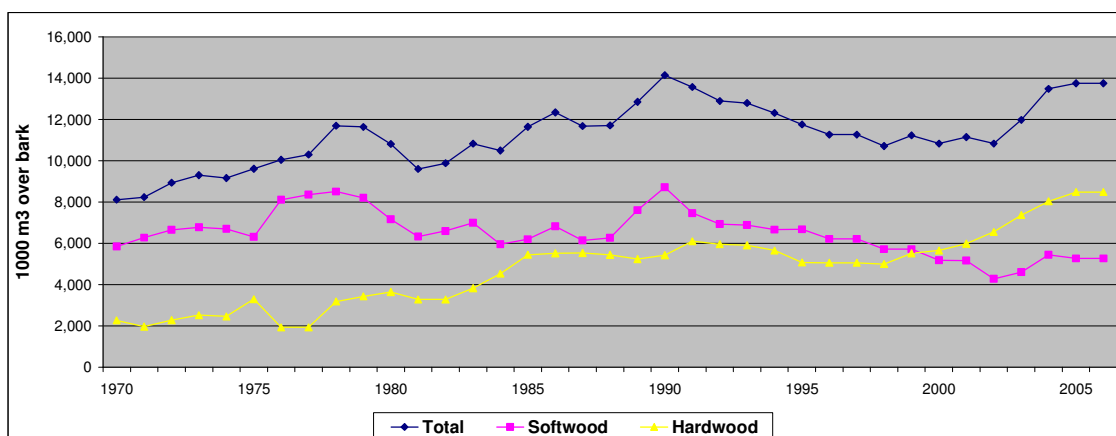
Note: 2004-06 data refer to 2003.

Source: FAO, DGRF

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 6.2 – Volumes of harvested wood (1000 m³ over bark) (1970-2006)



Source: DGRF; FAO

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. Other wooded land ("matos" - bush land, shrubs) is 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 ground biomass for forest trees, undergrowth cover (only for non-CO₂ emissions), and biomass from litter existing in forest land.

In earlier submissions, CO₂ emissions from forest fires were quantified assuming that all biomass burnt was removed through harvesting as salvaged wood volumes, based on the premise that these quantities were largely used in industry, and were considered to be fully included in the harvest volumes which refer to wood consumption. However, in reality, due to scarcity of information (e.g. the % of salvaged volumes within harvest), it is difficult to determine exactly which part of salvaged wood are considered in the harvest volumes, or if part of the burnt trees are not removed from the burnt forest, which would generate emissions from dead wood, non-harvested fallen logs, and snags remaining in the forest.

Despite the efforts developed by the inventory team, it is still not possible to have an assessment of the proportion of the harvested wood coming from burnt areas, or estimates about the fraction of burnt trees that are not removed after a fire. In the absence of this information, the carbon loss in above living biomass of trees resulting from wildfires was estimated as follows:

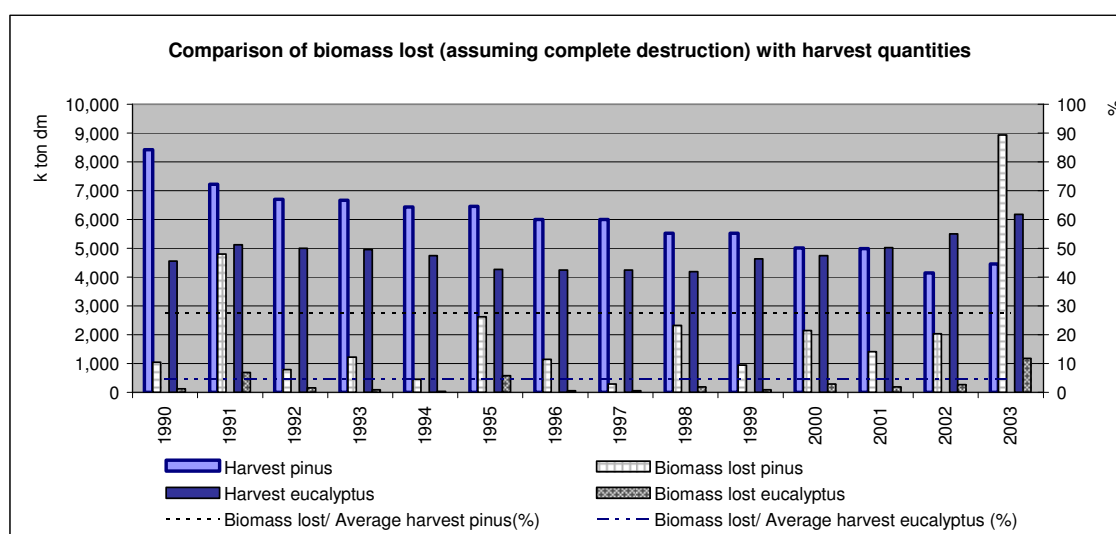
- 1) For pinus pinaster and eucalyptus, the two representative species in terms of industrial wood consumption, the same approach as in previous submissions has been used, i.e., it was assumed that the affected trees are harvested as salvaged wood and used in the industry, and are considered to be included in the harvest volumes which refer

to wood consumption. However, if the extent of the volumes burnt exceed by large the industrial wood consumption, then the whole amount of the burnt volume are accounted in the estimates, which is the case of the year 2003 for coniferous species.

2) For the other species, the calculation of annual carbon loss in above ground biomass, was based on the estimated fraction of biomass affected by the disturbance. Considering that the other species do not have the same economic importance as pinus pinaster and eucalyptus, it was assumed that the affected trees are left in the forest after a fire and regenerating in majority afterwards.

In order to assess the magnitude of the assumption made concerning the use of burnt biomass from trees in industry, the total of biomass removed in commercial harvest were compared to the estimated lost of biomass in wildfires, converted in quantities of dry matter of carbon. These last were calculated based on the yearly burnt forest surface multiplied by the estimated average biomass above ground for coniferous species and eucalyptus (92.7 t dm/ha and 38.63 t dm/ha respectively, as presented in Figure 6.3). The results, presented in next figure, show that for the majority of years the total biomass removed in commercial harvest is significantly higher than the estimated lost of biomass in wildfires, with the exception of 2003 for coniferous species. As the figure shows, the estimated percentual average for the commercial harvest in relation to the estimated lost of biomass is 28% (not taken in account the exceptional year of 2003) for coniferous species, and 4% for eucalyptus. If the period 1990-99 is considered, corresponding to the years for each the information on the species burnt are available (Cardoso Pereira (2003)), the ratio drops to 24% for coniferous species.

Figure 6.3 – Comparison of total biomass removed in commercial harvest and estimated biomass lost in wildfires (1990-2003)

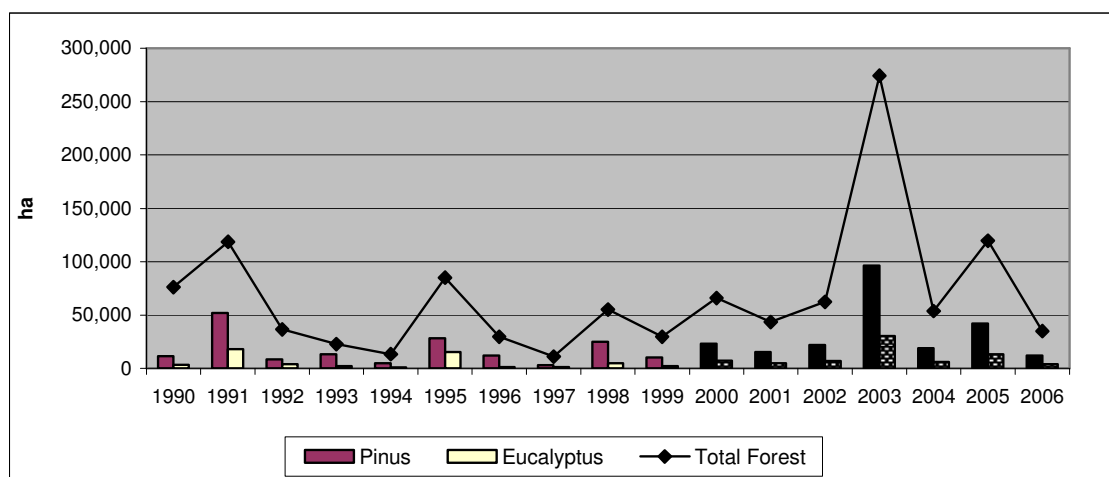


Source: FAO; APA estimates

Yearly data on burnt area are available from DGRF (General Direction for Forest Resources). The information on the share of burnt area by specie (pinus and eucalyptus), was based on data from Cardoso Pereira (2003), "Fire Risk and Burned Area Mapping in Portugal", MADRP, which refer to the period 1990-99. Data for the years 2000-03 refer to estimates from APA based on the average percentage of the burnt area by specie in relation to the total burnt area in the 1990-99 period.

Bush land ("matos") was not considered in the inventory, as it is generally non-managed land.

Figure 6.4 – Forest fires: human and natural origin (hectares) (1990-2006)



Notes: Data on burnt species: 2000-06 refer to APA estimates based on the average percentage of the burnt area by specie in relation to the total burnt area in the 1990-99 period from Cardoso Pereira (2003).
Source: DGRF; Cardoso Pereira (2003); APA estimates

Table 6.7 – Forest fires: human and natural origin (hectares) (1990-2006)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Forest	76,240	118,516	36,438	22,801	13,388	84,964	29,583	10,989	55,006	29,760	65,791	43,433	62,450	274,154	53,775	119,556	35,002
Pinus	11,302	51,765	8,453	13,254	4,944	28,214	12,307	3,075	25,031	10,275	23,147	15,281	21,971	96,454	18,920	42,063	12,315
Eucalyptus	3,356	17,882	3,983	2,228	743	15,110	1,460	1,433	4,817	2,353	7,325.5	4,836.1	6,953.5	30,526	5,987.7	13,312	3,897.3

Notes: Data on burnt species: 2000-06 refer to APA estimates based on 1990-99 averages in relation to total area burnt from Cardoso Pereira (2003).
Source: DGRF; Cardoso Pereira (2003); APA estimates

Emissions of air pollutants depend on the fuel type and fuel loading, among other factors. Nevertheless, for the time being, the calculations were done keeping data for the combustible material constant.

For the above ground biomass for forest trees, an average index for dry biomass above ground for forest trees was estimated, considering the same characterisation of the burnt species for all the years considered.

The estimation of this indicator was done on the basis of the relation area/volume for 1995 from INF 3rd rev., and the country volume stem factors used to convert the stem volume into dry biomass above ground, which were applied to the forest area in 1990. The value obtained is 45.6 t dm/ha as shown in the table below.

Table 6.8 – Estimates for biomass above ground in trees

	Volume stem factor into above ground (t dm/m3)	1990			
		Forest area (1000 ha)	Stem Volume a) (1000 m3)	Biomass above ground	
				(1000 t dm)	(t dm/ ha)
<i>Pinus pinaster</i>	0.78	1,069	108,194	84,391	78.96
<i>other softwood</i>	1.44	104	6,727	9,687	92.70
<i>Eucalyptus</i>	0.7	554	30,593	21,415	38.63
<i>Quercus suber</i>	0.57	693	24,276	13,837	19.96
<i>Quercus ilex</i>	0.57	462	9,856	5,618	12.15
<i>other Quercus</i>	1.12	123	4,480	5,018	40.91
<i>Castanea sativa</i>	0.56	37	1,887	1,057	28.83
<i>other hardwood</i>	0.57	97	3,852	2,196	22.61
Total/ Average b)		3,140	189,865	143,219	45.61

Note:

a) Estimated based on the relation area/volume for 1995 (INF 3rd revision).

b) Biomass above ground: weighed average based on forest type area.

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.

Next table presents the dry biomass data used in the estimates for the undercover and litter parts of forest land.

Table 6.9 – Biomass for undergrowth cover

	Area (1990) ha	Understorey shrubs a) ton/ha	Litter ton/ha
<i>Pinus pinaster</i>	1 068 828	7.811	10
<i>Eucalyptus</i>	554 418	5.589	6
<i>Quercus suber</i>	693 209	4.728	7
<i>Quercus ilex</i>	462 446	3.259	7
<i>Castanea sativa</i>	36 654	7.226	4.5
<i>other Quercus</i>	122 662	7.226	4.5
<i>other softw ood</i>	104 498	9.275	7
<i>other hardw ood</i>	97 128	7.226	4.5
Total b)	3 139 843	6.069	7.640

Notes:

a) Values correspond to 70% of total shrubs biomass.

b) Understorey and litter: weighted averages based on forest type areas.

Source:

Tiago Pereira da Silva (ISA), et al., "Estimativa de Emissões Atmosféricas Originadas por Fogos Rurais em Portugal".

The faction of the tree biomass affected by the wildfires ($1 - f_{BB}$) was estimated based on the following assumptions (PNAC):

- 50% of the trees in a burnt area are affected;
- 10% of the total biomass of the affected trees, corresponding to the fine parts of the trees (branches and leaves), is consumed;
- 80% of the fine materials burn.

Concerning the undergrowth cover, it was considered that 80% of shrub and bush biomass undercover is combusted in average during a fire (Botelho et al.1994 e Fernandes et al. 2000).

For the litter part it was assumed that in average 63% of the biomass burns (Botelho et al.1994 e Fernandes et al. 2000a).

Next table presents the average biomass combusted values used in the calculs of the annual carbon loss from wildfires. The C content of dry matter for above ground and understorey biomass was the IPCC default 0.5; for the litter part the value used (0.37) was taken from LULUCF GPG.

Table 6.10 – Average biomass combusted in wildfires

	Average biomass ton/ ha	Fraction of biomass combusted	Average biomass combusted ton/ ha
Above ground biomass a)	45.61	0.04	1.82
Understorey biomass b)	6.07	0.80	4.85
Litter b)	7.64	0.63	4.81

Notes:

a) Fraction of above ground biomass combusted was estimated based on the following assumptions: 50% of the trees is affected by fire; out of the affected trees, only the thin parts (diameter<0,6cm) are lost (10% of the total biomass); 80% of the thin materials are burnt.

Sources:

a) Fraction of above ground biomass combusted: (PNAC, 2003)¹⁴⁶.

b) Fraction of above ground biomass combusted: Botelho et al.1994 e Fernandes et al. 2000a.

6.2.A.2 LAND CONVERTED TO FOREST LAND (LF)

Methodologies, activity data and parameters for this category are presented in 6.1 which refer to Land Use Conversion.

¹⁴⁶ PNAC (Julho 2003), Floresta e Produtos Florestais – Cenário de Referência, Volume 8.

6.2.B Cropland (CRF 5 B)

6.2.B.1 CROPLAND REMAINING CROPLAND (CC)

Methodologies, activity data and parameters for this category are presented in 6.1 which refer to Land Conversion.

6.2.B.2 LAND CONVERTED TO CROPLAND (LC)

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.

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).

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).

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 6.1.

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.

6.2.C Grassland (CRF 5 C)

Methodologies, activity data and parameters for this category are presented in 6.1 which refer to Land Conversion.

6.2.D Wetlands (CRF 5 D)

Methodologies, activity data and parameters for this category are presented in 6.1 which refer to Land Use Conversion.

6.2.E Settlements (CRF 5 E)

Methodologies, activity data and parameters for this category are presented in 6.1 which refer to Land Use Conversion.

6.2.F Other Land (CRF 5 F)

Methodologies, activity data and parameters for this category are presented in 6.1 which refer to Land Use Conversion.

6.2.G Land Use Conversion

6.2.G.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 growth 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 period¹⁴⁷;
- 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.

		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

¹⁴⁷ 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.

The release and uptake of carbon for the following carbon pools was considered in the estimates made. However, dead wood is not considered separately:

Pool			Definition
Living biomass	above-ground		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 biomass	below-ground		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, fomic, humic layers, but also dead wood. Verificar
Soil Organic Carbon (SOC)			Includes organic carbon in mineral soils to a the depth of 30 cm.

6.2.G.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 gain¹⁴⁸:

Bibliography

Key Categories

Uncertainty

¹⁴⁸ 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.

$$\Delta C = \sum_{csLL} [A_{csLL} * (C_g - C_L)_{csLL}]$$

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 initiation¹⁴⁹. For a specific land conversion LL, net emissions (ΔC_{net}) are determined from removals (ΔC_L) and uptake (ΔC_g):

$$\Delta C_{net} = A_{csLL} * (\Delta C_L - \Delta C_g)$$

$$\Delta C_{net} = A * [(\sigma C_{LAB} + \sigma C_{LBB} + \sigma C_{DOM}) - (\delta C_{LAB} + \delta C_{LBB} + \delta C_{DOM}) * T_e + (C_{SOC,t} - C_{SOC,i}) * T_e / T_e]$$

Were:

A_{csLL} - area of land, for a specific climate type c, for the specific conversion LL, and in soil type s (ha/yr);

Bibliography

Key Categories

Uncertainty

¹⁴⁹ 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.

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;

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 pool¹⁵⁰;

- the rate of carbon change in soil organic carbon (SOC) occurs in each parcel at a rate $(C_i - C_t)/T_e$, where 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 $(C_i - C_t)$;

- 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 (T_e) 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, can not be detected from the available data and it is not considered. It causes a slight over-estimation of carbon uptake.

Bibliography

Key Categories

Uncertainty

¹⁵⁰ This scheme is valid under the Convention, but must be different for the reporting or emissions and uptakes under article 3.3 of the Kyoto protocol, which only accounts for conversions occurring after 1990.

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.

6.2.G.3 EMISSION FACTORS AND PARAMETERS

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 6.11, 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 T_e , time to equilibrium, are presented in Table 6.12. 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 6.12. 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 6.11 - Biomass Carbon Stocks Present on Land Previous to Land Use Change

			Above ground (tonnes C ha ⁻¹)	Below ground	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) 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
		Quercus Rotundifolia (Holm Oak)	9.73	4.19	0.43	
		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	
	Sparse Vegetation: Cold Temp. - Wet		0.60	2.40	4.00	Sparse vegetation assumed half the biomass of grassland
	Sparse Vegetation: Warm Temp. - Dry		0.40	1.12	2.80	
Settlements	Artificial Areas (General)		NO	NO	-	
	Gardens, parks, etc: Cold Temp. - Wet		3.59	5.83	1.62	Assumed equal to Mixed Montado
	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 6.12 - Annual growth of living biomass

			Above ground	Below ground	Root-shoot ratio	Te (yrs)	Documentation
			(t C/ha/yr)				
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	-	-	

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 per cent 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 6.13.

Table 6.13 - Litter biomass stocks by forest type

Forest Type	Litter Stock		Litter Increment		Documentation Source
	(t dm/ha)	(t C/ha)	(t dm/ha/yr)	(t C/ha/yr)	
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)

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:

$$SOC = SOC_{ref} * F_{LU} * F_{MG} * F_I$$

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 6.14. The additional parameters for SOC determination (F_{LU} , F_{MG} and F_I) are presented below for agricultural soils (Table 6.15) and for grazing lands (Table 6.16). 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 6.14 - 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 6.15 - 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 6.16 - 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

6.2.G.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.

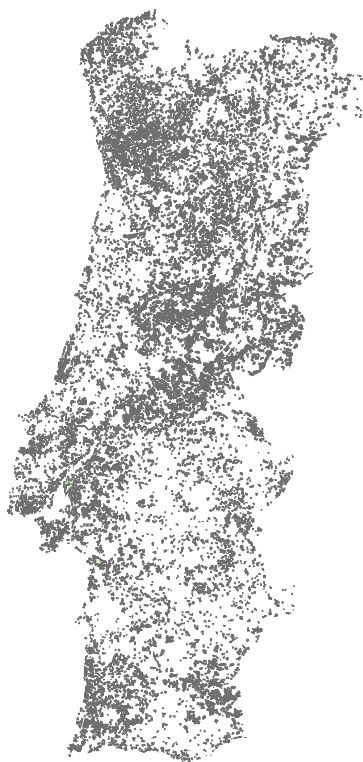
The set of polygons was further divided for consideration of variables originally not considered in the CLC Changes database:

- Soil cartography, using data from the Environment Atlas¹⁵¹ (IA,1971);
- Total annual precipitation, using data from the Environment Atlas (IA, 1974);
- Forest land cartography on forest types, from DGRF.

¹⁵¹ Atlas do Ambiente (<http://www.ambiente.pt>)

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 6.5.

Figure 6.5 - Total individual polygons identified in continental Portugal



The collection of activity data is classified as a polygon approach 3 of the LULUCF-GP.

CLC CHANGES

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 1990¹⁵².

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 coloboration 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.

In Portugal both CORINE products (CLC90 and CLC2000) rely on data from the Landsat satellite¹⁵³, 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;

Bibliography

Key Categories

Uncertainty

¹⁵² The reference year could vary from 1985 to 1995.

¹⁵³ Thematic Mapper (TM) and Multispectral Scanner (MSS) from Landsat-5 (1985-87) and Enhanced Thematic Mapper (ETM+) from Landsat-7 (2000)

- CLC - Changes¹⁵⁴. 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-R¹⁵⁵.

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 classes¹⁵⁶ at the lowest (3rd) level, as presented in the next table.

Bibliography

Key Categories

Uncertainty

¹⁵⁴ CLC-alterações in Portuguese.

¹⁵⁵ 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.

¹⁵⁶ 42 classes were used in the Portuguese cartography (Painho & Caetano, 2005).

Table 6.17 - 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	
	Agricultural areas	Arable land		non irrigated arable land	Wetlands
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).

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 per cent to 2.7 per cent (66 738 ha). Slight increases were

also verified in what concerns Forest areas, 48.1 per cent to 48.2 per cent (11 931 ha), and water bodies, 0.8 per cent to 0.9 per cent (5 390 ha). By the contrary, agricultural areas decreased from 48.9 per cent to 48.1 per cent (84 055 ha). Finally wetland areas remain constant, 0.3 per cent of the continental territory. Nevertheless, at a more detailed level (level 3), about 11 per cent 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 6.18 – 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.

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

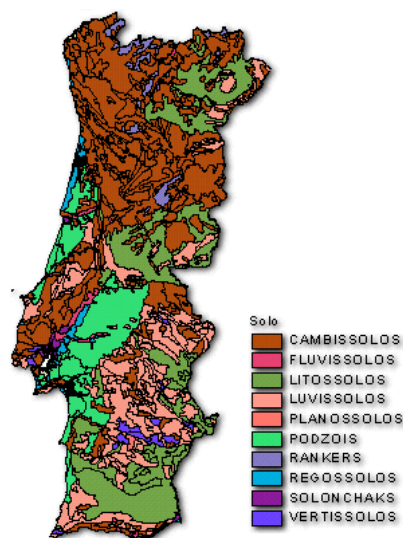
SOIL CLASSES

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 6.19 - Soil Types used in calculation of carbon release/uptake from the soil pool

Soil	Qualifiers	Association with	Soil	Qualifiers	Association with
Fluvisols	eutric	Fluvisols calcareo	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 calcareo			orthic	Cambisols dystic
Solonchaks	gleyic			orthic	Cambisols eutric
Cambisols	dystic			orthic	Luvisols gleyic
	dystic	shales and quartzites (Ordovician)		orthic	Cambisols calcareo
	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 quartzites (Ordovician). Moderate atlantic influence			
		post-paleozoic sedimentary rocks			
	humic chromic				
	eutric	eruptive rocks			
	eutric	shales and quartzites (Ordovician)			
	eutric	post-paleozoic sedimentary rocks			
	calcic				
	chromic				
	chromic calcareo				
	chromic calcareo vertic				

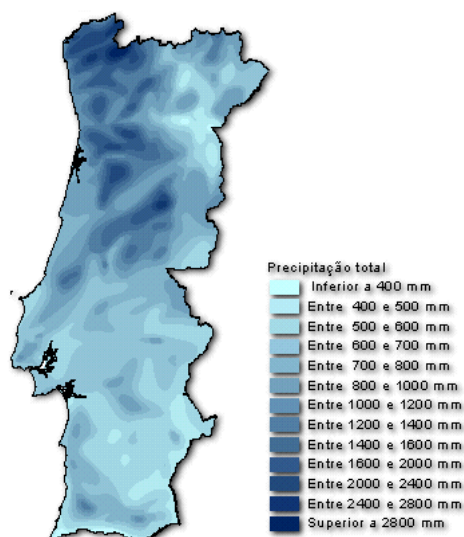
Figure 6.6 - Soil Classes according to the FAO-UNESCO classification scheme in Continental Portugal (IA,1971)



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 IPPC,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 6.7. 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 6.7 - Mean Annual Total Precipitation in Continental Portugal (IA,1974)



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 (DGRF,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 most close 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 DGRF mapping in next table.

Table 6.20 - 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

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 update¹⁵⁷. 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

¹⁵⁷ 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.

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 6.21, also showing the rules of conversion from the original cartography classes. All land use types in Table 6.21 were further classified according to soil type, Table 6.19, and, for forestall systems, also in accordance with the dominant tree, Table 6.22. 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 6.21);

USE_f - Land use resultant from the conversion of land use (Table 6.21);

CLIM - Climate conditions (MOIST/DRY) prevailing in the land use area;

SOIL - Soil type existing in the land use area (Table 6.19);

TREE - Dominant tree species in forest areas or land uses including forest species (Table 6.22).

Table 6.21 - 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
					Construction sites
RICE	Rice Paddies	Rice fields			Sport and leisure facilities
GRASS	Managed Grasslands	Pastures	SURB	Mixed urban areas and parks	Discontinuous Urban Fabric
PRAI	Natural Grasslands	Natural grasslands	WET	Wetlands	Peatbogs
CHARN	Sparse Grassland	Sparsely vegetated areas			Salt marshes
FOR	Forest	Broadleaved forest			Salines
		Coniferous forests	H2O	Water bodies	Inland marshes
		Mixed forests			Intertidal flats
		Transitional woodland/shrub (Forest areas degraded, recently harvested and new plantations)			Water courses
		Burnt areas			Water bodies
MONT	Grasslands with Dispersed trees (Montado)	Agro-Forestry areas			Coastal lagoons
MOSC	Agriculture Areas mixed with forest	Agriculture and natural areas			Estuaries
BUSH	Bush areas (Matos)	Moors and heathland			Sea and Ocean
GAR	Urban gardens & parks	Sclerophyllous vegetation			Beaches, dunes and sand plains
		Green urban areas	OTH	Other Land Uses	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 6.22 - 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.

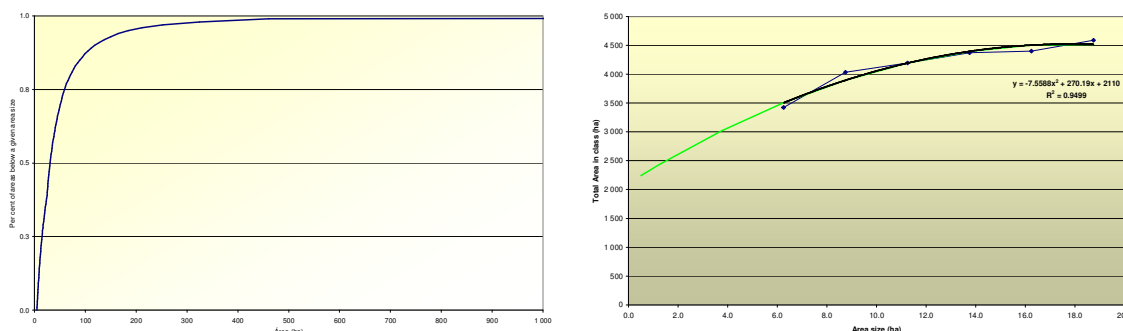
Table 6.23 - Conversion of Land Use Classes in calculus to Land Use Classes under the Inventory

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

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 6.8) 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 per cent of total. This per cent was applied for all estimated of all land use changes.

Figure 6.8 - Distribution of area sizes in CLC changes and adjustment of curve to the lower range of areas



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.

6.3 Recalculations

Recalculations refer mainly from the recommendations from the in-country review of the 2006 submission and the IIR under the Kyoto Protocol:

- estimates of the emissions and removals from the Autonomous regions which have been estimated and included in the national total for the first time (previously, only wildfires emissions included the Islands).:
- minor differences in the LUC areas and related estimated emissions which refer to revised estimates of the limit detection (1 ha instead of 0.5 ha), an issue that was raised during the in-depth IRR.

Furthermore, forest land area has been revised in order to consider young plantations, clear-cuts and damaged (burnt) areas (i.e. temporally unstocked areas), that were previously not included in the forest area considered.

Figure 6.9 – Differences between 2007 and 2008 submissions (CO₂, CH₄ and N₂O)

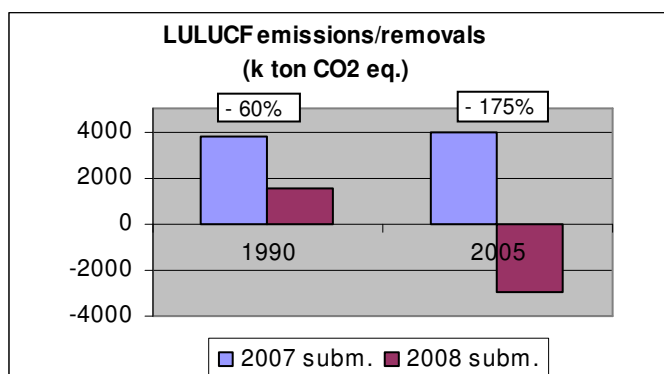


Table 6.24 – Recalculations (differences between 2007 and 2008 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2			CH4			N2O		
			2007	2008	Diff. (1)	2007	2008	Difference	2007	2008	Diff. (1)
			subm.	subm.		subm.	subm.	(1)	subm.	subm.	
			CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)
1990											
5. Land Use, Land-Use Change and Forestry (net)			3.650,24	1.365,93	-62,58	137,09	137,08	-0,01	40,23	40,23	0,00
5.A.	Forest Land		2.231,96	-50,43	-102,26	137,09	137,08	-0,01	13,91	13,91	-0,01
5.B.	Cropland		190,60	190,38	-0,12	NO	NO		24,24	24,24	0,00
5.C.	Grassland		-24,77	-24,74	0,12	NO	NO		NO	NO	
5.D.	Wetlands		104,87	104,75	-0,12	NO	NO		NO	NO	
5.E.	Settlements		1.114,94	1.113,65	-0,12	NO	NO		NO	NO	
5.F.	Other Land		32,64	32,33	-0,95	NO	NO		NO	NO	
5.G.	Other		NO	NO		NO	NO		2,07	2,07	0,00
2005											
5. Land Use, Land-Use Change and Forestry (net)			3.664,13	-3.238,71	-188,39	214,85	215,47	0,29	48,12	48,18	0,13
5.A.	Forest Land		2.245,85	-4.655,07	-307,27	214,85	215,47	0,29	21,80	21,87	0,29
5.B.	Cropland		190,60	190,38	-0,12	NO	NO		24,24	24,24	0,00
5.C.	Grassland		-24,77	-24,74	0,12	NO	NO		NO	NO	
5.D.	Wetlands		104,87	104,75	-0,12	NO	NO		NO	NO	
5.E.	Settlements		1.114,94	1.113,65	-0,12	NO	NO		NO	NO	
5.F.	Other Land		32,64	32,33	-0,95	NO	NO		NO	NO	
5.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.

6.4 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 per cent.

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 per cent according to GP-LULUCF¹⁵⁸, with the biased error of the not

¹⁵⁸ According to Painho & Caetano (2005) the global thematic accuracy was estimated to be 82.84 per cent, following the methodology defined in the EEA (2002) Technical Guidance for the I&CLC2000 Project.

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:

$$U_{Total} = \Sigma \{ [A_i * (U_{Ai}^2 + U_{Gi}^2 + U_{BEFi}^2 + U_{RSi}^2 + UC^2)]^{0.5} / \Sigma A_i$$

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} - Composited uncertainty of both density of biomass and BEF, set as 32 per cent from GP-LULUCF;

U_{Ri} - Uncertainty of the root to shoot ratio (GP-LULUCF);

U_{Gi} - Uncertainty in carbon content of biomass. A constant value of 30 per cent 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 per cent 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 6.25 – 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 per cent;

- The uncertainty in CH₄ and N₂O, both 70 per cent, are those proposed by GP LULUCF, pag 3.50.

6.5 Further Improvements

Efforts are still on going to improve the methodology that will be used to report emissions under the Kyoto Protocol. At present, a pilot study is under way, in order to define Portugal's reporting methodology under the UNFCCC and the Kyoto Protocol. Although these efforts aim mainly the Kyoto Protocol, the methodology that will be used under the Convention will be 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:

- Revision of the carbon content of soils, with the inclusion of country specific studies and monitoring;
- Development of yield tables per age and per Forest Planning Regions (PROF) using models of biomass production for main species (P. pinaster, Eucalyptus, Q. suber); and tables at national level for other species (Q. Rotundifolia, Quercus, C. Sativa, etc); this will in principle revise the use of the BEF methodology;
- Revision of the methodology used to estimate emission from forest fires, considering the per cents that remain alive after the fire, and avoiding the double counting of harvest and biomass loss during fires. The main questions of concern are: (1) some trees are used in industry or fuel; (2) avoid double counting of harvesting; (3) not all biomass is lost; (4) some forest became unproductive; (5) differences by specie;

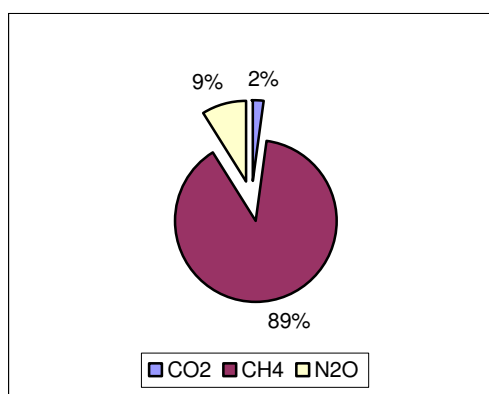
CHAPTER: 7 WASTE (CRF 6)

7.1 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 7.1 – Emissions of GHG from waste by gas (2006)



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 per cent CH₄ and 50 per cent CO₂ by volume. However, this carbon dioxide results in its major part from oxidation of biomass materials and does not contribute hence to ultimate CO₂. Additionally, a much smaller percentage of landfill gas is composed of NMVOC and NH₃.

The biodegradation of soluble organic matter in wastewater can occur under aerobic or anaerobic conditions. CH₄ emissions result from handling of wastewater and the biomass (sludge) produced under anaerobic conditions. The amount of CH₄ produced depends on the extent of biodegradation occurring under anaerobic versus aerobic conditions. CH₄ produced during deliberate anaerobic wastewater treatment processes can be collected and flared or combusted for energy. Untreated wastewater may originate CH₄ if held under anaerobic circumstances.

CH₄ emissions are affected by:

- Wastewater characteristics. Determines how much organic compounds are degraded. Also the degradable organic content of wastewater determines the CH₄ producing potential of wastewater, because it affects the extent to which oxygen is removed from the system. Under anaerobic conditions and all the same conditions, such as temperature, wastewater with higher BOD (Biochemical Oxygen Demand) or COD

(Chemical Oxygen Demand) concentrations will produce more CH₄ than wastewater with lower BOD or COD concentrations);

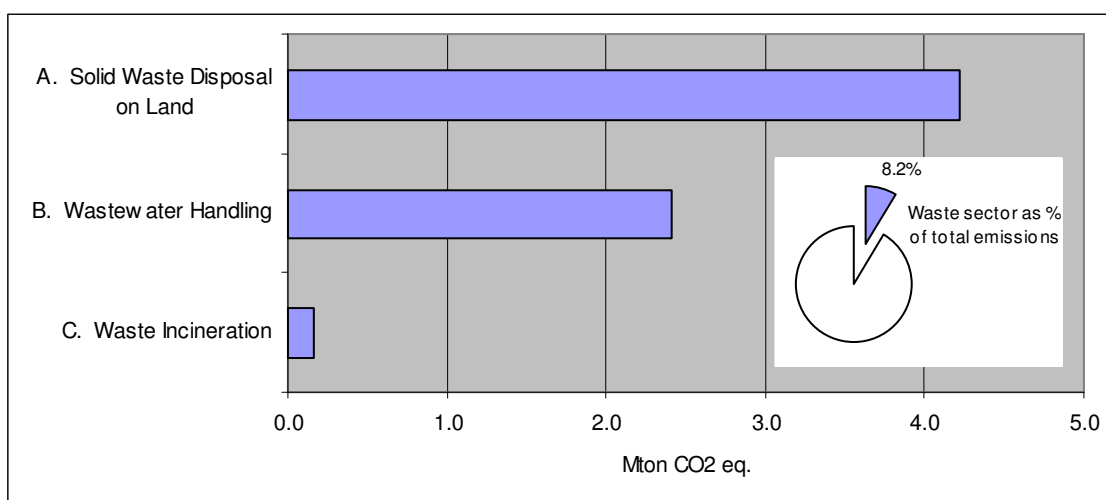
- Handling Systems – anaerobic versus aerobic conditions in system design and operation (the management conditions of collection and wastewater treatment systems determine the potential of CH₄ generation; systems providing anaerobic conditions will generally produce higher CH₄ emissions than systems having aerobic conditions);
- Temperature (CH₄ generation increases with temperature; CH₄ production occurs with temperatures higher than 15°; this factor is specially 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 municipal solid wastes (MSW) and hazardous 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.

Emissions generated from waste activities represented in 2006 8.2% of total GHG emissions (excluding LULUCF). The biggest sub-category within the sector refers to solid waste disposed on land – 4.2 Mton CO₂ eq. - corresponding to 62% of the sector emissions.

Figure 7.2 – Sources of GHG in waste sector (2006)

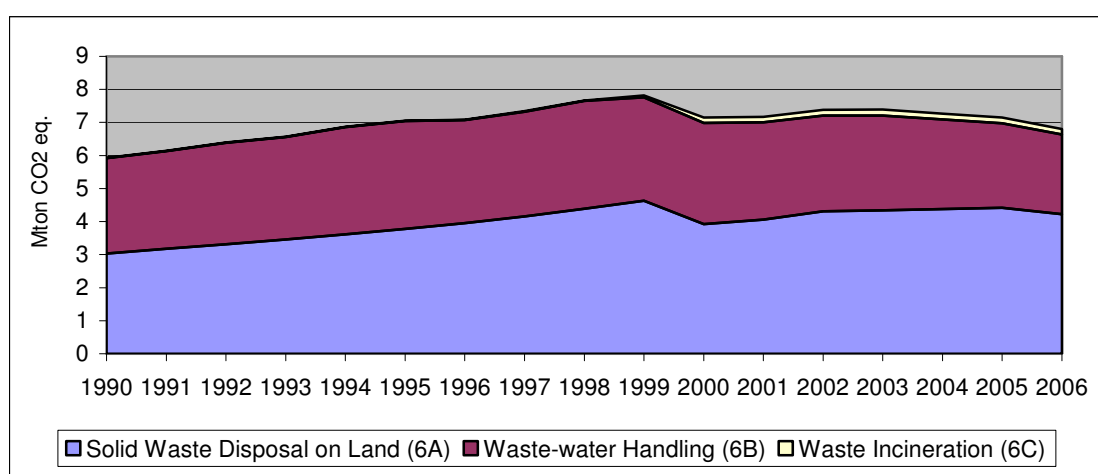


In the period 1990-2006 GHG emissions from waste activities are estimated to have increased 15%, having reached a peak in 1999. The increase in the sector is strongly related to the change of consumption patterns registered in Portugal in the last decades, associated with new commercial structures. The 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 lead 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)¹⁵⁹.

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.

Figure 7.3 – Emission trends of GHG from waste



¹⁵⁹ APED, Anuário da Distribuição Portuguesa 1999.

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 CRF 1.

Furthermore, the category CRF 6A registers a decline in emissions since 1999, which is also related to biogas flaring in landfills, where biogas burners have been installed. 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 the emission reductions in recent years.

7.2 Source categories

7.2.A Solid Waste Disposal on Land (CRF 6 A)

7.2.A.1 CH₄ EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

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 CO₂¹⁶⁰. 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.

¹⁶⁰ Although not ultimate CO₂.

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:

$$L_0 = MCF * DOC * DOC_F * F * 16/12$$

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.

$$DOC = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)$$

where:

A = fraction of waste that is paper and textiles;

B = fraction of waste that is garden waste, park waste or other non-food organic putrescibles;

C = fraction of waste that is food waste;

D = fraction of waste that is wood or straw.

Fraction of degradable organic carbon dissimilated (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 landfill gas is usually considered to be composed dominantly by half of CO₂ and half of CH₄¹⁶¹.

ACTIVITY DATA AND PARAMETERS

SWDS include solid municipal or urban waste (household, garden, commercial-services wastes) and industrial wastes.

Urban waste

Quantities of waste landfilled

In 2005, 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:

¹⁶¹ Other gases exist in lesser quantities however.

- PERSU - “Plano Estratégico dos Resíduos Sólidos Urbanos” (Strategic Plan on Municipal Solid Waste), which was approved by the Government in 1997. This plan includes data from annual municipal registries;

- a study performed by Quercus (1995) – “Caracterização dos Resíduos Sólidos Urbanos e Inventariação dos Locais de Deposição em Portugal” (Characterization of Municipal Solid Waste and Survey of Disposal Sites in Portugal). The study of Quercus (1995) considered open dump sites, managed landfills, composting and incineration units, covering aspects as the quantities of waste treated or landfilled and other characteristics (opening and closure year of operation, waste composition, existence of flaring equipment, etc). Data was based on a survey performed in 1994, which enabled the calculation of per capita generation rates for 1994, based on the amounts of waste collected and the population served by waste collection.

The use of the FOD method requires building a data time series for several decades in the past concerning waste quantities, composition and disposal practices. According to IPCC (2000), it is good practice to estimate historical data if such data are not available, when this is a key source category (Annex A). In what concerns the extent of the time series, it was adopted the criteria from USA, based on the emissions model from EPA(1993), and it was considered that landfill waste produces CH₄ for 30 years after disposal.

Before 1994, data on landfill wastes had to be estimated based on expert 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 were estimated for each municipality as follows:

$$[\text{Population (inhabitants)} * \text{Annual per capita generation rate (ton/inhabitants/year)}]$$

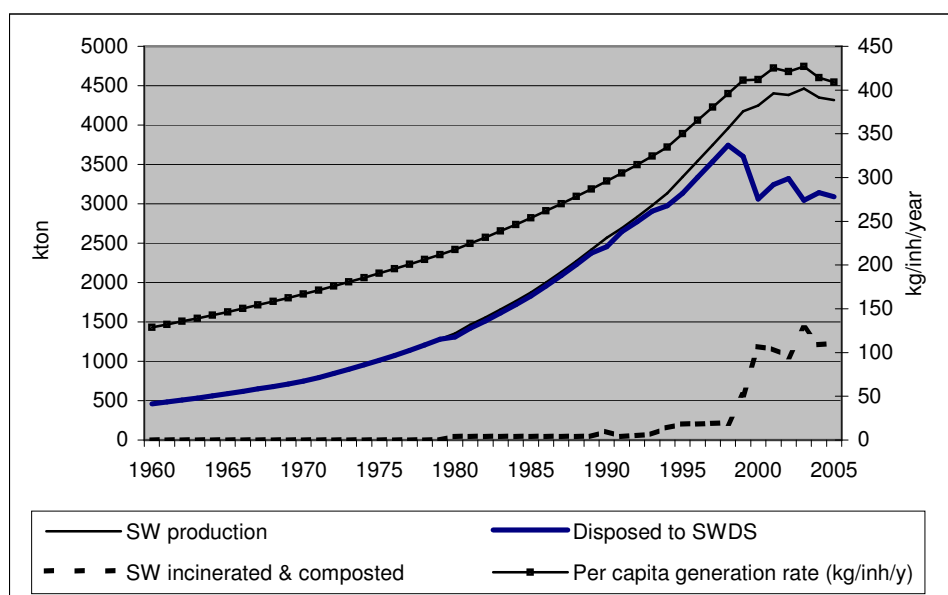
Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991 e 2001. Data for intermediate years were estimated, by interpolation, for each municipality. Figures for 2001 onwards are forecasts.

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:

$$\begin{aligned} \text{Waste disposed to SWDS} = & [\text{Population} * \text{Annual per capita generation rate} * \\ & \text{Percentage of Population served by waste collection}] \\ & - \text{Quantity of incinerated waste} - \text{Quantity of composted waste} \end{aligned}$$

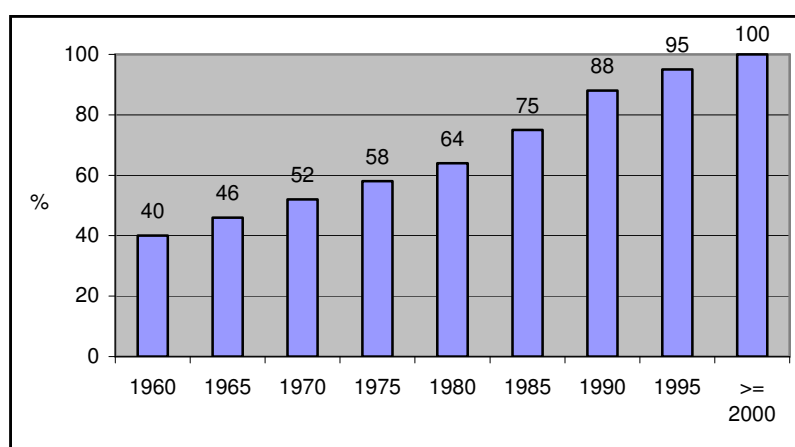
Next figure presents the trends of the per capita generation rates, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series. For the more recent years (for 1994, and since 1999) the information 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 7.4 – Urban waste (excluding selective collection) in the period 1960-2006



Source: APA estimates; INR; Quercus study

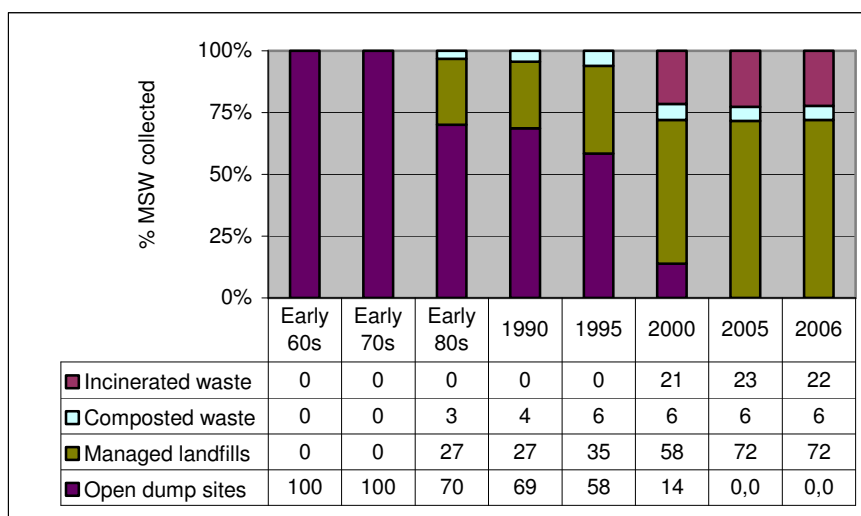
Figure 7.5 - Population served by solid waste collection systems



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 2006 this figure fall to 71.6%, and the percentage of waste incinerated represents 23%).

Figure 7.6 – Final disposal of waste (% of municipal solid waste without selective collection)



Source: APA estimates; Quercus; INR

CH₄ generation potential (Lo)

The parameters used in the calculation are mainly IPCC default values.

Table 7.1 – 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 7.2 - 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

Other parameters

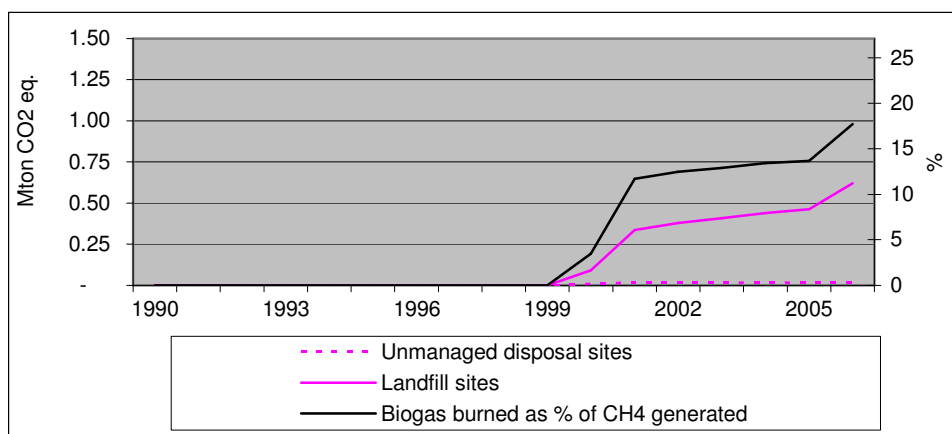
The value of CH₄ generation rate constant (k) depends on several factors as the composition of the waste and the conditions of the SWDS. In the absence of national studies to determine this parameter, and following the recommendations of the in-depth review, the values used in previous submissions were 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.

In the absence of metering landfill gas recovered data, estimates of recovered CH₄ were done based on: the information from INR for each waste management system - existence of burners, and the starting year of landfill operation; and on an average efficiency for the gas capture (75%) and for the burners (97%).

Figure 7.7 – Quantities of CH₄ recovered and combusted (urban waste)



Source: APA estimates based on data for the number of landfills with burners and where flaring occurs.

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. It was assumed that gas burning starts typically 2-3 years after the beginning of the landfill operation.

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.

Industrial waste

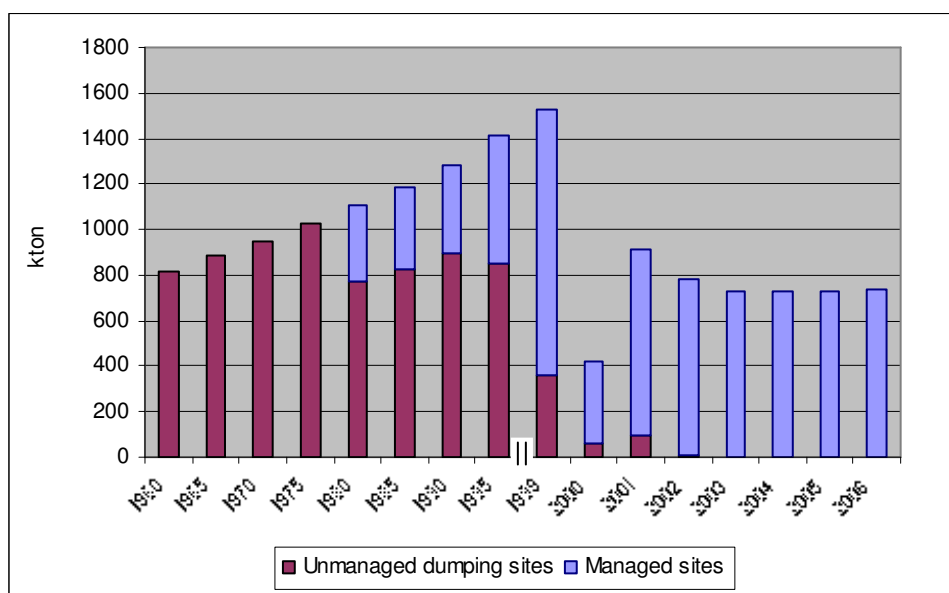
Quantities of waste landfilled

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 2006 are also estimates based on interpolation (2001) and last available data (2004-06 refer to 2003 data).

All industrial waste generated was considered 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 7.8 – Quantities of fermentable industrial waste disposed to SWDS



Source: APA (include estimates)

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 2006 (2003 data).

Available data on industrial waste production come from INR (Waste Institute) and refer to annual registries from industrial units declarations. These 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 were classified according to a group and were 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.

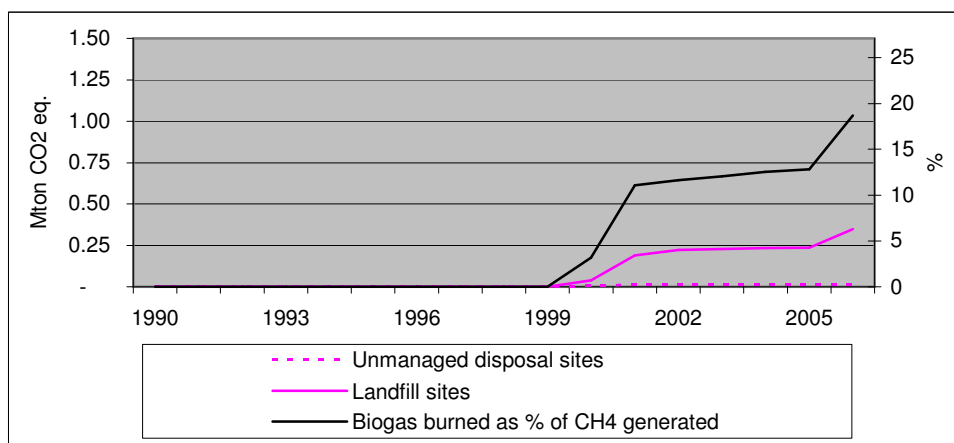
Table 7.3– Base table for industrial waste C content estimation

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

Other parameters

Data on quantities of CH₄ recovered and combusted are estimates based on the assumptions presented for urban waste, considering that they share the same disposal places. Data trends are presented in the following figure.

Figure 7.9 - Quantities of CH₄ recovered and combusted (industrial waste)



Source: APA (include estimates).

7.2.B Other (CRF 6.A.3)

This category includes emissions from the open burning of industrial solid waste on land which was previously reported in the category 6D. This change relates to a in-depth review recommendation to report these emissions under category 6.A.3 Solid Waste Disposal on Land – Other.

7.2.B.1 CO2 EMISSIONS

METHODOLOGY

The methodology used refers to IPCC Guidelines (IPCC,1997). Ultimate CO2 emissions estimation from open combustion of industrial waste on land were calculated as follows:

$$\text{CO2 emissions (Gg/yr)} = \text{IW} * \text{CCW} * \text{FCF} * \text{EF} * 44 / 12$$

where:

IW - Amount of burned waste (Gg/yr);

CCW - Fraction of carbon content in waste;

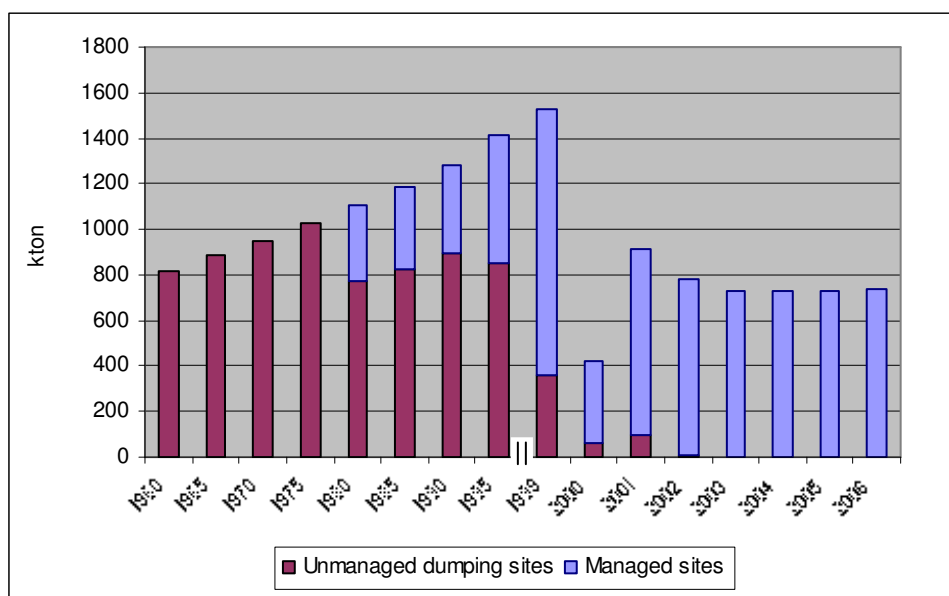
FCF - Fraction of fossil carbon in waste;

EF - Burn out efficiency of combustion of incinerators for waste (fraction).

ACTIVITY DATA AND PARAMETERS

Data refer to uncontrolled combustion of industrial solid waste on land 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 2004-06 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 7.10– Quantities of open combusted industrial waste (1990-2006)



Source: APA (include estimates).

Table 7.4- 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)

- a) C content of waste: until 1999 - 14; 2000 - 18; 2002 – 17.
b) IPCC default.
c) % 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 7.3). 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 on land”.

7.2.B.2 NON-CO2 EMISSIONS

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.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \text{IW} * \text{EF} * 10^{-6}$$

where:

IW = Amount of combusted waste (Gg/yr);

EF = Pollutant emission factor (kg pollutant/Gg)

ACTIVITY DATA AND PARAMETERS

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 7.5 - Emissions factors of GHG and precursors gases from open burning of Industrial Solid Wastes

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.8	PROET study
CH4	kg/ton MSW	6.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
N2O	kg/ton MSW	0.1	Corinair 3rd version. Activity 090201. No NOx abatement
SOx	kg/ton MSW	0.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
NOx	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)

7.2.C Wastewater Handling (CRF 6 B)

7.2.C.1 DOMESTIC WASTEWATER

The accounting of this category is based on data trends for the wastewater treatment systems which was compiled by INAG (National Institute for Water, the National Focal Point of the National System for this sector).

CH₄ EMISSIONS FROM WASTEWATER HANDLING (WWH)

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:

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.

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 (B₀) and a weighted average of CH₄ conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_{0i} \times \sum_x (WS_{ix} \times MCF_x)$$

where:

EF_i - emission factor (kg CH₄ /kg DC) for waste type i (e.g., domestic wastewater or sludge, etc);

B_{0i} - 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 (B₀) 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.

3 – Calculation of emissions

Emissions are a function of total organic waste generated and an emission factor characterising the extent of CH₄ generation for each wastewater handling system. CH₄ that is recovered and flared or used for energy should be subtracted from total emissions, as it is not emitted into the atmosphere.

$$M = \sum_i (TOW_i * EF_i - MR_i)$$

where:

M - Total CH₄ emissions from wastewater and sludge handling in kg CH₄

TOW_i - total organic waste for waste type i in kg DC/yr. (Step 1)

EF_i - emission factor for waste type i in kg CH₄/kg DC (Step 2)

MR_i - total amount of methane recovered or flared from wastewater type i in kg CH₄.

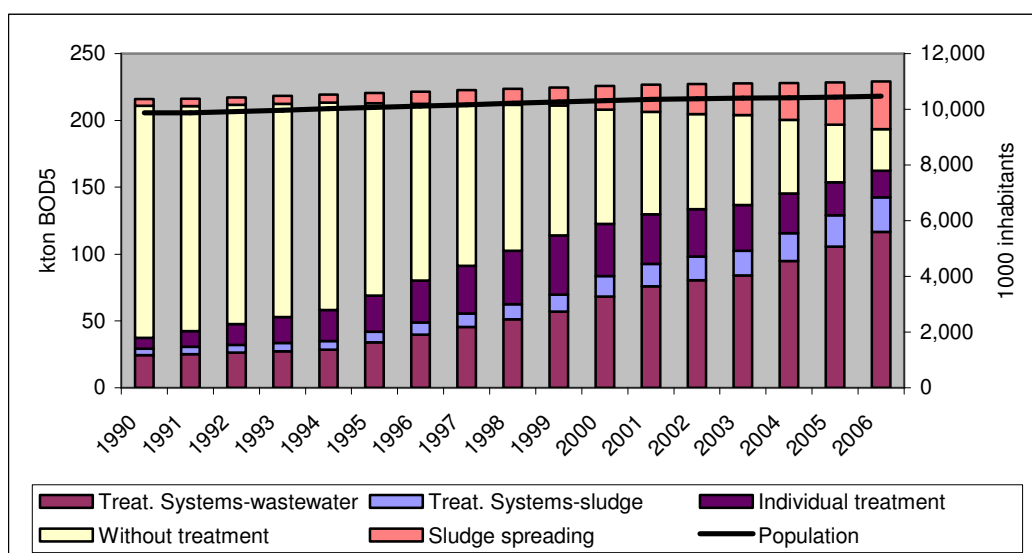
Activity data and parameters

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.

New background data for wastewater handling systems and types of treatment were 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. From 2000 onwards, data refer to estimates performed by APA which are based in some assumptions, such as the 90% target in 2007 for the % of population served by sewerage and sewage treated from the Water National and Regional Development Plan. The estimates for the % of population served by collective septic tanks, primary treatment, biodisks, laguning, percolation beds and imhoff tanks; were estimated based on the assumption that the respective quantities of organic loads in relation to the total amount of organic material remain constant (assuming that no new treatment systems of this kind were built), making their treated quantities reduce in relative terms. In what refers to the % of population served by activated sludge, oxidation ponds and other treatment the estimates for the years after 2000 were based on the assumption that these treatments accommodate the remaining treatment growth (90% target in 2007 for the % of population served by sewerage and sewage treated). In the future, the 2000 and following years estimates for % of population served by wastewater handling types should be replaced by real data from a new database (INSAAR – Inventário Nacional de Sistemas de Abastecimento e de Águas Residuais/ National survey on water supply and wastewater systems) which is being implemented by INAG.

Total organic waste (TOW in terms of BOD₅ produced) was divided into different fractions (Figure 7.11), 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 7.7).

Figure 7.11 – 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 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); 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 and Percolation beds with anaerobic sludge digestion (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, oxidation ponds and other treatment.

Table 7.6 - Percentage of population by wastewater handling system

Wastewater handling systems		1990	1994	1999	2000	2001	2002	2003	2004	2005	2006
		% population									
1.1-	% de Pop: with discharge into the ocean, without treatment	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
1.2-	% de Pop: with discharge into inland waters, without treatment	36.8	40.8	30.3	25.0	20.9	18.5	16.6	11.3	5.9	0.6
1.3-	% Pop: without sewerage (latrines)	37.0	23.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
1.4-	% Pop: individual treatment (private septic tanks)	1.5	8.2	14.8	12.2	11.3	10.6	10.1	8.0	5.9	3.9
2-	% Pop: with greater than preliminary treatment	18.2	21.1	42.0	49.9	54.9	58.0	60.4	67.8	75.2	82.6
2.1-	% Pop: colective septic tanks	2.2	2.3	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9
2.2-	% Pop: with primary treatment	5.2	5.2	9.0	9.0	8.9	8.9	8.9	8.9	8.9	8.8
2.3-	% Pop: with secondary and tertiary treatment	10.8	13.6	28.0	36.0	41.0	44.2	46.6	54.0	61.4	68.9
2.3.1-	Biodisks w ith anaerobic sludge digestion	1.1	1.4	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9
2.3.2-	Activated sludge w ithout anaerobic sludge digestion	1.4	2.0	4.6	7.6	9.5	10.6	11.5	14.3	17.0	19.8
2.3.3-	Activated sludge w ith anaerobic sludge digestion	1.4	2.0	4.6	7.6	9.5	10.6	11.5	14.3	17.0	19.8
2.3.4-	Laguning, w ith anaerobic pond	1.7	1.9	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5
2.3.5-	Laguning, w ithout anaerobic pond	0.6	0.6	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
2.3.6-	Percolation beds w ith anaerobic sludge digestion	3.6	4.6	8.8	8.8	8.8	8.7	8.7	8.7	8.7	8.7
2.3.7-	Imhoff Tank	0.6	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2.3.8-	Oxidation ponds	0.3	0.4	1.6	2.7	3.4	3.8	4.1	5.1	6.0	7.0
2.3.9-	Other treatment	0.0	0.3	1.6	2.6	3.3	3.7	4.0	5.0	5.9	6.9

Source: INAG, 2005.

Parameters: Bo and MCF - The default IPCC (2000) value for Bo 0.6 kg CH₄/kg BOD was used for wastewater and sludge. Table 7.7 presents MCF factors used for each wastewater treatment system considered.

Table 7.7 - 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
		Wastewater	Sludge	Wastewater	Sludge	e)
				(% of organic load)		
1.1-	% de Pop: with discharge into the ocean, without treatment	0.00	-	-	-	-
1.2-	% de Pop: with discharge into inland waters, without treatment a)	0.30	-	-	-	-
1.3-	% Pop: without sewerage (latrines) b)	0.61	-	-	-	-
1.4-	% Pop: individual treatment (private septic tanks)	0.50	-	-	-	-
2-	% Pop: with greater than preliminary treatment	-	-	-	-	-
2.1-	% Pop: colective septic tanks	0.50	-	-	-	-
2.2-	% Pop: with primary treatment	0.00	0.00	70%	-	30%
2.3-	% Pop: with secondary and tertiary treatment	-	-	-	-	-
2.3.1-	Biodisks w ith anaerobic sludge digestion c)	0.17	0.80	63%	37%	-
2.3.2-	Activated sludge without anaerobic sludge digestion	0.10	0.00	63%	-	37%
2.3.3-	Activated sludge with anaerobic sludge digestion	0.17	0.80	63%	37%	-
2.3.4-	Laguning, w ith anaerobic pond d)	0.20	0.00	100%	-	-
2.3.5-	Laguning, w ithout anaerobic pond	0.00	0.00	63%	-	37%
2.3.6-	Percolation beds w ith anaerobic sludge digestion c)	0.17	0.80	63%	37%	-
2.3.7-	Imhoff Tank	0.80	0.00	100%	-	-
2.3.8-	Oxidation ponds	0.00	0.00	63%	-	37%
2.3.9-	Other treatment	0.00	0.00	63%	-	37%

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).

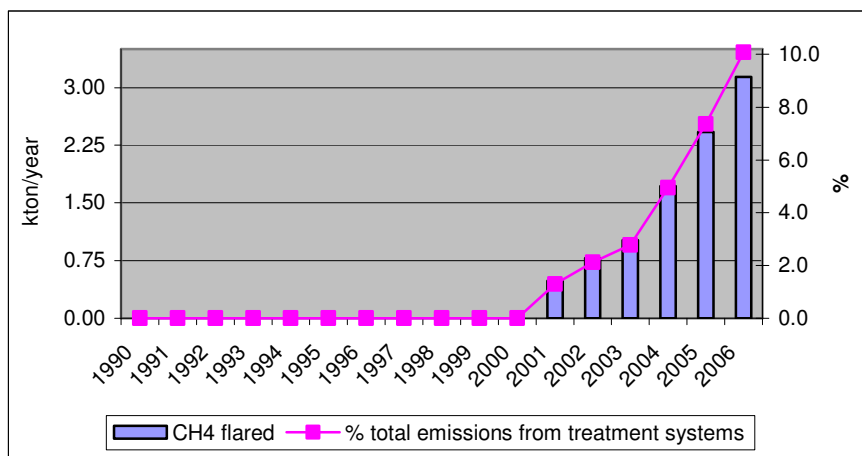
c) Wastewater: expert judgement, assuming a value between "well management" and "aerobic treatment plant, not well managed.

d) Value corresponding to shallow lagoons (majority of systems).

e) Unknown disposal.

Recovery of CH₄: since 2001 it was assumed that new treatment systems such as, biodisks, activated and percolation beds with anaerobic sludge digestion, recover and burn biogas.

Figure 7.12 - Estimated quantities of CH₄ flared

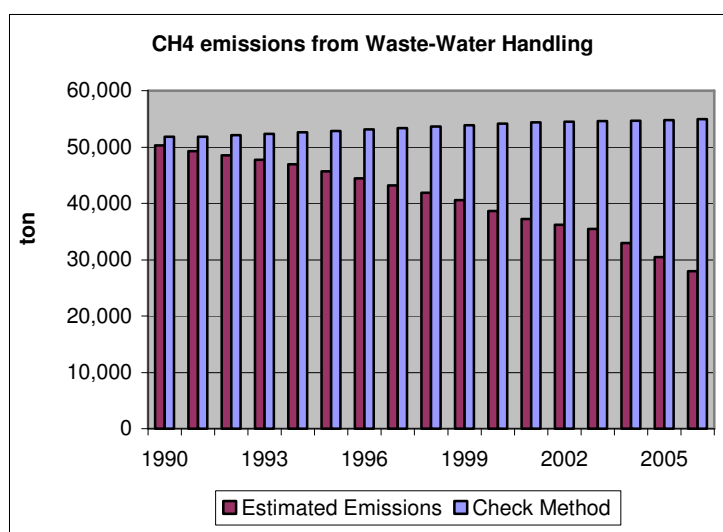


COMPARISON BETWEEN ESTIMATES FOR CH₄ EMISSIONS FROM WASTE-WATER HANDLING AND IPCC “CHECK METHOD”

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 2006 (~ 55 kton) was around 49% higher than estimated emissions (~ 28 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 7.13— Comparison between estimated CH₄ domestic emissions and “check method”



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

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 1990-2006 is contradictory. The “check method” accounts for a 6% increase in the 1990-2006 period, as a result of the population growth, while the national reported emissions are estimated to decrease around 44%.

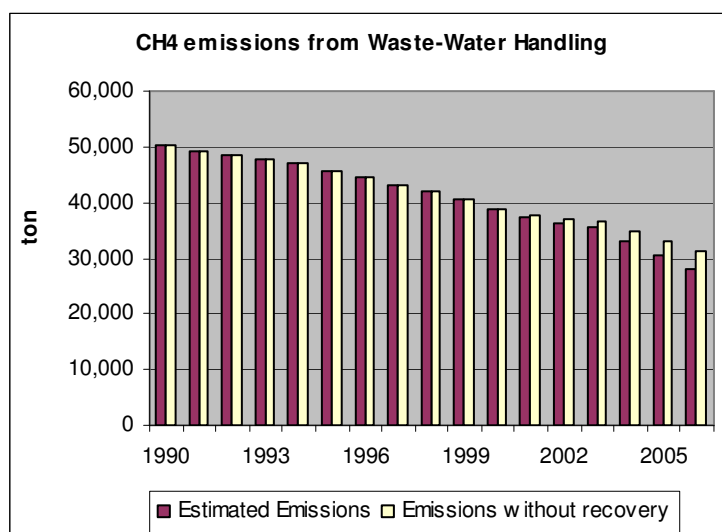
The variables Population (P), Organic load in biochemical oxygen demand per person (D), and the EF (g CH₄/g BOD, default = 0.6) are the same in both approaches. Consequently the differences result from other parameters, i.e., the fraction of BOD that degrades anaerobically, and the consideration of CH₄ 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 7.6), 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 2006 they represented around 10% of emissions generated in treatment systems).

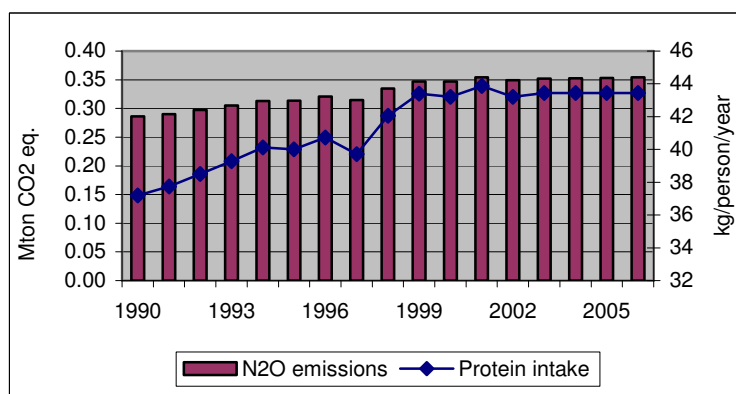
Figure 7.14– Comparison between CH₄ domestic emissions with and without recovery



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 7.15 – N₂O emissions from human sewage and per capita protein intake



Source: Protein intake: FAO database (August 2004); 2003-06 figures: 2002 value.

Methodology

Emissions of N₂O from domestic wastewater were estimated following the proposal of IPCC 1996 Revised Guidelines (IPCC,1997), that considers that the amount of protein consumed by humans determines the quantity of nitrogen contained in sewage.

$$N_2O_{(S)} = \text{Protein} * \text{Frac}_{NPR} * \text{Pop} * \text{EF} * 44/28$$

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 .

Activity data and parameters

Activity data results of protein intake, according to FAO database (Table 7.8), 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 7.8 - 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 (August 2004)	1990	37.2
		1991	37.7
		1992	38.5
		1993	39.3
		1994	40.1
		1995	40.0
		1996	40.7
		1997	39.7
		1998	42.0
		1999	43.4
		2000	43.2
		2001	43.9
		2002	43.2
		2003	43.4
		2004	43.4
		2005	43.4
		2006	43.4
Fraction of nitrogen in protein	IPCC96 default	16%	(constant)
Emission factor	IPCC96 default	0.01 kg N_2O-N/kg N	(constant)

Note: 2003-06 figures: 2002 value.

7.2.C.2 INDUSTRIAL WASTEWATER

CH₄ EMISSIONS FROM INDUSTRIAL WASTEWATER HANDLING

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 CH_4 /yr;

$TOW_{(j)}$ – Total Organic wastewater generated from industrial sector j, expressed in COD, t O_2 /yr;

$WHS_{(l,h)}$ – Part of the total organic wastewater generated in industrial sector j that is handled by system h, fraction;

$MCF_{(h)}$ – Methane Conversion Factor, fraction;

$Rec_{CH_4(l,h)}$ – 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 CH_4 /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.

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 system¹⁶² 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.

¹⁶² The INSAAR systems is a data collected data implemented by INAG

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 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 sectors¹⁶³. 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.

¹⁶³ -Cork Granulation; Aliphatic hydrocarbons; Cyclic hydrocarbons; Kraft pulping; Synthetic fertilizers; Acid sulphite pulping.

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.

Table 7.9 – Pollution Coefficients to estimate Industrial organic wastewater production

Industry	Unit prod (PU)	Discharge (m3/PU)	CBO5 (kg/PU)	CQO (kg/PU)	in.eq. (kg yr/PU)
Slaughter House	ton	6	18	27	0.881
Slaughter House, swine	ton	6	18	42	0.900
Slaughter House, Poultry	ton	9	6	13	0.269
Meat Packing	ton	10	20	30	0.978
Milk processing	m3	1	1	2	0.044
Cheese	m3 milk	8	13	20	0.651
Other dairy products	m3 milk	5	7	10	0.347
Fruit and vegetables conservation	ton	15	15	27	0.734
Tomato juice	ton	100	19	32	0.930
Fruit Juices	ton	9	45	77	2.216
Fish processing and canning	ton	35	18	35	0.856
Olive oil production	ton olives	1	15	45	0.734
Olive oil processing	ton	6	1	1	0.044
Edible oils	ton	3	13	19	0.612
Margarine	ton	25	3	8	0.161
Grains milling and processing	ton	3	5	9	0.220
Sugar processing	ton	8	2	4	0.093
Yeast	ton	120	600	1 080	29.354
Ethanol	m3	17	328	1 192	16.068
Spirits Distillation	m3	8	95	218	4.628
Wine Cellars	ton grapes	2	5	8	0.220
Beer	m3	5	4	9	0.215
Mineral water and similars	ton	8	6	10	0.294
Wool production	ton	44	89	366	4.354
Wool processing	ton	537	87	347	4.256
Synthetic fibres processing	ton	155	155	268	7.583
Artificial fibres processing	ton	42	30	52	1.468
Cotton fibres processing	ton	317	155	268	7.583
Leather industry	ton	85	85	213	4.159
Cork processing	ton	1	2	8	0.073
Cork granulation	m3	1	83	1 104	4.061
Kraft pulping	ton	140	28	158	1.345
Acid sulphite pulping	ton	270	283	1 050	13.845
Kraft paper	ton	14	1	3	0.034
Wafer board and Strand board	ton	1	14	43	0.695
Chorine and alkalis	ton ClNa	28	0	39	1.336
Inorganic acids	ton	100	0	50	1.712
Cyclic Hydrocarbons	ton	190	285	570	13.943
Aliphatic Hydrocarbons	ton	190	285	570	13.943
Synthetic fertilizers	ton	15	15	38	0.734
Pesticides	ton	4	23	30	1.111
Polymers	ton	15	15	45	0.734
Synthetic rubber	ton	15	15	45	0.734
Artificial fibres production	ton	300	150	450	7.339
Polyester fibres production	ton	348	6	16	0.313
Acrylic fibres production	ton	65	50	121	2.422
Paints, varnishes and lacquers	ton	0	1	9	0.029
Pharmaceutical products	employee	0	0	14	0.462
Soaps	ton	4	6	12	0.294
detergents	ton	3	1	2	0.029
Petroleum refining	ton	2	1	2	0.029

For each industrial sector identified, several statistical information sources - although obtained from the same institution - had to be used to establish the full time series from 1990 to 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 restrains existing in certain sectors.

For the construction of the time series the following methodology was used:

- Identification of the industrial sectors witch represented 95 per cent of the total wastewater CH₄ emissions in the Initial Report. From a total of 51 industrial sectors 15 represent 95 per cent 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 per cent 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 7.10 and Table 7.11 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 2006, 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 information¹⁶⁴. The checking of the time series was based on graph plotting of the data, and basically the aim was to detected 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.

¹⁶⁴ 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 7.10 - Sources of Information used to define the time-series of industrial production (1/2)

Industry	IAIT CAE rev1	IAPI PRODCOM	Infoline	Note
Slaughter House			1990-2005	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2005	
Slaughter House, Poultry			1990-2005	Broilers, Turkeys, ducks, quails, ostrich, guinea-fowl, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200	-	
Milk processing	3112		1994-2004	
Cheese	3112	15510	-	
Other dairy products	3112		1994-2005	Cream, yogurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2004	
Tomato juice			1994-2004	
Fruit Juices	3131+3132		1994-2004	
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			1993-2004	
Ethanol	313110	159101070; 1592011	-	
Spirits Distillation	3131+3132	1591010-159101070+1592012	-	
Wine Cellars	3131+3132	15930; 15950	2001-2003	
Beer	3133	1596010	-	
Mineral water and similars			1993-2004	

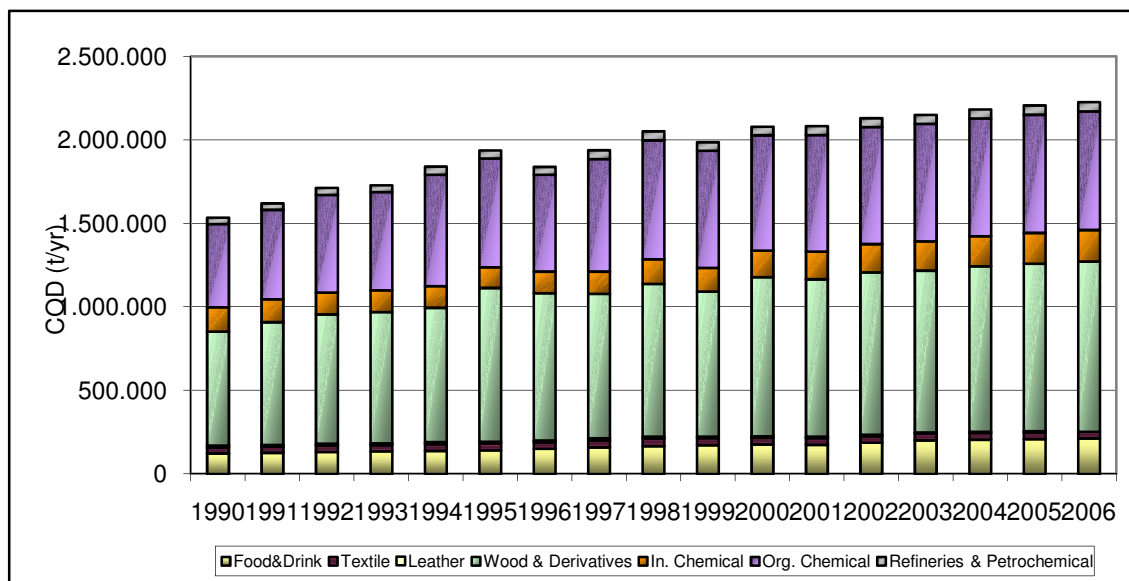
Table 7.11 - Sources of Information used to define the time-series of industrial production (2/2)

Industry	IAIT CAE rev1	IAPI PRODCOM	Infoline	Note
Wool production		171002021	-	
Wool processing		171002027; 1710042; 1710053	-	
Synthetic fibres processing	321130	171003031; 171003039; 1710052 31/32/33/39/91/92/93 /99; 1710055	171003039+17 1005231/32/33/ 39/91/92/93/99 +1710055	
Artificial fibres processing	321130	171003050; 1710054/ 55	-	
Cotton fibres processing	321130	1710043; 171004553; 171004555; 171004557; 1720020; 173001023	-	
Leather industry		19101; 19102	-	
Cork processing		2010	-	AD is cork consumption in all industrial activities
Cork granulation		2052213; 2052214	-	
Kraft pulping			-	LPS Data
Acid sulphite pulping			-	LPS Data
Kraft paper	3412	2112022; 2112023	-	
Wafer board and Strand board	33 (code 15460)	20202	-	
Choline and alkalis		241301111; 2413015; 2413022	-	
Inorganic acids		2413014-241301453- 241301475- 241301477	-	
Cyclic Hydrocarbons		2414312; 2414314	-	
Aliphatic Hydrocarbons		2414311	-	
Synthetic fertilizers		2415	-	Original units is kg N, kg P ₂ O ₅ and K ₂ O 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			1999-2004	
Soaps		2451131	-	
detergents		2451120/32	-	
Petroleum refining			-	Energy Balance (DGGE): 1990-2004

It was assumed that there was no methane recovery for all Industrial Wastewater Handling Systems, i.e. Rec_{CH_4} is zero for all sectors and wastewater handling systems.

Total wastewater load aggregated per industrial group is presented in Figure 7.16 below, from where it is evident the continuous growth of discharge from 1990 to 2005, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry.

Figure 7.16 - Industrial Wastewater load, expressed in COD, from major groups of industrial activity (1990-2006)



Emission Factors

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*¹⁶⁵ and a *Specific Plan of Elaboration*¹⁶⁶. 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;

¹⁶⁵ Caracterização da Situação Ambiental, in the original Portuguese nomenclature.

¹⁶⁶ Plano Específico de Adaptação, in the original Portuguese nomenclature.

- 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;
- 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 2004.

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 per cent.

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).

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 7.12 - 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 per cent in 1990 to 13 per cent 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 per cent in 1990 to 14 per cent in 2004.

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 possible¹⁶⁷, the comparison of the PC of Cartaxo et al (1985) (named CS) were compared with the equivalent IPCC in the next table¹⁶⁸:

¹⁶⁷ The level of detail of the IPCC Pollutant Coefficients is not so detailed as the CS data set.

¹⁶⁸ 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 7.13 – 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	-
Choline 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	employe	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 7.17 - Comparison between COD estimates using CS PC and IPCC defaults.

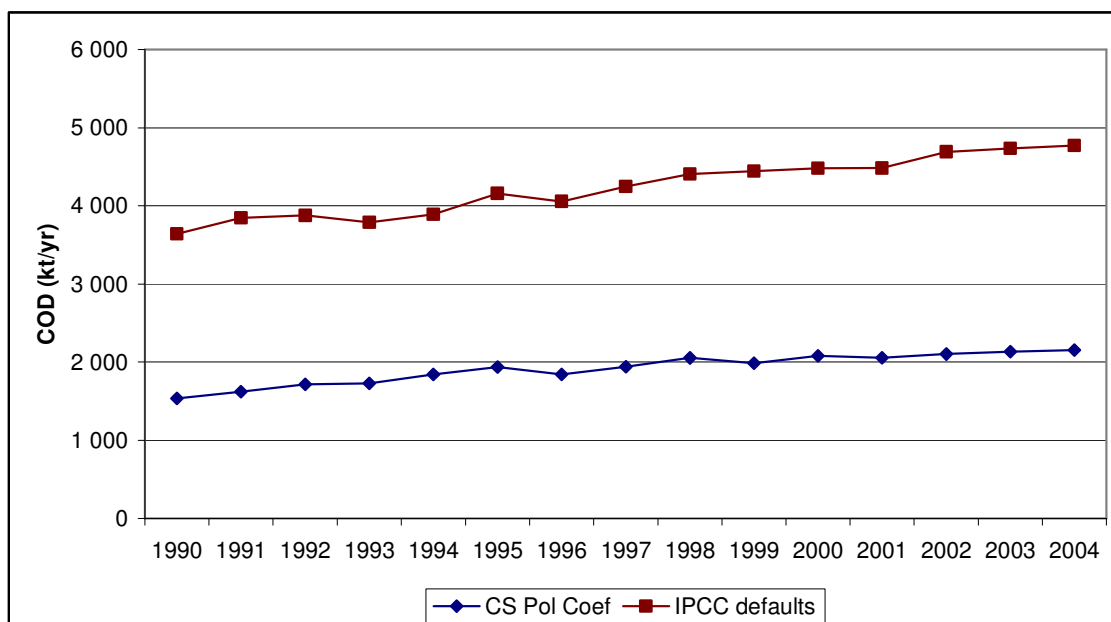
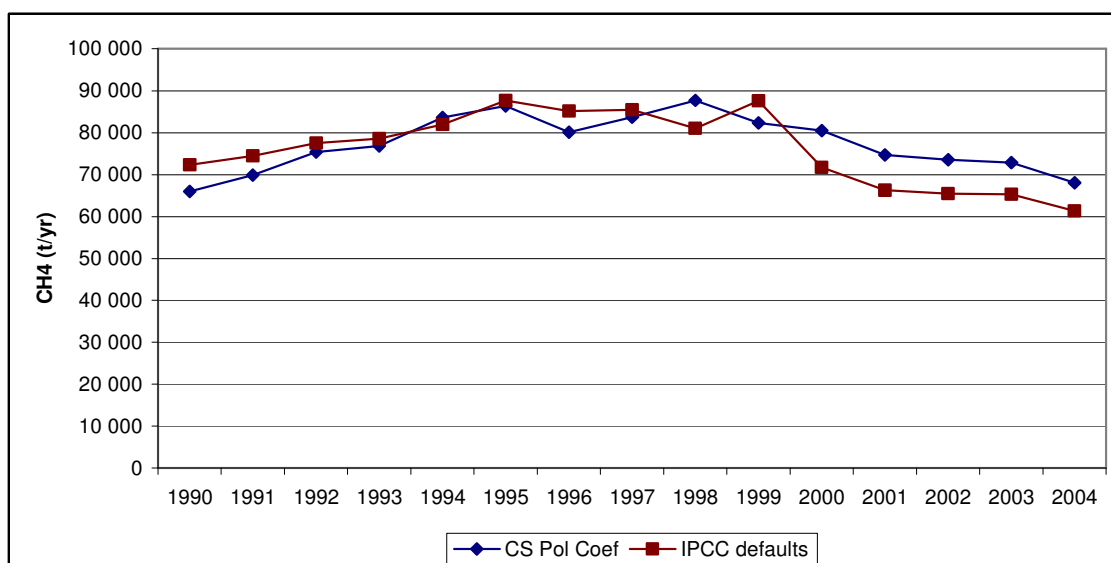


Figure 7.18 - Comparison between CH₄ emission estimates using CS PC and IPCC defaults.



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.

Recalculations

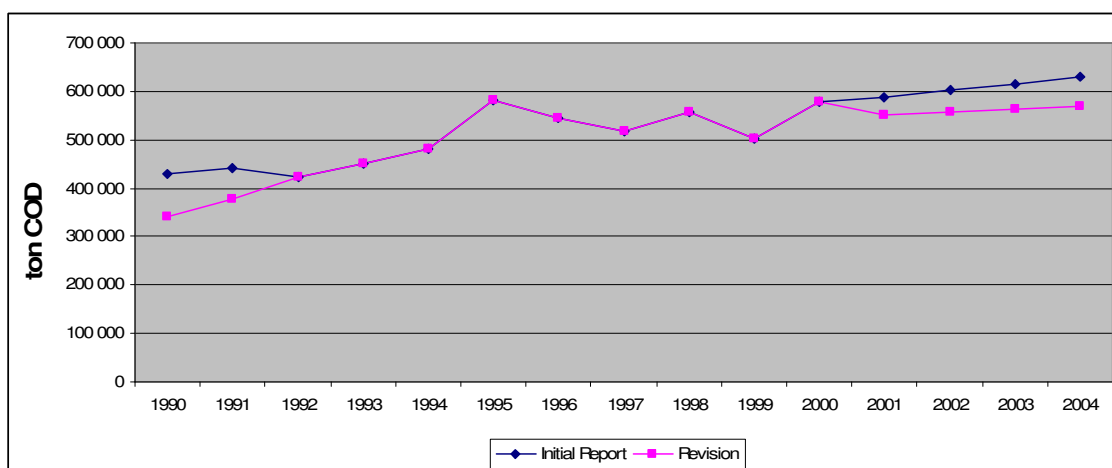
Substantial changes have occurred in this source category, following the recommendations made during the in-country review of submission 2006 of UNFCCC and IIR under the Kyoto Protocol, that were done in 2007. The following description summarizes the recalculations made.

Following the consultation in late 2007 with Leonor Cartaxo, the lead author of the study on Portuguese industrial pollution loads (please see **Erro! A origem da referência não foi encontrada.**), and after careful revision of the industrial initial data, some changes were made to the activity data of specific industrial sectors. The most important changes occurred in industrial sectors: Cork processing and Cotton fibres processing. Due to an error in the Cork procession activity data compilation, the previous production values were overestimated. In the Cotton fibres processing sector, previously COD coefficient were applied to the total fibre and total fabric produced, but according tp Leonor Cartaxo it was realized that the coefficient should only be applied to the fabric because this is the product that receives the most printing and ink application.

In the review of the time series we adopted the following methodology:

- Identification of the industrial sectors which represent 95 per cent of the total wastewater CH₄ emissions in the Initial Report. From a total of 51 industrial sectors 15 represent 95 per cent 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 per cent 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 made. Again extrapolations of activity data were made when required and feasible.

Figure 7.19 - Comparison between COD estimated in the Initial Report and the revised values – Total COD generated.



This graphic represents the comparison between the total industrial sector wastewater COD generated in the Initial Report and the revision made after the in-country review. It is possible to see that the revision of activity data represented a decrease of COD generated both in 1990 and 2004. For the period 1990-1991 the Initial Report had a soft decreasing trend in industrial wastewater COD generated. As a result of the activity data revision, the trend, for the same time period, is now increasing. For the 1992-2004 time period the two series maintain the same trend. The difference between time series in this graphic is mostly a result of the production data revision on the Cork processing and Cotton fibres processing industries.

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.

7.2.C.3 N₂O EMISSIONS FROM INDUSTRIAL WASTEWATER HANDLING

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;

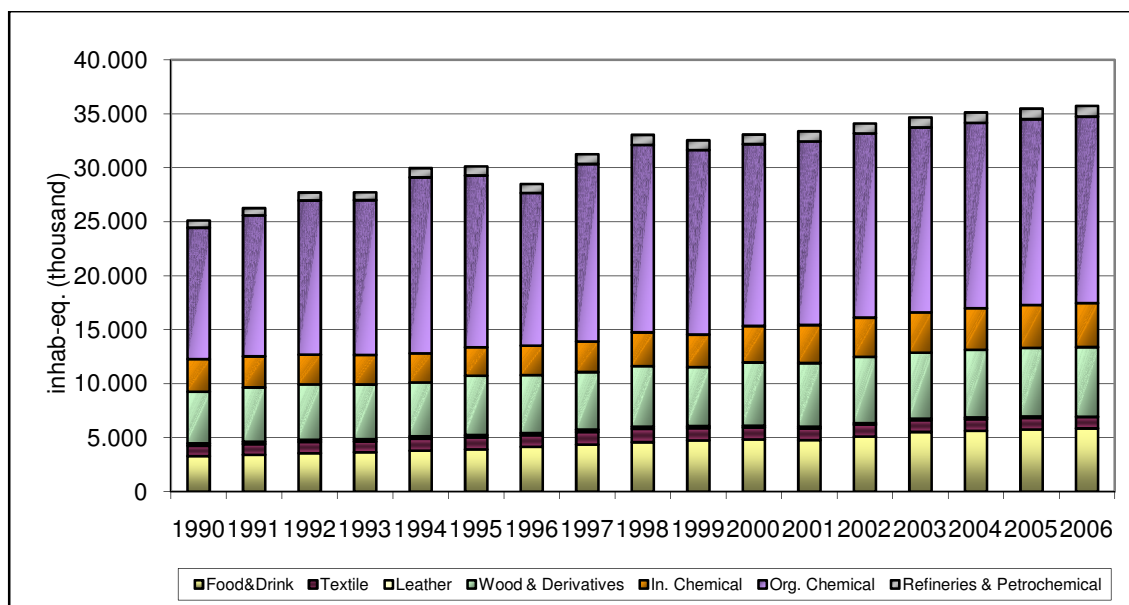
$TLH_{(j)}$ – Total Wastewater Load generated from industrial sector j, expressed in inhabitants-equivalent;

EF_{N_2O} - Emission factor, kg N₂O/inhab-eq/yr.

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 7.20.

Figure 7.20 - Industrial Wastewater load, expressed in inhabitants-equivalent, from major groups of industrial activity (1990-2006)



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.

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.

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.

7.2.D 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.

7.2.D.1 CO2 EMISSIONS

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):

$$\text{CO2 emissions (Gg/yr)} = \sum_i (IW_i * CCW_i * FCF_i * EF_i * 44 / 12)$$

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;

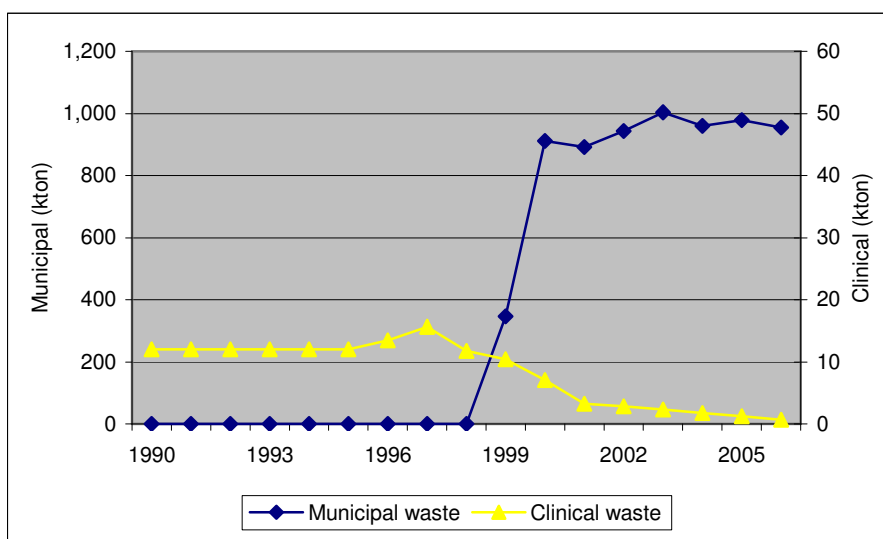
FCF_i - Fraction of fossil carbon in waste of type i;

EF_i - Burn out efficiency of combustion of incinerators for waste of type i (fraction).

ACTIVITY DATA AND PARAMETERS

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 7.21 – Quantities of municipal and clinical wastes incinerated (1990-2006)



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, were 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 7.14 - 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)	

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 7.15– 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

7.2.D.2 NON-CO2 EMISSIONS

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)

ACTIVITY DATA AND PARAMETERS

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 7.16 - Emissions factors of GHG and precursors gases from incineration of MSW

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH ₄	g/GJ	6.500	CORINAIR 94
N ₂ O	kg/ton MSW	0.100	Corinair 3rd version. Activity 090201. No 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 7.17 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: until 2004

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH ₄	g/GJ	6.500	CORINAIR 94
N ₂ O	kg/ton	0.100	Corinair 3rd version. Activity 090201. No NOx abatement
SO _x	kg/ton	1.090	AP-42 Uncontrolled
NO _x	kg/ton	1.780	AP-42 Uncontrolled
COVNM	kg/ton CW	7.400	Corinair 3rd version. Activity 090202. Particle abatement
CO	kg/ton	1.480	AP-42 Uncontrolled

Table 7.18 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: after 2005

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.82	PROET study
CH ₄	g/GJ	6.5	CORINAIR 94
N ₂ O	kg/ton	0.1	Corinair 3rd version. Activity 090201. No NOx abatement
SO _x	kg/ton	0.357	AP-42 Control level: Dry Sorbent Injection/C injection/Fabric Filter
NO _x	kg/ton	1.78	AP-42 Uncontrolled
COVNM	kg/ton CW	7.4	Corinair 3rd version. Activity 090202. Particle abatement
CO	kg/ton	1.48	AP-42 Uncontrolled

7.3 Uncertainty Assessment

Solid Waste Disposal on Land

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.

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 constant¹⁶⁹. An overall error of 62 %, for managed systems and 86 % for unmanaged systems, was therefore obtained and used for both urban and industrial wastes.

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 per cent for human population and 30 per cent for BOD per capita, a final 30.4 per cent 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 (B_o), for which the GPG default of 30 per cent was used, and the error determination in the fraction of water treated anaerobically. For urban water

¹⁶⁹ The uncertainty for this variable affects nevertheless when emissions occur and not how much and affects emission estimates exponentially.

the uncertainty in this last fraction was estimated as 22 per cent, considering the percentage of individual septic tanks and the lack of knowledge of in which conditions they operate.

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 per cent, for the dairy industry, up to 100 per cent;

- the uncertainty of production data is 20 per cent if data was obtained from National Statistics and 50 per cent if was interpolated.

The uncertainty considering all industrial activities, according to their production, varied between 22 and 24 per cent, 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 per cent according to the GP;

- the error of the allocation of each specific treatment system, established from the per cent of unknown situations, adds 20 per cent to the error for the known cases;

- the uncertainty in MCF for each specific treatment system, set from the GP, and varying from 10 per cent for Secondary Treatment, well managed, to 50 per cent for the no treatment situation.

Finally the error was determined for each industry and propagated accordingly. The final uncertainty varies in time from 29 per cent to 35 per cent.

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.

7.4 Recalculations

The recalculations made since last submission result mainly from the issues raised during the UNFCCC in-depth review of the IIR (May 2007).

The changes for this sector refer in majority to CH_4 emissions and result basically from:

- the revision of the DOCf value (CRF 6A) from the previous default from the 1996 Revised IPCC Guidelines (0.77) to the reviewed guidance from 2000 IPCC Good Practice Guidance. The new DOCf value considered (0.6) takes into account the presence of lignin C in the industrial waste disposed in SWDS;
- the revision of the background time series and some corrections for the category 6B (industrial).

Other differences refer to a different allocation of the emissions:

- emissions from open burning of industrial solid waste on land that were previously reported in the category 6D, are now reported under category 6.A.3 Solid Waste Disposal on Land – Other;
- emissions from municipal solid waste incineration with energy recovery, that were previously reported under category 6C, have been reallocated to the energy sector (sub-category 1A(a) Public electricity and heat production). Further to this allocation change, some differences occur from 1999 on, as a result of a slight variation for the composition of incinerated MSW. GPG refers that it is good practice to assume that the composition of incinerated MSW is the same as the composition of MSW. As this was not done before, the situation has been corrected in this submission.

Synthesis of changes may be observed in Figure 7.22 and Table 7.19

Figure 7.22 – Differences between 2007 and 2008 submissions (CO₂ equivalent)

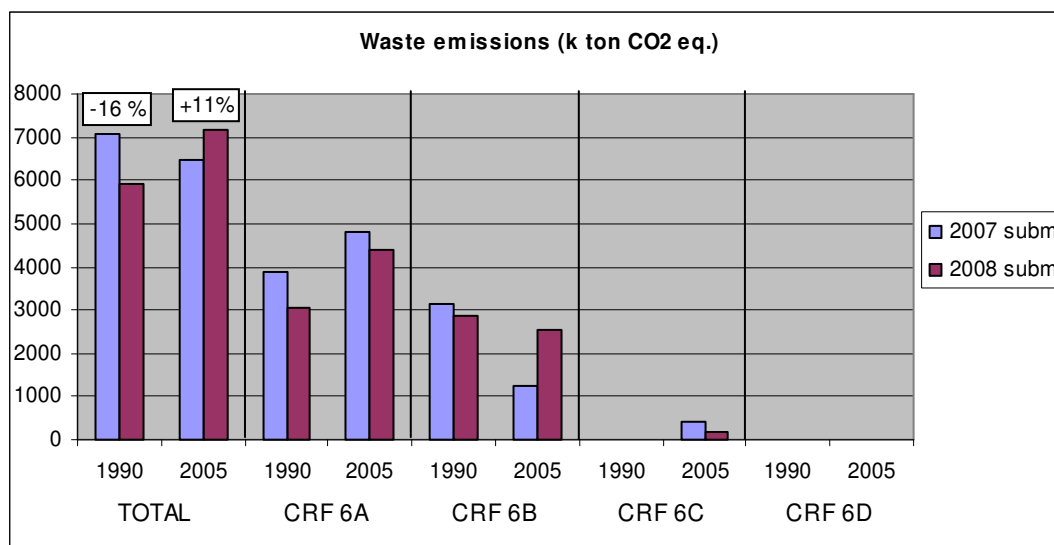


Table 7.19 – Recalculations (differences between 2007 to 2008 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES				CO2			CH4			N2O		
				2007	2008	Diff. (1)	2007	2008 subm.	Difference (1)	2007	2008	Diff. (1)
				subm.	subm.		subm.	subm.		subm.		
				CO2 equivalent (Gg)	(%)	CO2 equivalent (Gg)	(%)	CO2 equivalent (Gg)	(%)			
1990												
6. Waste	10,10	10,10	0,00	6.581,52	5.474,86	-16,81	470,83	442,79	-5,95			
6.A. Solid Waste Disposal on Land	NA	0,02		3.891,80	3.032,60	-22,08						
6.B. Wastew ater Handling				2.689,68	2.442,25	-9,20	469,71	441,67	-5,97			
6.C. Waste Incineration	10,08	10,08	0,00	0,01	0,01	0,00	0,37	0,37	0,00			
6.D. Other	0,02	NA		0,03	NA		0,74	NA				
2005												
6. Waste	383,20	142,97	-62,69	5.469,93	6.402,78	17,05	613,71	604,91	-1,44			
6.A. Solid Waste Disposal on Land	NA	0,06		4.815,06	4.411,72	-8,38						
6.B. Wastew ater Handling				653,77	1.990,01	204,39	581,84	573,07	-1,51			
6.C. Waste Incineration	383,14	142,92	-62,70	1,05	1,05	-0,11	30,40	30,37	-0,11			
6.D. Other	0,06	NA		0,05	NA		1,47	NA				

Notes:(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = $100\% \times [(LS-PS)/PS]$, where LS = Latest submission and PS = Previous submission.

7.5 Further improvements

One of the issues that still needs to be improved in the near future is the better quantification of the amount of CH₄ recovered and flared. Data used presently refer to estimates of CH₄ based on the existence of operating flares in the waste management units, and not on metering of gas recovered and flared as proposed in good practice guidance (IPCC,2000).

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 soon, after the implementation of a new survey system and data base by the National Water Institute.

CH₄ emissions from CH₄ recovery for the category Industrial Waste-Water Handling should be quantified and reported in the future.

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.

Annex WASTE: Background Data Tables

Table W-1 – National population, per capita generation rates, and urban waste production: 1960-2006

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	409.1	100	4,254.6	0.0	3,074.4	243.3	954.6

Notes:
Selectively collected wastes (deviated to recycling) excluded.

Sources:INE: APA estimates: Quercus Study

Table W - 2 – Fermentable industrial waste disposal: 1960-2006

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			

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 W - 3 – Quantities of CH₄ recovered and combusted (Urban waste): 1990-2006

	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	0.46	4.28	0.01	0.09	3
2001	0.82	16.00	0.02	0.34	12
2002	0.76	18.08	0.02	0.38	12
2003	0.78	19.42	0.02	0.41	13
2004	0.85	20.91	0.02	0.44	13
2005	0.79	22.02	0.02	0.46	14
2006	0.86	29.53	0.02	0.62	18

Source: APA estimates

Table W - 4 – Quantities of CH₄ recovered and combusted (Fermentable industrial waste): 1990-2006

	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	0.28	1.85	0.01	0.04	3
2001	0.62	9.02	0.01	0.19	11
2002	0.64	10.60	0.01	0.22	12
2003	0.64	10.87	0.01	0.23	12
2004	0.68	11.14	0.01	0.23	13
2005	0.63	11.31	0.01	0.24	13
2006	0.69	16.54	0.01	0.35	19

Source: APA estimates

Table W - 5 – National population and wastewater BOD produced by handling systems: 1990-2006

	Population (1000 inhabitants)	BOD ₅ 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	68	15	39	86	18
2001	10,356	227	76	17	37	77	21
2002	10,375	227	80	18	35	71	22
2003	10,393	228	84	19	34	67	24
2004	10,412	228	95	21	29	55	28
2005	10,430	228	106	23	25	43	32
2006	10,463	229	117	26	20	31	36

Source: APA estimates

Notes:

Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Laguning, without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Laguning, 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 and Percolation beds with anaerobic sludge digestion (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, laguning without anaerobic pond, oxidation ponds and other treatment.

Table W - 6 – Estimated quantities of CH₄ flared from wastewater handling systems: 1990-2006

Year	Sludge treatment systems	
	kton/year	% emissions of total treat.
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	0.00	0.0
2000	0.00	0.0
2001	0.49	1.3
2002	0.78	2.1
2003	1.02	2.8
2004	1.72	4.9
2005	2.42	7.4
2006	3.14	10.1

Source: APA estimates

Table W - 7 – Quantities of waste incinerated: 1990-2006

Year	MSW quantities incinerated	Clinical waste quantities incinerated
	kton	
1990	-	12
1991	-	12
1992	-	12
1993	-	12
1994	-	12
1995	-	12
1996	-	13
1997	-	16
1998	-	12
1999	346	10
2000	911	7
2001	892	3
2002	944	3
2003	1,003	2
2004	960	2
2005	978	1
2006	955	1

Note: Estimates in italics

Sources: APA; DGS

Table W - 7 – Quantities of industrial waste open burned: 1990-2006

Year	Industrial solid waste incinerated
	kton
1990	24
1991	24
1992	25
1993	25
1994	26
1995	27
1996	27
1997	28
1998	28
1999	29
2000	15
2001	27
2002	38
2003	47
2004	47
2005	47
2006	48

Note: Estimates in italics

Sources: APA (include estimates).

Table W - 8 – Comparison between estimates for CH₄ emissions from waste-water handling and IPCC check-method

Year	CH ₄ emissions			National CH ₄ emissions	
	Check method ton	National estimates ton	% difference %	w ithout recovery ton	recovered ton
1990	51,844	50,305	3.0	50,305	0
1991	51,862	49,312	4.9	49,312	0
1992	52,119	48,540	6.9	48,540	0
1993	52,376	47,759	8.8	47,759	0
1994	52,633	46,968	10.8	46,968	0
1995	52,890	45,714	13.6	45,714	0
1996	53,147	44,445	16.4	44,445	0
1997	53,404	43,163	19.2	43,163	0
1998	53,661	41,865	22.0	41,865	0
1999	53,918	40,554	24.8	40,554	0
2000	54,175	38,649	28.7	38,649	0
2001	54,432	37,209	31.6	37,695	486
2002	54,529	36,225	33.6	37,008	783
2003	54,626	35,493	35.0	36,509	1,016
2004	54,723	32,984	39.7	34,700	1,717
2005	54,820	30,465	44.4	32,885	2,420
2006	54,996	27,966	49.1	31,102	3,136
% variation 1990-2006	6.1	-44.4	-	-38.2	-

CHAPTER: 8 RECALCULATIONS AND IMPROVEMENTS

This section presents an overview of the recalculations made in the 2008 submission.

The recalculations made since last submission result mostly from the recommendations issued during the UNFCCC in-depth review of the IIR, that took place in May 2007, and that resulted in the final establishment of the Assigned Amount for the first commitment period.

8.1 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 concern mostly the LULUCF sector, reflecting the inclusion of estimates for the Azores and Madeira Islands in the national total. Other recalculations refer to a revision of forest land area in order to consider young plantations, clear-cuts and damaged (burnt) areas (i.e. temporally unstocked areas). In addition minor differences refer to LUC areas and are related to a revision of the limit detection (1 ha instead of 0.5 ha), an issue that was raised during the in-depth IIR. Differences for the waste sector refer to a reallocation of emissions from urban waste incineration that occurs with energy recovery to the energy sector. Other revisions for energy industries (1A1) refer to the update of activity data for some LPS. Furthermore, as proposed by the ERT, emissions from a previously missing source (military fuel use) were also estimated (1A5), and the values reported in international bunkers were revised in order to get a better consistency between the national bottom-up approach and the top-down Energy Balance data.

Changes in CH₄ emissions estimates are related in majority to the waste sector and result from the revision of the DOC_f value (CRF 6A) and the revision of the background time series and some corrections for the category 6B (industrial), that have been done on the following of the IIR in-depth review. Other recalculations refer to rice cultivation and field burning of crop residues, and were based on information received from the Portuguese Ministry of Agriculture on the destiny of rice residues.

N₂O emissions recalculations are mostly associated with the Agriculture sector (Agriculture Soils), and in essence related to an issue identified by the ERT concerning: the a fraction (20 per cent) of manure stored in anaerobic lagoon that was not considered previously in the inventory, as it was considered to be discharged to the water system, is now added as AD and accounted for indirect emissions. Also, the Nitrogen excretion rates for sheep were revised as a result of discussions during IIR in-depth review.

F-gases recalculations refer to a major revision of the HFCs estimates, that include methodological revisions for Commercial Refrigeration and activity data improvements for Commercial Refrigeration, Industrial Stationary Air-Conditioning Equipments and Metered Dose Inhalers Activity Data.

Table 8.1 – Recalculation difference of CO₂ emissions

GHG SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	kton CO ₂ eq.															
Total National Emissions and Removals	-2.192	-2.163	-2.176	-2.176	-2.144	-2.144	-2.109	-2.109	-2.091	-2.266	-2.313	-2.725	-3.210	-3.684	-6.027	-6.374
1. Energy	92	104	79	73	83	80	107	102	106	26	92	117	87	63	292	810
1.A. Fuel Combustion Activities	92	104	79	73	83	80	107	102	106	26	92	117	87	63	280	773
1.A.1. Energy Industries												27	27	32	255	1.063
1.A.2. Manufacturing Industries and Construction	-3	-3	-1	-2	-1	-1	3	2	2	3	-2	-1	-1	-14	-8	-298
1.A.3. Transport	0	0	0	0	0	0	0	0	0	0	-1	-4	-6	-8	-8	-64
1.A.4. Other Sectors										-56			0	0	0	0
1.A.5. Other	95	106	80	75	84											
1.B. Fugitive Emissions from Fuels														0	13	37
1.B.1. Solid fuel																
1.B.2. Oil and Natural Gas														0	13	37
2. Industrial Processes	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0	-41
2.A. Mineral Products		0					0	0	0	0	0	0	0	0	0	-41
2.B. Chemical Industry												0	0	0	0	0
2.C. Metal Production	0	0	0	1	1	0	0	1	1	1	1	1				0
2.D. Other Production																
2.G. Other																
3. Solvent and Other Product Use												0	0	0	0	0
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	-2.284	-2.267	-2.255	-2.250	-2.227	-2.224	-2.217	-2.211	-2.198	-2.195	-2.187	-2.630	-3.072	-3.501	-6.089	-6.903
5.A. Forest Land	-2.282	-2.265	-2.253	-2.249	-2.225	-2.222	-2.215	-2.209	-2.196	-2.193	-2.186	-2.628	-3.070	-3.499	-6.087	-6.901
5.B. Cropland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.C. Grassland	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
5.E. Settlements	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
5.F. Other Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.G. Other																
6. Waste										-98	-218	-212	-225	-246	-230	-240
6.A. Solid Waste Disposal on Land																
6.B. Wastewater Handling																
6.C. Waste Incineration										-98	-218	-212	-225	-246	-230	-240
6.D. Other																
Memo Items:																
International Bunkers	-263	-400	-371	-607	-765	-789	-932	-889	-902	-403	-470	-808	-895	-478	-362	-911
Multilateral Operations																
CO₂ Emissions from Biomass														355		-78

Table 8.2 - Recalculation difference of CH₄ emissions

GHG SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	kton CO ₂ eq.															
Total National Emissions and Removals	-1.123	-1.116	-983	-1.024	-1.071	-1.119	-1.130	-1.165	-1.211	-1.261	-880	-450	-433	-394	-355	1.090
1. Energy	0	-1	-1	-1	-1	-1	-1	-1	0	0	2	4	4	5	7	8
1.A. Fuel Combustion Activities	0	-1	-1	-1	-1	-1	-1	-1	0	0	2	4	4	5	7	8
1.A.1. Energy Industries												0	0	0	0	0
1.A.2. Manufacturing Industries and Construction													0	-1	0	1
1.A.3. Transport	0	-1	-1	-1	-1	-1	-1	-1	0	0	2	4	4	6	7	7
1.A.4. Other Sectors										0			0	0	0	0
1.A.5. Other	0	0	0	0	0											
1.B. Fugitive Emissions from Fuels					0									0	0	0
1.B.1. Solid fuel																
1.B.2. Oil and Natural Gas														0	0	0
2. Industrial Processes												0	0	0	0	0
2.A. Mineral Products																
2.B. Chemical Industry												0	0	0	0	0
2.C. Metal Production																
2.D. Other Production																
2.G. Other																
3. Solvent and Other Product Use																
4. Agriculture	-16	-15	-9	-5	-10	-8	31	53	70	85	97	117	134	153	167	149
4.A. Enteric Fermentation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
4.B. Manure Management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.C. Rice Cultivation	-29	-29	-18	-11	-21	-19	18	41	59	76	89	110	128	148	163	143
4.D. Agricultural Soils ⁽²⁾																
4.E. Prescribed Burning of Savannas																
4.F. Field Burning of Agricultural Res.	13	13	9	6	11	10	13	12	10	9	7	7	6	5	4	3
4.G. Other																
5. Land Use, Land-Use Change and Forestry (n	0	1	1	0	2	0	0	0	1	0	0	0	0	3	1	1
5.A. Forest Land	0	1	1	0	2	0	0	0	1	0	0	0	0	3	1	1
5.B. Cropland																
5.C. Grassland																
5.D. Wetlands																
5.E. Settlements																
5.F. Other Land																
5.G. Other																
6. Waste	-1.107	-1.102	-975	-1.018	-1.063	-1.110	-1.160	-1.217	-1.282	-1.346	-979	-571	-570	-555	-530	933
6.A. Solid Waste Disposal on Land	-859	-899	-939	-981	-1.024	-1.069	-1.121	-1.177	-1.244	-1.312	-944	-506	-488	-458	-421	-403
6.B. Wastewater Handling	-247	-203	-35	-37	-38	-41	-39	-40	-38	-35	-34	-66	-82	-98	-109	1.336
6.C. Waste Incineration															0	0
6.D. Other																
Mem o Items:																
International Bunkers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Multilateral Operations																
CO ₂ Emissions from Biomass																

Table 8.3 - Recalculation difference of N2O emissions

GHG SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	kton CO2 eq.															
Total National Emissions and Removals	222	204	211	198	187	123	121	117	107	104	88	83	75	70	75	-349
1. Energy	13	13	12	11	10	7	4	-1	-12	-15	-30	-32	-36	-37	-35	-29
1.A. Fuel Combustion Activities	13	13	12	11	10	7	4	-1	-12	-15	-30	-32	-36	-37	-35	-29
1.A.1. Energy Industries												0	0	0	2	8
1.A.2. Manufacturing Industries and Construction							0	0	0	0	0	0	0	1	0	-1
1.A.3. Transport	12	12	11	10	9	7	4	-1	-13	-16	-30	-33	-37	-39	-38	-37
1.A.4. Other Sectors										0			0	0	0	0
1.A.5. Other	1	1	1	1	1											
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
2.A. Mineral Products																
2.B. Chemical Industry												0	0	0	0	0
2.C. Metal Production																
2.D. Other Production																
2.G. Other																
3. Solvent and Other Product Use																
4. Agriculture	237	217	206	194	183	123	123	124	125	125	124	122	120	117	120	-311
4.A. Enteric Fermentation																
4.B. Manure Management	12	12	12	12	12	12	13	12	13	13	13	13	12	12	12	12
4.C. Rice Cultivation																
4.D. Agricultural Soils ⁽²⁾	221	201	191	180	167	107	106	107	109	109	109	108	106	104	107	-324
4.E. Prescribed Burning of Savannas																
4.F. Field Burning of Agricultural Res.	4	4	3	2	4	4	4	4	3	3	2	2	2	1	1	0
4.G. Other																
5. Land Use, Land-Use Change and Forestry (n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.A. Forest Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.B. Cropland																
5.C. Grassland																
5.D. Wetlands																
5.E. Settlements																
5.F. Other Land																
5.G. Other																
6. Waste	-28	-26	-7	-7	-7	-7	-7	-7	-7	-6	-6	-7	-8	-10	-10	-9
6.A. Solid Waste Disposal on Land																
6.B. Wastewater Handling	-28	-26	-7	-7	-7	-7	-7	-7	-7	-6	-6	-7	-8	-10	-10	-9
6.C. Waste Incineration															0	0
6.D. Other																
Mem o items:																
International Bunkers	-2	-3	-3	-5	-6	-6	-8	-7	-7	-3	-4	-7	-7	-4	-3	-8
Multilateral Operations																
CO ₂ Emissions from Biomass																

Table 8.4 - Recalculation difference of F-gases emissions

GHG SOURCE AND SINK CATEGORIES	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	kton CO2 eq.										
Total Actual Emissions	44	56	75	96	117	169	223	291	323	354	398
HFCs	43	55	74	94	115	166	221	289	320	349	395
PFCs											
SF6	1	1	1	2	3	3	1	2	3	5	3

Figure – Recalculation of total CO₂, CH₄ and N₂O emissions (LULUCFs excl.)

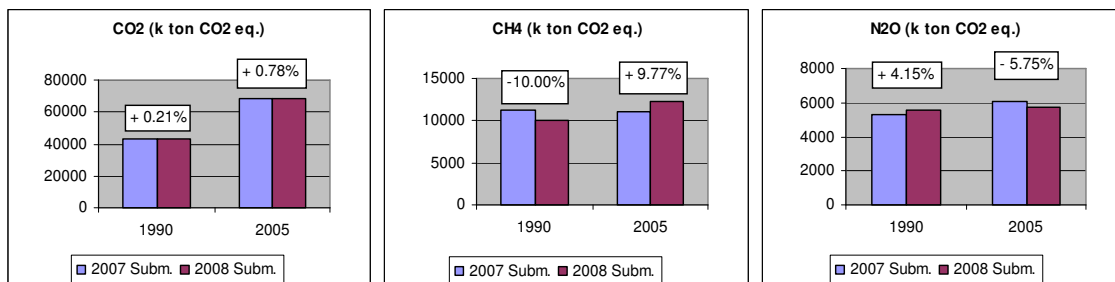


Table 8.5 – Recalculation of total CO₂, CH₄ and N₂O emissions (LULUCFs excl.)

Year	CO ₂			CH ₄			N ₂ O		
	2007 Subm. (kton CO ₂ eq.)	2008 Subm. (kton CO ₂ eq.)	Difference (%)	2007 Subm. (kton CO ₂ eq.)	2008 Subm. (kton CO ₂ eq.)	Difference (%)	2007 Subm. (kton CO ₂ eq.)	2008 Subm. (kton CO ₂ eq.)	Difference (%)
1990	43.352	43.444	0,21	11.227	10.103	-10,00	5.340	5.561	4,15
1991	45.167	45.271	-0,03	11.491	10.374	-0,03	5.376	5.580	-0,03
1992	49.309	49.389	-0,03	11.481	10.497	-0,03	5.355	5.566	-0,03
1993	47.908	47.982	-0,04	11.533	10.509	-0,04	5.268	5.466	-0,04
1994	49.117	49.200	-0,04	12.061	10.988	-0,04	5.542	5.729	-0,04
1995	53.077	53.157	-0,10	12.353	11.234	-0,10	5.682	5.806	-0,10
1996	50.179	50.286	-0,16	12.493	11.362	-0,16	5.993	6.114	-0,16
1997	53.429	53.532	-0,21	12.737	11.572	-0,21	6.002	6.119	-0,21
1998	58.109	58.216	-0,21	13.247	12.035	-0,21	5.756	5.863	-0,21
1999	64.766	64.695	-0,20	13.537	12.275	-0,20	6.183	6.286	-0,20
2000	63.538	63.412	-0,35	12.406	11.525	-0,35	6.171	6.258	-0,35
2001	64.789	64.694	-0,35	12.308	11.858	-0,35	6.192	6.276	-0,35
2002	68.993	68.855	-0,37	12.602	12.170	-0,37	6.278	6.354	-0,37
2003	64.342	64.159	-0,40	12.610	12.213	-0,40	5.705	5.774	-0,40
2004	66.146	66.208	0,65	12.290	11.934	0,65	5.879	5.954	0,65
2005	67.918	68.447	0,78	11.147	12.236	9,77	6.072	5.723	-5,75

8.2 Implications in emissions trends

The combined effect of the reduction in the base year (1990: -1.4 per cent) with the increase in 2005: +1.9 per cent, resulted in an accentuation of the growing trend from 42.8. per cent (2007 submission without LULUCFs) to 47.5 per cent (2008 submission without LULUCFs) .

If the LULUCF sector is included, recalculations are more significant, reflecting the revisions and new estimates in this sector. The comparison of 2008 GHG emissions considering LULUCF net emissions with the previous 2007 submission, indicates a difference in 1990 total emissions of -4.9% and -9.4% for 2005.

Table 8.6 – Recalculation of total emissions trends (LULUCFs excl.)

Year	2007 Submission (kton CO ₂ eq.)	2008 Submission (kton CO ₂ eq.)	Difference (%)
1990	59918	59109	-1,4
1991	62034	61225	-1,3
1992	66146	65452	-1,0
1993	64709	63957	-1,2
1994	66721	65917	-1,2
1995	71127	70255	-1,2
1996	68689	67843	-1,2
1997	72208	71337	-1,2
1998	77173	76270	-1,2
1999	84586	83475	-1,3
2000	82260	81512	-0,9
2001	83469	83230	-0,3
2002	88089	87885	-0,2
2003	82952	82765	-0,2
2004	84659	84793	0,2
2005	85538	87205	1,9

8.3 Future improvements

Future improvements are defined annually under the Methodological Development Plan (PDM) which is settled each year in the context of the National Inventory System (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 PDM 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.

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 Comission	Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
CELPA	Portuguese Paper Industry Association	Associação da Indústria Papeleira
CFC	Chlorofluorocarbons	Clorofluorcarbonetos
CH4	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 Cálcio0
CO	Carbon Monoxide	Monóxido de Carbono
CO2	Carbon Dioxide	Dióxido de Carbono ou anidrido carbónico
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

DGGE (ex DGE)	General Directorate for Geology and Energy	Direcção Geral de Geologia e Energia
DGE (ex DGI)	Enterprises General Directorate	Direcção Geral da das Empresas
DGRF	General Directorate for Forestry Resources	Direcção Geral dos Recursos Florestais
DGTT	General Directorate of Terrestrial Transportation	Direcção Geral dos Transportes Terrestres
DGV	National Entity responsible for road traffic	Direcção Geral de Viação
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	Hydrochlorofluorcarbons	-

HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias
HFC	Hydrofluorcarbons	-
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
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-UNL	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
NAVE	National Entity responsible for air traffic	Navegação Aérea
NCV	Net Calorific Value	-
NFI	National Forestry Inventories	Inventário Florestal Nacional
NFR	New Format Reporting	-
NH3	Ammoniac	Amoníaco
NMVOC	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NOx	Nitrogen Oxides (NO + NO2)	Óxidos de Azoto (NO+NO2)
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 Hydrocarbons	-
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	Software criado para a estimativa de emissões atmosféricas a partir de

	storage tanks (USEPA, September 27, 2001)	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 2008 Portuguese inventory estimates (1990-2006), the determination of key categories was conducted using the Tier 2 including LULUCF.

Tier 2 - Level assessment

The level assessment is based on the quantified uncertainties presented in the introduction, according to the equation:

Level Assessment with Uncertainty= Tier 1 Level Assessment • Relative category Uncertainty

$$LU_{x,t} = L_{x,t} \cdot U_{x,t}$$

Where,

$LU_{x,t}$ = Level Assessment with Uncertainty

$L_{x,t}$ = calculated as in Tier 1 equation

$U_{x,t}$ = relative category uncertainty in the year t

Tier 2 - Trend assessment

The trend assessment is based according to the equation:

Trend Assessment with Uncertainty= Tier 1 Trend Assessment • Relative category Uncertainty

$$TU_{x,t} = T_{x,t} \bullet U_{x,t}$$

Where,

$TU_{x,t}$ = Trend Assessment with Uncertainty

$T_{x,t}$ = calculated as in Tier 1 equation

$U_{x,t}$ = relative category uncertainty in the year t

The key categories are those that add up to 90% of the total value of either $LU_{x,t}$ and $TU_{x,t}$.

A.3 Presentation of results

Key category analysis can be very influenced by the definitions of source categories (extent of the split). If a large category is broken into many subcategories, then these subcategories may not have a significant contribution to the total inventory to be considered as a key source. On the opposite, several non-key sources categories may become key source categories if aggregated into a unique source category.

In a general way, the source and removal categories have been split into (sub) categories that have been estimated using the same methodology and emission factors.

Following the recommendations from the ERT report, LULUCF and Agricultural sectors have been disaggregated according to the IPCC GPG (IPCC 2000 and 2003).

The analysis was based on the application of Tier 2 method with the LULUCF sector, and resulted in the identification of 49 key categories.

Table A-1 presents a summary of identified key categories for 1990-2006 using Tier 2 analysis including LULUCF, and the criteria used (level and trend) in the identification.

Three other tables are presented, Tables A-2.1 to A-2.3 for 1990 and 2006 inventory year's level assessment and trend assessment for 1990-2006.

Table A-1 – Portuguese key categories (1990-2006) based on Tier 2 with LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source category	Criteria for identification	Comments on level assessment	2006 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	18754
1A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level Trend	All years	1250
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1999, 2004, 2005, 2006	4226
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level	All years	3602
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level	1990, 1991, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	3581
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level	All years	3044
1A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2005	2784
6 A Municipal SWDL	SWD Disposal on Land	CH ₄	✓	Level Trend	All years	2747
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level Trend	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	2005
4 D a AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1989
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	1990, 1991, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	1903
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level	All years	1762
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	All years	1476
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level Trend	All years	1249
4 D b AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	✓	Level Trend	All years	1246
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1169
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	✓	Level Trend	All years	1108
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	All years	876
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2000, 2001, 2002, 2003, 2004, 2005, 2006	800
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	699
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	✓	Level Trend	All years	590
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	587
1A 3 b Road Transportation	All Fuels	N ₂ O	✓	Trend		579
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	558
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	1990, 1991	539
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	All years	478
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level Trend	All years	436
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level	1990, 2002, 2003, 2004, 2005, 2006	360
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998, 2003	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	222
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	176
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO ₂	✓	Level Trend	All years	149
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend	1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	101
3 D OTHER	Other Use of Chemicals	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2003, 2004, 2005	80
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	70
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	✓	Level Trend	1991, 2003, 2005	67
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend	All years	66
1A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level Trend	All years	58
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	48
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	33
1A 2 f Other	Biomass	N ₂ O	✓	Level	All years	25
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	✓	Level	1992, 1993, 2004, 2006	18
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		15
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level Trend	All years	12
1A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend	1992	8
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	-503
Sub-total with LULUCF		All gases				67264
% of total with LULUCF		All gases				82.1
TOTAL EMISSIONS WITH LULUCF		All gases				81937

Table A-2.1 and 2.2 – Tier 2 Level assessment with LULUCF: 1990 and 2006

Tier 2 Level Assessment (1990)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Combined	Level	Share	Cumulative
			Estimate (kton CO ₂ eq.)	Estimate (kton CO ₂ eq.)			Uncert. %	Level* Uncert. %	Total
			1990	1990					
4 Da AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	2110	2110	0.03	282.18	9.59	0.25	0.25
6 A3 Industrial SWDL	Industrial Waste Disposal	CH ₄	1599	1599	0.03	110.56	2.85	0.08	0.33
6 B1 Industrial Wastewater	Wastewater	N ₂ O	156	156	0.00	1000.28	2.51	0.07	0.40
4 B MANUREMANAGEMENT	Animal Excretion	CH ₄	1176	1176	0.02	81.96	1.55	0.04	0.44
1 A4 c Agriculture/ Forestry/ Fishing	Liquid Fuels	CO ₂	1660	1660	0.03	50.05	1.34	0.04	0.47
4 Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	1326	1326	0.02	60.69	1.30	0.03	0.51
6 A Municipal SWDL	SWD/Disposal on Land	CH ₄	1433	1433	0.02	53.83	1.24	0.03	0.54
1 A4 b Residential	Biomass	N ₂ O	73	73	0.00	1001.80	1.17	0.03	0.57
6 B1 Industrial Wastewater	Wastewater	CH ₄	1386	1386	0.02	44.23	0.99	0.03	0.60
4 B MANUREMANAGEMENT	Animal Excretion	N ₂ O	575	575	0.01	104.64	0.97	0.03	0.62
1 A4 b Residential	Biomass	CH ₄	343	343	0.01	161.55	0.89	0.02	0.65
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CH ₄	86	86	0.00	634.54	0.88	0.02	0.67
6 B2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	1056	0.02	48.28	0.82	0.02	0.69
5 E2 Land converted to Settlements	Emissions/Removals	CO ₂	1108	1108	0.02	44.14	0.79	0.02	0.71
1 A1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7659	7659	0.12	5.10	0.63	0.02	0.73
1 A1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	36	0.00	1000.00	0.58	0.02	0.75
4 A ENTERIC FERMENTATION	Population size	CH ₄	2622	2622	0.04	13.70	0.58	0.02	0.76
1 A3 b Road Transportation	All Fuels	CO ₂	9249	9249	0.15	3.58	0.53	0.01	0.78
2 A1 Cement Production	Production Quantities	CO ₂	3107	3107	0.05	10.10	0.51	0.01	0.79
1 A1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6301	6301	0.10	4.36	0.44	0.01	0.80
2 A6 Road Paving with Asphalt	Production Quantities	CO ₂	3	3	0.00	10000.05	0.42	0.01	0.81
5 A1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	526	526	0.01	43.20	0.37	0.01	0.82
5 A2 Land converted to Forest Land	Emissions/Removals	CO ₂	-577	-577	0.01	34.66	0.32	0.01	0.83
2 A2 Lime Production	Production Quantities	CO ₂	178	178	0.00	105.34	0.30	0.01	0.84
1 A4 b Residential	Liquid Fuels	CO ₂	1621	1621	0.03	11.18	0.29	0.01	0.85
2 B1 Ammonia Production	Production Quantities	CO ₂	569	569	0.01	31.57	0.29	0.01	0.85
3 D OTHER	Other Use of Chemicals	CO ₂	80	80	0.00	203.56	0.26	0.01	0.86
1 A2 f Other	Biomass	N ₂ O	21	21	0.00	780.99	0.26	0.01	0.87
5 B2 Land converted to Cropland	Emissions/Removals	CO ₂	354	354	0.01	43.32	0.25	0.01	0.87
1 A4 c Agriculture/ Forestry/ Fishing	Liquid Fuels	N ₂ O	151	151	0.00	95.81	0.23	0.01	0.88
1 A2 f Other	Liquid Fuels	CO ₂	3368	3368	0.05	3.86	0.21	0.01	0.89
1 A3 a ii Domestic	Liquid Fuels	CO ₂	165	165	0.00	75.75	0.20	0.01	0.89
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	227	0.00	54.66	0.20	0.01	0.90
1 A2 f Other	Solid Fuels	CO ₂	2103	2103	0.03	5.83	0.20	0.01	0.90
1 A1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	15	0.00	755.33	0.19	0.00	0.91
1 A4 b Residential	Liquid Fuels	N ₂ O	11	11	0.00	1000.05	0.18	0.00	0.91
3 A PAINT APPLICATION	Paint application	CO ₂	42	42	0.00	261.76	0.18	0.00	0.92
1 A2 d Pulp, Paper and Print	Biomass	N ₂ O	11	11	0.00	935.03	0.17	0.00	0.92
5 A1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	137	137	0.00	76.16	0.17	0.00	0.93
5 B1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-164	-164	0.00	61.14	0.16	0.00	0.93
1 A1 b Petroleum refining	Liquid Fuels	CO ₂	1910	1910	0.03	5.10	0.16	0.00	0.93
1 A3 d ii National navigation	Liquid Fuels	CO ₂	240	240	0.00	39.29	0.15	0.00	0.94
1 A2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	820	820	0.01	11.18	0.15	0.00	0.94
1 A1 b Petroleum refining	Liquid Fuels	N ₂ O	9	9	0.00	1000.00	0.15	0.00	0.95
6 B2 Domestic and Commercial wastewater	Wastewater	N ₂ O	286	286	0.00	30.41	0.14	0.00	0.95
1 A4 a Commercial/ Institutional	Liquid Fuels	CO ₂	744	744	0.01	11.18	0.13	0.00	0.95
2 A7 Other	Production Quantities	CO ₂	64	64	0.00	113.66	0.12	0.00	0.96
1 A2 c Chemicals	Liquid Fuels	CO ₂	1372	1372	0.02	4.56	0.10	0.00	0.96
2 B5 Other	Production Quantities	CO ₂	65	65	0.00	90.72	0.10	0.00	0.96
2 B2 Nitric Acid Production	Production Quantities	N ₂ O	567	567	0.01	10.05	0.09	0.00	0.96
1 A2 e Food Processing, Beverages and Tobacco	Biomass	N ₂ O	5	5	0.00	1001.80	0.09	0.00	0.97
1 A2 f Other	Liquid Fuels	N ₂ O	11	11	0.00	453.51	0.08	0.00	0.97
1 A2 c Chemicals	Liquid Fuels	N ₂ O	6	6	0.00	774.15	0.08	0.00	0.97
5 D2 Land converted to Wetlands	Emissions/Removals	CO ₂	105	105	0.00	44.54	0.08	0.00	0.97
1 A2 f Other	Solid Fuels	N ₂ O	5	5	0.00	1000.00	0.07	0.00	0.97
5 F2 Land converted to Other Land	Emissions/Removals	CO ₂	32	32	0.00	124.28	0.06	0.00	0.98
1 A2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	743	743	0.01	5.22	0.06	0.00	0.98
1 A3 b Road Transportation	All Fuels	N ₂ O	137	137	0.00	26.53	0.06	0.00	0.98
2 A3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	33	0.00	105.02	0.06	0.00	0.98
1 B2 a Oil	Liquid Fuels	CO ₂	65	65	0.00	46.63	0.05	0.00	0.98
1 A2 d Pulp, Paper and Print	Biomass	CH ₄	19	19	0.00	148.48	0.05	0.00	0.98
5 C2 Land converted to Grassland	Emissions/Removals	CO ₂	-25	-25	0.00	104.48	0.04	0.00	0.98
1 B2 a Oil	Liquid Fuels	CH ₄	35	35	0.00	72.92	0.04	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH ₄	30	30	0.00	81.01	0.04	0.00	0.99
1 B2 c Venting and flaring	Liquid Fuels	CO ₂	49	49	0.00	50.09	0.04	0.00	0.99
1 A4 a Commercial/ Institutional	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.04	0.00	0.99
1 A2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.04	0.00	0.99
1 B2 d Other (Geothermal)	Energy Production	CO ₂	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	91.19	0.03	0.00	0.99
1 A3 b Road Transportation	All Fuels	CH ₄	72	72	0.00	24.00	0.03	0.00	0.99
1 A2 d Pulp, Paper and Print	Liquid Fuels	N ₂ O	2	2	0.00	877.48	0.03	0.00	0.99
1 A3 d ii National navigation	Liquid Fuels	N ₂ O	2	2	0.00	767.92	0.02	0.00	0.99
1 A2 c Chemicals	Biomass	N ₂ O	1	1	0.00	1001.80	0.02	0.00	0.99
1 A3 c Railways	Liquid Fuels	CO ₂	173	173	0.00	7.07	0.02	0.00	0.99
1 A3 a ii Domestic	Liquid Fuels	N ₂ O	1	1	0.00	765.90	0.02	0.00	1.00
5 A1 Forest Land remaining Forest Land	Emissions/Removals	N ₂ O	14	14	0.00	76.16	0.02	0.00	1.00
1 A2 a Iron and Steel	Liquid Fuels	CO ₂	154	154	0.00	5.09	0.01	0.00	1.00
2 C2 Ferroalloys Production	Production Quantities	CO ₂	3	3	0.00	278.57	0.01	0.00	1.00
1 A2 f Other	Solid Fuels	CH ₄	4	4	0.00	150.03	0.01	0.00	1.00
2 B5 Other	Production Quantities	CH ₄	8	8	0.00	74.18	0.01	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry	CO ₂	12	12	0.00	49.31	0.01	0.00	1.00
1 A3 c Railways	Liquid Fuels	N ₂ O	11	11	0.00	50.25	0.01	0.00	1.00
1 A2 f Other	Liquid Fuels	CH ₄	7	7	0.00	83.58	0.01	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO ₂	10	10	0.00	50.25	0.01	0.00	1.00

Tier 2 Level Assessment (2006)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level Assess.	Combined Uncert.	Level * Uncert.	Share Level * Uncert.	Cumulative Total
			Estimate	Estimate					
			(kton CO ₂ eq.) 1990	(kton CO ₂ eq.) 2006					
4 Da AGRICULTURAL SOILS, Direct Emissions	Input to soils	N ₂ O	2110	1989	0.02	282.18	6.22	0.17	0.17
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	156	222	0.00	1000.28	2.46	0.07	0.24
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	526	-5103	0.06	43.20	2.44	0.07	0.31
6 A 3 Industrial SWDL	Industrial Waste Disposal	CH ₄	1599	1476	0.02	110.56	1.81	0.05	0.36
6 A Municipal SWDL	SWD Disposal on Land	CH ₄	1433	2747	0.03	53.83	1.64	0.05	0.41
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	12	0.00	10000.05	1.32	0.04	0.44
1 B 2 b Natural gas	Gaseous Fuels	CH ₄	0	699	0.01	150.33	1.16	0.03	0.47
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1176	1169	0.01	81.96	1.06	0.03	0.50
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO ₂	86	149	0.00	634.54	1.04	0.03	0.53
4 Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N ₂ O	1326	1246	0.01	60.69	0.84	0.02	0.56
1 A 3 b Road Transportation	All Fuels	CO ₂	9249	18754	0.21	3.58	0.74	0.02	0.58
1 A 4 b Residential	Biomass	N ₂ O	73	66	0.00	1001.80	0.73	0.02	0.60
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7659	12150	0.13	5.10	0.69	0.02	0.62
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	575	590	0.01	104.64	0.68	0.02	0.64
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	1903	0.02	31.57	0.67	0.02	0.65
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	58	0.00	1000.00	0.64	0.02	0.67
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	800	0.01	69.83	0.62	0.02	0.69
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1386	1249	0.01	44.23	0.61	0.02	0.71
2 A 2 Lime Production	Production Quantities	CO ₂	178	478	0.01	105.34	0.56	0.02	0.72
1 A 4 b Residential	Biomass	CH ₄	343	310	0.00	161.55	0.55	0.02	0.74
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	1108	1108	0.01	44.14	0.54	0.02	0.75
1 B 2 d Other (Geothermal)	Energy Production	CO ₂	2	48	0.00	1000.05	0.54	0.01	0.77
1 A 4 c Agriculture/ Forestry / Fishing	Liquid Fuels	CO ₂	1660	876	0.01	50.05	0.49	0.01	0.78
4 A ENTERIC FERMENTATION	Population size	CH ₄	2622	3044	0.03	13.70	0.46	0.01	0.79
2 A 1 Cement Production	Production Quantities	CO ₂	3107	3602	0.04	10.10	0.40	0.01	0.81
1 A 3 a ii Domestic	Liquid Fuels	CO ₂	165	436	0.00	75.75	0.37	0.01	0.82
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	0	33	0.00	1000.00	0.36	0.01	0.83
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	587	0.01	48.28	0.31	0.01	0.83
3 A PAINT APPLICATION	Paint application	CO ₂	42	101	0.00	261.76	0.29	0.01	0.84
1 B 2 a Oil	Liquid Fuels	CO ₂	65	558	0.01	46.63	0.29	0.01	0.85
1 A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	744	2005	0.02	11.18	0.25	0.01	0.86
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	0	4226	0.05	5.10	0.24	0.01	0.86
2 A 7 Other	Production Quantities	CO ₂	64	176	0.00	113.66	0.22	0.01	0.87
5 A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-577	-577	0.01	34.66	0.22	0.01	0.88
1 A 2 f Other	Biomass	N ₂ O	21	25	0.00	780.99	0.22	0.01	0.88
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	360	0.00	54.66	0.22	0.01	0.89
1 A 4 b Residential	Liquid Fuels	CO ₂	1621	1762	0.02	11.18	0.22	0.01	0.89
1 A 2 d Pulp, Paper and Print	Biomass	N ₂ O	11	18	0.00	935.03	0.19	0.01	0.90
3 D OTHER	Other Use of Chemicals	CO ₂	80	80	0.00	203.56	0.18	0.01	0.91
1 A 3 b Road Transportation	All Fuels	N ₂ O	137	579	0.01	26.53	0.17	0.00	0.91
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	354	354	0.00	43.32	0.17	0.00	0.91
1 A 2 f Other	Liquid Fuels	CO ₂	3368	3581	0.04	3.86	0.15	0.00	0.92
1 A 1 b Petroleum refining	Liquid Fuels	CO ₂	1910	2598	0.03	5.10	0.15	0.00	0.92
1 A 4 b Residential	Liquid Fuels	N ₂ O	11	12	0.00	1000.05	0.13	0.00	0.93
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6301	2784	0.03	4.36	0.13	0.00	0.93
2 B 5 Other	Production Quantities	CO ₂	65	131	0.00	90.72	0.13	0.00	0.93
1 A 1 b Petroleum refining	Liquid Fuels	N ₂ O	9	11	0.00	1000.00	0.12	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	286	354	0.00	30.41	0.12	0.00	0.94
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	-164	-164	0.00	61.14	0.11	0.00	0.94
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	94	0.00	105.02	0.11	0.00	0.95
1 A 3 d ii National navigation	Liquid Fuels	CO ₂	240	201	0.00	39.29	0.09	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	820	706	0.01	11.18	0.09	0.00	0.95
1 A 2 f Other	Gaseous Fuels	N ₂ O	0	15	0.00	518.71	0.08	0.00	0.95
1 A 2 f Other	Gaseous Fuels	CO ₂	0	1877	0.02	3.98	0.08	0.00	0.96
1 A 4 c Agriculture/ Forestry / Fishing	Liquid Fuels	N ₂ O	151	70	0.00	95.81	0.07	0.00	0.96
1 A 4 a Commercial / Institutional	Liquid Fuels	N ₂ O	2	6	0.00	1000.05	0.07	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	567	619	0.01	10.05	0.07	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO ₂	1372	1359	0.02	4.56	0.07	0.00	0.96
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	8	0.00	755.33	0.07	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N ₂ O	6	7	0.00	774.15	0.06	0.00	0.97
2 F 2 Foam Blowing	Consumption	HFC	0	38	0.00	140.70	0.06	0.00	0.97
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	137	67	0.00	76.16	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 b Residential	Gaseous Fuels	CO ₂	0	429	0.00	11.18	0.05	0.00	0.97
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	105	105	0.00	44.54	0.05	0.00	0.98
1 A 2 f Other	Liquid Fuels	N ₂ O	11	9	0.00	453.51	0.05	0.00	0.98
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	0	370	0.00	11.18	0.05	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	CH ₄	19	27	0.00	148.48	0.04	0.00	0.98
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	32	32	0.00	124.28	0.04	0.00	0.98
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N ₂ O	0	4	0.00	946.95	0.04	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CH ₄	35	45	0.00	72.92	0.04	0.00	0.98
1 A 2 f Other	Solid Fuels	CO ₂	2103	539	0.01	5.83	0.03	0.00	0.98
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	0	467	0.01	6.69	0.03	0.00	0.98
1 A 3 a ii Domestic	Liquid Fuels	N ₂ O	1	4	0.00	765.90	0.03	0.00	0.99
1 A 4 a Commercial / Institutional	Gaseous Fuels	N ₂ O	0	3	0.00	1000.05	0.03	0.00	0.99
1 A 2 c Chemicals	Gaseous Fuels	N ₂ O	0	3	0.00	1000.01	0.03	0.00	0.99
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	-25	-25	0.00	104.48	0.03	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO ₂	49	50	0.00	50.09	0.03	0.00	0.99
1 A 2 c Chemicals	Gaseous Fuels	CO ₂	0	341	0.00	7.07	0.03	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N ₂ O	1	2	0.00	1001.80	0.02	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	743	377	0.00	5.22	0.02	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	0	173	0.00	11.18	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH ₄	30	19	0.00	81.01	0.02	0.00	0.99

Table A-2.3 – Tier 2 Trend assessment with LULUCF: 1990-2006

Tier 2 Trend Assessment (1990-2004)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year		Trend	Combined	Level	Share	Cumulative
			Estimate	Estimate					
			(kton CO ₂ eq.)	(kton CO ₂ eq.)			Uncert.	Uncert.	Total
			1990	2004		%	%	%	
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N ₂ O	2110	1989	0.01	282.18	2.03	0.14	0.14
1B 2 b Natural gas	Gaseous Fuels	CH ₄	0	699	0.01	150.33	1.05	0.07	0.21
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	3	12	0.00	10000.05	0.85	0.06	0.27
6 A 3 Industrial SWDL	Industrial Waste Disposal on	CH ₄	1599	1476	0.01	110.56	0.64	0.04	0.32
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	1660	876	0.01	50.05	0.63	0.04	0.36
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	800	0.01	69.83	0.56	0.04	0.40
6 A Municipal SWDL	SW Disposal on Land	CH ₄	1433	2747	0.01	53.83	0.49	0.03	0.43
1B 2 d Other (Geothermal)	Energy Production	CO ₂	2	48	0.00	1000.05	0.46	0.03	0.47
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	1056	587	0.01	48.28	0.37	0.03	0.49
2 B 1 Ammonia Production	Production Quantities	CO ₂	569	1903	0.01	31.57	0.37	0.03	0.52
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	0	33	0.00	1000.00	0.33	0.02	0.54
5A 1 Forest Land remaining Forest Land	Emissions/Removals	CO ₂	526	-5103	0.01	43.20	0.29	0.02	0.56
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	1176	1169	0.00	81.96	0.28	0.02	0.58
1A 4 b Residential	Biomass	N ₂ O	73	66	0.00	1001.80	0.28	0.02	0.60
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N ₂ O	1326	1246	0.00	60.69	0.28	0.02	0.62
2 A 2 Lime Production	Production Quantities	CO ₂	178	478	0.00	105.34	0.26	0.02	0.64
5A 2 Land converted to Forest Land	Emissions/Removals	CO ₂	-577	-577	0.01	34.66	0.26	0.02	0.65
1A 3 b Road Transportation	All Fuels	CO ₂	9249	18754	0.07	3.58	0.25	0.02	0.67
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO ₂	86	149	0.00	634.54	0.25	0.02	0.69
6 B 1 Industrial Wastewater	Wastewater	CH ₄	1386	1249	0.01	44.23	0.23	0.02	0.70
1A 1 a Public Electricity and Heat Production	Liquid Fuels	CO ₂	6301	2784	0.05	4.36	0.23	0.02	0.72
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	156	222	0.00	1000.28	0.23	0.02	0.74
1B 2 a Oil	Liquid Fuels	CO ₂	65	558	0.00	46.63	0.22	0.02	0.75
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	0	4226	0.04	5.10	0.22	0.01	0.77
1A 4 b Residential	Biomass	CH ₄	343	310	0.00	161.55	0.21	0.01	0.78
1A 3 a ii Domestic	Liquid Fuels	CO ₂	165	436	0.00	75.75	0.17	0.01	0.79
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	575	590	0.00	104.64	0.15	0.01	0.80
5 E 2 Land converted to Settlements	Emissions/Removals	CO ₂	1108	1108	0.00	44.14	0.14	0.01	0.81
5 B 1 Cropland remaining Cropland	Emissions/Removals	CO ₂	164	-164	0.00	6.14	0.13	0.01	0.82
1A 2 f Other	Solid Fuels	CO ₂	2103	539	0.02	5.83	0.13	0.01	0.83
3 A PAINT APPLICATION	Paint application	CO ₂	42	101	0.00	261.76	0.12	0.01	0.84
1A 1 a Public Electricity and Heat Production	Solid Fuels	CO ₂	7659	12150	0.02	5.10	0.12	0.01	0.85
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	151	70	0.00	95.81	0.12	0.01	0.86
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	744	2005	0.01	11.8	0.12	0.01	0.86
1A 1 a Public Electricity and Heat Production	Solid Fuels	N ₂ O	36	58	0.00	1000.00	0.11	0.01	0.87
1A 3 b Road Transportation	All Fuels	N ₂ O	137	579	0.00	26.53	0.11	0.01	0.88
2 A 7 Other	Production Quantities	CO ₂	64	176	0.00	113.66	0.11	0.01	0.89
1A 1 a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	15	8	0.00	755.33	0.09	0.01	0.89
5A 1 Forest Land remaining Forest Land	Emissions/Removals	CH ₄	137	67	0.00	76.16	0.08	0.01	0.90
1A 2 f Other	Gaseous Fuels	N ₂ O	0	15	0.00	518.71	0.08	0.01	0.90
1A 2 f Other	Gaseous Fuels	CO ₂	0	1877	0.02	3.98	0.07	0.01	0.91
2 F 2 Foam Blowing	Consumption	HFC	0	38	0.00	140.70	0.05	0.00	0.91
2 A 3 Limestone and Dolomite Use	Production Quantities	CO ₂	33	94	0.00	105.02	0.05	0.00	0.92
1A 4 b Residential	Gaseous Fuels	CO ₂	0	429	0.00	11.8	0.05	0.00	0.92
1A 2 f Other	Solid Fuels	N ₂ O	5	1	0.00	1000.00	0.05	0.00	0.92
3 D OTHER	Other Use of Chemicals	CO ₂	80	80	0.00	203.56	0.05	0.00	0.93
4 A ENTERIC FERMENTATION	Population size	CH ₄	2622	3044	0.00	13.70	0.04	0.00	0.93
5 B 2 Land converted to Cropland	Emissions/Removals	CO ₂	354	354	0.00	43.32	0.04	0.00	0.93
2 B 5 Other	Production Quantities	CO ₂	65	131	0.00	90.72	0.04	0.00	0.94
1A 3 d ii National navigation	Liquid Fuels	CO ₂	240	201	0.00	39.29	0.04	0.00	0.94
1A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	0	370	0.00	11.8	0.04	0.00	0.94
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	820	706	0.00	11.8	0.04	0.00	0.94
2 A 1 Cement Production	Production Quantities	CO ₂	3107	3602	0.00	10.10	0.04	0.00	0.95
4 C RICE CULTIVATION	Culture Surface	CH ₄	227	360	0.00	54.66	0.04	0.00	0.95
1A 4 b Residential	Liquid Fuels	CO ₂	1621	1762	0.00	11.8	0.04	0.00	0.95
1A 2 d Pulp, Paper and Print	Gaseous Fuels	N ₂ O	0	4	0.00	946.95	0.03	0.00	0.95
5 C 2 Land converted to Grassland	Emissions/Removals	CO ₂	-25	-25	0.00	104.48	0.03	0.00	0.96
1A 4 a Commercial / Institutional	Liquid Fuels	N ₂ O	2	6	0.00	1000.05	0.03	0.00	0.96
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	0	467	0.00	6.69	0.03	0.00	0.96
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	11	18	0.00	935.03	0.03	0.00	0.96
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	743	377	0.01	5.22	0.03	0.00	0.97
1A 4 a Commercial / Institutional	Gaseous Fuels	N ₂ O	0	3	0.00	1000.05	0.03	0.00	0.97
1A 2 f Other	Liquid Fuels	CO ₂	3368	3581	0.01	3.86	0.03	0.00	0.97
1A 2 c Chemicals	Gaseous Fuels	N ₂ O	0	3	0.00	1000.01	0.03	0.00	0.97
1A 2 c Chemicals	Gaseous Fuels	CO ₂	0	341	0.00	7.07	0.02	0.00	0.97
1A 4 b Residential	Liquid Fuels	N ₂ O	11	12	0.00	1000.05	0.02	0.00	0.97
1A 2 f Other	Liquid Fuels	N ₂ O	11	9	0.00	453.51	0.02	0.00	0.98
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	0	173	0.00	11.8	0.02	0.00	0.98
1A 2 c Chemicals	Liquid Fuels	CO ₂	1372	1359	0.00	4.56	0.02	0.00	0.98
1A 2 e Food Processing, Beverages and Tobacco	Biomass	N ₂ O	5	5	0.00	1001.80	0.02	0.00	0.98
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH ₄	30	19	0.00	81.01	0.02	0.00	0.98
1A 3 a ii Domestic	Liquid Fuels	N ₂ O	1	4	0.00	765.90	0.02	0.00	0.98
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N ₂ O	0	1	0.00	1000.05	0.01	0.00	0.98
1A 2 f Other	Gaseous Fuels	CH ₄	0	10	0.00	135.57	0.01	0.00	0.98
5 D 2 Land converted to Wetlands	Emissions/Removals	CO ₂	105	105	0.00	44.54	0.01	0.00	0.98
1A 2 d Pulp, Paper and Print	Liquid Fuels	N ₂ O	2	1	0.00	877.48	0.01	0.00	0.99
5 F 2 Land converted to Other Land	Emissions/Removals	CO ₂	32	32	0.00	124.28	0.01	0.00	0.99
1A 2 f Other	Biomass	N ₂ O	21	25	0.00	780.99	0.01	0.00	0.99
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	567	619	0.00	10.05	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N ₂ O	22	16	0.00	91.19	0.01	0.00	0.99
1A 3 c Railways	Liquid Fuels	CO ₂	173	75	0.00	7.07	0.01	0.00	0.99
1A 3 b Road Transportation	All Fuels	CH ₄	72	55	0.00	24.00	0.01	0.00	0.99
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N ₂ O	2	2	0.00	1000.05	0.01	0.00	0.99
5A 1 Forest Land remaining Forest Land	Emissions/Removals	N ₂ O	14	7	0.00	76.16	0.01	0.00	0.99

ANNEX B - UNCERTAINTY ANALYSIS

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 CO₂ equivalent (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 AP42¹⁷⁰;
- 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.



Bibliography



Key Categories



Uncertainty

¹⁷⁰ 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 %

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;

$$U_{Total} = \frac{\{\sum_i [U_i * x_i]^2\}^{0.5}}{\sum_i [x_i]}$$

Where:

U_{total} is the percentage uncertainty in the sum of the quantities expressed as a percentage;

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:

$$U_{Total} = [\sum_i U_i^2]^{0.5}$$

- 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 tables¹⁷¹

A single table is presented including the most basic information used in uncertainty determination. The uncertainty was estimated in a consistent way for all years from 1990 to 2004. However, tables present only information for 2004.

All tables are equal 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 (Fuel gas). 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 values¹⁷². All emissions,



Bibliography



Key Categories



Uncertainty

¹⁷¹ Tables provided in excel annex

irrespective of the gas, are reported as CO₂ equivalent (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));

- AD Uncertainty: uncertainty value attributed to the activity data, half the 95 per cent 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 per cent 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 per cent 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)).

Finally, because there are confidentiality issues, for some categories the activity data and combined uncertainty are reported as “C”. Nevertheless, the importance of the uncertainty for each source may still be assessed from the tables.

¹⁷² Note: all calculation is done with absolute values.

