



**PORTUGUESE NATIONAL INVENTORY REPORT  
ON GREENHOUSE GASES, 1990 - 2012**

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

Amadora

May, 27th 2014

## Technical Reference

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## Preface

The Portuguese Environmental Agency (Agência Portuguesa do Ambiente)/ Ministry for the Environment, Land Use Planning and Energy (Ministério do Ambiente, do Ordenamento do Território e Energia - MAOTE), in accordance to its attributions of national entity responsible for the overall coordination and reporting of the Portuguese inventory of air pollutants emissions, prepares each year the National Inventory of Greenhouse Gas (GHGs) Emissions and Sinks in order to comply with the international commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the European Commission. The Conference of Parties to the UNFCCC and the Council Decision 280/2004/EC, concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, define that each Party should provide each year an update of its inventory of emissions and removals of Greenhouse Gases (GHG) not controlled by the Montreal Protocol, taking into account the UNFCCC Reporting Guidelines on Annual Inventories. This includes a report on annual emissions estimates (CRF tables), accompanied by a National Inventory Report (NIR), describing the input data, methodologies, background information and explanation on the whole process of inventory preparation. The report describes all formulas used for calculation of emissions, and is an important piece in the process of consultation with sectoral experts in the National System, as well as people who want to learn and get a general view of the methods and data used in the Portuguese inventories.

The 2014 NIR objective is to present a general overview of the inventory, overall results for 2012 and trends since 1990. More detailed information about emissions, activity data and emission factors are presented in the CRF tables that are also part of the 2014 Portuguese Submission on GHG emissions.

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

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

- 1 – National Inventory Report (the present report);
- 2 – CRF (Common Reporting Format) data tables for the period 1990-2012, and KP-LULUCF for the years 1990, 2008-2012, which were compiled with the CRF Reporter software (version 3.6.2);
- 3 – SEF (Standard Electronic Tables) for the reporting of Kyoto units in the national registry in 31.12.2013 and transfers of units during 2013.



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## EXECUTIVE SUMMARY

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

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

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

The NIR presents a description of the methods, assumptions and background data used in the preparation of the 2014 national inventory submission of GHG. The Revised (1996) IPCC Guidelines for National Greenhouse Gas Inventories (IPCC,1997), the 2006 IPCC Guidelines (2006, IPCC), and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC,2000) have been applied as far as possible.

The GHG emission inventory includes estimates for the six gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF<sub>6</sub>), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO<sub>x</sub>). The period covered is 1990-2012.

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

Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for all years in the period from 1990 to 2012, i.e., the inventory is internally consistent.

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

This report includes also supplementary information in accordance with Article 7, paragraph 1, of the Kyoto Protocol, following the requirements of the Annex of Decision 15/CMP.1 and includes information on changes in the national system and nations registry, information related



to Article 3, paragraphs 3 and 4, and Article 3, paragraph 14. It also presents information on the accounting of Kyoto units, including the Standard Electronic Tables (SEF).

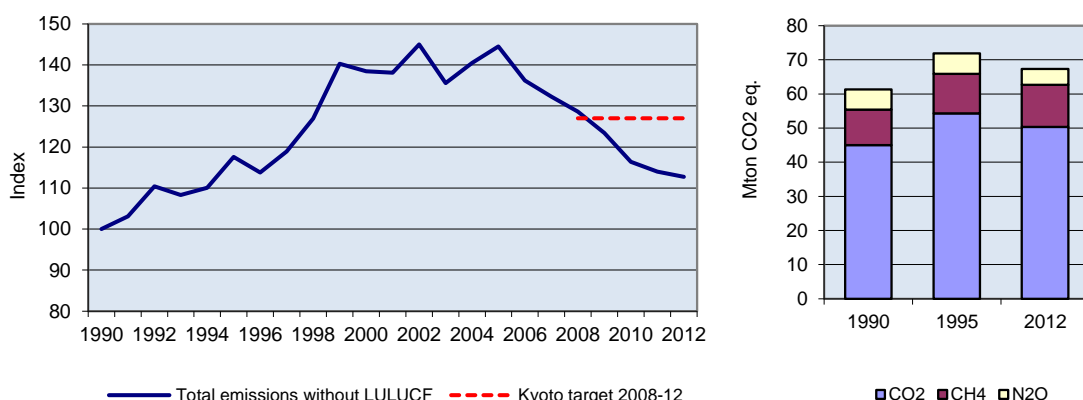
The Portuguese Environmental Agency (APA)/ Ministry for Agriculture, Sea, Environment and Land Use Planning (MAMAOT), is the national entity responsible for the overall coordination and updating of the National Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants (INERPA) and the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

## ES.2 Summary of national emissions and removal related trends

### ES.2.1 Greenhouse Gas Inventory – UNFCCC

In 2012, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated at about 68.8 Mt CO<sub>2</sub>e, representing an increase of 13.1 per cent compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27% compared to the 1990 level.

Figure ES. 1 – GHG emissions (without LULUCF)



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

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

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

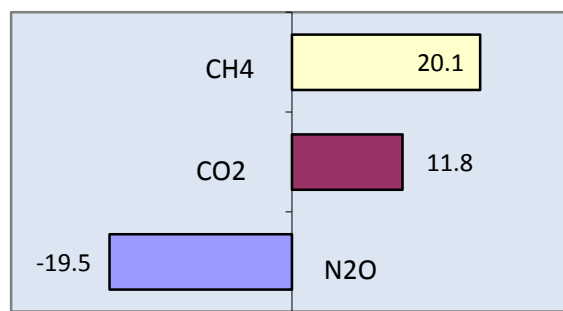
The trends of the most recent years have however been strongly influenced by the slowdown in industrial activity and consequent reduction in fuel consumption, and the cessation of some activities in the country such as the production of ammonia in 2009 with the relocation of the production facilities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

In the years 2011 and 2012 there has been a decrease in the consumption of electricity in Portugal, fact that may be explained by the austerity measures and the general implementation of the financial assistance Program under IMF and EU, as well as the current European economic and financial crisis.

The principal source of GHGs in Portugal in 2012 is the energy sector. The largest gas emitted is CO<sub>2</sub> representing approximately 73 per cent of total GHGs emissions expressed as global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for almost 93 per cent of total CO<sub>2</sub> emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2012, 83% of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas) whereas the renewable energy represents the remaining part, i.e. 17% in average. (Figure 2-2) The situation is however changing in the most recent years, with a progressive increase of the renewable energy sources such as wind.

Figure below illustrates the GHG trend in the period 1990-2012. CH<sub>4</sub> is the gas having registered the biggest increase, 20 per cent<sup>1</sup>.

Figure ES. 2– Change of emissions by gas over the period 1990-2012 (per cent)



<sup>1</sup> 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 2012: 2.5%)

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

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO <sub>2</sub> equivalent (Gg)												
CO2 emissions including net CO2 from LULUCF	42,152	43,142	44,228	41,773	41,322	44,444	39,085	41,392	46,989	54,563	55,376	51,852
CO2 emissions excluding net CO2 from LULUCF	45,013	46,688	50,961	49,660	50,320	54,346	51,720	54,579	59,131	66,877	65,746	65,449
CH4 emissions including CH4 from LULUCF	10,386	10,697	10,701	10,734	11,149	11,584	11,441	11,596	12,175	12,298	12,234	12,402
CH4 emissions excluding CH4 from LULUCF	10,203	10,451	10,622	10,668	11,042	11,356	11,357	11,562	11,995	12,203	12,069	12,304
N2O emissions including N2O from LULUCF	5,939	5,910	5,821	5,756	5,775	5,915	6,171	6,117	6,063	6,126	6,189	5,924
N2O emissions excluding N2O from LULUCF	5,551	5,544	5,522	5,493	5,528	5,664	5,971	5,949	5,886	5,976	6,033	5,790
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	27	42	61	86	157	243	318
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	0	0	0	0	0
SF6	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	7	7	9	9	10	10	11
<b>Total (including LULUCF)</b>	<b>58,478</b>	<b>59,750</b>	<b>60,750</b>	<b>58,263</b>	<b>58,246</b>	<b>61,975</b>	<b>56,745</b>	<b>59,174</b>	<b>65,322</b>	<b>73,155</b>	<b>74,051</b>	<b>70,506</b>
<b>Total (excluding LULUCF)</b>	<b>60,767</b>	<b>62,683</b>	<b>67,105</b>	<b>65,821</b>	<b>66,890</b>	<b>71,399</b>	<b>69,096</b>	<b>72,159</b>	<b>77,107</b>	<b>85,224</b>	<b>84,100</b>	<b>83,872</b>

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	% change 1990-12
CO <sub>2</sub> equivalent (Gg)												
CO2 emissions including net CO2 from LULUCF	55,677	56,467	55,028	61,827	51,962	46,216	42,885	40,342	37,028	34,609	36,583	-13.2
CO2 emissions excluding net CO2 from LULUCF	69,236	64,071	66,716	69,234	64,623	61,899	59,793	57,019	52,492	51,155	50,310	11.8
CH4 emissions including CH4 from LULUCF	12,685	13,095	12,569	12,955	12,234	12,124	12,043	11,860	12,058	12,167	12,419	19.6
CH4 emissions excluding CH4 from LULUCF	12,530	12,444	12,443	12,458	12,140	12,083	12,023	11,808	11,923	12,113	12,250	20.1
N2O emissions including N2O from LULUCF	5,981	5,482	5,577	5,415	5,118	5,361	5,134	4,827	4,905	4,595	4,588	-22.8
N2O emissions excluding N2O from LULUCF	5,845	5,254	5,465	5,232	5,021	5,282	5,065	4,749	4,808	4,513	4,479	-19.3
HFCs	416	542	649	736	836	968	1,115	1,237	1,368	1,493	1,667	-
PFCs	0	0	0	0	0	0	0	0	0	NA,NO	NA,NO	-
SF6	10	16	26	26	26	37	36	41	44	44	45	-
<b>Total (including LULUCF)</b>	<b>74,769</b>	<b>75,603</b>	<b>73,849</b>	<b>80,959</b>	<b>70,176</b>	<b>64,706</b>	<b>61,212</b>	<b>58,307</b>	<b>55,402</b>	<b>52,908</b>	<b>55,302</b>	-5.4
<b>Total (excluding LULUCF)</b>	<b>88,038</b>	<b>82,328</b>	<b>85,299</b>	<b>87,686</b>	<b>82,647</b>	<b>80,269</b>	<b>78,032</b>	<b>74,854</b>	<b>70,634</b>	<b>69,317</b>	<b>68,752</b>	13.1

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

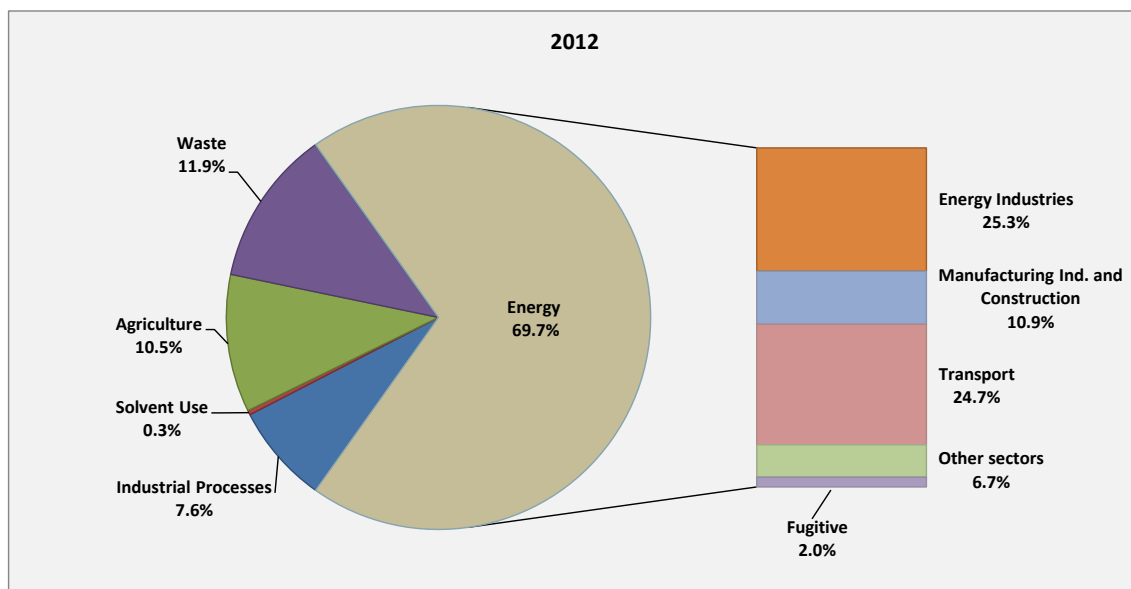
## ES.3 Overview of source and sink category's emission estimates and trends

### ES.3.1 Greenhouse Gas Inventory – UNFCCC

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into six large sectors: Energy, Industrial Processes, Solvent use, Agriculture, Land-Use Change and Forestry, and Waste. The figure below represents direct GHG emissions by sector for 2012.

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

Figure ES. 3 – GHG emissions in Portugal by sector: 2012



Energy is by far the most important sector, accounting for 69.7 per cent of total emissions in 2012, and presenting an increase of 15 per cent over the 1990-2012 period. Energy industries and transport are the two most important sources representing respectively 25.3 per cent and 24.7 per cent of total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation and transportation, which have grown steadily until the mid-2000s due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the growth of mobility. The situation seems to have changed in the most recent years where we can observe stagnation or even decrease of these trends.

Transport sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2012 these emissions increased 65 per cent, due to the steady growth of vehicle fleets and road travel, in association with the increase in family income and the strong investment in road infrastructure in the 90s. Indirectly the increase in road traffic activity also augmented the emissions from fossil fuel storage, handling and distribution. However, this situation has changed in the last years, as the growth of transport emissions has started to decline since 2002.

Agriculture, was in the period analyzed, one of the most significant sources of GHG emissions, and was responsible for 10.5 per cent of the Portuguese emissions in 2012, corresponding to a decrease of 11.0 per cent since 1990. The waste and industrial processes sectors represented, respectively, 11.9 per cent and 7.6 per cent of the country emissions in 2012, recording an increase of approximately 36.6 per cent and 7.8 per cent since 1990. Solvent use represents less than 1 per cent of total emissions, and is mainly related to NMVOC emissions<sup>2</sup>.

The accounting of land use change and forestry category has been revised for this submission on the basis of the new cartography product COS 1995/2007/2010, recently made available from the *Direcção Geral do Território*, and a revision of the soil emission factors, incorporating the LUCAS Data Set. According to the last estimates the sector is estimated as a net sink in the whole 1990-2012, representing a sequester of -13.5 Mt CO<sub>2</sub>e. in 2012.

The table below presents the overall sectorial trend for direct GHG emissions in the 1990-2012 period.

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<sup>2</sup> These are converted into ultimate carbon dioxide after being emitted to atmosphere.

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

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO <sub>2</sub> equivalent (Gg)												
1. Energy	41,506	43,066	47,648	46,421	47,088	50,639	47,993	50,630	55,142	62,609	61,137	61,551
2. Industrial Processes	4,834	4,908	4,623	4,547	4,532	5,242	5,344	5,606	5,758	6,175	6,418	6,040
3. Solvent and Other Product Use	317	319	304	287	289	281	298	308	314	313	314	315
4. Agriculture	8,119	8,201	8,125	8,002	8,125	8,175	8,398	8,303	8,277	8,421	8,663	8,364
5. Land-Use Change and Forestry <sup>(7)</sup>	-2,289	-2,933	-6,355	-7,558	-8,643	-9,423	-12,351	-12,985	-11,785	-12,068	-10,049	-13,366
6. Waste	5,992	6,190	6,405	6,565	6,855	7,062	7,062	7,313	7,616	7,706	7,568	7,603
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Total (including LULUCF)(5)</b>	<b>58,478</b>	<b>59,750</b>	<b>60,750</b>	<b>58,263</b>	<b>58,246</b>	<b>61,975</b>	<b>56,745</b>	<b>59,174</b>	<b>65,322</b>	<b>73,155</b>	<b>74,051</b>	<b>70,506</b>

GHGs SOURCE AND SINK CATEGORIES	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	% change 1990-12
CO <sub>2</sub> equivalent (Gg)												
1. Energy	65,259	60,201	62,209	64,786	60,169	57,038	55,342	54,242	49,231	48,373	47,897	15.4
2. Industrial Processes	6,330	6,368	6,984	6,999	6,797	7,373	7,292	5,684	5,929	5,199	5,213	7.8
3. Solvent and Other Product Use	316	303	291	283	282	283	268	252	253	245	233	-26.7
4. Agriculture	8,260	7,558	7,789	7,584	7,410	7,606	7,501	7,359	7,337	7,241	7,224	-11.0
5. Land-Use Change and Forestry <sup>(7)</sup>	-13,269	-6,725	-11,449	-6,727	-12,471	-15,564	-16,819	-16,547	-15,232	-16,409	-13,450	487.6
6. Waste	7,873	7,898	8,025	8,034	7,990	7,969	7,629	7,316	7,884	8,259	8,185	36.6
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-

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

## **ES.4 Information on indirect GHG and SO<sub>x</sub> emissions**

Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO<sub>x</sub> and NMVOCs are precursor substances for ozone which is a GHG. SO<sub>x</sub> produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

In 2012, all these gases emissions have decreased from 1990 levels: SO<sub>x</sub> -81.7 per cent, CO -61.3 per cent, NMVOC -43.4 per cent and NO<sub>x</sub> -30.6 per cent (following table).

Energy is the major responsible sector for emissions of NO<sub>x</sub>, SO<sub>x</sub> 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<sub>x</sub> emissions, 45.8 per cent of 2012 totals. Despite the fast growing trends of the transport sector (mainly road) since the 90s, the introduction of new petrol-engine passenger cars with catalysts converters and stricter regulations on diesel vehicles emissions, limited the growth of these emissions or even its decrease. In fact, the situation started to change in the last years, as transport emissions growth has first stabilised and started to decline in the most recent years. Since the early 2000s, NO<sub>x</sub> emissions from transport has been presenting a decreasing tendency; and CO and NMVOC emissions recorded real reductions in the 1990-2012 period, respectively, -81 per cent and -54 per cent.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 41 per cent of the 2012 totals.

SO<sub>x</sub> emissions are mainly generated in the energy industry sector (approximately 39 per cent of total emissions in 2012) and combustion in manufacturing industries (approximately 34 per cent of total emissions in 2012), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. The situation is however improving with a significant development of renewable sources (mainly wind) and energy efficiency measures, among other factors as reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 from November 10<sup>th</sup>). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO<sub>x</sub> emissions. The emissions variation in the period 1990-2012 shows in fact a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries and manufacturing industries -89 per cent and -73 per cent. Since 2007, SO<sub>x</sub> emissions from the energy industries registered a significant reduction (approximately -78 per cent) which is explained by the implementation of two new abatement systems (desulfurization in two Large Point Source Energy Plants in Mainland Portugal).

Table ES.3– Indirect GHG and SO<sub>x</sub> emissions

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
(Gg)												
CO	812	826	862	842	824	817	806	768	756	728	681	600
NO <sub>x</sub>	245	256	275	266	266	277	264	263	271	278	274	273
NM VOC	309	312	316	303	301	295	294	293	290	283	269	255
SO <sub>2</sub>	324	315	376	320	295	331	273	288	335	303	263	250

Gas emissions	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	% change 1990-12
(Gg)												
CO	582	546	517	479	445	422	406	380	374	348	315	-61.3
NO <sub>x</sub>	280	257	263	268	247	242	216	204	189	179	170	-30.6
NM VOC	251	234	227	215	209	204	197	185	187	180	175	-43.4
SO <sub>2</sub>	249	191	193	194	170	163	114	79	70	64	59	-81.7



## 1 INTRODUCTION

### 1.1 Background information

#### 1.1.1 Global warming and climate change

Although key greenhouse gases - CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, 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 SF<sub>6</sub>. 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<sub>x</sub>, and NMVOCs are precursor substances for ozone which is a GHG. SO<sub>x</sub> produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Land-Use and Land-Use Change (LULUCF), particularly deforestation, is another factor that contributes to the phenomenon of global warming and climate change as it changes carbon stocks and carbon sequestration and consequently the CO<sub>2</sub> fluxes from and to the atmosphere.

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

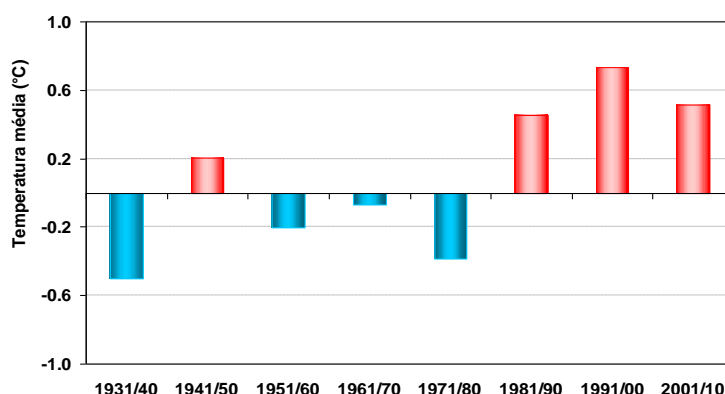
An increase in global temperatures can result in a cascade of environmental effects, including the rise of sea level and changes in the amount and pattern of precipitation. These changes may increase the frequency and intensity of extreme weather events, such as floods, droughts, heat waves, hurricanes,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

#### 1.1.2 Climate change in Portugal

The mean temperature has risen in all regions of Portugal since the 1970s, at a rate of approximately 0.3 °C per decade. The time-series analysis of the mean annual temperature since 1931, shows that 1997 was the warmest of the last 75 years and that 7 of the 10 warmest years occurred after 1990s (1997, 1995, 2006, 1996, 1990, 1998 and 2003).

In Portugal Mainland the decade of 1991/2000 was the warmest one (next figure).

Figure 1-1 – Mean air temperature anomalies, by decades, in Portugal Mainland



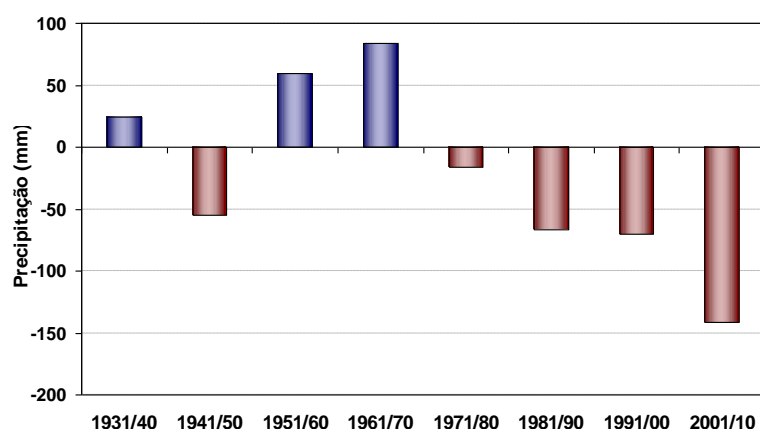
Source: IPMA, 2013

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 20<sup>th</sup> century were particularly dry in mainland Portugal as opposed to the average values registered between 1961 and 1990. In fact, only in 6 of the last 20 years of the past century the annual precipitation was higher than the average. In 2001 and 2002, however, the annual precipitation values were higher than the average observed in the reference period. The driest of the past 75 years was 2005, and 2004 was the second driest on record. The first decade of the 21<sup>st</sup> century (2001/2010) was the driest since 1932 (next figure).

Figure 1-2 – Precipitation anomalies, by decades, in Portugal Mainland



Source: IPMA, 2013

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

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

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

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

### 1.1.3 The Convention, the Kyoto Protocol and national commitments

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

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

The Kyoto Protocol (KP), adopted some years later in 1997, represents a deepening in the commitments inscribed in the Convention. The Protocol introduced legally binding commitments

for developed countries to reduce their collective emissions of greenhouse gases by at least 5 per cent by the period 2008-12 (first commitment period of the Protocol), below their 1990 level.

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

The KP entered into force on the February 16<sup>th</sup>, 2005, after Russia's ratification in November 2004 which fulfilled the requirement that at least 55 Parties to the Convention, including developed countries accounting for at least 55% of that group's CO<sub>2</sub> emissions in 1990.

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

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

#### **1.1.4 History of national inventories**

Air emission inventories in Portugal were only initiated in the late 80s, early 90s when the first estimates of NO<sub>x</sub>, SO<sub>x</sub> and VOC emissions from combustion were made under the development of the National Energetic Plan (PEN - Plano Energético Nacional), and emissions from combustion and industrial processes were made under OECD inventory and under CORINAIR85 programme. A major breakthrough occurred during the CORINAIR90 inventory realized during 1992 and 1993 by General-Directorate of Environment (DGA, renamed now as APA). This inventory exercise, aiming also EMEP and OECD/IPCC, extended the range of the pollutants (SO<sub>x</sub>, NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, CO, CO<sub>2</sub>, N<sub>2</sub>O and NH<sub>3</sub>) 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 fulfillment of international compromises under conventions UNFCCC and CLRTAP, together with the publication of the IPCC Draft Guidelines for National Greenhouse Gas Inventories (IPCC, 1995) and latter of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), has result in substantial improvement of the methodologies that are used in the inventory, particularly for agriculture and wastes, and that were included at first time in the First National Communication in 1994. The inventory that resulted from CORINAIR90 (CEC, 1992) and subsequent modifications from IPCC methodology still structures the present day methodology in what concerns activity data and methodology. Under the evaluation of the first communication the inventory was subjected to a review made by an international team. The second, third, fourth and fifth communications were also reviewed

by international experts. These exercises had an important role in problem detection and contribute to overall improvement.

Since its first compilation, the Portuguese inventory has been continuously amended mainly from the use of more detailed methodologies, better access to underlying data allowing the development of the comprehensiveness of the inventory, and better database storage and calculation structure. Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for the different years considered (1990-2011), i.e., the inventory is internally consistent. Some major studies have contributed to the improvement of the inventory:

- Study of VOC emissions in Portugal, in 1995. This study made in collaboration with FCT (Faculdade de Ciências e Tecnologia) led to an important improvement in emission estimates from solvent sector, which is still used as basic information source for this sector;
- Study of Emission and Control of GHG in Portugal (Seixas et al, 2000). This project aimed the first development of projections toward 2010 and the identification of control measures to accomplish the Kyoto Protocol. This also led to improvements in the inventory: extension of the inventory including for the first time also carbon dioxide sinks (forest); a first attempt to estimate solid waste methane emissions from urban solid wastes using a Tier2 approach and, in general terms, a better insight into additional parameters used in the inventory methodologies, and that has resulted from interaction with several institutional agents: General Directorate of Energy, Ministry of Agriculture; and the inter-ministerial transport group;
- Study for the quantification of carbon sinks in Portugal (Pereira *et al.*, 2002), made under the development of PNAC and PTEN national programmes;
- Revision of the Energy Balances with comparison of information collected at APA (LCP Directive) and Statistical Information received at DGEG: Energy Balances. The 1990s – DGE (2003);
- PNAC 2004 (National Plan for Climate Change) approved by Ministers Council and published recently in the National Official Journal (OJ nº 179, 31 July 2004, I Série B/ Resolução do Conselho de Ministros nº 119/2004);
- PNAC 2006 (National Plan for Climate Change) approved by Ministers Council and published in the National Official Journal (OJ nº 162, 23 August 2006, I Série B/ Resolução do Conselho de Ministros nº 104/2006)
- Sectorial Studies and Proposal for a PTEN (National Plan on Emission Ceilings);
- PNALE (National Plan for Allocation of Emissions) 2005-2007 or Portuguese PNALE I, adopted by Ministers Council (Resolução do Conselho de Ministros n.º 53/2005) and published in the National Official Journal (OJ nº 44, 3 March 2005, I Série B);

- Bilateral meetings (APA/UE) for the determination of the Baseline Scenario under the CAFE program (APA,2004);
- Methodological Development Programme (PDM) under the implementation of the National Inventory System;
- UNFCCC reviews, in particular the in-depth review (September/October 2004), and the centralised reviews (October 2005 and September 2008).
- UNFCCC in-depth review of the Initial Report in May 2007 which fixed the Assigned Amount for the first commitment period.
- 2012 technical review of the greenhouse gas emission inventory of Portugal to support the determination of annual emission allocations under Decision 406/2009/EC.
- UNFCCC in-depth review of the 2012 greenhouse gas emission inventory in September 2012.
- UNFCCC centralised review of the 2013 greenhouse gas emission inventory in September 2013.

#### **1.1.5 Greenhouse gas emissions inventories**

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

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

The inventory covers the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFC), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO<sub>x</sub>). Emissions are estimated for each civil year from 1990 to 2012.

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

The economic sectors covered are the following: energy production and transformation, combustion in industry, domestic, agriculture, fisheries, institutional and commerce sectors,

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

### 1.1.6 Global warming potentials

A Global Warming Potential (GWP) is defined as the cumulative radiative forcing over a specified time horizon resulting from the emission of a unit mass of gas relative to some reference gas (IPCC, 1997). The reference gas used is CO<sub>2</sub>. The mass emission of each gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide equivalents (CO<sub>2</sub> e). The parties to the UNFCCC have agreed to use GWPs based on a 100-year time horizon.

Table 1-1 – Global Warming Potentials (100-year time horizon)

GHG	GWP
CO <sub>2</sub>	1
CH <sub>4</sub>	21
N <sub>2</sub> 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 <sup>a</sup>	1 300
HFC-152 <sup>a</sup>	140
HFC-143	300
HFC-143 <sup>a</sup>	3 800
HFC-227ea	2 900
HFC-236fa	6 300
HFC-245ca	560
PFC	
CF <sub>4</sub>	6 500
C <sub>2</sub> F <sub>6</sub>	9 200
SF <sub>6</sub>	23 900

## 1.2 Institutional arrangements for inventory preparation

### 1.2.1 Institutional arrangements in place

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

The principal objective of the national system is to prepare and ensure the transparency, consistency, comparability, completeness, accuracy and timeliness of the inventory of air pollutants (INERPA), in accordance with the directives defined at international and EC levels, in

order to make easier and more cost-effective the tasks of inventory planning, implementation and management,

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

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

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

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

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

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

The RCM (Council of Ministers Resolution 68/2005, of 17 March) also includes a procedure for the official consideration of the inventory, defining, in its article 19, that the final approval of INERPA is the responsibility of APA (ex-IA), after hearing the focal points (FP) and the involved entities (IE). For that, alinea a) stipulates that the APA should prepare a draft version of the inventory and send this draft version to the FP and IE to enable these entities to provide comments. In alinea b) of the same article, it is mentioned that APA should prepare the final version of INERPA, taking into account the proposals and comments received from those entities.

The final version of inventory shall be considered and approved by the President of APA before the submission of the inventory to the international/community submissions.



Figure 1-3 – SNIERPA 's main elements relations

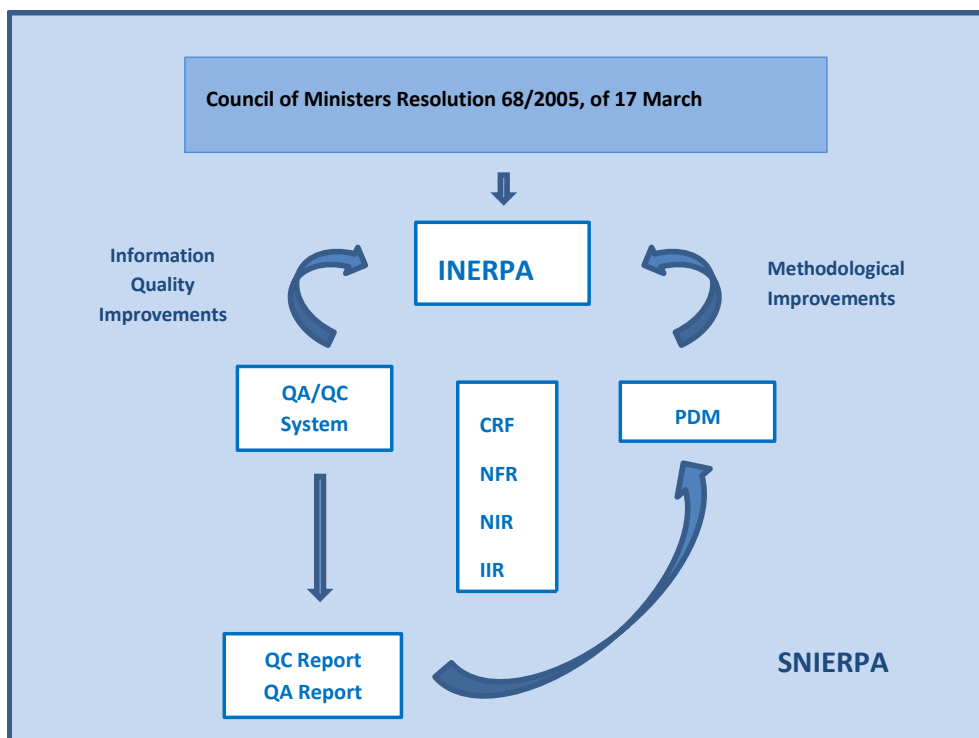


Table below lists the main focal points and involved entities, by sector of activity.

Table 1-2 – Bodies that contribute information relevant to the preparation of the INERPA

Sector of Activity	Focal Point	Involved Entities
National Statistics <sup>3</sup>	National Statistics Institute	
Environment Statistics <sup>4</sup>	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

Following several restructuring of Portuguese Public Administration since 2005, the actual names of the institutions referred in RCM 68/2005 have been replaced.

Changes in national system since the last submission are described in chapter 12.

### 1.2.2 Overview of inventory planning

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

Future planned improvements are compiled annually for each sector by the relevant inventory experts and the inventory coordinator, having as a basis the issues raised and the recommendations from the annual review processes and the problems identified from the application of QA/QC procedures, as well as future new reporting obligations. All identified items are gathered in a Methodological Development Plan (PDM – *Plano de Desenvolvimento Metodológico*) which is updated every year. Each issue identified is attributed a priority,

considering their importance in terms of the contribution to total CO<sub>2</sub> equivalent emissions, the level of uncertainty associated and the economic and technical resources available.

Each year, typically in June according to the agreed calendar of INERPA, the APA, the coordinator of GT SNIERPA, organizes a kick off meeting to plan and launch, in coordination with the sectoral focal points and the involved entities, the work for the following inventory submission(s). Bilateral meetings occur as necessary as consequence of this meeting aiming at discussing the specific issues related to each sector and to agree on the actions to be implemented in the framework of SNIERPA during this inventory compilation regarding the next submission.

The following table presents the overall calendar of the INERPA's elaboration process, which includes four main phases: planning, compilation, QA/QC verification and improvement (PDM activities).

Table 1-3 - Calendar for the inventory process

Date	Task	Process	Tasks
May - June	- Elaboration of QA/QC plan - Definition/update of inventory development priorities (PDM)	Inventory Planning	- setting of quality objectives - identification of priorities taking into account the latest reviews and QA/QC checks
June	Kick-off meeting of SNIERPA WG for the launch of the annual inventory work	Inventory Planning	- discussion and approval of the QA/QC plan - discussion and approval of the inventory development priorities (PDM)
June - mid December	- end September: deadline for routine data collection/ delivery by FP and/or IE to the APA - end October: deadline for the implementation of Methodological Development Plan (PDM) improvements	Inventory Compilation/ Improvement/ Verification	- collection of background data - implementation of methodological improvements - estimation of emissions/ removals - implementation of QC checks
15 December	NFR submission to FP and/or IE for review	Inventory Verification	- inventory revision by FPs
22 December	Deadline for NFR comments from FP and/or IE	Inventory Verification	- preparation of submission by the inventory team
30 December	<i>Official consideration/approval of the NFR submission [under National Emissions Ceilings]</i>	<i>Approval</i>	<i>Approval by President of APA</i>
31 December	<i>Official NFR submission to EC (DG ENV) [under National Emissions Ceilings]</i>	<i>Reporting</i>	-
15 January	<i>Preliminary CRF and Short NIR submission to EC (DG CLIMA) [Monitoring Mech. of GHG under EU]</i>	<i>Reporting</i>	-
1 February	NFR submission to FP and/or IE for review if changes since NEC	Inventory Verification	-
11 February	Deadline for NFR comments from FP and/or IE	Inventory Verification	-
14 February	<i>Official consideration/approval of the NFR submission to UNECE [CLRTAP]</i>	<i>Approval</i>	<i>Approval by President of APA</i>
15 February	<i>Official NFR submission to UNECE [CLRTAP]</i>	<i>Reporting</i>	-
15 February	- CRF and NIR and IIR submission to FP and/or IE for review	Inventory Verification	-
9 March	- Deadline for NIR and IIR comments from FP and/or IE - Deadline for implementation of QC checks	Inventory Verification	-
14 March	<i>Official consideration/approval of the CRF and Short NIR submission to EC (DG CLIMA) [Monitoring Mech. of GHG under EU]</i>	<i>Approval</i>	<i>Approval by President of APA</i>
15 March	<i>Submission of CRF and NIR (final versions) to the EC (DG CLIMA) [Monitoring Mech. of GHG under EU]</i>	<i>Reporting</i>	-
15 March	<i>Submission of IIR to UNECE [CLRTAP]</i>	<i>Reporting</i>	-
15 April	<i>Submission of CRF and NIR (final version) to the UNFCCC [UNFCCC and Kyoto Protocol]</i>	<i>Reporting</i>	-

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### 1.2.3 Institutional arrangements for Kyoto Protocol

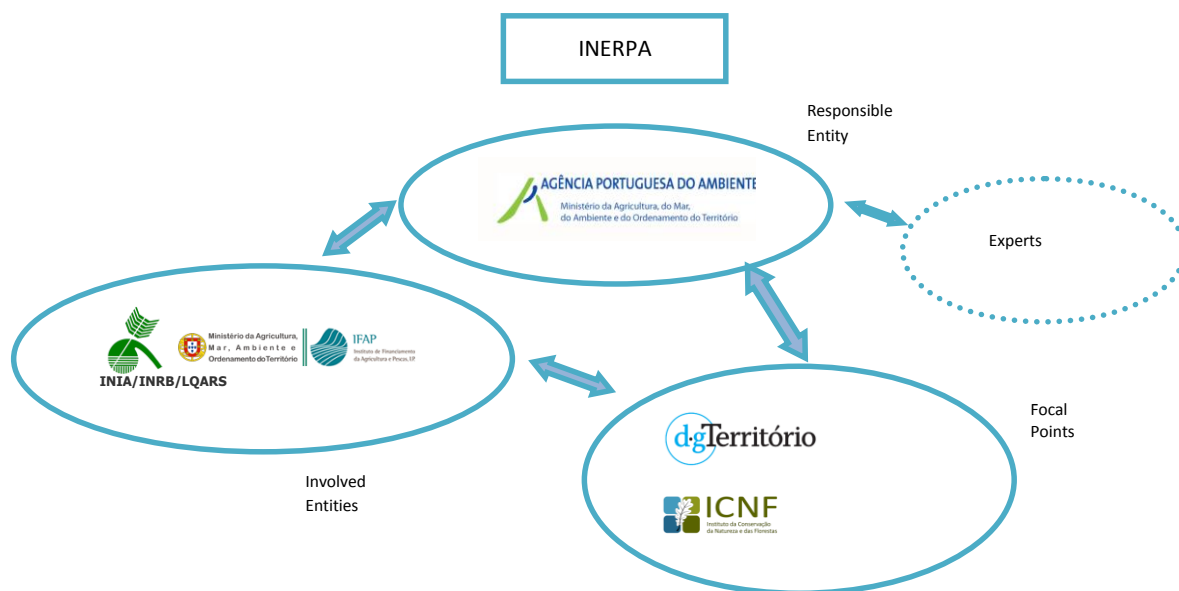
Additional provisions to deal with the supplementary information under Kyoto Protocol refer mainly to arrangements to account for further requirements concerning Art. 3.3 and 3.4.

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

- MAOTE – Ministry for the Environment, Land Use Planning and Energy (Ministério do Ambiente, do Ordenamento do Território e Energia)
  - APA – Portuguese Agency for the Environment ([www.apambiente.pt](http://www.apambiente.pt))
  - GPP – Office for Policies and Planning of MAMAOT (<http://www.gpp.pt>)
  - ICNF – Institute for Biodiversity and Forests ([www.icnf.pt](http://www.icnf.pt))
  - IFAP (ex-INGA) – Payment Agency for Agriculture and Fisheries ([www.ifap.pt](http://www.ifap.pt))
  - INIAV – Agriculture State Laboratory (<http://www.inia.pt>)
- ISA – Instituto Superior de Agronomia / Technical University of Lisbon (<http://www.isa.utl.pt>)
- DGT – Territory General Directorate (<http://www.igeo.pt/gdr/projectos/prek/>)
- IST – Instituto Superior Técnico/ Technical University of Lisbon (<http://www.ist.utl.pt>)
- UE – Universidade de Évora

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

Figure 1-4 – Main elements of Working Group 3.3&3.4



## 1.3 Inventory Preparation Process

### 1.3.1 Responsibility

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

The designated representative is:

Agência Portuguesa do Ambiente

Departamento de Alterações Climáticas (DCLIMA)

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

Telephone: +351 21 472 83 82

Fax: + 351 21 471 90 74

Contact: Eduardo Santos – [eduardo.santos@apambiente.pt](mailto:eduardo.santos@apambiente.pt)

### 1.3.2 Calculation, data archiving and documentation system

The emissions calculations have been performed by APA. However many other institutions and agencies contributed to the inventory process, providing activity data, sectorial expert judgment, technical support and comments. All calculation and reporting rely in a set of different Excel

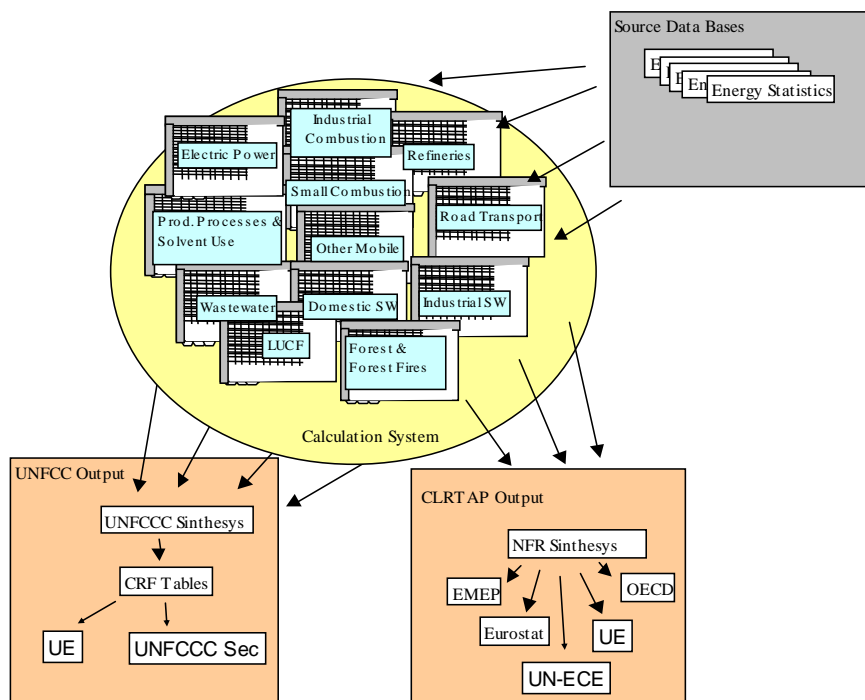
spreadsheet workbooks which had been developed in order that all information and calculations occur automatically. The structure of the information system is outlined in figure below.

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

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

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

Figure 1-5 – Electronic System Structure of the estimation and reporting system



Annually reported data, e.g. CRF tables, are stored both in paper and magnetic format. Furthermore, the present system is considered to ensure the basic requirements/functions of an IT system: centralized data processing and storage.

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## **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 2014 submission.

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



Table 1-4 – Summary of methods and emission factors (CRF summary 3 table)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		HFCs		PFCs		SF <sub>6</sub>	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
<b>1. Energy</b>	CR,D,T1,T2	CR,CS,D,OTH,PS	CR,OTH,T1,T2,T3	CR,D,OTH	CR,D,T1,T2,T3	CR,D						
A. Fuel Combustion	CR,T1,T2	CR,CS,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,CS,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,T1	CS,D	CR,OTH,T1	CR,D,OTH	D	D						
1. Solid Fuels	T1	D	T1	D	NA	NA						
2. Oil and Natural Gas	D	CS,D	CR,OTH	CR,OTH	D	D						
<b>2. Industrial Processes</b>	CR,D,OTH,T2,T3	CR,CS,D,OTH,PS	D,OTH,T3	CR,OTH,PS	D	CR,OTH,PS						
A. Mineral Products	D,OTH,T3	D,OTH	D,OTH	OTH	NA	NA						
B. Chemical Industry	D	CS	D	CR,OTH	D	CR,OTH,PS	NA	NA	NA	NA	NA	NA
C. Metal Production	T2	PS	T3	PS	NA	NA	NA	NA	NA	NA	NA	NA
D. Other Production	CR	CR										
E. Production of Halocarbons and SF <sub>6</sub>							NA	NA	NA	NA	NA	NA
F. Consumption of Halocarbons and SF <sub>6</sub>												
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>3. Solvent and Other Product Use</b>	CR,D	CR,CS,OTH			D	D						
<b>4. Agriculture</b>			D,T1,T2	CS,D	D,T1a,T1b	D						
A. Enteric Fermentation			T1,T2	CS,D								
B. Manure Management			T2	CS	D	D						
C. Rice Cultivation			D	CS,D								
D. Agricultural Soils			NA	NA	T1a,T1b	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						
<b>5. Land Use, Land-Use Change and Forestry</b>	CS,D,T2	CS,D	D	D	D	D						
A. Forest Land	CS,T2	CS,D	D	D	D	D						
B. Cropland	D,T2	CS,D	D	D	D	D						
C. Grassland	T2	CS,D	D	D	D	D						
D. Wetlands	T2	CS,D	NA	NA	NA	NA						
E. Settlements	T2	CS,D	NA	NA	NA	NA						
F. Other Land	T2	CS,D	NA	NA	NA	NA						
G. Other	D	D	NA	NA	NA	NA						
<b>6. Waste</b>	D	CS,D	D,T2	CR,CS,D	D	CR,D						
A. Solid Waste Disposal on Land	NA	NA	T2	CS,D	NA	NA						
B. Waste-water Handling			D	CS,D	D	CR,D						
C. Waste Incineration	D	CS,D	D	CR	D	CR						
D. Other	NA	NA	NA	NA	NA	NA						
<b>7. Other (as specified in Summary 1.A)</b>			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.

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

Table 1-5 – Inventory Data Sources

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

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

## 1.5 Brief description of key source categories

Key category analysis to the 2014 Portuguese inventory estimates (1990-2012) was conducted using Tier 2 approach with the LULUCF sector. Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2012 period.

The Tier 2 analysis with LULUCF resulted in the identification of 50 key categories, listed in the following table.

Table 1-6 – Summary overview of Portuguese key categories (1990-2012) based on Tier 2 approach

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category Flag	Criteria for Identification	Comments on level assessment	2012 emissions estimate (kton CO <sub>2</sub> eq.)
1A 3 b Road Transportation	All Fuels	CO <sub>2</sub>	✓	Level Trend	All years	16,185.5
1A 1 a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	✓	Level Trend	All years	10,886.7
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	✓	Level Trend	2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011	3,038.1
4 A ENTERIC FERMENTATION	Population size	CH <sub>4</sub>	✓	Level	All years	2,727.2
6 A Municipal SWDL	SWD Disposal on Land	CH <sub>4</sub>	✓	Level Trend	All years	2,626.1
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	✓	Level	All years	2,550.4
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH <sub>4</sub>	✓	Level Trend	All years	2,418.2
5 E 2 Land converted to Settlements	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	2,355.6
1A 2 f Other	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	All years	2,239.9
1A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	✓	Level Trend	2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	1,997.6
4 D a AGRICULTURAL SOILS, Direct Emissions	Input to soils	N <sub>2</sub> O	✓	Level Trend	All years	1,859.2
6 B 1 Industrial Wastewater	Wastewater	CH <sub>4</sub>	✓	Level Trend	All years	1,786.8
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	1,609.6
1A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	✓	Level	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2010, 2011	1,426.3
4 D b AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N <sub>2</sub> O	✓	Level Trend	All years	1,076.3
4 B MANURE MANAGEMENT	Animal Excretion	CH <sub>4</sub>	✓	Level	All years	1,036.0
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	✓	Trend		988.0
1A 1 a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2005	899.1
1B 2 a Oil	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	804.0
5 B 2 Land converted to Cropland	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	793.2
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	✓	Level Trend	All years	743.2
1A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	✓	Trend		666.6
1A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	✓	Trend		605.0
5 C 2 Land converted to Grassland	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	535.3
1A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	✓	Level	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007	435.0
5 D 2 Land converted to Wetlands	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	2006, 2007, 2008, 2009, 2010, 2011, 2012	404.0
1A 3 a ii Domestic	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	1990, 1995, 1996, 1997, 1998, 1999, 2007, 2008, 2009, 2010, 2012	368.0
1B 2 b Natural gas	Gaseous Fuels	CH <sub>4</sub>	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2012	353.1
2 A 2 Lime Production	Production Quantities	CO <sub>2</sub>	✓	Level Trend	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	317.5
2 A 3 Limestone and Dolomite Use	Production Quantities	CO <sub>2</sub>	✓	Level Trend	2008, 2012	237.2
6 B 1 Industrial Wastewater	Wastewater	N <sub>2</sub> O	✓	Level Trend	All years	213.6
1A 4 b Residential	Biomass	CH <sub>4</sub>	✓	Level Trend	All years	193.8
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N <sub>2</sub> O	✓	Level Trend	All years	90.2
5 B 2 Land converted to Cropland	Emissions/Removals	N <sub>2</sub> O	✓	Trend		76.1
1A 1 a Public Electricity and Heat Production	Solid Fuels	N <sub>2</sub> O	✓	Level Trend	All years	50.0
1B 2 b Natural gas	Gaseous Fuels	CO <sub>2</sub>	✓	Trend		46.3
2 F 2 Foam Blowing	Consumption	HFC	✓	Trend		45.6
1A 4 b Residential	Biomass	N <sub>2</sub> O	✓	Level Trend	All years	41.0
1A 2 f Other	Solid Fuels	CO <sub>2</sub>	✓	Level Trend	1990, 1991, 1992, 1994	35.2
1A 1 a Public Electricity and Heat Production	Biomass	N <sub>2</sub> O	✓	Level Trend	2000, 2003, 2006, 2007, 2008, 2009, 2010, 2011, 2012	26.3
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	N <sub>2</sub> O	✓	Level Trend	1999, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	23.4
1A 2 d Pulp, Paper and Print	Biomass	N <sub>2</sub> O	✓	Level Trend	2012	17.7
1A 2 f Other	Gaseous Fuels	N <sub>2</sub> O	✓	Trend		11.8
1A 1 a Public Electricity and Heat Production	Other Fuels	N <sub>2</sub> O	✓	Trend		11.7
1A 2 f Other	Biomass	N <sub>2</sub> O	✓	Level Trend	1990, 1991, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	7.4
1A 4 c Agriculture / Forestry / Fishing	Biomass	N <sub>2</sub> O	✓	Trend		7.3
2 A 6 Road Paving with Asphalt	Production Quantities	CO <sub>2</sub>	✓	Level	All years	2.8
1A 1 a Public Electricity and Heat Production	Liquid Fuels	N <sub>2</sub> O	✓	Level Trend	1992	2.2
5 A 2 Land converted to Forest Land	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	-4,606.3
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	-10,439.4
<b>Sub-total with LULUCF</b>		All gases				<b>49,825.0</b>
<b>% of total with LULUCF</b>		All gases				<b>90.1</b>
<b>TOTAL EMISSIONS WITH LULUCF</b>		All gases				<b>55,302.2</b>

## 1.6 Information on QA/QC

APA has the overall responsibility for the national inventories in Portugal, including the competence for the coordination of the Quality Assurance (QA) and Quality Control System (QC).

The inventory staff is responsible for the implementation of QA/QC procedures related to data gathering, handling, processing, documenting, archiving and reporting procedures related to the inventory, namely QC1

Each Involved Entity (IE) within the Portuguese national system (SNIERPA) contributing with data to the inventory is responsible for the quality of their own data. A request for information on

the specific QC or QA procedures is to be sent to IEs in order to document such procedures, its results and also the uncertainty calculations.

A QA/QC coordinator is designated annually in order to ensure that the objectives of the QA/QC plan are met and to guarantee the good implementation of the QA/QC procedures defined.

The QA/QC system is composed of two main elements:

- QA/QC Plan;
- Procedures Manual.

The first schedules the application of the general (QC1) and specific (QC2) as well as QA procedures, described in detail in a Manual (in Portuguese language), to be applied to defined source/sink categories. The procedures were defined according to Good Practice and Uncertainty Management Guide (IPCC, 2000) and adapted to the specific National Inventory (INERPA) characteristics.

QC1 procedures defined in the QA/QC Manual include a series of checklists, which consider basic checks on the accuracy of data acquisition processes (including, e.g, transcription errors) and checks on calculation procedures, data and parameters. It includes also cross-checking among subcategories in terms of data consistency, verification of NIR and CRF tables. Documentation and archiving procedures include checks on information handling which should enable the recalculation of the inventory.

QC2 procedures, on the other hand, include technical verifications of emission factors, activity data, comparison of results among different approaches.

Both QC1 and QC2 procedures are to be applied by the inventory team during the inventory calculation and compilation following a yearly defined QA/QC plan.

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

## **1.7 General uncertainty assessment**

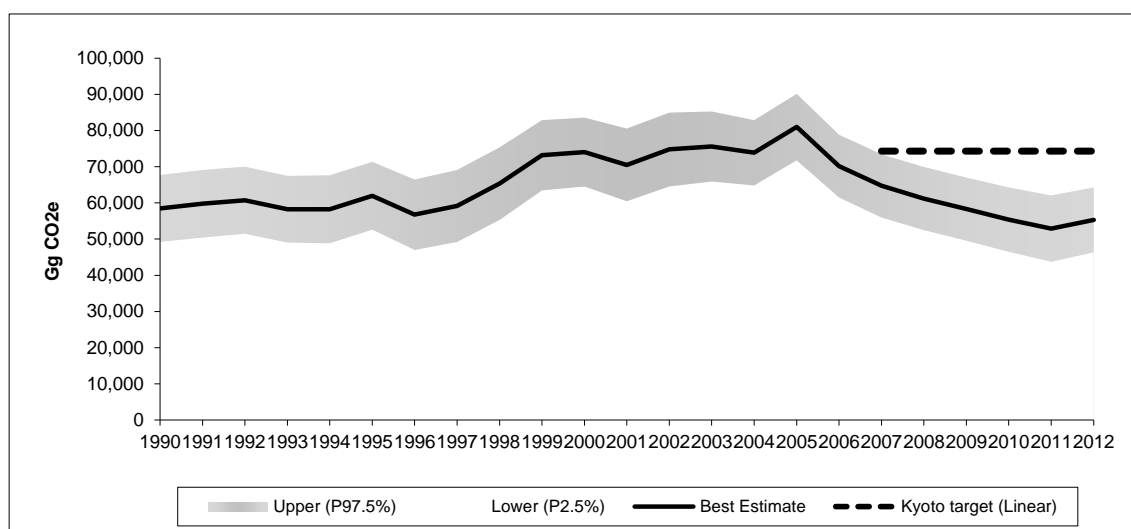
Emission estimates from the GHG inventory pretend to express the best estimate of emissions, which should not be over-estimated neither under-estimated. Nevertheless, natural variability of certain emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameters due to errors in original monitoring data, reference studies and expert judgment, all this factors lead to a certain error or level of uncertainty in emission estimates. However, the main purpose of the realization of the uncertainty assessment is not to contest the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of future inventories and guide future methodological developments. The uncertainty analysis was performed only for the direct GHG: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC and SF<sub>6</sub>, considering all emissions in CO<sub>2</sub> equivalent (CO<sub>2</sub>e). The uncertainty of all source activities was determined including the LULUCF categories.

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

The uncertainty analysis was performed using inventory data for all years from 1990 to 2012. The results are presented in the table below. The full range of emission possibilities, considering the confidence limit may be observable in Figure 1-6.

Total uncertainty varies along years from a minimum value of 11.4 per cent up to 17.3 per cent, in the period from 1990 to 2012. The uncertainty in trend from 1990 to 2012 is 13.4 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.

Figure 1-6 - Trend of total GHG emissions with LULUCF and lower and upper estimates considering the 95% confidence interval



## 1.8 Overview of the completeness

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

The inventory covers the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFC), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO<sub>x</sub>).

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

## **1.9 Future developments**

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

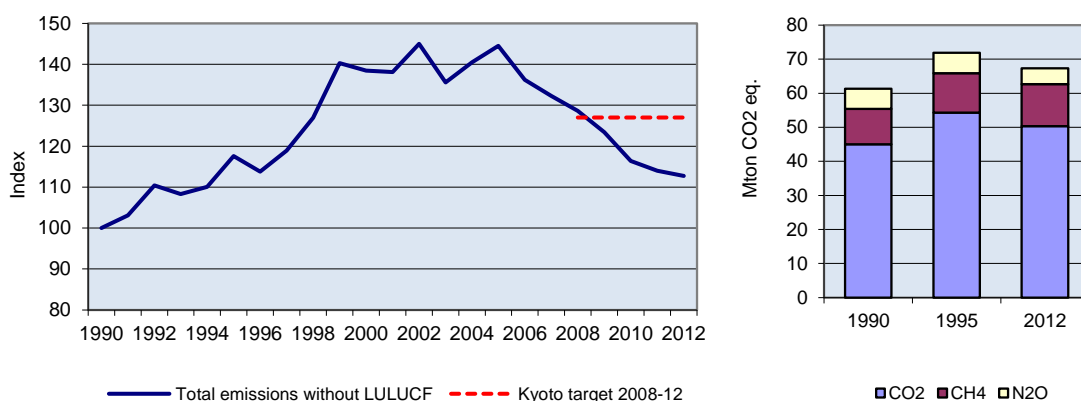


## 2 TRENDS IN PORTUGUESE GHG EMISSIONS

### 2.1 Trends of Total Emissions

In 2012, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated at about 68.8 Mt CO<sub>2</sub>e, representing an increase of 13.1 per cent compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions in the first commitment period to +27% compared to the 1990 level.

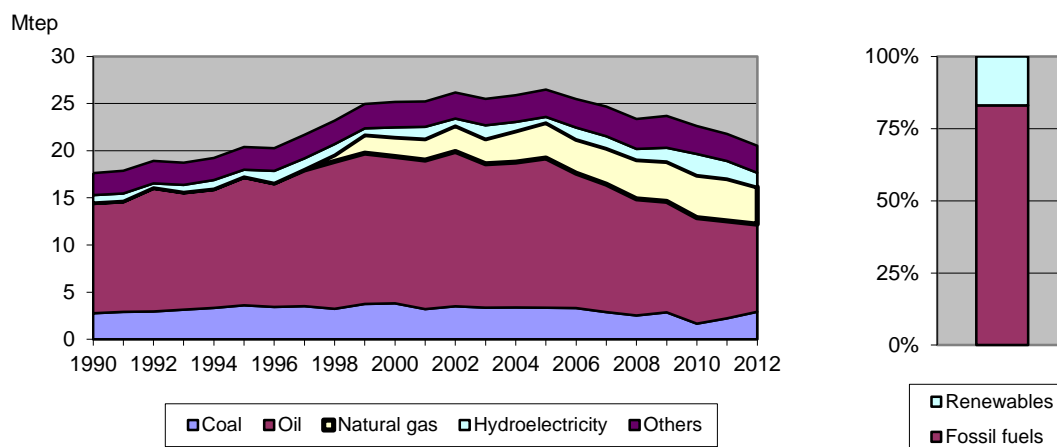
Figure 2-1– GHG emissions (without LULUCF)



Throughout the report, the reference to “total emissions” is meant to refer to “total emissions without CO<sub>2</sub> from LUCF on a carbon equivalent basis”. Furthermore the references to the base year or 1990 represent the year 1990 as estimated for this submission which is different from the assign amount (except when specify otherwise). This difference is mainly due to the revision of the time series or methodology improvements.

The principal source of GHGs in Portugal in 2012 is the energy sector. The largest gas emitted is CO<sub>2</sub> representing approximately 73 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 93 per cent of total CO<sub>2</sub> emissions. This situation is primarily related to the pattern of energy sources used in Portugal. In average, during the period 1990-2012, 83 per cent of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas) whereas the renewable energy represents the remaining part, i.e. 17 per cent in average (Figure 2-2). The situation is however changing in the most recent years, with a progressive increase of the renewable energy sources such as wind.

Figure 2-2 – Primary energy consumption trends and share of fossil/renewables in 2012

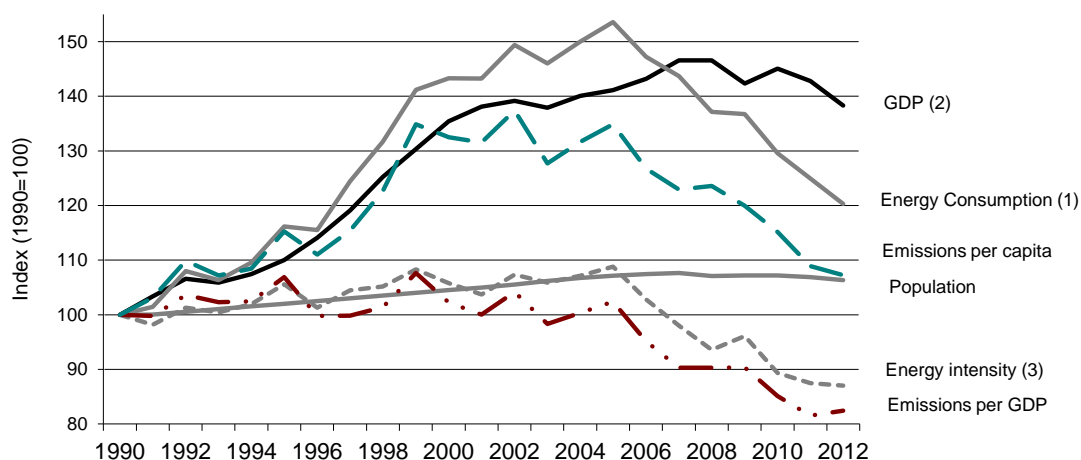


The average annual emissions growth rate for the overall period 1990-2012 is less than 1 per cent. However, as illustrated in there are roughly three different periods that can be identified in terms of the annual average rate evolution: from 1990 to 1995 3.7 per cent; from 1995 to 1999 4.7 per cent, and since 2000 a more moderate increase and a decreasing tendency since 2005 can be recognized.

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

During the 1990s Portugal experienced a significant economic growth with an increase in GDP of about 38 per cent in the period 1990-2012, corresponding to an average annual increase of 1.7 per cent. The most rapid growth occurred from the years 1993 to 2000, where the average annual growth rate reached the 4.0 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) GDP at 2005 prices; (3) Energy Consumption per GDP.

Sources: INE, DGEG.

During the period analyzed, the country has achieved a decoupling of emission trends from economic growth, in particular for the most recent years. The decrease of carbon intensity (GHG emissions per GDP unit) observed in the recent years (see previous figure), is surely related to the implementation of some important measures that had a positive effect in the emissions levels, such as the introduction of natural gas (1997), the installation of 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. Furthermore, in most recent years there has been an expressive development of renewable energy sources with a particular expansion of windmills. Another fact to note is the introduction of the use of high-performance catalysts and optimization of the ratio ammonia / air in the production of nitric acid which had an influence in the decrease of emissions.

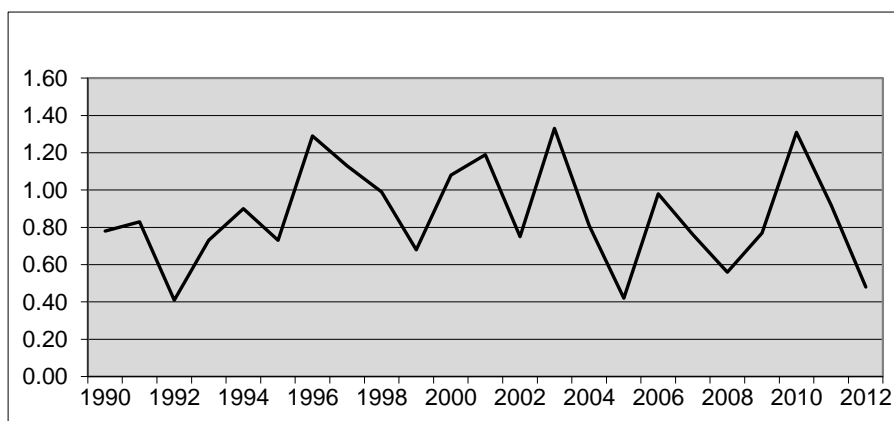
The tendencies of the latest years reflect also the recession effect of the Portuguese economy, which has been accompanied by the slowdown of industrial activity and consequent reduction in fuel consumption, and the cessation of some activities in the country such as the production of ammonia in 2009 with the relocation of the production facilities to India.

In the years 2011 and 2012 there has been a decrease in the consumption of electricity in Portugal, fact that may be explained by the austerity measures and the general implementation of the financial assistance Program under IMF and EU, as well as the current European economic and financial crisis.

The level of emissions shows significant inter-annual variations, which are related to the pronounced fluctuations of hydroelectric power generation that is highly affected by annual variations in precipitation. The year 2003 had a higher value of total annual water availability (hydraulic index (HI) of 1.33, meaning that it rained 33% more than an average hydrologic year) (see Figure 2-4) which has allowed a considerable increase of hydroelectric power production and the subsequent reduction in CO<sub>2</sub> emissions from electricity production in thermal plants

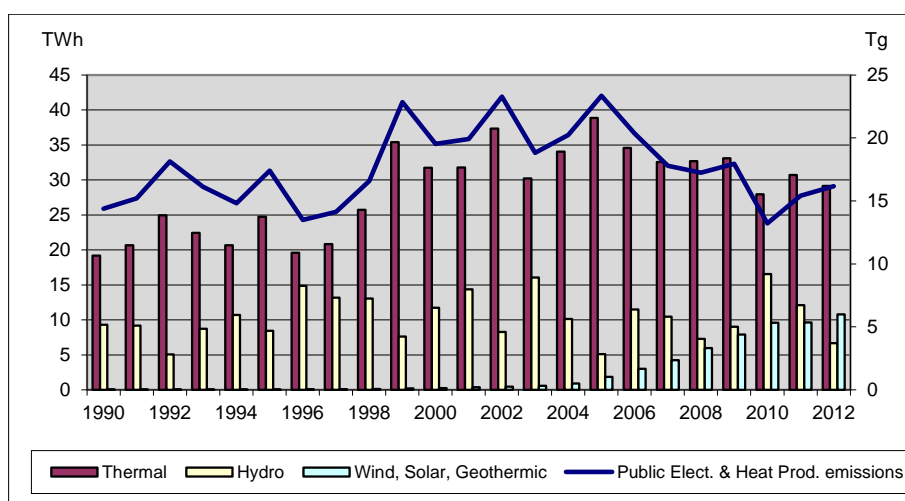
(see Figure 2-5). As compared to 2003, hydroelectric power production decreased in 2004 (HI of 0.81) and 2005 leading to the increase in GHG emissions. The year 2005 recorded in fact one the lowest figures on record concerning water availability (HI of 0.42), which resulted in a significant increase in fossil fuel consumption and consequently on emissions. The latest years 2007 to 2009 present nevertheless a change in this relation, since the precipitation was lower (HI/2007=0.76, HI/2008=0.56, HI/2009=0.77) than the previous year (HI/2006= 0.98) and the emissions from the energy sector were lower these years. This is due to a conjunction of factors as the decrease in the primary energy consumption, the bigger importance of electricity importation, the proliferation of renewable and low-carbon fuels. In the most recent years this tendency has been accentuated by the slowdown of industrial activity and the consequent reduction of fuel consumption. The hydrological conditions throughout 2012 were extremely unfavourable, with a hydro capability factor of only 0.48, leading to the increase of production at thermal power stations using more coal as compared to prior periods. This situation was accentuated by the low prices of coal face to natural gas, with a reflection on the increase of emissions.

Figure 2-4 – Hydraulic index



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

Figure 2-5 – Gross electric power production and emissions from electricity and heat generation



Source: DGGE.

## 2.2 Trends by Gas

Over the 1990-2012 period, CH<sub>4</sub> is the gas having registered the biggest increase (20.1%) and N<sub>2</sub>O decreased by about 19.5%.

Figure 2-6 – Change of GHG emissions by gas over the period 1990-2012

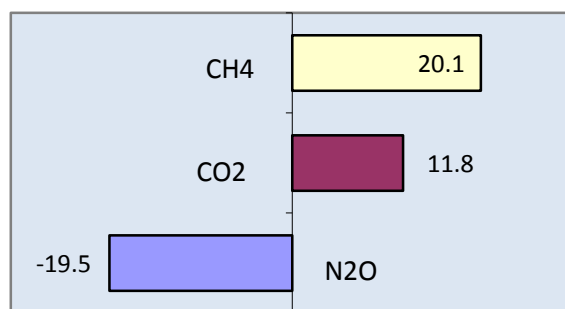


Figure below illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2012, being evident CO<sub>2</sub> as the primary GHG, accounting for about 73.2% of Portuguese emissions on a carbon equivalent basis in 2012 (LULUCF excluded). The second most important gas is CH<sub>4</sub>, followed by N<sub>2</sub>O, representing, respectively, 17.8% and 6.5% of total emissions in 2012. Portugal has chosen 1995 as the base year for fluorinated gases. In 2012 these gases represented about 2.5% of total GHG emissions.

Figure 2-7 – GHG emissions by gas

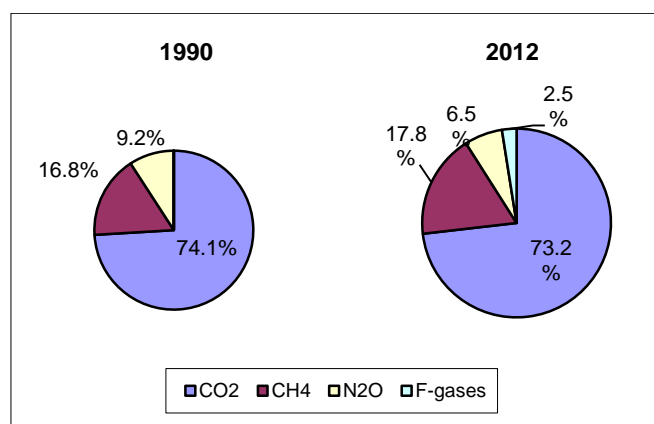


Table 2-1 – GHG emissions and removals in Portugal by gas

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO <sub>2</sub> equivalent (Gg)												
CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF	42,152	43,142	44,228	41,773	41,322	44,444	39,085	41,392	46,989	54,563	55,376	51,852
CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF	45,013	46,688	50,961	49,660	50,320	54,346	51,720	54,579	59,131	66,877	65,746	65,449
CH <sub>4</sub> emissions including CH <sub>4</sub> from LULUCF	10,386	10,697	10,701	10,734	11,149	11,584	11,441	11,596	12,175	12,298	12,234	12,402
CH <sub>4</sub> emissions excluding CH <sub>4</sub> from LULUCF	10,203	10,451	10,622	10,668	11,042	11,356	11,357	11,562	11,995	12,203	12,069	12,304
N <sub>2</sub> O emissions including N <sub>2</sub> O from LULUCF	5,939	5,910	5,821	5,756	5,775	5,915	6,171	6,117	6,063	6,126	6,189	5,924
N <sub>2</sub> O emissions excluding N <sub>2</sub> O from LULUCF	5,551	5,544	5,522	5,493	5,528	5,664	5,971	5,949	5,886	5,976	6,033	5,790
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	27	42	61	86	157	243	318
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	0	0	0	0	0
SF <sub>6</sub>	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	7	7	9	9	10	10	11
<b>Total (including LULUCF)</b>	<b>58,478</b>	<b>59,750</b>	<b>60,750</b>	<b>58,263</b>	<b>58,246</b>	<b>61,975</b>	<b>56,745</b>	<b>59,174</b>	<b>65,322</b>	<b>73,155</b>	<b>74,051</b>	<b>70,506</b>
<b>Total (excluding LULUCF)</b>	<b>60,767</b>	<b>62,683</b>	<b>67,105</b>	<b>65,821</b>	<b>66,890</b>	<b>71,399</b>	<b>69,096</b>	<b>72,159</b>	<b>77,107</b>	<b>85,224</b>	<b>84,100</b>	<b>83,872</b>

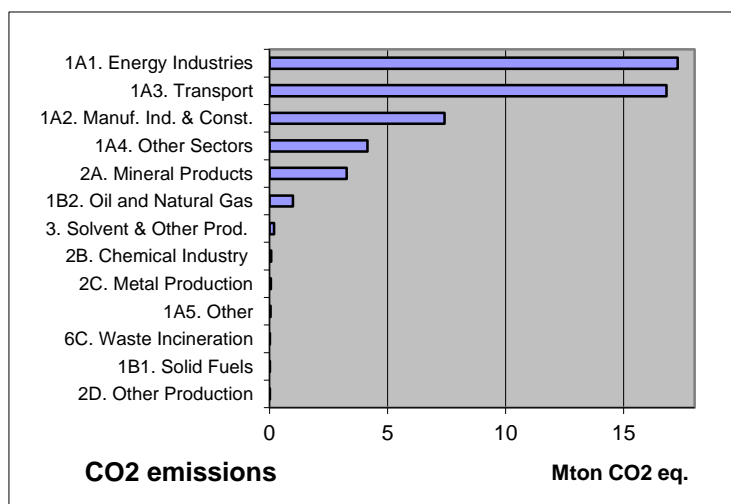
GHGs EMISSIONS	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	% change 1990-12
CO <sub>2</sub> equivalent (Gg)												
CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF	55,677	56,467	55,028	61,827	51,962	46,216	42,885	40,342	37,028	34,609	36,583	-13.2
CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF	69,236	64,071	66,716	69,234	64,623	61,899	59,793	57,019	52,492	51,155	50,310	11.8
CH <sub>4</sub> emissions including CH <sub>4</sub> from LULUCF	12,685	13,095	12,569	12,955	12,234	12,124	12,043	11,860	12,058	12,167	12,419	19.6
CH <sub>4</sub> emissions excluding CH <sub>4</sub> from LULUCF	12,530	12,444	12,443	12,458	12,140	12,083	12,023	11,808	11,923	12,113	12,250	20.1
N <sub>2</sub> O emissions including N <sub>2</sub> O from LULUCF	5,981	5,482	5,577	5,415	5,118	5,361	5,134	4,827	4,905	4,595	4,588	-22.8
N <sub>2</sub> O emissions excluding N <sub>2</sub> O from LULUCF	5,845	5,254	5,465	5,232	5,021	5,282	5,065	4,749	4,808	4,513	4,479	-19.3
HFCs	416	542	649	736	836	968	1,115	1,237	1,368	1,493	1,667	-
PFCs	0	0	0	0	0	0	0	0	0	NA,NO	NA,NO	-
SF <sub>6</sub>	10	16	26	26	26	37	36	41	44	44	45	-
<b>Total (including LULUCF)</b>	<b>74,769</b>	<b>75,603</b>	<b>73,849</b>	<b>80,959</b>	<b>70,176</b>	<b>64,706</b>	<b>61,212</b>	<b>58,307</b>	<b>55,402</b>	<b>52,908</b>	<b>55,302</b>	-5.4
<b>Total (excluding LULUCF)</b>	<b>88,038</b>	<b>82,328</b>	<b>85,299</b>	<b>87,686</b>	<b>82,647</b>	<b>80,269</b>	<b>78,032</b>	<b>74,854</b>	<b>70,634</b>	<b>69,317</b>	<b>68,752</b>	13.1

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

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

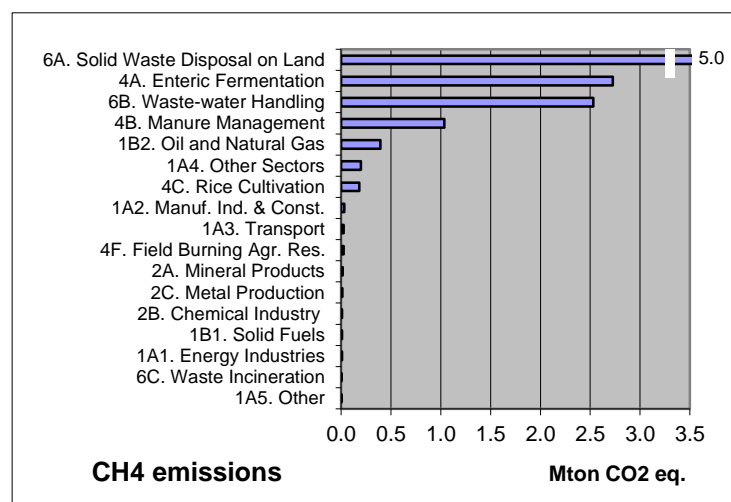
The largest GHG gas emitted is CO<sub>2</sub> which is mainly generated from fossil fuel combustion in energy-related activities (IPCC categories 1). Some other non-energy production processes, such as cement production (included in category 2A), are also responsible for considerable quantities of CO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

Figure 2-8 – 2012 sources categories of CO<sub>2</sub>



CH<sub>4</sub> is primarily generated through anaerobic decomposition of organic matter in biological systems, like decomposition of municipal and animal wastes, waste-water handling systems, or enteric fermentation in animals. Other sources are also responsible for these emissions, such as biomass burning, the distribution of natural gas and petroleum, and the incomplete fossil fuel combustion.

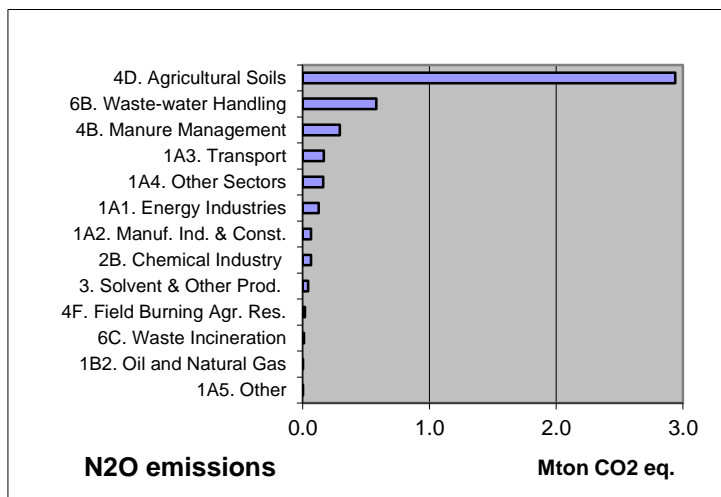
Figure 2-9 – 2011 sources categories of CH<sub>4</sub>



N<sub>2</sub>O emissions are associated with direct and indirect emissions from agricultural soils, mainly related to the use of synthetic and manure fertilizers, manure deposition by livestock, nitrogen fixation by N-fixing crops (leguminous plants), and incorporation of crop residues into soils. Other significant sources are fossil fuel combustion particularly in the transport sector, chemical

industry (nitric acid production), wastewater treatment, and biomass burning (agricultural residues and residential combustion, and waste incineration).

Figure 2-10 – 2011 sources categories of N<sub>2</sub>O



## 2.3 Trends by Sector

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

Emissions have risen for all the sectors with the exception of Agriculture and Solvents Use (Figure 2-11, Table 2-2).

Figure 2-11 – GHG emissions and removals by sector

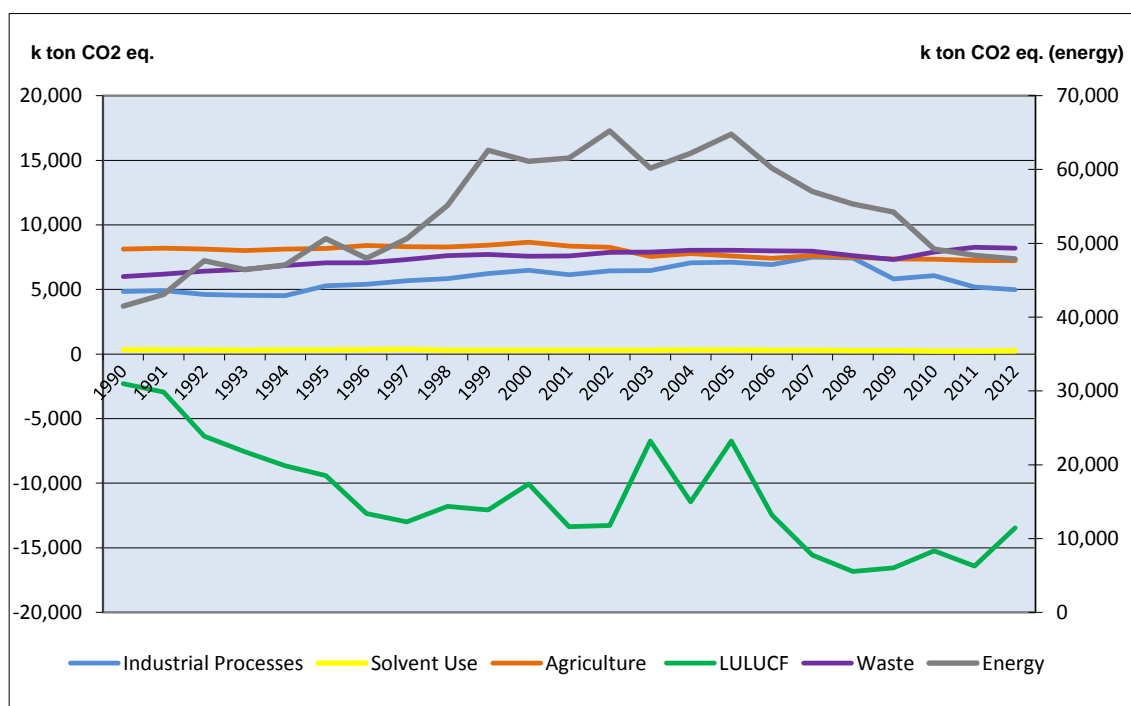




Figure 2-12 – GHGs emissions percentage change (1990-2012) by IPCC category (LULUCF excluded)

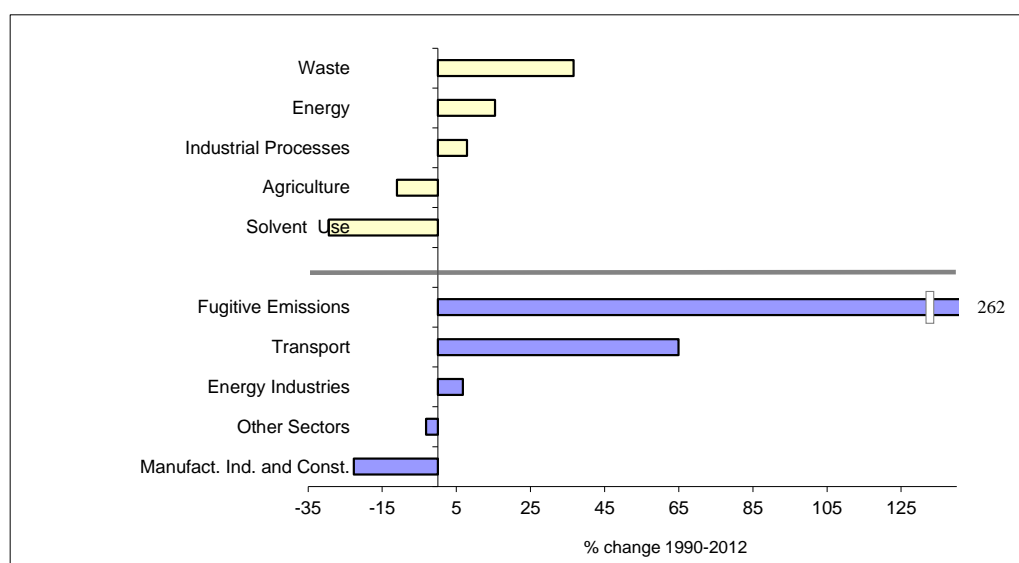


Table 2-2 – GHG emissions and removals by sector

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO <sub>2</sub> equivalent (Gg)												
1. Energy	41,506	43,066	47,648	46,421	47,088	50,639	47,993	50,630	55,142	62,609	61,137	61,551
2. Industrial Processes	4,834	4,908	4,623	4,547	4,532	5,242	5,344	5,606	5,758	6,175	6,418	6,040
3. Solvent and Other Product Use	317	319	304	287	289	281	298	308	314	313	314	315
4. Agriculture	8,119	8,201	8,125	8,002	8,125	8,175	8,398	8,303	8,277	8,421	8,663	8,364
5. Land-Use Change and Forestry <sup>(7)</sup>	-2,289	-2,933	-6,355	-7,558	-8,643	-9,423	-12,351	-12,985	-11,785	-12,068	-10,049	-13,366
6. Waste	5,992	6,190	6,405	6,565	6,855	7,062	7,062	7,313	7,616	7,706	7,568	7,603
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Total (including LULUCF)(5)</b>	<b>58,478</b>	<b>59,750</b>	<b>60,750</b>	<b>58,263</b>	<b>58,246</b>	<b>61,975</b>	<b>56,745</b>	<b>59,174</b>	<b>65,322</b>	<b>73,155</b>	<b>74,051</b>	<b>70,506</b>

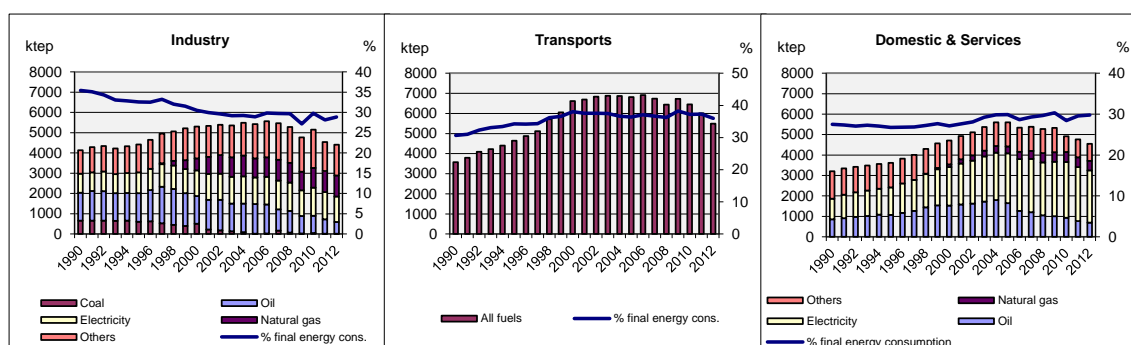
GHGs SOURCE AND SINK CATEGORIES	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	% change 1990-12
CO <sub>2</sub> equivalent (Gg)												
1. Energy	65,259	60,201	62,209	64,786	60,169	57,038	55,342	54,242	49,231	48,373	47,897	15.4
2. Industrial Processes	6,330	6,368	6,984	6,999	6,797	7,373	7,292	5,684	5,929	5,199	5,213	7.8
3. Solvent and Other Product Use	316	303	291	283	282	283	268	252	253	245	233	-26.7
4. Agriculture	8,260	7,558	7,789	7,584	7,410	7,606	7,501	7,359	7,337	7,241	7,224	-11.0
5. Land-Use Change and Forestry <sup>(7)</sup>	-13,269	-6,725	-11,449	-6,727	-12,471	-15,564	-16,819	-16,547	-15,232	-16,409	-13,450	487.6
6. Waste	7,873	7,898	8,025	8,034	7,990	7,969	7,629	7,316	7,884	8,259	8,185	36.6
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-

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

Energy is by far the most important sector, accounting for 69.7 per cent of total emissions in 2012, and presenting an increase of 15 per cent over the 1990-2012 period. Transport and energy industries are the two most important sources representing each one, 25% of total emissions. Within the energy industries, public electricity and heat production represents alone approx. 22% of the total emissions. This reflects the country important dependence on fossil fuels for electricity generation and transportation, which have grown steadily until the mid-2000s due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the growth of mobility. The situation seems to have changed in the most recent years, where we can observe stagnation and decrease of these trends.

The sectoral evolution of energy consumption presented in the next figure, shows that the sectoral structure of the energy demand has been changing. The share of the industrial sector, which represented in 1990, 35 per cent of the final energy demand, decreased to 29 per cent in 2012. On the other hand, as previously mentioned, transports have been increasing importance, having raised from 31 per cent in 1990 to 38 per cent of the final energy consumption in the early 2000s. The increase of energy consumption of this sector was 91 per cent from 1990 to 2005, but a reduction was registered since then (-19% 2005-2012 period). Also, the services is one of the sectors that have increased the most, having registered approx.. a 200 per cent rise of energy consumption from 1990 to 2005, and having register a reduction of 20 per cent from 2005 to 2012. In 2012, this sector, together with the domestic sector, represented 30 per cent of the share of the total energy consumed.

Figure 2-13 – Final energy consumption by main sectors and fuel



Mobile sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. The overall energy consumed for transportation is supplied by petroleum-based products, with nearly one third being gasoline (29 per cent in 2004). This fuel has been losing relatively importance since 1990, when the share was 40 per cent of the sectoral energy consumption. In the period 1990-2002 the emissions of transportation sources increased 97 per cent, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel from 1990 to the early 2000s, reflecting the increase in family income and the strong investment in the road infrastructure of the country in the 1990s decade. Indirectly the increase in road traffic activity also augments the emissions from fossil fuel storage, handling and distribution. As previously said, the situation seems to have stabilized in the early 2000s and then started to decline since 2005. In the years from 2005 to 2012 the emissions of transport reduced approx. 15 per cent.

Still within the energy sector, the category “other sectors”, which include the residential and commercial activities, also registered a significant increase of emissions in the 1990-2005 period (with almost 55.5 per cent rise), but this tendency has decelerated (a reduction of 3 per

cent was registered in the 1990-2012 period), due to a certain extent to the stagnation of the economic growth, and also to other factors as energy conservation measures.

Agriculture, was in the period analyzed, one of the most significant sources of GHG emissions, and was responsible for 10.5 per cent of the Portuguese emissions in 2012, corresponding to a decrease of 11.0 per cent since 1990. This fact is related to the relatively decrease of importance of the sector in terms of the national economy, and is associated for instance with the reduction of the livestock production of certain categories of animals (e.g. swine), the extensification of cattle production and the decrease of fertilizer consumption.

Waste represented approximately 12 per cent of Portuguese emissions in 2012, recording an increase of approximately 37 per cent since 1990. This increase in emissions is primarily related to the rise of waste generation (associated with development of the family income and the urbanization growth registered in the country during the last decade) and the deposition of waste in landfills.

Industrial processes represented 7 per cent of the Portuguese emissions in 2012, and have grown 8 per cent since 1990. These emissions which are generated as by-product of many non-energy-related activities, are mostly related to the increase of cement production, road paving, limestone and dolomite use, lime production, glass and ammonia production.

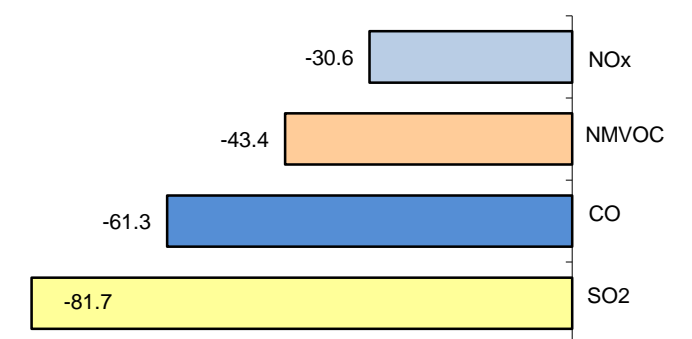
Solvent use represents less than 1 per cent of total emissions, and is mainly related to NMVOC emissions<sup>3</sup>.

Estimates of emissions and sinks from land use change and forestry category suffered a revision for this 2014 submission. The sector is estimated to be a net sink in the 2012, representing a sequester of -13.5 Mt CO<sub>2</sub>e. in 2012.

## 2.4 Indirect GHG and SO<sub>x</sub> emissions

Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO<sub>x</sub>, and NMVOC are precursor substances for ozone which is a GHG. SO<sub>x</sub> produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Figure 2-14 – Indirect GHG and SO<sub>x</sub> emissions: 1990-2012 variation



<sup>3</sup> These are converted into ultimate carbon dioxide after being emitted to atmosphere.

In 2012, all these gases emissions have decreased from 1990 levels: SO<sub>x</sub> -81.7 per cent, CO -61.3 per cent, NMVOC -43.4 per cent and NO<sub>x</sub> -30.6 per cent per cent (following table).

Energy is the major responsible sector for emissions of NO<sub>x</sub>, SO<sub>x</sub> 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<sub>x</sub> emissions, 45.8 per cent of 2012 totals. Despite the fast growing trends of the transport sector (mainly road) since the 90s, the introduction of new petrol-engine passenger cars with catalysts converters and stricter regulations on diesel vehicles emissions, limited the growth of these emissions or even its decrease. In fact, the situation started to change in the last years, as transport emissions growth has first stabilised and started to decline in the most recent years. Since the early 2000s, NO<sub>x</sub> emissions from transport has been presenting a decreasing tendency; and CO and NMVOC emissions recorded real reductions in the 1990-2012 period, respectively, -81 per cent and -54 per cent.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 41 per cent of the 2012 totals.

SO<sub>x</sub> emissions are mainly generated in the energy industry sector (approximately 39 per cent of total emissions in 2012) and combustion in manufacturing industries (approximately 34 per cent of total emissions in 2012), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. The situation is however improving with a significant development of renewable sources (mainly wind) and energy efficiency measures, among other factors as reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 from November 10<sup>th</sup>). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO<sub>x</sub> emissions. The emissions variation in the period 1990-2012 shows in fact a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries and manufacturing industries -89 per cent and -73 per cent. Since 2007, SO<sub>x</sub> emissions from the energy industries registered a significant reduction (approximately -78 per cent) which is explained by the implementation of two new abatement systems (desulfurization in two Large Point Source Energy Plants in Mainland Portugal).

Table 2-3 – Indirect GHG and SOx emissions: 1990-2012

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
(Gg)												
CO	812	826	862	842	824	817	806	768	756	728	681	600
NOx	245	256	275	266	266	277	264	263	271	278	274	273
NM VOC	309	312	316	303	301	295	294	293	290	283	269	255
SO2	324	315	376	320	295	331	273	288	335	303	263	250

Gas emissions	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	% change 1990-12
(Gg)												
CO	582	546	517	479	445	422	406	380	374	348	315	-61.3
NOx	280	257	263	268	247	242	216	204	189	179	170	-30.6
NM VOC	251	234	227	215	209	204	197	185	187	180	175	-43.4
SO2	249	191	193	194	170	163	114	79	70	64	59	-81.7

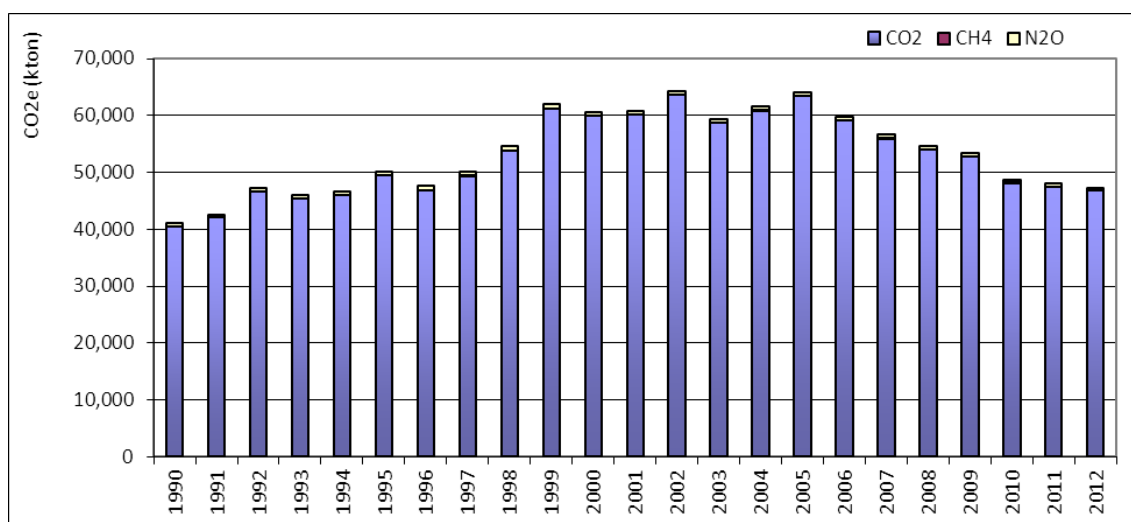
### 3 ENERGY (CRF 1.)

#### 3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting in 2012 for 69.7 per cent of total emissions of CO<sub>2</sub>e excluding LULUCF. Total emissions from this sector have increased 15.4 per cent from base year to last year, although the rise in emissions did not occur in a continuous manner. Thus, the year with maximum emissions occurred in 2002, as may be seen in Figure 3.1. The oscillations in CO<sub>2</sub>e emission for the energy sector are mainly due to inter-annual variation in availability of hydropower. In recent years there has been a decreasing trend in emission resulting not only from a period of economic stagnation in Portugal but also with the implementation of measures that had a positive impact in the reduction of emissions, such as the introduction of lower carbon intensive fuels, the installation of combined cycle thermoelectric plants and co-generation units, and the use of renewable energy sources.

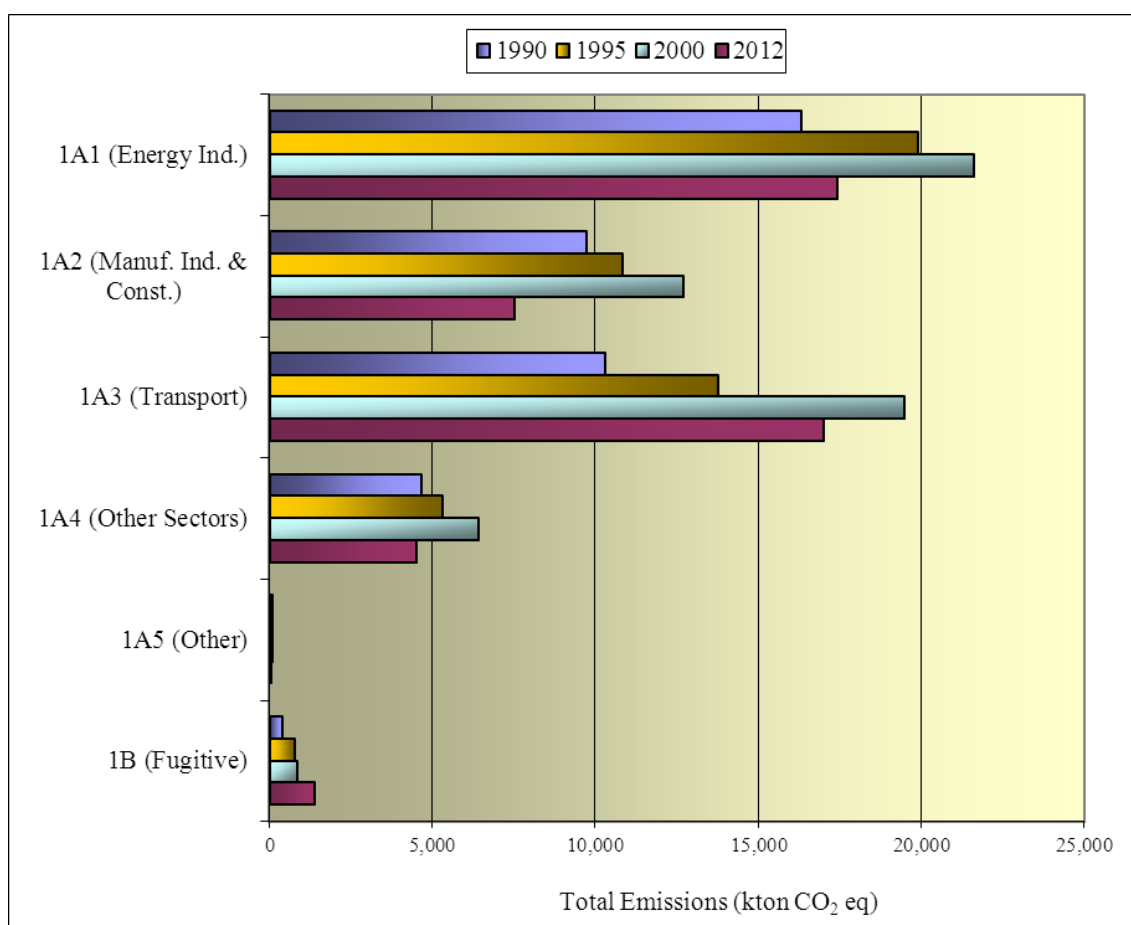
The relative importance of total CO<sub>2</sub>e emissions from the Energy sector has increased, from 68.3 per cent in 1990 to 69.7 per cent in 2012. By far the most important gas emitted by this sector in 2012 is CO<sub>2</sub>, with 97.5 per cent of sector emissions expressed in CO<sub>2</sub>e.

Figure 3-1 – Total CO<sub>2</sub>e emissions from the Energy Sector (CRF 1)



Considering the importance of each of the sub-sectors, which are presented in Figure 3.2, it is clearly visible the dominance of emissions from the Energy Industry (1A1) and from Transportation activities (1A3). It is also clear the accentuated increase that emissions from this last category have suffered during the period from 1990 till 2000, and the decrease in emission for all sector from 2000 to 2011 (except for 1B). The Energy Industry the Manufacturing Industries and Construction sectors represent, in terms of absolute values, the biggest decrease in emission from 2008 to 2011.

Figure 3-2 – Importance of CO<sub>2</sub>e emissions from sub-sectors in Energy sector in selected years – 1990, 1995, 2000 and 2012.



### 3.1.1 Fuel Combustion Activities (CRF 1.A.)

Energy emissions are primarily related to fossil fuel combustion. In Portugal transport and public electricity and heat production industries were the primary sources of Portuguese GHG emissions, representing, respectively, 23.8 per cent and 22.2 per cent of total GHG emissions excluding LULUCF in year 2012. 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 6.6 per cent of total emissions in 2012. GHG emissions from Refining of Petroleum Products is another relevant source with 3.1 per cent of total emissions for this sector. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 6.6 per cent of total sector emissions. Emissions for each sector in selected years are presented in Figure 3.3, and the full time trend in Figure 3.4.

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



Figure 3-3 – Total GHG emissions in source 1A, expressed as CO<sub>2</sub>e, in 1990, 1995, 2000 and 2012

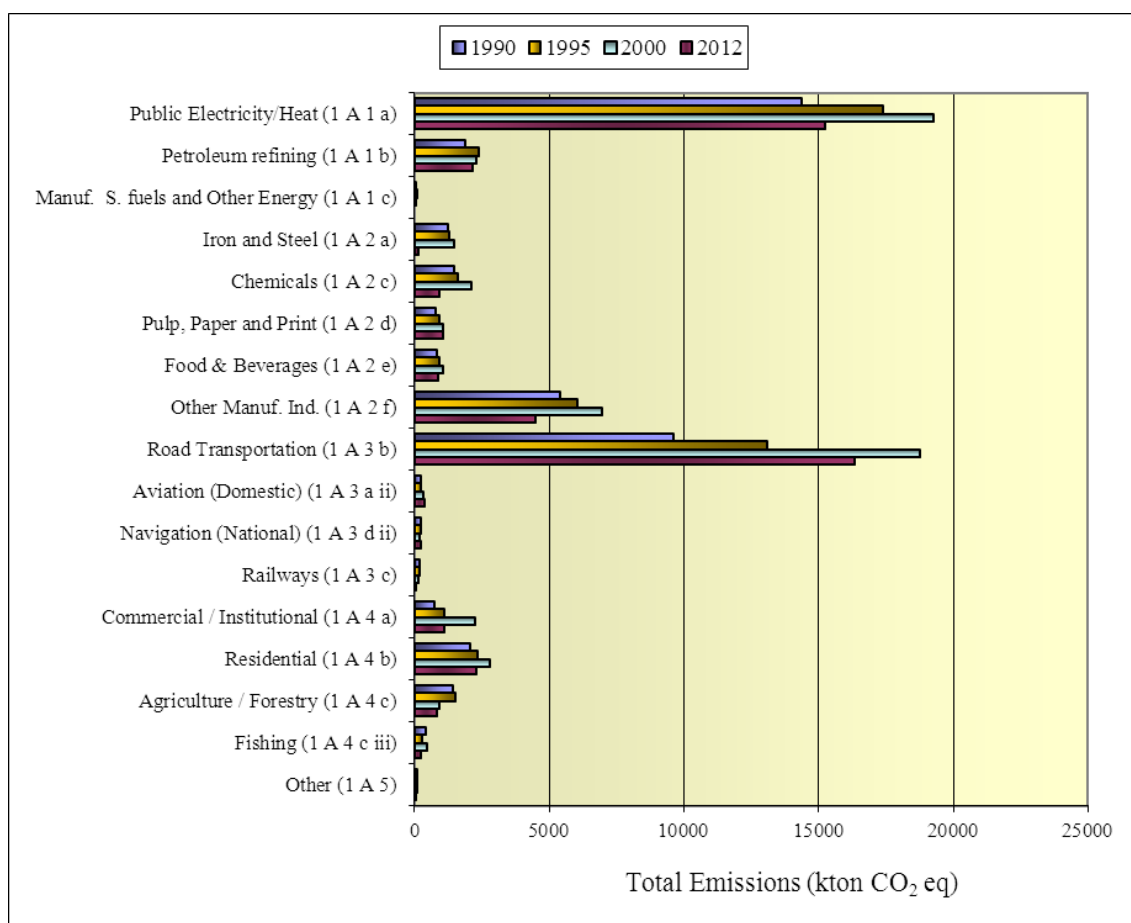
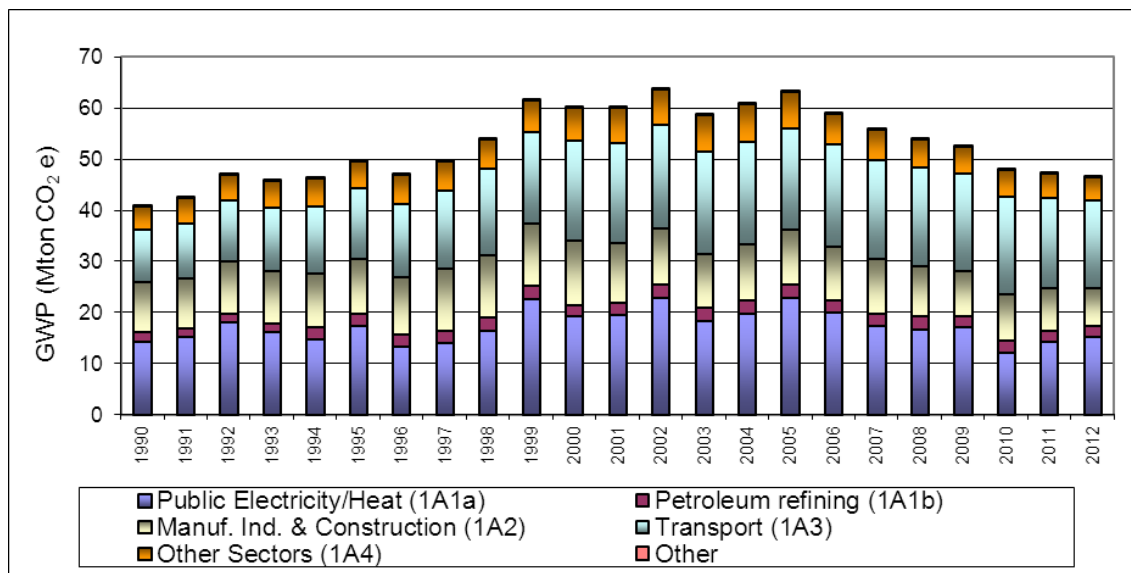


Figure 3-4 – Trend of total GHG emissions in source 1A, expressed as CO<sub>2</sub>e, by sub-sector



GHG emissions from this activity sector are almost fully dominated by direct CO<sub>2</sub> emissions, which represent about 98.3 per cent of GHG emissions in 2012. CH<sub>4</sub> and N<sub>2</sub>O are minor sources, respectively 0.6 per cent and 1.1 per cent of total GHG emissions from the 1 A sector in 2012.

CO<sub>2</sub> emissions are dependent on the carbon content of the fuel used and, for this reason, estimates of CO<sub>2</sub> 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 CH<sub>4</sub>, CO, NMVOC and airborne particulate matter. It is presumed that all these other carbon containing non-CO<sub>2</sub> gases oxidise to CO<sub>2</sub> in the atmosphere and are include in carbon dioxide estimates (ultimate CO<sub>2</sub>)<sup>4</sup>.

Emissions from fossil fuel combustion include also other atmospheric contaminants such as N<sub>2</sub>O, NO<sub>x</sub>, SO<sub>x</sub>, NH<sub>3</sub>, particulate matter, heavy metals and toxic organic compounds. Unlike CO<sub>2</sub>, emissions estimates of these air contaminants require more detailed information, such as operating conditions, combustion and emission control technologies and fuel characteristics.

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

Biomass combustion also generates gas emissions. Carbon dioxide emissions from this source are estimated in the inventory but not included in national emissions totals being considered that there are no net emissions of CO<sub>2</sub>, as carbon released during biomass combustion had

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

been in fact fixed from atmosphere by the photosynthetic process and when is burnt and returns to atmosphere does not increase the atmospheric/biosphere CO<sub>2</sub> pool. This activity is reported separately for information purposes only. Nevertheless non-CO<sub>2</sub> emissions from combustion of biofuels and other biomass fuels are however considered in inventory totals.

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

Apart from fuel combustion emissions, the Energy sector includes also other from production, transmission, storage and distribution of fossil fuels. Generated gases from these sources are CO<sub>2</sub>, NMVOC, SO<sub>x</sub>, CH<sub>4</sub>, NO<sub>x</sub> and CO, and emissions per sub-sector source are presented in Figure 3-5 where the major importance of emissions due to oil refining, transport and distribution for the beginning of the period may be seen, while the importance of emissions from storage and transportation of natural gas, became more relevant in recent years.

GHG emissions occurring as CO<sub>2</sub> are responsible for 70.8 per cent of 1B total emissions in 2011, emissions occurring as CH<sub>4</sub> represent 29.0 per cent of 1B total emissions and N<sub>2</sub>O represent only 0.2 per cent. Emissions by gas are represented in Figure 3-6.

Figure 3-5 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>e, by sub-sector

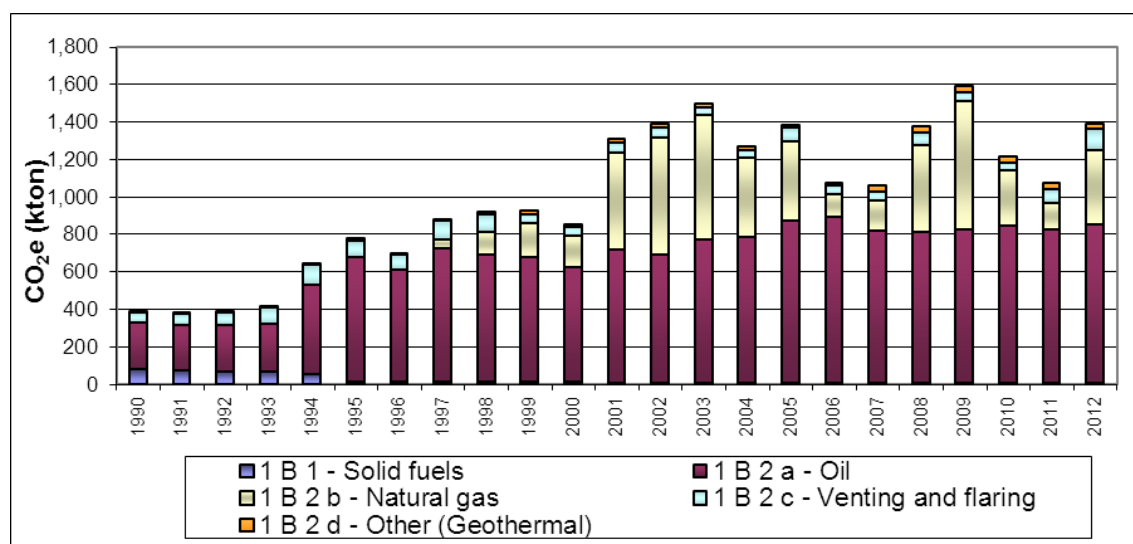
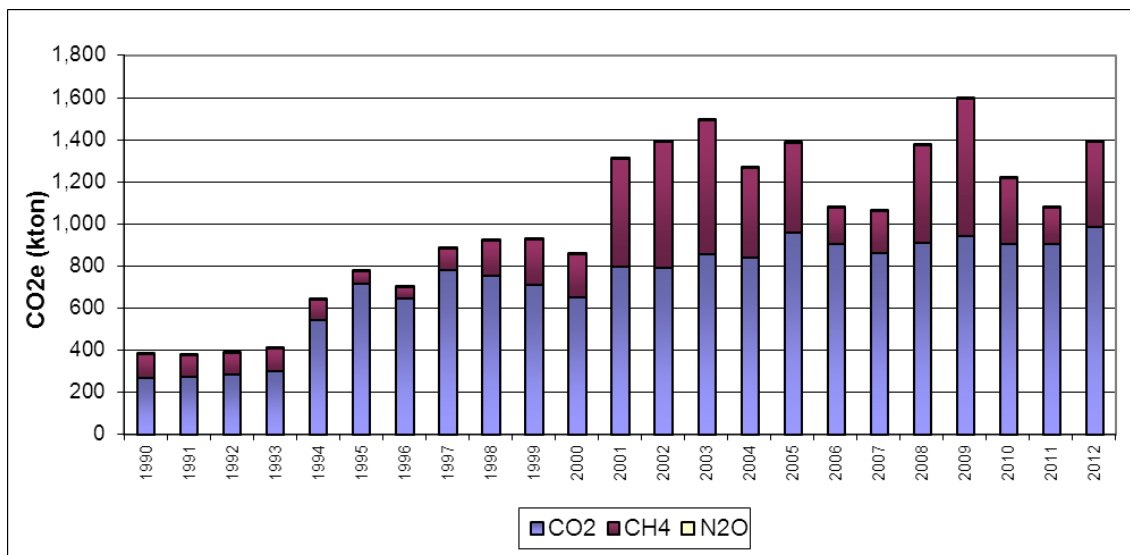


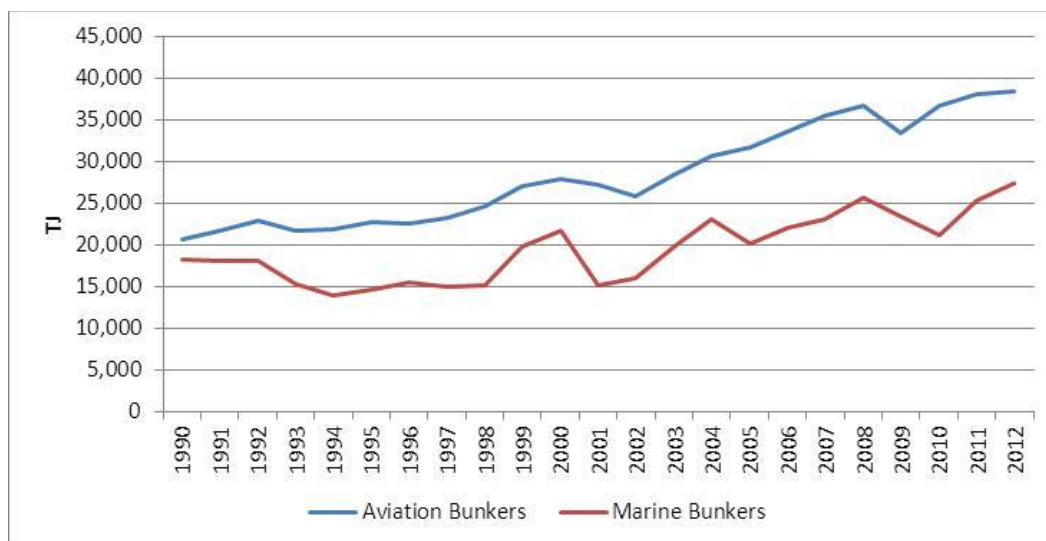
Figure 3-6 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>e, by GHG



### 3.2 International Bunker Fuels

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

Figure 3-7 – International navigation and aviation bunkers



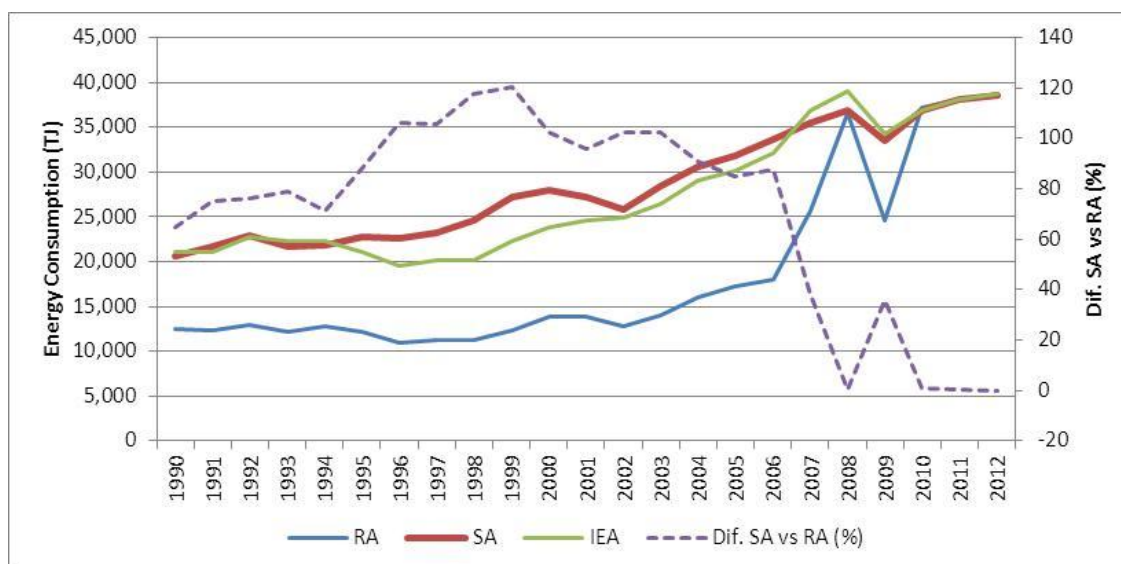
### 3.2.1 International aviation bunkers

The majority of jet fuel is used for international aviation. In 2012 the quantity of jet fuel for international aviation was about 88% of total jet fuel. This percentage was estimated according with the origin and destiny of the flight as recommended by 2006 IPCC guidelines.

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

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

Figure 3-8 – International aviation bunkers

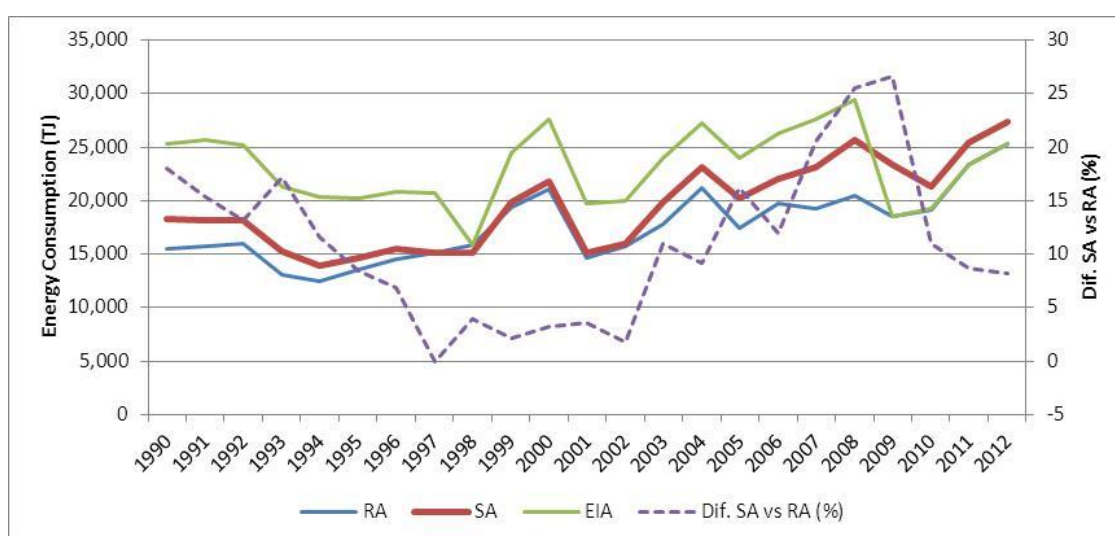


### 3.2.2 International marine bunkers

In 2012 the energy consumption for international navigation was about 90% of the total energy used in marine navigation. This percentage was estimated according with the origin and destiny of the flight as recommended by 2006 IPCC guidelines.

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

Figure 3-9 – International marine bunkers



### 3.3 Category Sources

#### 3.3.1 Energy Industries

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

###### 3.3.1.1.1 Overview

Until 1950 electric energy production in Portugal was based in small power plant units using coal as energy source. In the 50s increase in the demand for industry consumers induced the development of hydro-electric production units and the built of *Tapada do Outeiro* power plant using low energy coal (lignite) obtained from Portuguese mines. The next decade saw the entrance of petroleum products as the main energy sources, and three additional power plants were built: *Carregado*, *Barreiro* and *Setúbal*. After the energy crisis of 1973/74 and 1979/81 there was a political shift towards the preference for imported coal (*Sines* and *Pêgo* power plants, started in 1985 and 1993 respectively) and, more recently, towards natural gas (*Turbogás* power plant already in operation and the new TER<sup>5</sup> 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 producers<sup>6</sup>.

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

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

###### 3.3.1.1.1.1 *Large Point Source Energy Plants in Mainland Portugal*

The number of Large Point Source Energy Plants (LPS-EP) in continental Portugal has increased from 6 units in 1990 to 20 units at present. Power plants and installed power are listed in table below together with their main relevant characteristics.

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<sup>5</sup> TER – Termoelétrica do Carregado

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

**Table 3-1 – Large Point Sources in the sector of Public Electricity and Heat Production**

<b>Power Plant</b>	<b>Location</b>	<b>Start</b>	<b>Situation</b>	<b>Fuel***</b>	<b>Power</b>	<b>Technology</b>	<b>Treatment of Gas Effluents****</b>	<b>Stack Height (m)</b>	<b>Comments</b>
Tapada do Outeiro	Gondomar	1959	Deactivated (2003)	LIG + FO	150/100/47* MWe	Boiler + Steam Turbine.	ESP	60 (x3)	Lignite use stopped in 1997
Portgen (new Tapada do Outeiro)	Gondomar	1998	Working	NG + GO + LPG	990 (3x330) MWe	Combined Cycle.	DLE (only for one group)	60 (x3)	-
Soporgen	Lavos	2001	Working	NG	67 (44+23) MWe	Co-generation. Combined Cycle	DLE	50 (x2)	-
Energim	Alhambra	2002	Working	NG	43.7 MWe	Co-generation. Combined Cycle	-	31 (x1)	-
Mortágua	Mortágua	1999	Working	WW + NG + GO	30 MWe	Boiler + Steam Turbine.	ESP	-	-
Pêgo	Abrantes	1993	Working	HC + FO + GO + LPG	628 MWe	Boiler + Steam Turbine.	ESP + LNOX + WFGD + SCR	225 (x1)	WFGD after 2008 SCR after 2008
Pêgo (Elecgás)	Abrantes	2010	Working	NG + GO	800 MWe	Combined Cycle	DLE	80 (x2)	
Carregado	Alenquer	1968	Deactivated (2011)	FO + NG + GO + LPG	750 (6x125) MWe	Boiler + Steam Turbine.	ESP	100 (x3)	Natural gas introduced in 1997
TER	Alenquer	2004	Working	NG + GO	1170 MWe	Combined Cycle.	-	75 (x3)	-
Carriço	Sines	2006	Working	NG + GO	487 MWe	Co-generation.	-	30 (x1)	-
Alto do Mira	Amadora	1975	Deactivated (2003)	GO	132 MWe	Gas Turbine.	-	13.5 (x1)	-
Barreiro	Barreiro	1978	Deactivated (2010)	FO + LPG	65 (32+33) MWe	Co-generation.	-	104 (x1)	-
Fisigen	Barreiro	2009	Working	NG	121 MWt	Co-generation.	-	-	-



Power Plant	Location	Start	Situation	Fuel***	Power	Technology	Treatment of Gas Effluents****	Stack Height (m)	Comments
Setúbal	Setúbal	1979	Working	FO + GO + LPG	1000 (4x250) MWe	Boiler + Steam Turbine.	ESP	201 (x2)	-
Sines	Sines	1985	Working	HC + FO	1256 (4X314) MWe	Boiler + Steam Turbine.	ESP + LNOX + WFGD + SCR	225 (x2)	WFGD after 2008 SCR after 2011
Tunes	Silves	1973	Working	GO	199.2 (2x16.3 + 2x83.3) MWe	Gas turbine.	-	13.5	Groups 1 and 2 deactivated in 2007.
Lares	Figueira da Foz	2009	Working	NG + GO	1428 MWt	Combined Cycle.	-	-	-
Constância	Constância	2009	Working	WW + FO + LPG	39.2 MWt	Boiler + Steam Turbine.	-	-	-
Figueira da Foz	Figueira da Foz	2009	Working	WW + NG	31.2 MWt	Boiler + Steam Turbine.	DLE + ESP	80	-
Cacia	Cacia	2009	Working	WW + NG + GO	49.75 MWt	Boiler + Steam Turbine.	-	-	-
CB Setúbal	Setúbal	2009	Working	WW + NG + GO	49.75 MWt	Boiler + Steam Turbine.	-	-	-
Rodão	Vila Velha do Rodão	2008	Working	WW + FO + LPG + GO	39.1 MWt	Boiler + Steam Turbine.	-	-	-
Artelia	Sines	2011	Working	NG + BG	269.7 (135.9 + 33.8 + 100) MWt	Combined Cycle.	LNOX	45	-

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

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

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

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

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

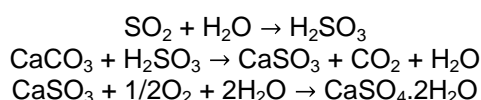
There has also been a change in the production structure since 1990, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase in the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was Orimulsion, that was used as fuel in Setúbal power plant but only in 1994 and its use had no continuation. In most recent years new power plants using wood waste were commissioned.

- In 1990 three units (Carregado, Setúbal and Barreiro) were using fuel-oil, one unit (Sines) was consuming imported hard coal and another unit (Tapada do Outeiro) was using lignite coal and fuel-oil;
- A new build coal unit (Pêgo) using hard coal, started producing electricity in 1993 and doubled its production capacity in 1995;
- The old unit in northern Portugal (Tapada do Outeiro) that was burning low heating value lignite coal, partly mined in Portugal, stopped using this fuel in 1997 but was kept producing electricity with a small consumption of fuel-oil since;
- Between 1995 and 1997 Carregado power plant shifted part of its production groups from residual fuel-oil to natural gas;
- A new unit (Portgen) consuming natural gas was build in northern Portugal near the old unit of Tapada do Outeiro and started producing in 1998;
- A new unit - TER - also using natural gas was installed, and started activity in the end of 2003, near the old unit of Carregado;
- The Mortágua unit in central Portugal initiated production in 1999 using a combination of natural gas and wood wastes;
- Soporgen and Energin, in central Portugal and Carriço (in the south) start production (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;
- In 2009 a new power plant was built in Lavradio – Fisigen. This new plant replaced the Barreiro plant in 2010. Also in 2009 a new power plant was built in Figueira da Foz – Lares, which burn NG as fuel;
- In later years (2008 and 2009) new small power plants were built that burn wood waste;
- In 2010 a new combined cycle plant was inaugurated in Abrantes;
- Artelia new combined cycle plant began its operation in 2011.

### 3.3.1.1.1.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

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

In a wet flue gas desulfurization the SO<sub>2</sub> emissions are absorbed by lime, forming CO<sub>2</sub> and plaster (gypsum + H<sub>2</sub>O) as by-products:



These equations show that the wet flue gas desulfurization reduces the SO<sub>2</sub> emissions but increment de CO<sub>2</sub> emissions.

Since there is no CRF category specific for desulfurization, total CO<sub>2</sub> emissions from this abatement system were included together with the Limestone, Dolomite and Carbonate Use in CRF 2.A.3.

### 3.3.1.1.1.3 Energy Plants in Azores and Madeira Autonomous Regions

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

Table 3-2 - Electricity Power Plants in the Azores and Madeira

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

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

### 3.3.1.1.1.4 Non public co-generation Energy Producers

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

production. Consequently they were included in this source sector and not in industry sector as emissions from other co-generation units are.

#### 3.3.1.1.1.5 *Municipal Solid Waste incineration*

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

#### 3.3.1.1.2 *Methodology*

##### 3.3.1.1.2.1 *Thermo-electricity Power Plants*

A bottom-up sectoral Tier 2 approach was used to estimate emissions of CO<sub>2</sub> 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 CO<sub>2</sub> from fossil fuel combustion are expressed on a per unit energy basis because the carbon content of fuels is generally less variable when expressed on a per unit energy basis than when expressed on a per unit mass basis" (IPCC, 1996).

Total CO<sub>2</sub> and ultimate CO<sub>2</sub> emissions from fossil origin were estimated from:

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

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

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

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

$EF_{CO_2}$  – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

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

This formula reflects the fact that some carbon in fuel is not oxidized and not emitted to atmosphere. Although, some carbon in the fuel is not released directly as carbon dioxide but instead in the form of carbon monoxide, methane, volatile organic compounds and even in soot, ash and particulate matter as consequence of the incomplete combustion of fuel. Emissions of these compounds in airborne fraction are transformed sooner or later into CO<sub>2</sub> in the atmosphere or after deposition on soil. Emissions of CO<sub>2</sub> at stack exhaust (End-of-pipe emissions) may be estimated from final CO<sub>2</sub> 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<sub>CO2</sub> - end of pipe emissions of carbon dioxide (kton);

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

CO - carbon monoxide emissions (ton);

CH<sub>4</sub> - Methane emissions (ton);

TPM - Total Particulate Matter emissions (ton);

C<sub>NM VOC</sub> - Carbon content in NM VOC (w/w);

C<sub>TPM</sub> - Carbon content of Total Particulate Matter (w/w).

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

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

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

where:

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

Energy<sub>Cons(u,f,y)</sub> - Consumption of energy (Low Heating Value/ Net Calorific Value) from fuel f in power plant u in year y (GJ);

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

### 3.3.1.1.2.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

In the desulfurization processes it's important to determine the emission of CO<sub>2</sub> and the reduction of SO<sub>2</sub>. For both determinations the lime consumption was used as activity data:

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

CO<sub>2</sub> Emission<sub>(u,y)</sub> – Emission of CO<sub>2</sub> estimated from CaCO<sub>3</sub> consumption in power plant u in year y(ton);

SO<sub>2</sub> Removal<sub>(u,y)</sub> – Quantity of SO<sub>2</sub> not emitted estimated from CaCO<sub>3</sub> consumption in power plant u in year y(ton);

CaCO<sub>3Cons(u,y)</sub> – Consumption of CaCO<sub>3</sub> in power plant u in year y(ton);

CO<sub>2</sub>Ratio – Ratio between CO<sub>2</sub> emitted and CaCO<sub>3</sub> consumption;

SO<sub>2</sub>Ratio – Ratio between the SO<sub>2</sub> removed and CaCO<sub>3</sub> consumption;

Since both energy plants are included in the EU-ETS the CO<sub>2</sub> ratio reported under this scheme was used in the inventory – 0.44 ton CO<sub>2</sub>/ton Ca. Monitoring data from the two plant was used for determining the SO<sub>2</sub> ratio: estimation based in CaCO<sub>3</sub> consumption and the difference between the expected SO<sub>2</sub> emissions without abatement system (based in the fuel sulphur content) and what was actually emitted. Because of this the SO<sub>2</sub> ration is plant specific and varies over time.

Since the methodology for determining combustion SO<sub>2</sub> does not consider the use of abatement systems, the quantity of SO<sub>2</sub> removed in the desulfurization equipment will be subtracted to the total SO<sub>2</sub> emissions.

### 3.3.1.1.3 Emission Factors

#### 3.3.1.1.3.1 Large Point Source Energy Plants

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

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

Table 3-3 – Emission Factors for energy production sector. Greenhouse Gases

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

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

The following table shows the plant specific CO<sub>2</sub> emission factors obtained in the EU-ETS.

<sup>7</sup> Mainly used in Gas Turbine plants.

Table 3-4 – CO<sub>2</sub> Emission Factors for energy production sector – Plant specific.

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

### 3.3.1.1.3.2 Other Thermo-electricity Power Plants

The other smaller - non LPS - power plants are seldom subjected to the continuous *Autocontrolo* program and the scarce available information does not allow the establishment of plant specific emission factors. Therefore emission factors reflect an expert best guess from the available bibliography, which again is available from:

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

The emission factors that were used in the inventory are shown in Table 3-5 for the power plants belonging to the public system in Azores and Madeira, and in Table 3-6 for the non public co-generation self producers<sup>8</sup>.

Table 3-5 – Emission Factors for thermo-electricity production in Azores and Madeira. Greenhouse Gases

Region	Fuel	UCO <sub>2</sub> <sup>(i)</sup> kg/GJ	Fac <sub>ox</sub> <sup>(i)</sup> 0..1	Fossil <sub>c</sub> %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O <sup>(i)</sup> g/GJ
Azores	Fuel-oil	77.4	0.990	100	<sup>(ii)</sup> 2.9	0.6
Azores	Diesel oil	74.1	0.990	100	0.14	0.6
Madeira	Fuel-oil	77.4	0.990	100	<sup>(ii)</sup> 2.9	0.6
Madeira	Diesel oil	74.1	0.990	100	0.14	0.6
Madeira	LPG	63.1	0.995	100	1.4	1.4

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

Table 3-6 – Emission Factors for non public co-generation self producers. Greenhouse Gases

Fuel	UCO <sub>2</sub> <sup>(i)</sup> kg/GJ	Fac <sub>ox</sub> <sup>(i)</sup> 0..1	Fossil <sub>c</sub> %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O <sup>(i)</sup> g/GJ
LPG	63.1	0.995	100	<sup>(iii)</sup> 0.06	1.4
Fuel –oil	77.4	0.990	100	<sup>(ii)</sup> 2.9	0.6
Diesel oil	74.1	0.990	100	<sup>(i)</sup> 5	0.6
Natural Gas	56.1	0.995	100	<sup>(ii)</sup> 1.4	1.4

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

<sup>8</sup> Power producers as main activity only.

#### 3.3.1.1.4 Activity Data

Activity data has different origins according to specific energy plants:

##### 3.3.1.1.4.1 Large Point Source Energy Plants

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

- Large Combustion Plants (LCP) directive - which relies in direct information reported from the individual plant producer to the Environment Ministry;
- Self-control program (*Programa Autocontrolo*)<sup>9</sup>;
- Plant activity reports from EDP;
- EU-ETS – European Union Emission Trading System.

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

As a general rule power plant units report information about consumption in tons or cubic meters of gas together with the Low Heating Value <sup>10</sup> 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.

<sup>9</sup> The *Auto-controlo* program is a legal obligation for major emitters.

<sup>10</sup> 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.



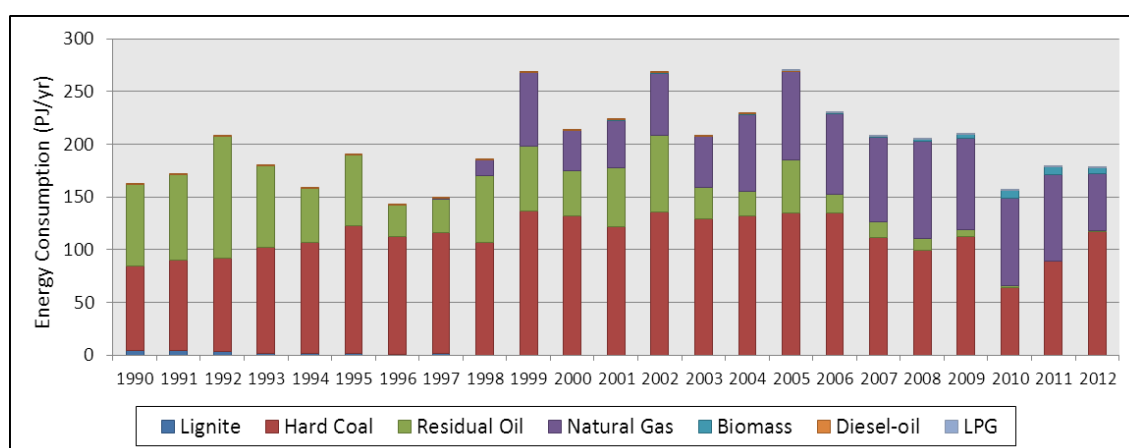
Table 3-7 – Low Heating Value per fuel type

Fuel	LHV/NCV	
Lignite	16.42 (15.57 - 17.02)	MJ/kg
Hard Coal	25.62 (24.45 - 27.23)	MJ/kg
Fuel-oil	40.24 (39.42 - 41.61)	MJ/kg
Orimulsion	28.00	MJ/kg
Diesel oil	43.30	MJ/kg
Natural Gas	38.16 (36.02 - 39.16)	MJ/Nm <sup>3</sup>
GPL	47.44 (47.28-48.55)	MJ/kg
Biomass	7.8	MJ/kg

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

Total consumption per fuel type in comparable energy units (PJ) may be verified in Figure 3-10.

Figure 3-10 – Trends of fuel consumption per fuel type



Not visible in the graph is the increase in biomass consumption (wood waste) from 1999 to 2012 (mostly in 2010 and 2011). The consumption of diesel-oil presents no clear trend since 1990 even though we can identify a slight decrease in the later years of the time series. LPG represents only a small fraction of total fuel consumption in this sector (less than 0.001 per cent). The relevancy of residual oil has been decreasing since 2005, representing only a fraction of total consumption in 2012 due to Barreiro power plant deactivation. Also visible in the last three years it's the increase of energy consumption from Hard Coal, in 2012 the consumption of hard coal was similar to the consumption of the same fuel in 2009.

#### 3.3.1.1.4.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

Values for the total lime consumed for desulfurization in each plant were obtained in the EU-ETS. For confidentiality constrains and since there are only two plants in Portugal that use this kind of abatement system, the CaCO<sub>3</sub> consumption cannot be reported.

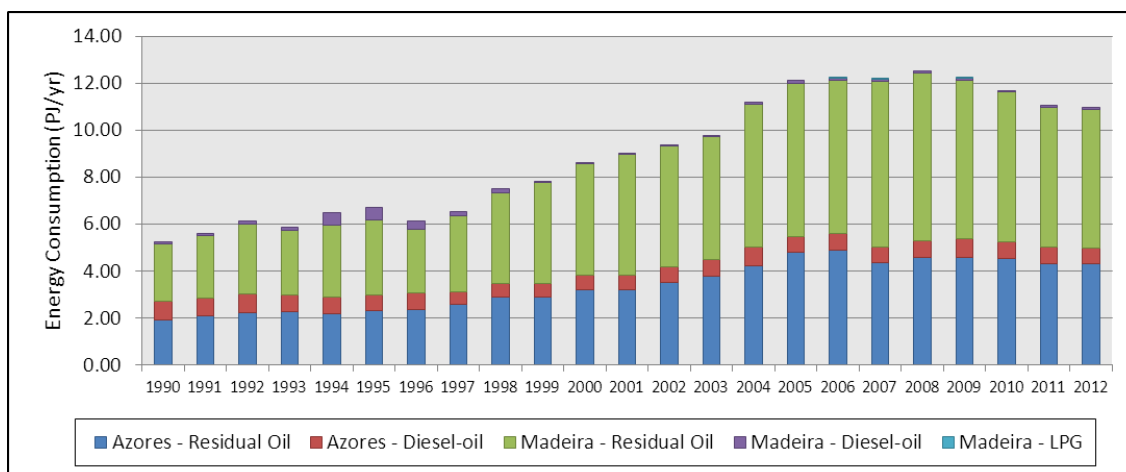
#### 3.3.1.1.4.3 Energy Plants in Azores and Madeira Autonomous Regions

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

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

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

Figure 3-11 – Trends of fuel consumption in Azores and Madeira Archipelagos



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

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

Table 3-8 - LHV per fuel type

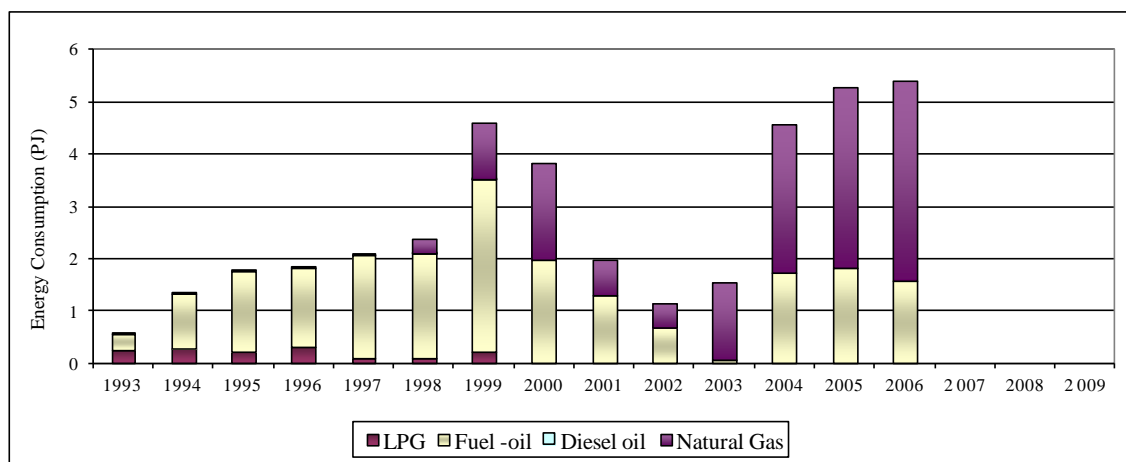
Region	Fuel type	LHV/NCV (MJ/kg)
Azores	Residual fuel oil	40.17
	Diesel oil	43.30
Madeira	Residual fuel oil	40.17
	Diesel oil	43.30
	LPG	47.28

Source: The same as for the fuel consumption

#### 3.3.1.1.4.4 Non-public co-generation Energy Producers

Consumption of fuels in the auto-producers co-generation units (classified as energy producers) are reported in toe units in the Energy Balance (DGEG). These values can be observed in Figure 3-12.

Figure 3-12 – Trends in consumption of fuels in non-public co-generation plants



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

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

Table 3-9 - LHV per fuel type used for non-public co-generation plants estimates

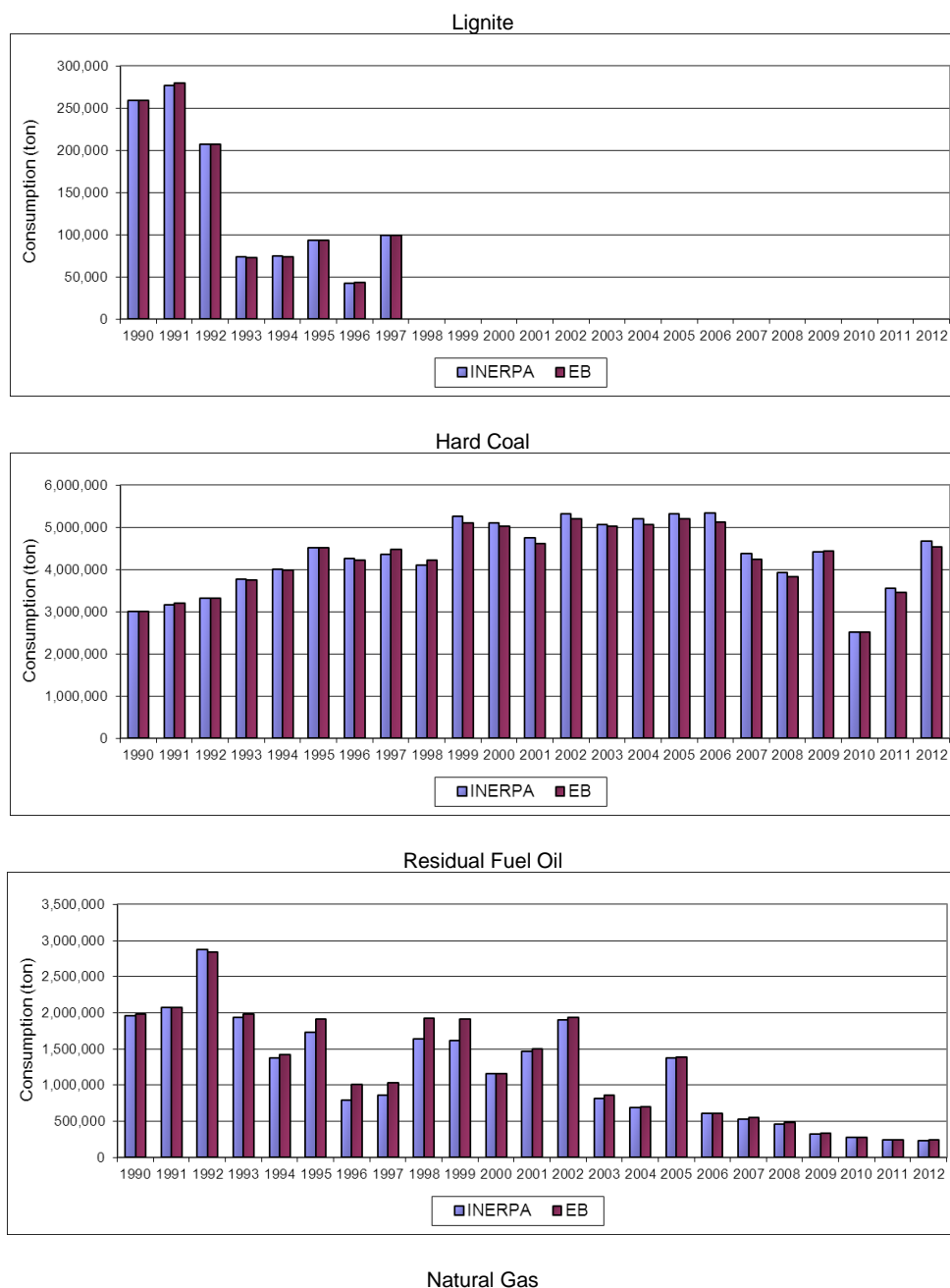
Fuel	LHV (MJ/kg)
LPG	49.76
Fuel -oil	40.00
Diesel oil	42.60
Natural Gas	38.72 (MJ/Nm <sup>3</sup> )

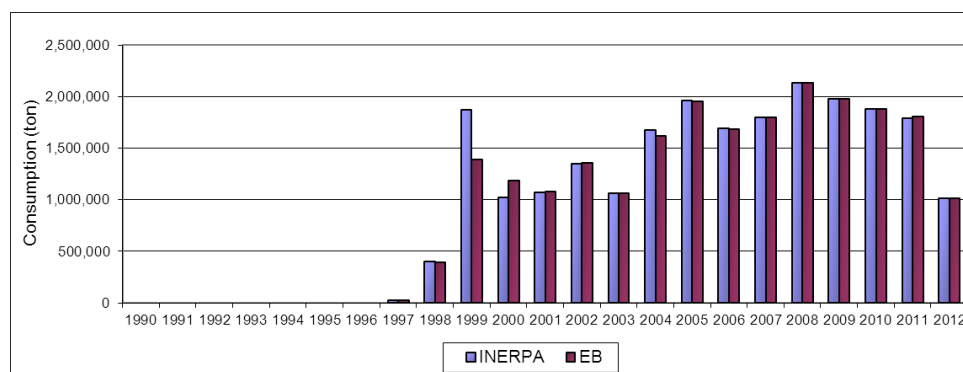
Source: The same as for the fuel consumption

#### 3.3.1.1.4.5 Comparison of LPS data vs. National Statistics

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

Figure 3-13 – Comparison of total fuel consumption in large power plants, between values used in the inventory (INERPA) and in the Energy Balance

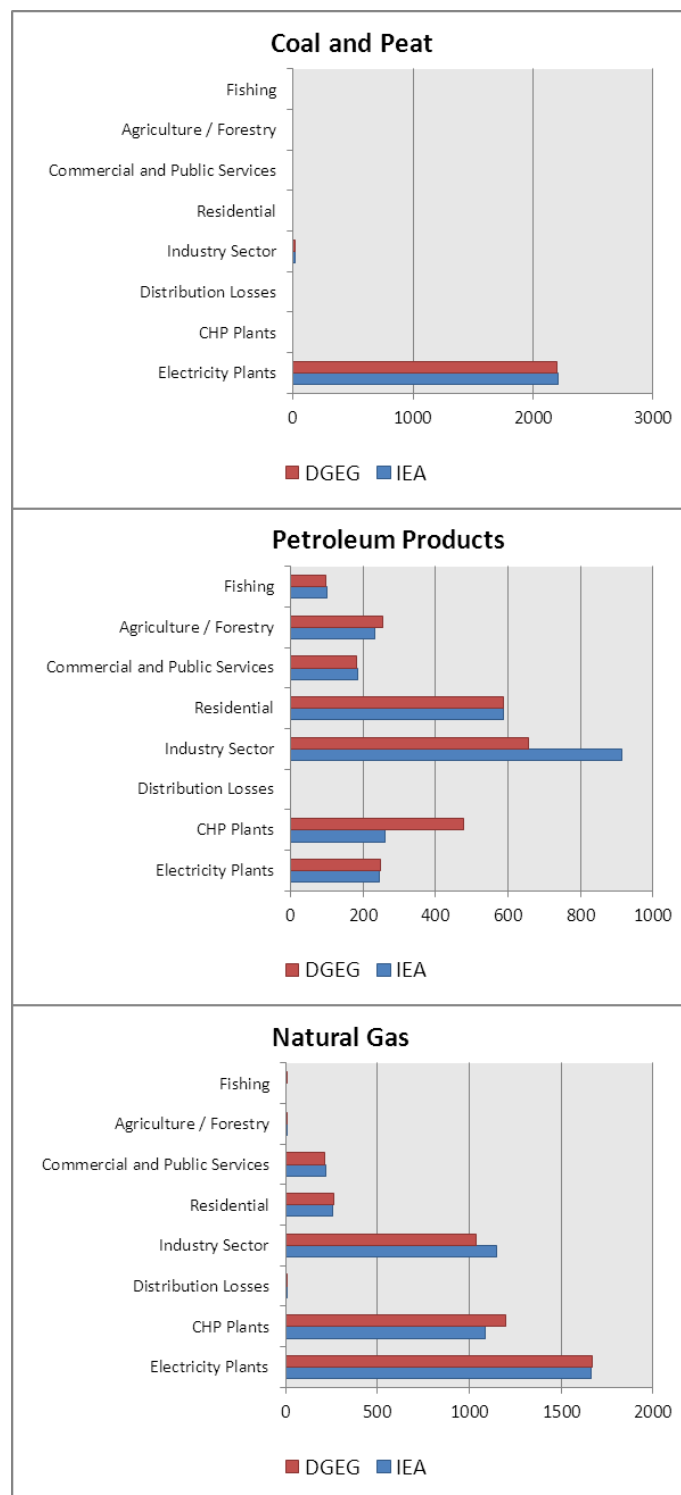




#### 3.3.1.1.4.6 Comparison of Energy Balance vs. IEA Energy Statistics

Total energy consumption reported in DGEG energy balance was compared with IEA (International Energy Agency) energy statistics values. This comparison is included in the QA/QC procedures applied to this inventory. The energy statistic values from IEA were collected from their website. Unfortunately IEA data is only publicly available for the n-1 year (n being the latest inventory year). Following the fuel classification presented in the IEA energy statistics, three fuel types were analyzed: coal and peat, petroleum products and natural gas, connected to 8 emission sources: Electricity Plants, CHP Plants, Industry, Residential, Commercial and Public Services, Agriculture/Forestry, Fishing and Distribution Losses. The comparison between DGEG energy balance and IEA energy statistics, for 2011, is shown in the figure below.

Figure 3-14 – Comparison of fuel consumption between DGEG energy balance and IEA energy statistics



For natural gas and coal and peat the differences between the two data sources are very small. The consumption of petroleum products shows discrepancies for five of the eight analysed sectors: CHP Plants, Industry, Commercial and Public Services, Fishing and Distribution

Losses. These differences are greater for CHP Plants and Industry which may imply a problem in the fuel consumption classification. Upon our contact DGEG reported that there were compilation errors in the information sent to IEA, which may explain the differences found between the two data sources.

#### 3.3.1.1.5 Uncertainty Assessment

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

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

The uncertainty associated with the CO<sub>2</sub> 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 CH<sub>4</sub> and 1000 per cent for N<sub>2</sub>O.

The EU-ETS defines a maximum uncertainty value of 7.5 per cent for the CaCO<sub>3</sub> consumption data reported by each plant.

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

#### 3.3.1.1.6 Category-specific QA/QC and verification

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

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

#### 3.3.1.1.7 Recalculations

Recalculations for this sector comprise the allocation of CO<sub>2</sub> emissions from the desulfurization process, total CO<sub>2</sub> emissions from this abatement system were included together with the

Limestone, Dolomite and Carbonate Use in CRF 2.A.3.) The difference between newer and older values of this sector is less than 1%.(1990-2011)

#### 3.3.1.1.8 Further Improvements

Even though efforts were made to increase the percentage of units treated as LPS in this year inventory, the inclusion of more LPS plants is an ongoing objective for this sector as well as for industrial combustion. These efforts are in accordance with the goals that the EC<sup>11</sup> has set to streamline data collection for the inventories and for the EU-ETS<sup>12</sup>. In the same sense on-going efforts should be maintained for the compatibilization of data acquisition by APA and DGEG in order for a better consistency of the data that is used for the Energy Balance and for the LPS data used in the inventory.

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

##### 3.3.1.2.1 Overview

In 1990 there were three oil refining plants in Portugal: Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed 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 (dissulphurization). This refinery unit has also units for the production of oils, lubricants and aromatics (Benzene, Hexane, toluene, xylene, etc). Sines refinery, installed in 1978 in southern Portugal, has also extensive transformation of crude products after atmospheric and vacuum distillation, which are subjected to Fluid Catalytic Cracking (FCC), platforming, hydrocracking, alkylation and asphalts blowing. The nowadays closed refinery at Lisbon performed mostly cracking. Refinery gas from this unit was used as combustible gas for domestic, service and industry use in Lisbon city.

Following the UNFCCC source categories classification, only emissions resulting from combustion in boilers and furnaces are included in this source sector. Process fugitive emissions, including combustion emissions realized in the FCC unit are included in CRF 1.B.2.a.iv.

SO<sub>x</sub> and NMVOC emissions do 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 (CRF 1.B.2.c).

##### 3.3.1.2.2 Methodology

A bottom-up sectoral Tier 2 approach was used to estimate emissions of CO<sub>2</sub> 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.

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<sup>11</sup> European Commission.

<sup>12</sup> European CO<sub>2</sub> trading scheme.



As explained in more detailed for the sector “Public Electricity and Heat Production”, emissions to atmosphere of total CO<sub>2</sub> and of ultimate CO<sub>2</sub> 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 CO<sub>2</sub>/GJ);

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

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

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

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

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

Where

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

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

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

### 3.3.1.2.3 Emission Factors

For Oporto and Sines refineries, CO<sub>2</sub> emission factors were obtained directly from EU-ETS data. For Lisbon refinery, CO<sub>2</sub> emission factors were derived from IPCC (1997).

The same set of CH<sub>4</sub> and N<sub>2</sub>O emission factors were used for all three refineries and were derived from international bibliography such as IPCC (IPCC, 1997), EMEP/CORINAIR (EEA, 2002) and AP-42 (USEPA, 1996b; USEPA, 1998b; USEPA, 1991e; USEPA, 1995c). The chosen Emission Factors are presented in the table below.

Table 3-10 – Emission Factors for combustion sources in Refining of Petroleum Products. Greenhouse Gases.

Fuel	Equipment	U <sub>CO2</sub> kg/GJ	Fa <sub>COX</sub> <sup>(i)</sup> 0..1	Fossil <sub>c</sub> %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O <sup>(i)</sup> g/GJ
Fuel-oil	Boilers	var <sup>(iii)</sup>	0.990	100	2.9	0.6
	Furnaces	var	0.990	100	2.9	0.6
Fuel gas	Boilers	var	0.990	100	2.5	1.4
	Furnaces	var	0.990	100	2.5	1.4
LPG	Boilers	var	0.995	100	4.0	1.4
	Furnaces	var	0.995	100	4.0	1.4
Diesel oil	Engines	var	0.990	100	9.9	0.6
Natural Gas	Boilers	var	0.995	100	0.1	1.4
Acid Soluble Oil (ASO)	Furnaces	var	0.995	100	3.0	0.6
Off Gas	Furnaces	var	0.995	100	3.0	0.6
Tail Gas	Furnaces	var	0.995	100	3.0	0.6

(i) IPCC (1997); (ii) EEA (2002); (iii) EU-ETS

#### 3.3.1.2.4 Activity Data

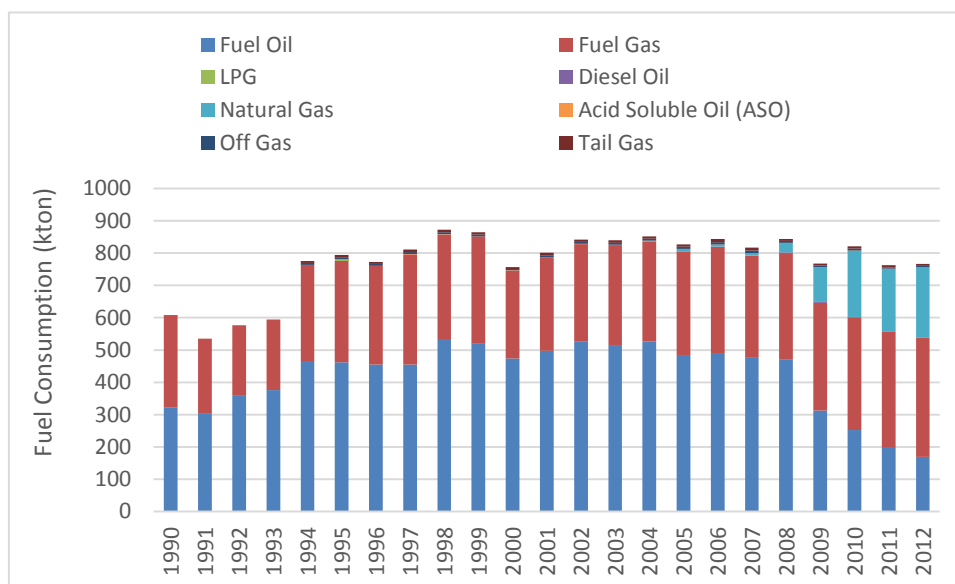
In 1990 there were three oil refining plants in Portugal: Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed and only two units remain now in operation.

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

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

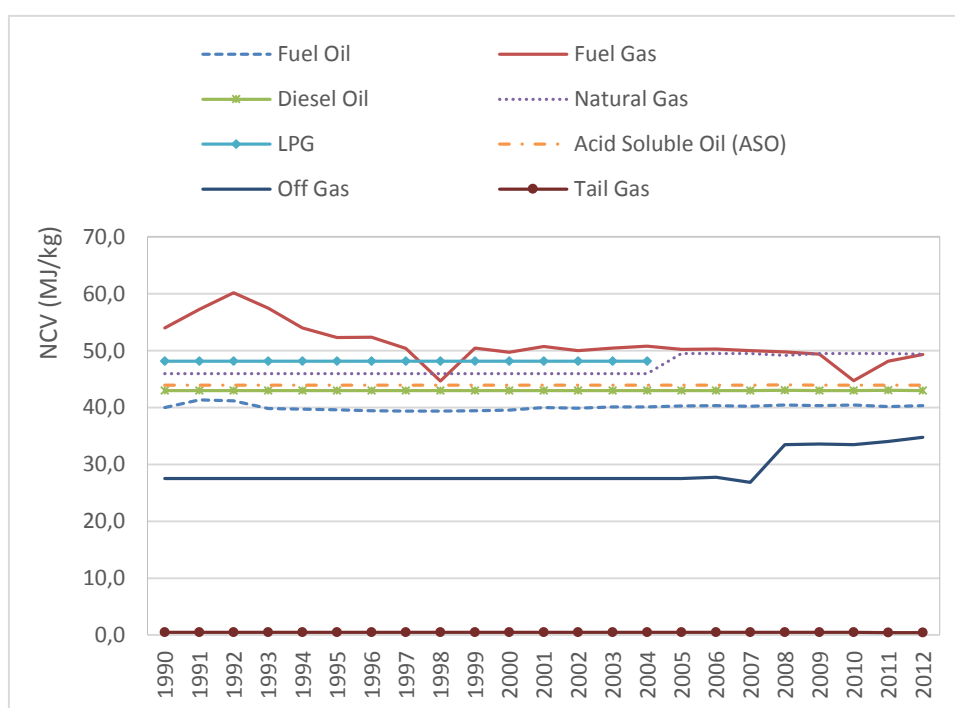
The quantities of fuel consumption from 1990 to 2004 were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in the next figure. Since 2005 data source is EU-ETS. The use of natural gas is becoming more relevant since 2008. In one of the refineries there is also consumption of Acid Soluble Oil (ASO), Off Gas and Tail Gas.

Figure 3-15 – Fuel consumption in Refineries



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

Figure 3-16 – Net Calorific Value (NCV) expressed in MJ/ kg by type of fuel



#### 3.3.1.2.5 Uncertainty Assessment

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

The uncertainty associated with the CO<sub>2</sub> emission factor is 5 percent, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 percent for CH<sub>4</sub> and 1000 percent for N<sub>2</sub>O.

#### 3.3.1.2.6 Recalculations

No recalculations were made.

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

##### 3.3.1.3.1 Overview

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

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

##### 3.3.1.3.2 Methodology

Emissions to atmosphere of total CO<sub>2</sub> and of ultimate CO<sub>2</sub> from fossil origin were estimated using the following equation set:

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

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

where,

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

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

$EF_{CO_2}$  – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

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

For  $CH_4$  and  $N_2O$  the following equation was applied to estimate emissions:

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

where

$Emission_{(y,p)}$  - Emission of pollutant  $p$  in year  $y$  (ton except  $CO_2$  in ton);

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

$EF_{(f,p)}$  - Emission factor pollutant  $p$  from coke gas combustion (g/GJ except  $CO_2$  in kg/GJ).

### 3.3.1.3.3 Emission Factors

Emissions factors for combustion of coke gas in the coquerie unit and in the city gas factory were set from IPCC96, EMEP/CORINAIR and AP-42. They are reported in Table 3-11.

Table 3-11 – Emission Factors used for the coquerie and city gas production

Source	Coquerie	City Gas Production			Unit
Fuel	Coke Gas	FO	Naphta	NG	
$U_{CO_2}^{(i)}$	<sup>(iii)</sup> 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	<sup>(ii)</sup> 2.9	<sup>(ii)</sup> 2.9	<sup>(i)</sup> 1.4	g/GJ
$N_2O^{(i)}$	1.40	0.60	0.60	1.40	

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

### 3.3.1.3.4 Activity Data

#### 3.3.1.3.4.1 Coke Production

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

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

where

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

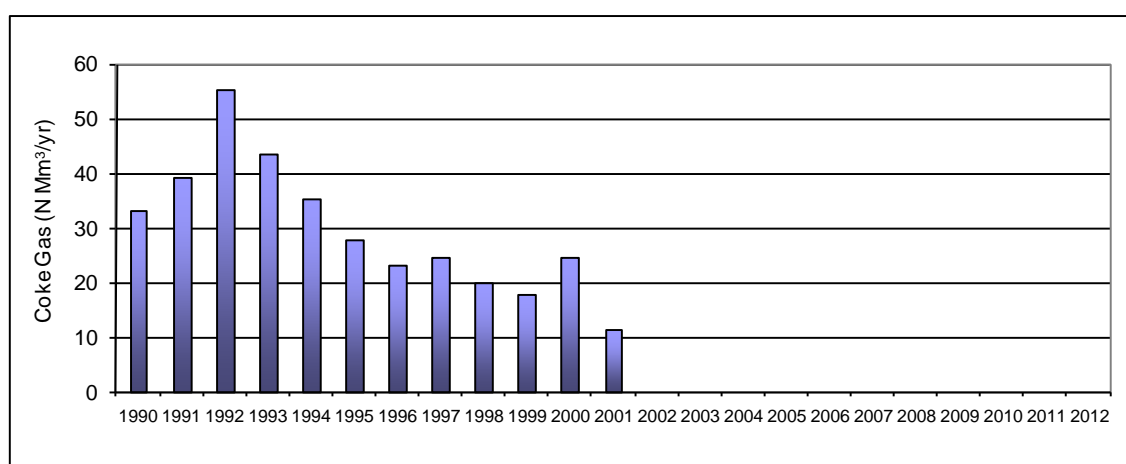
Coquerie<sub>CONS (91-94)</sub> - consumption of coke gas in the coquerie from 1990 till 1994;

TotalPlant<sub>CONS (91 - 94)</sub> - total consumption of coke gas in the iron and steel sector, from 91 to 94, as reported in DGEG's energy balance;

TotalPlant<sub>CONS (y)</sub> - 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 3-17. Conversion in energy units was calculated using a LHV of 18.78 MJ/Nm<sup>3</sup>, the value that is reported under LCP directive.

Figure 3-17 – Coke gas consumption in the coquerie

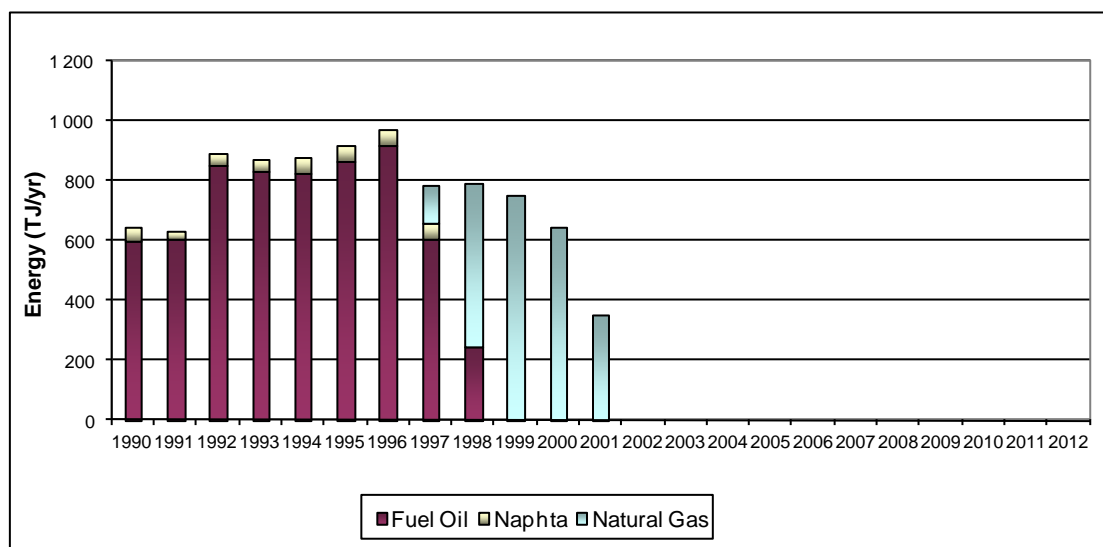


#### 3.3.1.3.4.2 City Gas Production

According to the energy balances from DGEG, this activity has used fuel oil, naphtha and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001<sup>13</sup>. The available time series is presented in Figure 3-18.

<sup>13</sup> This activity uses also fuel gas, LPG, fueloil, naphta and natural gas as feedstocks. These quantities, separated in the energy balance, are not included in the inventory at this point but in use of city gas as fuel

Figure 3-18 – Consumption of fuels in co-generation in city gas production



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

Table 3-12 – NCV/LHV per fuel type for city gas production

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

#### 3.3.1.3.5 Uncertainty Assessment

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

In a similar way to all other stationary combustion sources, the uncertainty associated with the CO<sub>2</sub> 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 CH<sub>4</sub> and 1000 per cent for N<sub>2</sub>O.

#### 3.3.1.3.6 Recalculations

No major recalculations were made to this sector.

#### 3.3.1.3.7 Further Improvements

No further improvements are planned for this sector.

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

Emissions covered in this source category are those resulting from combustion activities in manufacturing industry and building and construction industry. Excluded are the emissions of CO<sub>2</sub> from decarbonising in the cement and glass industries, which are covered under production processes (Chapter 4.3.1). The following sub-source categories are considered individually: Iron and Steel, Metallurgic industry, Chemicals, Pulp and Paper, Food Processing, Beverages and Tobacco, Textile, Ceramic, Glass and glass products, Cement, Clothing, shoes and leather industry, Wood, Rubber, Metal Equipment and Machines, Extractive industry, Construction and Building and Other Transformation Industry.

Total emissions for this sub-sector comprehend the sum of different industrial activities, using diverse fuels and combustion technologies and refer to the full combustion emissions of the industry sector: boilers, process dedicated fuel combustion in furnaces and kilns and all emissions originated in co-generation units<sup>14</sup>.

#### 3.3.2.1 Methodology

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

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

For Carbon Dioxide (CO<sub>2</sub>), total emissions and ultimate fossil emissions are estimated using:

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

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

where,

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

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

$EF_{CO_2}$  – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

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

For CH<sub>4</sub>, N<sub>2</sub>O and other GHG when the energy consumption approach is used the equation simplifies to:

<sup>14</sup> Only when the co-generation activity is reported in the energy balance as referring to the manufacturing industry. When economic activity is referred as Energy Production then emissions are included in source category CRF 1A1a (See chapter 3.2.A.1 for further explanations).



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

where:

$Emi_{(p)}$  - Total emissions of pollutant p (ton/yr except CO<sub>2</sub> 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 CO<sub>2</sub> in kg/GJ);

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

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

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

where:

$Emi_{(p)}$  - Total emissions of pollutant p (ton/yr except CO<sub>2</sub> in kton);

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

Production – Production activity rate (ton/yr).

It's important to point out that following a meeting with the energy balance team from DGEG new procedures were established to include biodiesel in the INERPA estimates. Hence all estimates derived from the energy balance consider biodiesel. This new approach for obtaining biodiesel results from the fact that from 2006 onwards the gas oil reported in the energy balance contained a percentage of biodiesel. The methodology for obtaining the total pure biodiesel and pure gas oil consumed in each industrial sector follows the steps<sup>15</sup>:

- Total pure gas oil consumed was obtained by subtracting the total biodiesel produced (that is going to be incorporated in gas oil) to the gas oil reported in the energy balance;
- With the pure gas oil and the pure biodiesel values an incorporation rate was derived;
- For each industrial sector this incorporation rate was applied to obtain value for total gas oil and total biodiesel consumed;

<sup>15</sup> Note: This procedure does not apply to gas oil reporter under co-generation in the energy balance. The DGEG has no documentation to differentiate this fuel as heating gas oil or as gas oil with biodiesel.

- Not all the gas oil reported has biodiesel. Because of this, before applying the incorporation rate the total gas oil for heating was subtracted;
- In the end we have, for which industrial sector, the total gas oil consumed (heating gas oil plus gas oil with biodiesel removed) and the total biodiesel consumed (biodiesel from gas oil plus pure biodiesel purchased directly by the industrial unit).

The table below represents the incorporation rate derived for the period 2006-2012.

Table 3-13 – Incorporation rate of biodiesel (% toe/toe)

	1990-2005	2006	2007	2008	2009	2010	2011	2012
Incorporation rate	0	1.33	2.50	2.43	4.34	6.42	6.42	6.66

Emissions from the following industries were estimated based only on fuel consumption as activity data (energy approach): metallurgy; chemical and plastic industry; food, beverages and tobacco, textile industry; clothing, shoes and leather manufacturing; wood industry; rubber manufacturing; machines manufacturing industry and other metal equipment industry; extractive industry; building and construction and all other unspecified industry. Following the recommendation made by the review team, since the 2011 inventory all emissions from lime production are reported in 2.A.2. For the following industrial sectors specific estimation procedures were taken.

#### 3.3.2.1.1 Paper and Pulp Production

Emissions of SO<sub>x</sub>, NO<sub>x</sub>, NMVOC and methane from the recovery boilers and lime kilns in the Kraft and Acid Sulphide paper pulp plants were estimated using production data, for each industrial plant, as activity data (production approach). The remaining pollutants emitted from these combustion equipments and all pollutants for the remaining combustion equipments of this industry sector were estimated using energy consumption as activity data (energy approach).

#### 3.3.2.1.2 Clinker Production

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

#### 3.3.2.1.3 Lime Production

Both this activity and Clinker production are included in the energy balance Cement sector.

#### 3.3.2.1.4 Ceramic Industry

Emissions of SO<sub>x</sub>, NO<sub>x</sub>, NMVOC, CH<sub>4</sub> and CO from combustion processes in furnaces in the ceramic industry are estimated using the production approach. Emissions estimates from

combustion in other equipment, boilers and engines, and emission estimates for the other pollutants, also for furnaces, are based on the energy approach

#### 3.3.2.1.5 Glass Production

Similarly to ceramic industry, emissions of SO<sub>x</sub>, NO<sub>x</sub>, CH<sub>4</sub> and CO are estimated using production information as activity data (production approach). Emissions for the remaining pollutants, CO<sub>2</sub> and N<sub>2</sub>O from furnaces and for all pollutants from other combustion equipments are estimated using energy consumption as activity data indicator. Carbon dioxide emissions from glass production comprehend both oxidation of carbon, that are estimated using the general emission factors based on energy consumption, and decarbonising or materials, which are included in production process and reported in CRF sector 2.

#### 3.3.2.1.6 Iron and Steel Production

Air emissions from sintering (SO<sub>x</sub>, NO<sub>x</sub>, NMVOC and CO) and production of lime (SO<sub>x</sub>, NO<sub>x</sub>, CO and CO<sub>2</sub>) integrated in the iron and steel production sector are estimated using production as activity data (production approach). The remaining pollutants resulting from the iron and steel industry were estimated using the energy approach. For simplicity, activity data and emission factors for the production approach are discussed in chapter 4.3.3.1 – Industrial Processes: Iron and Steel Production.

#### 3.3.2.2 Activity data

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

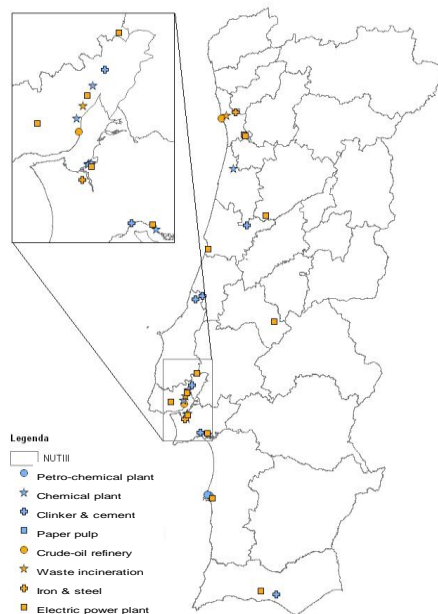
##### 3.3.2.2.1 Combustion Data

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

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

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

Figure 3-19 – Distribution of Large Point Sources in continental Portugal<sup>16</sup>



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 3-20 and in the following formula set:

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

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  $c$ ) (toe/yr);

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

$\text{Cons}_{\text{EB}}(f,s)$  – 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  $\text{Nkm}^3/\text{yr}$ );

$\text{Energy}_{\text{AREA}}(f,s,e)$  – 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);

<sup>16</sup> This map includes also LPS that are accounted as process emissions (CRF 2).

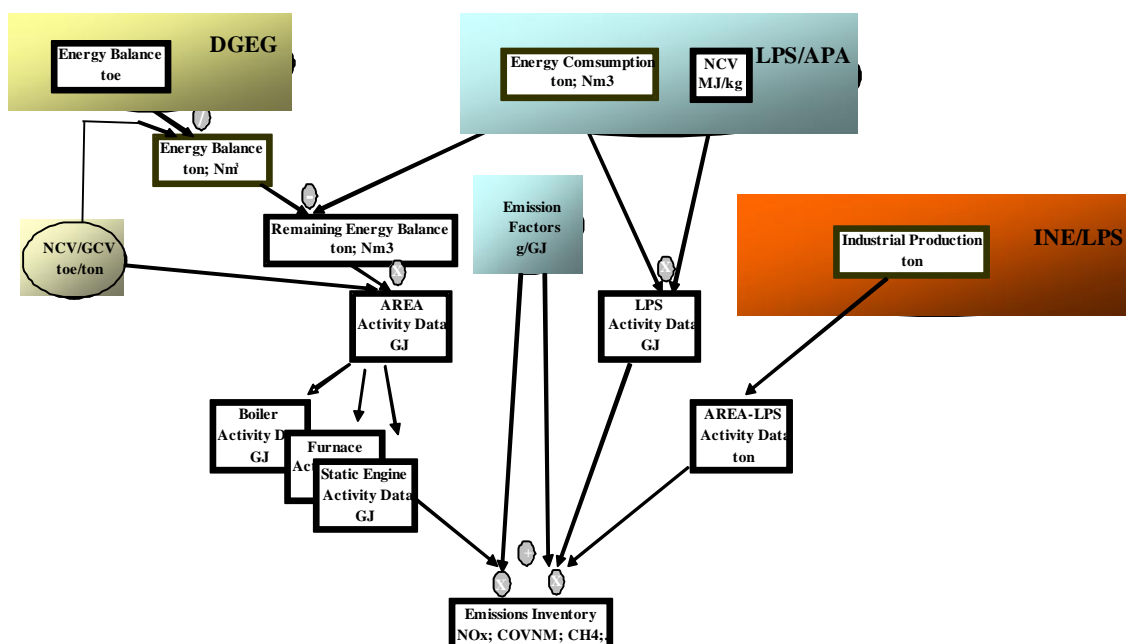
$\text{Frac}_{\text{Equi}(s,f)}$  – Fraction of consumption of fuel  $f$  in sector  $s$  that is used in equipment  $e$  (0..1);

$\text{LHV}_{\text{LPS}(u,f,e)}$  – Low Heating Value/ Net Calorific Value, reported by LPS unit  $u$ , for fuel  $f$  in combustion equipment  $e$  (MJ/kg or MJ/Nm<sup>3</sup>);

$\text{LHV}_{\text{EB}(f,s)}$  – Low Heating Value/ Net Calorific Value used by DGEG in the compilation of the Energy Balance for fuel  $f$  in activity sector  $s$  (toe/ton or toe/Nkm<sup>3</sup>);

$\text{LHV}_{\text{AREA}(f,s,e)}$  - 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/Nm<sup>3</sup>)<sup>17</sup>.

Figure 3-20 – 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. Hence separation of fuel consumption among boilers, furnaces and engines was made by expert judgment according to each economic sector, and also considering that the original data of fuel consumption in the DGEG's energy balances make a separation between quantities used in co-generation and quantities used without co-generation.

#### 3.3.2.2.1.1 The Energy Balance

The Portuguese Energy Balance (EB) is published annually by DGEG covering all national territory and without any disaggregation at regional level. The structure of the report table is summarized in the next tables. The Energy Balance for 2011 is presented in annex to the NIR.

<sup>17</sup> In most cases similar values to Energy Balance are used

Table 3-14 – Structure of the Portuguese Energy Balance. Sectoral categories

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

Table 3-15 – Structure of the Portuguese Energy Balance. Fuel categories

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

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

**Table 3-16 – Definition of Sectors in accordance with Economic Activity Classes**

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

### 3.3.2.2.1.2 Tables of consumption per activity

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

#### 3.3.2.2.1.2.1 Iron and Steel Industry

**Table 3-17 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Iron and Steel Industry**

Steam Coal	Coke	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm <sup>3</sup>
30.95	29.40	46.0	43.8	42.6	40.0	38.7

Coke Oven Gas	Blast Furnace Gas	Tar	Gasoline	Biodiesel	Other
MJ/Nm <sup>3</sup>	MJ/Nm <sup>3</sup>	MJ/kg	MJ/kg	MJ/kg	MJ/kg
17.6	3.8	40.1	44.0	37.0	34.7

Table 3-18 – Fuel consumption in the Iron and Steel Industry in boilers and furnaces (GJ) (1/2)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
1990	0	461,351	1,343	23,000	1,231,825	0
1991	0	452,225	1,631	14,960	324,431	0
1992	0	520,545	1,349	16,404	340,311	0
1993	0	598,970	1,788	18,819	1,373,593	0
1994	0	595,001	2,891	16,268	1,138,766	0
1995	0	603,060	2,916	15,681	942,280	0
1996	0	558,857	2,811	17,344	984,206	0
1997	0	408,945	3,295	5,667	941,755	200,078
1998	0	280,672	3,158	6,796	623,019	654,937
1999	0	326,230	2,927	6,902	712,221	703,232
2000	0	410,633	586	7,801	821,346	911,502
2001	0	395,280	0	8,004	748,872	965,747
2002	0	299,259	0	4,986	181,352	505,451
2003	0	239,643	0	8,899	38,372	587,537
2004	0	241,617	0	11,711	0	124,961
2005	0	240,766	0	17,365	0	266,620
2006	0	241,773	0	19,197	302,071	388,383
2007	266,699	241,368	0	23,298	118,400	545,870
2008	264,313	237,977	0	17,471	40,611	119,827
2009	153,279	237,809	84	17,649	0	0
2010	165,085	238,689	126	17,469	0	233,867
2011	182,335	2,596	0	20,485	0	228,598
2012	226,003	2,554	0	25,928	0	2,071,964



Table 3-19 – Fuel consumption in the Iron and Steel Industry in boilers and furnaces (GJ) (2/2)

Year	Coke oven gas	Blast furnace gas	Tar	Other
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
2007	0	0	333,420	10,255
2008	0	0	333,420	10,255
2009	0	0	333,420	10,255
2010	0	0	333,420	10,255
2011	0	0	0	0
2012	0	0	0	0

Table 3-20 – Fuel consumption in the Iron and Steel Industry in Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	1,674	23,000	0
1991	1,100	14,960	0
1992	1,728	16,404	0
1993	1,049	18,819	0
1994	1,807	16,268	0
1995	1,463	15,681	0
1996	2,253	17,344	0
1997	235	5,667	0
1998	142	6,796	0
1999	177	6,902	0
2000	151	7,801	0
2001	3,404	8,004	0
2002	164	4,986	0
2003	46	8,899	0
2004	0	11,711	0
2005	0	17,365	0
2006	0	19,197	262
2007	0	23,298	604
2008	0	17,471	443
2009	0	17,649	826
2010	0	17,469	1,220

2011	0	20,485	1,411
2012	0	25,928	1,851

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

Figure 3-21 – Total Energy Consumption in the Iron and Steel Industry

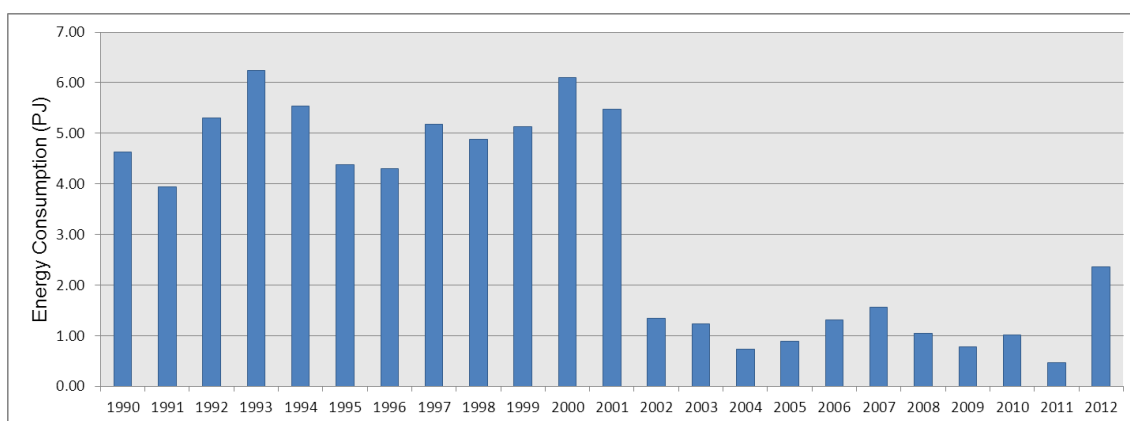
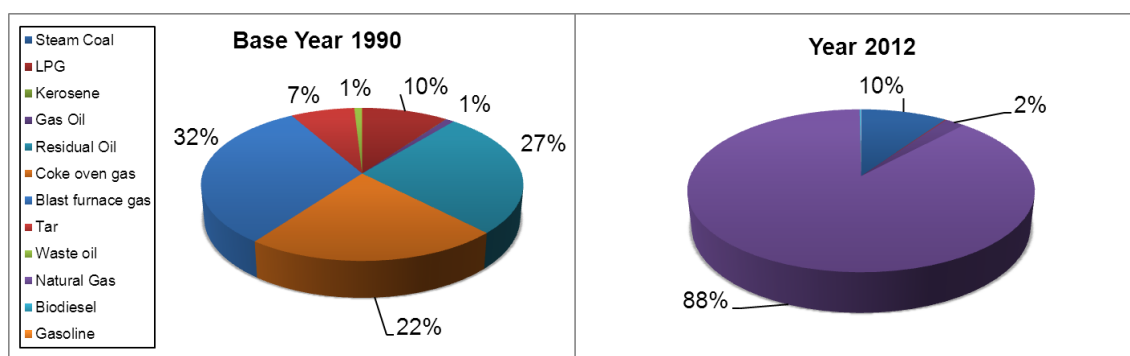


Figure 3-22 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2012



There is also Coke gas consumption associated with the Iron and Steel Sector, that consumption is realized in a coquerie unit that existed within the only integrated iron and steel plant in Portugal. That activity data is presented in sub-chapter 3.3.1.3 - Other Energy Industries.

### 3.3.2.2.1.2.2 Metallurgy Industry

Table 3-21 – Low Heating Values/ Net Calorific Value (LHV/NCV) in Metallurgy Industry

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

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

Table 3-22 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Coal Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	132,971	381,617	526,189	372	14,487	1,163,364	0	142,678	0
1991	121,117	240,375	520,732	3	19,589	958,702	0	140,167	0
1992	30,903	240,324	596,796	0	19,789	1,059,801	0	138,033	0
1993	50,879	0	495,350	0	20,301	721,327	0	135,272	0
1994	6,196	0	526,400	0	22,392	554,653	0	135,314	0
1995	0	0	588,598	0	18,324	387,450	0	135,314	0
1996	0	0	634,908	0	32,228	480,184	0	143,515	0
1997	0	0	549,121	0	28,725	78,987	1,057	143,515	0
1998	0	0	492,290	545	28,176	75,075	30,324	143,818	0
1999	0	0	375,702	1,578	44,187	66,686	173,261	144,351	0
2000	0	0	241,885	7	43,885	81,208	429,166	143,515	0
2001	0	0	317,853	8	77,634	99,082	473,481	143,515	0
2002	0	0	340,702	0	70,961	68,532	496,861	143,515	0
2003	0	0	332,094	0	54,573	60,430	540,034	223,898	0
2004	0	0	325,208	0	56,593	67,819	569,362	227,897	0
2005	0	0	298,108	16	83,207	64,698	616,185	232,894	0
2006	0	0	286,208	16	68,027	68,884	645,630	235,893	899
2007	19,176	0	276,452	42	60,639	80,846	671,144	239,874	1,534
2008	0	0	261,129	0	5,841	15,700	640,999	239,874	146
2009	0	0	181,789	0	11,535	35,420	395,988	239,874	523
2010	0	0	154,868	0	15,163	31,233	429,691	239,874	1,039
2011	0	0	134,646	0	15,124	0	491,530	1,046	1,037
2012	0	0	119,783	0	12,642	0	516,107	2,929	902

Table 3-23 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	0	14,487	0
1991	254	19,589	0
1992	678	19,789	0
1993	3,604	20,301	0
1994	6,465	22,392	0
1995	7,124	18,324	0
1996	8,210	32,228	0
1997	8,409	28,725	0
1998	7,047	28,176	0
1999	3,191	44,187	0
2000	311	43,885	0
2001	10,979	77,634	0
2002	729	70,961	0
2003	808	54,573	0
2004	332	56,593	0
2005	350	83,207	0
2006	199	68,027	899
2007	0	60,639	1,534
2008	0	5,841	146
2009	0	11,535	523
2010	0	15,163	1,039
2011	0	15,124	1,037
2012	0	12,642	902

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

Since 2007 the fuel consumption has been decreasing, explained with the abandonment of residual fuel oil and LPG and their substitution by natural gas in more recent years. The drop in total energy consumption in 2011 it's due to the significant reduction on wood fuel consumption.

Figure 3-23 – Total Energy Consumption in the Metallurgy Industry

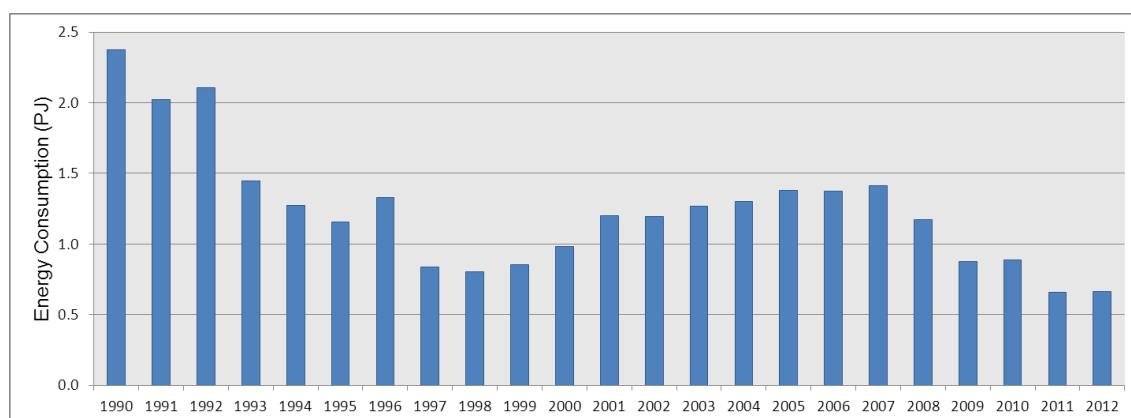
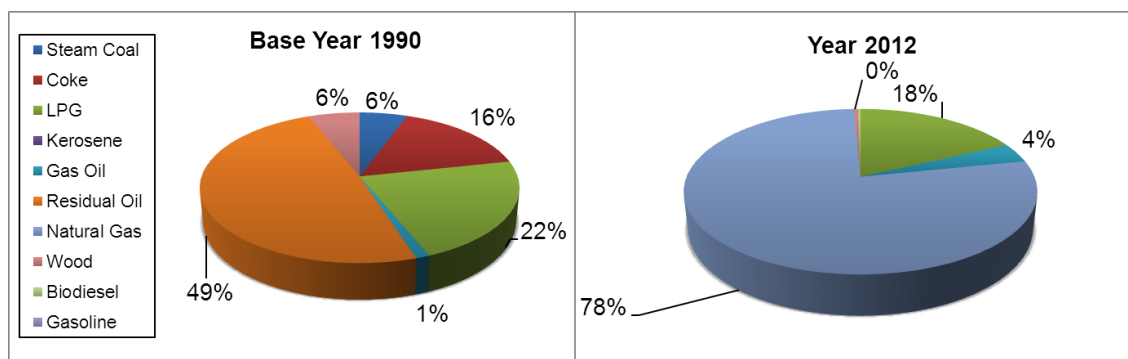


Figure 3-24 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2012



### 3.3.2.2.1.2.3 Chemical and Plastics Industry

Table 3-24 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Chemical and Plastics Industry

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

Natural Gas	Wood	Fuel Gas <sup>18</sup>	Gasoline	Flare Gas <sup>19</sup>	Biodiesel
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
38.7	12.6	47.7 - 52.8	44.0	47.8 - 53.1	37.0

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

<sup>18</sup> Several streams of intermediate gaseous products and tail gases that are used as energy source

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

Table 3-25 - Fuel consumption in Chemical and Plastics Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Coal Coke	LPG	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas	Wood	Fuel Gas	Biodiesel
1990	216,237	196,840	292,721	1,180	77,663	9,970,391	0	1,051,213	11,323,991	0
1991	164,543	276,731	128,258	516	122,917	11,692,840	0	1,032,803	9,038,284	0
1992	0	467,372	126,750	333	107,330	10,363,974	0	1,017,238	10,866,527	0
1993	0	427,819	223,856	118	99,347	7,793,157	0	996,904	10,235,911	0
1994	0	460,864	1,128,784	97	148,592	8,463,649	0	996,904	9,395,006	0
1995	0	492,226	1,609,725	54	167,034	10,502,784	0	996,904	10,383,744	0
1996	0	469,840	1,034,702	88	209,665	10,207,277	0	1,058,033	9,106,036	0
1997	0	404,872	873,379	9,758	166,955	10,766,995	0	1,058,033	11,604,809	0
1998	0	521,287	475,166	19,453	212,439	11,152,909	633,702	1,060,272	12,315,071	0
1999	0	521,287	420,476	45,564	212,027	11,199,606	1,853,917	1,343,390	12,667,516	0
2000	0	2,141,169	342,273	12,395	115,944	11,712,200	2,306,626	1,360,854	13,109,705	0
2001	0	576,830	585,682	5,892	173,761	11,274,543	2,615,674	1,360,837	9,085,408	0
2002	0	581,290	1,525,777	3,677	120,445	9,531,464	2,832,995	1,360,837	8,958,054	0
2003	382,395	283,436	790,348	3,093	99,646	8,058,174	3,252,166	1,414,358	10,140,940	0
2004	413,918	238,253	2,069,796	2,774	92,573	7,683,769	4,277,582	1,442,345	11,773,371	0
2005	482,572	135,743	1,184,269	2,360	98,055	7,811,818	3,904,192	1,471,332	12,972,282	0
2006	688,025	99,984	3,595,052	2,339	70,575	6,403,846	4,210,781	1,493,322	12,330,903	796
2007	533,566	118,697	4,688,952	2,177	42,045	6,150,193	4,512,598	1,536,318	13,975,868	915
2008	536,622	106,848	5,899,691	879	24,669	5,950,938	4,269,662	1,536,318	10,659,453	603
2009	448,239	86,123	1,814,218	837	30,493	3,788,755	5,833,125	1,536,318	7,150,397	1,294
2010	423,327	91,315	350,821	377	35,618	4,301,547	7,567,560	1,536,318	8,848,201	2,121
2011	420,187	102,996	480,957	293	37,160	3,362,900	8,515,293	23,598	6,853,637	2,241
2012	475,871	14,696	192,776	209	36,514	1,866,414	8,550,429	24,937	4,090,846	2,471

Table 3-26 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Fuel oil	Biodiesel
1990	7,803	80,157	160,712	0
1991	24,211	129,048	274,906	0
1992	66,734	115,720	425,762	0
1993	67,461	105,835	588,618	0
1994	107,787	151,737	203,808	0
1995	166,006	173,141	379,018	0
1996	131,720	214,851	321,823	0
1997	190,848	172,353	334,966	0
1998	188,291	218,213	358,303	0
1999	161,623	219,922	489,977	0
2000	48,157	123,786	486,645	0
2001	72,112	180,016	378,123	0
2002	56,488	127,377	418,988	0
2003	47,944	106,665	424,255	0
2004	32,195	98,984	387,512	0
2005	12,349	104,913	414,539	0
2006	3,747	77,014	389,226	796
2007	2,052	49,143	429,050	915
2008	293	30,488	351,723	603
2009	0	34,132	220,004	1,294
2010	0	39,457	232,103	2,121
2011	0	40,089	177,036	2,241
2012	0	38,160	99,505	2,471

Table 3-27 - Fuel consumption in Chemical and Plastics Industry – Flares (GJ)

Year	Flare Gas
1990	859,031
1991	538,730
1992	574,865
1993	1,217,549
1994	1,223,447
1995	1,011,512
1996	858,870
1997	893,948
1998	956,229
1999	1,307,636
2000	1,298,744
2001	1,036,071
2002	1,148,041
2003	1,162,474
2004	1,061,797
2005	1,135,850
2006	1,066,494
2007	1,175,611
2008	963,732
2009	602,818
2010	635,969
2011	485,084
2012	272,647

Two industrial plants in this sector were treated as Large Point Sources, representing a substantial component of total energy consumption, but for confidentiality constrains plant specific information cannot be published individually. In the beginning of the period under analysis, fuel consumption<sup>20</sup> was based on residual fuel oil, traded or by-product of the unit, and residual gases, also obtained as a by-product from the production processes. More recently, natural gas has gained a relevant importance as the third energy source. An increasing trend in total energy consumption - although irregular - is verifiable in Figure 3-25. The consumption of coke time series presents an anomalous value in 2000. When questioned about this, the energy balance team at DGEG could not justify the inconsistent value.

<sup>20</sup> 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 3-25 – Total Energy Consumption in the Chemical and Plastic Industry

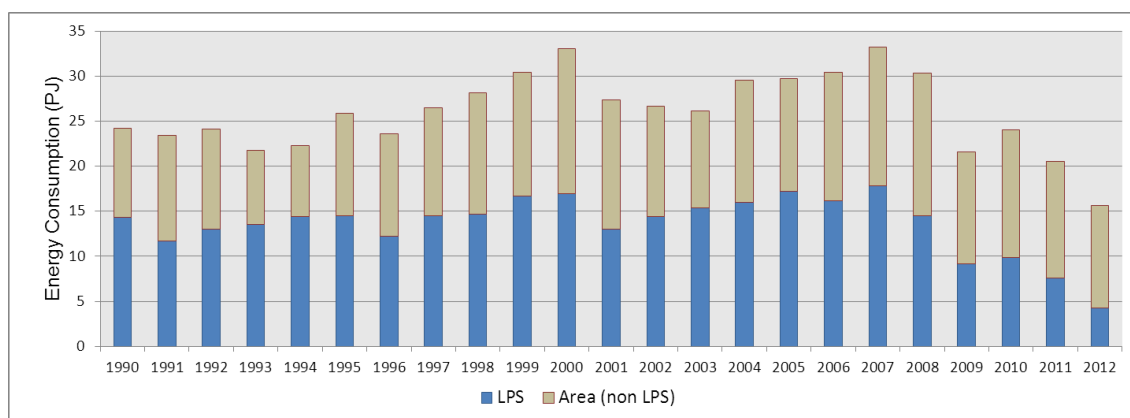
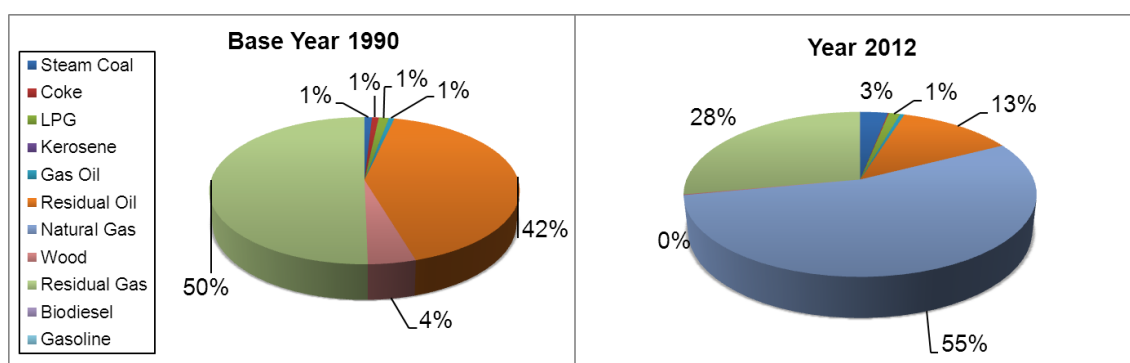


Figure 3-26 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2012



#### 3.3.2.2.1.2.4 Paper and Paper Pulp Industry

Table 3-28 – LHV/NCV in the Paper and Paper Pulp Industry

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

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

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

Table 3-29 - Fuel consumption in the Paper and Paper Pulp Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood & Wood Wastes <sup>21</sup>	Liquors	Biodiesel
1990	103,423	7	90,172	9,478,929	0	5,148,908	25,397,844	0
1991	192,057	51	78,864	10,289,568	0	5,717,707	28,352,132	0
1992	238,921	32	76,196	11,262,506	0	7,061,105	28,706,113	0
1993	201,008	7	70,972	11,651,070	0	7,681,878	27,159,242	0
1994	274,229	4	66,319	13,401,753	0	6,740,066	26,600,496	0
1995	283,226	23	72,544	11,038,222	0	7,360,136	27,222,347	0
1996	301,955	5	71,744	11,558,997	0	6,810,970	27,096,395	0
1997	326,409	6	80,331	10,885,350	0	7,373,382	30,025,613	0
1998	346,368	0	61,032	10,974,744	7,822	7,298,265	29,876,259	0
1999	265,576	0	59,618	10,809,553	337,899	7,854,467	30,739,205	0
2000	249,182	26	54,762	11,559,810	2,375,616	6,489,241	33,489,524	0
2001	240,268	109	79,638	8,501,738	957,144	6,183,349	31,461,749	0
2002	103,178	78	76,889	7,711,112	1,574,920	6,613,112	30,748,133	0
2003	99,506	79	77,148	6,710,693	2,100,156	5,837,012	27,846,161	0
2004	96,983	81	75,053	6,655,151	2,348,468	7,973,839	31,101,753	0
2005	92,399	55	81,294	4,988,837	3,578,750	7,431,556	31,534,746	0
2006	60,855	107	81,501	4,696,112	4,601,467	7,838,096	32,933,200	1,088
2007	55,223	84	76,761	4,012,043	4,835,374	7,604,510	33,204,529	1,970
2008	54,972	126	75,940	4,803,211	5,109,338	6,924,471	32,351,803	1,892
2009	84,991	126	71,986	3,972,499	8,528,610	6,115,997	33,017,163	3,249
2010	93,532	126	75,404	3,759,716	13,141,915	6,265,175	36,429,196	5,097
2011	75,027	251	74,172	2,479,418	14,837,154	6,983,823	35,921,898	5,061
2012	81,893	251	72,451	2,243,532	14,775,386	8,133,639	26,643,806	5,159

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal from 1990 to 2012 (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, except for 2010 where the increase is significant (20 per cent). The lower temporary value in 2003 reflects a re-qualification period for one unit. Considering the share of energy sources, there is a dominance of liquor, followed by residual fuel oil, wood waste and natural gas - this last only recently - as auxiliary primary energy sources.

<sup>21</sup> Wood waste includes methanol, NCG, tall-oil, biogas and gasified biomass.

Table 3-30 - Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ)

Year	Gasoline	Diesel Oil	Biogas	Biodiesel
1990	2,678	90,172	0	0
1991	6,339	78,864	0	0
1992	8,809	76,196	0	0
1993	4,835	70,972	0	0
1994	11,005	66,319	0	0
1995	6,137	72,544	0	0
1996	5,363	71,744	0	0
1997	9,484	80,331	0	0
1998	8,928	61,032	0	0
1999	7,702	59,618	0	0
2000	796	54,762	9,705	0
2001	24,311	79,638	17,804	0
2002	1,069	76,889	19,632	0
2003	1,283	77,148	19,056	0
2004	891	75,053	24,469	0
2005	911	81,294	28,895	0
2006	591	79,898	33,047	1,088
2007	335	76,761	31,230	1,970
2008	167	75,940	40,780	1,892
2009	167	71,329	38,815	3,249
2010	335	73,282	34,055	5,097
2011	0	73,639	36,542	5,061
2012	0	72,146	0	5,159

Figure 3-27 – Total Energy Consumption in the Paper and Paper Pulp Industry

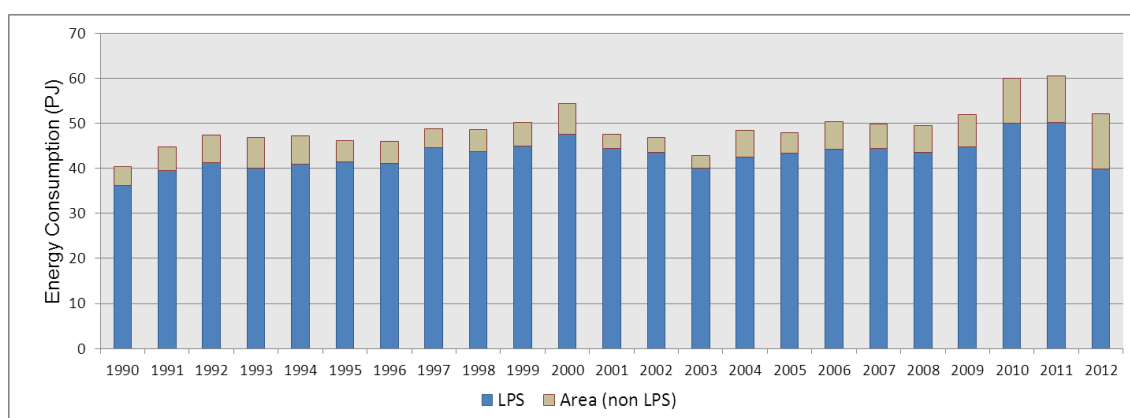
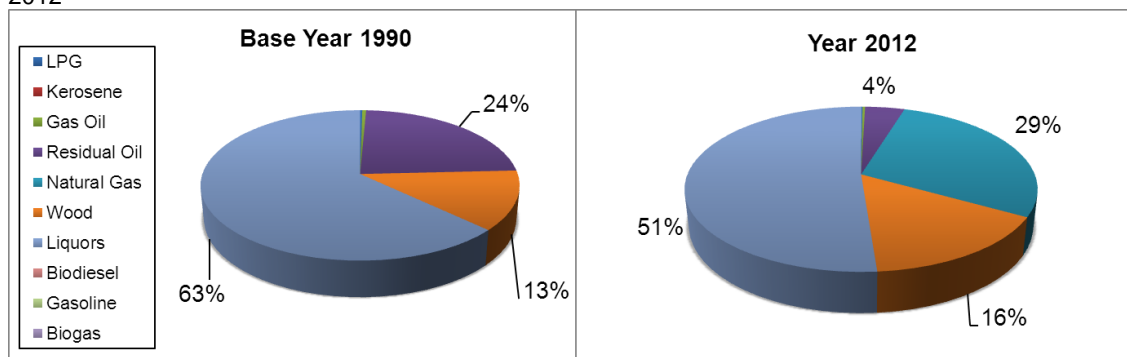


Figure 3-28 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2012



#### 3.3.2.2.1.2.5 Food Processing, Beverages and Tobacco Industries

Table 3-31 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Food Processing, Beverages and Tobacco Industries

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

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

Table 3-32 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas	Wood	Biodiesel
1990	12,416	906,272	13,318	545,639	8,902,333	0	3,981,464	0
1991	6,641	1,043,157	6,716	590,698	9,657,033	0	3,911,799	0
1992	432	1,147,678	7,586	683,319	9,558,680	0	3,852,887	0
1993	0	1,217,112	7,662	688,426	9,014,368	0	3,775,816	0
1994	0	1,363,652	6,223	728,505	8,945,629	0	3,775,858	0
1995	0	1,462,813	5,078	735,940	9,399,512	0	3,775,858	0
1996	0	1,626,766	2,130	798,673	9,403,558	0	4,006,695	0
1997	0	1,965,948	4,595	747,839	11,124,19	3,872	4,006,695	0
1998	0	1,944,223	5,540	720,126	11,360,55	393,125	4,015,170	0
1999	0	1,899,755	6,938	813,351	10,595,78	1,197,660	3,391,460	0
2000	0	1,699,805	1,729	669,262	9,384,736	1,800,027	3,435,549	0
2001	0	1,812,025	906	738,713	9,505,627	2,563,048	3,435,146	0
2002	0	1,703,146	802	650,597	9,554,549	3,839,320	3,435,146	0
2003	0	1,632,065	802	634,089	9,039,749	4,810,727	3,653,341	0
2004	0	1,438,067	742	678,022	6,543,490	4,916,785	3,642,346	0
2005	0	1,231,248	5	753,087	5,798,837	4,518,346	3,714,314	0
2006	0	1,117,981	0	660,586	6,983,886	4,632,042	3,769,289	8,694
2007	0	1,031,535	0	645,959	6,479,213	6,798,735	3,883,222	16,194
2008	0	1,009,136	42	530,191	5,969,437	6,225,604	3,883,222	12,682
2009	0	920,042	126	497,523	5,823,278	6,073,749	3,883,222	21,445
2010	0	927,704	209	485,414	5,782,876	6,842,069	3,883,222	31,502
2011	0	927,452	126	475,805	4,995,520	7,659,583	423,013	31,649
2012	0	962,244	167	469,520	3,850,073	8,051,928	422,636	32,554

Table 3-33 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biogas	Biodiesel
1990	17,588	545,639	0	0
1991	27,172	590,698	0	0
1992	68,262	683,319	0	0
1993	50,904	688,426	0	0
1994	103,964	728,505	0	0
1995	109,277	735,940	0	0
1996	118,108	798,673	0	0
1997	192,149	747,839	0	0
1998	174,625	720,126	0	0
1999	171,514	813,351	0	0
2000	117,945	669,262	0	0
2001	224,544	738,713	0	0
2002	101,376	650,597	0	0
2003	89,323	634,089	0	0
2004	73,178	678,022	0	0
2005	68,883	753,087	0	0
2006	53,825	660,586	0	8,694
2007	40,110	645,959	0	16,194
2008	27,089	530,191	0	12,682
2009	27,801	497,523	61	21,445
2010	22,023	485,414	61	31,502

2011	0	475,805	31	31,649
2012	0	469,520	0	32,554

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 3-29 – Total Energy Consumption in the Food Processing, Beverages and Tobacco Industry

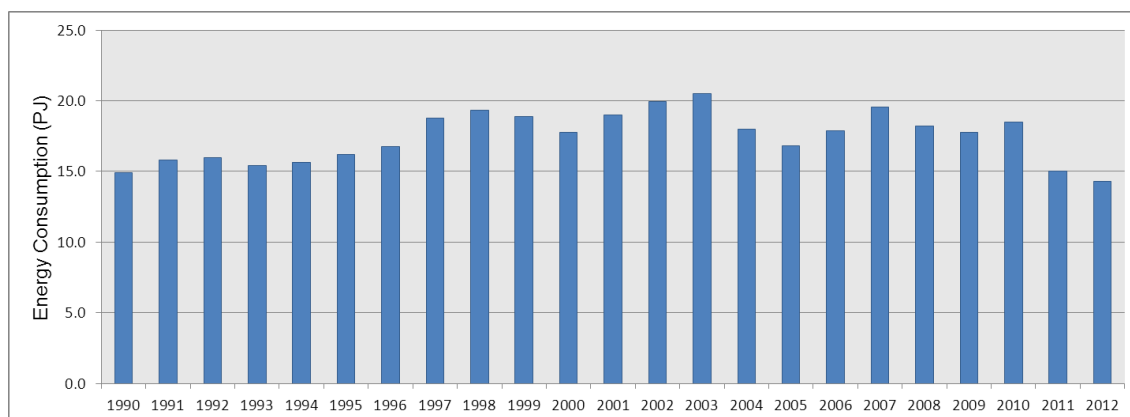
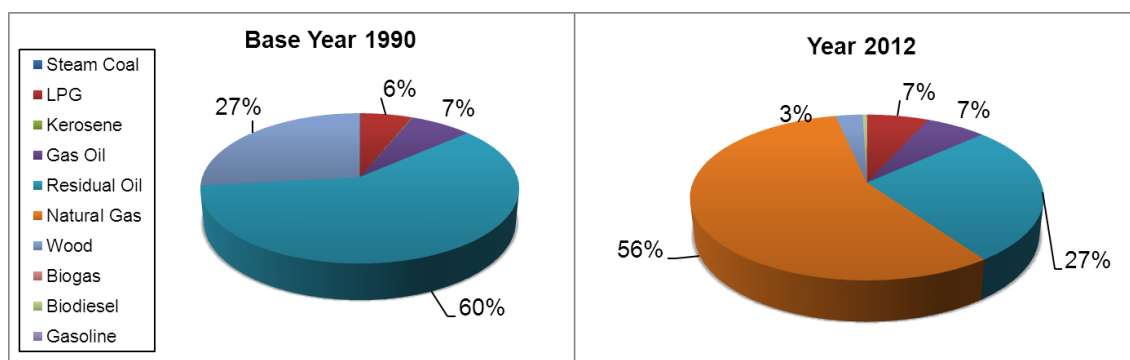


Figure 3-30 - Fuel consumption per fuel type in the Food Processing, Beverages and Tobacco Industries in 1990 and 2012



### 3.3.2.2.1.2.6 Textile Industry

Table 3-34 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Textile Industry

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

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3-35 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	211,214	125	27,579	10,404,993	0	1,136,569	0
1991	260,205	113	28,151	8,875,482	0	1,116,695	0
1992	313,552	104	31,073	8,143,021	0	1,099,874	0
1993	309,144	65	31,631	7,372,887	0	1,077,866	0
1994	327,132	24	37,277	8,360,703	0	1,077,866	0
1995	375,912	4	37,333	8,878,803	0	1,077,866	0
1996	446,600	6	40,491	11,406,256	0	1,143,933	0
1997	554,936	180	50,856	14,719,583	0	1,143,933	0
1998	658,786	175	52,487	14,167,006	15,730	1,146,353	0
1999	714,642	8	51,568	11,703,715	626,479	2,033,077	0
2000	508,000	0	75,347	11,337,089	4,196,215	2,059,507	0
2001	450,644	0	67,973	9,263,701	6,182,075	2,059,498	0
2002	406,246	0	91,024	9,179,144	7,928,179	2,059,498	0
2003	394,650	0	100,415	7,739,570	8,408,905	2,140,028	0
2004	415,336	0	114,222	7,117,438	8,620,985	2,183,009	0
2005	362,613	4	108,672	7,295,236	7,979,600	2,225,989	0
2006	311,168	6	87,504	7,214,990	8,293,554	2,258,974	1,084
2007	250,704	84	62,987	5,990,496	8,093,001	2,328,954	1,426
2008	159,223	42	53,845	4,417,459	8,711,475	2,328,954	1,211
2009	140,927	42	20,224	4,055,097	7,833,042	2,328,954	354
2010	134,730	42	19,565	3,921,248	7,845,017	2,328,954	636
2011	140,424	0	14,948	3,109,609	8,173,806	28,828	375
2012	126,482	0	9,598	1,257,484	9,313,285	28,828	387

Table 3-36 – Fuel consumption in Textile Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	4,315	27,579	0
1991	4,726	28,151	0
1992	12,066	31,073	0
1993	9,231	31,631	0
1994	18,629	37,277	0
1995	18,913	37,333	0
1996	19,253	40,491	0
1997	21,802	50,856	0
1998	22,731	52,487	0
1999	18,443	51,568	0
2000	66,391	75,347	0
2001	60,135	67,973	0
2002	59,054	91,024	0
2003	63,476	100,415	0
2004	50,115	114,222	0
2005	43,123	108,672	0
2006	37,732	87,504	1,084
2007	30,355	62,987	1,426
2008	2,638	53,845	1,211
2009	670	20,224	354
2010	0	19,565	636
2011	0	14,948	375
2012	0	9,598	387

Figure 3-31 – Total Energy Consumption in the Textile Industry

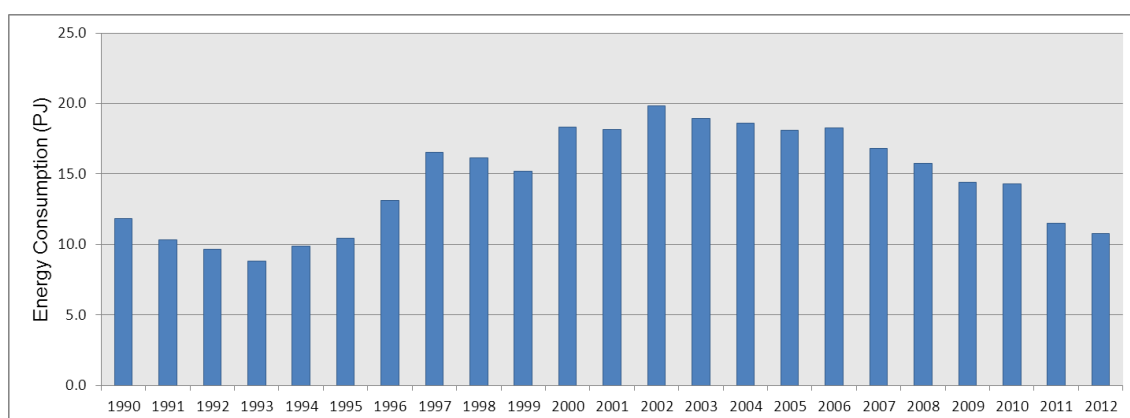
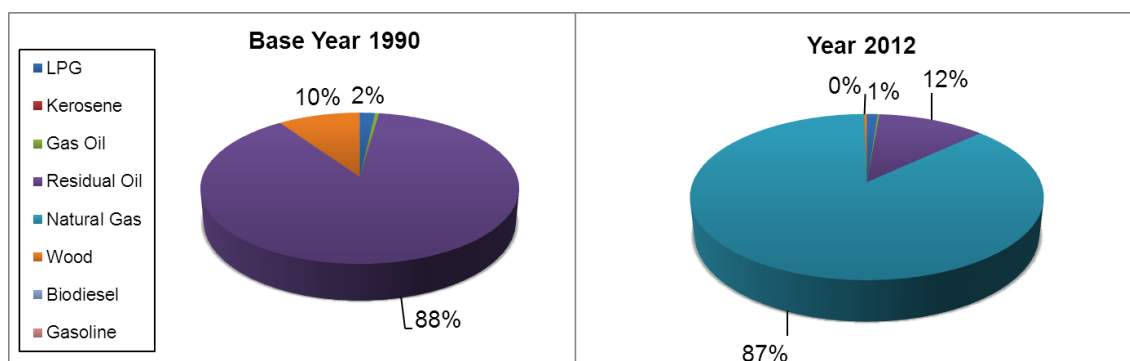




Figure 3-32 – Fuel consumption per fuel type in Textile Industry in 1990 and 2012



### 3.3.2.2.1.2.7 Ceramic Industry

Table 3-37 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Ceramic Industry

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

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

Table 3-38 - Fuel consumption in the Ceramic Industry – Boilers and Furnaces (GJ)

Year	Steam Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	6,556	0	6,150,865	28	128,086	3,301,796	0	12,476,234	0
1991	2,256	0	6,723,830	214	156,820	3,540,690	0	12,257,950	0
1992	0	0	7,327,807	4,322	157,373	3,342,813	0	12,073,347	0
1993	0	0	7,659,325	1,396	131,411	3,190,911	0	11,831,925	0
1994	0	0	8,226,958	109	133,584	3,288,727	0	11,831,883	0
1995	0	0	8,792,146	0	130,307	3,727,408	0	11,831,883	0
1996	0	0	9,082,825	1	135,921	3,923,131	0	12,556,485	0
1997	0	0	8,148,126	0	188,157	6,037,204	1,399,966	12,556,485	0
1998	0	0	4,500,669	0	199,676	5,884,312	6,409,738	12,583,047	0
1999	0	0	2,507,757	7	177,792	4,478,322	11,300,965	13,336,945	0
2000	0	0	1,410,200	347	181,234	3,754,710	13,870,518	13,510,325	0
2001	0	0	1,459,289	244	215,231	3,038,583	15,367,517	13,510,335	0
2002	0	0	1,120,472	256	171,444	2,074,805	16,154,119	13,510,335	0
2003	0	0	839,455	299	155,544	912,791	15,930,584	13,782,248	0
2004	0	843,393	691,344	193	157,760	826,023	15,478,382	14,059,122	0
2005	0	539,058	540,176	166	126,016	810,594	14,790,173	14,022,734	0
2006	0	0	439,528	220	98,605	549,847	14,256,020	14,355,156	1,329
2007	0	191,791	419,849	167	86,320	813,104	14,346,447	14,860,837	2,209
2008	0	319,414	365,881	209	80,663	692,694	13,326,501	14,824,895	2,004
2009	0	685,152	274,066	293	191,690	385,221	10,842,514	14,824,895	8,394
2010	0	462,743	244,800	251	57,248	375,633	11,517,845	13,913,347	3,879
2011	0	559,539	199,458	251	54,922	309,567	11,994,428	161,381	3,755
2012	0	398,660	167,303	167	41,347	158,216	10,692,669	1,046,569	2,949

Table 3-39 – Fuel consumption in the Ceramic Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	38,533	128,086	0
1991	41,482	156,820	0
1992	51,461	157,373	0
1993	50,728	131,411	0
1994	53,076	133,584	0
1995	48,847	130,307	0
1996	34,960	135,921	0
1997	30,044	188,157	0
1998	30,588	199,676	0
1999	20,682	177,792	0
2000	17,199	181,234	0
2001	17,688	215,231	0
2002	19,150	171,444	0
2003	21,423	155,544	0
2004	19,920	157,760	0
2005	435	126,016	0
2006	135	98,605	1,329
2007	0	86,320	2,209
2008	0	80,663	2,004
2009	8,374	191,690	8,394
2010	377	57,248	3,879
2011	0	54,922	3,755
2012	0	41,347	2,949

The figure below shows two periods: the first goes from 1990 to 2001 and characterizes a steady increase in fuel consumption, after that total energy consumption has declined until 2011 (except for 2007 and 2008). The pattern of fuel consumption has also changed, with the abandonment of residual fuel oil and LPG and their substitution by natural gas in more recent years. This sector, together with the glass industry, is in fact one in which the substitution was more visible. The decrease in use of biomass is only apparent in per cent, because values of consumption of these fuels did in fact increased slightly. Since 2004 the gasoline consumption has been dropping significantly. In 2011 and 2012 a significant decrease in wood consumption was reported in the energy balance.

Figure 3-33 – Total Energy Consumption in the Ceramic Industry

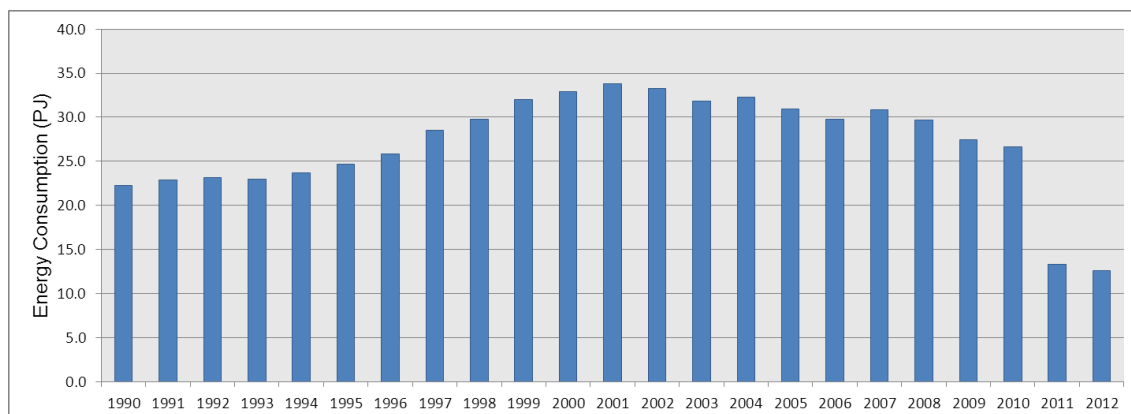
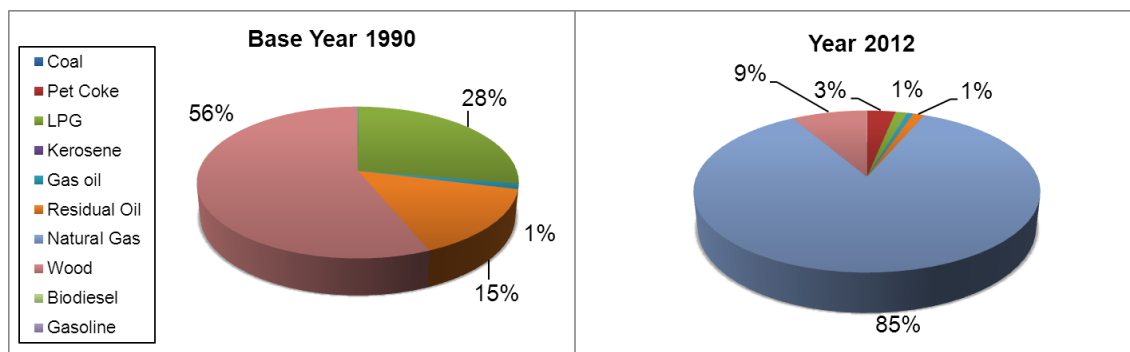


Figure 3-34 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2012



#### 3.3.2.2.1.2.8 Glass Industry

Table 3-40 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Glass Industry

Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3
25.2 - 28	27.0	46.0	43.8	42.6	40.0	38.7

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

Table 3-41 – Fuel consumption in the Glass Industry – Boilers and Furnaces (GJ)

Year	Coal	Pet Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	324	0	1,162,470	0	25,226	4,460,995	0	1,381	0
1991	255	0	1,250,623	0	23,672	5,507,908	0	1,339	0
1992	289	0	1,144,507	0	25,026	5,570,521	0	1,339	0
1993	135	0	1,134,877	0	16,996	6,086,942	0	1,297	0
1994	270	0	1,267,678	0	14,597	6,429,427	0	1,297	0
1995	272	0	1,383,684	0	21,384	6,578,946	0	1,297	0
1996	0	0	1,550,804	0	35,744	6,868,259	0	1,381	0
1997	380	0	1,736,648	0	29,416	7,661,098	28,312	1,381	0
1998	601	0	1,113,267	0	27,131	8,172,569	799,585	1,384	0
1999	555	0	570,586	0	31,200	5,951,368	2,821,682	1,381	0
2000	356	0	346,329	7	23,699	3,739,016	5,243,975	1,381	0
2001	129	0	242,756	0	35,212	3,087,907	6,003,147	1,381	0
2002	106	0	157,400	0	24,593	2,643,357	6,338,165	1,381	0
2003	0	0	134,774	0	26,248	2,030,033	6,510,740	1,381	0
2004	0	0	45,416	0	30,674	2,012,460	7,511,123	1,381	0
2005	0	0	20,930	0	19,841	1,998,340	6,675,198	0	0
2006	0	0	25,773	0	9,843	1,678,085	7,101,546	0	121
2007	466	0	21,981	0	9,795	855,938	8,506,973	0	215
2008	4,719	0	22,106	0	25,854	388,959	8,382,709	0	637
2009	5,592	0	14,215	0	26,268	151,166	7,798,147	0	1,172
2010	5,766	0	13,287	0	27,099	146,454	7,702,477	0	1,836
2011	5,944	383	21,046	0	24,585	0	7,621,023	0	1,668
2012	7,877	0	15,223	0	23,702	0	8,259,840	0	1,667

Table 3-42 – Fuel consumption in the Glass Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	4,001	25,143	0
1991	3,989	23,581	0
1992	5,229	24,930	0
1993	5,589	16,904	0
1994	4,933	14,492	0
1995	3,648	21,274	0
1996	3,816	35,628	0
1997	3,579	29,285	0
1998	4,315	27,003	0
1999	2,702	30,999	0
2000	1,030	23,474	0
2001	1,123	34,998	0
2002	283	24,176	0
2003	152	25,760	0
2004	171	29,943	0
2005	174	18,734	0
2006	123	8,968	121
2007	0	6,994	215
2008	0	25,234	637
2009	0	25,403	1,172
2010	0	26,474	1,836
2011	0	24,084	1,668
2012	0	23,007	1,667

In this sector 9 plants are treated as LPS, converging flat, container and crystal glass production. The fuel consumption contribution of these 9 plants has increased from 1990 to 2012, covering in this year more than 97 per cent of the total fuel consumption in this sector.

The consumption of energy in this sector has suffered stagnation in the most recent years after 1999, showing a slight increase in 2007 and a decrease thereafter. The introduction of natural gas has almost fully replaced the consumption of LPG and most of the consumption of residual fuel oil that was in dominance in 1990. The decrease in residual oil consumption in 2011 and 2012, results from fact that the only cogeneration plant from this sector did not work this years.

Figure 3-35 – Total Energy Consumption in the Glass Industry

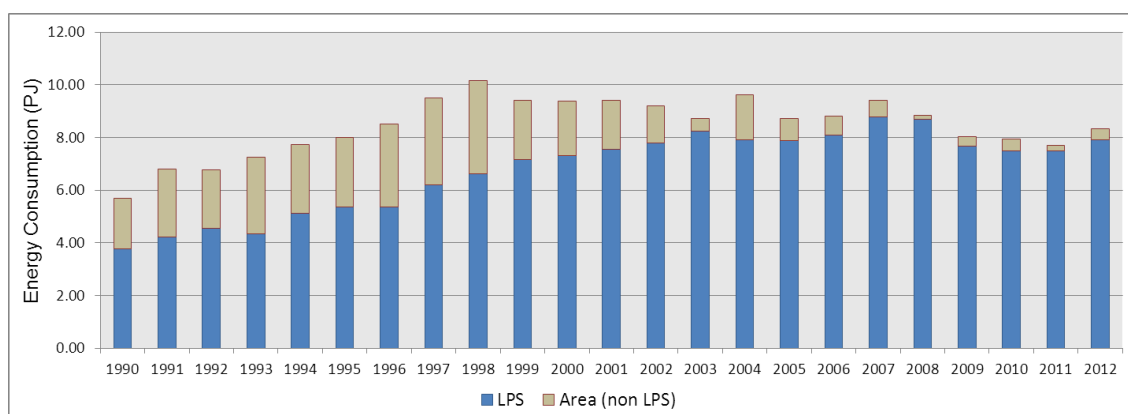
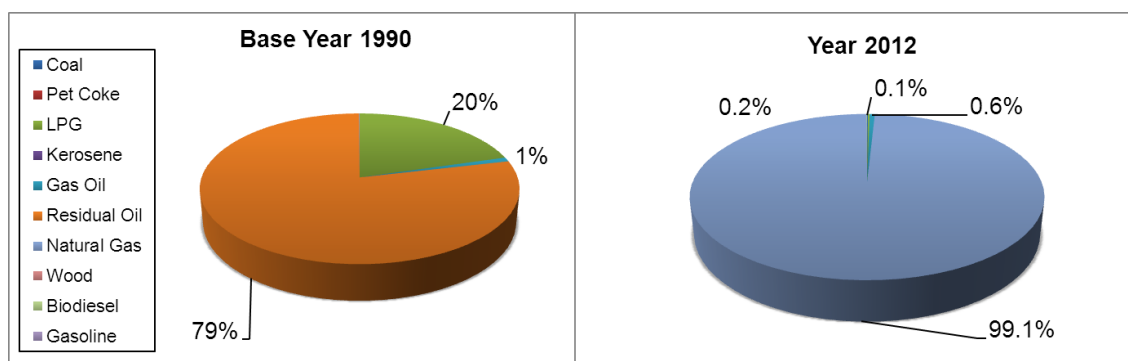


Figure 3-36 – Fuel consumption per fuel type in Glass Industry in 1990 and 2012



#### 3.3.2.2.1.2.9 Cement Industry

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

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

Other changes were made to this sector in the 2012 inventory. These changes concern the inclusion of Lime Production activities as LPS in the inventory. This improvement resulted from the ongoing integration of EU-ETS data in the inventory.

Table 3-43 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry

Steam Coal	Petcoke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
18.7 - 31	30.9 - 34.6	46.0	44.0	43.8	42.6	39.8 - 40.4

Biodiesel	Tires	Industrial Waste	Hazardous Industrial Waste	Animal + Wood Waste	Natural Gas (MJ/Nm3)
MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/Nm3
37.0	23.8 - 31.4	10.7 - 32.3	12.3 - 25.1	9.8 - 21.0	38.7

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

Currently there are 7 dedicated lime production plants in operation in Portugal which use natural gas as main fuel since 2000 (prior to that was residual oil). In this sector there is also consumption of petcoke and biomass, and small amounts of LPG and gas oil.

Even though fuel consumption in this sector includes at least 9 companies we consider this data to be confidential, because there are only two companies (associated with clinker production) for most fuels, and both represent more than 90 per cent of consumption for all other fuels. Because of this no table will be included in this report with energy consumption data desegregated by fuel type.

Figure 3-37 – Total Energy Consumption in the Cement Industry

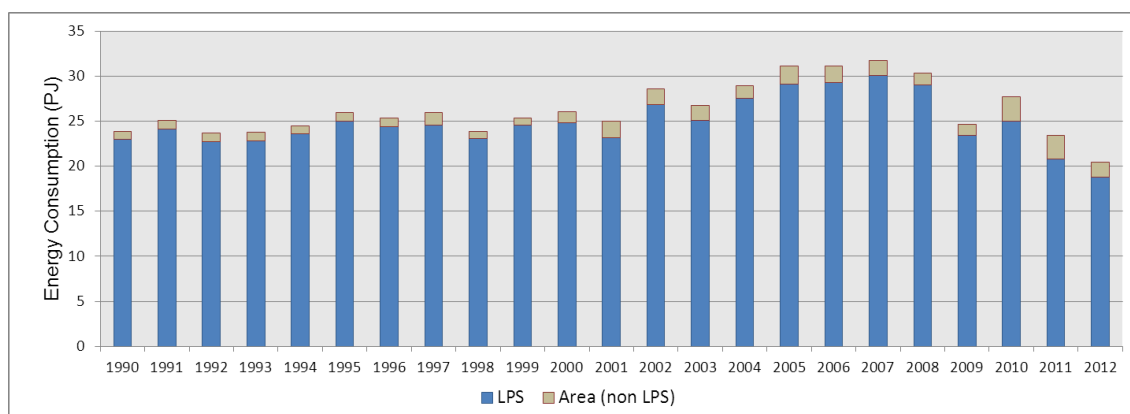
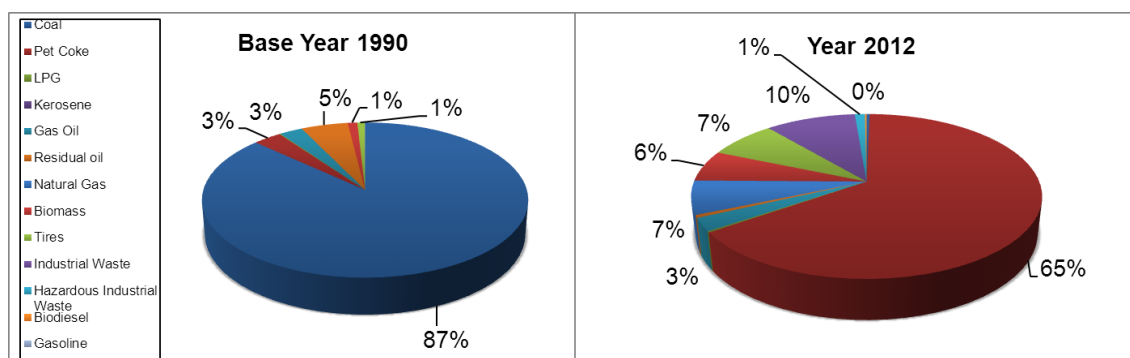


Figure 3-38 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2012



### 3.3.2.2.1.2.10 Clothing, Shoes and Leather Industries

Table 3-44 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Clothing, Shoes and Leather Industries

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

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0



Table 3-45 – Fuel consumption in the Clothing, Shoes and Leather Industries – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	56,737	28	27,665	766,086	0	279,958	0
1991	111,352	42	27,365	857,780	0	275,063	0
1992	162,183	35	25,769	1,392,16	0	270,921	0
1993	206,219	7	24,420	1,826,14	0	265,523	0
1994	222,108	0	25,347	1,336,45	0	265,481	0
1995	239,172	0	22,330	704,818	0	265,481	0
1996	305,659	0	24,048	791,568	0	281,590	0
1997	314,163	0	19,948	776,058	0	281,590	0
1998	330,170	0	20,230	714,889	7,699	282,186	0
1999	312,995	0	19,271	646,835	33,698	282,427	0
2000	226,044	0	15,078	350,076	148,572	282,636	0
2001	315,192	0	17,804	370,528	400,435	282,636	0
2002	297,487	0	14,775	466,430	259,659	282,636	0
2003	259,993	0	12,902	333,378	401,309	0	0
2004	242,081	0	11,756	323,717	478,345	0	0
2005	231,177	8	11,608	241,561	471,671	0	0
2006	212,729	0	8,234	244,972	508,817	0	111
2007	183,757	0	3,980	244,296	576,313	0	102
2008	202,053	0	4,672	263,261	664,655	0	100
2009	172,997	0	4,792	391,417	743,450	0	169
2010	155,078	0	7,357	373,331	767,189	0	409
2011	134,521	0	9,416	287,293	756,722	24,686	549
2012	127,445	0	8,620	63,638	835,350	24,686	591

Table 3-46 – Fuel consumption in the Clothing, Shoes and Leather Industries – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	1,962	27,665	0
1991	2,752	27,365	0
1992	7,815	25,769	0
1993	7,118	24,420	0
1994	9,400	25,347	0
1995	8,668	22,330	0
1996	8,252	24,048	0
1997	7,989	19,948	0
1998	7,529	20,230	0
1999	6,189	19,271	0
2000	3,836	15,078	0
2001	13,200	17,804	0
2002	2,321	14,775	0
2003	1,363	12,902	0
2004	801	11,756	0
2005	465	11,608	0
2006	211	8,234	111
2007	0	3,980	102
2008	0	4,672	100
2009	0	4,792	169
2010	0	7,357	409
2011	0	9,416	549
2012	0	8,620	591

Figure 3-39 – Total Energy Consumption in the Clothing, Shoes and Leather Industries

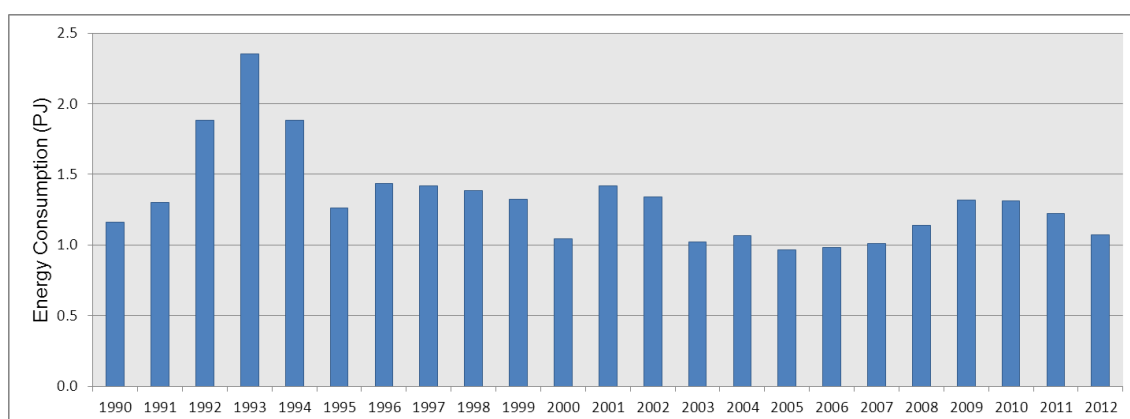
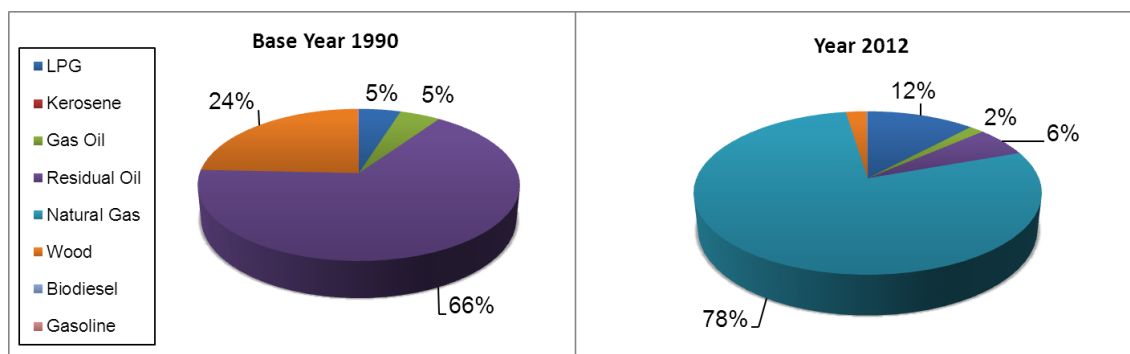


Figure 3-40 - Fuel consumption per fuel type in the Clothing, Shoes and Leather Industries in 1990 and 2012



#### 3.3.2.2.1.2.11 Wood Industry

Table 3-47 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Wood Industry

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

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3-48 – Fuel consumption in the Wood Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	85,312	69	250,404	1,346,386	0	1,309,205	0
1991	100,217	57	246,445	1,276,646	0	1,286,318	0
1992	96,645	11	208,220	689,356	0	1,266,946	0
1993	110,716	22	179,511	1,075,448	0	1,241,590	0
1994	115,891	21	185,097	1,786,302	0	1,241,590	0
1995	115,297	0	192,250	3,036,372	0	1,241,590	0
1996	131,603	0	204,648	3,087,875	0	1,317,573	0
1997	330,329	1,913	479,921	2,899,400	0	1,317,573	0
1998	343,536	2,902	578,339	2,839,822	12	1,320,360	0
1999	378,477	74	498,230	2,844,661	34,865	895,593	0
2000	467,887	85	206,253	2,939,646	237,201	907,236	0
2001	444,997	81	255,386	1,742,151	306,931	903,766	0
2002	426,701	84	208,273	2,119,550	345,241	618,075	0
2003	382,080	73	202,288	1,999,425	397,689	1,640,255	0
2004	303,590	57	323,109	2,071,844	525,713	1,693,231	0
2005	260,611	1,127	215,627	1,998,707	524,175	1,632,259	0
2006	208,727	1,653	239,281	2,032,255	513,470	1,656,248	3,097
2007	183,590	1,507	235,849	2,024,450	559,356	1,706,234	5,559
2008	54,763	42	158,228	1,645,049	293,202	1,706,234	3,694
2009	47,478	42	134,140	1,893,071	237,308	1,706,234	5,801
2010	59,326	0	122,013	1,667,574	335,823	1,706,234	8,048
2011	68,495	42	117,916	1,325,937	387,070	2,675,565	7,791
2012	60,499	0	105,721	991,836	375,095	2,905,272	7,007

Table 3-49 – Fuel consumption in the Wood Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	793	250,404	0
1991	1,833	246,445	0
1992	3,554	208,220	0
1993	3,625	179,511	0
1994	9,248	185,097	0
1995	11,017	192,250	0
1996	11,956	204,648	0
1997	132,910	479,921	0
1998	169,240	578,339	0
1999	129,639	498,230	0
2000	4,050	206,253	0
2001	30,957	255,386	0
2002	3,233	208,273	0
2003	2,503	202,288	0
2004	1,595	323,109	0
2005	1,373	215,627	0
2006	399	239,281	3,097
2007	0	235,849	5,559
2008	0	158,228	3,694
2009	0	134,140	5,801
2010	0	122,013	8,048
2011	0	117,916	7,791
2012	0	105,721	7,007

Although total consumption of energy from combustion has increased from 1990 to 2012, 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 3-41 – Total Energy Consumption in the Wood Industry

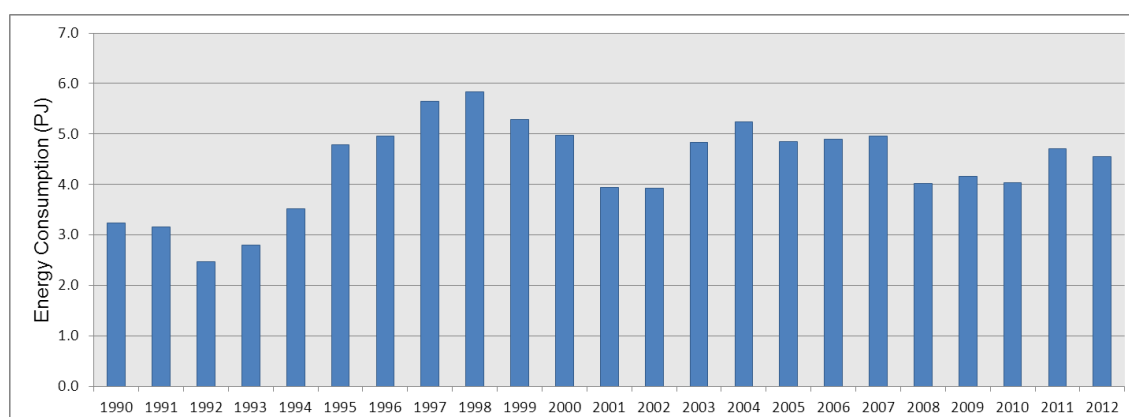
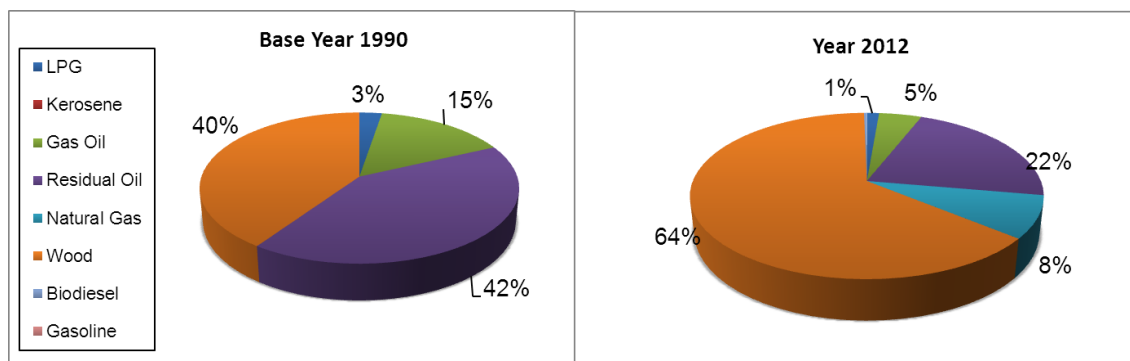


Figure 3-42 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2012



#### 3.3.2.2.1.2.12 Rubber Industry

Table 3-50 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Rubber Industry

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

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0

Table 3-51 – Fuel consumption in the Rubber Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	27,688	240	5,481	571,475	0	46,820	0
1991	30,088	268	6,785	462,494	0	45,983	0
1992	28,326	223	13,612	344,254	0	45,314	0
1993	27,900	188	13,630	286,945	0	44,393	0
1994	30,756	118	14,585	262,613	0	44,393	0
1995	33,286	135	13,470	270,653	0	44,393	0
1996	39,209	168	14,017	268,187	0	47,280	0
1997	71,154	60	11,593	281,383	0	47,280	0
1998	28,011	28	11,876	307,699	362	47,380	0
1999	26,034	13	16,811	352,972	1,570	47,322	0
2000	28,111	48	29,578	379,923	34,818	47,280	0
2001	35,400	15	33,386	203,323	137,685	47,280	0
2002	29,357	0	29,342	87,481	270,921	47,280	0
2003	27,680	1	24,560	67,653	313,684	0	0
2004	19,803	0	25,403	50,879	402,276	0	0
2005	20,546	0	1,314	27,107	419,232	0	0
2006	17,453	16	270	17,474	482,834	0	4
2007	11,932	42	3,131	11,430	475,620	0	9
2008	6,113	0	3,122	17,919	681,025	0	18
2009	3,140	42	1,957	21,352	672,819	0	32
2010	4,145	42	0	20,682	733,695	0	0
2011	4,731	0	0	9,001	774,181	30,042	0
2012	4,647	42	0	6,699	826,307	28,996	0

Table 3-52 – Fuel consumption in the Rubber Industry – Static Engines (GJ)

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

The figure below shows a significant increase in the total fuel consumption since 2008, mainly due to natural gas consumption. The sharp increase in natural gas consumption from 2007 to 2008 results from a reclassification of a co-generation plant in the energy balance (previously accounted in another sector).

Figure 3-43 – Total Energy Consumption in the Rubber Industry

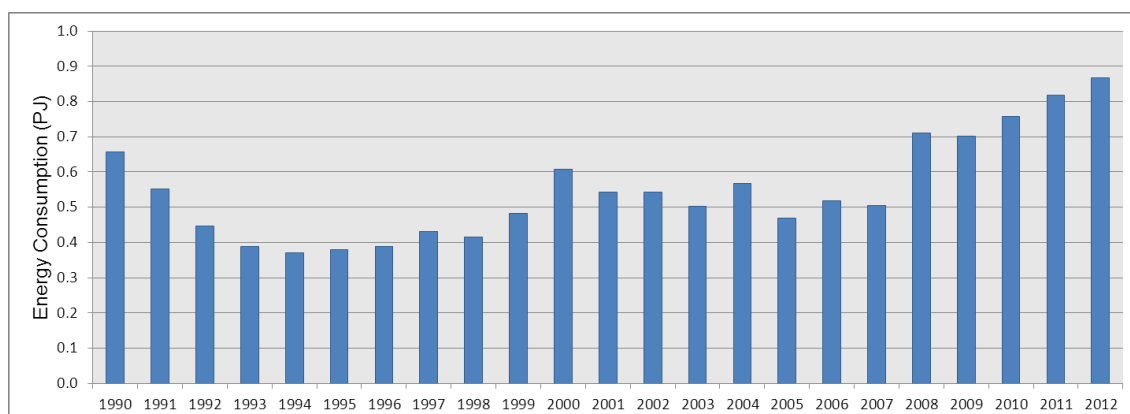
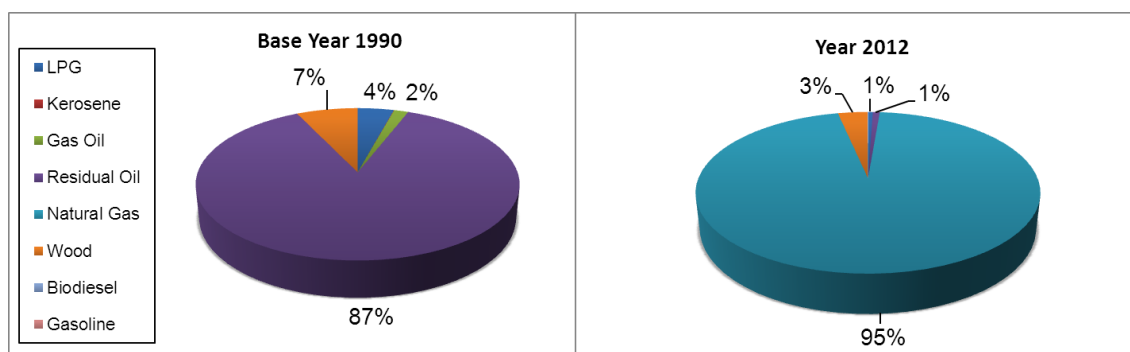


Figure 3-44 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2012



### 3.3.2.2.1.2.13 Manufacturing of Machines and Metallic Equipments Industry

Table 3-53 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Manufacturing of Machines and Metallic Equipments Industry

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

Gasoline	Biodiesel
MJ/kg	MJ/kg
44.0	37.0



Table 3-54– Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	1,464,554	5,901	166,018	885,983	0	28,368	0
1991	1,513,346	2,697	163,453	815,255	0	27,866	0
1992	1,535,201	1,233	176,195	863,221	0	27,448	0
1993	1,513,218	430	159,884	536,037	0	26,904	0
1994	1,620,994	106	154,892	648,010	0	26,904	0
1995	1,606,517	77	210,899	508,561	0	26,904	0
1996	1,629,591	206	254,712	1,022,150	0	28,452	0
1997	2,371,790	208	217,413	728,381	163,339	28,452	0
1998	2,457,574	238	250,399	976,233	433,672	28,512	0
1999	2,270,274	378	238,928	651,408	718,256	15,993	0
2000	1,785,009	324	117,664	770,616	1,196,654	16,201	0
2001	1,675,701	136	175,273	494,750	1,568,905	16,192	0
2002	1,422,586	182	170,618	401,471	1,715,150	16,192	0
2003	1,331,127	110	151,366	331,391	1,875,949	16,992	0
2004	1,327,801	111	135,563	281,902	2,059,192	17,992	0
2005	1,293,735	296	142,488	215,524	2,120,737	16,992	0
2006	1,224,299	225	169,726	250,084	2,153,779	17,992	2,253
2007	1,102,250	126	164,957	213,732	2,218,418	16,987	4,145
2008	1,074,031	42	159,514	4,145	2,267,571	16,987	3,538
2009	934,528	42	139,572	9,713	2,097,336	16,987	5,771
2010	927,704	921	105,863	111,618	2,040,186	16,987	6,426
2011	856,277	126	76,836	146,033	2,071,377	0	4,742
2012	756,549	126	84,445	13,523	2,107,928	5,900	5,758

Table 3-55 – Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	43,723	166,018	0
1991	50,451	163,453	0
1992	84,308	176,195	0
1993	70,038	159,884	0
1994	95,158	154,892	0
1995	101,341	210,899	0
1996	165,367	254,712	0
1997	162,969	217,413	0
1998	157,213	250,399	0
1999	139,014	238,928	0
2000	45,687	117,664	0
2001	100,614	175,273	0
2002	49,746	170,618	0
2003	104,229	151,366	0
2004	20,195	135,563	0
2005	10,951	142,488	0
2006	37,414	169,726	2,253
2007	31,109	164,957	4,145
2008	31,904	159,514	3,538
2009	28,596	139,572	5,771
2010	90,353	105,863	6,426
2011	5,987	76,836	4,742
2012	17,585	84,445	5,758

Figure 3-45 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry

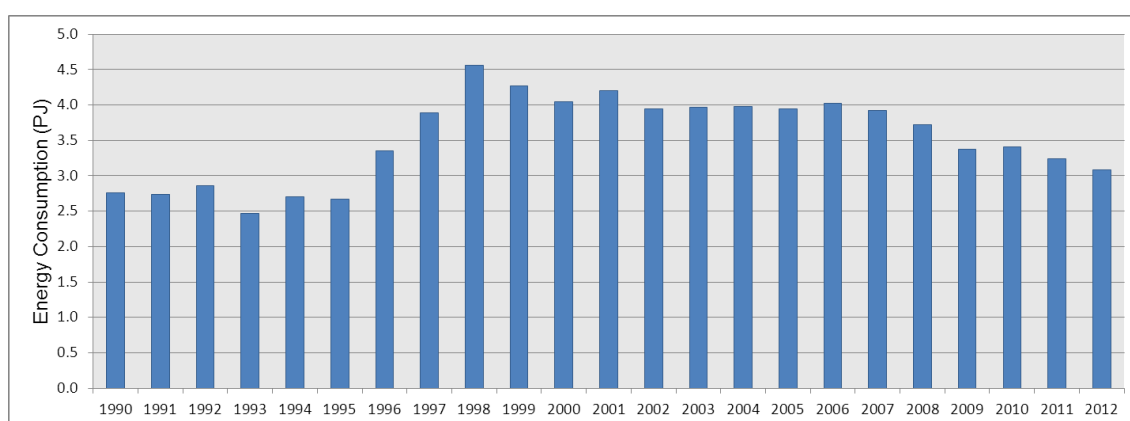
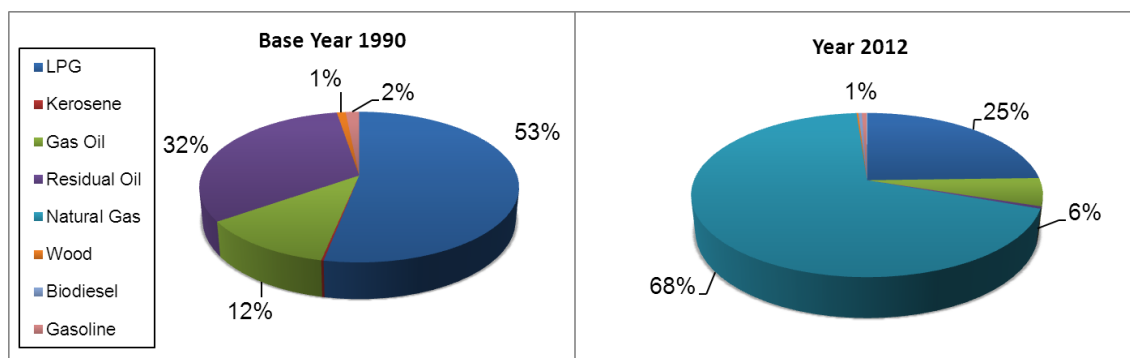


Figure 3-46 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2012



#### 3.3.2.2.1.2.14 Other Transformation Industry

Table 3-56 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Other Transformation Industry

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

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

Table 3-57 – Fuel consumption in Other Transformation Industry – Boilers and Furnaces (GJ)

Year	Lignite	LPG	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas	Wood	Biodiesel
1990	446	152,483	4,090	169,380	1,450,485	78	0	6,234	0
1991	206	203,577	3,984	219,362	1,386,959	2,746	0	6,109	0
1992	34	234,705	3,312	238,688	1,261,446	6,360	0	6,025	0
1993	463	341,042	2,198	363,689	939,151	64,686	0	5,900	0
1994	711	396,156	1,009	292,321	811,687	55,941	0	5,900	0
1995	0	431,055	37	180,662	168,426	55,690	0	5,900	0
1996	0	490,976	1,052	262,445	179,210	61,914	0	6,276	0
1997	0	114,740	0	20,034	332	72,929	0	6,276	0
1998	0	96,699	0	31,781	0	68,724	418	6,289	0
1999	0	128,819	0	27,421	0	60,544	18,177	6,276	0
2000	0	79,493	0	17,846	0	44,451	108,896	6,276	0
2001	0	50,002	30	24,959	0	6,056	144,785	6,276	0
2002	0	40,482	0	8,169	0	0	150,665	6,276	0
2003	0	33,289	0	7,453	0	0	184,583	33,985	0
2004	0	37,680	0	9,790	0	0	192,549	32,985	0
2005	0	33,769	0	8,023	0	0	198,239	34,984	0
2006	0	37,155	0	3,766	0	0	203,717	35,984	51
2007	0	36,509	0	0	0	0	227,511	34,979	0
2008	0	87,420	167	19,656	79,004	0	379,282	34,979	441
2009	0	108,730	84	259,607	116,391	0	402,100	34,979	11,631
2010	0	114,382	84	512,889	175,215	0	477,128	34,979	34,904
2011	0	99,687	0	417,793	67,699	0	533,398	203,849	28,514
2012	0	83,987	0	373,878	31,903	0	550,857	154,059	26,522

Table 3-58 – Fuel consumption in Other Transformation Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biogas	Biodiesel
1990	307	169,380	0	0
1991	4,852	219,362	0	0
1992	221,240	238,688	0	0
1993	896,540	363,689	0	0
1994	503,827	292,321	0	0
1995	51,541	180,662	0	0
1996	88,126	262,445	0	0
1997	28,535	20,034	0	0
1998	32,781	31,781	0	0
1999	23,952	27,421	0	0
2000	2,621	17,846	0	0
2001	14,207	24,959	0	0
2002	3,594	8,169	0	0
2003	3,248	7,453	0	0
2004	3,022	9,790	0	0
2005	2,706	8,023	0	0
2006	1,050	3,766	0	51
2007	0	0	0	0
2008	0	19,656	0	441
2009	0	259,607	9,120	11,631
2010	0	512,889	26,347	34,904
2011	0	417,793	29,971	28,514
2012	0	373,878	44,742	26,522

An increase in fuel consumption is noticeable from 2008 to 2010. This is mainly due to gas oil and natural gas fuel consumption.

Figure 3-47 – Total Energy Consumption in Other Transformation Industry

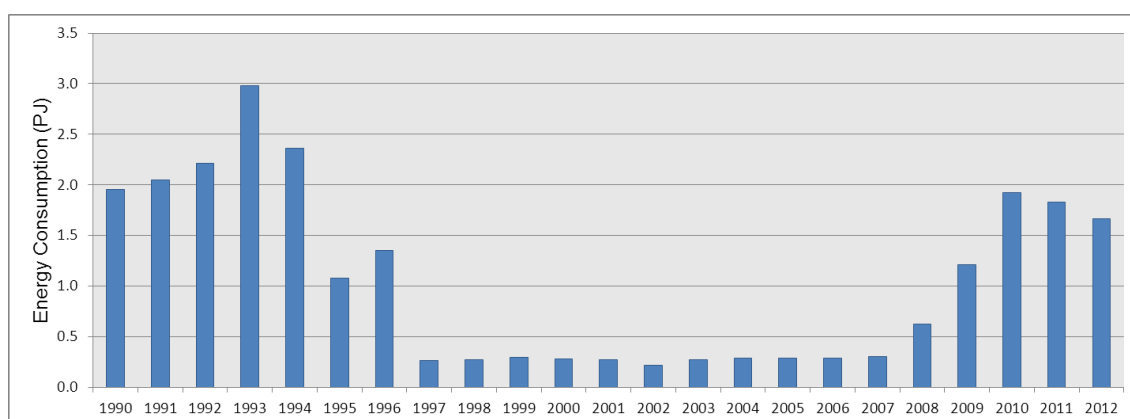
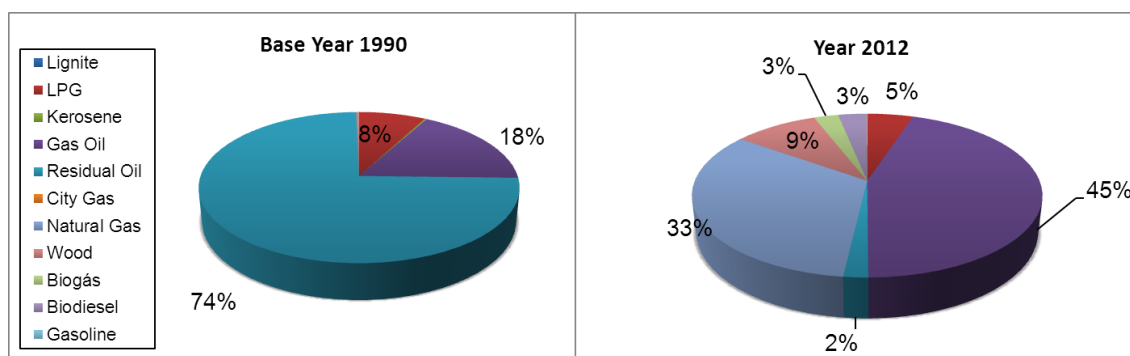


Figure 3-48 – Fuel consumption per fuel type in Other Transformation Industry in 1990 and 2012



### 3.3.2.2.1.2.15 Extractive Industry

Table 3-59 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Extractive Industry

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

Natural Gas	Biodiesel
MJ/Nm3	MJ/kg
38.7	37.0

Table 3-60 – Fuel consumption in the Extractive Industry – Boilers and Furnaces (GJ)

Year	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	2,402	77,421	0	1,925	496,782	119,787	0	0
1991	2,608	78,378	0	0	537,244	269,797	0	0
1992	1,904	77,084	17	1,255	612,714	169,190	0	0
1993	1,184	86,264	24	586	640,429	87,664	0	0
1994	412	103,733	8	628	481,288	54,028	0	0
1995	0	106,521	0	628	497,395	53,482	0	0
1996	0	127,632	0	209	598,911	57,224	0	0
1997	0	188,022	0	544	940,795	134,377	0	0
1998	0	205,356	0	502	838,763	112,387	0	0
1999	0	197,621	6	209	844,305	87,412	10,886	0
2000	0	176,933	28,632	0	1,054,326	103,473	14,989	0
2001	0	215,503	0	0	1,005,475	150,522	447,569	0
2002	0	142,693	7,249	0	947,978	120,039	57,569	0
2003	0	105,256	4,767	0	1,014,428	89,682	50,493	0
2004	0	67,560	2,941	0	1,011,796	0	862,313	0
2005	0	72,121	2,881	0	971,612	435,420	287,340	0
2006	0	73,799	2,506	0	899,924	140,809	276,831	10,932
2007	0	120,188	699	1,757	923,224	353,180	280,683	22,074
2008	0	161,799	0	0	1,014,439	45,913	353,575	24,831
2009	0	134,603	0	0	958,517	33,468	341,517	43,731
2010	0	89,764	0	0	846,056	40,153	332,892	58,750
2011	0	86,236	0	0	819,255	24,428	285,079	54,970
2012	0	47,980	0	0	589,668	30,441	216,374	41,513

Table 3-61– Fuel consumption in the Extractive Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	16,245	466,151	0
1991	15,826	505,621	0
1992	10,425	547,048	0
1993	8,625	544,410	0
1994	6,448	462,448	0
1995	2,052	495,088	0
1996	3,140	596,242	0
1997	5,736	937,642	0
1998	19,930	835,850	0
1999	30,271	842,956	0
2000	20,683	756,654	0
2001	82,147	1,005,475	0
2002	38,771	901,087	0
2003	25,163	900,108	0
2004	57,528	898,768	0
2005	22,484	880,958	0
2006	20,223	827,994	10,932
2007	30,899	890,588	22,074
2008	335	1,013,686	24,831
2009	23,237	958,517	43,731
2010	20,181	846,056	58,750
2011	0	819,088	54,970
2012	167	589,668	41,513

Figure 3-49 – Total Energy Consumption in the Extractive Industry

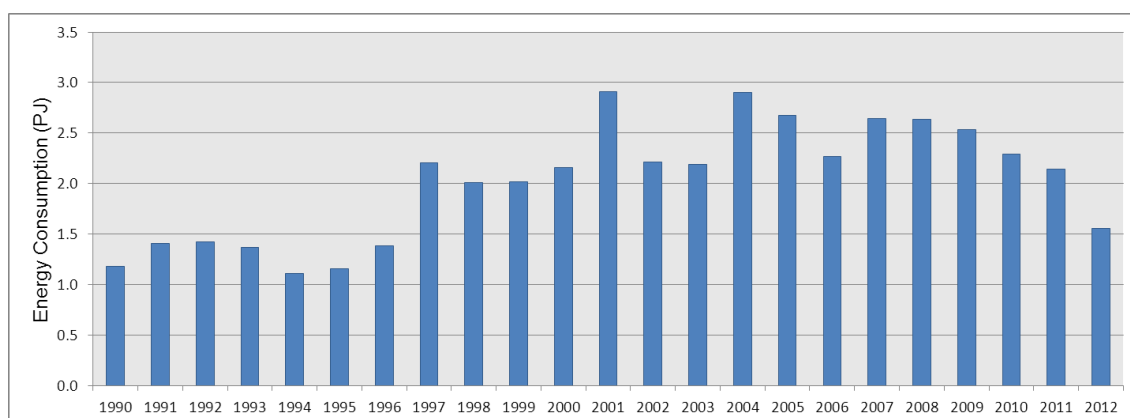
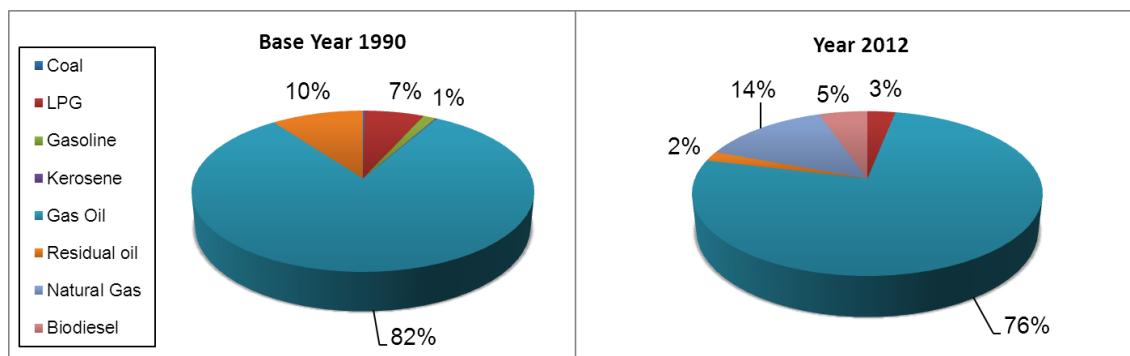




Figure 3-50– Fuel consumption per fuel type in the Extractive Industry in 1990 and 2012



#### 3.3.2.2.1.2.16 Construction and Building Industry

Table 3-62 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Construction and Building Industry

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

Table 3-63 – Fuel consumption in the Construction and Building Industry (GJ)

Year	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	226,695	27,676	6,859	5,864,312	668,507	0	0
1991	200,517	53,330	333	6,641,723	881,020	0	0
1992	257,260	165,177	2,108	6,358,531	872,358	0	0
1993	449,705	213,777	2,774	6,482,578	1,768,570	0	0
1994	677,512	357,378	1,180	7,037,664	1,407,088	0	0
1995	887,678	447,712	640	7,580,456	1,756,467	0	0
1996	1,037,883	670,960	178	7,799,976	1,348,200	0	0
1997	628,759	373,819	1,797	8,120,774	1,884,264	0	0
1998	558,547	349,408	11,050	8,117,508	1,999,855	676	0
1999	562,634	296,398	228	7,984,363	1,423,115	3,010	0
2000	545,639	72,532	130	7,548,443	1,467,006	8,455	0
2001	820,530	389,328	390	9,370,392	1,630,972	317,189	0
2002	532,463	60,560	280	9,309,392	1,848,438	631,622	0
2003	481,822	56,703	104	8,631,057	1,289,941	893,219	0
2004	482,645	54,850	93	10,025,92	1,565,488	903,641	0
2005	412,087	67,399	184	9,135,498	1,717,788	891,143	0
2006	396,598	67,860	1,472	7,107,330	1,301,954	804,712	95,845
2007	353,915	52,060	84	6,455,759	1,085,000	895,096	176,033
2008	487,274	90,262	167	5,673,574	1,138,042	712,504	139,765
2009	489,106	95,525	293	5,223,513	1,253,471	939,727	232,196
2010	484,791	91,783	126	5,560,974	1,072,740	1,202,436	376,859
2011	392,791	17,600	293	5,239,792	1,026,731	1,232,860	356,400
2012	387,825	3,907	42	3,551,224	1,086,618	738,481	250,516

Figure 3-51 – Total Energy Consumption in the Construction and Building Industry

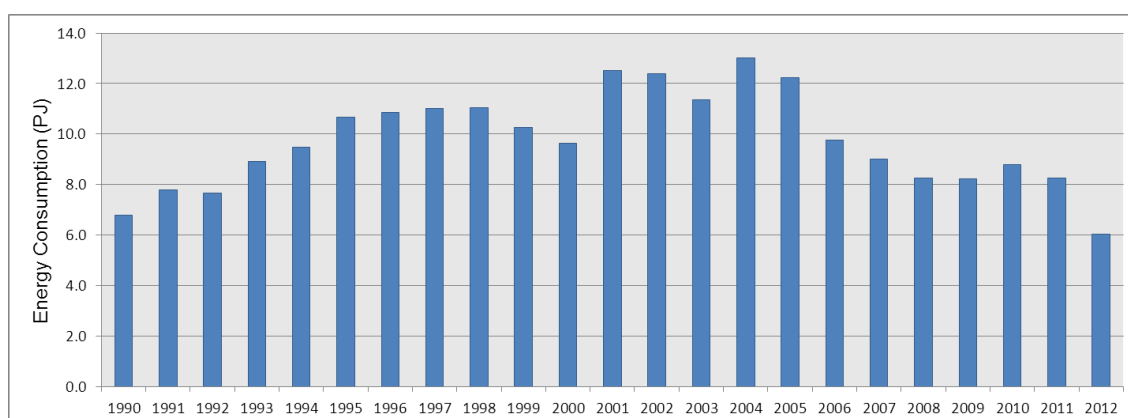
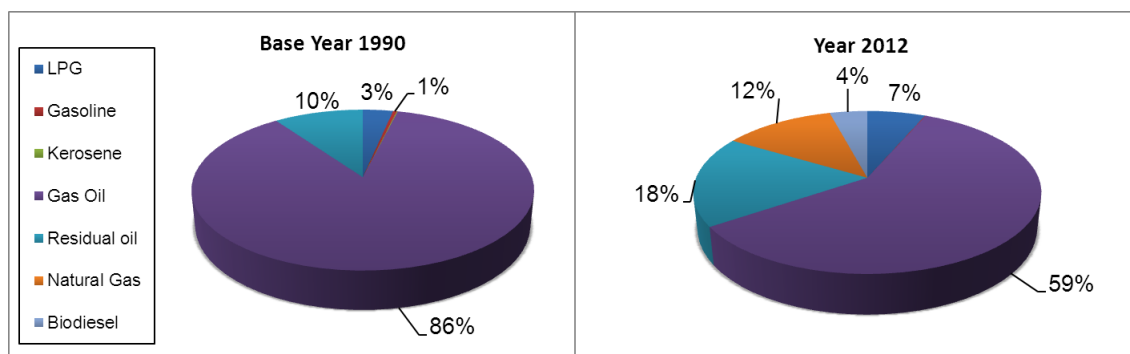


Figure 3-52 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2012

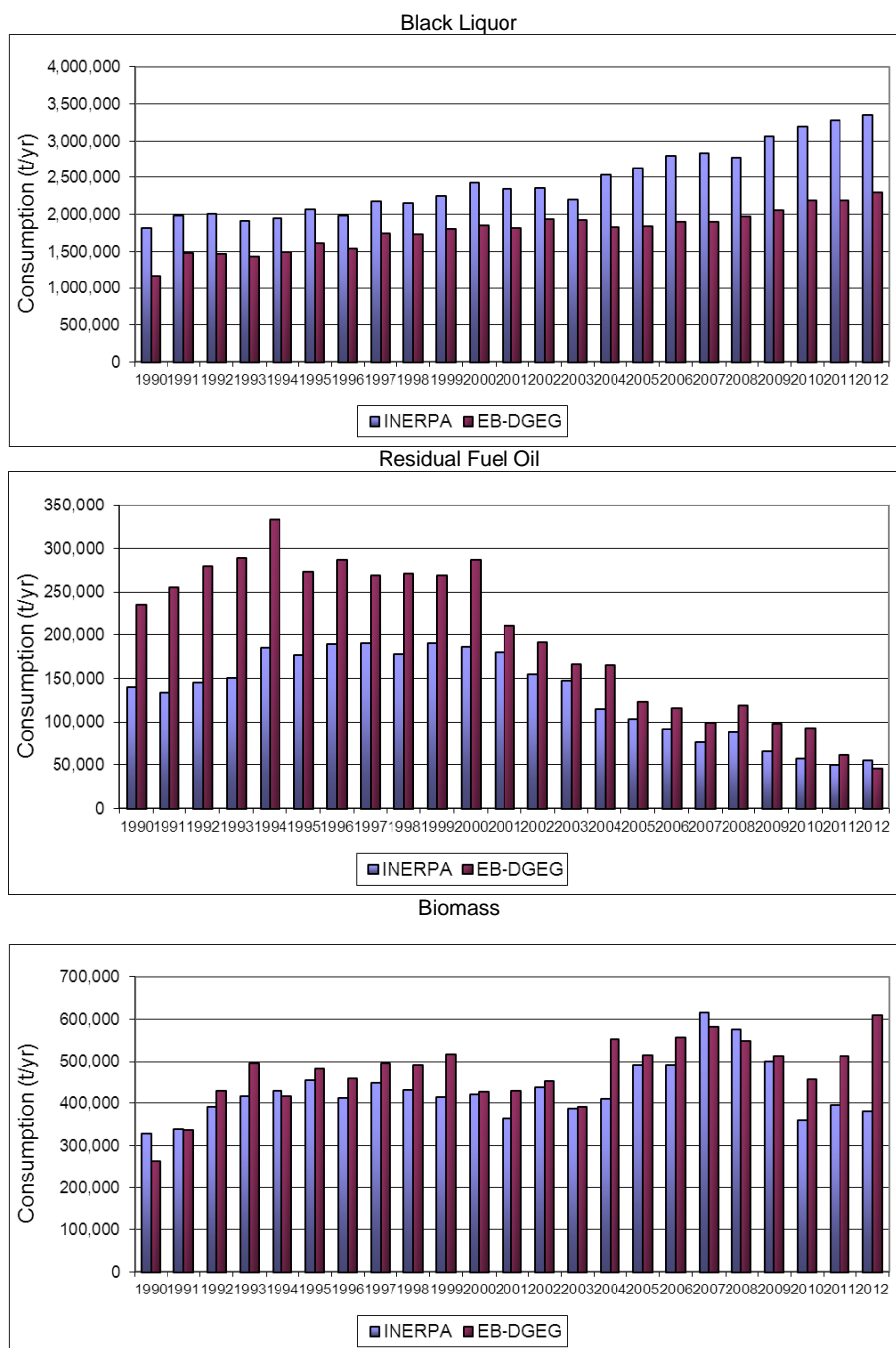


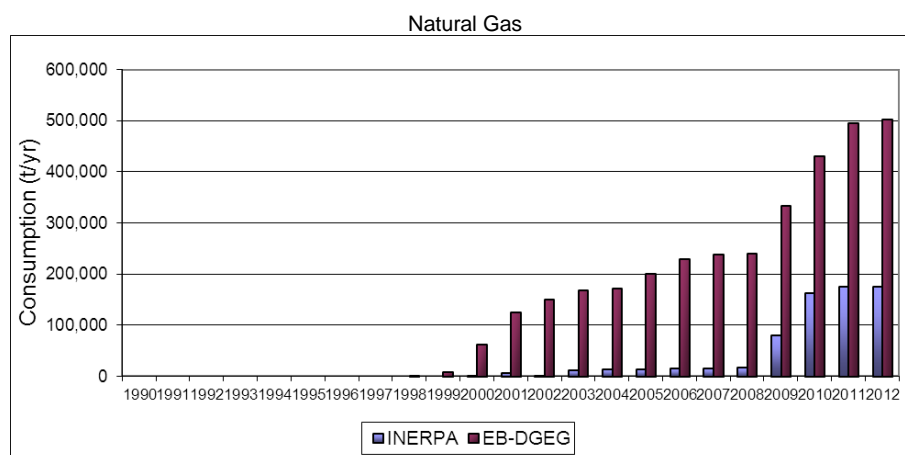
### 3.3.2.2.1.3 Comparison of LPS data vs. Energy Balance

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

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

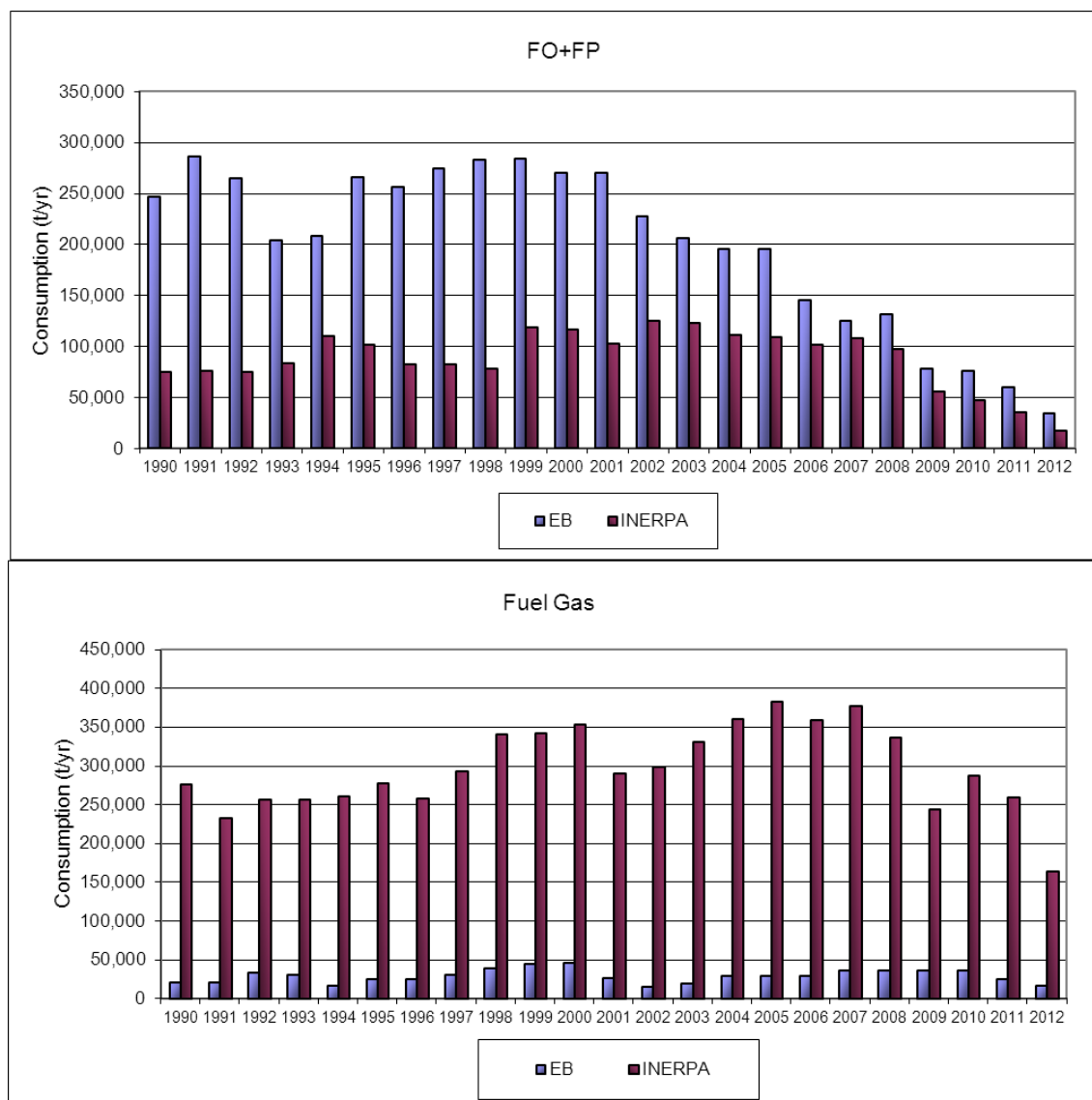
Figure 3-53 – Comparison of total LPS consumption in Paper Pulp units with the reported consumption in the EB for the sector “Paper pulp and paper production”





The comparison made for the paper and pulp industry shows that differences occur, but are not substantial for the major fuels: black liquor and biomass. Part of the differences were analysed before (DGEG,2003) and could be explained by the use of different LHV in the Energy Balance, which occurs commonly for biomass fuels, given the variability in water content. Careful estimations were made not double count the emissions.

Figure 3-54 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector “Chemical and Plastics”<sup>22</sup>



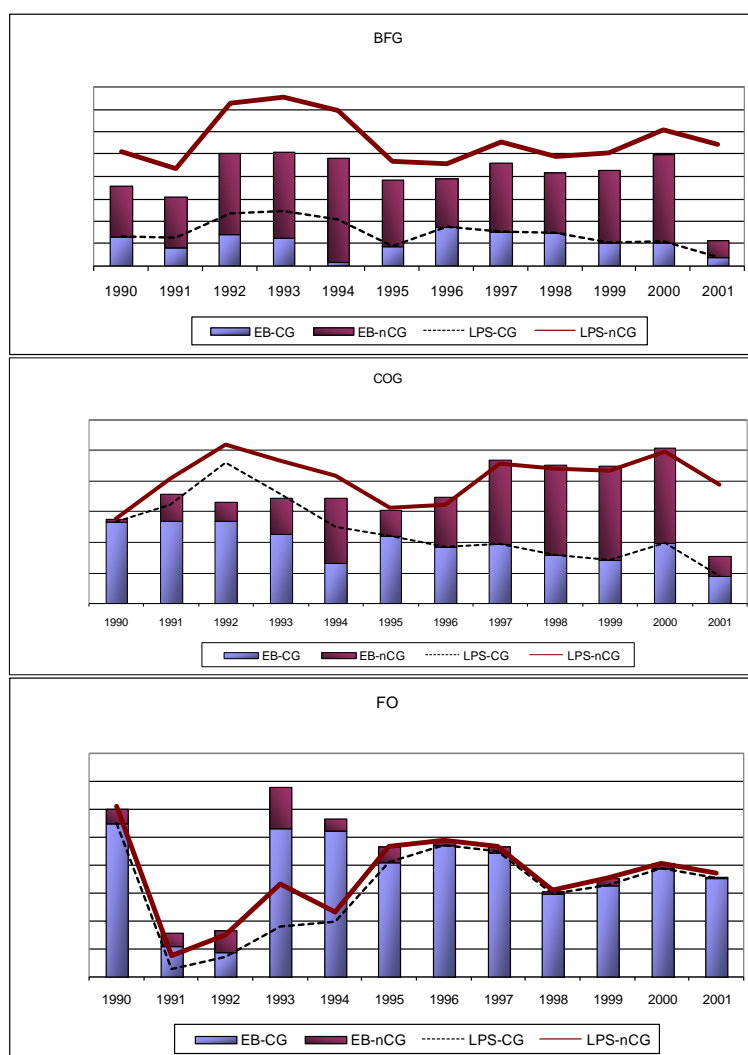
For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil<sup>23</sup> is about 50 per cent until 2005. The two values show a tendency to converge in the later years. Also important to note that in 2012 LPS values surpass energy balance data by 8 %. 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.

<sup>22</sup> Units in the vertical axis are not indicated due to confidentiality issues.

<sup>23</sup> 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.

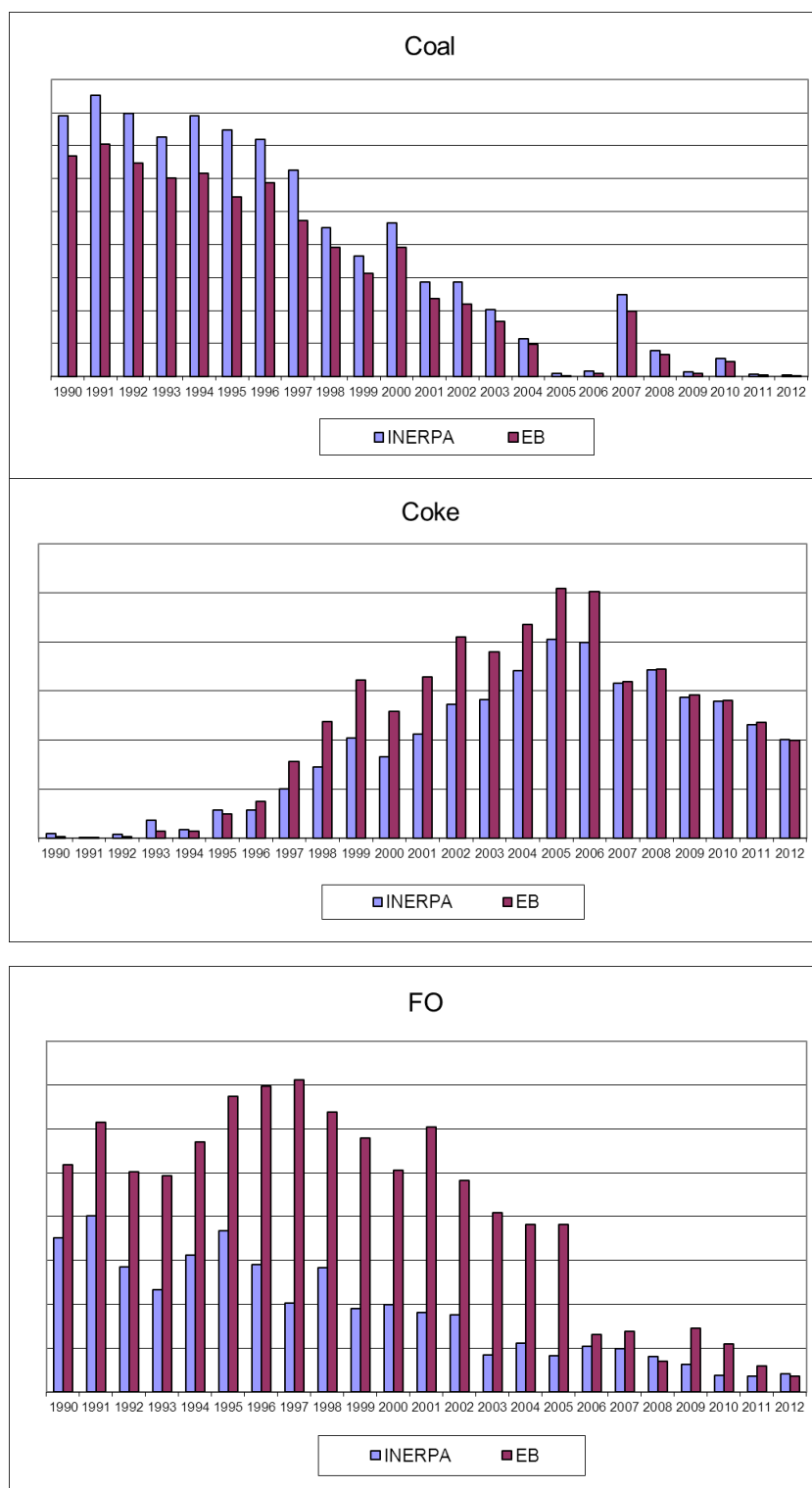
The match for the iron and steel industry show a good consistency, except for intermediate years, and for the slightly higher consumption of Blast Furnace Gas. This last difference may result from the use of different LHV values.

Figure 3-55 – 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”<sup>24</sup> (1990-2001)



<sup>24</sup> Units in the vertical axis are not indicated due to confidentiality issues.

Figure 3-56 – Comparison of total LPS consumption in Cement Plant with the reported consumption in the EB for the sector “Cement and Lime” (Due to confidentiality issue y axis values are not shown)





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

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

### 3.3.2.2.2 Production Data

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

Total production of paper pulp is reported in Table 3-64. Production data for Kraft paper pulp was obtained from the following data sources:

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

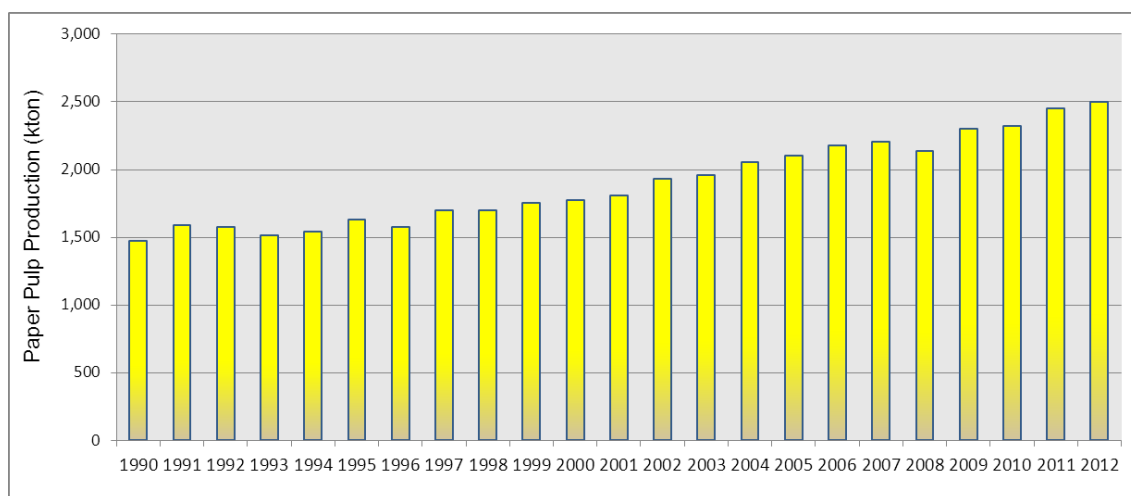
Even though different sources were used the ultimate data source was the same: the industrial plants.

Table 3-64 – Total Paper Pulp Production (Kraft and sulphide paper pulp)

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

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pulp Production (kton)	1 929	1 960	2 054	2 098	2 174	2 204	2 135	2 297	2 316	2 447	2 497

Figure 3-57 – Total paper pulp production: Kraft and sulphide paper pulp



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

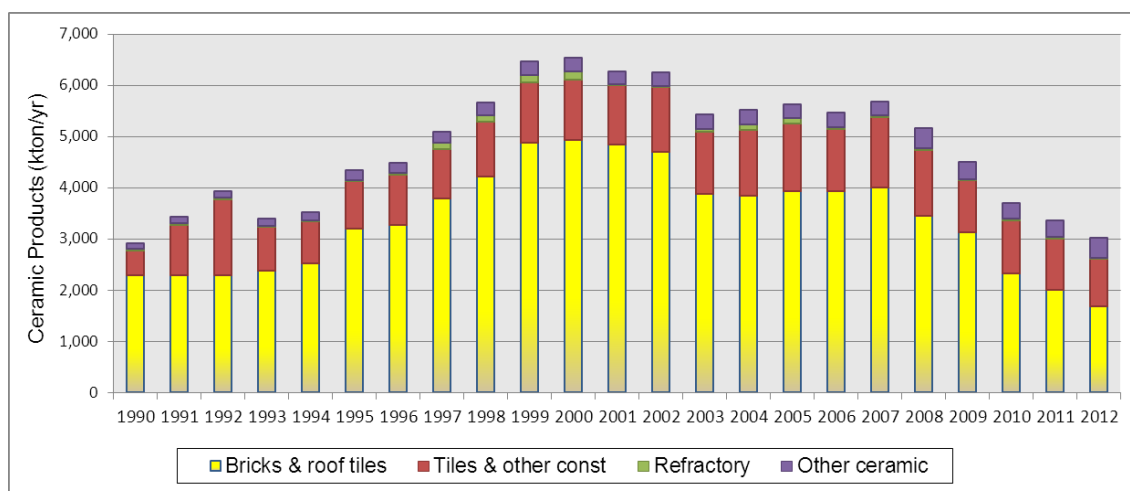
Data on annual manufacturing of ceramic products is available from 1990 to 2012 from INE statistical database. The time series for total production is shown in Table 3-65 and Figure 3-58, according to type of ceramic.

Table 3-65 – Ceramic Production according to type of ceramic (kton)

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

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bricks & roof tiles	4 697	3 873	3 831	3 923	3 917	3 993	3 453	3 122	2 321	1 995	1 675
Tiles & other const	1 253	1 221	1 289	1 327	1 224	1 377	1 276	1 013	1 043	1 009	929
Refractory	30	49	103	100	39	40	35	32	25	26	26
Other ceramic	258	282	290	278	277	270	399	339	310	323	386

Figure 3-58 – Ceramic Production according to type of ceramic



The production values for container glass and lead crystal glass are presented in Figure 3-59 and in Table 3-66, and they were established from the INE statistical databases and information received from Technology Centre for Ceramics and Glass (CTCV). More detailed discussion of the origins of data sources should be consulted in chapter 4.2.A.5. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 3-59 - Glass production by glass type (excluding flat glass production)

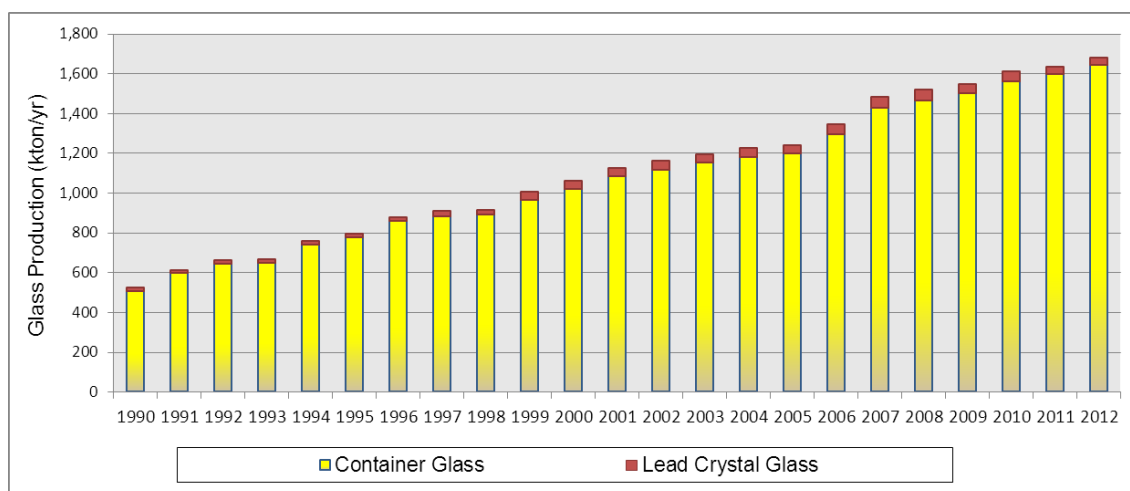


Table 3-66- Glass production by glass type (kton/yr) excluding flat glass production

Type of Glass	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Container Glass	507	595	641	648	738	774	856	882	890	965	1 017	1 084
Lead Crystal Glass	16	18	19	18	21	22	23	26	25	39	44	42

Type of Glass	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Container Glass	1 117	1 150	1 180	1 197	1 294	1 426	1 464	1 500	1 558	1 596	1 642
Lead Crystal Glass	42	44	46	45	49	55	54	46	52	39	38

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

### 3.3.2.3 *Emission Factors*

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

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

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

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

The CO<sub>2</sub> emission factors presented in the next tables correspond to values prior multiplication with the corresponding oxidation factor, unless specified otherwise.

Table 3-67 – Default emissions factors of Greenhouse gases for combustion equipments in Manufacturing Industry

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

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

Table 3-68 –Emission factors of Greenhouse gases in the extractive industry

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

**Table 3-69 – Emission factors for Greenhouse gases in the building and construction industry**

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

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

**Table 3-70 – Emission factors for use in LPS units in the Iron and steel Industry: Greenhouse Gases from combustion**

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

Table 3-71 – Emission factors for use in LPS units in the Chemical Industry: Greenhouse Gases from combustion

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

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

Table 3-72 – Emission factors used in LPS units in the Paper Pulp Industry: Greenhouse Gases from combustion – Energy Approach

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

(i) The CO<sub>2</sub> emission factors presented in this table include the corresponding oxidation factor.

NCG- Non-condensable gases



Table 3-73 – Emission factors used in LPS units in the Paper Pulp Industry: Greenhouse Gases from combustion – Production Approach

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

(i)Source EEA, 2002.

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

Table 3-74 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Greenhouse gases

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

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

Table 3-75 – Emission Factors for glass production using the Production Approach: SO<sub>x</sub> and Indirect Precursor gases (kg/ton glass)

Type of Glass	SO <sub>x</sub>	NO <sub>x</sub>	NMVOC	CO
Flat Glass	1.5	4	0.1	0.1
Container Glass	1.7	3.1	4.5	0.1
Lead Crystal Glass	2.8	4.3	4.7	0.1
Other Glass	2.8	4.3	4.7	0.1

Source: USEPA (1986)

Table 3-76 – Emission Factors for glass production using the Production Approach: Greenhouse Gases

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

Source: CH<sub>4</sub> USEPA (1986); CO<sub>2</sub> EUTS data

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

#### 3.3.2.4 *Uncertainty Assessment*

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

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

The uncertainty of CO<sub>2</sub> emission factors is 5 per cent for all situations, which is consistent with GPG recommendations. Finally the uncertainty for methane is 150 per cent and an order of magnitude for N<sub>2</sub>O.

#### 3.3.2.5 *Category-specific QA/QC and verification*

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

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

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

#### 3.3.2.6 *Recalculations*

There were several recalculations to this source category:

- Revision of the 2003, 2008, 2009, 2010 and 2011 energy balance data for several sectors/fuels (2003, 2008-2011);
- Revision of fuel consumption for Chemical industrial sector. New values from operators (2011);

- Update of Steam Coal and Coke Coal CO<sub>2</sub> emission factors in the Cement and Chemical Sectors.(1990-2011)

#### 3.3.2.7 *Further Improvements*

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

### 3.3.3 **Transport (CRF 1.A.3.)**

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

##### 3.3.3.1.1 Overview

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

In 2012 emissions from civil aviation in Portugal amounted to 3,121 Gg CO<sub>2</sub>e, from which 373 Gg CO<sub>2</sub>e are from domestic flights and 2,748 Gg CO<sub>2</sub>e are from international flights. Emissions from aviation come from the combustion of jet fuel and aviation gasoline. Emissions from combustion in aircraft mobile activities comprehend all air emissions associated with fuel combustion in airplanes, either realized in passenger or freight planes, and either realized during flight or in land activities: idle and taxi. Aircraft operations are divided into

Landing/Take-off cycle and;

Cruise.

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

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

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

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

For the elaboration of the greenhouse gases emissions inventory which is reported to the EU<sup>25</sup> and to the UNFCCC, emissions from flights to and from the autonomous regions of Azores and Madeira islands are included in national totals.

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<sup>25</sup> Decision 2004/280/CE

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 3-77 – IPCC 2006 source categories

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

### 3.3.3.1.2 Methodology

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

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

#### 3.3.3.1.2.1 Landing/Take-off

The general approach to estimate emissions during LTO is:

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

where

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

EmissionArrival(p,d,a,s,y), EmissionDeparture(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);

Narrival, Ndeparture – Number of arrival and departure movements performed in year y, by aircraft s in airport s from origin/destiny d.

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

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

p – pollutant;

d – origin/destination;

a – airport;

s – aircraft;

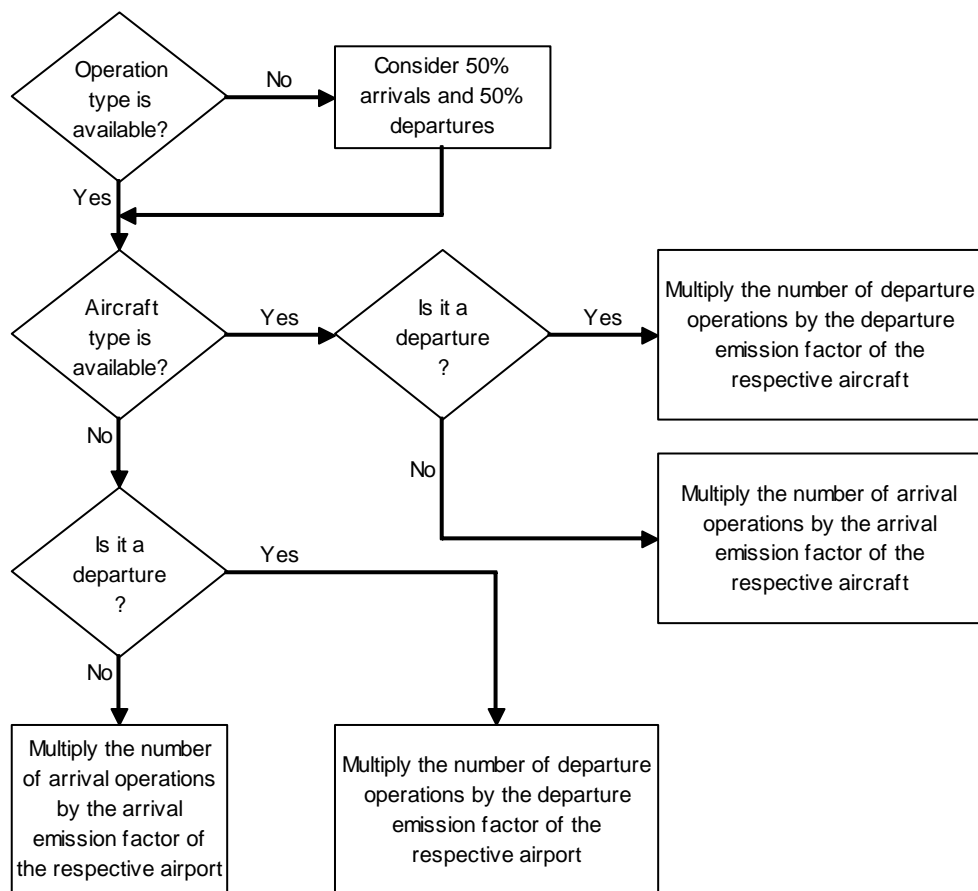
y – year.

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

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

Figure 3-60 outlines the process whereby LTO emissions are estimated.

Figure 3-60 – Decision tree for LTO emission calculation



#### 3.3.3.1.2.2 Cruise

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

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

where

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

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

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

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

#### 3.3.3.1.3 Emission Factors

##### 3.3.3.1.3.1 LTO

###### 3.3.3.1.3.1.1 Aircraft Based LTO Emission Factors

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

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

Arrival includes approach and taxi in (idle) conditions.

Table 3-78 - Emissions factors for most common aircraft movements in national airports.

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

#### 3.3.3.1.3.1.2 Airport Based LTO Emission Factors

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



Table 3-79 – Airport based LTO emission factors (kg/movement).

Airport	Operation	Parameter	1990	1995	2000	2005	2010	2011	2012
Lisboa (LIS)	Take-off	Fuel Consumption	670.2	608.9	567.4	452.6	451.6	443.6	450.9
		VOC	16.4	14.9	15.2	9.3	2.8	2.6	2.5
		CO	37.1	33.7	35.4	21.5	13.8	13.0	12.4
		NOx	26.3	23.9	23.6	16.2	15.9	15.8	16.4
		PM <sub>10</sub>	6.2	5.6	5.2	4.2	4.2	4.1	4.2
	Landing	Fuel Consumption	291.0	264.4	240.2	204.2	206.6	201.3	202.1
		VOC	7.0	6.4	6.0	4.4	1.5	1.4	1.3
		CO	17.8	16.2	16.3	11.1	7.0	6.7	6.4
		NOx	4.9	4.4	4.3	3.3	3.4	3.3	3.3
		PM <sub>10</sub>	3.1	2.8	2.6	2.2	2.2	2.2	2.2
Porto (OPO)	Take-off	Fuel Consumption	530.0	481.5	401.1	374.4	427.6	379.4	363.8
		VOC	8.2	7.5	6.5	4.1	3.3	2.8	2.9
		CO	26.3	23.9	23.0	13.7	12.8	12.0	11.2
		NOx	19.1	17.3	15.0	11.9	14.7	12.7	11.7
		PM <sub>10</sub>	4.9	4.5	3.7	3.5	4.0	3.5	3.4
	Landing	Fuel Consumption	236.2	214.6	181.3	172.9	191.7	165.5	167.3
		VOC	3.7	3.3	2.9	2.2	1.6	1.3	1.5
		CO	12.7	11.5	11.1	7.2	6.3	5.9	5.9
		NOx	3.8	3.5	3.0	2.6	3.2	2.6	2.6
		PM <sub>10</sub>	2.5	2.3	1.9	1.9	2.1	1.8	1.8
Faro (FAO)	Take-off	Fuel Consumption	514.8	467.7	443.6	348.7	339.1	262.5	276.9
		VOC	5.3	4.8	4.9	3.0	2.4	2.0	2.3
		CO	19.2	17.4	17.2	12.2	11.0	8.9	9.2
		NOx	17.4	15.8	16.0	11.0	10.0	7.6	8.0
		PM <sub>10</sub>	4.8	4.3	4.1	3.2	3.1	2.4	2.6
	Landing	Fuel Consumption	231.8	210.6	198.9	158.2	161.1	126.1	133.2
		VOC	2.7	2.5	2.5	1.7	1.4	1.3	1.4
		CO	10.0	9.1	9.0	6.5	5.9	5.2	5.2
		NOx	3.5	3.2	3.1	2.3	2.4	1.8	1.9
		PM <sub>10</sub>	2.5	2.3	2.1	1.7	1.7	1.3	1.4

### 3.3.3.1.3.2 Cruise Emissions

#### 3.3.3.1.3.2.1 Aircraft Based Cruise Emissions

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

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

Table 3-80 – Cruise emissions and fuel consumption.

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

Source: EMEP/CORINAIR

#### 3.3.3.1.3.2.2 Airport Based Cruise Emissions

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

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

#### 3.3.3.1.3.3 Correspondence between aircraft type and representative aircraft

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

Table 3-81 – Aircraft type and representative aircraft for LTO and cruise emission factors.

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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
343	Airbus A340-300	L JeK	L4J	343	340
346	Airbus A340-600	L JeK	L4J	346	340
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
A660	Ayres Turbo Thrush (S-2R-T660)	L JeK	L1T	C208	C208
AA5	Gulfstream American AA-5 Traveler	L AvG	L1P	AA5	DHO
AB3	Airbus Industrie A300 pax	L JeK	L2J	AB3	310
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
ABB	Airbus Industrie A300-600ST Beluga Freighter	L JeK	L2J	AB6	310
ABF	Airbus Industrie A300 Freighter	L JeK	L2J	AB3	310
AC11	Rockwell Commander	L AvG	L1P	C150	DHO
ACT	Gulfstream/Rockwell (Aero) Turbo Commander	L JeK	L2T	ACT	NA
ACD	Gulfstream/Rockwell (Aero) Commander/Turbo Commander	L JeK	L2T	ACD	NA
AEST	Aerostar 600	L AvG	L2P	AEST	DHO
AJET	Dassault Alpha Jet	L JeK	L2J	FA10	S20
ALO3	Aerospatiale Alouette 3	L JeK	H1T	ALO3	NA
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
A26	Antonov AN-26	L JeK	L2T	A26	AN6
AN4	Antonov AN-24	L JeK	L2T	AN4	NA
AN6	Antonov AN-26 / AN-30 /AN-32	L JeK	L2T	A26	AN6
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
APH	Eurocopter (Aerospatiale) SA330 Puma / AS332 Super Puma	L JeK	H2T	S61	NA
ARJ	Avro RJ70 / RJ85 / RJ100 Avroliner	L JeK	L4J	ARJ	146
AS32	Aerospatiale Super Puma	L JeK	H2T	S61	NA
AS50	Aerospatiale Fennec (AS-550)	L JeK	H1T	S61	NA
AS65	Aerospatiale Dolphin (AS-366)	L JeK	H2T	AS65	NA
ASTR	IAI Gulfstream G100	L JeK	L2J	WWP	S20
AT3	AIDC AT-3 Tzu-Chung	L JeK	L2J	AT3	NA
AT43	Aerospatiale/Alenia ATR 42-300 / 320	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5T	Air Tractor AT-502	L JeK	L1T	C208	C208
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT8T	Air Tractor AT-802 Fire Boss	L JeK	L1T	C208	NA
ATP	British Aerospace ATP	L JeK	L2T	ATR	AT42
ATR	Aerospatiale/Alenia ATR 42/ ATR 72	L JeK	L2T	ATR	AT42
B06	Agusta AB-206 LongRanger	L JeK	H1T	S61	NA
MBH	Eurocopter (MBB) Bo.105	L JeK	H2T	S61	NA

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
B12	British Aerospace (BAC) One Eleven 200	L JeK	L2J	B12	B11
BES	Beechcraft 1900/1900C	L JeK	L2T	BE1	BE1
B200	Beech 200 Super King Air	L JeK	L2T	BE20	BE20
B350	Beech Super King Air 350	L JeK	L2T	BE30	B350
B412	Bell 412	LJeK	H1T	BH2	NA
B36T	Allison 36 Turbine Bonanza	L JeK	L1T	C208	C208
70M	Boeing 707 Combi	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
B72	Boeing 720B pax	L JeK	L4J	B72	NA
72X	Boeing 727-100 Freighter	L JeK	L3J	721	727
72S	Boeing 727-200 Advanced pax	L JeK	L3J	722	727
731	Boeing 737-100 pax	L JeK	L2J	731	731
73M	Boeing 737-200 Combi	L JeK	L2J	732	731
73Y	Boeing 737-300 Freighter	L JeK	L2J	733	731
735	Boeing 737-500 pax	L JeK	L2J	735	734
B735	Boeing 737-500	L JeK	L2J	735	734
736	Boeing 737-600 pax	L JeK	L2J	736	734
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
73H	Boeing 737-800 (winglets) pax	L JeK	L2J	73H	734
739	Boeing 737-900 pax	L JeK	L2J	739	734
741	Boeing 747-100 pax	L JeK	L4J	741	741
74C	Boeing 747-200 Combi	L JeK	L4J	742	741
74U	Boeing 747-300 / 747-200 SUD Freighter	L JeK	L4J	743	741
74J	Boeing 747-400 (Domestic) pax	L JeK	L4J	744	74J
B74S	Boeing 747SP	L JeK	L4J	B74S	741
B74R	Boeing 747SR	LJeK	L4J	74V	741
75M	Boeing 757 Mixed Configuration	L JeK	L2J	752	757
753	Boeing 757-300 pax	L JeK	L2J	752	757
76X	Boeing 767-200 Freighter	L JeK	L2J	762	767
76Y	Boeing 767-300 Freighter	L JeK	L2J	763	767
764	Boeing 767-400 pax	L JeK	L2J	764	767
772	Boeing 777-200 pax	L JeK	L2J	772	777
773	Boeing 777-300 pax	L JeK	L2J	773	777
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
BE1	Beechcraft 1900/1900C/1900D	L JeK	L2T	BE1	BE1
BE10	Beech King Air 100	L JeK	L2T	BE10	B350
BE18	Beech 18	L AvG	L2P	BE18	DHO
BE19	Beech 19 Sport	L AvG	L1P	BE19	DHO
BE2	Beechcraft twin piston engines	L AvG	L2P	BE55	DHO

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
BE20	Beech Huron	L JeK	L2T	BE20	BE20
BE30	Beech Super King Air 300	L JeK	L2T	BE30	B350
BE33	Beech Bonanza 33	L AvG	L1P	BE33	DHO
BE35	Beech Bonanza 35	L AvG	L1P	BE33	DHO
BE36	Beech Bonanza 36	L AvG	L1P	BE33	DHO
BE4	Beech Beechjet	L JeK	L2J	BE40	LOH
BE40	Beech Beechjet	L JeK	L2J	BE40	LOH
BE55	Beech Baron	L AvG	L2P	BE55	DHO
BE58	Beech Baron 58	L AvG	L2P	BE55	DHO
BE76	Beech Duchess	L AvG	L2P	BE55	DHO
BE95	Beech 95 Travel Air	LJeK	L2T	BE10	B350
BE9L	Beech King Air 90	L JeK	L2T	BE10	B350
BEC	Beechcraft light aircraft	L AvG	L1P	BE19	DHO
BEH	Beechcraft 1900D	L JeK	L2T	BE1	BE1
BEP	Beechcraft light aircraft - single engine	L AvG	L1P	BE19	DHO
BET	Beechcraft light aircraft - twin turboprop engine	L JeK	L2T	BE20	BE1
BH2	Bell Helicopters	L JeK	H1T	BH2	NA
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
C130	Lockheed Hercules	L JeK	L4T	C130	LOH
C150	Cessna 150	L AvG	L1P	C150	DHO
C160	Transall C-160	L JeK	L2T	C160	NA
C17	Boeing Globemaster 3	L JeK	L4J	C17	NA
C172	Cessna 172 Mescalero	L AvG	L1P	C150	DHO
C177	Cessna 177 Cardinal	L AvG	L1P	C150	DHO
C182	Cessna 182 Skylane	L AvG	L1P	C150	DHO
C185	Cessna 185 Skywagon	L AvG	L1P	C150	DHO
C206	Cessna 206 Stationair	L AvG	L1P	C150	DHO
C208	Cessna 208 Caravan	L JeK	L1T	C208	C208
C210	Cessna 210 Centurion	L AvG	L1P	C150	DHO
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
C303	Cessna T303 Crusader	L AvG	L2P	C404	DHO
C310	Cessna 310	L AvG	L2P	C337	DHO
C337	Cessna 337 Super Skymaster	L AvG	L2P	C337	DHO
C402	Cessna 402 Businessliner	L AvG	L2P	C404	DHO
C404	Cessna 402 Titan	L AvG	L2P	C404	DHO
C414	Cessna 414 Chancellor	L AvG	L2P	C404	DHO
C421	Cessna 421 Executive Commuter	L AvG	L2P	C404	DHO
C425	Cessna 425 Conquest	L JeK	L2T	C425	NA
C441	Cessna 441 Conquest	L JeK	L2T	C441	NA

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
C500	Cessna 500 Citation	L JeK	L2J	C500	DHO
C501	Cessna 501 Citation 1SP	L JeK	L2J	C500	DHO
C510	Cessna Citation Muatang	LJeK	L2J	C500	DHO
C525	Cessna 525 Citation	L JeK	L2J	C500	DHO
C550	Cessna 550 Citation 2	L JeK	L2J	C550	DHO
C551	Cessna 551 Citation 2SP	L JeK	L2J	C551	DHO
C560	Cessna 560 Citation 5	L JeK	L2J	C560	S20
C56X	Cessna 560XL Citation Excel	L JeK	L2J	C560	S20
C650	Cessna 650 Citation 3	L JeK	L2J	C680	SH6
C680	Cessna 680 Citation Sovereign	L JeK	L2J	C680	SH6
C750	Cessna 750 Citation 10	L JeK	L2J	C750	F50
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ
CL4	Canadair CL-44	L JeK	L4T	CL4	F28
CL30	BD-100 Challenge	LJeK	L2J	CL30	NA
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CN2	Cessna light aircraft - twin piston engines	L AvG	L2P	C404	DHO
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CNA	Cessna light aircraft	0	0	C150	DHO
CNJ	Cessna Citation	L JeK	L2J	C500	DHO
CNT	Cessna light aircraft - twin turboprop engines	L JeK	L2T	CNT	NA
CRJ	Canadair Regional Jet	L JeK	L2J	CR1	FRJ
CRV	Aerospatiale (Sud Aviation) Se.210 Caravelle	L JeK	L2J	CRV	D94
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CVF	Convair CV-240 / 440 / 580 / 600 / 640 Freighter	L JeK	L2T	CVF	NA
CVY	Convair CV-580 / 600 / 640 Freighter	L JeK	L2T	CVY	BE1
CVR	Convair CV-240 / 440 / 580 / 600 / 640 pax	L JeK	L2T	CVR	NA
D10	Douglas DC-10 pax	L JeK	L3J	D10	D10
D1F	Douglas DC-10 all Freighters	L JeK	L3J	D10	D10
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D8F	Douglas DC-8 all Freighters	L JeK	L4J	D8T	340
D8M	Douglas DC-8 all Combi models	L JeK	L4J	DC8	340
D9F	Douglas DC-9 all Freighters	L JeK	L2J	D9F	D91
D1X	Douglas DC-10-10 Freighter	L JeK	L3J	D11	D10
DC3T	Douglas DC-3	L JeK	L2T	DC3T	NA
DC8	Douglas DC-8 all pax models	L JeK	L4J	DC8	340

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
D8T	Douglas DC-8-50 Freighter	L JeK	L4J	D8T	340
D8L	Douglas DC-8-62 pax	L JeK	L4J	D8X	340
D8Y	Douglas DC-8-71 / 72 / 73 Freighters	L JeK	L4J	D8Y	340
DC9	Douglas DC-9 all pax models	L JeK	L2J	DC9	D91
DF3	Dassault (Breguet Mystere) Falcon 50 / 900	L JeK	L3J	FA50	F50
DFL	Dassault (Breguet Mystere) Falcon	0	0	FA10	S20
DHR	De Havilland Canada DHC-2 Turbo-Beaver	L AvG	L1P	DHB	DHO
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DH8	De Havilland Canada DHC-8 Dash 8 all models	L JeK	L2T	DH8	DH8
DH1	De Havilland Canada DHC-8-100 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH3	De Havilland Canada DHC-8-300 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH4	De Havilland Canada DHC-8-400 Dash 8Q	L JeK	L2T	DH8	DH8
DHB	De Havilland Canada DHC-2 Beaver / Turbo Beaver	L AvG	L1P	DHB	DHO
DHP	De Havilland Canada DHC-2 Beaver	L AvG	L1P	DHB	DHO
DHS	De Havilland Canada DHC-3 Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DHO	De Havilland Canada DHC-3 Otter / Turbo Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DR40	Robin DN-400	L AvG	L1P	C150	DHO
EMB	Embraer EMB.110 Bandeirante	L JeK	L2T	EMB	EMB
EM2	Embraer EMB.120 Brasília	L JeK	L2T	EM2	NA
E121	Embraer 121 Xingu	L JeK	L2T	E121	B350
ER3	Embraer RJ135	L JeK	L2J	ERJ	ERJ
ER4	Embraer RJ145 Amazon	L JeK	L2J	ERJ	ERJ
E70	Embraer 170	L JeK	L2J	EMJ	FRJ
E3CF	Boeing Sentry	L JeK	L4J	E3CF	NA
EM2	Embraer EMB.120 Brasília	L JeK	L2T	EM2	NA
EMB	Embraer EMB.110 Bandeirante	L JeK	L2T	EMB	EMB
EMJ	Embraer 170/190	L JeK	L2J	EMJ	FRJ
ERJ	Embraer RJ135 / RJ140 / RJ145	L JeK	L2J	ERJ	ERJ
100	Fokker 100	L JeK	L2J	100	100
F16	Lockheed F-16 Fighting Falcon	L JeK	L1J	F16	NA
F27	Fairchild FH.227	L JeK	L2T	FK7	NA
F28	Fokker F.28 Fellowship 3000	L JeK	L2J	F24	F28
F2TH	Dassault Falcon 2000	L JeK	L2J	F2TH	NA
F406	Cessna F406 Caravan 2	L JeK	L2T	F406	F406
F50	Fokker 50	L JeK	L2T	F50	F50
F70	Fokker 70	L JeK	L2J	F70	NA



Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
F900	Dassault Falcon 900	L JeK	L3J	F900	F50
FA10	Dassault Falcon 10	L JeK	L2J	FA10	S20
FA20	Dassault Falcon 20	L JeK	L2J	FA20	S20
FA50	Dassault Falcon 50	L JeK	L3J	FA50	F50
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
GALX	IAI Galaxi	L JeK	L2J	WWP	S20
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ
GLF2	Grumman Gulfstream 2	L JeK	L2J	GLF3	NA
GLF3	Grumman Gulfstream 3	L JeK	L2J	GLF3	NA
GLF4	Grumman Gulfstream 4	L JeK	L2J	GLF4	NA
GLF5	Grumman Gulfstream 5	L JeK	L2J	GLF5	NA
GRG	Grumman G.21 Goose	L AvG	A2P	GRG	B350
GRJ	Gulfstream Aerospace G-1159 Gulfstream II / III / IV / V	L JeK	L2J	GLF3	NA
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25B	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H60	Sikorsky Black Hawk	L JeK	H2T	S61	NA
HS7	Hawker Siddeley HS.748	L JeK	L2T	HS7	FRJ
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL8	Ilyushin IL18	L JeK	L4T	IL8	NA
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
ILW	Ilyushin IL86	L JeK	L4J	ILW	340
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
J41	British Aerospace Jetstream 41	L JeK	L2T	J41	J41
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
L10	Lockheed L-1011 Tristar pax	L JeK	L3J	L10	D10
L11	Lockheed L-1011 1 / 50 / 100 / 150 / 200 / 250 Tristar pax	L JeK	L3J	L10	D10
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
L1F	Lockheed L-1011 Tristar Freighter	L JeK	L3J	L10	D10
L29	Aero (2) L-29 Delfin	L JeK	L1J	F16	NA
L4T	LET 410	L JeK	L2T	L4T	NA
LJ31	Learjet 31	L JeK	L2J	LJ31	S20

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
LJ35	Learjet 35	L JeK	L2J	LJ35	S20
LJ40	Learjet 40	LJeK	L2J	LJ35	S20
LJ45	Learjet 45	L JeK	L2J	LJ35	S20
LJ60	Learjet 60	L JeK	L2J	LJ35	S20
LOE	Lockheed L-188 Electra pax	L JeK	L4T	LOE	NA
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
LOH	Lockheed L-182 / 282 / 382 (L-100) Hercules	L JeK	L4T	C130	LOH
LOM	Lockheed L-188 Electra Mixed Configuration	L JeK	L4T	LOM	NA
LRJ	Gates Learjet	L JeK	L2J	LJ23	S20
LYNX	Westland Lynx	L JeK	H2T	S61	NA
M11	McDonnell Douglas MD11 pax	L JeK	L3J	M11	D10
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M1M	McDonnell Douglas MD11 Mixed Configuration	L JeK	L3J	M11	D10
M20P	Mooney M-20	L AvG	L1P	M20P	DHO
M20T	Mooney TLS	L AvG	L1P	M20P	DHO
M80	McDonnell Douglas MD80	L JeK	L2J	M81	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M82	McDonnell Douglas MD82	L JeK	L2J	M82	M82
M83	McDonnell Douglas MD83	L JeK	L2J	M83	M82
M88	McDonnell Douglas MD88	L JeK	L2J	M88	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MU2	Mitsubishi Mu-2	L JeK	L2T	MU2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
NDC	Aerospatiale SN.601 Corvette	L JeK	L2J	NDC	DHO
P180	Piaggio P-180 Avanti	L JeK	L2T	P180	B350
P28A	Piper Archer 2	L AvG	L1P	P28A	DHO
PN6	Partenavia P.68	L AvG	L2P	PN6	DHO
PA18	Piper Super Club	L AvG	L1P	PA18	DHO
PA2	Piper light aircraft - twin piston engines	L AvG	L2P	PA31	DHO
PA24	Piper Comanche	L AvG	L1P	PA24	DHO
PA27	Piper Aztec	L AvG	L1P	PA27	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA31	Piper Navajo	L AvG	L2P	PA31	DHO
PA32	Piper Saratoga	L AvG	L1P	PA32	DHO
PA34	Piper Seneca	L AvG	L2P	PA44	DHO

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
PA44	Piper Seminole	L AvG	L2P	PA44	DHO
PA46	Piper Malibu	L AvG	L1P	PA46	DHO
PAG	Piper light aircraft	L AvG	L1P	P28A	DHO
PAT4	Piper T-1040	L JeK	L2T	PAT4	SWM
PL2	Pilatus PC-12	L JeK	L1T	PL2	C208
PL6	Pilatus PC-6 Turbo Porter	L JeK	L1T	PL6	C208
PL2	Pilatus PC-12	L JeK	L1T	PL2	C208
PL6	Pilatus PC-6 Turbo Porter	L JeK	L1T	PL6	C208
PN6	Partenavia P.68	L AvG	L2P	PN6	DHO
PUMA	Aerospatiale Puma	L JeK	H2T	S61	NA
S05F	Siai-Marchetti S-205-20F	L AvG	L1P	C150	DHO
S20	Saab 2000	L JeK	L2T	S20	S20
S58	Sikorsky S-58T	L JeK	H1T	S58	NA
S58P	Sikorsky S-58	L AvG	H1P	S61	NA
NDC	Aerospatiale SN.601 Corvette	L JeK	L2J	NDC	DHO
S61	Sikorsky S-61	L JeK	H2T	S61	NA
S76	Sikorsky S-76	L JeK	H2T	S61	NA
SA3	Stits Playboy	L AvG	L1P	SA3	DHO
S20	Saab 2000	L JeK	L2T	S20	S20
SBR1	North American Sabreliner	L JeK	L2J	SBR1	NA
SF3	Saab SF340A/B	L JeK	L2T	SF3	SF3
SF3	Saab SF340A/B	L JeK	L2T	SF3	SF3
SH3	Shorts SD.330	L JeK	L2T	SH3	SH3
SH3	Shorts SD.330	L JeK	L2T	SH3	SH3
SH6	Shorts SD.360	L JeK	L2T	SH6	SH6
SH6	Shorts SD.360	L JeK	L2T	SH6	SH6
SHB	Shorts SC-5 Belfast	L JeK	L4T	SHB	NA
SR20	Cirrus SR-20	L AvG	L1P	C150	DHO
SR22	Cirrus SR-22	L AvG	L1P	C150	DHO
SSC	Aerospatiale/BAC Concorde	L JeK	L4J	SSC	NA
SW2	Swearingen Merlin 2	L JeK	L2T	SW2	NA
SW3	Swearingen Merlin 3	L JeK	L2T	SW3	SHS
SW4	Swearingen Merlin 4	L JeK	L2T	SW4	NA
SWM	Fairchild (Swearingen) SA26 / SA226 / SA227 Metro / Merlin / Expediter	L JeK	L2T	PA31	SWM
TU3	Tupolev Tu134	L JeK	L2J	TU3	NA
TU5	Tupolev Tu154	L JeK	L3J	TU5	727
T20	Tupolev Tu-204 / Tu-214	L JeK	L2J	T20	NA
T20	Tupolev Tu-204 / Tu-214	L JeK	L2J	T20	NA
TBM	Grumman Avenger	L AvG	L1P	C150	NA
TBM7	Socata TBM-700	L JeK	L1T	TBM7	C208
TOBA	Socata Tobago	L AvG	L1P	C150	DHO

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
TRIN	Scata Pashosh	L AvG	L1P	C150	DHO
TU3	Tupolev Tu134	L JeK	L2J	TU3	NA
TU5	Tupolev Tu154	L JeK	L3J	TU5	727
VC10	Bac VC-10	L JeK	L4J	VC10	NA
VCV	Vickers Viscount	L JeK	L4T	VCV	NA
WG30	Westland WG-30	L JeK	H2T	S61	NA
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK5	Yakovlev Yak 50	L AvG	L1P	C150	DHO

#### 3.3.3.1.3.4 Fuel dependent emission factors

Fuel dependent emission factors were set for CO<sub>2</sub> and N<sub>2</sub>O. Emission factors for CO<sub>2</sub> and N<sub>2</sub>O are IPCC default. The LHV were obtained from the national energy authority (DGEG).

Table 3-82 – Fuel dependent emission factors.

Pollutant	Aviation Gasoline	Jet Fuel
LHV (MJ/kg)	44.0	43.0
CO <sub>2</sub> (t/TJ) <sup>26</sup>	69.5	70.6
N <sub>2</sub> O (kg/TJ)	2.00	2.00

Source: IPCC; DGEG

#### 3.3.3.1.4 Activity Data

##### 3.3.3.1.4.1 Flight movements in Airports

Very important activity data for this source activity is the number of arrival and departure movements. The number of movements by airport, aircraft, origin/destiny and movement type (arrival or departure) for the period between 1990 and 2012 was provided by the *Instituto Nacional de Aviação Civil* (INAC). This database is being improved and the coverage of it is increasing as new airports (mostly regional and local airports) are connected to the movements' database from INAC.

<sup>26</sup> The CO<sub>2</sub> emission factor takes into account an oxidation factor of 0.99.

Table 3-83 – LTO per airport

Region	Airport Code	1990	1995	2000	2005	2010	2011	2012
Mainland	LIS	30 862	34 932	56 073	68 168	73 783	74 031	80 091
	OPO	11 574	13 348	23 280	25 910	28 502	30 839	31 964
	FAO	11 252	13 067	18 243	20 397	22 359	22 426	22 081
	<b>TOTAL</b>	<b>53 688</b>	<b>61 347</b>	<b>97 596</b>	<b>114 475</b>	<b>124 644</b>	<b>127 296</b>	<b>134 136</b>

Region	Airport Code	1990	1995	2000	2005	2010	2011	2012
Islands	FNC	6 475	9 460	12 040	15 952	12 697	12 263	12 591
	TER	3 801	4 049	4 501	4 875	4 988	4 955	5 180
	PDL	2 954	3 382	4 134	7 196	8 182	7 867	8 457
	PXO	2 403	4 243	3 788	3 688	2 325	2 165	2 058
	HOR	1 237	1 542	1 756	2 964	2 919	2 772	2 695
	SMA	634	893	1 557	1 649	1 275	1 333	1 113
	FLW	281	357	552	1 101	1 136	1 116	1 088
	<b>TOTAL</b>	<b>17 785</b>	<b>23 926</b>	<b>28 328</b>	<b>37 425</b>	<b>33 522</b>	<b>32 471</b>	<b>33 180</b>

Source: INAC

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

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

On the other hand, for records with missing information on origin and destiny, a 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.

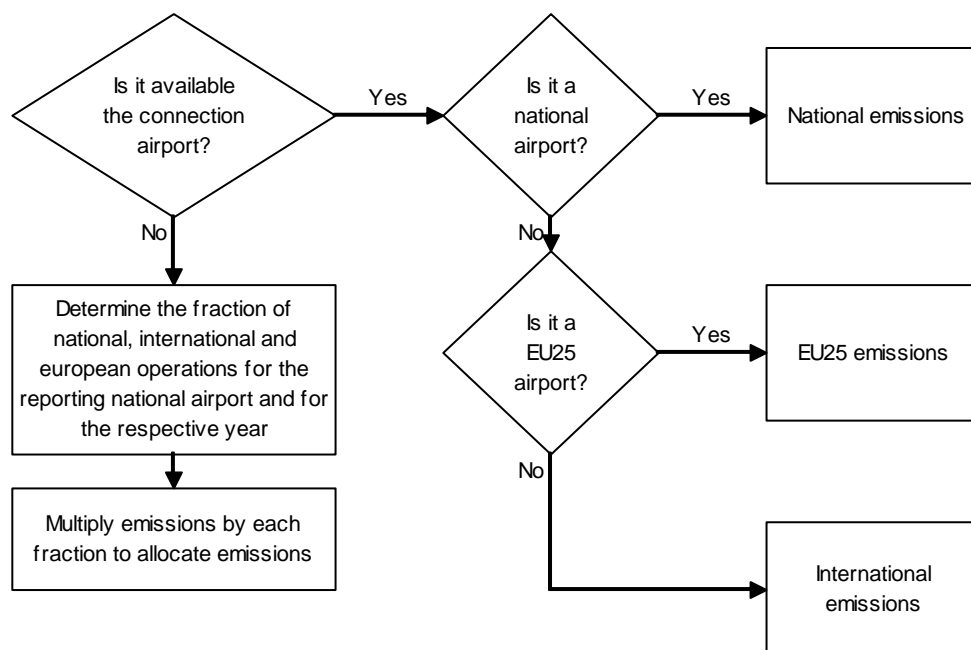


Figure 3-61 – Decision tree for distinction between domestic and international emissions.

#### 3.3.3.1.4.2 Fuel Consumption

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

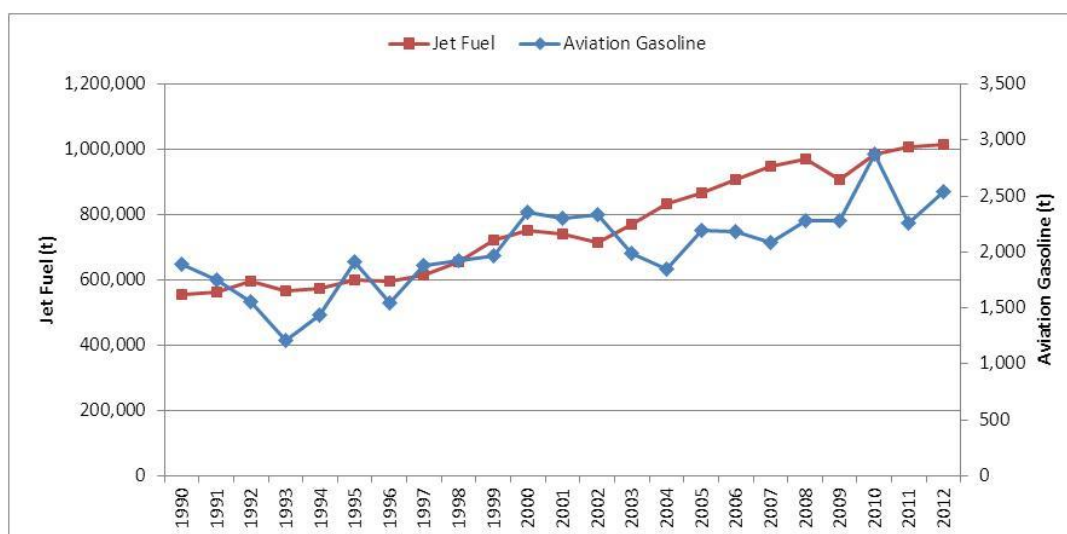


Figure 3-62 – Total Fuel consumption of aviation gasoline and jet fuel (Source: DGEG)

### 3.3.3.1.5 Uncertainty Assessment

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

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

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

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

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

Where,

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

Table 3-84 – Aviation activity level uncertainty.

Source	Parameter	Unit	1990	1995	2000	2005	2010	2011	2012
All	Uglobal	%	74	72	35	36	35	35	36
Cruise	Ucruise	%	99	99	47	49	48	47	48
LTO	Ulto	%	100	100	48	49	48	47	49

The uncertainties of emissions factors were set at 5% for CO<sub>2</sub>, 100% for methane and one order of magnitude for N<sub>2</sub>O, following the recommendations from GPG.

### 3.3.3.1.6 Category-specific QA/QC and verification

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

### 3.3.3.1.7 Recalculations

Update of the 2011 emissions values due to compilation error detected in the estimation spreadsheet. The routine procedure was not correctly applied, with implications on the estimative of emissions regarding aircraft movements where information about the aircraft type is not available and is supposed to use averaged airport LTO and cruise emission factors.

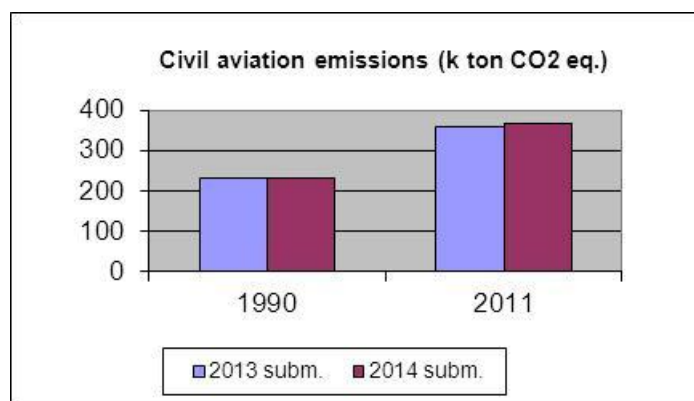


Figure 3-63 – Differences between submissions 2014 and 2013 for CO<sub>2</sub> emissions from civil aviation



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

#### 3.3.3.2.1 Overview

Road transportation is one of the most important emitter of greenhouse gases (GHG) such as carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O).

Exhaust greenhouse gases emissions from road transportation were estimated at about 16 370 kton CO<sub>2</sub>e. in 2012 representing an increase of 70% when compared to 9 628 kton CO<sub>2</sub>e., estimated for 1990 (see Table 3-85).

Emissions of N<sub>2</sub>O have increased by a factor of 2.4 since 1990 due to the introduction of catalytic converters. As could be observed the introduction of catalytic converters have some disadvantages including also the increase of CO<sub>2</sub> and NH<sub>3</sub> emissions which contribute to climate change and acid deposition. It is difficult to assess the extent to which CO<sub>2</sub> emissions have increased as a result of fitting catalytic converters, because improvements in fuel economy have been made at the same time as development of the engine management systems that are required to minimize NO<sub>x</sub> and VOC emissions

Table 3-85 – Estimated emissions from road transport

Pollutant	Unit	1990	2012	Var (%)
CO2 Fossil	kt	9 476	16 185	71
CH4	t	4 065	1 225	-70
N2O	t	216	514	138
CO <sub>2</sub> e.	kt	9 628	16 370	70

#### 3.3.3.2.2 Methodology

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

Emissions from heavy duty vehicles, buses and coaches were estimated from vehicle-kilometers obtained from national statistics. Disaggregation by vehicle technology was then obtained using the data from the vehicle inspection centers.

Estimated emissions from road transport are based in Tier 2 method for CO<sub>2</sub> emissions and Tier 3 for non-CO<sub>2</sub> emissions.

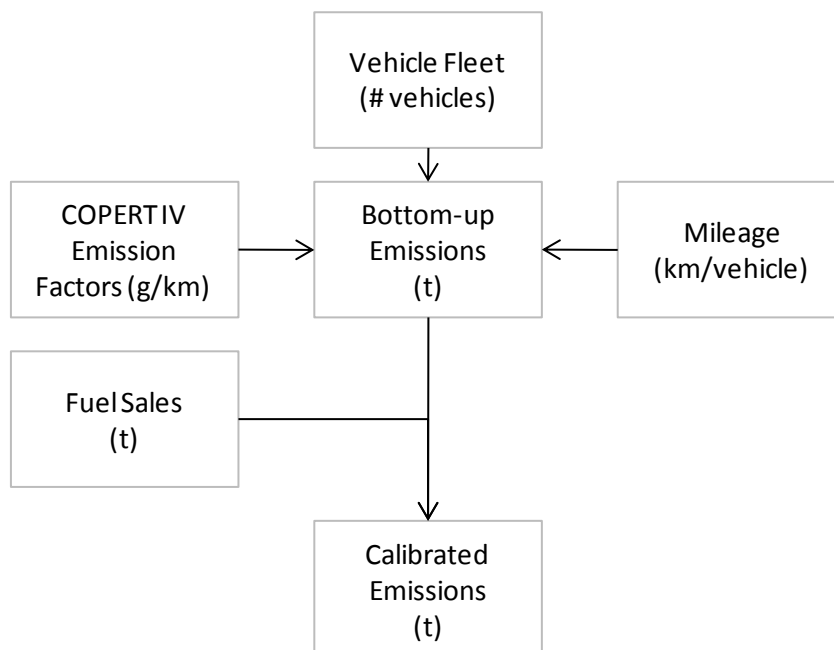


Figure 3-64 – General scheme of methodology applied for road transport emissions estimates (Passenger cars, light duty vehicles and motorcycles)

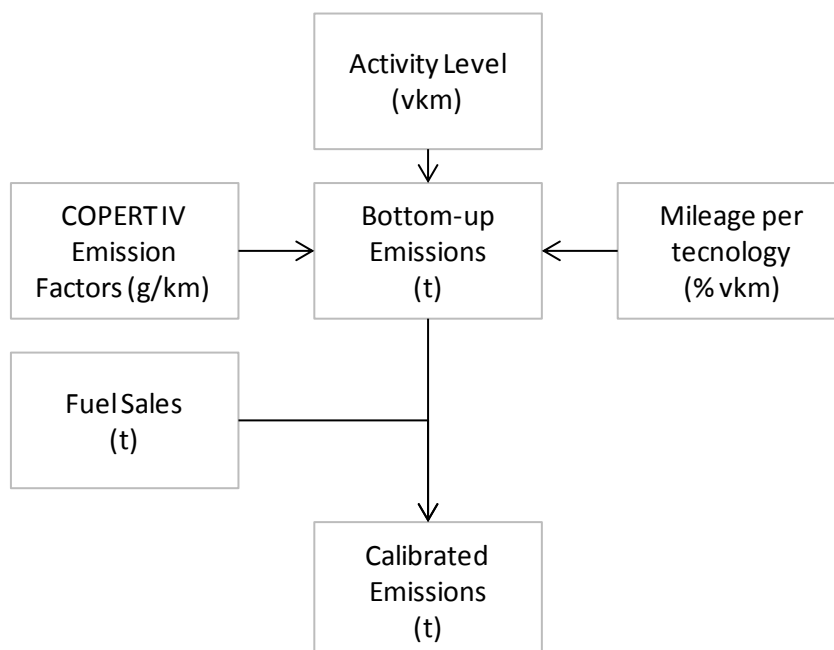


Figure 3-65 – General scheme of methodology applied for road transport emissions estimates (Heavy duty vehicles, buses and coaches)

### 3.3.3.2.2.1 Vehicle Fleet

A function for vehicle abatement based on vehicle age was applied to vehicle sales in order to determine the active fleet per year. This function derives from *Associação Automóvel de Portugal* (ACAP) data and is valid for passenger cars, light duty vehicles and motorcycles and is summarized in the following couple equations:

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

$$T_{c,a,f,y1} = S_{c,y2} \times \left[ 1 - \frac{0.2721 \times A_{c,y1-y2} - 35.199}{100} \right]; 10 \leq A \leq 20$$

Where,

$T(c,a,y1)$  = number of vehicles of class c, with age a, using fuel f in year y1;

$S(c,y2)$  = sales of vehicles of class c, using fuel f in year y2;

$A(c,y1-y2)$  = age of vehicles of class c, using fuel f in year y1.

The number of mopeds was obtained from the insurance institute as information on mopeds sales and abatements is not available.

National statistics institute provides information on the total activity level for heavy duty trucks, Buses and Coaches. The activity level is then disaggregated by technology using the information from vehicle inspection centers.

### 3.3.3.2.2.2 Distance Travelled

Distance driven was established using a model based on data from vehicle inspection centers.

Distance travelled by heavy duty vehicles, buses and coaches was established from national statistics. Disaggregation by vehicle technology was then obtained using the data from the vehicle inspection centres.

Mopeds and motorcycles are excluded from the vehicle maintenance program therefore it was assumed an average mileage of 12000 km/year for motorcycles (Bennetts, 2009) and 5000 for mopeds.

Table 3-86 – Km per year per vehicle as function of vehicle age for passenger cars and light duty vehicles.

Vehicle Category	Sub Categories	Mileage Function	Parameters
Passenger Cars	Gasoline <1,4 l Hybrid Gasoline <1,4 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 11059.2452 A2 = -2885.12141 x0 = 23.28806 p = 2.56847
	Gasoline 1,4 - 2,0 l Hybrid Gasoline 1,4 - 2,0 l	$\text{km/year} = y0 + A * \text{Exp}(-0.5 * ((\text{age} - xc) / w) ^ 2)$	y0 = 13010.25545 xc = 26.65915 w = 8.63531 A = -8623.92117
	Gasoline >2,0 l LPG 2-Stroke Hybrid Gasoline >2,0 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 13354.66789 A2 = 737.09264 x0 = 19.69152 p = 2.4209
	Diesel <2,0 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 19241.06557 A2 = 6603.86725 x0 = 17.45625 p = 2.53695
	Diesel >2,0 l	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 20445.94606 A2 = 9728.01464 x0 = 14.25834 p = 3.25053
Light Duty Vehicles	Diesel <3,5 t	$\text{km/year} = A2 + (A1 - A2) / (1 + (\text{age} / x0) ^ p)$	A1 = 20800.21535 A2 = 2597.42606 x0 = 15.44257 p = 2.32592

Table 3-87 – Km per year per vehicle type

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2012
Passenger Cars	Gasoline <1,4 l	PRE ECE	5 145	3 720	0	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	7 731	5 637	3 989	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/02	9 316	7 268	5 098	3 454	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/03	10 457	9 009	6 941	4 895	3 454	0
Passenger Cars	Gasoline <1,4 l	ECE 15/04	11 021	10 655	9 478	7 561	5 523	4 852
Passenger Cars	Gasoline <1,4 l	Improved Conventional	0	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	Open Loop	0	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	PC Euro 1 - 91/441/EEC	0	11 049	10 692	9 452	7 455	6 579
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	0	0	11 036	10 541	9 134	8 352
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	10 982	10 252	9 701
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	11 059	10 949	10 744
Passenger Cars	Gasoline <1,4 l	PC Euro 5 (post 2005)	0	0	0	0	11 059	11 048
Passenger Cars	Gasoline <1,4 l	PC Euro 6	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	6 277	4 721	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	9 583	6 875	4 938	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	11 401	9 112	6 237	4 544	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	12 332	10 969	8 515	5 888	45 44	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	12 877	12 584	11 621	9 591	6 917	5 997
Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	0	12 898	12 551	11 477	9 262	8 127
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	0	0	12 880	12 430	11 172	10 338
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	12 803	12 173	11 683
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	12 937	12 758	12 560
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 (post 2005)	0	0	0	0	12 937	12 917
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	PRE ECE	6 686	5 485	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	9 082	7 059	5 670	0	0	0

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2012
Passenger Cars	Gasoline >2,0 l	ECE 15/02	10 921	8 664	6 640	5 272	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/03	12 190	10 208	7 997	6 197	5 272	0
Passenger Cars	Gasoline >2,0 l	ECE 15/04	13 288	12 723	11 154	8 992	7 027	6 435
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	0	13 331	12 735	11 050	8 816	7 952
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	0	0	13 312	12 549	10 726	9 830
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13 211	12 109	11 376
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 171	12 862
Passenger Cars	Gasoline >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	13 355	13 340
Passenger Cars	Gasoline >2,0 l	PC Euro 6	0	0	0	0	0	0
Passenger Cars	Diesel <2,0 l	Conventional	18 516	18 089	16 360	14 000	11 863	11 194
Passenger Cars	Diesel <2,0 l	PC Euro 1 - 91/441/EEC	0	19 198	18 445	16 380	13 803	12 872
Passenger Cars	Diesel <2,0 l	PC Euro 2 - 94/12/EEC	0	0	19 196	18 299	16 092	15 038
Passenger Cars	Diesel <2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	19 127	17 943	17 095
Passenger Cars	Diesel <2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	19 241	19 031	18 649
Passenger Cars	Diesel <2,0 l	PC Euro 5 (post 2005)	0	0	0	0	19 241	19 221
Passenger Cars	Diesel <2,0 l	PC Euro 6	0	0	0	0	0	0
Passenger Cars	Diesel >2,0 l	Conventional	18 690	17 521	15 735	13 871	12 317	11 848
Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	0	20 428	19 808	17 394	14 327	13 365
Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	0	0	20 433	19 762	17 201	15 895
Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	20 381	19 230	18 212
Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	20 446	20 333	20 032
Passenger Cars	Diesel >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	20 446	20 440
Passenger Cars	Diesel >2,0 l	PC Euro 6	0	0	0	0	0	0
Passenger Cars	LPG	Conventional	13 109	12 455	10 806	8 689	6 816	6 210
Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	0	13 294	12 546	10 769	8 551	7 716
Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	0	0	13 295	12 442	10 554	9 652
Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13 166	11 942	11 166
Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 330	13 185
Passenger Cars	LPG	PC Euro 5 (post 2005)	0	0	0	0	13 355	13 305
Passenger Cars	LPG	PC Euro 6	0	0	0	0	0	0

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2012
Passenger Cars	2-Stroke	Conventional	0	0	0	0	0	13 351
Passenger Cars	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	10 228	9 879	9 134	9 121	10 174	10 797
Passenger Cars	Hybrid Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	12 937	12 914	12 843	12 866
Passenger Cars	Hybrid Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	13 355	13 242	13 191	13 199
Light Duty Vehicles	Gasoline <3,5t	Conventional	10 433	8 828	6 292	4 092	2 460	1 287
Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	0	13 331	12 735	11 050	8 816	7 952
Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	0	0	13 312	12 549	10 726	9 830
Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	13 211	12 109	11 376
Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 171	12 862
Light Duty Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards	0	0	0	0	13 355	13 340
Light Duty Vehicles	Gasoline <3,5t	LD Euro 6	0	0	0	0	0	0
Light Duty Vehicles	Diesel <3,5 t	Conventional	17 571	16 481	13 978	11 295	9 067	8 367
Light Duty Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	0	20 733	19 497	16 114	12 248	10 935
Light Duty Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	0	0	20 741	19 246	15 618	13 999
Light Duty Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	20 649	18 597	17 173
Light Duty Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	0	20 491	19 834
Light Duty Vehicles	Diesel <3,5 t	LD Euro 5 - 2008 Standards	0	0	0	0	0	20 785
Light Duty Vehicles	Diesel <3,5 t	LD Euro 6	0	0	0	0	0	0

### 3.3.3.2.2.3 Allocation of distance travelled

Vehicle-kilometers (vkm) were allocated to urban, rural and highway driving modes. Information on vkm driven under highways derives from the *Instituto da Mobilidade e dos Transportes* (IMT) which is the national authority for terrestrial transportation. Originally this data is communicated to IMTT by the highway service providers. The remaining vkm are allocated to urban and rural driving modes according with the population living in each area.

### 3.3.3.2.2.4 Speed

Three driving modes were individualized in accordance with source categories SNAP97 from CORINAIR/EMEP methodology: urban, rural and highway. For each driving mode average speeds had to be set by vehicle type whereas vehicle fuel consumption and exhaust emissions are strongly dependent on speed.

Table 3-88 – Assumed vehicle speeds by driving mode and vehicle type.

Driving Mode	Vehicle Type	Assumed Speed (km/h)	Source
Highway	Passenger Car	124	Lemonde, 2000
	Light Duty Vehicles	124	Lemonde, 2000
	Heavy Duty Vehicles	103	LNEC, 2002
	Coaches	103	LNEC, 2002
	Motorcycles	124	Lemonde, 2000
Rural	Passenger Car	61	LNEC, 2002
	Light Duty Vehicles	61	LNEC, 2002
	Heavy Duty Vehicles	56	LNEC, 2002
	Coaches	56	LNEC, 2002
	Mopeds	40	Maximum Legal Value
	Motorcycles	61	LNEC, 2002
Urban	Passenger Car	24.9	Gois et al., 2005
	Light Duty Vehicles	24.9	Gois et al., 2005
	Heavy Duty Vehicles	24.9	Gois et al., 2005
	Buses	14.8	Carris, 2005
	Coaches	24.9	Gois et al., 2005
	Mopeds	24.9	Gois et al., 2005
	Motorcycles	24.9	Gois et al., 2005

### 3.3.3.2.2.5 Fuel consumption

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



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

where,

$FC_{f,y}$  = fuel consumption of fuel type f by all vehicles in year y (km/y) using bottom-up approach;

$km_{c,t,m,f,y}$  = total kilometres driven by vehicles of class c, with technology t, under driving mode m using fuel f in year y (km/y);

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

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

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

m=driving mode: highway, rural, urban

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

y = civil year.

### 3.3.3.2.2.6 Adjustment of bottom-up and top-down approaches

Fuel adjustments are necessary so that the sum of estimated fuel consumption equals the total fuel sales from the DGEG. Fuel consumption estimates were corrected with the following factor for car type c, technology t, fuel f, driving mode d and year y.

$$Correc_{Factor_{c,y}} = \frac{FuelSales_{c,y}}{FuelEstimates_{1stFC_{c,y}}}$$

Correction factors are later applied to the first approach fuel consumption and emissions. This correction guarantees that emission estimates are in accordance with the good practices (IPCC, 2000; IPCC, 1996). Although emissions were derived from estimate of vehicle kilometres travelled and from fuel consumption per kilometre (bottom-up approach), they were corrected for total national fuel sales (top-down correction).

### 3.3.3.2.2.7 Emission Factors

Ultimate CO<sub>2</sub> emission factors were established according with IPCC guidelines.

Energy content was first estimated using national specific LHV provided by DGEG.

Table 3-89 – National specific LHV

Fuel	GJ/ton
Gasoline	44.00
Diesel	42.60
LPG	46.00
CNG	45.97
Biodiesel	37.00

Source: DGEG

Then IPCC default CO<sub>2</sub> emission factors (kgCO<sub>2</sub>/GJ) were multiplied by the energy consumption.

Table 3-90 - CO<sub>2</sub> emission factors

Fuel	EF <sub>CO2</sub> (kg CO <sub>2</sub> /GJ)
Gasoline	73.00
Diesel	74.00
LPG	63.00
CNG	55.82

Source: IPCC, 1996

Emissions factors for CH<sub>4</sub> and N<sub>2</sub>O, expressed in g/km, were determined using COPERT IV (version 9.0 - November 2011).

This set of equations allows the estimation of emission factors as function of driving conditions and vehicle properties:

- Vehicle class: light passenger vehicles, LDV, HDV, Mopeds with cylinder capacity under 50 cc and; Motorcycles with cylinder capacity greater than 50 cc;
- Fuel type: gasoline, diesel and LPG;
- Technology standard;
- Vehicle dimensions: motor size (cubic centimetres) for light vehicles and two wheelers and vehicle weight for heavy vehicles;
- Average vehicle speed under each driving mode.

European technology standards were determined according with the vehicle built year as present in table below.

Table 3-91 – Technology classification according to built year

Vehicle Category	Legislation	Built year	
		from	to
Passenger Cars	PRE ECE	...	1971
	ECE 15/00-01	1972	1977
	ECE 15/02	1978	1980
	ECE 15/03	1981	1985
	ECE 15/04	1986	1991
	Euro 1	1992	1996
	Euro 2	1997	2000
	Euro 3	2001	2004
	Euro 4	2005	2008
	Euro 5 <sup>(27)</sup>	2009	2014
	Euro 6 <sup>(1)</sup>	2014	...
Light Duty Vehicles	Conv	...	1991
	Euro 1	1992	1997
	Euro 2	1998	2001
	Euro 3	2002	2006
	Euro 4	2006	2009
	Euro 5 <sup>(1)</sup>	2010	2015
	Euro 6 <sup>(1)</sup>	2015	...
Heavy Duty Vehicles	Conv	...	1991
	Euro I	1992	1995
	Euro II	1996	2000
	Euro III	2001	2005
	Euro IV	2006	2008
	Euro V	2009	...
Mopeds	Conv	...	1999
	Euro 1	2000	2002
	Euro 2	2003	2005
	Euro 3	2006	...
Motorcycles	Conv	...	1999
	Euro 1	2000	2003
	Euro 2	2004	2005
	Euro 3	2006	

<sup>27</sup> Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information. (OJ L 171 29.6.2007, p. 1).

According with COPERT IV method, driving condition parameters, such as the average trip length, must be set in order to derive adequate emission factors.

There is no available updated data regarding  $L_{trip}$  for Portugal. Therefore it was decided to use an European average value of 12 km ( $L_{trip}$ ) as proposed by COPERT IV. The European average value is closed to the value for Spain which is assumed to be adequate also for Portugal

Emissions factors for  $SO_2$  and heavy metals were estimated from the fraction S and heavy metals in the fuel. For LPG, CNG and Biodiesel it was assumed a 0% sulphur content.

Table 3-92 – Sulphur content in gasoline and diesel (%)

Fuel	1990-1999	2000-2004	2005-2008	2009-2012
Gasoline	0.100	0.015	0.005	0.001

Fuel	1990-1994	1995	1996-1999	2000-2004	2005-2008	2009-2012
Diesel	0.300	0.200	0.050	0.035	0.005	0.001

Source: National Legislation (Portaria n.º125/89, Portaria n.º1489/95, Decreto-Lei n.º104/2000 Decreto-Lei n.º 235/2004, Decreto-Lei n.º 142/2010));

For evaporative emission calculations, monthly maximum and minimum average ambient temperatures were inputted into COPERT IV. Meteorological data was received from 9 climatological stations of the *Portuguese Sea and Atmosphere Institute* (IPMA). The data concerns a long period average from 1971 to 2000 and is the most updated long period average available from the IPMA. The same values were used for all years in analysis.

Table 3-93 – Monthly average ambient temperatures (°C)

Month_	Max.	Min.
January	14.0	6.6
February	15.2	7.4
March	17.3	8.5
April	18.4	9.7
May	20.8	11.9
June	24.5	14.7
July	27.7	16.8
August	28.0	16.8
September	26.0	15.6
October	21.6	12.8
November	17.5	9.8
December	14.9	7.3

Source: IM (<http://www.meteo.pt/pt/oclima/normais/>)

Monthly values of fuel volatility (RVP - Reid Vapour Pressure) were established from Portuguese legislation (Decreto-lei n.º 104/2000; Portaria 1489/95; Portaria 125/89). RVP

values considered in national legislation 104/2000 are applicable since the beginning of year 2000 although the regulatory document was valid only after May 2000. The new national regulation, Decreto-Lei nº 142/2010, keeps the same RVP values.

Table 3-94 – Reid Vapour Pressure (kPa)

Month	1990 to 1995	1996 to 1999	2000 to 2012
January	98	95	90
February	98	95	90
March	98	95	90
April	83	80	90
May	83	80	60
June	70	70	60
July	70	70	60
August	70	70	60
September	70	70	60
October	83	95	90
November	98	95	90
December	98	95	90

#### Emissions from biofuels

Use of biodiesel as a blend with diesel may also lead to some change in emissions. The following table proposes differences in emissions caused by different fuel blends on fossil diesel and correspond to a Euro 3 vehicle/engine technology.

Table 3-95 – Effect of biodiesel blends on diesel vehicles emissions

Pollutant	Vehicle Type	B10	B20	B100
CO <sub>2</sub>	Passenger Cars	-1.5%	-2.0%	
	Light duty vehicles	-0.7%	-1.5%	
	Heavy duty vehicles	0.2%	0.0%	0.1%
NO <sub>x</sub>	Passenger Cars	0.4%	1.0%	
	Light duty vehicles	1.7%	2.0%	
	Heavy duty vehicles	3.0%	3.5%	9.0%
PM	Passenger Cars	-13.0%	-20.0%	
	Light duty vehicles	-15.0%	-20.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-47.0%
CO	Passenger Cars	0.0%	-5.0%	
	Light duty vehicles	0.0%	-6.0%	
	Heavy duty vehicles	-5.0%	-9.0%	-20.0%
HC	Passenger Cars	0.0%	-10.0%	
	Light duty vehicles	-10.0%	-15.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-17.0%

Source: (EEA/EMEP, 2009)

The effect of biodiesel may vary with the vehicle technology but the extent of the variation is difficult to estimate in the absence of detailed literature data. With regard to NO<sub>x</sub>, CO<sub>2</sub> and CO, any effect of technology should be negligible, given the marginal effect of biodiesel on these pollutants in general. The effect of biodiesel on PM for different technologies is more difficult to assess (EEA/EMEP, 2009).

Considering that detailed literature data on biodiesel effects is scarce and that the actual blend used for road transportation in Portugal was about 7.7% in 2012 (Table 3-96), emission factors from biodiesel use were assumed to be the same as for diesel.

Table 3-96 – National biodiesel blends with diesel (%v/v)

2006	2007	2008	2009	2010	2012
1.6	3.0	2.9	5,1	7,4	7,7

Source: (DGEG, 2013)

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

### 3.3.3.2.3 Implied Emission Factors

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

Table 3-97 – Road transportation emission factors (kg/GJ)

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010	2012
CO <sub>2</sub>	Passenger Cars	Gasoline	73.000	73.000	73.000	73.000	73.000	73.000
		Diesel	74.000	74.000	74.000	74.000	74.000	74.000
		LPG	63.000	63.000	63.000	63.000	63.000	63.000
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.000	0.000
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	74.000	74.000	74.000	74.000	74.000	74.000
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.000	0.000
	Heavy Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	74.000	74.000	74.000	74.000	74.000	74.000
		LPG	-	-	-	-	-	-
		CNG	-	-	55.82	55.82	55.82	55.82
		Biodiesel	-	-	-	-	0.000	0.000
	Motorcycles	Gasoline	73.000	73.000	73.000	73.000	73.000	73.000
		Diesel	-	-	-	-	-	-
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-
CH <sub>4</sub>	Passenger Cars	Gasoline	0.044	0.036	0.026	0.019	0.014	0.012
		Diesel	0.006	0.005	0.003	0.002	0.001	0.001
		LPG	0.021	0.022	0.020	0.018	0.015	0.014
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.001	0.001
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	0.004	0.004	0.003	0.002	0.001	0.001
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.001	0.001
	Heavy Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	0.007	0.007	0.007	0.006	0.005	0.005
		LPG	-	-	-	-	-	-
		CNG	-	-	0.095	0.097	0.092	0.092
		Biodiesel	-	-	-	-	0.005	0.005
	Motorcycles	Gasoline	0.179	0.169	0.146	0.107	0.081	0.072
		Diesel	-	-	-	-	-	-
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010	2012
N <sub>2</sub> O	Passenger Cars	Gasoline	0.003	0.012	0.006	0.005	0.002	0.002
		Diesel	0.000	0.001	0.001	0.002	0.003	0.003
		LPG	0.000	0.004	0.005	0.005	0.004	0.004
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.003	0.003
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	0.000	0.000	0.001	0.001	0.002	0.002
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.002	0.002
	Heavy Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	0.002	0.002	0.002	0.002	0.001	0.001
		LPG	-	-	-	-	-	-
		CNG	-	-	0.000	0.000	0.000	0.000
		Biodiesel	-	-	-	-	0.001	0.001
	Motorcycles	Gasoline	0.001	0.001	0.001	0.001	0.001	0.001
		Diesel	-	-	-	-	-	-
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-



The implied emission factors expressed in grams per kilometer were also derived.

Table 3-98 – Road transportation distance based implied emission factor (MJ/km; g/km)

Pollutant	Fuel	Vehicle Type	1990	1995	2000	2005	2010	2012
Energy Consumption (MJ/km)	Diesel	Passenger Cars	2.689	2.606	2.671	2.570	2.524	2.518
		Light Duty Vehicles	3.518	3.424	3.276	3.200	3.167	3.159
		Heavy Vehicles	9.993	9.864	11.624	11.605	11.238	11.498
	Gasoline	Passenger Cars	2.729	2.679	2.655	2.585	2.559	2.557
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	1.100	1.100	1.050	0.789	0.572	0.523
		Motorcycles	1.722	1.752	1.757	1.662	1.599	1.570
	CNG	Heavy Vehicles	-	-	21.574	21.623	21.514	21.514
	LPG	Passenger Cars	2.602	2.635	2.644	2.603	2.580	2.575
		Light Duty Vehicles	-	-	-	-	-	-
CO <sub>2</sub> (g/km)	Diesel	Passenger Cars	199.022	192.845	197.670	190.182	174.693	173.740
		Light Duty Vehicles	260.340	253.397	242.388	236.825	219.159	217.960
		Heavy Vehicles	739.491	729.970	860.154	858.784	777.743	793.319
	Gasoline	Passenger Cars	199.187	195.575	193.782	188.675	186.780	186.697
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	80.298	80.298	76.682	57.592	41.739	38.158
		Motorcycles	125.670	127.894	128.297	121.319	116.705	114.591
	CNG	Heavy Vehicles	-	-	1 382.922	1 386.016	1 200.903	1 200.903
	LPG	Passenger Cars	163.946	165.991	166.542	163.993	162.547	162.253
		Light Duty Vehicles	-	-	-	-	-	-
CH <sub>4</sub> (g/km)	Diesel	Passenger Cars	0.017	0.014	0.009	0.005	0.002	0.002
		Light Duty Vehicles	0.014	0.014	0.010	0.006	0.003	0.003
		Heavy Vehicles	0.068	0.067	0.077	0.073	0.054	0.055
	Gasoline	Passenger Cars	0.121	0.097	0.069	0.048	0.035	0.030
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	0.219	0.219	0.199	0.106	0.045	0.032
		Motorcycles	0.192	0.192	0.188	0.159	0.131	0.115
	CNG	Heavy Vehicles	-	-	2.050	2.106	1.979	1.979
	LPG	Passenger Cars	0.054	0.058	0.053	0.046	0.040	0.036
		Light Duty Vehicles	-	-	-	-	-	-
N <sub>2</sub> O (g/km)	Diesel	Passenger Cars	0.000	0.002	0.003	0.006	0.007	0.007
		Light Duty Vehicles	0.000	0.001	0.003	0.004	0.006	0.006
		Heavy Vehicles	0.019	0.019	0.019	0.019	0.014	0.015
	Gasoline	Passenger Cars	0.008	0.033	0.015	0.012	0.006	0.005
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	0.001	0.001	0.001	0.001	0.001	0.001
		Motorcycles	0.002	0.002	0.002	0.002	0.002	0.002
	CNG	Heavy Vehicles	-	-	0.000	0.000	0.000	0.000
	LPG	Passenger Cars	0.000	0.010	0.012	0.012	0.011	0.009
		Light Duty Vehicles	-	-	-	-	-	-

### 3.3.3.2.4 Activity Data

#### 3.3.3.2.4.1 Vehicle Fleet

The following table shows the number of vehicles between 1990 and 2012 was based in data available from ACAP, *Instituto de Seguros de Portugal* (ISP) and INE.

Table 3-99 – Vehicle fleet synthesis

Vehicle Type	1990	1995	2000	2005	2010	2012
Passenger Cars	1 616 142	2 702 220	3 743 313	4 185 544	4 191 284	3 953 014
Light Duty Vehicles	449 918	545 091	684 953	751 144	718 869	661 532
Mopeds	834 675	682 031	529 387	330 528	283 369	278 252
Motorcycles	66 129	92 239	144 595	157 055	215 987	222 557

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

#### 3.3.3.2.4.2 Distances Travelled

Total road traffic activity has increased 97.4% since 1990.

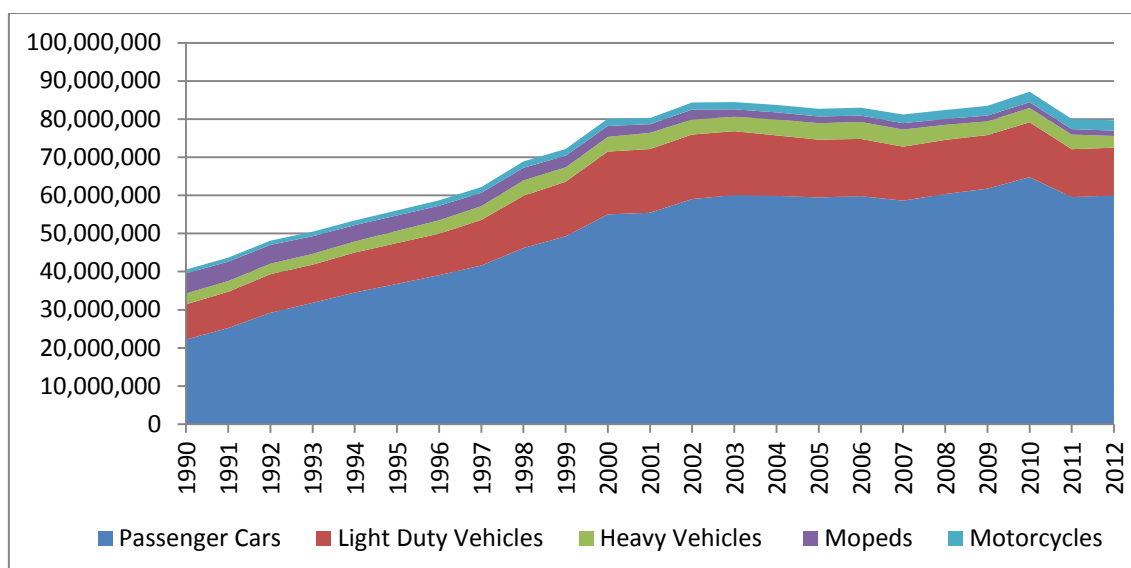


Figure 3-66 – Kilometers travelled by vehicle type (vkmx10<sup>3</sup>)

Table 3-100 – Kilometers travelled per vehicle type (vkmx10<sup>3</sup>)

Tipo Veículo	1990	1995	2000	2005	2010	2012
Passenger Cars	22 206 741	36 791 100	55 019 287	59,461,128	64 775 839	59 974 976
Light Duty Vehicles	9 236 067	10 705 643	16 461 643	15,138,272	14 384 437	12 520 756
Heavy Vehicles	2 839 603	3 194 763	3 851 053	4,332,297	3 762 647	3 082 250
Mopeds	5 265 495	4 047 894	2 883 789	1,759,306	1 505 049	1 404 043
Motorcycles	1 001 210	1 313 865	1 890 404	2,006,301	2 753 197	2 695 223
<b>TOTAL</b>	<b>40 549 115</b>	<b>56 053 266</b>	<b>80 106 175</b>	<b>82,697,305</b>	<b>87 181 169</b>	<b>79 677 250</b>

#### 3.3.3.2.4.3 Fuel Consumption

Fuel consumption from road transport sector is available from the revised energy balances from DGEG. Total consumption of petrol, diesel-oil and LPG are shown in Table 3-101.

Table 3-101 – Fuel consumption from road transport sector

Fuel	Unit	1990	1995	2000	2005	2010	2012
Gasoline	t	1 376 217	1 885 861	2 052 007	1 791 425	1 379 897	1 126 235
Diesel	t	1 603 658	2 110 210	3 759 009	4 167 113	4 280 447	3 644 891
LPG	t	21	289	22 329	20 935	28 944	31 229
CNG	t	0	0	648	9 572	11 459	10 946
Biodiesel	t	0	0	0	0	342 604	304 266

Source: DGEG

Fuel consumption was also estimated from the fuel consumption factors given from COPERT IV. The bottom-up versus top-down correction factor was derived from the differences between estimated and real fuel consumption as explained.

#### 3.3.3.2.5 Uncertainty Assessment

In accordance with the chapter of Road Vehicles in the GPG, the uncertainty of methane emission factor is 40% and the uncertainty for nitrous oxide should be at least 50%. The uncertainty in CO<sub>2</sub> is 5%, also in accordance with the same source of information. The uncertainty of activity data was assumed to be 5%.

#### 3.3.3.2.6 Category-specific QA/QC and verification

Differences were found in fuel consumption time series taken as a sum from COPERT IV compared to total fuel sales data taken from the energy balance. In 2012 the estimated fuel consumption compared to sales are: Gasoline -0.9%; Diesel -1.0%; LPG -78.6%; CNG -94.7%. These differences are corrected in COPERT IV to equal fuel sales in order to ensure full consistency between Energy Statistics and GHG inventory. Corresponding CO<sub>2</sub> emissions are corrected as well.

### 3.3.3.2.7 Recalculations

No recalculations for this sector.

### 3.3.3.2.8 Further Improvements

Improvements for this sector refer to the development of country-specific parameters for gasoline and diesel oil in order to follow the UNFCCC recommendations.

### 3.3.3.3 Railways (CRF 1.A.3.c)

#### 3.3.3.3.1 Overview

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

#### 3.3.3.3.2 Methodology

Emissions to atmosphere of ultimate CO<sub>2</sub> from fossil origin were estimated from CO<sub>2</sub> 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 CO<sub>2</sub> emissions (kgCO<sub>2</sub>/GJ);

$\text{C}_{\text{Fossil}}$  - Percentage of carbon from fossil origin in fuel f (%);

$\text{Fac}_{\text{OX}(f)}$  - Oxidation factor for fuel f (ratio 0..1);

$\text{Cons}_{\text{Fuel}(f,y)}$  - Consumption of fuel f in year y (ton/yr);

$\text{LHV}_{(f)}$  - Low Heating Value (MJ/kg).

For all other pollutants the following formula was used:

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

where

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

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

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

### 3.3.3.3.3 Emission Factors

Emission factors were set from available proposed emission factors in EMEP/CORINAIR Handbook (EEA,2002), IPCC 1996 Revised Guidelines (IPCC,1997) and MEET project, and are presented in next table.

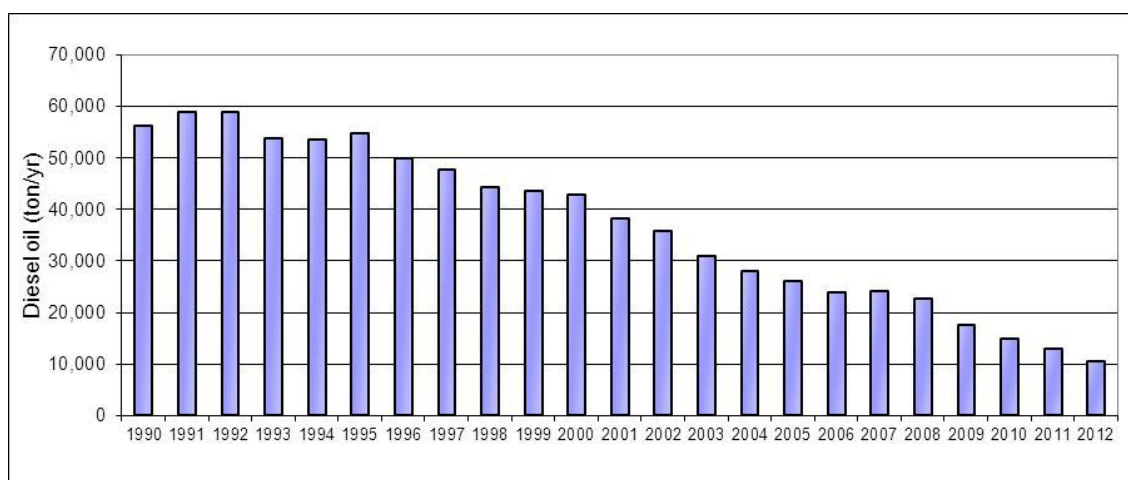
Table 3-102 - Emission factors in Railways

Fuel	LHV	Oxidation Factor	% C fossil	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
	MJ/kg			kg/GJ	g/GJ	g/GJ
Coal	31.0	0.980	100	101.9	6.9	21.3
Coke	29.4	0.990	100	107.3	7.3	22.4
Diesel-oil	42.6	0.990	100	74.1	5.0	15.5
Biodiesel	37.0	1.000	0	85.3	5.8	17.8

### 3.3.3.3.4 Activity Data

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2012 from the energy balance. Besides some very small use of coal and coke until 1996, the majority of combustible energy refers to use of gas oil<sup>28</sup>. The quantities that were consumed have been decreasing steadily since 1992 due to electrification of the power lines, as can be seen in Figure 3-67.

Figure 3-67 - Consumption of diesel oil in the railway transport sector



### 3.3.3.3.5 Uncertainty Assessment

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

<sup>28</sup> Gas oil represents no less than 98.4 per cent of total annual use of combustible energy.

#### 3.3.3.3.6 Category-specific QA/QC and verification

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

#### 3.3.3.3.7 Recalculations

Recalculations for this source category comprise the revision of 2008 energy data.

Railways CO<sub>2</sub> emission factor for diesel oil fuel was revised and changed from 74,37 kg/Gj to 74,07 kg/Gj. The new EF is the same that is being used for this type of fuel by the other mobile sources to ensure consistency across all sectors.

#### 3.3.3.3.8 Further Improvements

No further improvements are planned for this sector.

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

#### 3.3.3.4.1 Overview

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

#### 3.3.3.4.2 Methodology

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

The methodology used for the calculation of emissions from shipping activities is in accordance with the ship movement methodology from the detailed methodology of EEA/EMEP air pollutant emission inventory guidebook (version from August 2002).

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

The general approach could be described as follows:

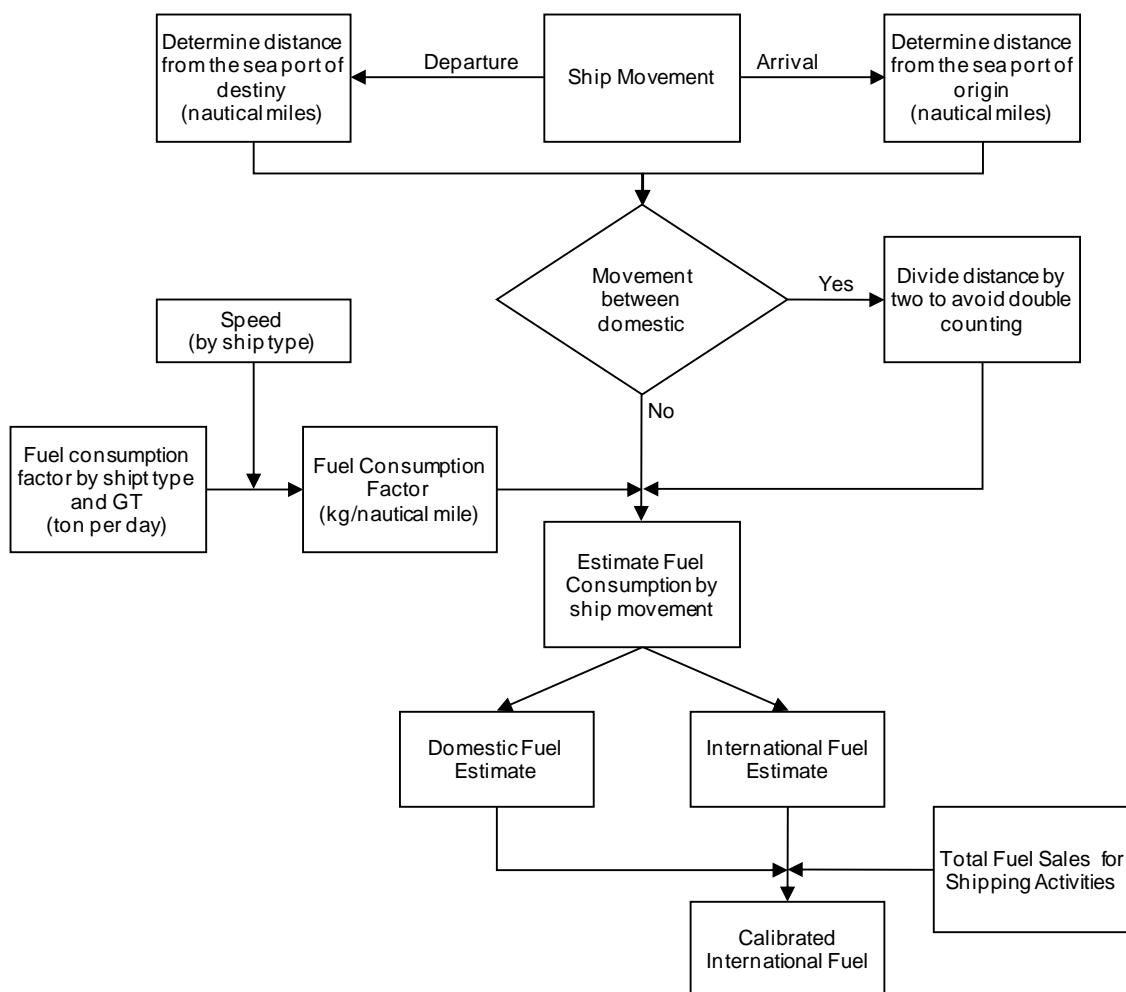
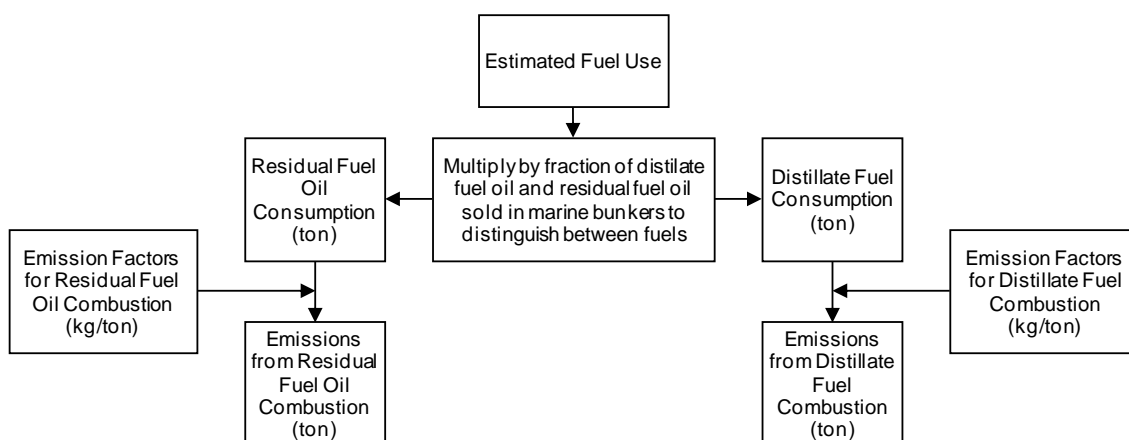


Figure 3-68 – Generic methodology flowchart.

Emissions factors vary according with the type of fuel used. To distinguish between residual and distilled fuel an additional calculation step is required:



#### 3.3.3.4.3 Emission Factors

Emission factors and energy content were obtained from several sources. The energy content of residual and distillate fuels was provided by the energy authority (DGEG). The carbon

emission factors, expressed in t C/TJ are from IPCC (IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual). Emission factors for CH<sub>4</sub> and N<sub>2</sub>O were obtained from EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook.

When estimating CO<sub>2</sub>, it was assumed that a fraction of carbon (0,01) remains unoxidized and stored indefinitely, as follows:

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

Table 3-103 – Emission factors for navigation

Pollutant	Unit	Gas-oil	Residual fuel oil
LHV	MJ/kg	42.60	40.00
Carbon	t C/TJ	20.20	21.10
CO <sub>2</sub>	t CO <sub>2</sub> /TJ	73.33	76.59
CH <sub>4</sub>	kg/tonne fuel	0.050	0.050
N <sub>2</sub> O	kg/tonne fuel	0.080	0.080

Source: EMEP/CORINAIR, IPCC, DGEG.

The fuel consumption factors (expressed in tonne per day) are dependent from the ship type and from the gross tonnage. The equations used to derive fuel consumption factors were obtained from EMEP/CORINAIR.

Table 3-104 – Consumption factors

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

Legend:

gt – gross tonnage

<sup>(a)</sup> – a factor of 0.8 was applied to obtain consumption for cruise.

Source: (EEA/EMEP, 2005)



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#### 3.3.3.4.4 Activity Data

##### 3.3.3.4.4.1 *Ships movements in national sea ports*

The activity data from navigation is based on ship movement for individual ships in each national seaport comprehending nine ports in Portugal mainland and four in islands of Madeira and Azores.

The data provided by national seaports reports to the years 1990 and 1995; and to the period between 2000 and 2012. The number of movements and the distances travelled for the period 1991-1994 and 1996-1999 were estimated according with an interpolation established between years with available data.

For most cases, data on origin and destiny was also available per movement which allowed to estimate the distances travelled and to distinguish between domestic and international movements.

Table 3-105 – Ship docks

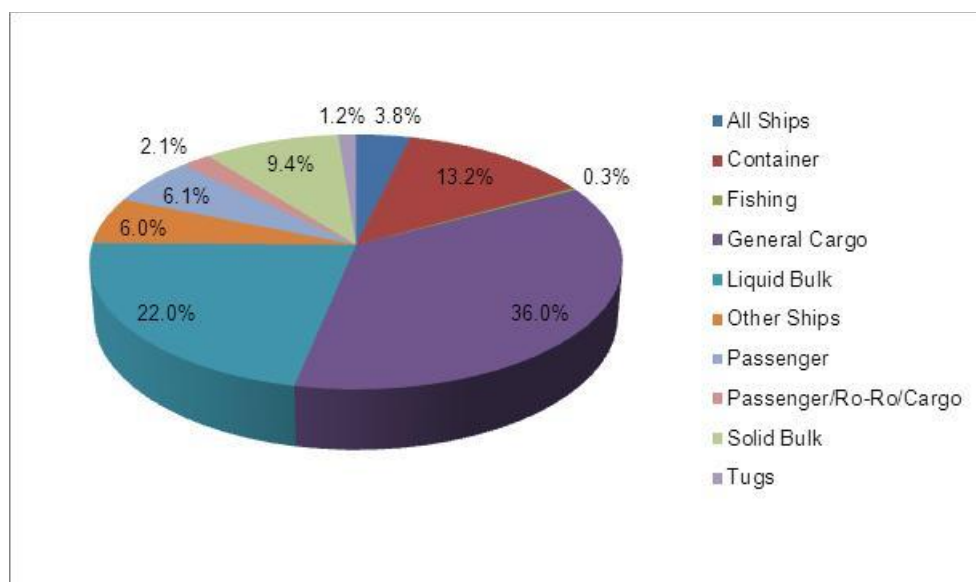
Sea Port	Location	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aveiro	Mainland	docks	876	920	965	1 009	1 054	1 098	1 080	1 062	1 045	1 027	1 009	1 042
Canical	Madeira	docks	76	76	76	76	76	76	76	76	76	76	76	76
Faro	Mainland	docks	163	163	163	163	163	163	163	163	163	163	163	89
Figueira da Foz	Mainland	docks	315	311	308	304	301	297	299	301	303	305	307	309
Funchal	Madeira	docks	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063	1 063
Leixões	Mainland	docks	2 742	2 773	2 804	2 834	2 865	2 896	2 927	2 958	2 988	3 019	3 050	3 113
Lisboa	Mainland	docks	5 586	5 586	5 586	5 586	5 554	4 993	5 332	4 927	4 776	4 323	3 869	3 597
Ponta Delgada	Azores	docks	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080	1 080
Portimão	Mainland	docks	34	34	34	34	34	34	34	34	34	28	37	24
Porto Santo	Madeira	docks	402	402	402	402	402	402	402	402	402	402	402	402
Setúbal	Mainland	docks	1 453	1 453	1 453	1 453	1 453	1 453	1 502	1 551	1 601	1 650	1 699	1 625
Sines	Mainland	docks	1 038	1 026	1 014	1 003	991	979	945	911	876	842	808	728
Viana do Castelo	Mainland	docks	254	315	310	228	247	293	304	315	326	337	348	369

Sea Port	Location	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aveiro	Mainland	docks	1 021	1 013	1 053	1 028	1 002	977	1 010	848	961	874	837
Canical	Madeira	docks	57	76	94	76	76	76	76	347	390	345	276
Faro	Mainland	docks	69	51	36	32	27	23	17	15	12	24	70
Figueira da Foz	Mainland	docks	260	262	292	271	271	271	406	359	476	477	471
Funchal	Madeira	docks	1 076	1 090	1 022	1 063	1 063	1 063	1 063	800	758	902	771
Leixões	Mainland	docks	3 090	2 952	2 815	2 814	2 814	2 813	2 727	2 637	2 612	2637	2 608
Lisboa	Mainland	docks	3 735	3 713	3 473	3 474	3 474	3 475	3 455	3 251	3 129	3063	2 652
Ponta Delgada	Azores	docks	1 047	1 125	1 067	1 080	1 080	1 080	1 112	1 095	1 035	1035	912
Portimão	Mainland	docks	28	33	56	42	29	15	42	97	136	122	56
Porto Santo	Madeira	docks	402	399	398	400	400	400	400	405	392	429	383
Setúbal	Mainland	docks	1 603	1 609	1 669	1 592	1 516	1 439	1 389	1 404	1 632	1609	2 604
Sines	Mainland	docks	806	753	927	1 124	1 321	1 518	1 518	1 458	1 632	1565	1 636
Viana do Castelo	Mainland	docks	315	262	208	214	220	226	246	179	179	218	248

#### 3.3.3.4.4.2 Ship Fleet

The fleet is composed mainly by general cargo ships. The fleet from the figure below refers to all ships that docked in national seaports irrespective of domestic or international movements.

Figure 3-69 – Ship fleet.



#### 3.3.3.4.4.3 Fuel consumption

Fuel consumption is estimated with a bottom-up approach using fuel consumption factors combined with a top-down calibration with the energy balance. In a first step, domestic and international consumption are estimated with the bottom up approach. Then the international consumption is re-calculated by subtracting the estimated domestic consumption from the total sales reported in the energy balance, this is considered the top down calibration. This calibration does not affect the domestic fuel consumption calculated with the bottom-up approach.

$$FuelConsumption_{International} = FuelSales - FuelConsumption_{Domestic}$$

Table 3-106 – Total fuel sales<sup>29</sup>

Fuel Sales	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
L ResO	t	407 823	406 206	403 591	334 853	305 775	290 920	306 451	311 196	320 960	416 843	475 743	331 358
L GasD	t	126 903	123 797	123 902	120 747	114 490	141 272	148 771	137 420	132 235	142 877	125 554	104 612

Fuel Sales	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
L ResO	t	366 423	444 170	529 904	457 115	516 191	552 950	590 249	547 252	506 320	597 752	664 621
L GasD	t	94 901	110 683	108 590	110 197	97 014	88 729	114 495	105 133	94 064	96 886	87 549

Source: DGEG

<sup>29</sup> L ResO – Residual fuel oil; L GasD - Diesel

Table 3-107 – Estimated fuel consumption (t)

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
L ResO	Domestic	61 244	60 348	59 288	58 035	57 009	53 023	55 409	57 417	58 675	52 793	46 988	45 396
L ResO	International	431 554	440 413	447 537	452 636	451 432	448 716	456 698	442 048	427 584	429 029	430 253	412 368
<b>L ResO</b>	<b>Total</b>	492 797	500 762	506 825	510 672	508 441	501 739	512 107	499 465	486 259	481 822	477 242	457 764
L GasD	Domestic	23 132	22 794	22 394	21 921	21 533	20 027	20 929	21 687	22 162	19 940	17 748	17 147
L GasD	International	163 002	166 349	169 039	170 965	170 510	169 485	172 499	166 966	161 503	162 049	162 511	155 756
<b>L GasD</b>	<b>Total</b>	186 135	189 143	191 433	192 886	192 043	189 512	193 428	188 653	183 665	181 989	180 259	172 902

Fuel	Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
L ResO	Domestic	47 600	47 939	48 931	48 804	48 828	48 852	49 836	52 816	53 458	47 488	53 052
L ResO	International	420 785	415 054	423 117	411 428	399 120	386 812	402 246	479 587	515 738	486 036	463 147
<b>L ResO</b>	<b>Total</b>	468 384	462 993	472 048	460 233	447 948	435 664	452 082	532 403	569 196	533 523	516 199
L GasD	Domestic	17 979	18 107	18 482	18 434	18 443	18 452	18 824	19 949	20 192	17 937	20 038
L GasD	International	158 935	156 770	159 816	155 401	150 752	146 103	151 932	181 145	194 799	183 581	174 935
<b>L GasD</b>	<b>Total</b>	176 914	174 877	178 297	173 835	169 195	164 555	170 756	201 094	214 991	201 517	194 974

Table 3-108 – Estimated fuel consumption after top-down calibration (t).

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
L ResO	Domestic	61 244	60 348	59 288	58 035	57 009	53 023	55 409	57 417	58 675	52 793	46 988	45 396
	International	346 579	345 858	344 303	276 817	248 766	237 897	251 042	253 780	262 285	364 051	428 754	285 962
	<b>Total</b>	407 823	406 206	403 591	334 853	305 775	290 920	306 451	311 196	320 960	416 843	475 743	331 358
L GasD	Domestic	23 132	22 794	22 394	21 921	21 533	20 027	20 929	21 687	22 162	19 940	17 748	17 147
	International	103 770	101 003	101 508	98 826	92 957	121 244	127 843	115 733	110 073	122 936	107 806	87 465
	<b>Total</b>	126 903	123 797	123 902	120 747	114 490	141 272	148 771	137 420	132 235	142 877	125 554	104 612

Fuel	Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
L ResO	Domestic	47 600	47 939	48 931	48 804	48 828	48 852	49 836	52 816	53 458	47 488	53 052
	International	318 823	396 231	480 974	408 311	467 363	504 098	540 413	494 436	452 862	550 264	611 569
	<b>Total</b>	366 423	444 170	529 904	457 115	516 191	552 950	590 249	547 252	506 320	597 752	664 621
L GasD	Domestic	17 979	18 107	18 482	18 434	18 443	18 452	18 824	19 949	20 192	17 937	20 038
	International	76 922	92 576	90 109	91 763	78 571	70 277	95 672	85 184	73 872	78 949	67 511
	<b>Total</b>	94 901	110 683	108 590	110 197	97 014	88 729	114 495	105 133	94 064	96 886	87 549

### 3.3.3.4.4.3.1 Tugs Fuel consumption

Data concerning tugs assistance operations within the national seaports allowed the incorporation of these emissions in the inventory. Tug fuel consumption was estimated for each manoeuvring ship in a seaport following the criteria shown in the Table 3-109. Specific tug fuel consumption factors were supplied by IPTM.

Table 3-109 – Criteria employed in the tugs fuel consumption estimation.

Ship Type	Seaport	Assisted Arrivals (%)	Assisted Departures (%)	N.º Of Tugs/Arrival	N.º Of Tugs/Departure
Small Size	All	20	0	1	0
Medium Size	All	50	25	1	1
Large Size	All	100	100	2	1
Super Large Size	Sines and Leixões	100	100	3	2
Super Large Size	All except Sines and Leixões	100	100	2	2

This estimation required the ship size classification expressed in table below.

Table 3-110 – Ship type classification for tugs fuel consumption estimation.

Ship Type	gt
Small Size	gt≤1000
Medium Size	10000≤gt<10000
Large Size	50000≤gt<100000
Super Large Size	gt>50000
gt: gross tonnage	

Finally the fuel consumption was added to the ship that needed the tugs service. The fuel tables presented above include fuel consumption in tugs operations.

### 3.3.3.4.5 Uncertainty Assessment

Activity level uncertainty refers to the fuel consumption uncertainty which depends on the number of movements, the distance travelled and fuel consumption factors. The global uncertainty is therefore obtained from:

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

Movement's uncertainty was assumed to be 5% as suggested in IPCC Good Practice Guidance and Uncertainty Management. The distance uncertainty was calculated assuming that ships speeds were constant between origin and destiny seaports. This allows the indirect assessment of the uncertainty trough the travelling time between seaports. For the same OD it is possible to estimate uncertainty

according with differences between travelling times performed by the same type of ships. Finally, it was assumed an uncertainty of 48% for fuel consumption factors proposed by EMEP/CORINAIR. Activity level uncertainty was estimated about 50% as referred in Table 3-111.

Table 3-111 – Navigation activity level uncertainty.

Source	Parameter	Value
All	Uglobal	50%
Movements	Umovements	5%
Distance Travelled	Udistance	15%
Fuel Consumption Factor	Ufc	48%

Following the recommendations of GPG the uncertainties of emission factor for CH<sub>4</sub> and N<sub>2</sub>O, and for all types of vessels and navigation, were set respectively to 100% and 1000%.

#### 3.3.3.4.6 Category-specific QA/QC and verification

Energy consumption was compared with data from the energy balance reported by DGEG. The difference in total fuel was around 0.3% in 2012 which could result from rounding values.

#### 3.3.3.4.7 Recalculations

No recalculations for this sector

#### 3.3.3.4.8 Further Improvements

No further improvements are planned for this sector.

### 3.3.3.5 Other Mobile Sources (CRF 1.A.3.e)

#### 3.3.3.5.1 Overview

There is not much information allowing the estimation of emissions from off-road vehicles and machines, mainly because they are not individualized in the energy balances from DGEG. The only exceptions is the agriculture/forestry sector, where it is more or less evident that all gas-oil is used as energy source to vehicles and mobile machines, and the fishing vessels.

Emissions from off-road vehicles and machines from other sectors: industry, residential and institutional, are however quantified and included in emission totals but under activity-specific emission estimates. The fact that they are different equipments with different emission factors is also considered in the inventory because when emission factors were established for all those activities some assumptions were made concerning where the fuel was used. For instance, it was assumed that all petrol/gasoline and half of the diesel-oil was used in engines, and these may be either static or mobile.

Since there is very little information to completely characterize 1 A 3 e Other Transportation the notation key “Included Elsewhere” was associated with this source category:

- off-road vehicles and machines from manufacturing industries, residential and commercial/institutional are included together with the other combustion equipment of these source categories;



- emissions from off-road vehicles and machines from agriculture/forestry and fishing sectors are included in 1 A 4 c Agriculture/Forestry/Fisheries.

All methodologic descriptions associated with each of these sources are presented in the appropriate chapter (1.A.2 and 1.A.4).

### 3.3.4 Other Sectors (CRF 1.A.4.)

#### 3.3.4.1 Overview

This source category refers to combustion in stationary and mobile sources (off-road) equipments that occur in commercial/institutional, residential, and agriculture/forestry/fishing activity sectors. The following stationary combustion equipments were included in this sector: boilers, co-generation equipment, machines and static engines are included in sector. Also included in 1.A.4 are emissions from fisheries bunkers and off road-road vehicles in agriculture/ forestry sector (both will have their own sub chapter in this report). As explained in 1.A.3.e due to constraints in DGEG's energy balance off-road vehicles and machines from commercial/institutional and residential sectors could not be individualized from stationary combustions.

#### 3.3.4.1.1 Commercial/Institutional (CRF1.A.4.a)

##### 3.3.4.1.1.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in commercial, services and institutional sector. In this sector small other mobile sources are considered because no separation between fuel consumption is possible in the energy balance.

##### 3.3.4.1.1.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance ( $\text{CO}_2$ ) or emission factors, according to the pollutant, and using an IPCC Tier 2 methodology.

For Carbon Dioxide ( $\text{CO}_2$ ), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{\text{CO}_2(s,f)} = EF_{\text{CO}_2(f)} * Fac_{\text{OX}(f)} * Energy_{\text{Cons}(s,f)} * 10^{-3}$$

$$Fossil_{\text{CO}_2(s,f)} = U_{\text{CO}_2(s,f,y)} * C_{\text{Fossil}(f)} * 10^{-2}$$

where,

$U_{\text{CO}_2(s,f)}$  - Emissions to atmosphere of total carbon dioxide emissions from fuel f in sub-sector s (ton);

$Fossil_{\text{CO}_2(s,f)}$  - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

$EF_{\text{CO}_2(f)}$  - Carbon content of fuel f expressed in total Carbon Dioxide emissions ( $\text{kg CO}_2/\text{GJ}$ );

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

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

$Energy_{\text{Cons}(u,f)}$  - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p)}$  - Total emissions of pollutant p for sub-sector s (ton/yr except CO<sub>2</sub> in kton/yr);

$EF_{(f,s,t,p)}$  - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO<sub>2</sub> in kg/GJ);

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

#### 3.3.4.1.1.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following table and figures.

Table 3-112 - Fuels consumed in the commercial, services and institutional sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	2 377 775	2 082 473	1 987 019	2 067 733	3 669 386	4 274 308	3 304 671	1 388 428	2 838 261	3 440 598	3 314 158	3 449 183
Diesel/Gas Oil	L	204	5 639 815	6 917 498	8 280 078	8 445 426	8 591 550	7 888 815	8 726 269	13 105 635	16 719 028	18 351 231	18 391 384	21 956 952
Kerosene	L	206	74 919	33 396	64 201	73 783	24 510	13 467	12 685	25 068	27 142	17 200	6 137	7 572
Motor Gasoline	L	208	579 621	638 690	617 687	605 093	1 036 563	1 174 935	1 419 347	2 593 860	3 262 569	3 219 051	2 217 473	2 854 812
LPG	L	303	1 198 048	1 373 765	1 580 371	1 897 820	1 870 938	1 268 113	2 562 028	3 836 555	4 010 705	4 233 884	4 414 101	5 206 806
City Gas	L	308	504 399	556 773	528 075	643 808	647 871	732 803	785 507	777 866	908 944	1 044 085	732 238	69 195
Natural Gas	G	301	0	0	0	0	0	0	0	15 786	563 881	1 593 080	2 579 983	4 042 999
Biogas	B	309	0	0	0	0	0	0	0	0	0	37 572	76 912	41 033
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	3 534 234	2 907 217	3 152 344	3 182 777	3 540 956	3 560 519	2 220 557	1 905 882	2 672 347	1 379 485	1 030 689
Diesel/Gas Oil	L	204	24 194 942	29 771 236	33 061 615	28 690 066	14 637 324	14 949 743	12 587 345	12 093 159	4 804 180	3 310 004	3 209 387
Kerosene	L	206	9 494	7 344	7 216	6 334	8 228	4 563	1 298	5 191	879	2 303	1 968
Motor Gasoline	L	208	2 486 947	2 364 277	2 426 561	1 637 165	1 025 939	797 979	28 471	27 801	37 473	2 177	42
LPG	L	303	5 113 787	5 287 262	5 413 453	4 806 060	4 349 043	4 487 167	5 143 317	4 804 021	2 146 848	1 931 774	1 921 851
City Gas	L	308	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	G	301	5 152 623	6 000 040	6 592 309	6 494 120	7 344 546	8 433 471	8 545 510	10 053 470	10 731 187	11 128 389	11 942 889
Biogas	B	309	45 650	36 551	76 039	102 253	97 016	81 522	130 750	135 839	157 677	166 930	146 480
Biodiesel	B	223	0	0	0	0	98 637	176 804	128 939	199 180	54 483	54 331	80 090

The Diesel/Gas Oil time series show a drop in consumption from 2005 to 2006. This fact results from reallocation, in the energy balance, of road gas oil from services not specified to agriculture (DGEG). There is a decrease in diesel oil consumption in 2010 for the services sector that results from the incorporation of data from the 2010 Survey on Energy Consumption in the Residential Sector. This decrease is coupled with an increase in diesel consumption in the residential sector.

Figure 3-70 – Total Energy Consumption in fuels in the commercial, services and institutional sector

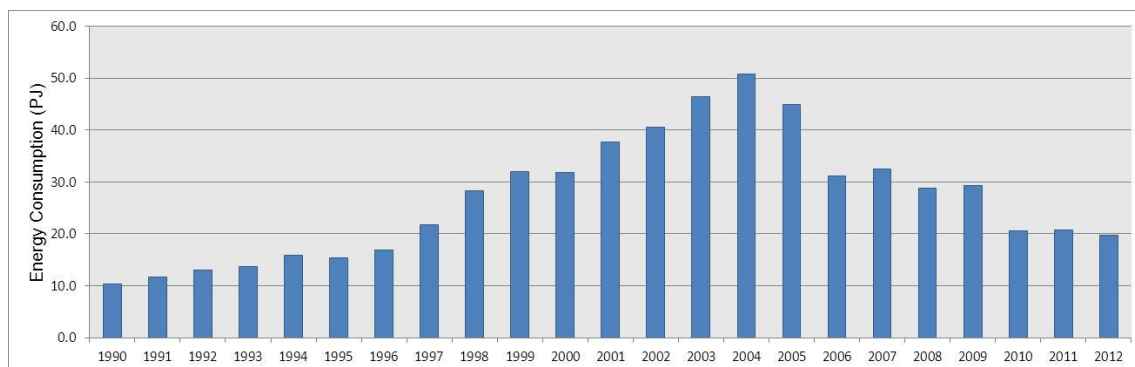
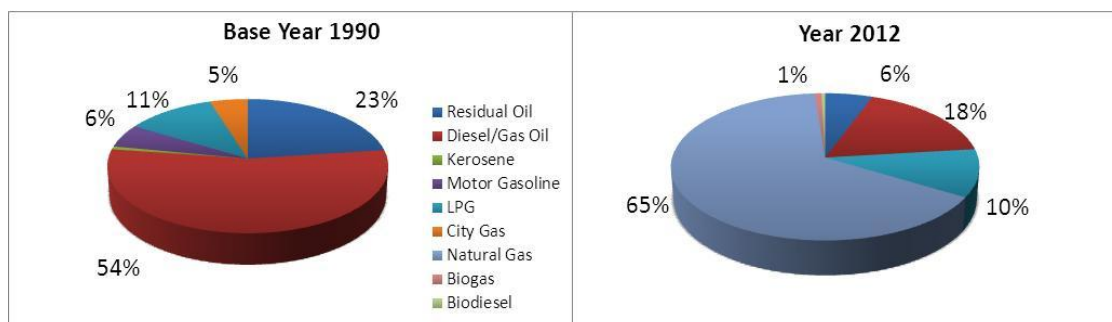


Figure 3-71 – Consumption of energy in fuels in the commercial, services and institutional sector in 1990 and 2012



#### 3.3.4.1.1.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3-113 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Commercial, services and institutional sector

Fuel		NAPFUE	LHV	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	1.6	0.6
Gas Oil	L	204	42.6	74.1	0.990	100	2.5	0.6
Diesel Oil	L	205	42.6	74.1	0.990	100	0.6	0.6
Kerosene	L	206	43.8	71.9	0.990	100	2.5	0.6
Motor Gasoline	L	208	44.0	73.7	0.990	100	2.5	0.6
LPG	L	303	46.0	63.1	0.995	100	1.5	1.4
City Gas	L	308	15.7	60.0	0.995	100	1.5	1.4
Natural Gas	G	301	46.1	56.1	0.995	100	1.2	1.4
Biogas	B	309	34.7	52.0	1.000	0	0.72	1.4
Biodiesel	B	223	37.0	74.1	1.000	0	2.5	0.6

#### 3.3.4.1.1.5 Uncertainty Assessment

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

The uncertainty of CO<sub>2</sub> 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 N<sub>2</sub>O were set respectively at 150 per cent and an order of magnitude.

#### 3.3.4.1.1.6 Category-specific QA/QC and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Only minor differences in natural gas consumption between data sources were identified for Commercial and Public Services sector (less than 10 per cent). For petroleum product the differences between data sources are greater than natural gas (around 30 per cent). DGEG reported that there were compilation errors in the information sent to IEA, which may explain the differences found.

#### 3.3.4.1.1.7 Recalculations

Recalculations for this source category comprise the revision of 2003, 2008, 2009, 2010 and 2011 energy balance data.

CH<sub>4</sub> emission factor revision based on COVNM EF from EMEP/EEA air pollutant emission inventory guidebook 2013.

#### 3.3.4.1.1.8 Further Improvements

No further improvements are planned for this sector.

### 3.3.4.1.2 Residential (CRF1.A.4.b)

#### 3.3.4.1.2.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in the residential sector. In this sector small other mobile sources are considered because no separation between fuel consumption is possible with DGEG's energy balance data.

#### 3.3.4.1.2.2 Methodology

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

For Carbon Dioxide (CO<sub>2</sub>), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

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

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

where,

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

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

$EF_{CO_2(f)}$  - Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

$Energy_{Cons(u,f)}$  - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p)}$  - Total emissions of pollutant p for sub-sector s (ton/yr except CO<sub>2</sub> in kton/yr);

$EF_{(f,s,t,p)}$  - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO<sub>2</sub> in kg/GJ);

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

#### 3.3.4.1.2.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following table and figures. Charcoal consumption was obtained from an inquiry made to the residential sector by DGEG.

Table 3-114 - Fuels consumption in the residential sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	63 570	62 136	55 570	51 491	66 733	42 592	43 339	40 296	10 922	3 883	2 596	0
Diesel/Gas Oil	L	204	158 313	210 952	285 685	205 156	190 401	201 062	132 690	91 954	106 045	144 312	90 483	82 460
Kerosene	L	206	793 847	753 503	626 435	530 823	514 054	356 029	416 128	728 737	761 963	705 693	365 545	194 522
Motor Gasoline	L	208	6 189	7 791	5 904	5 653	6 256	9 584	13 758	14 908	14 701	6 081	773	93
LPG	L	303	23 458 865	24 712 407	26 379 429	27 970 640	28 407 682	28 700 786	30 988 266	30 036 100	31 626 170	33 487 398	34 345 777	31 576 352
City Gas	L	308	1 923 876	1 950 110	1 984 435	2 073 096	1 984 456	1 929 958	1 977 160	1 991 632	2 106 088	2 039 388	1 212 913	156 763
Natural Gas	G	301	0	0	0	0	0	0	0	35 408	400 760	1 506 342	3 192 297	4 927 459
Wood	B	111	53 770 921	51 344 184	49 611 501	48 513 399	48 000 716	48 033 473	48 172 943	46 841 627	45 510 311	44 178 995	42 847 679	41 516 363
Charcoal	B	112	749 950	738 791	727 632	716 473	705 314	694 155	682 996	671 837	660 678	626 132	591 586	557 041
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	0	0	0	0	0	0	0	0	0	0	0
Diesel/Gas Oil	L	204	120 375	380 360	667 243	600 226	1 439 028	574 557	332 928	395 813	5 189 557	3 670 449	2 725 909
Kerosene	L	206	147 927	89 834	88 654	50 117	30 792	25 203	28 678	22 398	27 213	26 711	18 463
Motor Gasoline	L	208	24 864	36 183	37 371	57	79	0	0	0	0	0	0
LPG	L	303	31 565 739	30 542 812	30 029 737	29 312 438	27 074 925	25 417 104	22 777 808	21 795 551	23 214 739	20 873 374	19 522 514
City Gas	L	308	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	G	301	6 165 244	6 647 494	7 618 313	8 394 267	8 512 134	9 250 483	11 924 258	11 103 017	12 571 537	10 847 538	10 839 207
Wood	B	111	40 185 047	38 853 731	37 522 415	36 191 099	34 859 783	33 528 467	32 197 151	30 865 835	29 534 519	31 643 682	30 510 586
Charcoal	B	112	522 495	487 949	453 404	418 858	384 312	349 767	315 221	280 675	246 130	246 130	246 130
Biodiesel	B	223	0	0	0	0	1 566	2 794	1	42	28 620	729	3 128

There is an increase in diesel oil consumption in 2010 for the residential sector that results from the incorporation of data from the 2010 Survey on Energy Consumption in the Residential Sector. This increase is coupled with a decrease in diesel consumption in the services sector.

Figure 3-72 – Total Energy Consumption in fuels in the residential sector

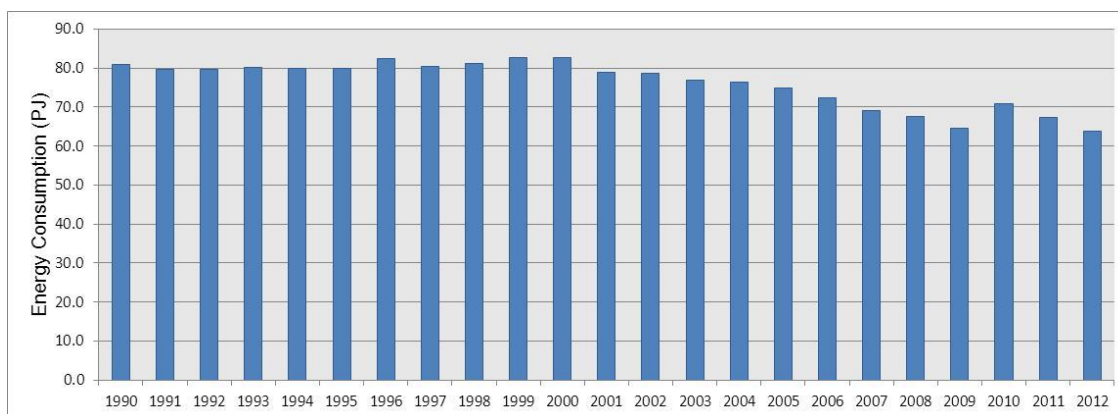
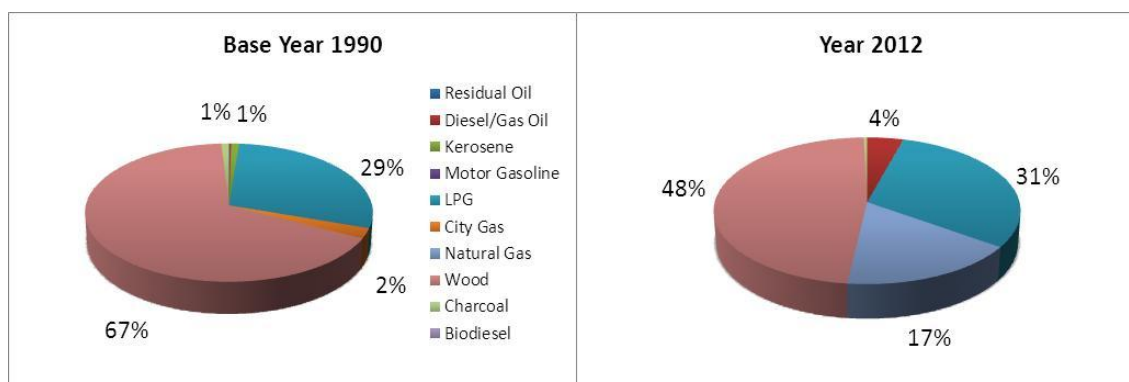


Figure 3-73 – Consumption of energy in fuels in the residential sector in 1990 and 2012





#### 3.3.4.1.2.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3-115– Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Residential sector

Fuel		NAPFUE	LHV	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.00	77.4	0.990	100	5.1	0.14
Diesel/Gas Oil	L	204	42.60	74.1	0.990	100	0.02	1.55
Kerosene	L	206	43.75	71.9	0.990	100	0.02	1.55
Motor Gasoline	L	208	44.00	73.7	0.990	100	0.1	0.6
LPG	L	303	46.00	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	46.07	56.1	0.995	100	2.5	1.4
Wood	B	111	12.55	109.6	1.000	0	300	4.3
Charcoal	B	112	25.10	109.6	1.000	0	300	4.3
Biodiesel	B	223	37.00	74.1	1.000	0	0.02	1.55

#### 3.3.4.1.2.5 Uncertainty Assessment

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

The uncertainty of CO<sub>2</sub> 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 N<sub>2</sub>O were set respectively at 150 per cent and an order of magnitude.

#### 3.3.4.1.2.6 Category-specific QA/QA and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). There is a general agreement between data source for this source category.

#### 3.3.4.1.2.7 Recalculations

Recalculations in this source category results from the revision of the 2003, 2008 and 2011 energy balance data.

### 3.3.4.1.2.8 Further Improvements

No further improvements are planned for this sector.

### 3.3.4.1.3 Agriculture / Forestry / Fishing – Stationary (CRF1.A.4.c.i)

#### 3.3.4.1.3.1 Overview

Emission considered in this source category cover stationary combustion in the agriculture and forestry sectors. Stationary combustion in the fishing industry was included together with fishing bunker in 1.A.4.c.iii.

#### 3.3.4.1.3.2 Methodology

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

For Carbon Dioxide (CO<sub>2</sub>), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

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

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

where,

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

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

$EF_{CO_2(f)}$  – Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

$Energy_{Cons(u,f)}$  - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p)}$  - Total emissions of pollutant p for sub-sector s (ton/yr except CO<sub>2</sub> in kton/yr);

$EF_{(f,s,t,p)}$  - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO<sub>2</sub> in kg/GJ);

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

### 3.3.4.1.3.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following table and figures.

Table 3-116 - Fuels consumed in agriculture and forestry sector (GJ) (excluding mobile sources)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	524 617	376 193	286 335	343 681	488 068	426 845	511 483	547 071	474 723	677 941	889 643	799 840
Kerosene	L	206	350 338	311 043	272 158	207 862	200 980	191 157	183 421	427 000	494 010	24 166	44 397	47 082
Motor Gasoline	L	208	33 650	35 681	47 407	44 936	134 763	129 648	162 646	197 586	174 417	159 737	42 723	119 538
LPG	L	303	329 856	405 427	478 962	575 900	580 807	572 444	826 953	560 179	713 861	674 638	496 882	673 259
Natural Gas	G	301	0	0	0	0	0	0	0	0	36	174	4 897	213 356
Biogas	B	309	0	0	0	0	0	0	0	0	0	0	9 294	7 773

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	1 207 470	1 083 548	768 101	880 752	620 646	311 135	292 210	138 346	244 196	253 210	262 879
Kerosene	L	206	50 284	47 237	48 915	54 581	56 434	32 446	38 935	45 173	39 019	29 725	33 660
Motor Gasoline	L	208	106 820	116 977	117 435	208 555	153 501	100 611	36 091	32 407	24 033	13 147	18 590
LPG	L	303	639 651	532 506	523 451	541 228	493 957	449 407	362 700	296 549	308 858	271 637	267 451
Natural Gas	G	301	284 851	292 066	295 599	325 872	319 153	360 944	305 260	370 699	423 872	483 617	516 693
Biogas	B	309	5 939	6 344	11 122	29 039	26 931	20 251	13 766	19 833	23 013	24 686	18 787

Figure 3-74 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources)

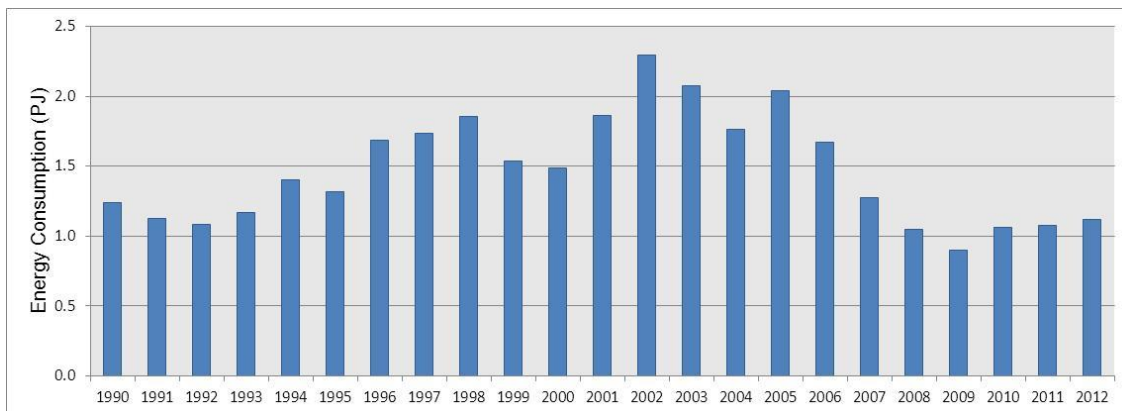
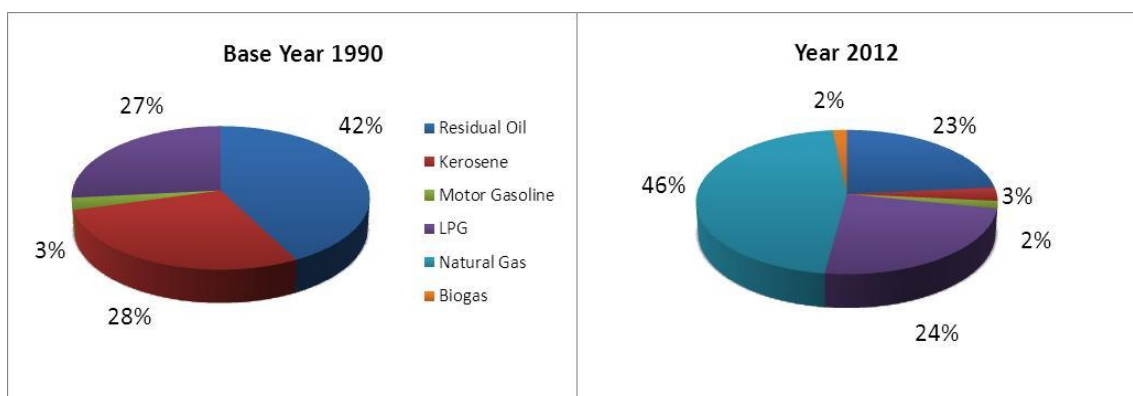


Figure 3-75 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2012



#### 3.3.4.1.3.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3-117 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Commercial, services and institutional sector - Agriculture / Forestry / Fishing – Stationary sector

Fuel		NAPFUE	LHV	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	1.6	0.6
Kerosene	L	206	43.8	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.0	73.7	0.990	100	9.9	0.6
LPG	L	303	46.0	63.1	0.995	100	1.5	1.4
Natural Gas	G	301	46.1	56.1	0.995	100	1.2	1.4
Biogas	B	309	34.7	52.0	1.000	0	0.72	1.4

#### 3.3.4.1.3.5 Uncertainty Assessment

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

The uncertainty of CO<sub>2</sub> 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 N<sub>2</sub>O were set respectively at 150 per cent and an order of magnitude.

#### 3.3.4.1.3.6 Category-specific QA/QA and Verification

Following the same procedure as in other 1.A.4 source categories where energy balance was used as the main data source, a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Only minor differences between data sources were identified for this source category.

#### 3.3.4.1.3.7 Recalculations

Recalculations in this source category results from the revision of the 2003, 2008, 2009 and 2011 energy balance data.

#### 3.3.4.1.3.8 Further Improvements

No further improvements are planned for this sector.

#### 3.3.4.1.4 Agriculture / Forestry / Fishing – Off-road Vehicles and Other Machinery (CRF1.A.4.c.ii)

##### 3.3.4.1.4.1 Overview

Due to typical operation in vast land areas, agriculture and forestry activities are heavily dependent on machines and off-road vehicles: tractors from 5 kW up to 250 kW, harvesters, sprayers, mowers, tillers, chain saws, haulers, shredders and log loaders among others.

Only gas-oil is assumed to be an energy source for mobile equipments in this activity. Consumption of biodiesel with gas oil was assumed in the energy balance data, in accordance with the explained in 1A2 methodology chapter.

##### 3.3.4.1.4.2 Methodology

Emissions to atmosphere of ultimate CO<sub>2</sub> from fossil origin were estimated from CO<sub>2</sub> total emissions by:

$$\text{Fossil}_{\text{CO}_2(y)} = \sum_f [\text{EF}_{\text{CO}_2} * \text{Fac}_{\text{OX}} * \text{Cons}_{\text{Fuel}(y)} * \text{LHV}] * 10^{-5}$$

where

Fossil<sub>CO<sub>2</sub>(y)</sub> - Emissions of carbon dioxide to atmosphere from combustion of diesel oil in agriculture off road vehicles and machinery (ton);

EF<sub>CO<sub>2</sub></sub> – Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

Fac<sub>OX</sub> – Oxidation factor for diesel oil (ratio 0-1);

Cons<sub>Fuel(f,y)</sub> - Consumption of diesel oil in year y (ton/yr);

LHV<sub>(f)</sub> - Low Heating Value (MJ/kg).

Emissions for other pollutants are estimated with the following formula:

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

where

Emission<sub>(p,y)</sub> - Emission of pollutant p in year y (ton/yr);

EF<sub>(p)</sub> - Emission factor for pollutant p (kg/ton);

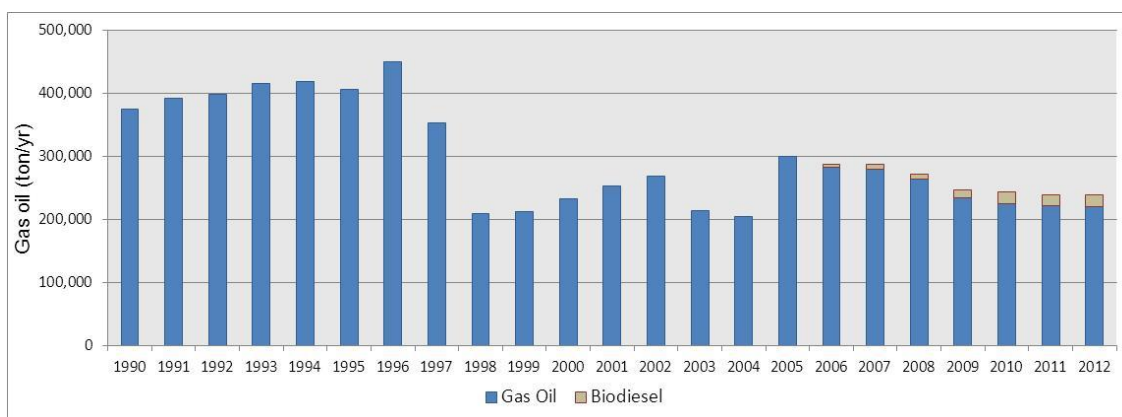
Cons<sub>Fuel(y)</sub> - consumption of gas oil in agriculture machines and off-road vehicles during in year y (ton/yr).

##### 3.3.4.1.4.3 Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to the latest inventory year from DGEG in the energy balance. Although there is no clear specification, in the original database, in which combustion equipment each fuel is used it was assumed that all gas-oil is used in machines and other off-road vehicles. The same suppositions were made for biodiesel since

both are used together. Quantities that were consumed are presented in figure below. The increase in gas oil from 2007 to 2008 results from a fuel reclassification in the energy balance.

Figure 3-76 - Consumption of gas-oil in machines and other off-road vehicles



#### 3.3.4.1.4.4 Emission Factors

The set of emission factors utilized to estimate air emissions from use of gas oil in agriculture machines and other off-road vehicles were determined as the average value of the values proposed in tables I-47 and I-49 of the Revised 1996 IPCC Guidelines (IPCC,1997). In general for biodiesel EF were considered the same as for gas oil, with the exceptions shown in the following table.

Table 3-118 – Emission factors for gas oil use in agriculture machines and other off-road vehicles

Parameter	EF		Unit
	Gas oil	Biodiesel	
LHV	42.6	37.0	MJ/kg
SOx	0.3	0	%
NOx	56.9	56.9	g/kg
NMVOC	8.4	8.4	
CH4	0.3	0.3	
CO	20.7	20.7	
CO2	73.3	74.1	kg/GJ
%CO2 Fossil	100	0.0	%
FaCOx	0.990	1	0..1
N2O	1.3	1.3	g/kg

#### 3.3.4.1.4.5 Uncertainty Assessment

The time trend of diesel oil consumption in this activity shows significant annual variations. 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, 94 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 CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O.

#### 3.3.4.1.4.6 Category-specific QA/QA and Verification

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

#### 3.3.4.1.4.7 Recalculations

No recalculations for this sector.

#### 3.3.4.1.4.8 Further Improvements

No further improvements are planned for this sector.

### 3.3.4.1.5 Agriculture / Forestry / Fishing – Fishing (CRF1.A.4.c.iii)

#### 3.3.4.1.5.1 Overview

Emission in this source category include both stationary and other mobile source (fisheries bunkers). Stationary equipment included those associated with fishing industry, aquaculture or sea ports that are realized inland and not in water vessels. Fishing bunker represent emission from local costal fishing, deep-see fishing and cod-fish fishing vessels.

In the inventory process it was assumed that marine diesel engines are the main power source for ships either for transport or shipping activities. Small local fishing and sport ships do in fact use petrol-engines but they represent a small proportion of total consumption and for most situations their fuel consumption cannot be individualised from road traffic consumption. Again consumption of biodiesel was determined as a part of the gas oil since 2006.

#### 3.3.4.1.5.2 Methodology

##### 3.3.4.1.5.2.1 Stationary Equipment

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

For Carbon Dioxide (CO<sub>2</sub>), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

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

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

where,

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

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

$EF_{CO_2(f)}$  – Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

$Energy_{Cons(u,f)}$  - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).



Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p)}$  - Total emissions of pollutant p for sub-sector s (ton/yr except CO<sub>2</sub> in kton/yr);

$EF_{(f,s,t,p)}$  - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO<sub>2</sub> in kg/GJ);

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

#### 3.3.4.1.5.2.2 Fishing Bunker

Emissions for all pollutants other than CO<sub>2</sub> are estimated for each ship type using the following formula:

$$Emission_{(n,p,y)} = \sum_f [EF_{(n,f,p)} * Cons_{Fuel(n,f,y)}] * 10^{-3}$$

where

$Emission_{(n,p,y)}$  - Total emission of pollutant p in year y from ships of class n (ton/yr);

$EF_{(n,f,p)}$  - Quantity of pollutant p emitted, variable with fuel type f and ship class n (kg/ton);

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

Emissions of carbon dioxide are estimated from:

$$Fossil_{CO2(n,y)} = \sum_f [EF_{CO2(f)} * Fac_{OX(f)} * C_{Fossil(f)} * Cons_{Fuel(n,f,y)} * LHV_{(f)}] * 10^{-5}$$

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 CO<sub>2</sub>/GJ);

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

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

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

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

#### 3.3.4.1.5.3 Activity Data

Data on fuel consumption in the fishing sector was obtained from DGEG's energy balance. Since there is no distinction between fishing vessels and static equipment in this data source (situation similar to

that found in other 1.A.4 and 1.A.2 source categories), new data was obtained concerning bunker fuel sales (source: DGEG). With this new data a separation between fuel consumption in mobile and non-mobile equipment was possible. The resulting fuel consumption for static equipment can be found in the following table and figures.

Table 3-119 - Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Oil	L	203	4 004	5 415	7 458	9 303	7 681	12 145	5 132	8 888	6 383	49 680	6 483	18 055
Diesel/Gas Oil	L	204	99 086	95 355	84 795	74 186	77 645	84 915	64 556	209 384	597 882	0	1 081 354	2 179 005
Kerosene	L	206	7	0	7	7	0	0	0	0	2 652	74 960	10 079	94
Motor Gasoline	L	208	1 406	0	214	85	278	707	985	728	4 040	61 587	279 165	286 314
LPG	L	303	2 847	5 792	4 077	1 499	2 148	0	110	3 902	2 531	8 434	20 809	32 648
Natural Gas	G	301	0	0	0	0	0	0	0	0	0	0	0	0
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residual Oil	L	203	28 129	25 341	0	0	13 012	0	48 147	0	91 830	47 735	84 842
Diesel/Gas Oil	L	204	1 097 824	596 445	568 387	587 681	692 877	445 143	519 129	0	636 659	907 993	858 013
Kerosene	L	206	47	47	320	15	0	0	0	0	0	0	0
Motor Gasoline	L	208	280 882	278 706	260 910	29 919	31 819	26 126	5 569	30 062	21 060	18 255	4 145
LPG	L	303	21 140	20 708	91 294	5 903	5 967	2 303	5 778	3 014	1 675	461	209
Natural Gas	G	301	0	0	0	0	1 363	2 261	2 010	3 098	4 396	4 145	2 219
Biodiesel	B	223	0	0	0	0	48 124	73 390	70 525	117 356	208 389	224 117	233 296

Figure 3-77 – Total Energy Consumption in fuels in fisheries (excluding consumption in fishing vessels)

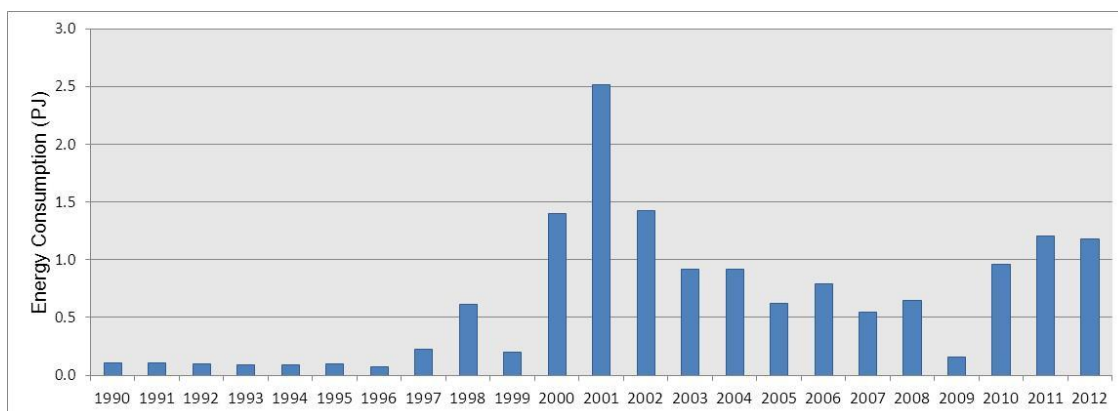
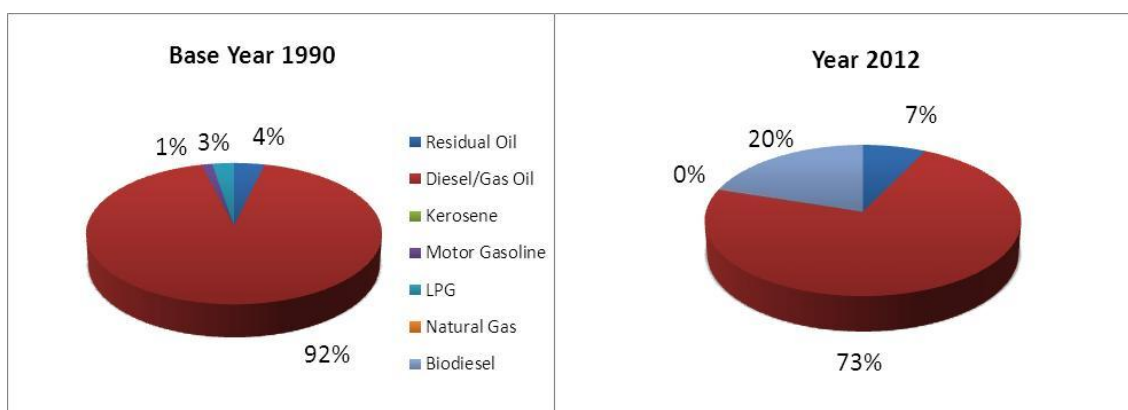


Figure 3-78 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2012



Total fuel consumption in fishing bunkers can be seen in the following table and figure.

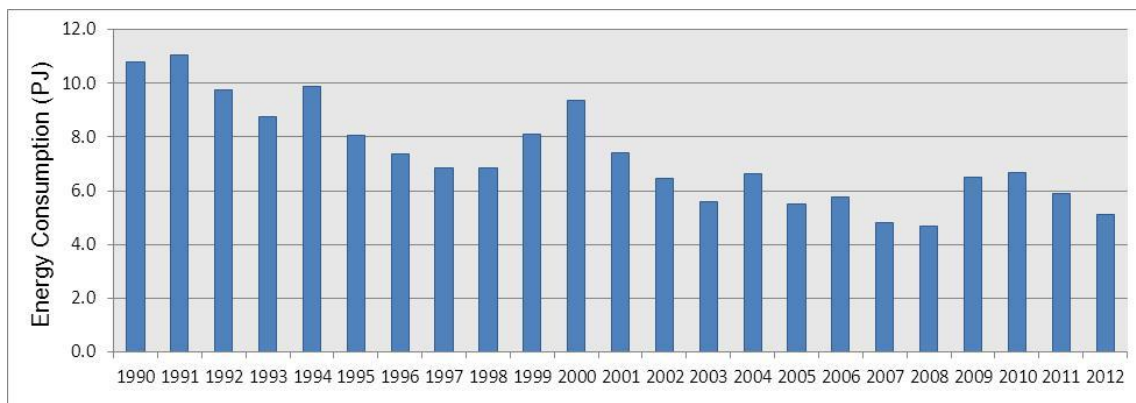
Table 3-120 - Fuels consumed in fishing bunkers (GJ)<sup>30</sup>

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Thin Fuel-oil	L	203	0	6 000	0	81 600	552 240	53 520	32 000	19 520	21 760	12 880	4 000	0
Thick Fuel-oil	L	203	0	0	0	0	413 200	96 000	24 000	22 400	42 240	21 120	0	0
Diesel/Gas Oil	L	204	10 783 849	11 035 700	9 752 418	8 671 656	8 912 346	7 898 551	7 321 406	6 789 503	6 794 700	8 072 743	9 350 785	7 398 427
NATO's Nafta	L	203	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Thin Fuel-oil	L	203	0	0	0	0	0	0	0	0	0	22 014	18 018-
Thick Fuel-oil	L	203	0	0	0	0	0	0	0	714 669	765 555	717 098	9 158
Diesel/Gas Oil	L	204	6 446 147	5 591 932	6 630 905	5 496 620	5 749 321	4 798 240	4 694 265	5 765 758	5 916 129	5 142 046	5 082 892
NATO's Nafta	L	203	0	0	0	0	0	0	0	0	0	0	0

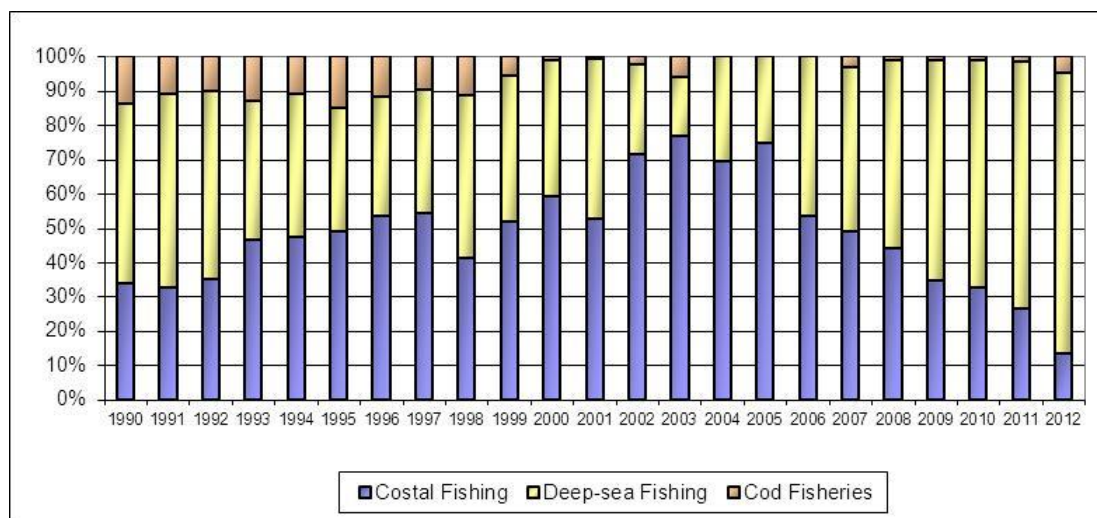
<sup>30</sup> The same situation that was described for transport navigation is true here. It was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha, gas-oil and diesel oil, but available emission factors again do not distinguish these fuel types

Figure 3-79 – Consumption of fuel oil in fishing bunkers



Additional information in DGE annual reports, allows for the division of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels<sup>31</sup>. Percentage for each type of fisheries is presented in next figure.

Figure 3-80 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries



#### 3.3.4.1.5.4 Emission Factors

##### 3.3.4.1.5.4.1 Stationary Equipment

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);

<sup>31</sup> 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.

- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3-121 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Fisheries – stationary equipment sector

Fuel		NAPFUE	LHV	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	0.990	100	1.6	0.6
Gas Oil	L	204	42.6	74.1	0.990	100	5.0	0.6
Diesel Oil	L	205	42.6	74.1	0.990	100	0.6	0.6
Kerosene	L	206	43.8	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.0	73.7	0.990	100	9.9	0.6
LPG	L	303	46.0	63.1	0.995	100	1.5	1.4
Natural Gas	G	301	46.0	56.1	0.995	100	1.2	1.4
Biodiesel	B	223	37.0	74.1	1.000	0	5.0	0.6

#### 3.3.4.1.5.4.2 Fishing Bunker

Except for carbon dioxide and sulphur oxide, emissions were estimated using default emission factors (kg/ton) from IPCC 1996 Revised Guidelines (table I-47 in IPCC,1997) for most pollutants. The following criteria were used to choose the most suitable emission factors:

- “Ocean-going ships” for national and international transport navigation, deep-sea fishing and cod fishing;
- “Boat” in the case of coastal fishing vessels.

For carbon dioxide emission factors are in kg/GJ in a similar mode to other combustion activities. Sulphur oxide emissions are dependent on sulphur content of fuel. Emission factors are presented in next table.

Table 3-122 – Emission factors for Water Borne Navigation and Fishing Vessels

EF	Units	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries
		Gas-oil		Biodiesel		Fuel-oil	
LHV	MJ/kg	42.6		37.0		40.0	
SO <sub>x</sub>	%	0.3		0.0		3	
NO <sub>x</sub>	g/kg	67.5	87	67.5	87	67.5	87
NMVOC	g/kg	4.9					
CH <sub>4</sub>	g/kg	0.23					
CO	g/kg	21.3	1.9	21.3	1.9	21.3	1.9
EF <sub>CO2</sub>	kg/GJ	74.07		74.05		77.37	
C <sub>Fossil</sub>	%	100		0.0		100	
Fa <sub>COX</sub>	0..1	0.99		1.0		0.99	
N <sub>2</sub> O	g/kg	0.08					

#### **3.3.4.1.5.5 Uncertainty Assessment**

##### **3.3.4.1.5.5.1 Stationary Equipment**

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

The uncertainty of CO<sub>2</sub> 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 N<sub>2</sub>O were set respectively at 150 per cent and an order of magnitude.

##### **3.3.4.1.5.5.2 Fishing Bunkers**

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

Following the recommendations of GPG the uncertainties of emission factors for CH<sub>4</sub> and N<sub>2</sub>O, and for all types of vessels and navigation, were set respectively to 100 per cent and 1000 per cent.

#### **3.3.4.1.5.6 Category-specific QA/QA and Verification**

For this sector the comparison between DGED and IEA fuel consumption values was also made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). There are major differences between the two data sources for this source category. No precise justification for this difference was found, apart from the reported compilation errors made by DGEG in the information sent to IEA.

##### **3.3.4.1.5.7 Recalculations**

No major recalculations were made to this sector.

##### **3.3.4.1.5.8 Further Improvements**

No further improvements are planned for this sector.

### **3.3.5 Other (Not Else-where specified) (CRF 1.A.5.)**

#### **3.3.6 Mobile (CRF 1.A.5.b)**

##### **3.3.6.1.1 Military Use**

Emissions from military reported under category 1 A 5 b include only military aviation.

The energy balance does not provide a specific fuel consumption classification for military operations. Fuel consumed in military operations is reported under category “Serviços”. Therefore emissions from military operations, except military aviation, are reported under category NFR 1 A 4 Small Combustion. For military aviation it was assumed that all jet fuel reported under category “Serviços” was used for military aviation since jet fuel could be considered as an aviation specific fuel.



According with the IPCC Good Practice Guidelines, all the jet fuel for military operations was considered to be domestic since there is no information available regarding origins and destinies of the military aircraft movements that could be used to distinct domestic from international consumption.

The following table shows the amount of jet fuel used for military operations provided by the national energy balance under the *Serviços* classification. All fuels under *Serviços* were already considered in the inventory besides jet fuel. Energy was estimated using a country specific LHV of 43.00 MJ/kg reported by the national energy authority.

Table 3-123 – Activity data.

Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Energy	TJ	1 344	1 504	1 127	1 065	1 188	1 149	1 471	1 413	1 474	1 127	1 338	1 338

Parameter	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Energy	TJ	939	749	570	1 025	1 064	1 026	1 200	1 205	1 208	1 086	683

The emission factors used to estimate emissions are IPCC default emission factors. CO<sub>2</sub> emission factor was obtained from:

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

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

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

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

Table 3-124 – Emission factors.

Parameter	EF	EF Unit
CO <sub>2</sub>	70.79	tCO <sub>2</sub> /TJ
CH <sub>4</sub>	0.5	kg/TJ
N <sub>2</sub> O	2	kg/TJ

#### 3.3.6.1.1.1 Uncertainty Assessment

The uncertainty of fuel consumption was set equal to the uncertainty that was considered for road traffic: 5 per cent.

In a similar way, the uncertainties for emission factors used were the same as for road transportation: methane and nitrous oxide emission factors were set at 40 per cent and 50 per cent respectively. The general error of 5 per cent was used for the calculation of uncertainties of carbon dioxide emissions.

#### 3.3.6.1.1.2 Recalculations

No recalculations were made for this subsector.

### 3.3.6.1.1.3 Further Improvements

No further improvements are planned for this sector.

## 3.3.7 Fugitive Emissions from Fossil Fuels (CRF 1.B.)

### 3.3.7.1 Fugitive Emissions from Solid Fuels (CRF 1.B.1.)

#### 3.3.7.1.1 Coal Mining and Handling

##### 3.3.7.1.1.1 Overview

Coal contains some proportion of methane trapped in its structure that it is usually emitted to atmosphere during and after extraction of coal from mines to open air. Emissions at extraction result from ventilation of mine gas which is done for safety reasons at underground mines. 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 - *Peirão* and *S. Pedro da Cova* - are located in northern region of Portugal. Coal from these mines is classified as lignite, it has a low energy value and it was used mainly as fuel for one public power energy plant near Oporto (*Tapada do Outeiro* power plant). Moreover the coal production during the exploration period was of small importance (less than 300 kt in 1990, see figure below). Both mines (*Peirão* and *S. Pedro da Cova*) are of the underground 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.

Emissions from fuel combustion for coal extraction are included under category 1.A.1.c.1.

##### 3.3.7.1.1.2 Methodology

Emission estimates include emissions occurring during extraction of coal, emissions resulting from processing and emissions from abandoned underground mines.

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) and is used to estimate emissions related to extraction and pos-extraction activities:

$$Emi_{CH_4} = [(EF_U^{ex} + EF_U^{post}) * Coal_U] * 0.67 * 10^{-3}$$

where

$Emi_{CH_4}$  - Methane emissions in year y (ton);

$Coal_U$  - quantity of coal extracted from underground mines (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 ( $m^3/ton$ );

0.67 is the conversion factor, the density of methane at 20°C and at atmospheric pressure ( $kg/m^3$ ).

To estimate  $CH_4$  emissions related to abandoned underground mines, it is used the Tier 1 approach proposed in equation 4.1.10 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories:

$$Emi_{CH_4} = Number_{ACM} * f_{GCM} * EF * 0.67 * 10^{-3}$$

where

$Emi_{CH_4}$  - Methane emissions in year y (ton);

$Number_{ACM}$  – Number of abandoned coal mines remaining unflooded in year y (number);

$f_{GCM}$  – Fraction of gassy Coal Mines (adimensional);

$EF_{CH_4}$  –  $CH_4$  emission factor for abandoned underground mines ( $10^6 m^3 CH_4/mine$ );

0.67 is the conversion factor, the density of methane at 20°C and at atmospheric pressure ( $kg/m^3$ ).

$$Emi_{NMVOC} = EF_{NMVOC} * Coal_U * 10^{-3}$$

where

$Emi_{NMVOC}$  - NMVOC emissions in year y (ton);

$EF_{NMVOC}$  - NMVOC emission factor (kg/ton of coal);

$Coal_U$  - Coal extracted from underground mines (ton).

Ultimate carbon dioxide emissions, also in ton/yr, are calculated from the carbon emitted as methane:

$$Emi_{CO_2} = 44 / 12 * Emi_{CH_4} * 12/16$$

where

$Emi_{CO_2}$  - Ultimate carbon dioxide emissions (ton);

$Emi_{NMVOC}$  - NMVOC emissions in year y (ton);

$Emi_{CH_4}$  -  $CH_4$  emissions in year y (ton).

### 3.3.7.1.1.3 Emission Factors

Although it is known that high rank coals contain usually more methane than lower rank coals such as lignite, average emission factors from IPCC96 (IPCC, 1997) defaults were used for both mines, which are presented in next table. The same emission factor range was maintained in GPG (IPCC, 2002).

Table 3-125– Emission Factors for coal extraction and processing

Parameter	Type of Emission	Emission Factor	Value (kg/ton)	Source
$CH_4$	Extraction	$EF_U^{ex}$	11.73	Revised 1996 IPCC Guidelines
	Post-mining	$EF_U^{post}$	1.64	Revised 1996 IPCC Guidelines
NMVOC	-	-	0.8	EMEP/EEA emission inventory guidebook 2013

The fraction of gassy coal mines was estimated assuming the average value of 8% (Low) and 100% (High) for underground mines abandoned in the period 1976-2010 (Table 4.1.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

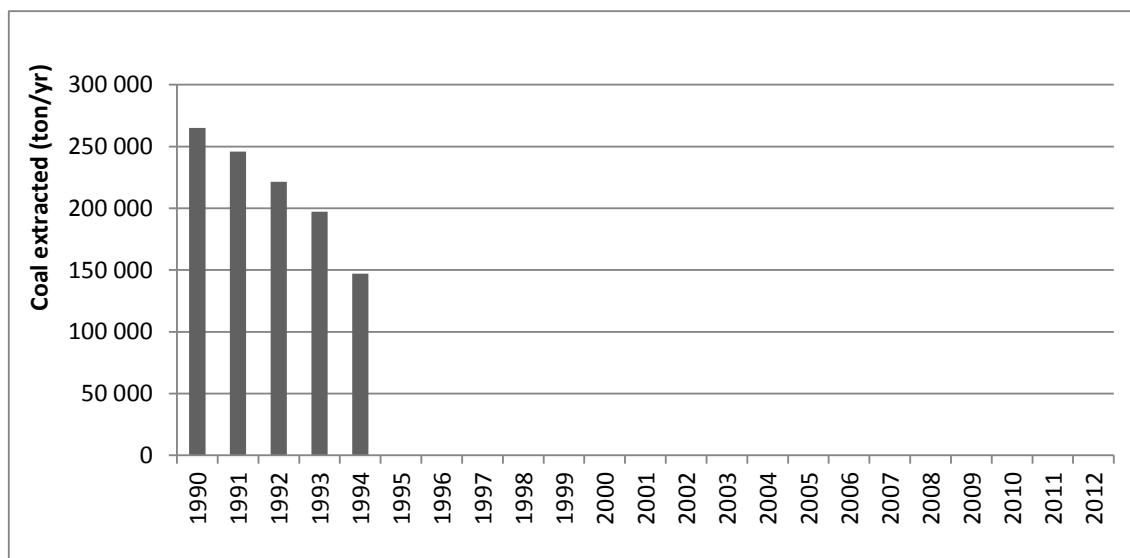
Table 3-126– Emission Factors for abandoned underground mines

Parameter	Unit	Value	Source
Fraction of gassy coal mines	%	54 (8-100)	2006 IPCC Guidelines
$CH_4$ Emission factor	$10^6 m^3 CH_4/mine$	0.507-1.561	2006 IPCC Guidelines

#### 3.3.7.1.1.4 Activity data

The quantity of extracted coal has decreased towards the final closure of both mines in 1994, as may be seen in next figure. Statistical information is from Geological Resources reports from DGEG.

Figure 3-81 – Quantities of coal extracted from mines in Portugal



From 1993-1994, it was considered one abandoned underground mine. From 1995 onwards it were considered two abandoned underground mines.

#### 3.3.7.1.1.5 Uncertainty Assessment

A value of 5 percent was considered for the uncertainty of coal production (activity data) which is a conservative factor according to the proposed values by IPCC (2000). Also in accordance with table 2.14 of the GPG, the uncertainty values for methane emission factors were set at 100 percent for underground mines. The uncertainties in CO<sub>2</sub> emission factors were set equal to uncertainties of CH<sub>4</sub> emission factors, considering that CO<sub>2</sub> emissions are simply atmospheric conversion of methane emissions.

#### 3.3.7.1.1.6 Recalculations

Coal production data has been revised based on statistical data from Geological Resources reports from DGEG. Previously it was wrongly assumed that one of the mines was an underground mine and the other was an open cast mine. From revised data obtained from DGEG experts, both mines are now considered underground mines.

We start estimating emissions from abandoned mines.

#### 3.3.7.1.1.7 Further Improvement

No further improvements are planned for this sector.

### 3.3.7.2 *Fugitive Emissions from Oil Production and Refining (CRF 1.B.2.a.)*

#### 3.3.7.2.1 Overview

Extraction and production of crude oil did never occur in the Portuguese territory. Therefore, fugitive emissions comprehend only those resulting from refining, storage and transport of crude oil, other raw materials, intermediate products and final products - particularly gasoline - from terminal receiving of crude oil and other petroleum products till delivering to final consumer. According to available methodologies air emissions considered include:

- Marine Terminals and Ballast water;
- Emissions from refinery operations not including emissions from combustion of fuels, such as: Flaring and venting in oil refining and; Emissions due to storage of raw materials, intermediate products and final products in the refinery;
- Emissions from refinery dispatch station;
- Emissions from the transport and distribution of petroleum products in the Portuguese Territory, including transport depots and service stations.

#### 3.3.7.2.2 Fugitive emissions from oil exploration (1.B.2.a.i)

There is no oil exploration in Portugal.

#### 3.3.7.2.3 Fugitive emissions from the production of crude oil (1.B.2.a.ii)

There is no crude oil production in Portugal.

#### 3.3.7.2.4 Transport of Crude/ Marine Terminals (1.B.2.a.iii)

##### 3.3.7.2.4.1 Overview

Emissions from this source consist mainly of volatile organic compounds, including methane, that escape to atmosphere during transport of crude oil to refineries for processing. The three oil refineries considered in the inventory where all located at a small distance from the sea coast. Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

##### 3.3.7.2.4.2 Methodology

Emissions of CH<sub>4</sub> and NMVOC where estimated from:

$$\text{Emission} = \text{Source}_{\text{InFlow}} * \text{EF} * 10^{-9}$$

where

Emission - CH<sub>4</sub> or NMVOC emissions (ton/y);

Source<sub>InFlow</sub> - is total crude oil, gasoline, naphtha, residual oil or distillate oil received at each marine terminal (L/y);

EF - emission factor for CH<sub>4</sub> or NMVOC (mg/ton crude oil).

Emissions of VOC will ultimately be oxidized in atmosphere and contribute to ultimate carbon dioxide, which estimates are also included in the inventory. Emissions of ultimate carbon dioxide result from conversion of carbon in NMVOC and CH<sub>4</sub>:

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

### 3.3.7.2.4.3 Emission Factors

Table 3-127– Total Organic Emission Factors for Marine Vessel Loading Operations

Loading Operations	Gasoline (mg/L)	Crude <sup>32</sup> (mg/L)	Jet Naphta – JP-4 (mg/L)	Jet Kerosene (mg/L)	Distillate Oil n°2 (mg/L)	Residual Oil n°6 (mg/L)
Ships/ocean barges	215	73	60	0.63	0.55	0.004

Source: Tables 5.2-2 and 5.2-6 of USEPA AP-42 Emission Factors

The chosen Emission factor for Gasoline is the “Typical overall situation”. For other petroleum products it is used “Ships/ocean barges” emission factors.

For products for which there are not emission factors available, they were estimated using the following expression:

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

Where,

EF<sub>LL</sub> - Emission Factor associated to Loading Losses (lb/1000 gal);

F<sub>s</sub> - Saturation Factor (0 to 1);

P<sub>v</sub> - True Vapour Pressure (psia);

M<sub>v</sub> - Molecular Weight (lb/mol);

T - Temperature of Petroleum Product (520 °R – Rankin);

eff - Overall Reduction Efficiency (Both Recovery and Collection Efficiencies);

True Vapour Pressure and Molecular Weight Values were obtained from “International Chemical Safety Cards”.

<sup>32</sup> VOC Emission Factors for a typical crude oil are 15% lower than the total organic factors shown, in order to account for methane and ethane. All products other than crude oil can be assumed to have VOC factors equal to total organic factors.

CH<sub>4</sub> emission factor (60 g/ton of Crude) is obtained from EMEP/Corinair.

#### 3.3.7.2.4.4 Activity data

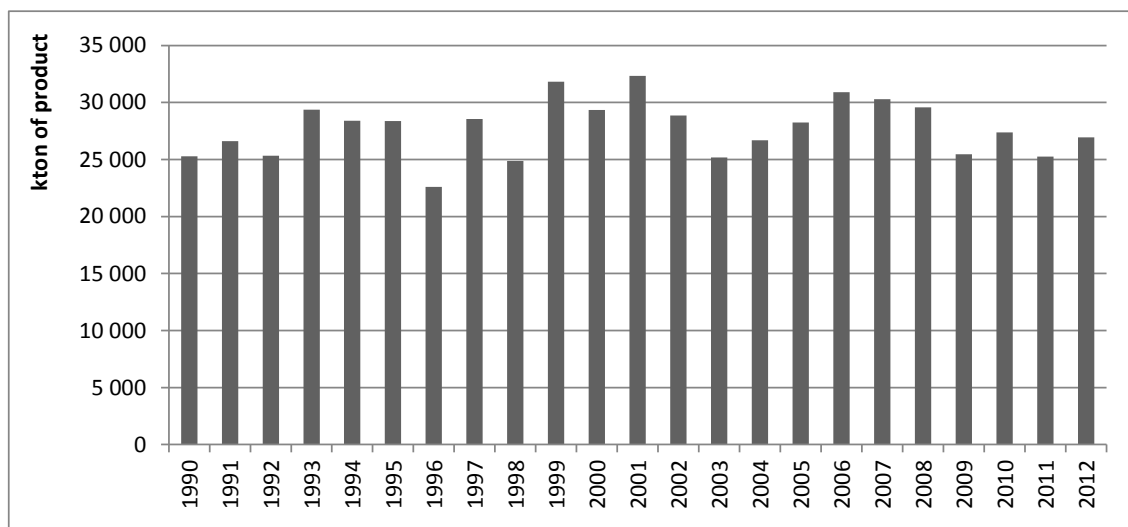
Data was obtained for year 2005, from:

- Ports Authorities (Port of Sines, Port of Lisbon, Port of Leixões, Port of Setúbal);
- Depots Companies (BP, Cepsa, CLCM, Esso, ETC, LBC Tanquipor, Petrogal, Repsol, Saaga, Sapec Química);
- Responsible company for the transport of Petroleum Products between Mainland and Madeira and São Miguel (Azores) Islands – Galpenergia;
- Responsible company for the transport of Petroleum Products between São Miguel Island (Azores) and other Azores Islands – BP (the transport is made by a ship rented by the Regional Government of Azores and is assured by BP company).

For the period 1990-2004 and from 2006 onwards data was extrapolated using Crude Oil stock changes obtained from DGEG energy balance.

It was made a cross-check between data obtained from different sources.

Figure 3-82 – Total amounts of loaded and unloaded crude and fuels in Marine Terminals (kton)



#### 3.3.7.2.4.5 Uncertainty Assessment

An uncertainty value (3 percent) similar to that that was considered for fuel consumption data in industrial LPS was also used for quantification of uncertainty of activity data for this source sector reflecting the fact that in this case data was also collected directly from refinery plants, where crude oil is uploaded, and used to build the energy balance of DGEG. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO<sub>2</sub> emissions, was considered to be 50 percent, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases. The uncertainty of methane emission factor was set to 100 percent, the double of the emission factor for



CO<sub>2</sub>/NMVOC in accordance with the fact that methane is obtained as a VOC fraction and hence with double uncertainty.

#### 3.3.7.2.4.6 *Recalculations*

No recalculations were made.

#### 3.3.7.2.5 Refining and Storage (1.B.2.a.iv)

##### 3.3.7.2.5.1 *Overview*

In 1990 there were three oil refining plants in Portugal, located in Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed for all activity and only two units remain now operating.

The refining process converts crude oil - which is a complex mixture of hydrocarbon compounds with impurities of sulphur, nitrogen, oxygen and heavy metals - into oil products used as fuels, asphalts, lubricants or feedstock for the organic and inorganic chemical industry. Processes included in Portuguese refineries include:

- Separation process: isolation of individual constituents of crude using differences in boiling-point, using atmospheric and vacuum distillation and recovery of light end gases;
- Conversion process. These may be also classified as:
  - Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular weight into smaller ones, including visbreaking;
  - Polymerization of small molecules combined in bigger molecules with different characteristics. Alkylation has similar purposes;
  - Chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing
- Treatment processes. Operations which include hydrodesulphurization, hydrotreating, chemical sweetening, acid gas removal, deasphalting and desalting, that are used to remove impurities, the most important is sulphur;
- Blending of individual fractions and intermediate products to obtain final commercial products with characteristics as desired.

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

NMVOC and methane emissions may also result from “normal” leaks<sup>33</sup> scattered through the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and

<sup>33</sup> Sometimes only these emissions are referred as fugitive emissions from refineries.

compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NMVOC emissions resulting from non-condensable fraction at the steam ejectors or vacuum pumps of the Vacuum distillation. Emissions in flares are discussed in "Venting and Flaring in Oil Industry" below.

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

### 3.3.7.2.5.2 Methodology

#### 3.3.7.2.5.2.1 Storage and Tanks

GALP, the company operating all refineries in Portugal, made annually estimates of emissions from storage in the tanks existing inside the refineries. The estimates, relying on the TANKS4.0 model, are available from 2002 till 2005. This detailed information lead to the establishing of plant specific emission factors, and its evolution, for 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 activity<sup>34</sup>.

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

#### 3.3.7.2.5.2.2 Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations where estimated from:

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

where

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

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

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

Total crude use was used as activity data to estimate fugitive emissions from leakages, according to the available emission factors in literature. Concerning Catalyst recovery activity data is coke burnt during catalyst regeneration.

<sup>34</sup> This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

### 3.3.7.2.5.2.3 Ultimate CO<sub>2</sub> 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 CO<sub>2</sub> (kton/yr) by:

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

### 3.3.7.2.5.3 Emission Factors

#### 3.3.7.2.5.3.1 Storage/ Tanks

For the period 2002-2005, GALP, the single petroleum refinery operator in Portugal, in collaboration with APA, performed a detailed inventory of NMVOC emissions from tanks in Oporto and Sines refineries using TANKS 4.0 (USEPA, 1990). The inventory has been extended to marketing terminal storage tanks (including data from all companies operating in the Portuguese territory). For the period 1990-2001 and from 2006 onwards, data was estimated using stock changes values from DGEG's energy balance.

TANKS4.0 software was designed to estimate air emissions from organic liquids in storage tanks, according to the methodology proposed in "Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources" (AP-42), Section 7.1, Organic Liquid Storage Tanks (USEPA, 1997).

Determination of emission factors for Oporto and Sines refineries were performed for each tank, considering the following detailed information:

- Site information: meteorological data such as the daily average ambient temperature, the annual average minimum and maximum temperatures, the annual average wind speed, the annual average solar insolation factor, and the atmospheric pressure;
- Liquid characterization: For individual substances the model requires chemical nomenclature, average liquid temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. For mixtures, the information may be as detailed as the mixture name, average, minimum and maximum liquid surface temperatures, bulk temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights;
- Tank information is slightly different according to tank type, but in general terms comprehends: shell and roof colour and condition, height, diameter, average and maximum liquid height, working volume, turnover rate and net output, heating conditions and pressure and vacuum settings and the existence and type of seals<sup>35</sup>.

Emissions were determined relying on methodologies that vary according to each tank type. The possible type of tanks, a very short description of their characteristics and the percentage of each tank type in existence in 2005 in Oporto and Sines refineries are presented in the table below.

<sup>35</sup> This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

Table 3-128 – Type of tanks classes distinguished in TANKS4.0 model and percentage of tanks per tank type in Oporto and Sines refineries in 2005 (percent).

Tank Type	Description	Oporto	Sines (a)
External Floating Roof Tank	cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid	55	170
Horizontal Tank	above-ground or underground storage with the axis parallel to the foundation	4	0
Internal Floating Roof Tank	permanent fixed roof and a floating deck	30	58
Vertical Fixed Roof Tank	cylindrical shells with permanently affixed roofs; the tank axis is perpendicular to the foundation. The fixed roof may be dome-shaped or cone shaped	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 Vapour Pressure above 27kPa

TANKS4.0 methodology differentiates the following emissions, according to the cause of release:

Table 3-129 – 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 vapour tight if the deck is not welded

Finally the resultant emission factors, obtained dividing total tank emissions by total throughput<sup>36</sup> in each refinery, are presented in next table. From 2006 onwards the emission factors were forecasted based on total throughput.

<sup>36</sup> Crude oil input added to input of other materials.

Table 3-130 – 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 <sup>(a)</sup>	NA	NA	NA

(a) Average value from Sines and Oporto refineries

#### 3.3.7.2.5.3.2 Fugitive Emissions

The following emission factors were used to estimate emissions from other processes, mainly leaks. These emission factors were still established from Corinair90 Emission Factor Handbook (EMEP/CORINAIR 3<sup>rd</sup> ed).

Table 3-131 – Emission Factors for fugitive emissions of NMVOC in operation processes in petroleum refineries

Pollutant	EF kg NMVOC/ ton crude
NMVOC	0.9
CH <sub>4</sub>	0.1

#### 3.3.7.2.5.3.3 Recovery of Catalysts

From information collected at the refinery of Sines (quantities of coke burnt in FCC unit during 2002 plant specific emission factors were established for this process). For carbon monoxide emission factors from USEPA (1995) were used, but because original emission in the original reference source are expressed in volume of fresh feed – and this activity rate it is not available from the refinery – the original emission factor was corrected, by multiplication by the ratio of the NO<sub>x</sub> emission factor in both information sources (monitoring data and USEPA). Carbon dioxide emission factor was set assuming that coke is 92 percent carbon. Final emission factors may be verified in the next table.

This set of emission factors was also applied to coke burning in the platforming unit, also in Sines refinery, and regeneration of catalysts at Oporto refinery.

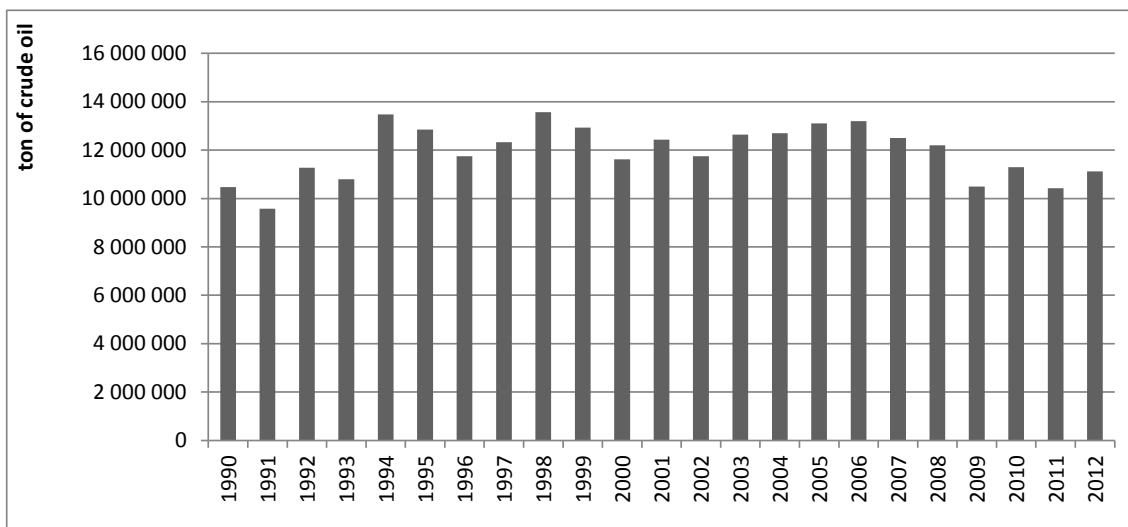
Table 3-132 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Parameter	Emission Factor kg/ton coke
UCO <sub>2</sub>	3 373

#### 3.3.7.2.5.4 Activity data

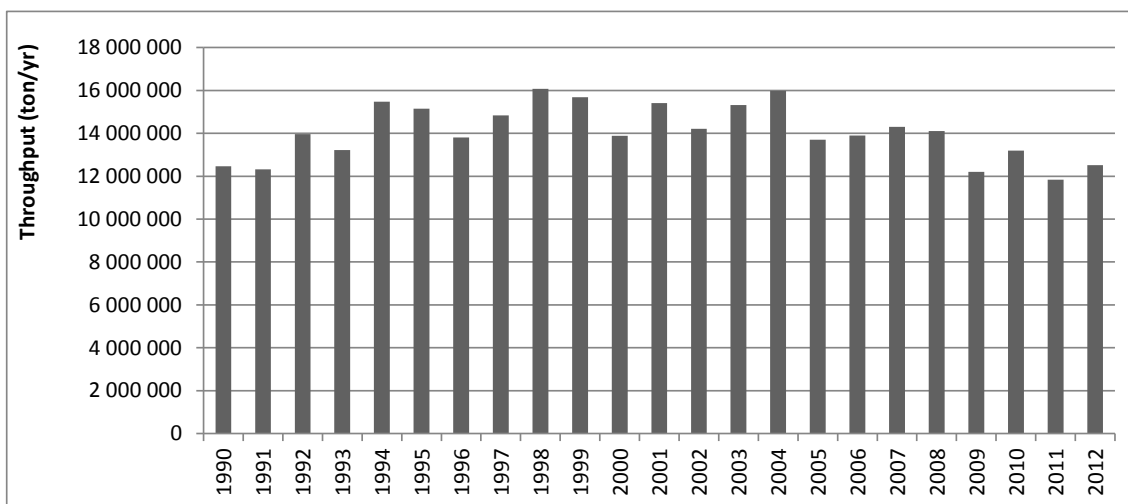
The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed (see next figure).

Figure 3-83 – Total Crude Oil Processed in Refineries (ton)



Total throughput in each refinery was used to estimate NMVOC emissions from storage and tanks. Total throughput represents not only crude oil entered into the refinery but also other petroleum products that are imported or moved between refineries. This indicator was considered the most suitable variable to be multiplied by the national emission factor. Total throughput for all refineries, according to information delivered by GALP, is presented in the next figure.

Figure 3-84 – Total throughput entered in Lisbon, Oporto and Sines refineries (ton)



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 period 1990-2004. From 2005 onwards, data is obtained directly from EU-ETS for both Sines and Oporto refineries.

#### 3.3.7.2.5.5 Uncertainty Assessment

Most of the activity data that was obtained to estimate emissions comes directly from the refinery units or indirectly by the Energy Balance of DGEG (which is based also in information

surveyed from the industrial plants). Therefore a low uncertainty of 3 percent may be assumed for this sub-source in a similar mode to other LPS combustion data.

Uncertainty of emission factors for NMVOC<sup>37</sup> were set as 50 percent, at the higher range of possible uncertainties proposed by IPCC (2000), although the fact that some emission factors use plant specific information. Estimates of methane emissions were assumed to have the double uncertainty that was determined for CO<sub>2</sub> (100 percent).

#### *3.3.7.2.5.6 Recalculations*

No recalculations were made.

#### *3.3.7.2.5.7 Further Improvements*

No further improvements are planned for this sector.

### **3.3.7.2.6 Distribution of Oil Products (1.B.2.a.v)**

#### *3.3.7.2.6.1 Overview*

This sub-source sector includes 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 vehicles - 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.

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<sup>37</sup> The uncertainty of NMVOC was considered to be the uncertainty of CO<sub>2</sub> emission factor.

### 3.3.7.2.6.2 Methodology

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

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

#### 3.3.7.2.6.2.1 Filling Underground Tanks

From “Portaria 646/97” it is assumed that since 2005 it is used “bottom loading with vapour return” (Stage IB) for latter recovering (VRU) or destruction (VDU). Before 2005 it is not known the type of filling used and it is assumed that 50% of the service stations had vapour return and 50% hadn't the Stage IB in place.

Before 2005 emissions estimates are based on:

$$E_{FUT} = V_{StageIB} \times TVP \times EF_{StageIB} + V_{other} \times TVP \times EF_{other}$$

Where,

$E_{FUT}$  - Emissions Filling Underground Tanks (kg)

TVP – True Vapour Pressure (kPa)

$V_{StageIB}$  - Gasoline throughput at Service Stations with Stage IB (m<sup>3</sup>)

$EF_{StageIB}$  - Emission Factor for Filling Underground Tanks at Service Stations with Stage IB (kg/m<sup>3</sup>/kPa TVP)

$V_{other}$  - Gasoline throughput at Service Stations without Stage IB (m<sup>3</sup>)

$EF_{other}$  – Emission Factor for Filling Underground Tanks at Service Stations without Stage IB (kg/m<sup>3</sup>/kPa TVP)

Since 2005, the emissions estimates are based on:

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

Where,

$E_{FUT}$  - Emissions Filling Underground Tanks (kg)

$V_{StageIB}$  - Gasoline throughput at Service Stations with Stage IB (m<sup>3</sup>)

$EF_{StageIB}$  – Emission Factor for Filling Underground Tanks at Service Stations with Stage IB (kg/m<sup>3</sup>/Kpa TVP)



### 3.3.7.2.6.3 Emission Factors

#### 3.3.7.2.6.3.1 Filling Underground Tanks

Emission factors were obtained from “Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1”.

Table 3-133 – Filling Underground Tanks NMVOC Emission Factors

Filling Underground Tank	Emission Factor (kg/m <sup>3</sup> /kPa TVP)
Without Stage IB	2.44E <sup>-02</sup>
With Stage IB	1.1E <sup>-03</sup>

#### 3.3.7.2.6.3.2 Underground Tank Breathing and Emptying

The NMVOC emission factor source is “Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1” (=3.30E<sup>-03</sup> kg/m<sup>3</sup>/kPa TVP).

#### 3.3.7.2.6.3.3 Vehicle Refueling Operations

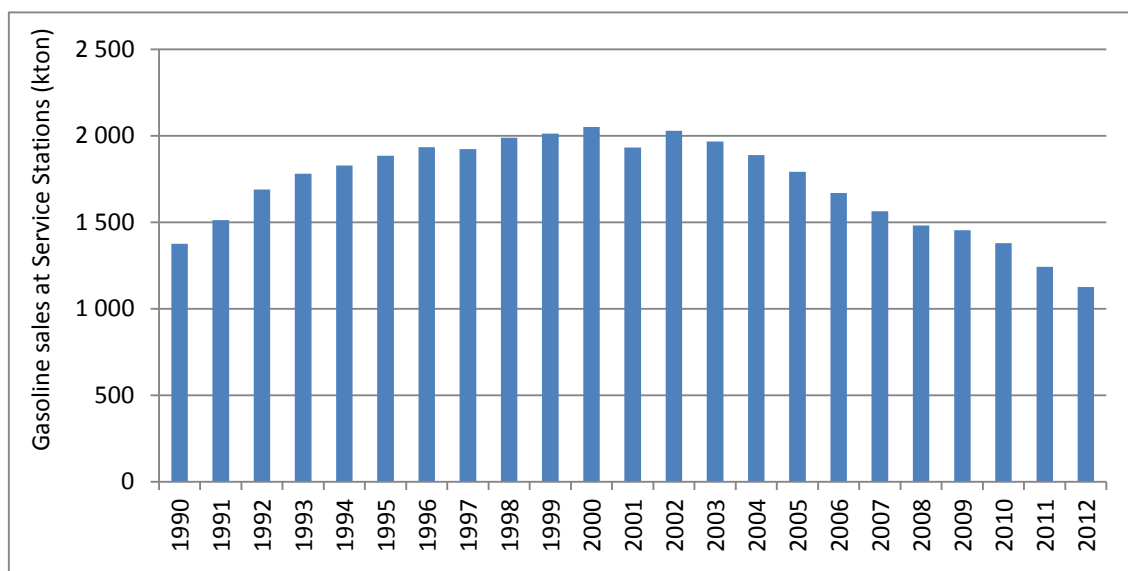
Table 3-134 – Vehicle Refueling Operations NMVOC Emission Factors

Vehicle Refuelling Operations	Emission Factor (kg/m <sup>3</sup> /kPa TVP)
Drips and Minor Spillage	2.20E <sup>-03</sup>
Refuelling with no emission controls in operations (without Stage II measures)	3.67E <sup>-02</sup>

#### 3.3.7.2.6.4 Activity data

Data on gasoline sales was obtained from DGEG Energy Balance for the entire period.

Figure 3-85 – Fuel Sales at Service Stations



#### 3.3.7.2.6.5 Uncertainty Assessment

An uncertainty value (3 percent) was considered for total crude oil processed at refineries (plants data). Data on gasoline sales obtained from DGEG Energy Balance was considered an uncertainty value of 10 percent. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO<sub>2</sub> emissions, was considered to be 50 percent, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases.

#### 3.3.7.2.6.6 Recalculations

No recalculations were made.

#### 3.3.7.2.6.7 Further Improvements

Efforts should be addressed in order to verify stage II implementation at service stations in Portugal.

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

#### 3.3.7.3.1 Overview

There is no production of natural gas in Portugal. The use of natural gas in Portugal was initiated only in 1997 (DGEG). At that time this energy source was received by ship from Algeria and used mainly in electric power production and in combustion in industry. Since then its use has become more widespread and its now consumed also in the manufacturing industry, domestic, service, institutions, commerce, building and construction, agriculture and even a small quantity in road transport. All natural gas is imported and received through shipping transport from Algeria and Nigeria as Liquefied Natural Gas (LNG). There are also no major processing operations in Portugal.

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

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

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

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

### 3.3.7.3.2 Methodology

Losses of Natural Gas are estimated equal to the quantity of gas that is lost in transport and distribution, according to the energy balance of DGEG. Therefore, total emissions are determined from:

$$Emi_{GHG(y)} = Losses_{NG(y)}$$

Where,

$Emi_{GHG(y)}$  – Emissions of total GHG from natural gas leakage, in year y;

$Losses_{NG(y)}$  – Losses of Natural Gas from the system and reported in the energy balance, in year y.

Emissions of methane, direct CO<sub>2</sub> and ultimate CO<sub>2</sub>, from transmission of Natural Gas in major pipelines is estimated from:

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

Where,

$Emi_{CH_4}$  – Emissions of CH<sub>4</sub> from losses of natural gas during transmission, t/yr;

$Emi_{CO_2direct}$  – Direct emissions of CO<sub>2</sub> from leakages, t/yr;

$Emi_{CO_2}$  – Total emissions of CO<sub>2</sub>, including conversion of carbon in methane and other gases in atmosphere, t/yr;

$EF_{CH_4}$ ,  $EF_{CO_2direct}$  – Emission factors, t/km;

$Pipeline_{Lenght}$  – Extension of pipeline in year y, km.

A similar procedure is used to estimate emissions in the re-gasification plant, although using total natural gas processes<sup>38</sup> 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,

$\text{EF}_{\text{CH}_4}$ ,  $\text{EF}_{\text{CO}_2\text{direct}}$  – Emission factors, per cent;

$\text{Import}_{\text{NG}}$  – Import of Natural Gas, t/yr.

Finally emissions during distribution ( $\text{Emi}_{\text{DIST}}$ ) are estimated from total losses ( $\text{Emi}_{\text{TOTAL}}$ ), after removal of transmission emissions ( $\text{Emi}_{\text{TRANS}}$ ) and emissions occurring at the re-gasification plant ( $\text{Emi}_{\text{GAS}}$ ):

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

### 3.3.7.3.3 Emission Factors

The emission factors are based on the IPCC Good Practice (IPCC, 2000), and are reported in Table 3-135.

Table 3-135 – Net Calorific Value and Emission Factor for fugitive emissions from natural gas

-	Transmission (t/km) <sup>#</sup>	NGL Plant (%) <sup>\$</sup>
CH <sub>4</sub>	2.5	0.05
CO <sub>2</sub>	0.016	0.00032

# - IPCC (2000), table 2.16

\$ - IPCC (2000), table 2.18, assuming same CO<sub>2</sub>/CH<sub>4</sub> ratio in transmission

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

### 3.3.7.3.4 Activity data

According to the above explained methodology, activity data comprehends:

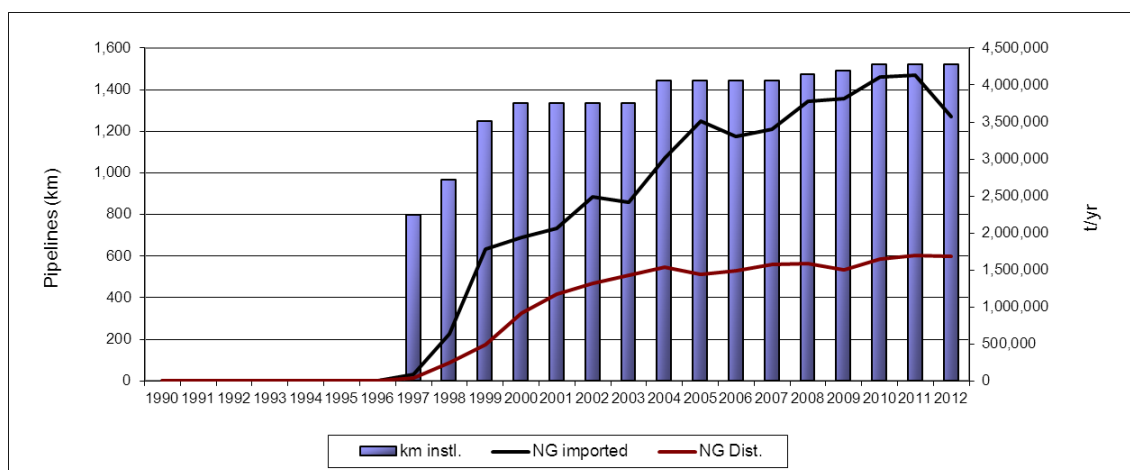
- extension of pipelines for transmission. Total extension of pipelines in kilometres was estimated from data concerning the operational launch of each pipeline. Because of this the activity data for transmission for each year since 1997 represents the new pipeline extension added to the total length from previous years. This pipeline data was received via DGEG from TRANSGAS;
- importation of natural gas, obtained from the DGEG's Energy Balances;

<sup>38</sup> Equals imports in Portugal

- 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 tree variables used as activity data are represented in the next figure.

Figure 3-86 – Activity data used to estimate GHG emissions from Natural gas transmission, distribution and transformation

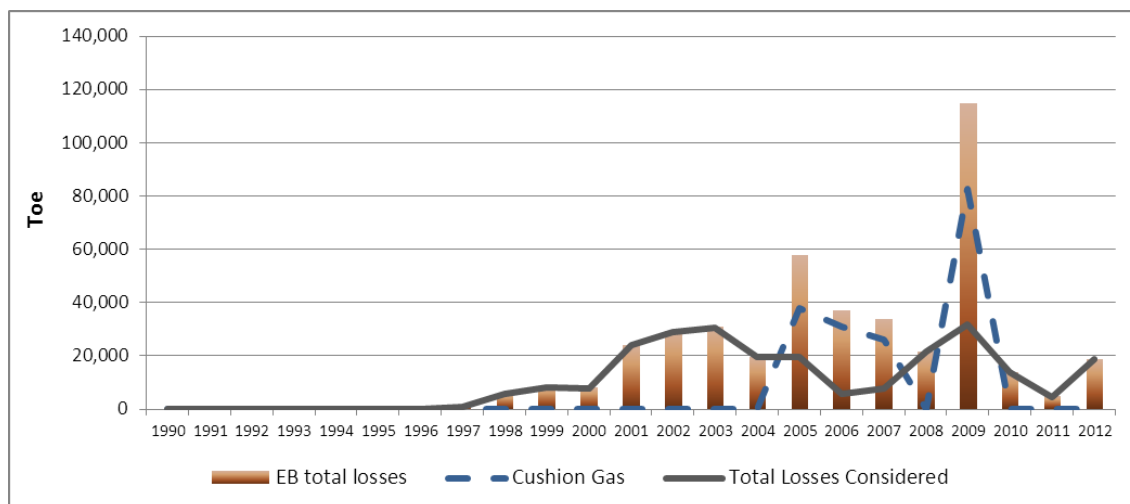


In 2009 new data was obtained from DGEG concerning the consumption of cushion gas. This gas is used for maintaining constant pressure within underground storage tanks and it is considered to be confined within the tank only resulting in emissions when the tank is deactivated. Because there is no specific category in the energy balance for this type of consumption, DGEG reports cushion gas together with natural gas Losses in Transmission and Distribution. This led to an overestimation of CH<sub>4</sub> emission in previous inventories.

The following figure shows both the total natural gas losses reported in the energy balance and the consumption of cushion gas. Also shown is the final time series considered for CH<sub>4</sub> emission estimation purposes (cushion gas subtracted to the total losses reported in the energy balance).

Please note that the consumption of cushion gas is only made when a storage tank beginnings operation which results in a large inter-annual variation in the consumption of this gas.

Figure 3-87 – Natural gas losses reported in the energy balance compared with the consumption of cushion gas



After contacting DGEG, the following explanations were provided concerning the variations in the natural gas losses:

The rapid increase from 2000 to 2003 results from the increase expansion of the natural gas distribution network to sectors with more ramifications (domestic and services);

The decline from 2004 to 2007 results from the stabilization in the pipeline extension in residential and service sectors coupled with improvements in pipeline quality and other general gains in efficiency;

The increase in 2008 results mainly from corrections done to the natural gas losses values reported to DGEG. For this year no Cushion Gas consumption was reported;

The increase in 2009 results from consumption of Cushion Gas in new natural gas storage facilities;

There was no consumption of Cushion Gas registered since 2010.

There is only one compressor station in Portugal that works at the entrance of an underground storage facility. This equipment has no fuel consumption for combustion. Throughout the pipeline network there are small pressure regulation and measurement stations used for monitoring and small pressure adjustments. These equipment also have no fuel consumption for combustion. Natural gas losses from both the large compressor station and the small pressure regulation station are included in this source category (reported as total natural gas losses in the energy balance). This information was obtained from DGEG.

#### 3.3.7.3.5 Uncertainty Analysis

The uncertainty in activity data was considered to be 5 per cent, the value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in CH<sub>4</sub> emission factor, considering a low quality inventory, was assumed to be 150 per cent, and the same value was considered for CO<sub>2</sub> emissions which were determined simply from simple conversion of emissions in methane form.

#### 3.3.7.3.6 Category-specific QA/QC and verification

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). No significant differences were found between data sources for this category.

#### 3.3.7.3.7 Recalculations

Recalculations for this source category comprise only the revision of the 2003, 2008, 2009, 2010 and 2011 energy balance data (2003, 2008-2011);

#### 3.3.7.3.8 Further Improvements

A new update on pipeline extension is expected in the next inventory, mainly for low pressure pipelines. This new data will not be given by DGEG which explains the fact that it was not included in this year inventory exercise.

Efforts are being done with DGEG<sup>39</sup> and the major Portuguese company responsible for gross transport of natural gas<sup>40</sup>, in order to increase the tier level of the methodology. Results and changes in estimates are expected in the coming years.

### 3.3.7.4 *Flaring in Oil Industry (1.B.2.c.2)*

#### 3.3.7.4.1 Overview

Flares were used at the three refineries in Portugal to control and burn non-condensable gases recovered from leakages and blow down operations, which 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, CH<sub>4</sub> and CO.

#### 3.3.7.4.2 Methodology

All carbon emitted in compounds, such as CO, NMVOC and methane, has fossil origin and must be included in the estimate of ultimate carbon dioxide emissions. Individual pollutants (end of pipe carbon dioxide, NMVOC, methane and carbon monoxide) are converted into ultimate CO<sub>2</sub> according to:

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

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.

<sup>39</sup> Direcção Geral de Energia e Geologia/ General Directorate of Energy and Geology

<sup>40</sup> TRANSGAS

CO<sub>2</sub> emissions are estimated from:

$$\text{Emis}_{\text{CO}_2(y)} = \text{Flare}_{\text{Gas}(y)} * \text{LHV}_{\text{Gas}(y)} * \text{EF}_{\text{CO}_2} * \text{OF}_{\text{Gas}(y)} * 10^{-3}$$

Where,

Emis<sub>CO<sub>2</sub>(y)</sub> – Emission of CO<sub>2</sub> in year y (ton/yr);

Flare<sub>Gas(y)</sub> – Quantity of gas flared in year y (ton/yr);

LHV<sub>Gas(y)</sub> – Low Heating Value of gas flared in year y (GJ/ton);

EF<sub>CO<sub>2</sub></sub> – Emission factor of CO<sub>2</sub> (kg/GJ);

OF<sub>Gas(y)</sub> – Oxidation factor of gas flared in year y (dimensionless).

CH<sub>4</sub> and NMVOC emissions are estimated from:

$$\text{Emis}_{(p,y)} = \text{EF}_{(p)} * \text{Flare}_{\text{GAS}(y)} * m_{(p,y)}/m_{(\text{gas},y)} * 10^{-3}$$

Where,

Emis<sub>(p,y)</sub> – Emission of pollutant p in year y (ton/yr);

EF<sub>(p)</sub> – Emission factor (Kg/ton gas);

Flare<sub>GAS(y)</sub> – Quantity of gas flared in year y (ton/yr);

m<sub>(p,y)</sub>/m<sub>(gas,y)</sub> – Mass fraction of pollutant p in year y.

N<sub>2</sub>O emissions are estimated from:

$$\text{Emis}_{(y)} = \text{EF}_{(p)} * \text{Crude} * \text{Dens}_{\text{Crude}}$$

Where,

Emis<sub>(y)</sub> – Emission of N<sub>2</sub>O in year y (ton/yr);

EF<sub>(p)</sub> – Emission factor (ton/m<sup>3</sup> crude);

Crude – Quantity of crude processed in the refinery in year y (ton/yr);

Dens<sub>Crude</sub> – Density of the crude oil processed in the refinery in year y (ton/m<sup>3</sup>).

#### 3.3.7.4.3 Emission Factors

Emission factors for CO<sub>2</sub> were derived from EU-ETS data for Sines and Oporto refineries and from US-EPA (1991) for Lisbon refinery.



Emission factors for NMVOC and CH<sub>4</sub> were set from “Concawe – Air pollutant emission estimation methods for E-PRTR reporting by refineries – report no. 1/09”.

Emission factor for N<sub>2</sub>O was set from IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Feed density was assumed equal to 0.85 ton/m<sup>3</sup>.

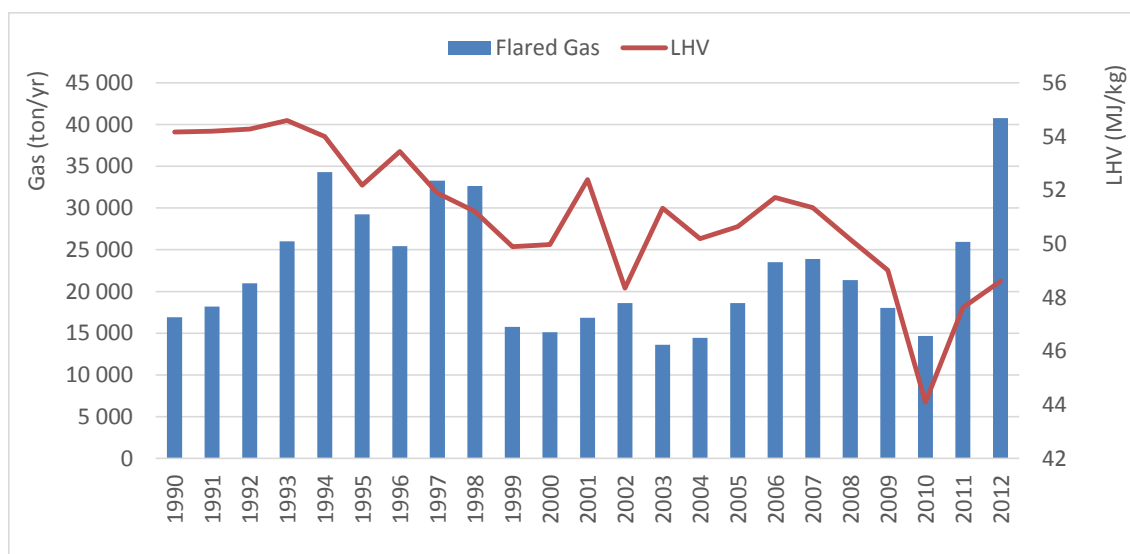
Table 3-136 – Emission Factors for flaring in refineries

Pollutant	EF Unit	EF
CO <sub>2</sub> (kg/GJ)	Kg/GJ	46.6 - 62.6
NMVOC	kg/ton gas	5
CH <sub>4</sub>	kg/ton gas	5
N <sub>2</sub> O <sup>41</sup>	ton/m <sup>3</sup> oil	6.4x10 <sup>-7</sup>

#### 3.3.7.4.4 Activity data

Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL for the period 1990-2004. From 2005 onwards data is obtained from EU-ETS.

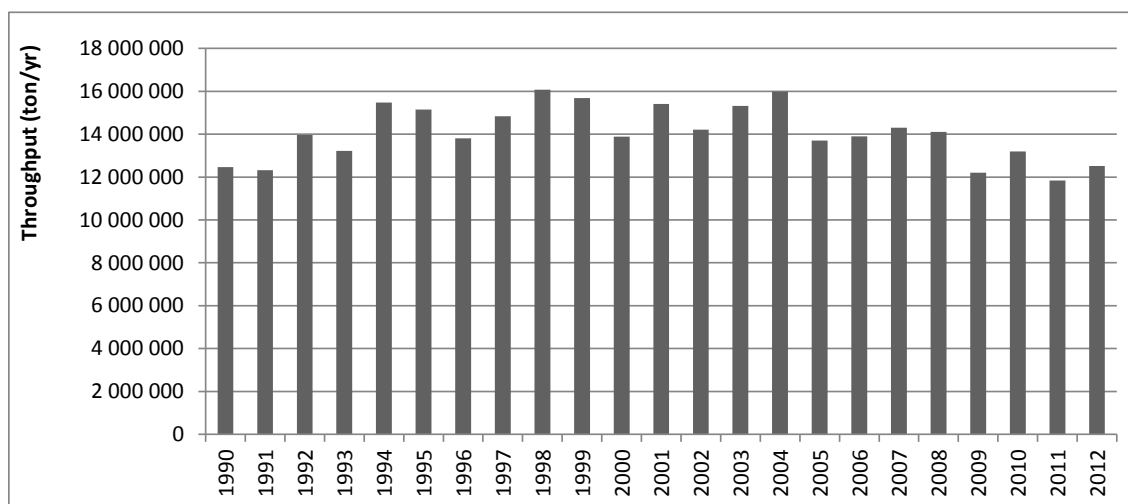
Figure 3-88 – Total consumption of flare gas in Portuguese refineries and Low Heating Value



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

<sup>41</sup> Table 2.16 of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Oil Production – Conventional Oil – Flaring)

Figure 3-89– Total throughput entered in Lisbon, Oporto and Sines refineries



#### 3.3.7.4.5 Uncertainty Assessment

The uncertainty in activity data was considered to be 3 percent, the value used when activity data refer data directly collected from the units. The uncertainty in NMVOC/CO<sub>2</sub> emission factor is 50 percent and the double of that value for methane emissions.

#### 3.3.7.4.6 Recalculations

No recalculations were made.

#### 3.3.7.5 *Other Fugitive Emissions (Geothermal Electricity Production) (CRF 1.B.2.d.)*

##### 3.3.7.5.1 Overview

A small amount of electricity is produced from two geothermic sources in Azores archipelago: *Pico Vermelho* (commissioned in 1980) and *Ribeira Grande* (commissioned in 1994) 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 CO<sub>2</sub> emissions from geothermal electricity production. Nevertheless, emissions from these activity are clearly related to sector 1 (Energy) and must be better considered as fugitive emissions. However, for fugitive emissions the CRF nomenclature allows only the classes Solid Fuels (1B1) and Oil and Natural Gas (1B2), which are not exactly suitable for this activity. Sector 7 (Other) could be used in principle, but would imply that emissions from this category would be no longer included in the energy sector.

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

The category has been identified as key in the KC analysis in previous submissions and was included the 2014 Methodological Development Plan (PDM), which lead to the revision of estimates based on new data collected by the Autonomous Region of Azores.

#### 3.3.7.5.2 Methodology

From 1994 till 1999, the Regional Authority of Economy (Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia) performed estimates of carbon dioxide released to atmosphere from geothermic units and these were considered in the National Inventory.

These data have been considered as inadequate and not consistent with reality by the authorities of the Autonomous Region of Azores, who made available new data referring to the characterization of a real situation of the Geothermal Electricity Production in Azores for 2008-2011 period.

The fraction from steam geothermal fluid captured in geothermal wells was chemical analysed. Those results allowed the estimation of CO<sub>2</sub> mass released to the atmosphere and the calculation of a CO<sub>2</sub> emission factor for unit of electricity produced.

Since the 2010 inventory all data concerning geothermal production is obtained from the Azores environmental entity (this time series starts in 2003). For the years prior to 2003 emissions of CO<sub>2</sub> were estimated from electricity production reported by DGEG

#### 3.3.7.5.3 Emission factors

Measurements of carbon dioxide emissions available from Ribeira Grande from 2008 till 2011, presented in next table, were provided by the regional authority of the Autonomous Region of Azores<sup>42</sup>. These results were used to estimate an average emission factor applied to the whole period on both plants (Ribeira Grande and Pico Vermelho)

Table 3-137 – Emission Factors for Geothermal Electricity Production

	2008	2009	2010	2011
<b>Production (GWh)</b>	171	162	174	186
<b>CO<sub>2</sub> (t)</b>	19 573	28 206	36 054	40 094
<b>Emission Factor observed (t/GWh)</b>	115	174	207	215
<b>Emission Factor to Geothermal Electricity Production (tCO<sub>2</sub>/GWh)</b> (Average of last three years)				198.7

Source: Grupo EDA – Energia dos Açores

The variation of the emission factor observed is due to the different flow of CO<sub>2</sub> emitted by each geothermal well and flexible operating regime of the geothermal plants. The CO<sub>2</sub> emission

<sup>42</sup> Secretaria Regional dos Recursos Naturais – Direcção Regional do Ambiente.

factor adopted for geothermal power plants is the average of the last three years, 199 tCO<sub>2</sub>/GWh.

#### 3.3.7.5.4 Activity Data

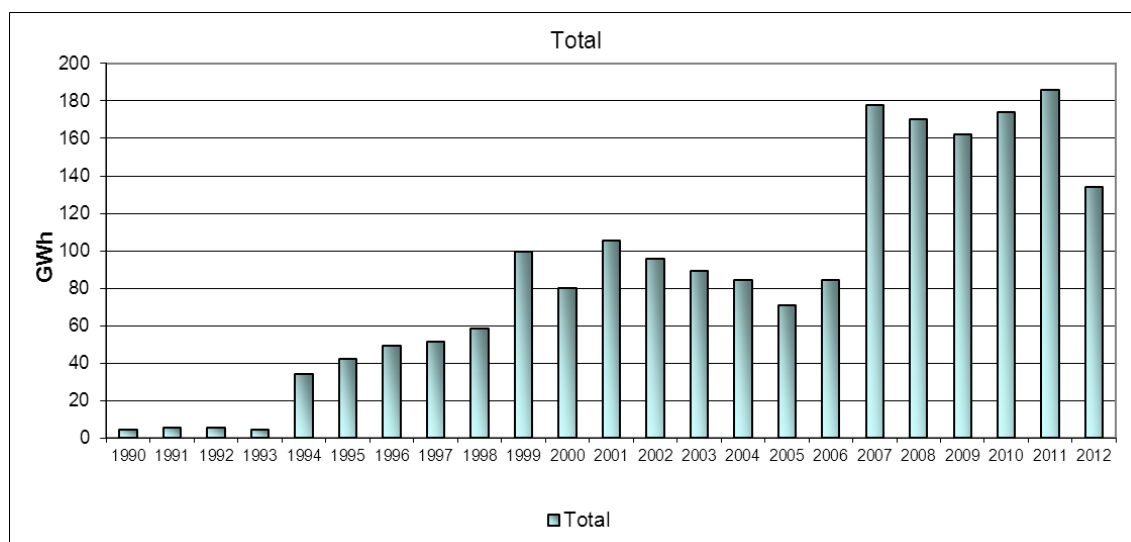
Activity data consists of geothermal production. The time series was constructed using data from the regional authority in Azores:

Pico Vermelho – from 2000 to 2012;

Ribeira Grande – from 1994 to 2012;

Data from DGEG was used to fill in information gaps mainly for Pico Vermelho 1990 to 1999 geothermal production. The following figure shows the total geothermal production time series in Azores

Figure 3-90 – Total Geothermal Production in Azores



In 2006 a new power plant was commissioned in *Pico Vermelho* following the decommissioning of the old installation. This new plant tripled the installed power of *Pico Vermelho* (from 3 MW to 10 MW). For *Ribeira Grande* improvements were made in 1998 to the existing installation that almost tripled the installed power (from 5MW to 13 MW).

#### 3.3.7.5.5 Uncertainty Analysis

The uncertainty of the activity data is 5 per cent considering that the statistical information is reliable but some extrapolations have been performed for earlier years, namely to separate data per power plant.

The uncertainty in the emission factor has been estimated as 21.9 per cent on the basis of the variation of the the EF (measured data)..

#### 3.3.7.5.6 Recalculations

Recalculations for this source category comprise:

- Revision of the CO<sub>2</sub> emission factor for the Geothermal Plants. These new data were provided by the Azores Environmental Authorities; That revision results in

a average decrease of 67% of CO<sub>2</sub> emission in this subsector, and less than 1% in the Energy Sector

#### 3.3.7.5.7 Further Improvements

No further improvements are planned for this sector.

### 3.4 Sector-specific QA/QC and verification

A Streamline of Emission Factors and Low Heating Values used in the estimation of CO<sub>2</sub> emissions was implemented to the Energy Sector, the goal of this activity was to bring closer the estimation process in this sector.

CO<sub>2</sub> Emission Factor (EF) and the Low Heating Value (LHV) for specific fuels were compared for the different categories in the Energy Sector:

- Electricity and Heat Production (1.A.1.a)
- Manufacturing Industries (Combustion) (1.A.2)
- Transports (1.A.3)

Low Heating Value:

The main sources of LHV data used in the inventory come from

- Energy Balance (DGEG)
- Operators measuring's for specific unit (CELE)
- Operators reporting's (Autocontrolo)

No major differences in values were detected between sub-sectors. Although, a deeper analysis to the solid fuel was needed to clarify different fuel nomenclature and the respective LHV's.

Whenever available, the operators measured data was kept for energy consumption estimations in specific units. The LHV data from DGEG was used as a default for the inventory.

CO<sub>2</sub> Emission Factor:

In the inventory the CO<sub>2</sub> EF from IPCC Guidelines 1996 was used as default; when available, measured data from operators (CELE and Autocontrolo) was used instead.

No major differences were detected.

### 3.5 Recalculations

The main recalculations that were made refer to the:

- Revision of the 2003, 2008, 2009, 2010 and 2011 energy balance data for several sectors/fuels (2003, 2008-2011);
- Update of Steam Coal and Coke Coal CO<sub>2</sub> emission factors in the Cement and Chemical Sectors.(1990-2011)

- Revision of fuel consumption for Chemical industrial sector. New values from operators (2011);
- Coal production data has been revised based on statistical data from Geological Resources reports from DGEG. Previously it was wrongly assumed that one of the mines was an underground mine and the other was an open cast mine. From revised data obtained from DGEG experts, both mines are now considered underground mines. (1990-2011)
- Revision of the CO<sub>2</sub> emission factor for the Geothermal Plants. These new data were provided by the Azores Environmental Authorities. (1990-2011)
- Recalculations for Energy Industries sector comprise the allocation of CO<sub>2</sub> emissions from the desulfurization process, total CO<sub>2</sub> emissions from this abatement system were included together with the Limestone, Dolomite and Carbonate Use in CRF 2.A.3.(1990-2011)
- Railways CO<sub>2</sub> emission factor for diesel oil fuel was revised and changed from 74,37 kg/Gj to 74,07 kg/Gj. The new EF is the same that is being used for this type of fuel by the other mobile sources to ensure consistency across all sectors. (1990-2011)
- Update of the 2011 emissions values from Civil aviation due to compilation error detected in the estimation spreadsheet. (2011)

Figure 3-91 – Differences between 2013 and 2014 submissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O)

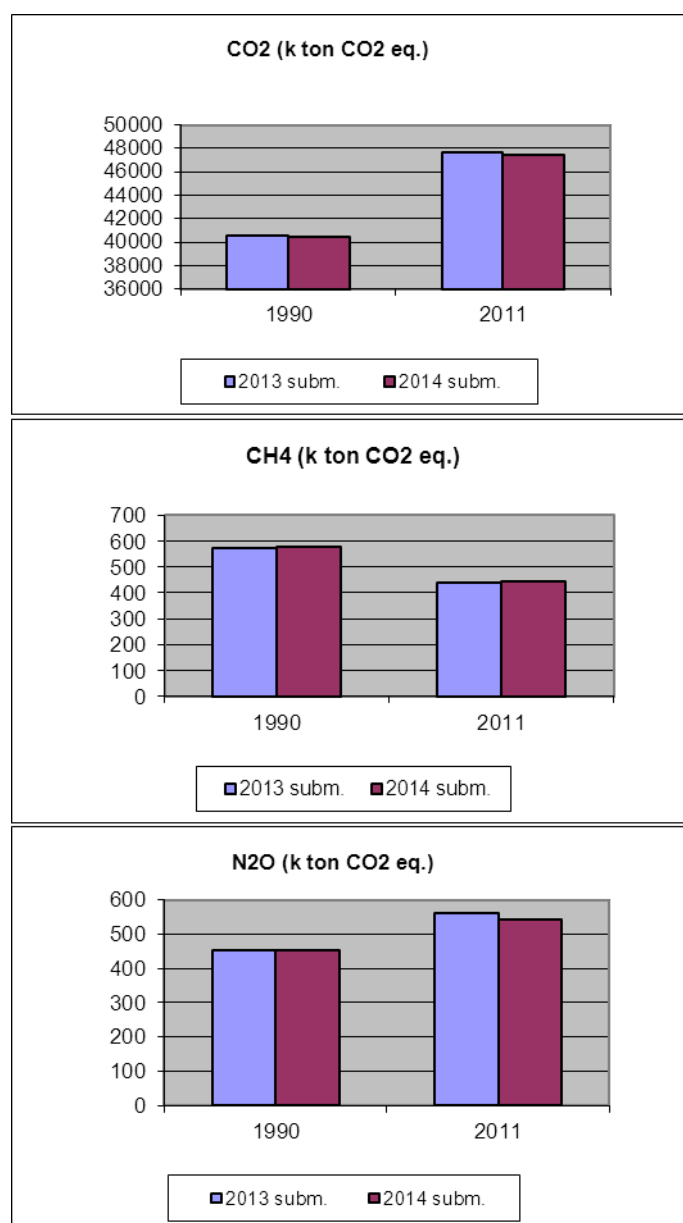


Table 3-138 – Recalculations (differences between 2013 and 2014 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2			CH4			N2O		
			2013 subm.	2014 subm.	Difference (1)	2013 subm.	2014 subm.	Difference (1)	2013 subm.	2014 subm.	Difference (1)
			CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)	CO2 equivalent (Gg)		(%)
1990											
1. Energy			40,609.21	40,472.43	-0.34	571.27	578.77	1.31	454.46	454.45	0.00
1.A.	Fuel Combustion Activities		40,333.54	40,194.79	-0.34	466.82	465.98	-0.18	452.02	452.01	0.00
1.A.1.	Energy Industries		16,260.71	16,260.71	0.00	4.32	4.32	0.00	61.02	61.02	0.00
1.A.2.	Manufacturing Industries and Construction		9,759.04	9,621.00	-1.41	27.36	27.04	-1.16	67.90	67.89	-0.01
1.A.3.	Transport		10,139.78	10,139.06	-0.01	86.59	86.59	0.00	82.50	82.50	0.00
1.A.4.	Other Sectors		4,070.32	4,070.32	0.00	348.38	347.85	-0.15	239.75	239.75	0.00
1.A.5.	Other		103.69	103.69	0.00	0.17	0.17	0.00	0.85	0.85	0.00
1.B.	Fugitive Emissions from Fuels		275.67	277.64	0.71	104.45	112.79	7.99	2.44	2.44	0.00
1.B.1.	Solid fuel		8.65	9.74	12.64	66.02	74.36	12.64	NO	NO	
1.B.2.	Oil and Natural Gas		267.02	267.90	0.33	38.43	38.43	0.00	2.44	2.44	0.00
2011											
1. Energy			47,609.98	47,385.82	-0.47	437.10	445.61	1.95	563.42	541.41	-3.91
1.A.	Fuel Combustion Activities		46,622.20	46,474.62	-0.32	273.82	275.04	0.45	560.99	538.98	-3.92
1.A.1.	Energy Industries		16,385.06	16,345.27	-0.24	8.23	8.40	2.03	131.81	133.05	0.94
1.A.2.	Manufacturing Industries and Construction		8,476.75	8,365.34	-1.31	33.73	31.23	-7.41	96.75	68.98	-28.71
1.A.3.	Transport		17,350.73	17,360.88	0.06	29.76	29.83	0.22	169.72	169.81	0.05
1.A.4.	2011.00		4,332.76	4,326.22	-0.15	202.09	205.58	1.73	162.04	166.47	2.74
1.A.5.	Other		76.90	76.90	0.00	0.01	0.01	0.00	0.67	0.67	0.00
1.B.	Fugitive Emissions from Fuels		987.77	911.20	-7.75	163.28	170.56	4.46	2.43	2.43	0.00
1.B.1.	Solid fuel		IE,NO	1.05		IE,NO	7.87		NO	NO	
1.B.2.	Oil and Natural Gas		987.77	910.15	-7.86	163.28	162.69	-0.36	2.43	2.43	0.00

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission).



### 3.5.1 Further Improvements

Considering that the energy sector is the most prevalent emission source, special efforts must always be made to improve emission estimates, even if they affect smaller energy sub-sectors. Future improvements to the inventory will depend on the conclusions of the MDP in the scope of SNIERPA's implementation, which is being made with direct contact with the main stakeholders of the energy sector, and in close collaboration of the inventory team from APA. Although the main conclusions from this report are still not set in a final report and plan, the following preliminary routes may be here identified.

- Better integration between activity data in the air emissions inventory and other surveys such as LCP directive, Autocontrolo program, EPER/E-PRTR, the EU-ETS and the energy surveys (co-generation) made annually by DGEG. Contacts are being made to implement it. Particular work is being done to streamline the collection of data and emission estimates between the inventory and the EU-ETS, following the promotion efforts that are being made by the European Commission;
- Determination of country-specific emission factors (SO<sub>x</sub> and NO<sub>x</sub>) from monitoring data collected from the Autocontrolo program and CO<sub>2</sub> emission factors for information collected under carbon market;
- Consistency Checks on Refining/Storage timeseries.

## 3.6 Reference Approach

### 3.6.1 Overview

The reference approach consists in the estimate of CO<sub>2</sub> 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”<sup>43</sup> for estimation of CO<sub>2</sub> emissions from fossil fuel combustion, in addition to the bottom-up sectoral methodology.

The Reference approach uses a very simple methodology, assuming that all carbon input to the national economy in fuel form, it is either stored in some way (fuel stocks, products or even left unoxidized in ash) or it must be released to the atmosphere. In order to calculate the carbon released it is not necessary to know exactly how and where the fuel was used or what intermediate transformations it underwent. In this respect the methodology may be termed a “top-down” approach compared with the “bottom-up” methods used for other gases (IPCC,1997).

The Reference Approach requires simple statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of values for the consumption of fossil products used for non-energy purposes, where carbon may be stored.

<sup>43</sup> This does not mean that a “bottom-up” approach should not be followed for estimating CO<sub>2</sub> emissions but the total emissions must be compared with those obtained from the Reference Approach.

### 3.6.2 Methodology

The following methodological steps were made in accordance with IPCC (1997):

- 1 Estimate consumption of fuels by fuel/product type;
- 2 Convert the fuel data to a common energy unit (TJ), if necessary;
- 3 Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels;
- 4 Estimate the amount of carbon stored in products for long periods of time;
- 5 Account for carbon not oxidized during combustion;
- 6 Convert emissions of carbon to full molecular weight of CO<sub>2</sub>.

#### 3.6.2.1 Fuel consumption

Apparent consumption was estimated from energy balances from DGEG according to:

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{Stock Change.}$$

for primary fuels and,

$$\text{Apparent Consumption} = \text{Imports} - \text{Exports} - \text{Bunkers} - \text{Stock Change.}$$

for secondary fuels.

National production is not considered because the carbon in these fuels was already included in the supply of primary fuels from which they were derived.

#### 3.6.2.2 Energy Consumption

The Portuguese National Balance reports consumption in energy units (toe<sup>44</sup>), apparent consumption needs only to be converted to TJ using the multiplier 41.868 GJ/toe.

#### 3.6.2.3 Carbon Content of Fuels

Carbon content in apparent consumption is estimated in reference approach from:

$$\text{Apparent Consumption}_{(\text{Gg C})} = \text{Apparent Consumption}_{(\text{TJ})} * \text{Carbon Content}_{(\text{MgC} / \text{TJ})} * 10^{-3}$$

The carbon content of fuels was determined using the Carbon Emission Factors used in the sectoral approach, which are presented in Table 3-139.

<sup>44</sup> Ton of oil equivalent

Table 3-139 – Carbon content of fuels and Oxidation Factor used in the Reference Approach

Fuel			C content	Fa <sub>Cox</sub>
			(t C/TJ)	0 - 1
Liquid Fossil	Primary Fuels	Crude Oil	20.0	0.99
		Orimulsion	22.0	0.99
		Natural Gas Liquids	17.2	
	Secondary Fuels	Gasoline	19.4	0.99
		Jet Kerosene	19.9	0.99
		Other Kerosene	20.0	0.99
		Gas / Diesel Oil	19.9	0.99
		Residual Fuel Oil	20.7	0.99
		LPG	17.7	0.99
		Naphtha	20.0	0.99
		Bitumen	22.0	0.99
		Lubricants	20.0	0.99
		Petroleum Coke	27.5	0.99
		Refinery Feedstocks	20.0	0.99
		Other Oil	20.0	0.99
Solid Fossil	Primary Fuels	Anthracite (a)	26.8	0.98
		Coking Coal	25.8	0.98
		Other Bit. Coal	25.1	0.98
		Sub-bit. Coal	26.2	0.98
		Lignite	27.3	0.98
		Oil Shale	29.1	0.99
		Peat	28.9	0.99
	Secondary Fuels	BKB & Patent Fuel	27.0	0.98
		Coke Oven/Gas Coke	29.5	0.98
Gaseous Fossil		Natural Gas (Dry)	15.3	1.00
Biomass		Solid Biomass	29.9	1.00
		Liquid Biomass	20.0	1.00
		Gas Biomass	30.6	1.00

#### 3.6.2.4 Carbon Stored in Products

For the IPCC Reference Approach, the suggested formula for estimating carbon stored in products for each country is:

$\begin{aligned} \text{Total Carbon Stored (Mg C)} &= \text{Non-Energy Use (toe)} \\ &\times \text{Conversion Factor (TJ/toe)} \\ &\times \text{Emission Factor (t C/TJ)} \\ &\times \text{Fraction Carbon Stored} \end{aligned}$
---

Presently the following products are taken from the National Energy Balance: lubricants, bitumen, and naphtha and residual fuel oils used as raw materials. Original statistical

information was already expressed in toe. Emission factors and the fraction of carbon stored are reported in Table 3-140.

Table 3-140 – Reference Approach. Carbon Emission Factor and Fraction of carbon stored

Fuel	C content	FacOX
	(t C/TJ)	0..1
Naphtha	20.0	0.8
Lubricants	20.0	0.5
Bitumen	22.0	1.0
Fuel Oil	21.1	0.8

### 3.6.3 Actual Carbon Dioxide Emissions

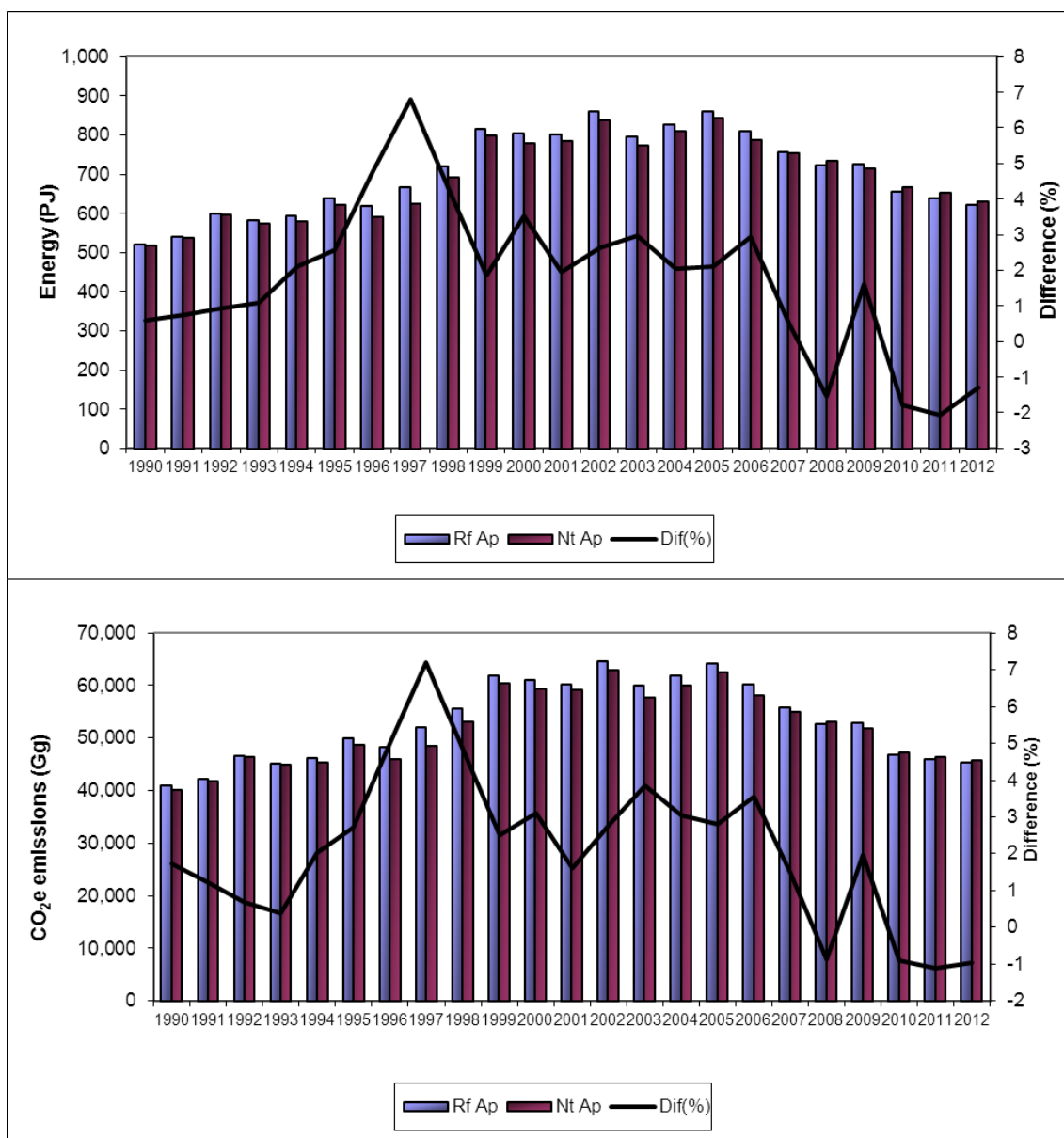
Estimated simply from:

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

### 3.6.4 Results - Comparison of Reference Approach and Sectoral Approach

Detailed data used in the reference approach calculation is reported in CRF tables and is not duplicated in NIR. The emissions estimated according to reference approach and national approach show differences in both energy consumption and carbon emissions, and are presented in Figure 3-92.

Figure 3-92 – Comparison of Energy Consumption and CO<sub>2</sub> emissions between the National approach and the Reference Approach



Differences are mostly explained by the following:

- differences in the Energy Balance and the energy activity data used by the inventory – where data collected directly from emission units (Large Point Sources) play a very representative role – and a different approach to account for emissions from carbon stored in products;
- specific LHV values for LPS are not always considered in the Energy Balance;
- the per cent of feed-stocks which carbon is stored in products are default values and not specific of the national conditions reflected in the inventory;

- the energy balance has been updated in order to follow the IPCC criteria to distinguish between domestic and international fuel use. This improvement contributes to decrease the difference between the reference and the sectoral approach. Portugal is still developing efforts to further improve the split between domestic and international consumption in the energy balance;

The difference between the approaches in terms of CO<sub>2</sub>, has been reduced after 2001, which is coincident with the efforts that were made by DGEG and APA in order to improve consistency between the different approaches. The slight increase in the difference between the two approaches from 2008 to 2009 may be due to the reclassification of lime production and the corrections of double counting for some co-generation power plants. The year 2012 keeps the general downward trend observed since 1997.

### **3.6.5 Feedstock**

Emissions of greenhouse gas emissions from feedstock use are only clearly accounted in the inventory in the following situations:

- emission of CO<sub>2</sub> 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 CO<sub>2</sub> liberated as sub-product in production processes such as ammonia production;
- emission of NMVOC from fossil fuel origin, and occurring from solvent use and evaporation. Although in this case it is not possible to establish which part results from feedstock consumption in Portugal in the energy balance;

However, some potential emissions are not estimated or are only partly estimated. Those that are estimated in the reference approach but not in sectoral approach are:

- emissions from mineral oil use as lubricants;
- emissions from wear of bitumen in roads.

It is evident that more efforts should be made to estimate other emissions from feedstock use, although it is expected that reporting guidelines should give more clear guidance in the future.

## 4 INDUSTRIAL PROCESSES (CRF 2.)

### 4.1 Overview

This source sector includes GHG emissions resulting from the chemical and physical transformation of raw materials in the industrial transformation processes, excluding emissions that result from combustion processes aiming for energy production<sup>45</sup>. According to UNFCCC reporting guidelines, also are included in this sector the emissions of fluorinated compounds (HFC, PFC and SF<sub>6</sub>) 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<sub>x</sub>, NMVOC and SO<sub>x</sub>. Industrial processes are also relevant sources of particulate matter (PM, PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub>) 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 Report<sup>46</sup>.

In terms of total GHG, emissions from the industrial production sector have increased from about 4.8 Mton CO<sub>2</sub>e in 1990 to 5.2 Mton CO<sub>2</sub>e in 2012, as may be seen from the figure below, i.e. emissions estimated for 2012 changed 7.8 percent when compared to emissions estimated for 1990<sup>47</sup>. The majority of emissions, expressed in CO<sub>2</sub>e, are associated with mineral industry, responsible for 72.4 percent of total emissions from this sector in 1990, and 62.9 percent of total emissions from this sector in 2012, as may be seen in Figure 4-2. The remaining sub-source sectors (2B, 2C, 2D and 2F<sup>48</sup>) have a lower importance, contributing to 37.1 percent of total emissions. There is a relevant increase in sub-category 2F, consumption of Halocarbons and SF<sub>6</sub>, which represents in 2012 about 32.9 percent of total GHG emissions from this source sector, and shows a fast grow over years.

<sup>45</sup> 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.

<sup>46</sup> 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>.

<sup>47</sup> Base year for F-gases is however 1995.

<sup>48</sup> No emissions were allocated to sub-category 2G – Other. Emissions for category. Sector 2 F - Production of Halocarbons and SF<sub>6</sub> does not occur in Portugal.

Figure 4-1 – Total GHG emissions from Industrial Processes per source sub-sector

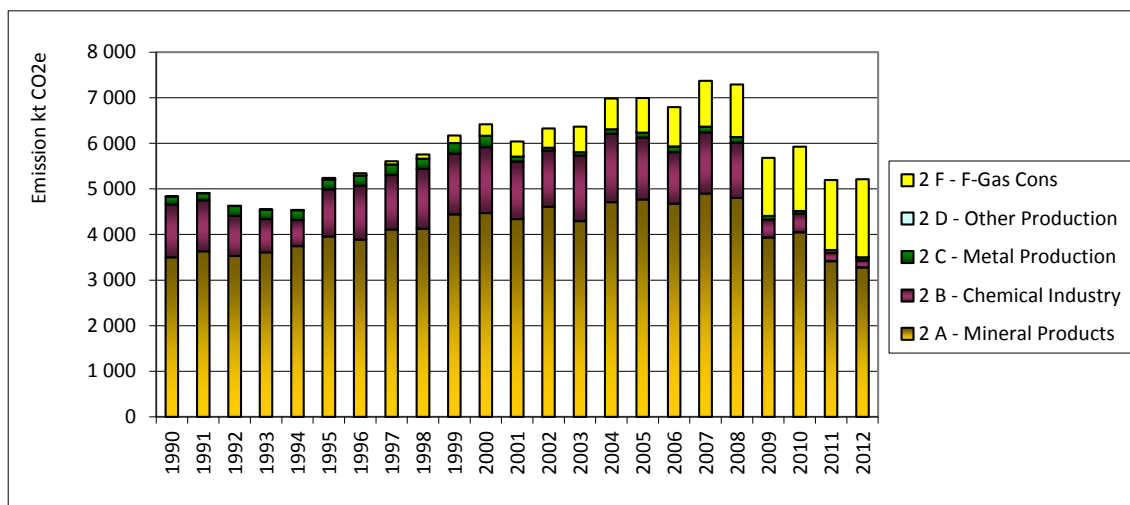
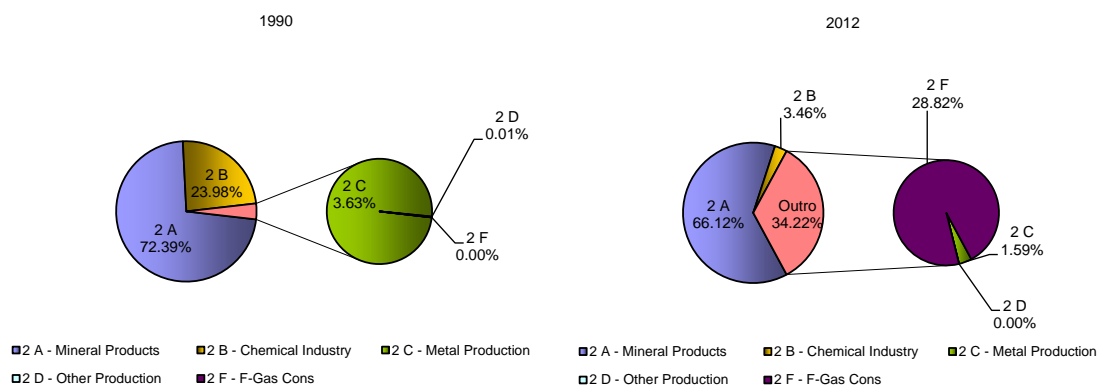


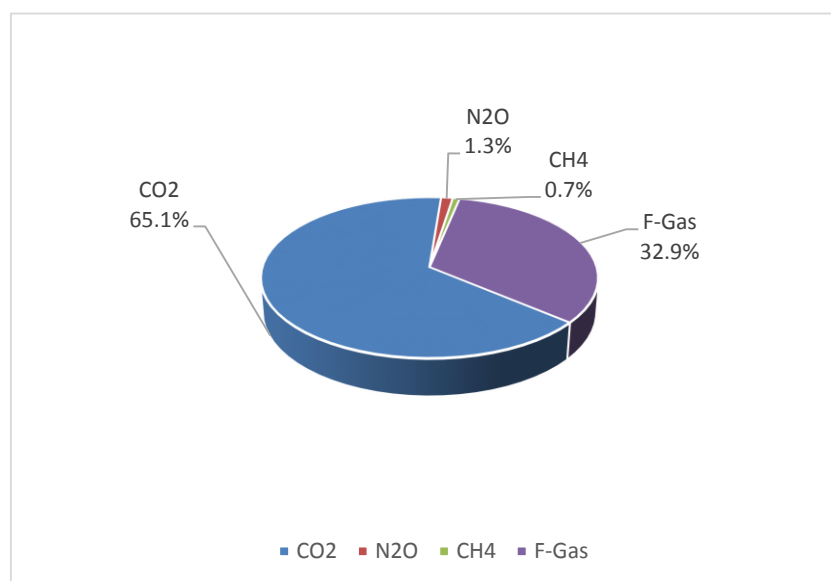
Figure 4-2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2012



The major part of greenhouse gas emissions are released directly as CO<sub>2</sub>; while N<sub>2</sub>O represents a smaller proportion of emissions and methane emissions are a non-relevant part, as may be seen in the figure below for year 2012. Fluoride gases are becoming a relevant source and have already surpassed the relative relevance of nitrous oxide.



Figure 4-3 - GHG emissions from Industrial Processes per greenhouse gas in 2012



## 4.2 Recalculations

Detailed explanation of the recalculations made will be presented for each category.

Figure 4-4 - Differences between 2013 and 2014 submissions for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions

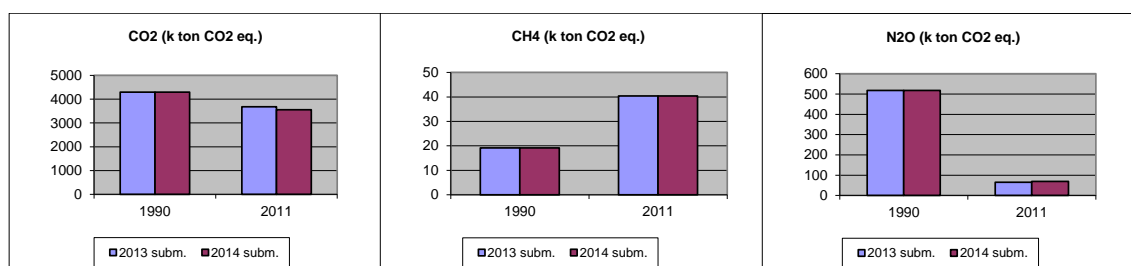


Table 4-1 - Recalculations (differences between 2013 and 2014 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2013 subm.	2014 subm.	Difference (1)	2013 subm.	2014 subm.	Difference (1)	2013 subm.	2014 subm.	Difference (1)
	CO <sub>2</sub> equivalent (Gg)	CO <sub>2</sub> equivalent (Gg)	(%)	CO <sub>2</sub> equivalent (Gg)	CO <sub>2</sub> equivalent (Gg)	(%)	CO <sub>2</sub> equivalent (Gg)	CO <sub>2</sub> equivalent (Gg)	(%)
<b>1990</b>									
<b>2. Industrial Processes</b>	<b>4 296.59</b>	<b>4 296.59</b>	<b>0.00</b>	<b>19.19</b>	<b>19.19</b>	<b>0.00</b>	<b>517.92</b>	<b>517.92</b>	<b>0.00</b>
2.A. Mineral Products	3 493.38	3 493.38	0.00	5.73	5.73	0.00	NO	NO	
2.B. Chemical Industry	632.69	632.69	0.00	8.32	8.32	0.00	517.92	517.92	0.00
2.C. Metal Production	170.08	170.08	0.00	5.15	5.15	0.00	NO	NO	
2.D. Other Production	0.44	0.44	0.00						
2.G. Other	NO	NO		NO	NO		NO	NO	
<b>2011</b>									
<b>2. Industrial Processes</b>	<b>3 684.38</b>	<b>3 553.01</b>	<b>-3.57</b>	<b>40.38</b>	<b>40.37</b>	<b>-0.01</b>	<b>64.81</b>	<b>69.32</b>	<b>6.97</b>
2.A. Mineral Products	3 503.39	3 396.49	-3.05	16.71	16.70	-0.04	NO	NO	
2.B. Chemical Industry	109.05	106.38	-2.45	10.50	10.50	0.00	64.81	69.32	6.97
2.C. Metal Production	71.70	49.88	-30.44	13.18	13.18	0.00	NO	NO	
2.D. Other Production	0.24	0.27	10.28						
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).

## 4.3 Category Sources

### 4.3.1 Mineral Industry (CRF 2.A.)

#### 4.3.1.1 Cement Production (CRF 2.A.1.)

##### 4.3.1.1.1 Overview

During the 1990-2012 period there were six cement production plants operating in Portugal, mostly dedicated to Portland cement production<sup>49</sup> 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-calciners<sup>50</sup>.

Carbon dioxide emissions from cement production process result from the conversion of  $\text{CaCO}_3$  and  $\text{MgCO}_3$ , the main constituents of limestone, to lime ( $\text{CaO}$ ) and  $\text{MgO}$ , while leaving  $\text{CO}_2$  as by product to atmosphere (Decarbonization).

Only emissions of  $\text{CO}_2$  from limestone decarbonizing 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.  $\text{CO}_2$  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.

##### 4.3.1.1.2 Methodology

EU-ETS method A from number 9 of Annex IV of Regulation (EU) No. 601/2012 is used from 2005 onwards. Calculation is based on the raw meal characterization (Tier 3). It is assumed a complete calcination (conversion factor = 1).

Emissions of carbon dioxide resulting from carbon in raw meal are determined according to the following equation:

$$\text{Emi}_{\text{CO}_2} = \text{Raw meal} * \text{EF} * \text{CF}$$

Where

$\text{Emi}_{\text{CO}_2}$  – emissions of  $\text{CO}_2$  from cement production, originated from carbon in raw meal (kton/yr);

Raw meal – Net amount of relevant kiln input (ton/yr);

EF – emission factor (kton  $\text{CO}_2$ /ton of raw meal);

CF – Conversion factor (0 to 1).

<sup>49</sup> 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 but that do not produce clinker.

<sup>50</sup> One calciner is a false pre-calciner.

We estimated plant specific carbon content (ton CO<sub>2</sub>/ton raw meal) based on CO<sub>2</sub> reported under ETS and plant specific raw meal consumption from 2005 onwards. For the period 1990-2004 we made a back cast based on plant specific raw meal consumption and on plant specific average carbon content for the period 2005-2009.

#### 4.3.1.1.3 Emission Factors

From 2005 onwards we have used raw meal carbon content characterization to estimate CO<sub>2</sub> emissions based on raw meal consumption in the kilns.

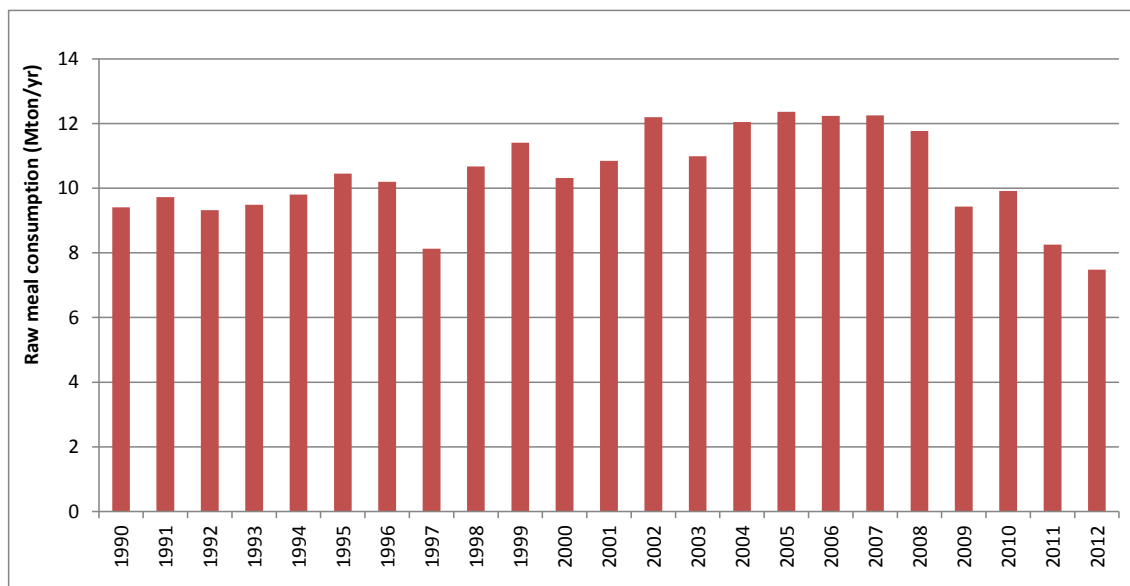
Detail	Unit	1990-2004	2005	2006	2007	2008	2009	2010	2011	2012
Average Carbon content	t CO <sub>2</sub> /t raw meal	0.341	0.341	0.340	0.340	0.341	0.342	0.341	0.341	0.341

We estimated plant specific carbon content (ton CO<sub>2</sub>/ton raw meal) based on CO<sub>2</sub> reported under ETS and plant specific raw meal consumption from 2005 onwards. For the period 1990-2004 we made a back cast based on plant specific raw meal consumption and on plant specific average carbon content for the period 2005-2009.

#### 4.3.1.1.4 Activity Data

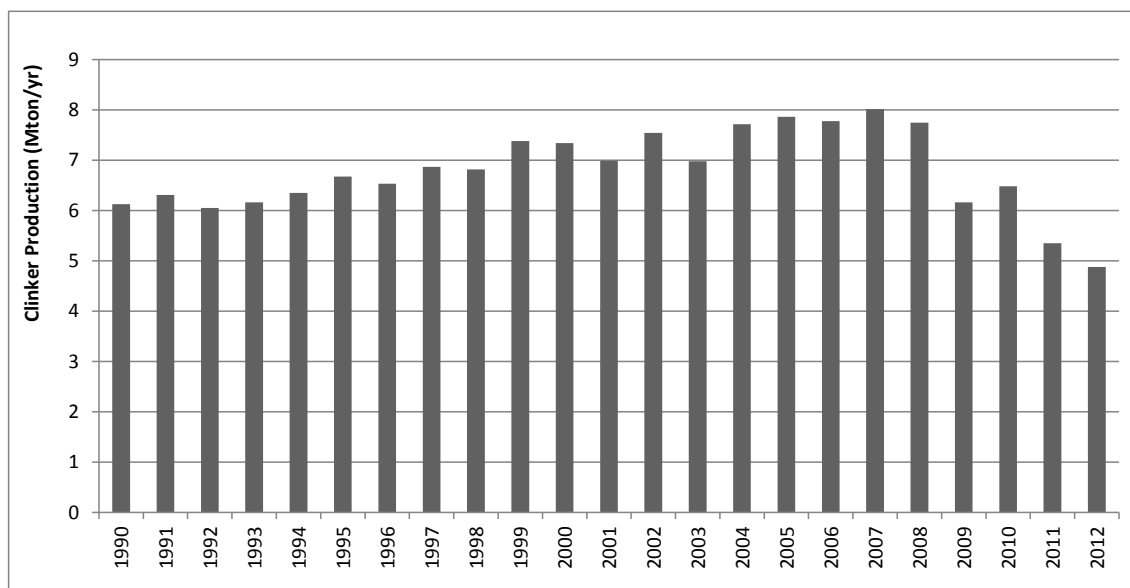
EU-ETS data on raw meal consumption is used from 2005 onwards. From 1990-2004, raw meal consumption was obtained directly from the plants.

Figure 4-5 – Raw meal consumption in Portugal



Clinker production was received directly from each industrial plant, and the correspondent time series may be observed in next figure.

Figure 4-6 – Total Production of cement clinker in Portugal



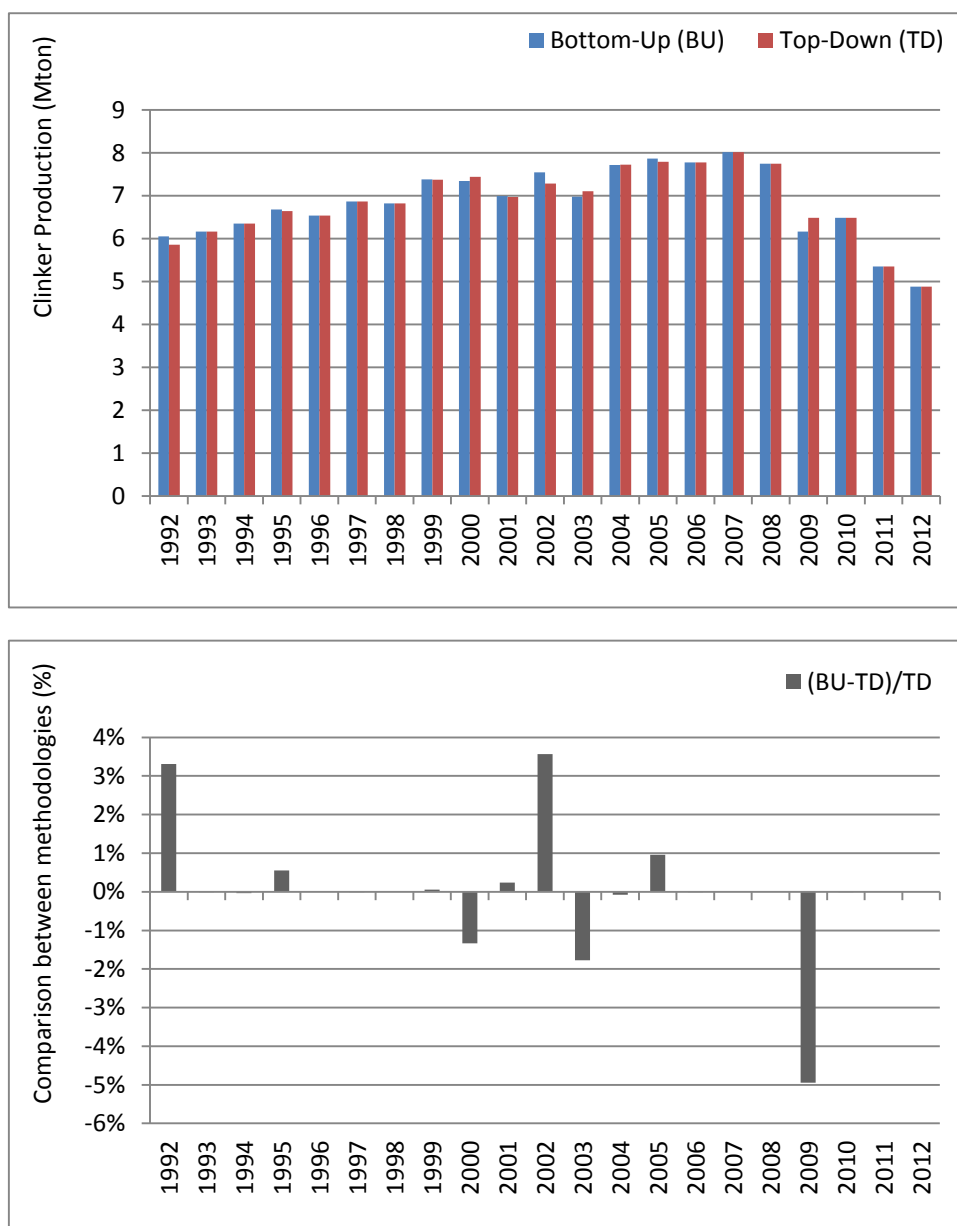
Data trends for clinker production show a general decrease in the late years. The reduction from 2011 to 2012 was 0.47 Mton. This decrease is due to a demand decrease in Portugal, Spain and North Africa market.

#### 4.3.1.1.5 Uncertainty assessment

The uncertainty value of the emission factor was determined to be 10 percent for all years which results from the consideration of uncertainty error in the assumption that all CaO is from CaCO<sub>3</sub>, CaO content of clinker and CKD parameter. In all cases the maximum values of uncertainty in the GP (IPCC, 2000) was considered using a conservative approach. In a similar conservative mode the uncertainty associated with activity data was set at 2 percent.

#### 4.3.1.1.6 Category-specific QA/QC and verification

Emissions estimates were based on a bottom-up approach with collection of plant specific clinker production data. A comparison was made using a top-down approach based on clinker production data obtained from national production statistics (IAP) from 1992 onwards. There are slight differences using the two different approaches, but, generally, data is consistent.



#### 4.3.1.1.7 Recalculations

No recalculations were made.

#### 4.3.1.1.8 Further Improvements

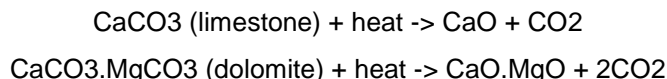
There are no further improvements planned for this sector.

### 4.3.1.2 Lime Production (CRF 2.A.2.)

#### 4.3.1.2.1 Overview

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200°C) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving

calcium oxide (CaO) or magnesium oxide (MgO) as valuable products. The following chemical conversion equation applies, where for each mol of oxide a mol of carbon dioxide is emitted.



Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy  $\text{CaCO}_3$  content (at least 50 percent) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of  $\text{Na}_2\text{CO}_3$ , NaOH, steel, refractory material,  $\text{SO}_2$  absorption,  $\text{CaC}_2$ , glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;
- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45 percent in content). Dolomite quicklime is a mixture of CaO and MgO;
- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime:  $\text{Ca}(\text{OH})_2$ . 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  $\text{Ca}(\text{OH})_2$  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  $\text{CaCO}_3$  (Sharp, 1981);
- Hydraulic Lime. A mixture of calcium oxide (CaO) and silicates, it is an intermediate product between lime and cement.

Besides the production of lime in the lime industry to furnish market requirements, lime is also produced and consumed inside industrial sectors. That is the case of the production of lime in Kraft paper pulp plants, where quicklime is produced from carbonates in lime kilns and it is used to regenerate green liquor to white liquor. That is also the case of iron and steel production whereas emissions from this activity are also reported in this source category.

#### 4.3.1.2.2 Methodology

EU-ETS method A from Annex VIII of Decision 2007/589/EC is used from 2005 onwards. Calculation is based on the amount of calcium carbonate and magnesium carbonate in the raw materials consumed (Tier 3).

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to the following equation:

$$\text{Emi}_{\text{CO}_2} = \text{Kiln input} * \text{EF} * \text{CF}$$

Where

$\text{Emi}_{\text{CO}_2}$  – emissions of  $\text{CO}_2$  from lime production, originated from carbon in kiln input materials (kton/yr);

Kiln input – Net amount of relevant kiln input (ton/yr);

EF – emission factor (kton CO<sub>2</sub>/ton of each relevant kiln input);

CF – Conversion factor (0 to 1).

For the period 1990-2004, emissions were estimated based on lime production time series.

We estimated a national IEF (ton CO<sub>2</sub>/ton lime) based on ETS CO<sub>2</sub> data in year 2005 and on national statistics lime production data in the same year. For the period 1990-2004 we made a back cast based on national statistics lime production data and on the national IEF for the year 2005.

#### 4.3.1.2.3 Emission Factors

The CO<sub>2</sub> emission factors were estimated by converting kiln input materials composition data, using the following stoichiometric ratios (Table 1 of Annex VIII of Decision 2007/589/EC):

Substance	Unit	Stoichiometric ratios
CaCO <sub>3</sub>	t CO <sub>2</sub> /t CaCO <sub>3</sub>	0.440
MgCO <sub>3</sub>	t CO <sub>2</sub> /t MgCO <sub>3</sub>	0.522

#### 4.3.1.2.4 Activity Data

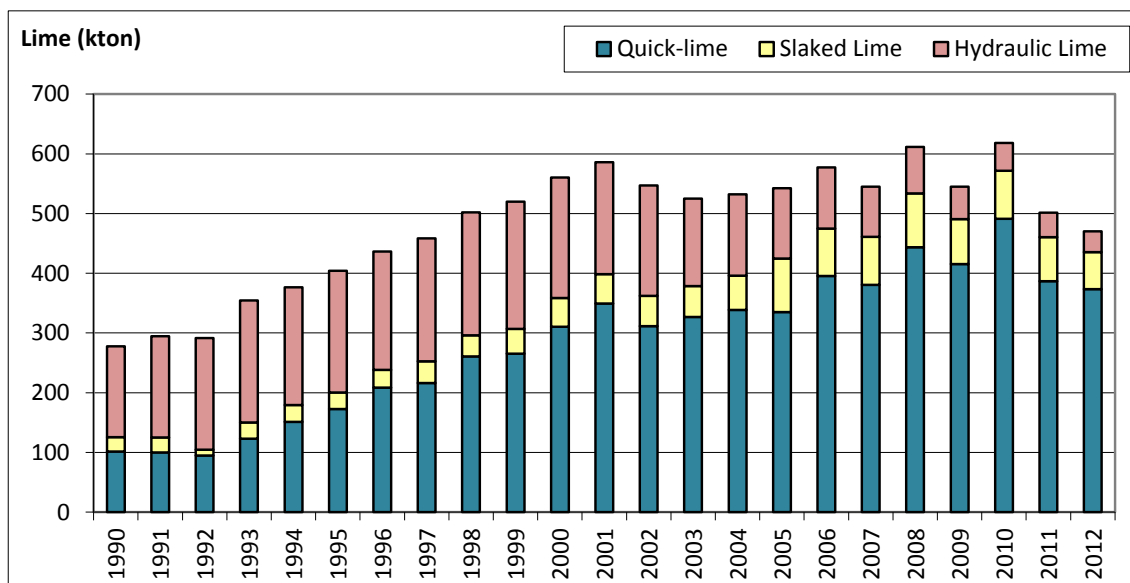
From 2005 onwards, data on consumption of raw materials was obtained from EU-ETS. Lime production was obtained from National Statistics (INE) IAPI industrial survey for 1990-2012 period.

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 annual lime production, for which data was unavailable, was forecasted using energy consumption as surrogate indicator. After year 2002 production of lime in this unit was interrupted and the production line dismantled. All lime produced in the iron and steel plant was high calcium lime.

In 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 that 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 from 1992 onwards from the IAPI industrial survey.

The Lime production values in 2012 are 1.7 times larger than in 1990. Quicklime production has more than doubled in the period.

Figure 4-7 – Production of lime in Portugal per lime type



#### 4.3.1.2.5 Uncertainty assessment

According to the GP the uncertainty associated with the carbon dioxide emission factor for lime production is 15 percent for hydraulic lime and 2 percent for all other lime types (IPCC, 2000). The resultant uncertainty value according to the share of each lime type in Portugal was set at about 8.5 percent.

The GP assumes that uncertainty in activity data is very high due to problems in gathering lime data. The national inventory recognizes that this is in fact the case for Portugal, particularly because in some situations lime is not produced for market but for internal consumption in the industrial plant, and may be not properly reported in statistical surveys. The maximum uncertainty value of 105 percent was therefore used in the uncertainty analysis.

#### 4.3.1.2.6 Recalculations

Revision of National Statistics (IAPI industrial survey) for the period 2011-2012.

#### 4.3.1.2.7 Further Improvements

There is still some possibility that the inventory is doubling the estimate of CO<sub>2</sub> emissions, if part of the quicklime that is produced in an industrial unit is sold and used again to produce slaked lime or hydraulic lime in a different industrial plant. To correct this effect, emissions estimated from lime production should be cross checked with emission estimates from limestone and dolomite consumption. Another contribution factor to over-estimation of emissions is the possible use of calcium materials to other used than lime<sup>51</sup> production in the paper pulp industry.

A better and detailed knowledge of the proportion of lime that is high calcium lime and which is dolomite lime should be achieved – however this separation cannot be done from National Statistical Databases except in the case of the paper pulp industry - allowing this differentiation to be used in activity data and not in emission factor as it was done in this submission.

<sup>51</sup> Or any other process not resulting in decarbonization.



#### 4.3.1.3 *Limestone, Dolomite and Carbonate Use (CRF 2.A.3.)*

##### 4.3.1.3.1 Overview

Carbon dioxide liberation to atmosphere occurs from several industrial activities that use limestone ( $\text{CaCO}_3$ ), 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,  $\text{CO}_2$  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. Use of carbonate materials in iron and steel industry are reported in source category 2A3. 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 fibers, and all food and beverage industry.

Lime production involves as well the consumption and decarbonizing of carbonate materials, limestone or dolomite rock. Carbon dioxide emissions from lime production are reported in source category 2A2 and were already discussed.

The use of lime in the wet flue gas desulfurization in Large Point Source (LPS) energy plants is reported under source category 2A3 but the methodology is described in source category 1A1a.

Non- $\text{CO}_2$  process emissions in the paper pulp and fertilizer industry are reported in other source categories, respectively 2B and 2C. Combustion emissions from these industrial activities are reported in source category 1A2.

##### 4.3.1.3.2 Methodology

$\text{CO}_2$  emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of  $\text{CO}_2$  that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

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

where

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

$\text{Mat}_{\text{Carb} (m,y)}$  - consumption of carbonate containing material m in year y (ton/yr);

$\text{C}_{\text{content} (m)}$  - carbon content of material m consumed in year y (ton C/ton).

#### 4.3.1.3.3 Emission Factors

Carbon content of materials consumed in Portugal was set from molecular stoichiometry<sup>52</sup>:

Table 4-2 - Carbon content of carbonate materials

Material	Ccontent
Sodium Carbonate	0.42
Barium Carbonate	0.22
Limestone*	0.44
Dolomite #	0.48
Magnesium Carbonate	0.52
Coal (Electrodes) to be removed	3.67

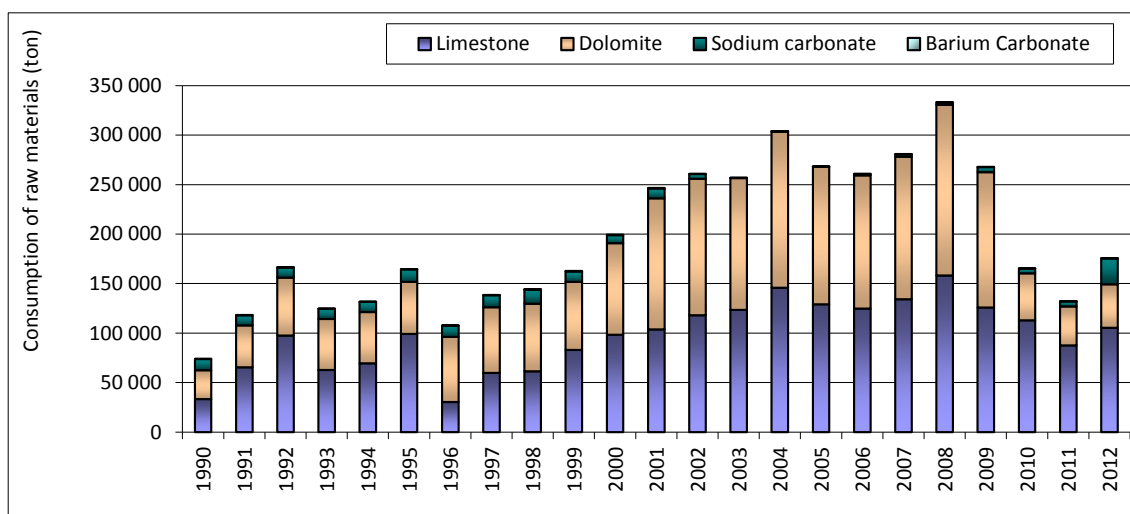
\* assumed pure calcium carbonate;# Ca and Mg carbonate in equal share

#### 4.3.1.3.4 Activity Data

The consumption of sodium carbonate in the paper and pulp industry was determined from the statistical information from INE from 1990 to 2012. 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  $\text{CaCO}_3$  or  $\text{MgCO}_3$ . Fertilizer production data was also available from INE database from 1990 to 2012. Final total consumption of carbonaceous materials is presented in the figure below. The ceramic industry, more particularly the brick and tile industry and the pavement industry, consumes limestone, dolomite and the carbonates of sodium and barium, and all these substances were considered to result in decarbonization. For this industry sector, although the consumption of carbonate bearing materials is not known for the whole period, a consumption factor was developed based on the information received under the European Emission Trading Scheme (EU-ETS), and production of construction ceramics and pavement ceramics, which is available from INE's industry surveys IAIT and IAPI, was used to obtain the full time series. In 2010 there is a strong decrease in limestone and dolomite consumption related to a decrease in calcium nitrate production.

<sup>52</sup> It was assumed that limestone was totally pure, which causes over-estimated emissions.

Figure 4-8 - Consumption of carbonate materials in industry



#### 4.3.1.3.5 Uncertainty Assessment

There are no proposed values in GPG for the consideration of uncertainty values for CO<sub>2</sub> emission factor from consumption of carbonate materials. The same uncertainty values that are proposed for lime production (non hydrated lime) were therefore assumed (2 percent), considering that the conversion is only a stoichiometric mass balance and that error results only from uncertainty in Calcium and Magnesium content of raw materials. The uncertainty value of activity data, also not referred to in GPG, was assumed also equal to the uncertainty set for lime production.

#### 4.3.1.3.6 Recalculations

Data on fertilizer production has been revised from 2010 onwards. This revision led to carbonate consumption values revision related to fertilizer production.

#### 4.3.1.3.7 Further Improvements

More efforts to obtain necessary statistical information or alternative methodologies will be envisaged to estimate emissions from emissions from carbonate use in the production of synthetic fertilizers (nitrates of calcium and magnesium and ammonium nitrate with calcium and magnesium).

### 4.3.1.4 Soda Ash Production and Use (CRF 2.A.4.)

#### 4.3.1.4.1 Soda Ash Production

In Portugal there is only one plant producing Soda Ash by the Solvay process. CO<sub>2</sub> is generated in two pyrolysis processes, captured, compressed and directed to Solvay precipitating towers for consumption in a mixture of brine (aqueous NaCl) and ammonia. Although CO<sub>2</sub> is generated as a by-product, it is recovered and recycled for use in the carbonation stage and in theory the process is neutral, i.e., generation of CO<sub>2</sub> equals uptake.

#### 4.3.1.4.2 Soda Ash Use

Soda Ash ( $\text{Na}_2\text{CO}_3$ ) is consumed as a raw material in the Glass Production (CRF 2.A.7.).

#### 4.3.1.5 *Road Paving with Asphalt (CRF 2.A.6.)*

##### 4.3.1.5.1 Overview

Emission estimates reported in this source category include emissions occurring from paving road surfaces with asphalt materials as well as emissions occurring during operation of hot mix asphalt plants. Emissions from production of asphalt emulsions and cold asphalt mixtures are not included in the inventory estimates, being assumed that they are negligible.

Roads pavement with asphalt is done by the application of several layers over road bed. In volume, the majority of pavement is composed of layers of a compact aggregate and an asphalt binder (asphalt concrete). Asphalt concretes are classified either as hotmix or as coldmixes: cutback and emulsified asphalts. Liquefied asphalts – cutbacks and emulsions - are also used directly in seal and priming roadbed operations, sometimes in intermediate layers between applications of asphalt cement layers. Aggregate materials incorporated in asphalt concrete are usually composed of coarse unconsolidated rock fragments, either obtained from rock crushing, natural alluvial deposits or by products from metal ore refining.

Hot mix asphalts are made by mixing the aggregate material together with the asphalt cement using high temperatures ( $150^\circ\text{--}160^\circ$ )<sup>53</sup>. Cold mix plants also involve mixing aggregate materials with an asphalt binder, but now the binder is an asphalt emulsion or is cutback cement, and this process takes place at much lower temperature ( $40\text{--}60^\circ$ ).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers<sup>54</sup>. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphtha (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12 percent of solvents. Hot mix asphalts in the other hand, result in minimum NMVOC emissions during application, because the organic component has high molecular weight and low vapour pressure (USEPA, 2001 – EIIP Volume III Chapter 17).

Asphalt pavements dominate road paving activity in Portugal, whereas rigid cement pavements are only about 5 percent of total paved areas (APORBET).

Emissions during fabrication of asphalt concretes are estimated only for hot mix asphalt and comprehend NMVOC and Particulate Material that escape mostly from the drier. Other pollutants are also emitted but they result mostly from combustion of fuels and are considered in

<sup>53</sup> That are needed to fluidize the asphalt cement.

<sup>54</sup> And also a solvent in several emulsion types.

chapter Energy (1A2)<sup>55</sup>. Emission estimates for hot-mix are only made here for pollutants NMVOC and PM, while emission of other pollutants are covered in emission estimates made for Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity<sup>56</sup>.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible<sup>57</sup>.

It was still not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation or asphalt roofing, and therefore all emissions from production of asphalts – except emissions from fuel combustion – are included in this source category.

#### 4.3.1.5.2 Methodology

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100 percent composed of VOC (USEPA, 2001) and that emitted VOC have on average 85 percent of carbon<sup>58</sup>:

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

Different methodologies were used to estimate emissions of NMVOC during asphalt application or from asphalt production.

##### 4.3.1.5.2.1 Application of Asphalt Concretes and Liquefied Asphalts

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA, 1997; USEPA, 2001):

$$Emi_{NMVOC(y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Emi_{NMVOC(y)}$  - Emissions of NMVOC from asphalt application during year y (ton/yr);

<sup>55</sup> To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

<sup>56</sup> It is not possible to distinguish fuel combustion in hot mix production activity.

<sup>57</sup> 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.

<sup>58</sup> Normal carbon content for medium linear simple hydrocarbons.

Binder (y) – Total quantity of asphalt binder used in road paving during year y (ton/yr);

SLV<sub>Fac</sub> - Fraction of distillate (solvent) in asphalt (m<sup>3</sup>/m<sup>3</sup>);

d<sub>SLV</sub> - density of solvent added to liquefied asphalt (kg/l);

d<sub>BIN</sub> - density of bitumen binder mixture (kg/l);

Cure<sub>FC</sub> - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

#### 4.3.1.5.2.2 Hot Mix Asphalt Production

For calculation of hot mix production emissions, emission calculation is based on total product:

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

Where,

Emi<sub>(p,y)</sub> – Total emissions for pollutant p occurring in year y from Hot mix asphalt production (ton);

Hotmix<sub>Batch(y)</sub> and Hotmix<sub>Drum(y)</sub> – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

EF<sub>(p)</sub> and EF<sub>(p)</sub> – 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, which would be under-estimated if they would be estimated solely from fuel combustion. Particulate matter is enhanced by manipulation of aggregate materials and some NMVOC result not from incomplete combustion of fuel but also from partial evaporation of bitumen components.

#### 4.3.1.5.3 Emission Factors and Parameters

The following parameters were chosen to determine emission factors for application of emulsified and cutback asphalts. These values were chosen according to recommendations in AP-42, EMEP/CORINAIR or industrial expert guess.

Table 4-3 - Emission Parameters for road paving with asphalt

Parameter	Cutback	Emulsions
SLV <sub>Fac</sub>	25 %	3 %
d <sub>SLV</sub>	0.95 kg/l	0.85 kg/l
d <sub>Bin</sub>	0.95 kg/l	0.85 kg/l
Cure type	Medium Cure (MC)	-
Cure <sub>FC</sub>	0.75 kg/kg	1 kg/kg

Emission factors used to estimate NMVOC and PM emissions from hot mix plants are from USEPA (2000) and are presented in next table.

Table 4-4 - Emission Parameters for Hot Mix asphalt production

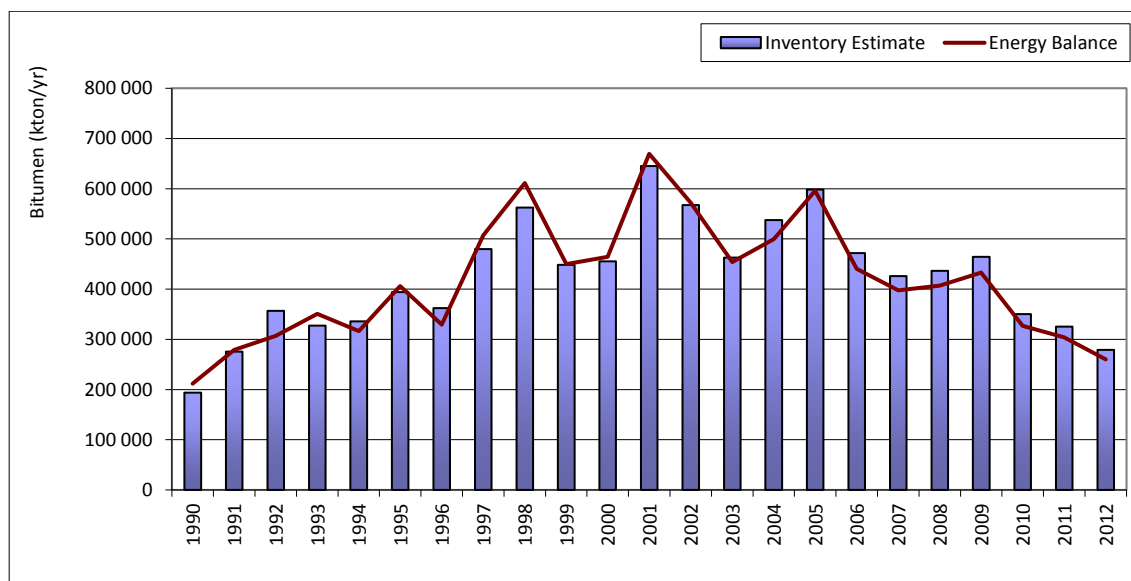
Pollutant	Continuous	Batch	Unit EF
NMVOC	32.0	22.1	g/ton
CH <sub>4</sub>	12.0	7.4	g/ton

Source: USEPA (2000)

#### 4.3.1.5.4 Activity Data

The total quantity of bitumen sold to construction and building economic sector is available from the Energy Balance and was collected by the General Directorate of Energy and Geology (DGEG) based on surveys<sup>59</sup>, and it is presented in the figure below. Although this time series was not used in the inventory, it is nevertheless used for the verification that the estimates made for each asphalt materials, which are subsequently explained, are coherent with total sale statistics.

Figure 4-9 - Total consumption of bitumen in the construction sector according to sales from DGEG Energy Balance and sum of values of asphalt used according to the inventory



Cutback asphalt is seldom used in Portugal and it is sold only by two companies, according to information gathered at APORBET, the Portuguese Association of Producers of Bitumen Materials. Annual sales were assumed equal to annual consumption and may be seen in the table below and in the figure above. Total emulsions applied are available from EAPA for 1997 and beyond. For previous years, use of emulsions was estimated from the total quantity of asphalt materials applied as road pavement, also from EAPA, and considering a percentage of that bitumen that is emulsions. It was also assumed that this percentage was zero in 1990 and has increased to 19 percent in 1996. From 1991 onwards, data on hot mix concrete asphalt

<sup>59</sup> Original data from DGEG is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGEG

production is obtained from EAPA. Bitumen in hot mix asphalt was estimated considering that it equals 5 percent of hot mix asphalt. Although this last figure is not necessary for the inventory it was nevertheless estimated in order to verify if total bitumen sales, from DGEG, match the sum of individual estimates. Total production of hot mix concrete asphalts is presented in the figure below.

Table 4-5 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (ton)

Asphalt	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cutback	ton	4 100	3 500	2 700	3 100	2 600	676	407	1 232	933	162	576	824
Emulsified	ton	0	10 567	21 133	36 576	49 852	65 025	100 517	110 000	130 000	95 000	86 000	107 000

Asphalt	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cutback	ton	501	340	0	0	0	0	0	0	0	0	0
Emulsified	ton	116 000	112 665	93 600	65 000	40 500	36 556	37 441	39 824	30 049	27 934	23 934

Figure 4-10 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal

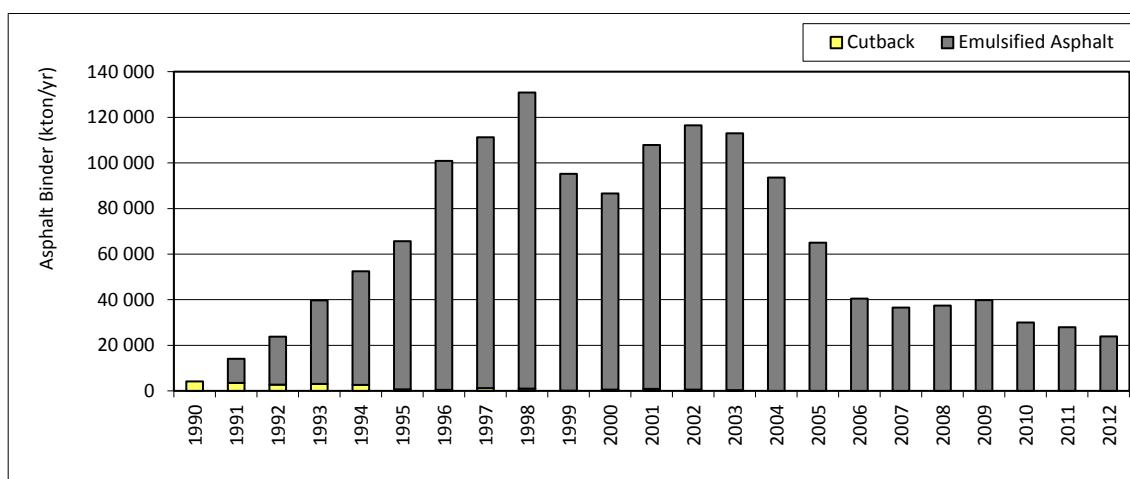
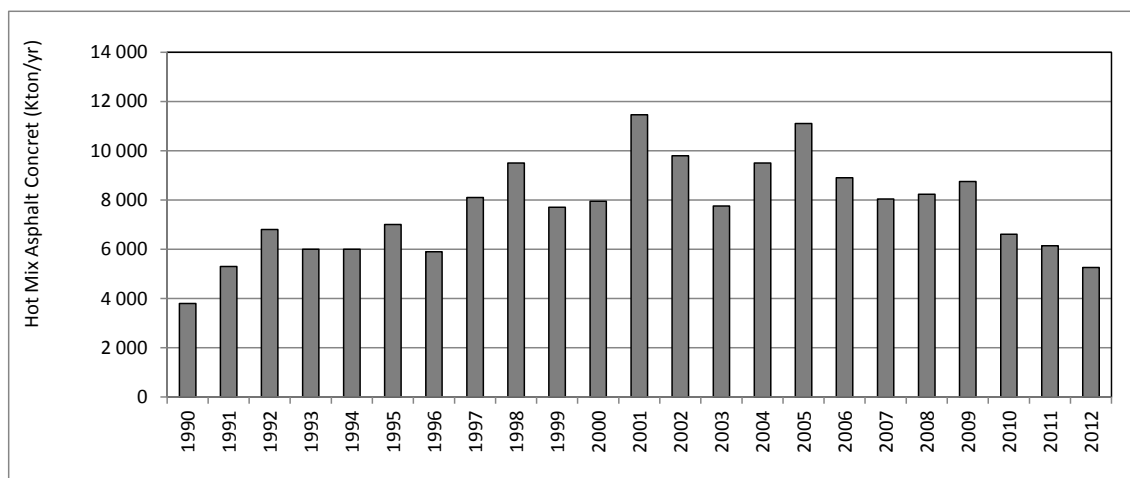




Figure 4-11 – Total Production of Hot Mix Asphalt



Emissions of Hot Mix Production depend if the equipment is batch or continuous. Desegregation of Hot Mix production per equipment was done assuming a constant proportion of 46 percent continuous equipment and 54 percent batch, which is an expert guess (PTEN, 2002).

#### 4.3.1.5.5 Uncertainty Assessment

There is no specific information in the GPG concerning uncertainty values for this source sector. Uncertainty in activity data was estimated as the maximum difference between the total bitumen quantities estimated by the inventory and reported in the DGGE energy balance: 14 percent.

The uncertainty in the emission factor for NMVOC/CO<sub>2</sub> is higher and mostly associated with the uncertainty in the share of asphalt that is applied as cut-back, emulsion of as hot mix. Because of the very variable emission factor according to which asphalt type is being considered two orders of magnitude was considered for the uncertainty value of the emission factors for NMVOC and CO<sub>2</sub>.

#### 4.3.1.5.6 Recalculations

Correction of a small error in the disaggregation of hot mix asphalt emissions between Drum Mix and Batch Plants.

#### 4.3.1.5.7 Further Improvements

It was still however not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation and asphalt roofing. Improvements in this separation are expected in following submissions.

### 4.3.1.6 Glass Production (CRF 2.A.7.)

#### 4.3.1.6.1 Overview

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. It is made submitting these materials to a high temperature which are thereafter made solid without crystallization (semi-solid state).

Glass involves carbon dioxide emissions, from decarbonizing 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 here<sup>60</sup>.

#### 4.3.1.6.2 Methodology

From 2005 onwards, carbon dioxide emissions from glass production were estimated from:

$$\text{Emission}_{\text{CO}_2(t,y)} = \text{EF}_{\text{CO}_2(t)} * \text{Carbonate}_{(t,y)}$$

where

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

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

$\text{EF}_{\text{CO}_2(t)}$  - emission factor from consumption of carbonate t (ton CO<sub>2</sub>/ton carbonate)

In the period 1990-2004, emissions were estimated assuming the same ratio between CO<sub>2</sub> emissions and the production of each type of glass (flat, container and crystal) verified in year 2005 multiplied by the production verified in each year and divided by the production of glass verified in 2005.

#### 4.3.1.6.3 Emission Factors

The following emission factors from Annex IX of Directive 2003/87/EC were considered.

Table 4-6 – Stoichiometric CO<sub>2</sub> Emission Factors for each carbonate

Carbonate	EF	Unit EF
CaCO <sub>3</sub>	0.440	t CO <sub>2</sub> /t carbonate
MgCO <sub>3</sub>	0.522	t CO <sub>2</sub> /t carbonate
Na <sub>2</sub> CO <sub>3</sub>	0.415	t CO <sub>2</sub> /t carbonate
BaCO <sub>3</sub>	0.223	t CO <sub>2</sub> /t carbonate
Li <sub>2</sub> CO <sub>3</sub>	0.596	t CO <sub>2</sub> /t carbonate
K <sub>2</sub> CO <sub>3</sub>	0.318	t CO <sub>2</sub> /t carbonate
NaHCO <sub>3</sub>	0.524	t CO <sub>2</sub> /t carbonate
X <sub>Y</sub> (CO <sub>3</sub> ) <sub>Z</sub>	var	t CO <sub>2</sub> /t carbonate

<sup>60</sup> They were not used to derive the country specific emission factors for instance.

#### 4.3.1.6.4 Activity Data

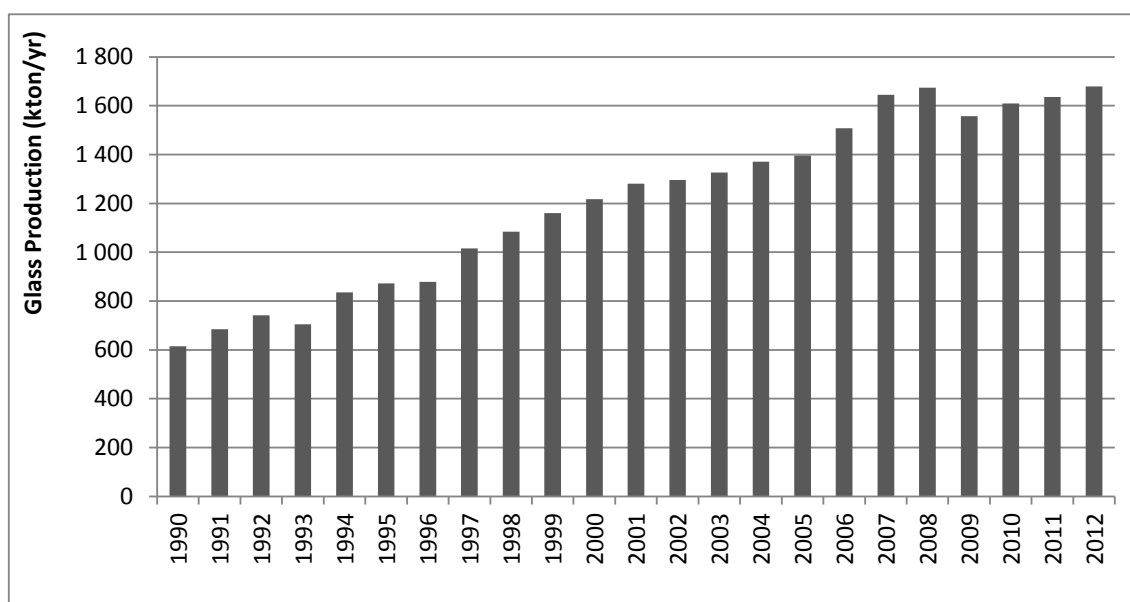
We don't use data from INE because not all products are reported in weight, but instead are measured in area-units ( $m^2$ ) or number of produced pieces.

Data on container glass production was obtained from AIVCERV/CTCV (Container Glass National Association).

Flat Glass production data was obtained from the only industrial unit in Portugal. From 2009 onwards there is no Flat Glass production in Portugal.

Crystal Glass production data was obtained from AIC (Crystal Glass National Association).

Figure 4-12 - Glass production

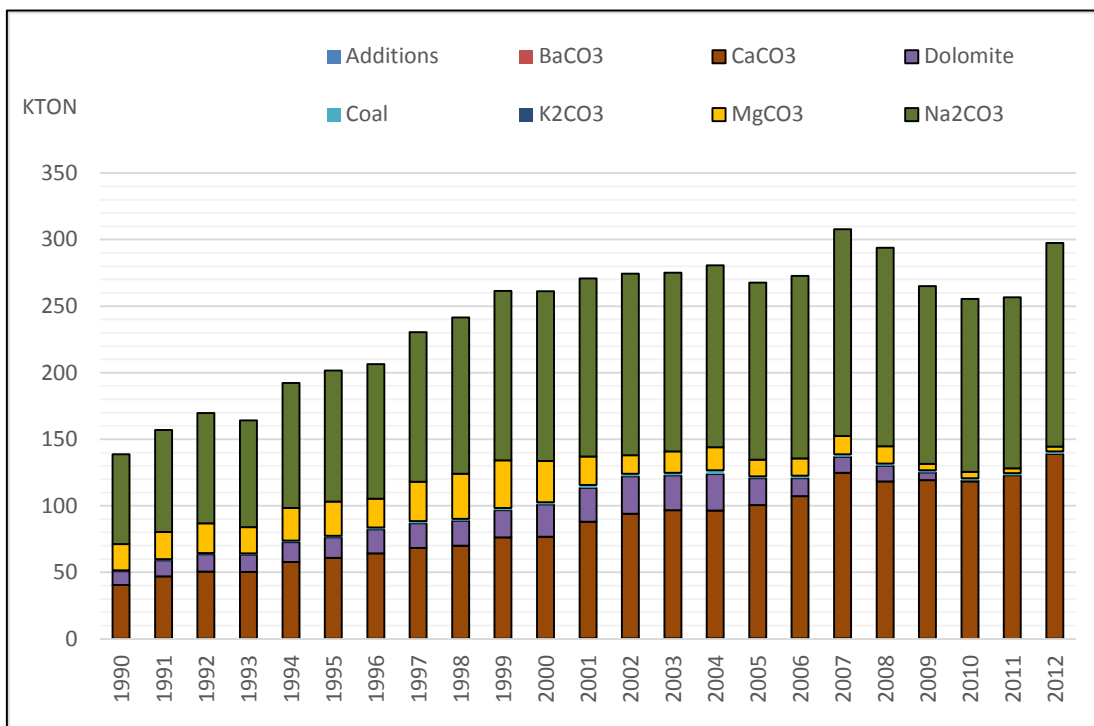


Due to confidentiality constraints concerning flat glass data (there was only one facility in Portugal until 2009), we don't present glass production data by glass type.

From 2005 onwards it is used ETS data on  $Na_2CO_3$ ,  $MgCO_3$ ,  $CaCO_3$ ,  $BaCO_3$ , coal and other carbonate raw materials consumption in the kilns. For flat glass and container glass the facilities that report data under ETS correspond to the national total. For crystal glass it is used the ETS data from the largest facility that reports data under ETS and extrapolate for the remaining crystal glass facilities based on crystal glass production. Stoichiometric  $CO_2$  emission factors for each carbonate from the Annex IX of Directive 2003/87/EC are used. Glass production data by type of glass (flat, container, crystal) is used to estimate emissions on the period 1990-2004, since there is no detailed data on carbonate raw material consumption from ETS in that period.

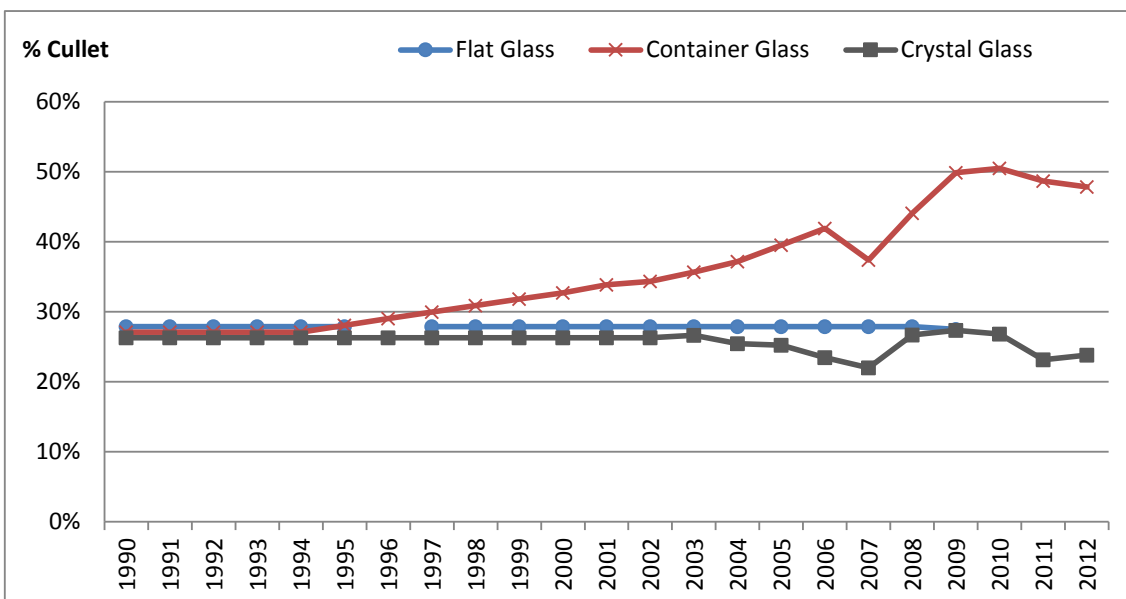
Raw materials consumption could be checked in the next figure.

Figure 4-13 – Raw materials consumption



Cullet incorporation ratio could be checked in the next figure.

Figure 4-14 - % of Cullet incorporation by type of glass



#### 4.3.1.6.5 Uncertainty Assessment

A 10 percent uncertainty value was set for activity data which refer to data collected from industrial facilities and sectoral associations. The double value of the standard deviation of the set of emission factors available for Portuguese units, and estimated from carbon market data, allows the consideration of an uncertainty value of 54 percent.

#### 4.3.1.6.6 Recalculations

No recalculations were made.

#### 4.3.1.6.7 Further Improvements

Estimates of emissions due to the production of glass wool and rock wool are still not available due to lack of statistical information for activity data. Although it is foreseen that this are minor emission sources, efforts are being made to obtain this information and establish emission estimates for this source.

### 4.3.2 Chemical Industry (CRF 2.B.)

#### 4.3.2.1 Ammonia Production (CRF 2.B.1.)

##### 4.3.2.1.1 Overview

In 2008 only one fertilizer industrial plant manufactures ammonia in Portugal, using Vacuum Residual Fuel Oil (VRF) as source of hydrogen (feedstock). In 2009, this plant was closed and the ammonia production has been relocated to India.

Ammonia is formed after reaction of hydrogen with nitrogen from air. In the start of year 1990 there was another unit operating in Portugal, but has stopped activity already in the beginning of that year. The conversion of feedstock to hydrogen results in the liberation of the associated carbon as ultimate CO<sub>2</sub> which is vented to atmosphere. Although actually some part of CO<sub>2</sub> liberated from VRF, during ammonia production, is in fact used in urea production, 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 CO<sub>2</sub> may be used in urea manufacturing, the option was not to deduce this CO<sub>2</sub> fixation in feedstock.

Other pollutants result from the process, either from escape of ammonia (NH<sub>3</sub>) or either from release of products from feedstock: CO and NMVOC.

##### 4.3.2.1.2 Methodology

Carbon dioxide emissions were estimated from feedstock consumption using the following formulation:

$$\text{Emi}_{\text{CO}_2(y)} = 44/12 * \text{Feedstock}_{(y)} * C_{\text{Feed}(y)} * 10^{-5}$$

where

$Emi_{CO_2(y)}$  - Emission of carbon dioxide (kton/yr);

$FeedStock_{(y)}$  - Annual consumption of feedstock (ton/yr)

$C_{Feed(y)}$  - Carbon content of feedstock (%).

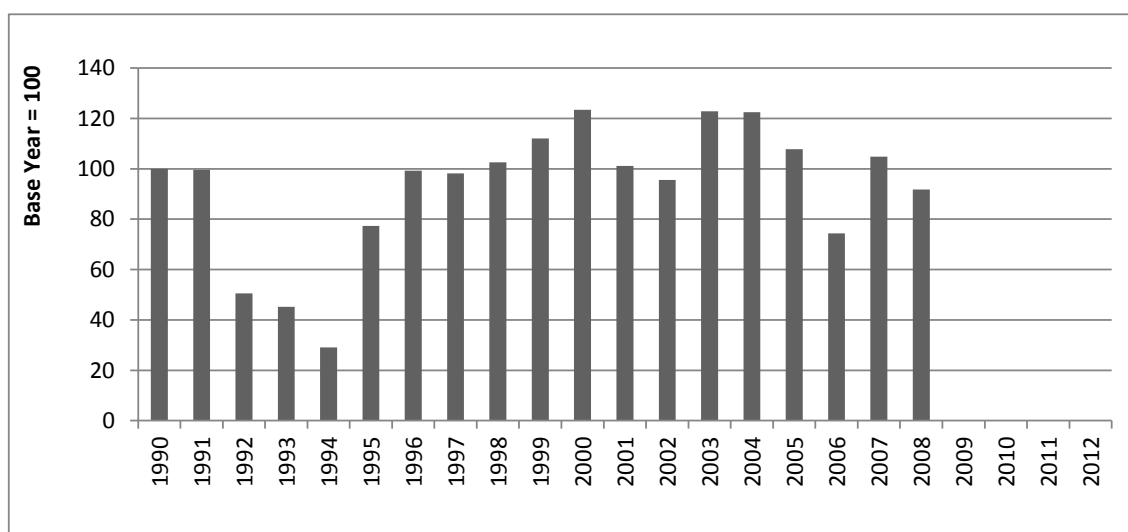
#### 4.3.2.1.3 Emission Factors

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

#### 4.3.2.1.4 Activity Data

Because there was only one industrial plant in operation in the period 1990-2009, it is not possible to present any absolute information concerning activity data for this source activity, neither ammonia production nor feedstock and methanol consumption. The overall trend in the amount of ammonia produced in the period may be however depicted in the figure below, from where it is evident the significant inter-annual changes in the period 1991-1996. In 2009 the only facility that produced ammonia in Portugal was closed and the production was relocated to India.

Figure 4-15 - Trend in Ammonia production



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

- total production of ammonia in Portugal is available from the only existing facility for the period 1990-2008. From 2009 onwards there is no ammonia production because the facility was closed and the production relocated to India;
- consumption of VRF feedstock could not however be determined from INE statistical database, because differentiation of residual fuel oil for feedstock and energy source was not clarified for this economic activity. Therefore, as explained before, consumption of feedstock VRF was estimated from limited information and relying on linear correlations: the quantity of VRF that was used

was set from data collected at the only industrial plant in Portugal for a limited number of years – 1990 till 1994 – and a strong linear relation between feedstock consumption and ammonia production could be established from available data;

- use of methanol was also estimated for the full time period from a linear regression which was determined from available information for a limited number of years.

The reason for the low emission values in the period 1992-1994 is the  $\text{NH}_3$  production decrease in this period. According to information provided by the facility, in this period there were technical problems that led to several interruptions in the production.

#### 4.3.2.1.5 Uncertainty Assessment

No specific guidelines exist in GPG (IPPC,2000) to estimate the uncertainty of this source sector. The greatest uncertainty of emission estimates for this source sector results from the uncertainty in knowledge of activity data (Feedstock consumption). Because the ratio of feedstock consumption over ammonia production was used to estimate feedstock consumption, the standard deviation of these ratios was used to estimate the error and then doubled to include an additional factor of conservativeness<sup>61</sup>. The final uncertainty value for activity data was set as 31 percent.

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

#### 4.3.2.1.6 Recalculations

No recalculations were made.

#### 4.3.2.1.7 Further Improvements

No further improvements are planned.

### 4.3.2.2 Nitric Acid (CRF 2.B.2.)

#### 4.3.2.2.1 Overview

Only three industrial plants produce nitric acid in Portugal, located in Estarreja, Alverca and Lavradio. In all units, weak nitric acid (60 percent) is produced from ammonia, using catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to  $\text{NO}_2$  at medium pressure, and subsequent absorption with water to form nitric acid in a dual-stage process.

<sup>61</sup> A further doubling was used to convert from standard deviation to 95% confidence interval.

Nitric Acid manufacture results in air emissions primarily of NO<sub>x</sub> (NO and NO<sub>2</sub>), trace amounts of HNO<sub>3</sub> acid mist, ammonia (NH<sub>3</sub>) and Nitrous Oxide (N<sub>2</sub>O). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of NO<sub>x</sub> are controlled by catalytic reduction. Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

#### 4.3.2.2.2 Methodology

For all pollutants emissions are estimated using the following equation:

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

where

Emission<sub>(p,y)</sub> - annual emission of pollutant p in year y (ton/yr);

ActivityRate<sub>(y)</sub> – production of Nitric Acid in year y (ton/yr);

EF<sub>(p)</sub> - emission factor for pollutant p (kg/ ton)

#### 4.3.2.2.3 Emission Factors

Due to confidentiality constraints it is not possible to publish the chosen emission factors. They were estimated based on monitoring data from the facilities.

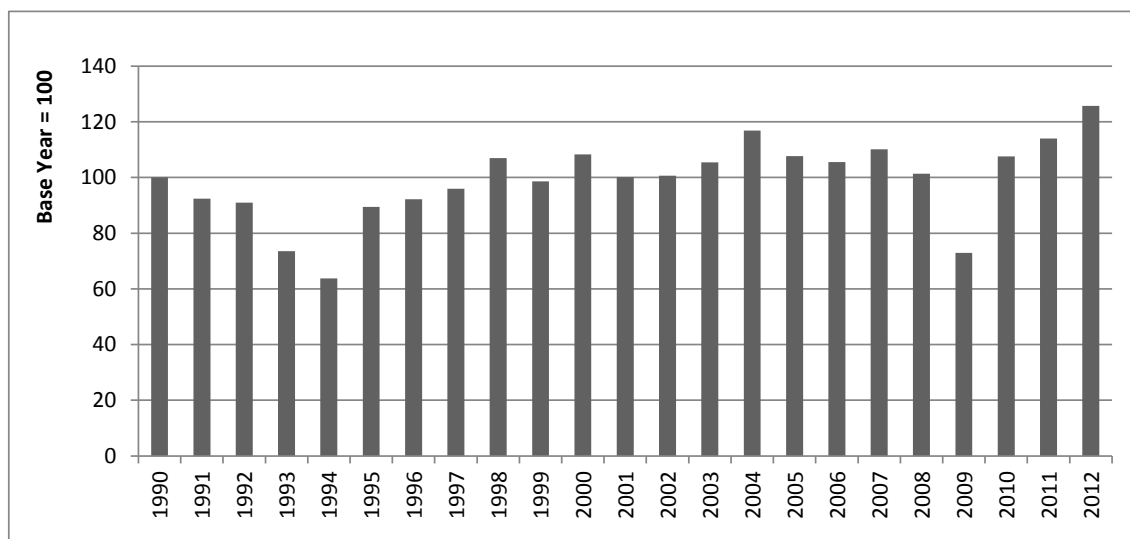
#### 4.3.2.2.4 Activity Data

The activity data that was used to estimate emissions from this sub-source sector is subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends).

Activity Data is obtained directly from the facilities. One of the plants was closed during year 2010 and was replaced by a new facility.



Figure 4-16 - Trend in Nitric Acid production



#### 4.3.2.2.5 Uncertainty Analysis

The uncertainty value for activity data is 1 percent, considering that data is obtained directly from a restricted number of units. The uncertainty value of the emission factor of Nitrous Oxide a value of 10 percent was chosen, which is in accordance with references to uncertainty ranges in GPG and also in accordance with the difference between the country specific emission factor determined from monitoring data and the proposed emission factor.

#### 4.3.2.2.6 Recalculations

We made a correction in the Nitric Acid  $N_2O$  emission factor in one plant based on revised monitoring data.

#### 4.3.2.2.7 Future Improvements

No further improvements are planned for this sector.

### 4.3.2.3 Organic Chemical Industry (CRF 2.B.5.)

#### 4.3.2.3.1 Overview

The organic chemical industry is responsible for greenhouse gas emissions in consequence of the release of carbon compounds that are transformed in carbon dioxide in the atmosphere. These emissions are mostly part of the carbon that is release from feed-stocks.

For this source sector emissions for some industrial units were estimated at individual unit plants – Large Point Sources (LPS) - and using detailed characterization of the plants and their industrial activities. Chemical organic industry in Portugal is not very extensive, however. The

major organic chemical plant in Portugal is BOREALIS unit, a petrochemical unit situated in the southern part of the country, near Sines. The basic process in this unit is Ethylene production by Thermal Steam Cracking of petroleum feedstock. From ethylene this unit produces Low Density Poly Ethylene (LDPE) and High Density Poly Ethylene (HDPE). As by product of ethylene production other organic compounds are produced, such as propylene, butadiene and C4 fraction, aromatics and a residual fuel oil used in the unit as energy source.

The second chemical industry LPS is the sole Carbon Black plant in Portugal. It is also situated in the southern part of the country, near Sines. CARBOGAL unit produces Carbon Black by the Oil Furnace Process, a partial combustion process where feedstock with a high content of aromatic material is converted by incomplete combustion, thermal cracking and dehydrogenation to carbon black. Emissions result from Gas Vent, combined dryer vent and fugitive emission in the vacuum system vent.

Finally the last individualized unit (LPS) is an industrial plant located in Lisbon producing Phthalic Anhydride from aromatic compounds.

Apart from those individualized industrial plants other chemical industrial activities were included as area sources in this sub-source sector<sup>62</sup>:

- Vinyl Chloride Monomer (VCM);
- Low Density Poly-ethylene (LDPE);
- Poly Vinyl Chloride (PVC);
- Poly propylene (PP);
- Poly styrene (PS);
- Formaldehyde;
- Explosives.

#### 4.3.2.3.2 Methodology

For this sub-sector emissions estimates are extensively based on the use of emission factors multiplied by quantity of material produced:

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

where

Emission<sub>(p,y)</sub> - annual emission of pollutant p in year y (ton/yr);

ActivityRate<sub>(y)</sub> - 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);

<sup>62</sup> 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

EF<sub>(p)</sub> - emission factor (kg/ ton)

In the case of carbon black, where CO<sub>2</sub> 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<sub>TailGas</sub> – carbon emitted in tail gas (ton C/yr);

C<sub>Feedstock</sub> – Carbon entered in feedstock (ton C/yr);

C<sub>AuxFuels</sub> – additional carbon entered into system in fuels (ton C/yr);

C<sub>CarbonBlack</sub> – carbon stored in carbon black and not emitted to atmosphere (ton C/yr).

#### 4.3.2.3.3 Emission Factors

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994<sup>63</sup>. 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 ethylene production as activity rate indicator<sup>64</sup>. Emissions from flares and flue gas combustor were included in the emission factors.

Table 4-7 – Emission Factors for determination of process emissions in Borealis (kg/ton)

Description	NM VOC	CH <sub>4</sub>
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 emission 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.

<sup>63</sup> Unpublished.

<sup>64</sup> This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Table 4-8 – Emission Factors in calculation of Carbon Black process emissions

Pollutant	Main Process Vent Gas (kg/ton gas)	Combined Dryer Vent Gas (kg/ton gas)	Process and Fugitive (kg/ton Carbon Black)
NMVOC	33.3 <sup>(a)</sup>	2.50 <sup>(b)</sup>	-
CH <sub>4</sub>	0.80	0.8 + 1.4 <sup>(b)</sup>	-
CO	104	100 + 17 <sup>(b)</sup>	-
N <sub>2</sub> O	-	1.40 <sup>(b)</sup>	-

(a) kg/ton Carbon Black

(b) g/GJ

(c) g/Nm<sup>3</sup> tail gas

Emission factors for the Phthalic Anhydride Plant are from US-EPA (1983) and are presented in table 4.8:

Table 4-9 - Emission Factors for the production of Phthalic Anhydride

Pollutant	kg/ton
NMVOC	1.2
CO	151

Source: USEPA (1983)

#### 4.3.2.3.4 Activity Data

Activity data used to estimate emissions may not be reported in NIR, due to confidentiality issues that result from the limited number of units concerned for each individual compound.

For BOREALIS Petrochemical Plant in Sines - produced quantities are available from 1990 to 1997 and were forecasted thereafter. Production of carbon black and explosives is available since 1990 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).

#### 4.3.2.3.5 Uncertainty Assessment

The uncertainty of activity data received from Large Point Sources was set as 10 percent. For area sources it depends if the data set is updated for the all time series or not. If it is not updated the uncertainty value was set as 100 percent and 10 percent if it is updated. The high uncertainty in the choice of emission factors from international references, which are themselves based in limited information and which conditions of determination are most of the time different from specific national conditions, lead to the choice of an uncertainty value of an order or magnitude for area sources and 100 percent for Large Point Sources<sup>65</sup>.

#### 4.3.2.3.6 Recalculations

It was made a revision on activity data based on National Statistics for the period 2011-2012.

<sup>65</sup> The uncertainty of emission factors refers to uncertainty of NMVOC determination. Uncertainty for conversion from NMVOC to CO<sub>2</sub> is comparatively irrelevant.

#### 4.3.2.3.7 Further Improvements

Because emissions from production processes depend largely on specific conditions in each industrial plant, and because there are very few units in Portugal using a specific chemical manufacturing process, it is essential that the national inventory relays more and more in detailed plant information, i.e. increasing the number of Large Point Sources. Only deep knowledge of LPS units will allow quantification of air emission with reduced uncertainty, either using technology specific emission factors from literature or either using monitoring data. This improvement may imply coordination with E-PRTR exercise, 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. Other expected improvements include:

- Obtaining a deeper knowledge for the limited number of the most relevant industrial units and performing emission estimates with more detailed methodologies, similar to those performed for BOREALIS and CARBOGAL industrial units;
- Revision of emission methodologies and possible inclusion of more manufacturing processes, such as Styrene Butadiene latex or rubber; Acrylonitrile Styrene Butadiene (ABS); Acrylonitrile and MTBE. Efforts must be done to verify that production of these products, and others, did exist in Portugal;
- Estimate of emissions from storage and handling of organic liquids, which presently are only done for carbon black.

### 4.3.3 Metal Production (CRF 2.C.)

#### 4.3.3.1 *Iron and Steel Production (CRF 2.C.1.)*

##### 4.3.3.1.1 Overview

Iron results from reduction of the iron element present in mineral ores by contact with coke - reducing agent - at high temperatures in the blast furnace. The resulting material, pig iron – and also scrap in some steel plants - is transformed into steel into subsequent furnaces which may be a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF). Coke, sinter and lime are intermediate materials necessary for iron and steel production.

Sintering modifies the structure of ore material making it more suitable for iron formation, by converting fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product. Sintering emissions occur from the windbox, discharge and sinter crusher, coolers and screens. Emissions from sintering, which result from a combustion process with contact, are reported under 1.A.2, although the emission factors are reported in this chapter.

Coke is produced by destructive distillation of imported fossil coal in coke ovens, where coal is subjected to heat in an oxygen-free atmosphere until all volatile components in the coal evaporate, forming a fuel used in industry, the Coke Gas. Process heat comes from the

combustion of gases between the coke chambers. Excluding emissions associated with coke production resulting from use of fuels in under-fired heating furnaces (which are accounted in Energy source sector 1A1), air emissions from the coquerie result from coal preparation, coal charging, oven leakage during the coking period, coke removal and hot coke quenching. Leaks may also occur from poorly sealed doors, charge lids, off take caps, collecting main and from cracks that may develop in oven brickwork (USEPA, 2000)

Coke and sinter are added to the Blast Furnace where iron oxides, coke and fluxes react with blast air to form molten reduced iron, carbon monoxide (CO), and slag. Emissions occur during casting and in the blast furnace top. However the gas resulting from process in the blast furnace, which has a high CO content, is normally not emitted to atmosphere but used as fuel in integrated units (Blast Furnace Gas). Emissions from its combustion are also quantified and discussed under chapter 1A2 – Combustion in Manufacturing Industries and Construction. The emissions that are quantified here, in source 2.C, are only those resulting from casting operations and seal leaks at top of furnace.

In Basic Oxygen Furnace original material are re-melted with the addition of substantial source of oxygen which is lanced (injected) and oxidizes part of the carbon associated with iron: This carbon is emitted mostly as CO (contributing nevertheless to ultimate CO<sub>2</sub> 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 CO<sub>2</sub> emissions from decarbonizing.

Emissions of ultimate fossil CO<sub>2</sub> 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 CO<sub>2</sub> 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.

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 cokerie, blast furnace and sintering were closed and only steel furnaces and trimming remain as emission sources. From 2001 onwards, there is only secondary steel production in Portugal.

#### 4.3.3.1.2 Methodology

Emissions are simply calculated from multiplication of activity levels by a suitable emission factor:

$$\text{Emission}_{(p,y)} = \sum_a [\text{EF}_{(p,a)} * \text{Activity}_{\text{Indicator}(p,a,y)}] * 10^{-3}$$

and,

$\text{Emission}_{(p,y)}$  - Emission of pollutant p in a specific year y from all sector activities and equipments (ton/yr);

$\text{Activity}_{\text{Indicator}(p,a,y)}$  - Most suitable indicator for emissions of a particular pollutant p resulting from a specific source activity or equipment a (ton/yr);

$\text{EF}_{(p,a)}$  - 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 cokerie 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 source sector 1A.2 - manufacturing industries and construction - and 1A.1.c.1 - Manufacture of Solid Fuels.

From 2002 onwards, combustion related CO<sub>2</sub> emissions are reported under source “1.A.2.a” and process related CO<sub>2</sub> emissions are reported under source “2.C.1.1”. CH<sub>4</sub> emissions are based on monitoring data and reported under source code “2.C.1.1”.

#### 4.3.3.1.3 Emission Factors

Emissions factors for production process on the period 1990-2001 were set mostly from CORINAIR/EMEP also with contributions from IPCC96 and US-EPA AP42. Emission factors in kg/ton are present in next table.

Table 4-10 - Emission Factors for Iron and Steel Production in the period 1990-2001

Pollutant	Coke Oven (kg/ton coke)	Sintering (kg/ton sinter)	Blast Furnace (kg/ton steel)	BOF (kg ton/steel)	EAF (kg/ton steel)	Rolling Mills (kg/ton steel)
CO <sub>2</sub>	151 <sup>(a)</sup>	200 <sup>(b)</sup>	-	98.3 <sup>(d)</sup>	71.6 <sup>(e)</sup>	-
NM VOC	0.09 <sup>(a)</sup>	0.14 <sup>(c)</sup>	-	-	0.11 <sup>(f)</sup>	0.007 <sup>(c)</sup>
CH <sub>4</sub>	0.10 <sup>(a)</sup>	0.07 <sup>(b)</sup>	-	-	0.32 <sup>(f)</sup>	-
CO	15.4 <sup>(a)</sup>	22.9 <sup>(d)</sup>	0.03 <sup>(d)</sup>	3.5 <sup>(c)</sup>	0.51 <sup>(f)</sup>	-

(a) USEPA AP-42; (b) 2006 IPCC Guidelines; (c) EEA/EMEP, 2009; (d) JRC Reference Report - BAT Reference Document for Iron and Steel Production (2013); (e) EU-ETS data; (f) Monitoring Data

The CO<sub>2</sub> 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 from 2002 onwards. 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. The CO<sub>2</sub> stoichiometric emission factors from carbon bearing materials could be checked in next table.

Table 4-11 – Carbon bearing materials CO<sub>2</sub> stoichiometric EF

Material	EF	Unit EF
CaCO <sub>3</sub>	0.440	t CO <sub>2</sub> /t material
MgCO <sub>3</sub> .MgCO <sub>3</sub>	0.477	t CO <sub>2</sub> /t material
FeCO <sub>3</sub>	0.380	t CO <sub>2</sub> /t material
EAF Carbon Electrodes	3.00	t CO <sub>2</sub> /t material
EAF Charge Carbon	3.04	t CO <sub>2</sub> /t material
Petroleum Coke	3.19	t CO <sub>2</sub> /t material
Scrap Iron	0.15	t CO <sub>2</sub> /t material
Steel	0.04	t CO <sub>2</sub> /t material

#### 4.3.3.1.4 Activity Data

There are differences in the activity data used in estimates for the period 1990-2001 and from 2002 onwards.

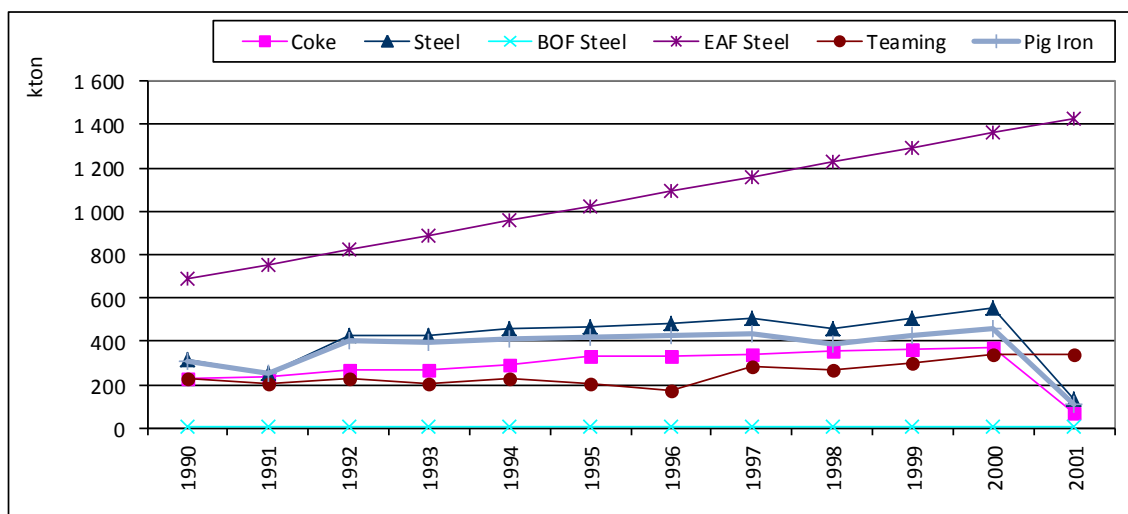
Activity data for emissions estimates from iron and steel production for the period 1990-2001 comprehend coke, sinter, pig iron and steel production and also scrap consumption, and time series for each product may be seen in the figure below. The following sources of information were used to establish activity data time series:

- Coke production is available from DGEG (Cokerie Balance) annually from 1990 to 2001. From 2002 onwards there is no coke production in the iron and steel industry in Portugal;
- production time series for sinter, pig iron and steel production in blast furnace are available from industrial plant from 1990 to 1994 (APA direct survey). Thereafter and until 2001, annual values were estimated using coke production as surrogate data. From 2002 onwards there is no sinter, pig iron and steel production in blast furnace;
- steel resulting from BOF in Seixal Iron and Steel Plant was estimated from production data in 1990 and forecasted until 2001; From 2002 onwards there is no steel production resulting from BOF.
- 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 and forecasted in the period 1991-2001 based on energy consumption;

Production of total steel and intermediate products in the period 1990-2001 could be checked in the next figure.

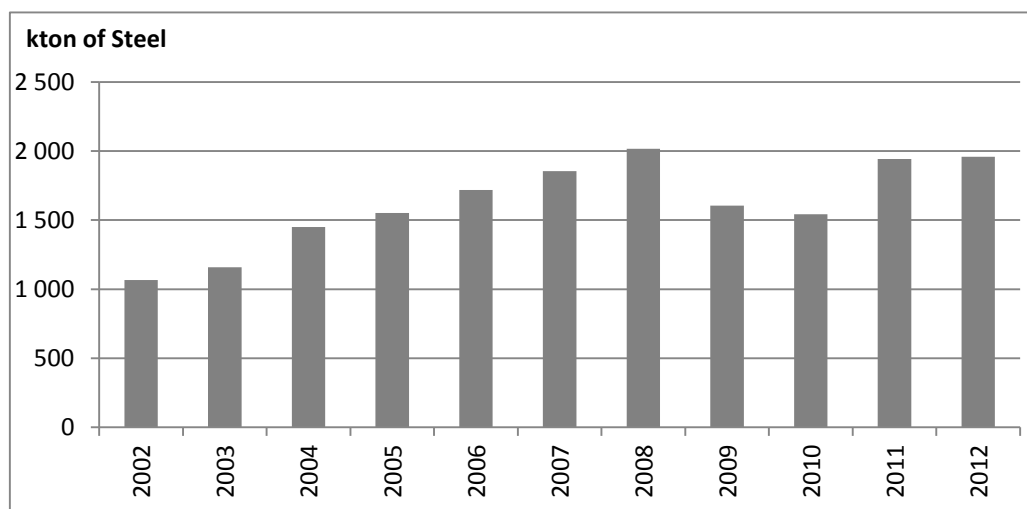


Figure 4-17 - Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2001)



Activity data for estimation of CO<sub>2</sub> emissions from iron and steel production from 2002 onwards comprehends fuel consumption, raw materials consumption and carbon content of raw materials.

Figure 4-18 - Production of secondary steel from 2002 onwards



#### 4.3.3.1.5 Uncertainty Assessment

The great majority of CO<sub>2</sub> 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 from 2002 onwards (plant specific and EU-ETS data). In the intermediate period information had to be collected from statistical information from INE, DGE or even estimated from surrogate data.

Quality of activity data for this period decreased substantially but does not affect overall trend of the inventory. The uncertainty in activity data was set as 10 percent the major value in the range proposed in GPG. The uncertainty value for the emission factor was determined considering and uncertainty of 25 percent in the carbon content of both raw materials and final steel and additional 5 percent in the quantity of reducing agent for EAF.

#### 4.3.3.1.6 Recalculations

It was made a correction of a relevant calculation error. Previously we presented the CO<sub>2</sub> emissions related to combustion two times and no emissions related to the process. Since the process related emissions are less relevant than the combustion related emissions, this correction leads to a decrease in the emissions values.

#### 4.3.3.1.7 Further Improvements

No further improvements are expected.

### 4.3.3.2 *Ferroalloys Production (CRF 2.C.2.)*

#### 4.3.3.2.1 Overview

There is no ferroalloys production in Portugal in the period considered in this inventory.

### 4.3.3.3 *Aluminium Production (CRF 2.C.3.)*

#### 4.3.3.3.1 Overview and Recalculations

Aluminium production will result in carbon dioxide emissions when it is reduced using carbon electrodes in smelting pots and ultimate CO<sub>2</sub> emissions are the result of consumption of electrodes. This situation occurs when aluminium is manufactured from bauxite ore, using the Soderberg process, for example.

In Portugal, according to information received from the General Directorate of Economic Activities (DGAE), aluminium is produced from ingots and not from bauxite ore. Consequently emissions of CO<sub>2</sub> for this source sector were removed from emission inventory.

### 4.3.4 *Other Production (CRF 2.D.)*

#### 4.3.4.1 *Paper pulp production (NFR 2.D.1)*

##### 4.3.4.1.1 Overview

In Portugal there were in 1990 six paper pulp plants using the kraft process and two units using the acid sulphide process. Later, in 1993, one of the smaller of the acid sulphide plants was decommissioned and nowadays only 6 plants remain in operation.

Kraft pulping is essentially a digestion process of wood by a solution of sodium sulphide (Na<sub>2</sub>S) and sodium hydroxide (NaOH) (white liquor) at elevated temperature and pressure that dissolves lignin and leaves cellulose fibers unbind. Apart from digestion other relevant industrial processes include pulp washing, pulp drying, chemical recovery of reactants (sulphur and quicklime) and possibly bleaching. Recovery of sulphur from the spend cooking liquor and washing water (black liquor) includes combustion in the recovery furnace, after concentration in evaporators, and reaction with water and quicklime of the green liquor in a causticizing tank generating white liquor and lime mud. Quicklime is recovered by combustion in a lime kiln.

Emissions of sulphur compounds, including mercaptans, dimethyl sulphide, dimethyl disulphide and H<sub>2</sub>S, occur in digester and blow tank relieves, in evaporators, and in the lime kiln. In the recovery furnace sulphur compounds are oxidized to SO<sub>x</sub>, but these are emissions already included in combustion in manufacturing industries (1A2 source sector).

Acid sulphide involves also chemical digestion of wood but using SO<sub>2</sub> absorbed in a base solution. Washing, drying and recovery of chemicals are also part of this production process.

Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from combustion equipments of this industry sector were estimated using energy consumption as activity data (energy approach) and were included in combustion in manufacturing industries (1A2 source sector).

#### 4.3.4.1.2 Methodology

Air emissions (ton/yr) for each pollutant are estimated from production of air dried paper pulp (Pulp<sub>PROD</sub> - ton AD/yr) after applying emission factors (EF - kg/ton AD) specific of each pollutant:

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

#### 4.3.4.1.3 Emission Factors

The following emissions factors (kg/ ton AD pulp) were used to estimate process emissions, respectively for the Kraft and sulphide process plants. They were set from US-EPA AP42 and other sources and include emissions realized in:

- Kraft process: Digester, Brown Stock Washers, Black Liquor Evaporators, Non condensable gases, Smelt dissolving tank, Fluid Bed Calcliner and Bleaching;
- Acid sulphide: Digester and Blow Pit.

Table 4-12 – Emission Factors for paper pulp production (non-combustion)

Process	SO <sub>x</sub>	NO <sub>x</sub>	NM VOC
Kraft	0.31	1.95	2.74
Sulphide	35.5	NA	NA

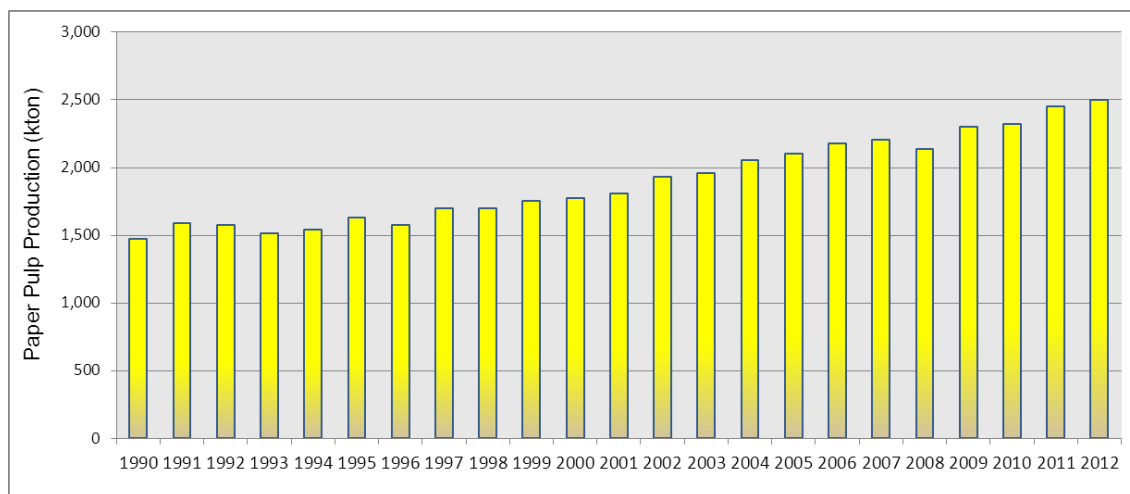
#### 4.3.4.1.4 Activity Data

Production of paper pulp expressed in air dried weight during the period 1990-2009 was obtained directly from CELPA (the Portuguese Paper Industry Association). Since 2010, activity data is obtained from EU-ETS. Acid Sulphide production is only a minor component of total production<sup>66</sup> but may not be published individualised due to confidentiality constraints. However, sulphide production is about 5 to 8 per cent of total paper pulp produced in Portugal, according to years. Paper pulp production has been increasing during the period 1990-2012

The following figure presents total production of paper pulp.

<sup>66</sup> Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

Figure 4-19 – Total production of paper pulp - Kraft and semi-sulphide



#### 4.3.4.1.5 Recalculations

No recalculations were made.

#### 4.3.4.2 Food Manufacturing (CRF 2.D.2)

##### 4.3.4.2.1 Overview

Emissions from food manufacturing include all processes in the food production chain which occur after the slaughtering of animals and the harvesting of crops.

Emissions occur primarily from the following sources:

- The cooking of meat, fish and poultry, releasing mainly fats and oils and their degradation products;
- The processing of sugar beet and cane and the subsequent refining of sugar;
- The processing of fats and oils to produce margarine and solid cooking fat;
- The baking of bread, cakes, biscuits and breakfast cereals;
- The processing of meat and vegetable by-products to produce animal feeds;
- The roasting of coffee beans.

##### 4.3.4.2.2 Methodology

Emissions were estimated by a Tier 2 methodology using EMEP/EEA emission inventory guidebook 2009 default 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);

$\text{ActivityRate}$  - Indicator of activity in the production process (ton/yr);

$\text{EF}_{\text{NMVOC}}$  - emission factor (kg/ ton)

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

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

#### 4.3.4.2.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (2.D.2. Food and Drink).

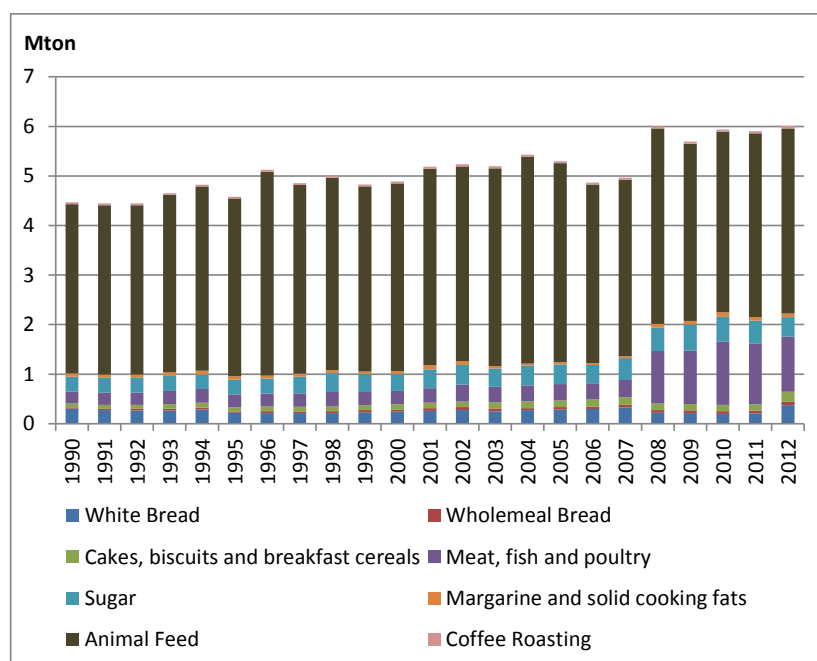
Table 4-13 – Emission Factor for each food product

Food Product	Unit	EF
White Bread	Kg/ton	4.50
Wholemeal Bread	Kg/ton	3.00
Cakes, biscuits and breakfast cereals	Kg/ton	1.00
Meat, fish and poultry	Kg/ton	0.30
Sugar	Kg/ton	10.00
Margarine and solid cooking fats	Kg/ton	10.00
Animal feed	Kg/ton	1.00
Coffee roasting	Kg/ton	0.55

#### 4.3.4.2.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4-20 – Food manufacturing by food product



#### 4.3.4.2.5 Recalculations

Activity data for the period 2011-2012 was updated based on National Statistics.

#### 4.3.4.2.6 Further Improvements

No further improvements are planned.

### 4.3.4.3 *Drink Manufacturing (CRF 2.D.2)*

#### 4.3.4.3.1 Overview

Emissions may occur during any of the four stages which may be needed in the production of an alcoholic beverage:

- Preparation of the feedstock;
- Fermentation;
- Distillation of fermentation products;
- Maturation.

#### 4.3.4.3.2 Methodology

We used the same methodology described in Food Manufacturing sector.

#### 4.3.4.3.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (2.D.2. Food and Drink).

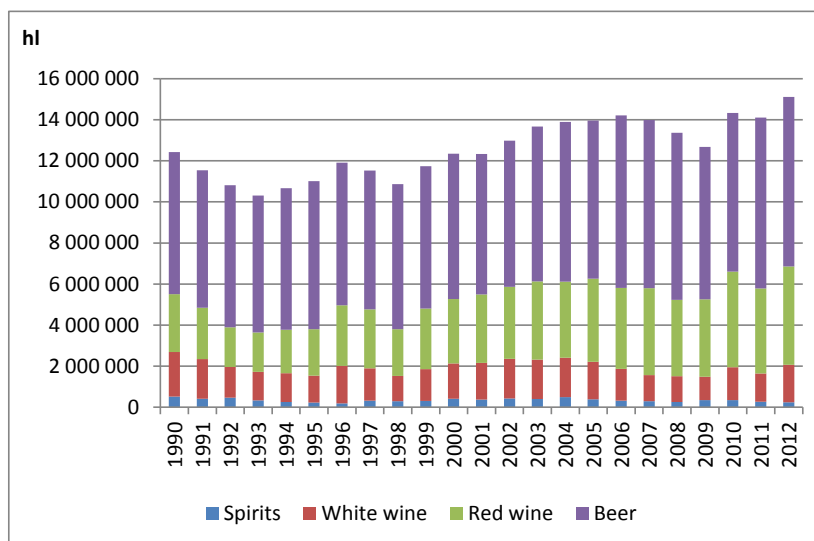
Table 4-14 – Emission Factor for each alcoholic beverage

Alcoholic Beverage	Unit	EF
White Wine	Kg/hl	0.035
Red Wine	Kg/hl	0.080
Beer	Kg/hl	0.035
Spirits	Kg/hl	6.000

#### 4.3.4.3.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4-21 – Drink manufacturing by alcoholic beverage



#### 4.3.4.3.5 Recalculations

Activity data for the period 2011-2012 was updated based on National Statistics.

#### 4.3.4.3.6 Further Improvements

No further improvements are planned.

#### 4.3.4.4 *Wood Chipboard Production (CRF 2.D.2)*

##### 4.3.4.4.1 Overview

Chipboard manufacturing involves solvent emission but it is included in this source sector.

##### 4.3.4.4.2 Methodology

We used the same methodology described in Food Manufacturing sector.

##### 4.3.4.4.3 Emission Factors

NMVOC emission factor is 0.9 kg/ton, from Corinair90 Default Emission Factor Handbook.

##### 4.3.4.4.4 Activity Data

Information about activity data for this sector is still scarce and limited to 1990, 2001-2007 and to 2010 onwards, from National Statistics (INE). For the period 1991-2000 and 2008-2009 data has been interpolated.

#### 4.3.4.4.5 Recalculations

Activity data for the period 2011-2012 was updated based on National Statistics.

#### 4.3.4.4.6 Further Improvements

The place where emissions from chipboard manufacture are located in the inventory should be subjected to revision and possibly moved to category “Solvent Use”. Also, NMVOC emissions from this activity should be estimated according to methodologies for this source sector avoiding double counting of emissions that result in fact from solvent use.

### 4.3.5 Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2.F.)

#### 4.3.5.1 Overview

Several simple halogenated organic compounds have high warming potentials and long atmospheric residence times. These include predominantly synthetic substances that have been used mostly as inert gases in such diverse applications as Refrigeration Fluid, aerosols propellants, foam fillers, gas insulation and fire suppressants. Chlorofluorocarbons (CFC), Hydrochlorofluorocarbons (HCFC), Perfluorinated hydrocarbons (PFC) and sulphur hexafluoride (SF<sub>6</sub>)<sup>67</sup> 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 SF<sub>6</sub>.

Some emission sources are still not included in the inventory:

- Aerosols. According to information from DGAE there are no fluorinated gases in the composition of produced or imported aerosols in Portugal;
- Solvents. According to information from DGAE there are no fluorinated gases in the composition of produced or imported solvents in Portugal;

Some emissions sources are not completely covered in the inventory, mainly as result of lack of adequate basic activity data, although there is a strong evidence that they are minor sources and thus do not decisively contribute to total emissions:

- some non-electrical use of SF<sub>6</sub> such as gas tracer in air dispersion and air emission studies.

One source, HFC-23 emissions from HCFC-22 manufacture, did not exist in Portugal during the reporting period and is reported as Not Occurring (NO).

#### 4.3.5.2 General Methodology

For those sources with sufficient available data, actual emissions were estimated with a Tier 2 (advanced or actual method) approach which is considered Good Practice in accordance with

<sup>67</sup> Other substances with greenhouse gas potential but less common are NF<sub>3</sub> and some halons. They are not included neither in Montreal Protocol neither in FCCC.



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 filled<sup>68</sup>;
- operation emissions - occurring during equipment lifetime or usage and resulting mainly from leaks;
- disposal emissions - the remaining charge that is released to the atmosphere at end of equipment life and where the remaining charge is neither recycled or destroyed.

#### 4.3.5.3 *Recalculations*

No recalculations were made.

#### 4.3.5.4 *Further Improvements*

It is expected that emission estimates will improve as a consequence of the inclusion of non-quantified sources and the upgrade of methodologies and parameters for the already quantified sources. The main aspects that will be subjected to future improvements include:

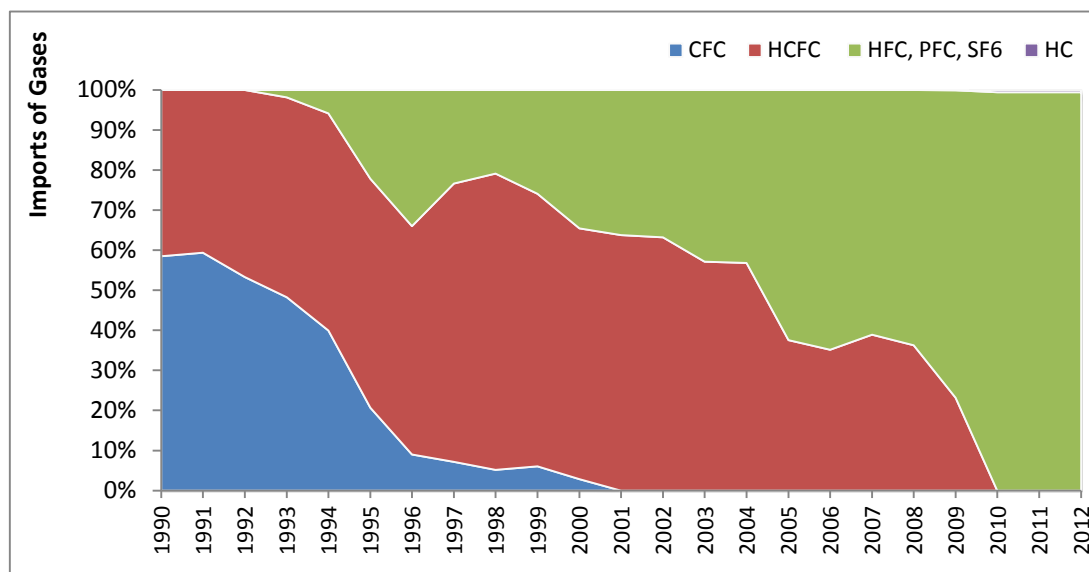
- It is known that SF<sub>6</sub> was used in Portugal as a tracer in scientific studies, even in the development of air emission methodologies (VOC from forest). But the quantities used in this activity remain unknown;
- The consideration of refilling of refrigeration equipments should be better addressed 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.

#### 4.3.5.5 *Importers Data*

The share of each F-gas used in the assembling of refrigeration equipments was estimated for each year relying on imports data from the major national suppliers of assembled units. Although data from suppliers does not cover the total national market, it was assumed to represent 60 percent (value agreed upon with suppliers) and there were made corrections to the total value in order to obtain a well representative situation. Fluorinated Gases have been imported since 1993 and have been increasingly replacing HCFC imports. The share of imports of each gas can be checked in the following figure.

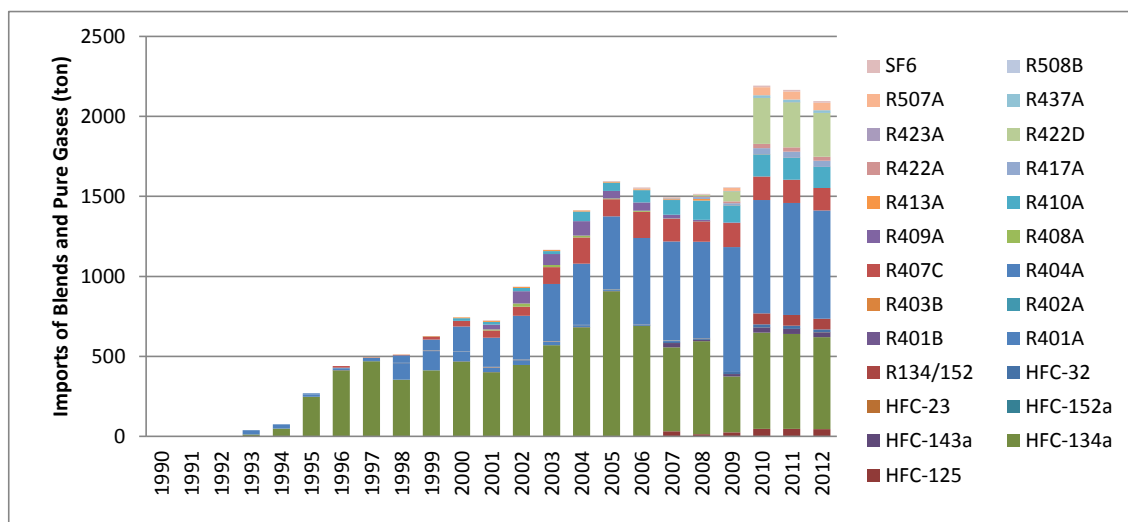
<sup>68</sup> Assembly emissions could include also emissions during refilling but no data was available to make this distinction

Figure 4-22 - Percentage of imported gases in Portugal by gas type



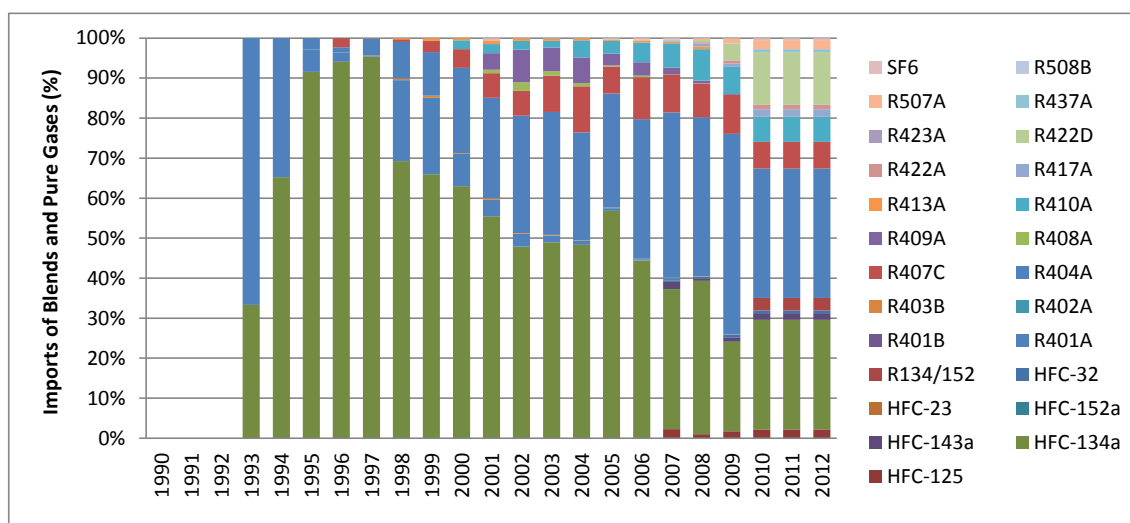
Source: Fluid Suppliers

Figure 4-23 – Imported amounts of pure HFC, PFC, SF<sub>6</sub> and Blends containing HFC and PFC



Source: Fluid Suppliers

Figure 4-24 – Percentual Distribution of pure HFC, PFC, SF<sub>6</sub> and Blends containing HFC and PFC



Source: Fluid Suppliers

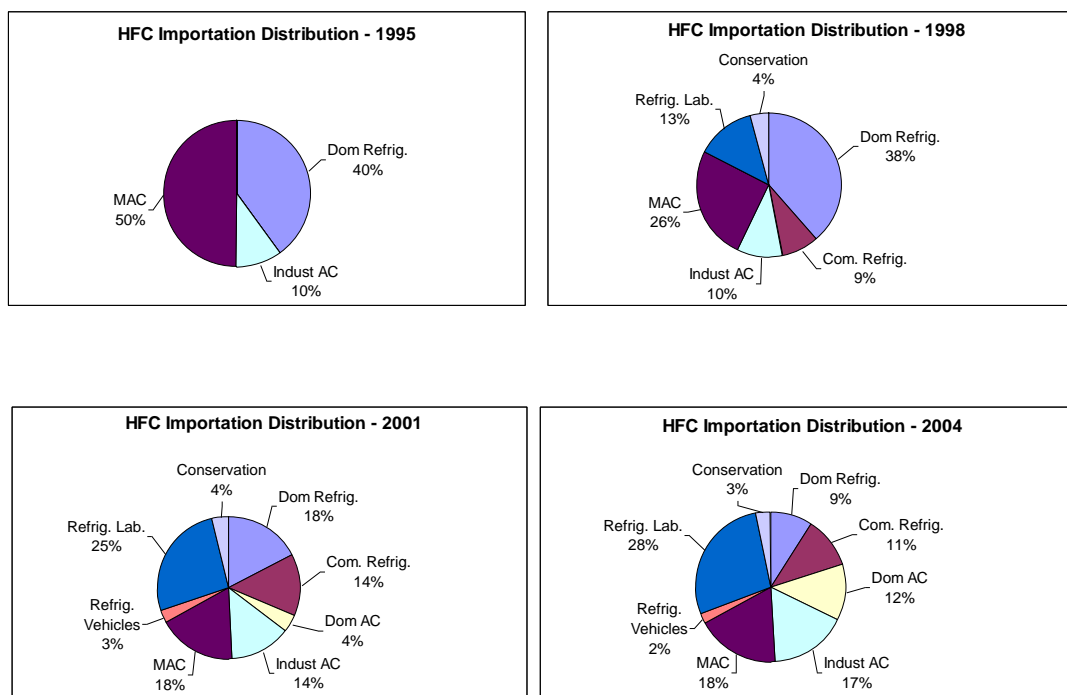
Table 4-15 – Constitution of each blend

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	HCFC-22	61%
	HCFC-124	28%
R-402a	HFC-125	60%
	HCFC-22	38%
R-403a	HC-290 (propane)	2%
	HCFC-22	75%
R-404a	PFC-218	20%
	HC-290 (propane)	5%
R-407c	HFC-143a	52%
	HFC-125	44%
R-408a	HFC-134a	4%
	HFC-125	52%
R-409a	HFC-125	25%
	HFC-32	23%

Blend Name	Gases in the Blend	% of each gas
R-408a	HCFC-22	47%
	HFC-143a	46%
R-409a	HFC-125	7%
	HCFC-142b	15%
R-410a	HCFC-22	60%
	HCFC-124	25%
R-413a	HFC-32	50%
	HFC-125	50%
R-502	HFC-134a	88%
	PFC-218	9%
R-507	HC-600a (iso-butane)	3%
	CFC-115	51%
R-508b	HCFC-22	49%
	HFC-125	50%
R-508b	HFC-143a	50%
	HFC-23	46%
R-508b	PFC-116	54%
	PFC-116	54%

Source: HRP – Supplier to the Refrigeration and Air Conditioning Equipment

Figure 4-25 - Percentage of imported F-Gases in Portugal by sub sector



Source: Importers

#### 4.3.5.6 Domestic Refrigeration

##### 4.3.5.6.1 Methodology

CFC, HCFC and F-Gases emissions from operation and disposal of Domestic Refrigeration Equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

The emissions were estimated according to the following set of equations from GPG:

Assembly/First fill

$$Ass_{Emi}(t) = Equip_{Assembly}(t) * Initial_{Charge}(t) * (k/100)$$

Operation/Lifetime

$$Oper_{Emi}(t) = Equip_{Stock}(t) * Initial_{Charge}(t) * (x/100)$$

Disposal

$$Disp_{Emi}(t) = Equip_{Disposal}(t) * Initial_{Charge}(t-lifetime) * (y/100) * (1-z/100)$$

F-Gases emissions for each particular compound were estimated from total Refrigeration Fluid emissions and considering the percentage of F-Gas use in total Refrigeration Fluid use in each year according to the following equations:

#### Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} \cdot F-Gas_{\% (j,t)}$$

#### Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\% (t,y)} \cdot F-Gas_{\% (j,y)}]$$

#### Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} [Equip_{\% (t,t-lifetime)} \cdot F-Gas_{\% (j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$ ,  $Oper_{Emi(t)}$ ,  $Disp_{Emi(t)}$  - total F-Gas emissions at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$ ,  $Oper_{Emi(t,j)}$ ,  $Disp_{Emi(t,j)}$  - F-Gas emissions of compound j at year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$  - Equipments assembled at year t;

$Equip_{Stock(t)}$  - Existing stock of equipment at year t;

$Equip_{Disposal(t)}$  - Number of equipments disposed at year t;

$Initial_{Charge(t)}$  - Initial charge of Refrigeration Fluid filled at year t;

$Equip_{\% (t,y)}$  - Percentage of equipments assembled at year y in the existing stock at year t;

$F-Gas_{\% (j,t)}$  - Percentage of use of Fluorinated compound j at year t;

K - percentage of initial charge that it is released during assembly;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

#### 4.3.5.6.2 Emission Factors

Prior to 1993 no F-gas was used in the assembling of refrigeration units. Lifetime of domestic equipments was set at 12 years to combined equipments (fridge+freezer) and 14 years to freezers.

The amount of Refrigeration Fluid charged into the equipment was assumed to be 110g/equipment for combined equipments (fridge+freezer) and 170 g/equipment unit for freezers, which are well within the range set in GPG table 3.22.

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 4-16 - Emission Factors of F-gases from Domestic Refrigeration

k (%)	x (%)	y (%)	z (%)
0.6	0.2	90.0	70.0

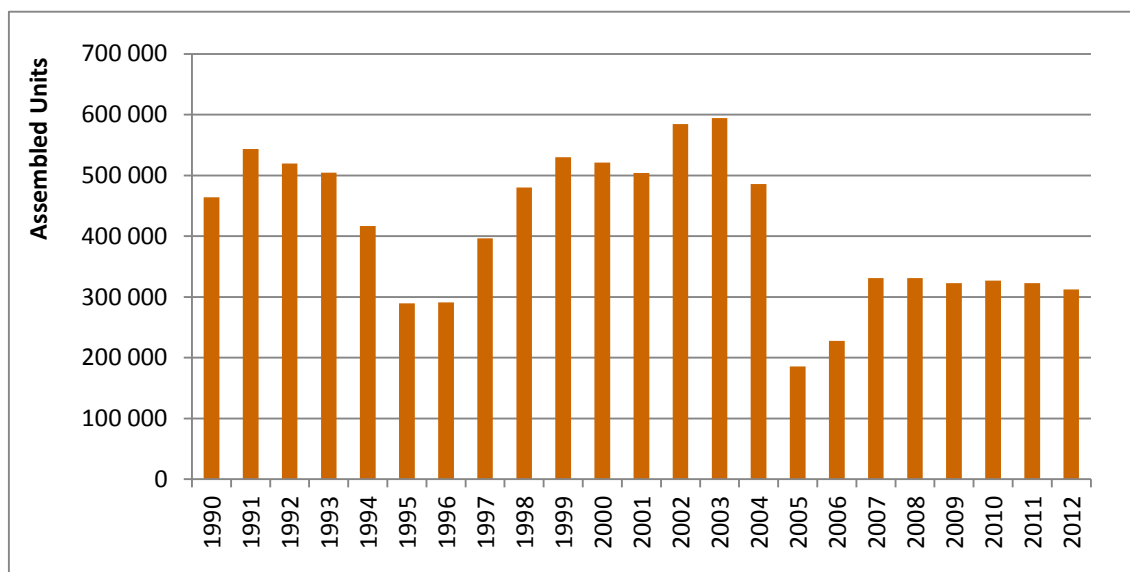
Source: IPCC GPG (table 3.22)

It was considered an initial emission factor (k) of 0.6% and a lifetime emission factor (x) of 0.2%. The residual amount of fluid remaining in the equipments (y) was considered 90.0% and the amount of fluid recovered (z) was assumed to be 70.0%.

#### 4.3.5.6.3 Activity Data

Time series of the number of assembled domestic refrigeration units in Portugal for the period 1990-2010 was provided by National Statistics (INE) and is presented in next figure. Values for the period 2011-2012 were forecasted by APA based on gross domestic product.

Figure 4-26 – Number of assembled refrigeration units



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 onwards, the evolution on the percentage of equipments per household was forecasted by APA based on expert judgement. The number of households refers to INE annual publication “Estatísticas da Construção e Habitação”.

Figure 4-27 – Number of Households

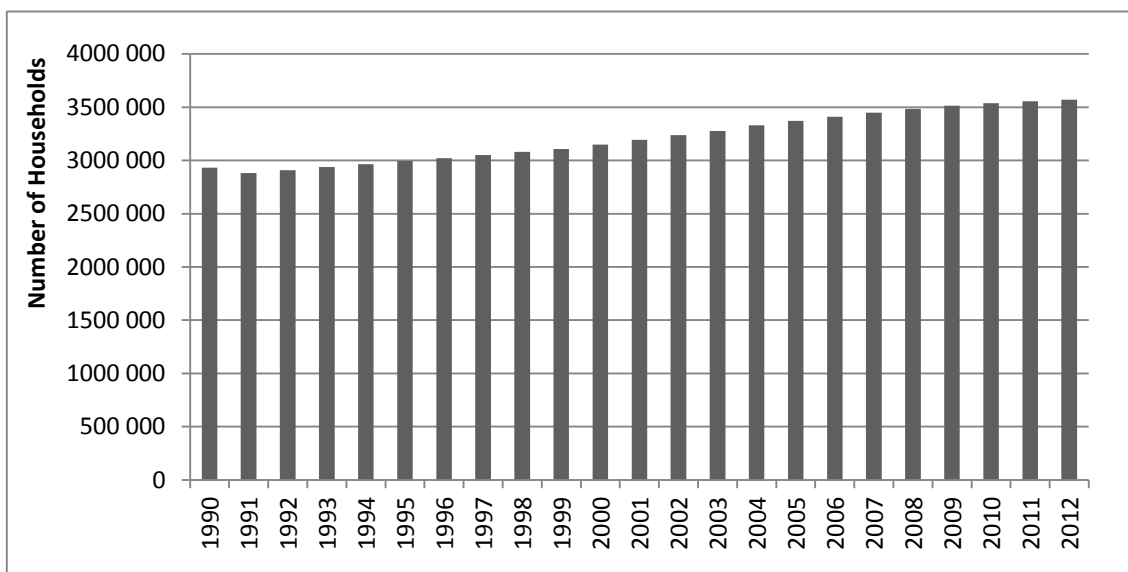


Table 4-17 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000	2012
Combined (Fridge and Freezer)	91.9	95.7	97.1	100.0
Freezers	34.4	49.5	53.5	55.0

The number of disposed equipments in each year was assumed equal to the number of assembled equipments 12 years before (combined equipments) or 14 years before (freezers). . It was possible to obtain the amount of fluid recovered by waste operators. 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 equipment<sup>69</sup>. It was assumed an average lifetime of 12 years to combined equipments (fridge+freezer) and 14 years to freezers.

#### 4.3.5.6.4 Recalculations

We made some adjustments in the methodology in order to fulfill the description above. The amount of fluid recovered (z), previously assumed to be 0.0% was updated to 70.0%.

#### 4.3.5.6.5 Uncertainty Assessment

An uncertainty of 10 percent was considered for the number of assembled units each year, and 20 percent was assumed as the number of existing equipment units. The number of disposed units was estimated from expert guess and a higher uncertainty of 50 percent was assumed. Uncertainty values for emission factors, or F gas liberation, incorporate the uncertainty in initial

<sup>69</sup> In consequence no emissions of HFC from disposal are estimated for the reported period.

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 4-18 – Uncertainty of Emission Factors for F-gases emissions from Domestic Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	48	67	5	96	127
Operation	48	67	13	96	127
Disposal	48	6	13	96	108

The overall uncertainty (combined uncertainty) is estimated to vary between 119 and 129 percent).

#### 4.3.5.7 *Commercial Refrigeration*

##### 4.3.5.7.1 Methodology

It was used the same methodology as for Domestic Refrigeration (**Erro! A origem da referência não foi encontrada.**).

##### 4.3.5.7.2 Emission Factors

In a similar way to domestic equipments, emission factors were set as the average values from the proposed range in IPCC GPG table 3.22.



Table 4-19 - Emission Factors for F-gas emissions from commercial, industry and services refrigeration equipments (hypermarkets not included)

	Charging (kg/unit)	Lifetime Emissions (%)	y (%)	z (%)
Mini-Fridge	0.05	0.20	90.00	70.00
Fridge	0.11	0.20	90.00	70.00
Horizontal Freezer	0.87	5.50	90.00	70.00
Congelation Chamber	1.20	5.50	90.00	70.00
Refrigeration Chamber	1.20	5.50	90.00	70.00
Supermarket Vertical Freezer Showcase	0.87	5.50	90.00	70.00
Vertical Freezer	0.87	5.50	90.00	70.00
Under Bench Refrigerator	1.31	5.50	90.00	70.00
Supermarket Horizontal Freezer Showcase	1.31	5.50	90.00	70.00
Fridge (Bottles)	1.31	5.50	90.00	70.00
Wine Fridge Showcase	0.87	5.50	90.00	70.00
Ice Machine	0.05	5.50	90.00	70.00
Juice Machine	0.05	5.50	90.00	70.00
Ice Cream Machine	0.05	5.50	90.00	70.00
Chantilly Machine	0.05	5.50	90.00	70.00
Tap drink cooler	0.05	5.50	90.00	70.00
Can Vendor	0.11	0.20	90.00	70.00
Tap beer cooler	0.05	5.50	90.00	70.00

Table 4-20 – Emission Factors for F-gas emissions in hypermarkets

Area (m <sup>2</sup> )	Category	Positive Temperature	Negative Temperature	Lifetime Emissions (%)	y (%)	z (%)
		Initial Charge (kg)	Initial Charge (kg)			
Area >4500	Big	1800	1250	16	90	70
1000 ≤ Area ≤ 4500	Medium	550	350	16	90	70
Area < 1000	Small	350	250	16	90	70

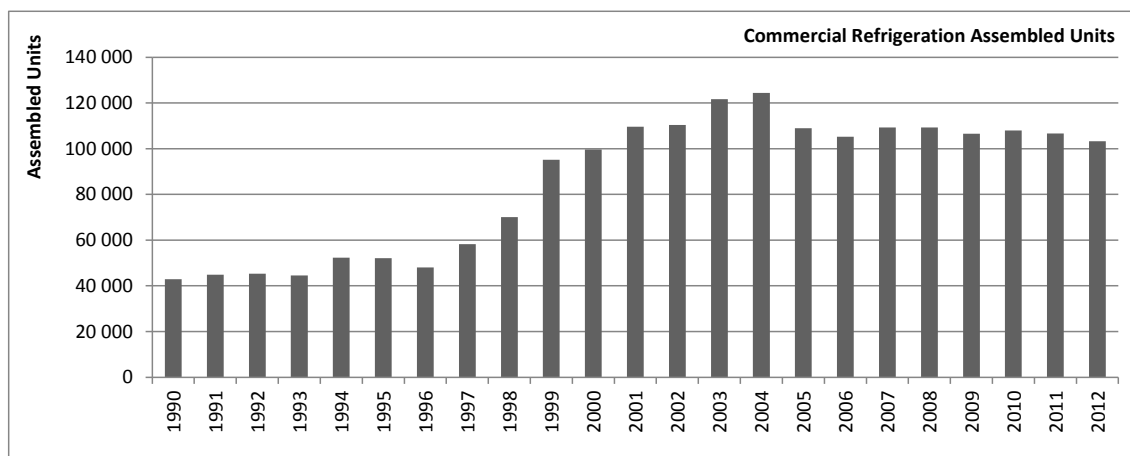
Equipments lifetime was set as 14 years.

The residual amount of fluid remaining in the equipments (y) was considered 90% and the amount of fluid recovered (z) was assumed to be 70%.

#### 4.3.5.7.3 Activity Data

Data on the assemblage of commercial and industrial refrigeration units from national statistics Industrial Survey (IAP) is only available after 1992 and refers to refrigeration units with a viewing monitor. The number of these units is comparatively smaller than domestic ones (see Figure 4.6). The number of units for 1990 and 1991 was estimated concerning the Gross Domestic Product (GDP) values for each year.

Figure 4-28 - Number of commercial and industrial refrigeration assembled units in Portugal



There are no available national statistics concerning the number and dimension of non-domestic refrigeration equipments used in commerce, industry, tourism, services and institutional activities. A survey to Hotels, Hostels and Camping Parks was conducted with the support of “Turismo de Portugal, ip” and “AHP – Associação da Hotelaria de Portugal”, in order to obtain real data concerning the number and dimension of non-domestic refrigeration equipments. Data pertaining to other commerce and services activities was estimated with the technical support of APIRAC, Importers and DGAE (Economic Activities General Directorate). Calculations for Hypermarkets were made separately.

The number of refrigeration equipments was estimated based on the unit numbers available from National Statistics Institute (INE), for the following economic activities:

Table 4-21 - 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 4-22 - 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 4-23 - 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 4-24 – Classification of refrigeration equipments by area

Area (m <sup>2</sup> )	Category	Showcase Fridge/Freezer (m)		Refrigeration Chambers (m <sup>2</sup> )	Congelation Chambers (m <sup>2</sup> )
		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 4-25 – Number of installations using F-Gas as Refrigeration Fluid

Category		Number of Units using HFC as Refrigeration Gas																	
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Positive Temperature	Big	0	0	0	0	2	3	5	6	7	7	10	10	20	23	35	36	37	38
	Medium	0	0	0	0	12	22	36	42	44	52	73	111	154	220	257	269	281	293
	Small	0	0	0	0	33	76	105	133	147	156	214	270	357	490	542	573	604	635
Negative Temperature	Big	0	0	0	0	0	1	3	4	5	5	8	8	18	21	33	34	35	36
	Medium	0	0	0	0	0	10	24	30	32	40	61	99	142	208	245	257	269	281
	Small	0	0	0	0	0	43	72	100	114	123	181	237	324	457	509	540	571	602

The number of disposed equipments in each year was assumed equal to the number of assembled equipments 14 years before. 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 equipment<sup>70</sup>. It was assumed an average lifetime of 14 years.

#### 4.3.5.7.4 Recalculations

We made some adjustments in the methodology in order to fulfill the description above. The amount of fluid recovered (z), previously assumed to be 0.0% was updated to 70.0%.

#### 4.3.5.7.5 Uncertainty Assessment

The uncertainty in the refrigeration equipment stock estimates was considered higher than that for domestic refrigeration. Using the same arguments that were used to derive activity data numbers, the actual values could be underestimated by 50 percent or overestimated by 200 percent. The uncertainty on the number of disposed units per year is probably even higher, reflecting the uncertainty in the lifetime of the equipment. That results in a range of 23 to 26 percent uncertainty for stock and the double was considered for disposal. In the other hand, the uncertainty in new units estimates results from the same source of information than that for domestic equipments and the uncertainty value of 10 percent was considered.

<sup>70</sup> In consequence no emissions of HFC from disposal are estimated for the reported period.

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 mixture<sup>71</sup>, 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.

Table 4-26 – 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	82	21	96	223
Disposal	183	11	21	96	208

#### 4.3.5.8 *Laboratory Refrigeration*

There was no information available related to technical specifications of laboratory refrigeration equipments, however PFCs are used in this kind of equipments. We have potential emissions data based on imports of PFCs and have estimated and used an emission factor that relates potential and actual emissions for other commercial equipments (0.5 %).

#### 4.3.5.9 *Transport Refrigeration*

##### 4.3.5.9.1 *Methodology*

It was used the same methodology as for Domestic Refrigeration (**Erro! A origem da referência não foi encontrada.**).

##### 4.3.5.9.2 *Emission Factors*

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 a yearly disposal of 10 percent of the vehicles (value agreed upon with Manufacturers Association).

Lifetime emissions were assumed to occur with a yearly rate of 32.5 percent of initial charge per year in accordance with the average rate proposed in table 3.22 of the GPG. The residual amount of fluid remaining in the equipments (y) was considered 90.0% and the amount of fluid recovered (z) was assumed to be 70.0%.

<sup>71</sup> This factor was not considered in the 2006 submission. It represents the change in final CO<sub>2</sub>e values given the possible range in the gas composition that is used in the final mixture.

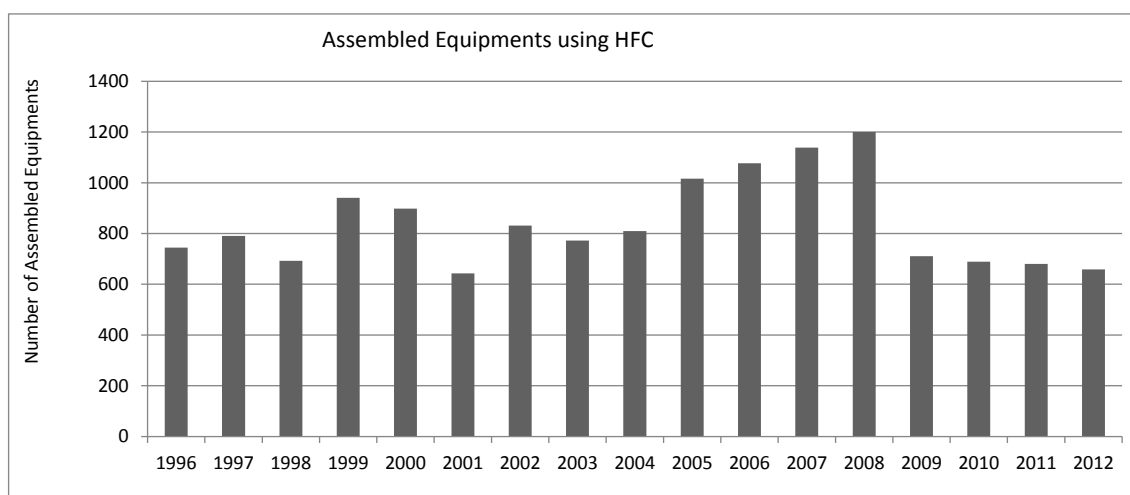
Table 4-27 – Transport Refrigeration emission factors

	Unit	Emission Factor
Initial Charge	Kg/equipment	5.35
Initial Emission (k)	%	0.60
Lifetime Emission (x)	%	32.50
Fluid remaining in the equipment at the end of lifetime (y)	%	90.00
Fluid recovered from the equipment at the end of lifetime (z)	%	70.00

#### 4.3.5.9.3 Activity Data

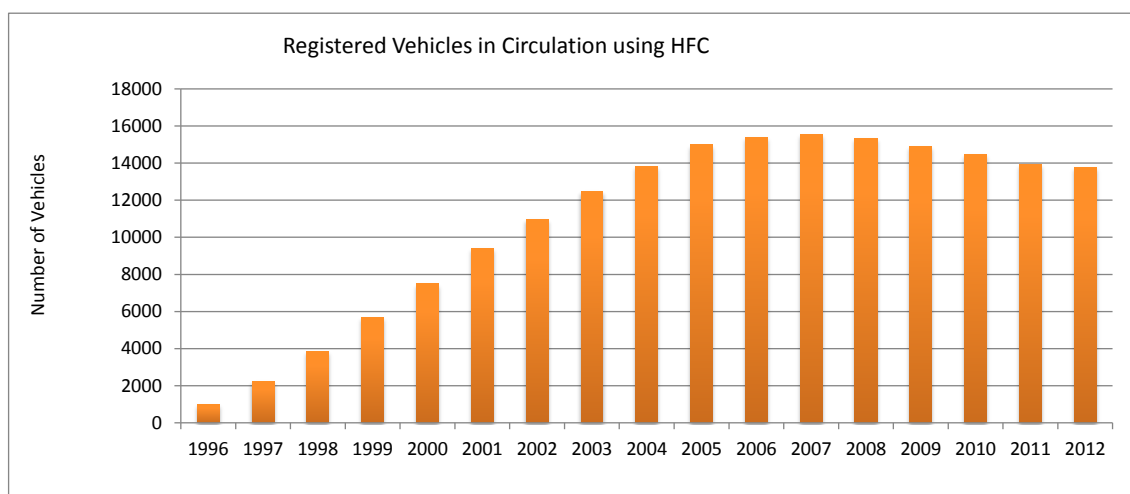
It was assumed that, before 1996, CFC-12 was used instead of HFC as Refrigeration Fluid in Portugal. Data on the number of equipments assembled in Portugal was collected from equipment manufacturers.

Figure 4-29 – Number of Equipments assembled in Portugal



Data on the number of registered vehicles was provided by the Portuguese Authority on Vehicles (ex-DGV) until 2005. From 2006 onwards it was assumed a yearly increase rate based on the average increase rate verified in the period 2002-2005.

Figure 4-30 – Number of Registered Vehicles in circulation in Portugal using HFC



#### 4.3.5.9.4 Recalculations

We made some adjustments in the methodology in order to fulfill the description above. The amount of fluid recovered (z) was updated to 70.0%.

#### 4.3.5.9.5 Uncertainty Assessment

For this source category there is also a high level of uncertainty in the determination of refrigeration equipment stock and it was assumed that the uncertainty varies from 20 percent (new units), 40 percent (stock) and up to 100 percent (disposal).

Uncertainty values for emission factors, in a similar way as for domestic refrigeration, incorporate the uncertainty in the: initial charge; emission factor; composition of the F gas mixture, which affects the overall GWP; and also an uncertainty component for the time of discharge – expressing the uncertainty in lifetime. Each value was determined in accordance with the range of default emission factors in GPG, except the uncertainty in the initial charge that was determined from the range of values referred from the three most important providers of the refrigeration equipment for vehicles in Portugal. Individual uncertainty values are presented in the next table.

Uncertainties in the previous submission were found to be underestimated.

Table 4-28 – 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

#### 4.3.5.10 Domestic Stationary Air conditioning

##### 4.3.5.10.1 Methodology

It was used the same methodology as for Domestic Refrigeration (**Erro! A origem da referência não foi encontrada.**).

##### 4.3.5.10.2 Emission Factors

The amount of initial gas charged per equipment, set at 300 g/unit, is based upon information collected from the Portuguese Association of Refrigeration Equipment Providers (APIRAC) by Seixas et al (2000). The F-gas composition was obtained by data from importers. It was assumed that during the first filling, 0.6 percent of the initial charge of gas is lost (arithmetic average of the values 0.2 and 1 recommended by the IPCC Good Practice Guidance).

Lifetime emission factor was set as 3 percent of initial charge per year, which is the average value from the proposed range in IPCC GPG table 3.22.

The residual amount of fluid remaining in the equipments (y) was considered 90.0% and the amount of fluid recovered (z) was assumed to be 50.0%.

Table 4-29 – Domestic Stationary Air conditioning emission factors

	Unit	Emission Factor
Initial Charge	Kg/equipment	0.3
Initial Emission (k)	%	0.6
Lifetime Emission (x)	%	3.0
Fluid remaining in the equipment at the end of lifetime (y)	%	90.0
Fluid recovered from the equipment at the end of lifetime (z)	%	50.0

##### 4.3.5.10.3 Activity Data

From industry statistics it is not possible to have a clear estimate on 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 Instituto Superior Técnico (IST-UTL), the following time series (**Erro! A origem da referência não foi encontrada.**), from 1990 to 2012, as adopted by the inventory. According to IAIT, 50 821 and 63 108 units were assembled, respectively, in 1990 and 1991<sup>72</sup>.

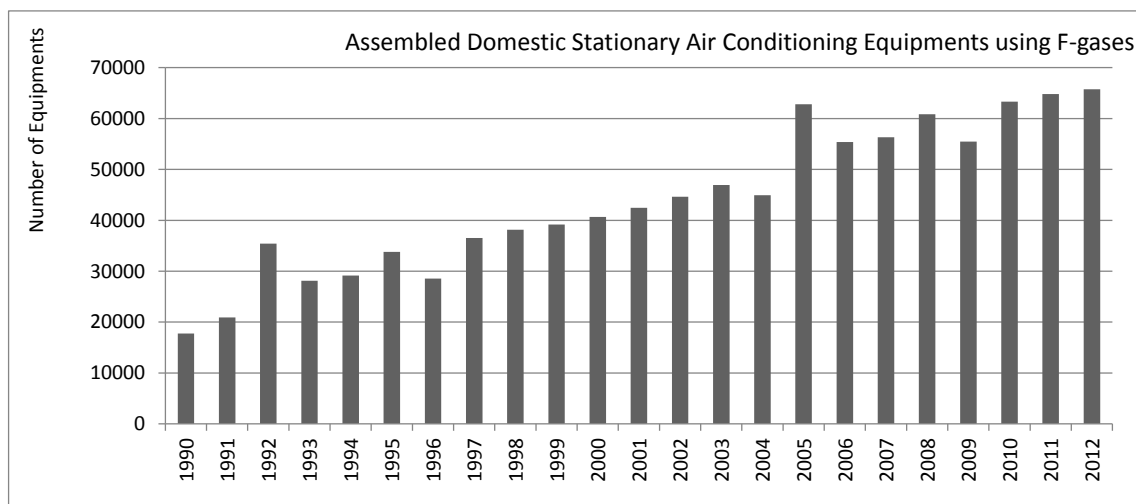
<sup>72</sup> Due to difference in magnitude order these values from IAIT are not shown in the graph



It was assumed that 90 percent of stocks and assembled air conditioning equipments are domestic equipments.

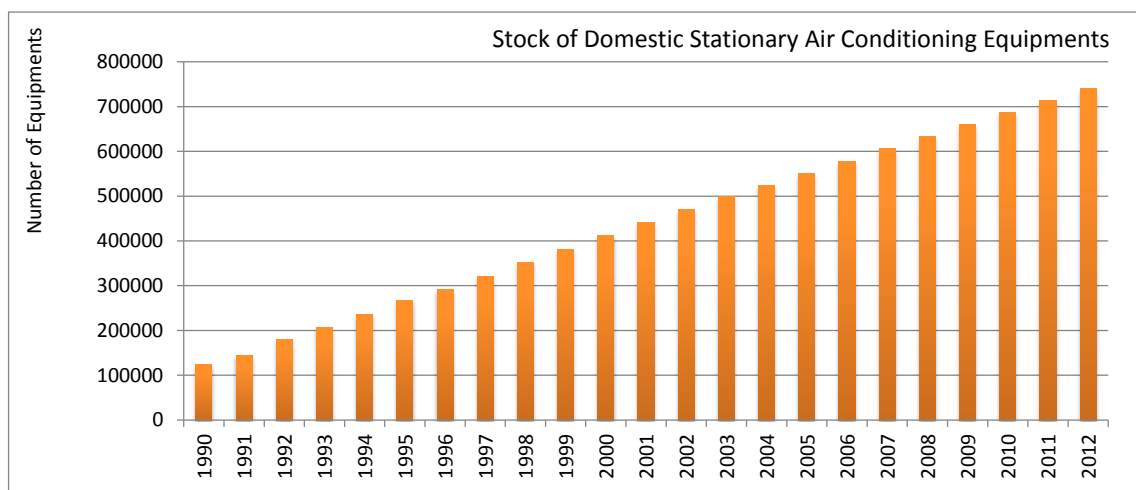
The number of assembled domestic stationary air conditioning equipments was available from unpublished information received from IST-UTL (see **Erro! A origem da referência não foi encontrada.**) for the period 1990-2012.

Figure 4-31 - Number of Domestic Stationary Air Conditioning Equipments assembled in Portugal



Annual stock of domestic stationary air conditioning equipments (see **Erro! A origem da referência não foi encontrada.**) and yearly disposed units were also available from the same unpublished information received from IST-UTL for the period 1990-2012.

Figure 4-32 - Annual Stock of Domestic Stationary Air Conditioning Equipments in Portugal



#### 4.3.5.10.4 Recalculations

The amount of fluid recovered (z) was updated to 50.0%.

#### 4.3.5.10.5 Uncertainty Assessment

The uncertainty in the number of newly assembled AC units is higher than the value that was considered for domestic refrigeration due to the incomplete time series data. An uncertainty value of 20 percent was assumed. Regarding stock in existence, an uncertainty of 40 percent was considered, and a higher value of 100 percent was used for disposal.

Similarly to domestic refrigeration, uncertainty values for emission factors incorporate the uncertainty in the: initial charge; emission factor; composition of the F gas mixture; and also an uncertainty component for time of discharge. The uncertainty in the initial charge of the equipments is based on the expert guess from APIRAC. The uncertainty associated to other parameters was established based on the range of default emission factors in GPG. Individual uncertainty values are presented in the following table.

Table 4-30 – Uncertainty of Emission Factors for F-gases emissions from A/C stationary equipments

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	20	67	5	83	108
Operation	20	67	19	83	110
Disposal	20	6	19	83	87

#### 4.3.5.11 Industrial Stationary Air Conditioning

##### 4.3.5.11.1 Methodology

It was used the same methodology as for Domestic Refrigeration (**Erro! A origem da referência não foi encontrada.**).

##### 4.3.5.11.2 Emission Factors

The charging emission factor was set to 0.6 percent (average of the values suggested by IPCC Guidelines for Chillers). A lifetime emission factor of 3.0 percent of initial charge per year, corresponding to the average value from the proposed range in IPCC GPG table 3.22, was considered.

The residual amount of fluid remaining in the equipments (y) was considered 90.0% and the amount of fluid recovered (z) was assumed to be 50.0%.

Table 4-31 – Industrial Stationary Air conditioning emission factors

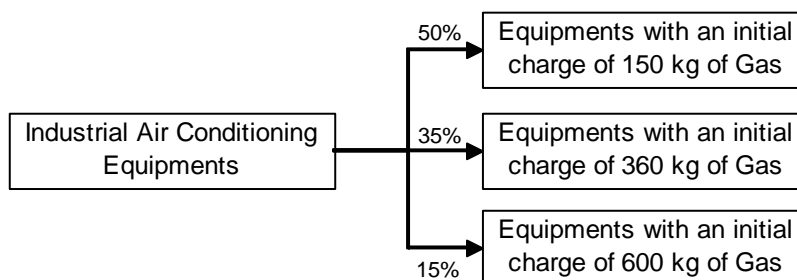
	Unit	Emission Factor
Initial Charge	Kg/equipment	291 <sup>73</sup>
Initial Emission (k)	%	0.6
Lifetime Emission (x)	%	3.0
Fluid remaining in the equipment at the end of lifetime (y)	%	90.0
Fluid recovered from the equipment at the end of lifetime (z)	%	50.0

#### 4.3.5.11.3 Activity Data

From industry statistics it is not possible to have a clear estimate on the number of assembled units over time, as consequence of the change that occurred in the industrial survey in 1992, when IAIT was replaced by IAPI, as the latter uses different products categories. IAIT survey categories are not detailed enough to differentiate the production of refrigeration components – from which no emissions occur - from their final assembling. The closedown of an important factory in that period further complicates the determination of the time series. This situation is nonetheless irrelevant for the inventory because F-gases emissions in the assembling of AC equipments did not occur in that period.

It was assumed that 10 percent of stocks and assembled air conditioning equipments are included in the industrial category (see **Erro! A origem da referência não foi encontrada.**).

Figure 4-33 – Subdivision of Industrial Air Conditioning Equipments by type



According to the available data from Luís Roriz (IST-UTL), the following time series (figure below), from 1993 to 2012, was considered in the inventory.

<sup>73</sup> We assume that 50% have an initial charge of 150 kg, 35% have an initial charge of 360 kg and 15% an initial charge of 600 kg. The combined initial charge is 291 kg/equipment.

Figure 4-34 – Number of Industrial Stationary Air Conditioning Equipments Assembled in Portugal

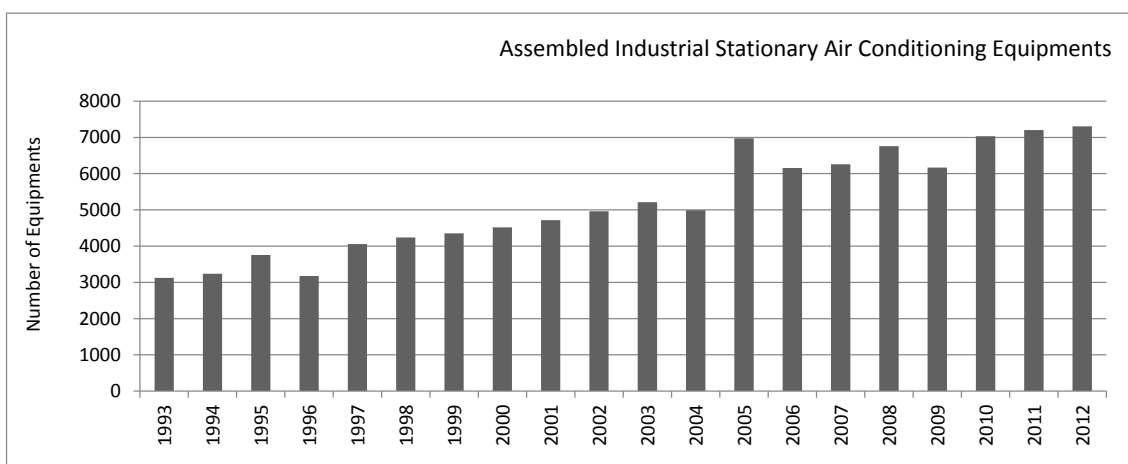
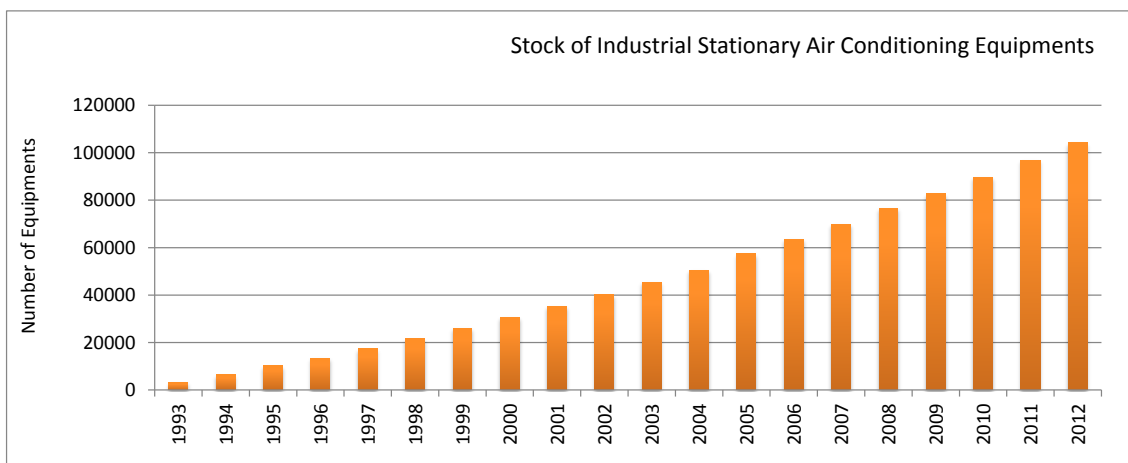


Figure 4-35 – Annual Stock of Industrial Stationary Air Conditioning Equipments in Portugal



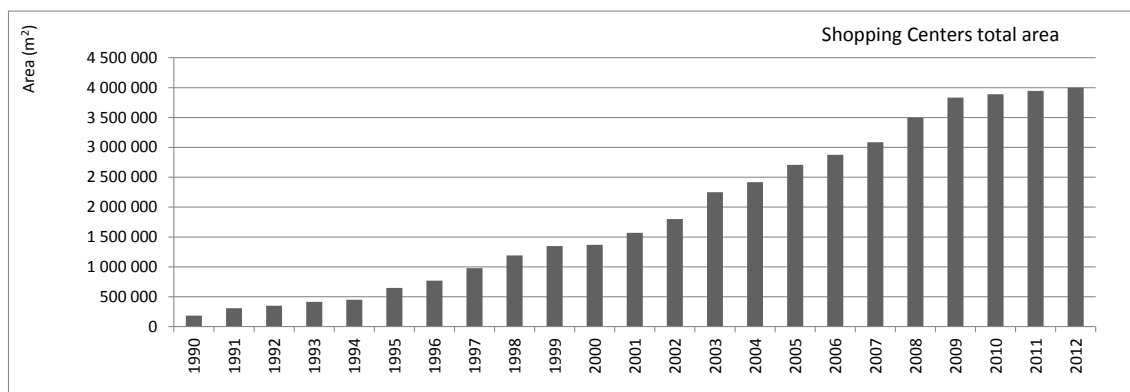
Data on the Temporal Distribution by type of gas was obtained from fluid suppliers.

#### 4.3.5.11.4 Air conditioning equipments from Shopping centers

When considering shopping centers with centralized air conditioning systems, a different methodology was used, considering specific data from each commercial area.

Data on the opening date and total area of each shopping center was provided by APCC (Portuguese Association of Shopping Centers) until 2010. The 2011 and 2012 data was forecasted assuming the same area increase verified in 2010. The figure below shows shopping centers total area.

Figure 4-36 – Shopping Centers total area (m<sup>2</sup>)



Some Shopping Centers provided data on the amount of gas used to charge the air conditioning equipments. Based on the available information, the ratio between the shopping center area and the amount of initial charge of gas was determined. This ratio was used to estimate the initial amount of gas used to fill air conditioning equipments in the Shopping Centers for which such information was not available. A ratio that relates the area and the annual loss of gas was also estimated. Based on collected information on the type of gas, it was assumed that after year 2000 (included) the gas used in assembled equipments was R-407c (HFC mixture), and before 2000 HCFC-22 was used.

#### 4.3.5.11.5 Recalculations

The amount of fluid recovered (z) was updated to 50.0%.

#### 4.3.5.11.6 Uncertainty Assessment

The uncertainty assessment is explained in the chapter describing Domestic Stationary Air Conditioning.

#### 4.3.5.12 Mobile Air Conditioning

##### 4.3.5.12.1 Methodology

It was used the same methodology as for Domestic Refrigeration (**Erro! A origem da referência não foi encontrada.**).

##### 4.3.5.12.2 Emission Factors

Operation emission factors were estimated at an annual rate of 15 percent, corresponding to the average of the updated default range (10-20 percent) in IPCC GPG (table 3.23). Lifetime was set to 12 years, also corresponding to the default value both in IPCC 96 and IPCC GPG.

Variable y was set to 40 percent (default value in IPCC GPG). Variable z was set to 70 percent.

##### 4.3.5.12.3 Activity Data

Estimates for Road Transportation and Railways were made separately.

The number of light vehicles with MAC was estimated from the total number of light vehicles sold each year, using the same information used to establish the time series of car sales and fleet in chapter 1A3, and the percentage of new cars sold with MAC at each year was estimated according to data provided by manufacturers. The total number of vehicles equipped with MAC is presented in **Erro! A origem da referência não foi encontrada..**

Figure 4-37 - % of Assembled Vehicles with AC by class of vehicle

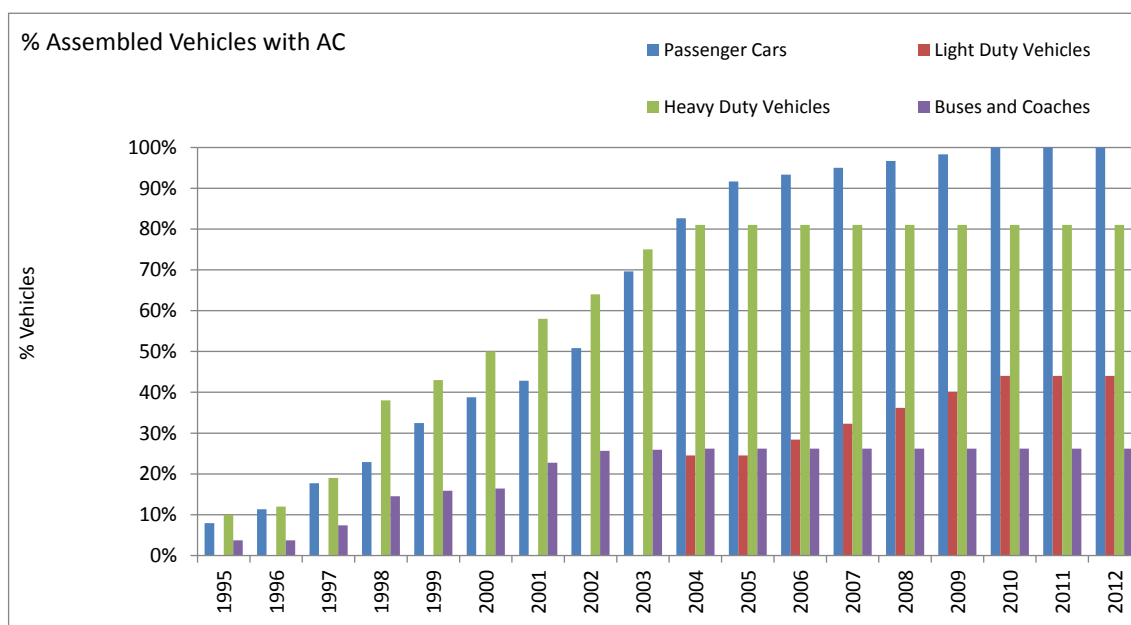
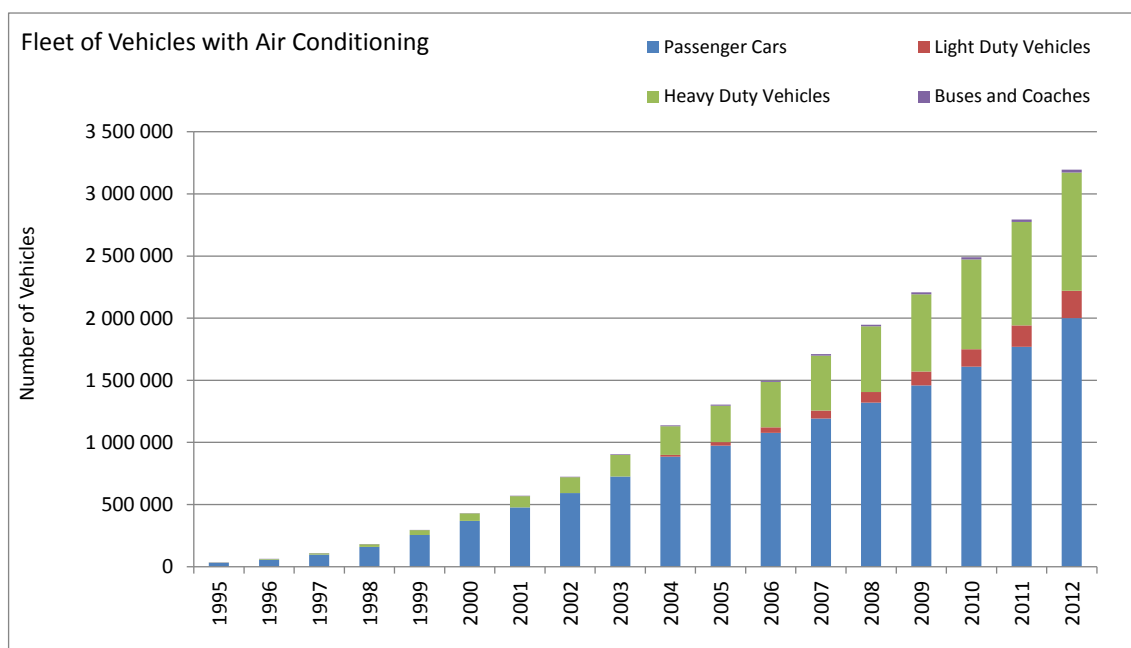


Figure 4-38 – Fleet of Vehicles equipped with AC systems



#### 4.3.5.12.4 Other Relevant Data and Parameters

The amount at initial charge of 0.77 kg/MAC unit for Passenger Cars and Light Duty Vehicles was considered. The initial charge values of 1.2 kg/MAC unit and 7.5 kg/MAC unit were

considered for Heavy Duty Vehicles and for Buses and Coaches, respectively (these values were agreed upon with equipment manufacturers).

It was assumed that HFC-134a is the only HFC replacing CFC and HCFC in MAC associated to Road Transportation, which is in accordance with IPCC GPG. In Portugal the use of HFC-134a associated to MAC equipments reports to year 1993.

In MAC equipments associated to Trains and Subway, both HFC-134a and R-407C are used. For trains, the initial charge amount was considered 1.05-1.5 kg/MAC unit and 4-20 kg/MAC unit, on the crew room and on passenger rooms, respectively.

#### 4.3.5.12.5 Uncertainty Assessment

The uncertainty in new units is higher than that of other refrigeration equipments due to the lack of specific national statistics information concerning the installation of these equipments in vehicles. Moreover, a survey directed to vehicle sellers, was only partially implemented. There is also a high level of uncertainty associated with the determination of MAC units, which are estimated based on sales, vehicle fleet and life time, and it was determined that the actual values could be up to twice higher than the number of new equipment entering the market. The number of units disposed annually is even harder to establish and an uncertainty of 100 percent was assumed.

Similarly to what was done for domestic refrigeration, uncertainty values for emission factors incorporate the uncertainty in the initial charge, in the emission factor and also a component for time of discharge – expressing the uncertainty in lifetime. Only one gas is mentioned in MAC systems and, therefore, no uncertainty in gas composition was considered. The uncertainty in the remaining parameters was established in accordance with the range of default emission factors in GPG, except the initial charge, that was established by comparing the information delivered by the major car sellers in Portugal. Individual uncertainty values are presented in the next table.

Table 4-32 – Uncertainty of Emission Factors for HFC emissions from MAC

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	20	11	5	0	24
Operation	20	33	19	0	44
Disposal	20	44	19	0	52

#### 4.3.5.13 Foam Blowing

##### 4.3.5.13.1 Overview

Fluorinated gases are nowadays used as blowing agents in the manufacture of foams that are used as insulating, cushioning and packaging materials.

The foams blowing agent is eventually ventilated to the atmosphere, but at a rate dependent on the type of foam and its structure. Open cell foams emit virtually all blowing agent at the time of manufacture. Closed-cell foams emit the HFC blowing agent during their lifetime at three distinct phases:

- Foam Manufacturing emissions, occurring during the first year at the location where the foam is manufactured;
- Annual losses, occurring where the foam is applied, result from the slow release of the blowing agent trapped inside the foam.
- Disposal. Emissions occurring when foam is removed and destroyed. The remaining gas in cells is emitted to atmosphere.

Activity data on the use of HFC in foam manufacturing in Portugal is available, allowing the estimation of manufacturing emissions. Annual losses are, however, harder to estimate because it is not known neither the quantity of closed-cells imported that were manufactured with F gases, nor the quantities of foams that were exported with HFC. Nonetheless, assumptions are based on expert judgements.

In Portugal, there is production of Polystyrene closed-cell foams and Polyurethane open-cell foams, associated to the use of HFC-134a and HFC-152a as blowing agents.

#### 4.3.5.13.2 Methodology

Methodology is classified as Tier 2a, using national data, but considering default emission factors. Therefore, emissions include:

First year losses from Foam Manufacture and Installation

$$FGas_{Emi(t,j)} = FillGas_{Consumption(t)} * HFC_{\%(j,t)} * (k/100)$$

Annual losses.

$$FGas_{Emi(t)} = FGas_{inFoam(t)} * (x/100)$$

$$FGas_{inFoam(t,j)} = \sum_{y=t}^{t-Lifetime} [FillGas_{Consumption(y)} * HFC_{\%(j,y)}]$$

Where:

$FGas_{Emi(t,j)}$  - gas emission at year t of fluorine gas j;

$FGas_{Consumption(t)}$  - Total F gas consumption at year t used in closed-cell manufacturing;

$HFC_{\%(j,t)}$  - Percentage of Fluorine gas J used at year t in closed-cell manufacturing;

$FGas_{inFoam(t,j)}$  - quantity of F gas j in closed-cell existing in the country at year t<sup>74</sup>;

K - first year loss emission factor;

X - annual loss emission factor.

This formulation is similar to equation 3.38 of the GPG.

<sup>74</sup> For the time being the stock is restricted to foam filled in Portugal;



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 larger<sup>75</sup> than the time between the first use of HFC and 2010.

#### 4.3.5.13.3 Emission Factors

Due to unavailability of country-specific information, default emission factors from GPG (table 3.17) shown in the following table were used:

Table 4-33 - Emission Factors to estimate F gas emissions from foam losses

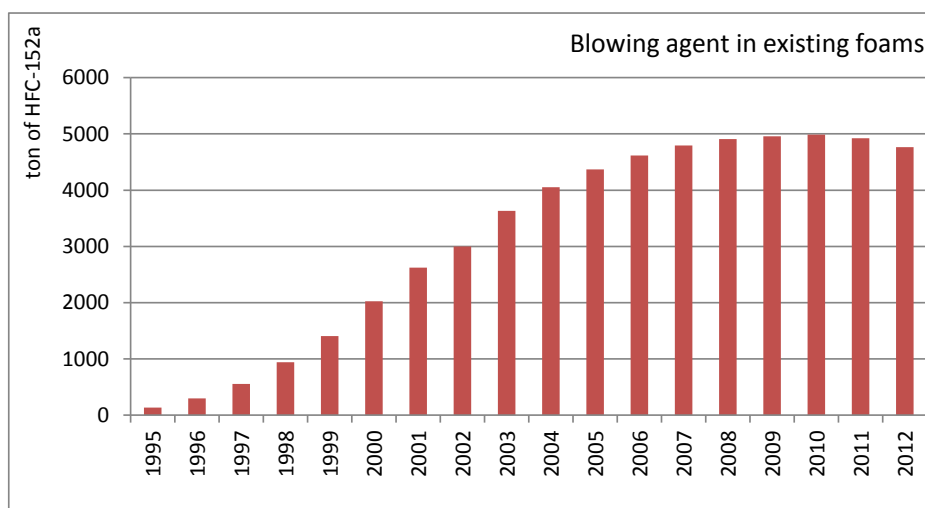
Type of Foam	Emission Factor		EF (% Original Charge)
Open Cell	K	First Year Losses	100
Closed Cell	K	First Year Losses	10
Closed Cell	x	Annual Losses	4.5

#### 4.3.5.13.4 Activity Data

Data on amounts of imported and exported foams by type of product were obtained from DGAE (Economic Activities General Directorate) and data on produced amounts of foam were provided by DGAE and manufacturers.

It was considered that the use of F-gases as foam blowing agents in foams produced in Portugal was introduced in 2003. For foams imported and applied in Portugal it was considered the use of F-gases from 1995 onwards. Foam industry is shifting to the use of non-HFC agents. The amount of F-gas blowing agent associated to existing foams is presented in the figure below.

Figure 4-39 – Amount of blowing agents used in Existing Foams in Portugal (ton/yr)



#### 4.3.5.13.5 Uncertainty Assessment

According to recommendations of GPG for country-specific top-down information, the uncertainty in fill gas consumption was maintained at 50 percent, but the establishment of a

<sup>75</sup> Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

better foam stock time series allowed the reduction of uncertainty in operation from one order of magnitude to 100 percent.

The uncertainty in emission factors result from the uncertainty in the release rate (emission), the life time, and also gas composition. The values set from the range in GPG (IPCC, 2000) are shown in the next table.

Table 4-34 – Uncertainty of Emission Factors for HFC emissions Foams

Origin	Uncertainty			
	Emission	Time of Release	Gas Composition	Combined
Blowing	425	5	81	433
Leakage	44	19	81	94

#### 4.3.5.14 *Metered Dose Inhalers*

##### 4.3.5.14.1 Overview

Fluorinated gases are used as propellants in pressurized solutions (metered dose inhalers) in the treatment of asthma.

##### 4.3.5.14.2 Methodology

It is assumed that the gas is partly emitted during the same year the inhaler is sold and in the subsequent year. The method is similar to the equation 3.35 of GPG (2000), but an arithmetic average was used in this case.

$$Emi_{HFCt} = [\Sigma(\text{Sold MDI}_{t-1} * K_{t-1}) + \Sigma(\text{Sold MDI}_t * K_t)] / 2 * 10^{-6}$$

Where

$Emi_{HFCt}$  - Emission of F-gas in year t

$\text{Sold MDI}_{t-1}$  - 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

$\text{Sold MDI}_t$  - Number of Sold units of each MDI in year t

$K_t$  - Charge of gas of each equipment sold in year t

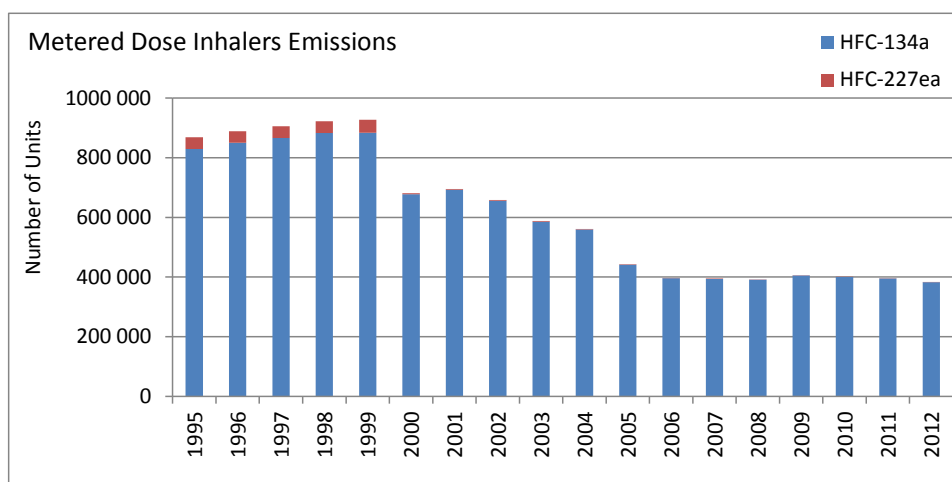
##### 4.3.5.14.3 Emission Factors

Each manufacturer provided charge values for each type of inhaler. However, the yearly average emission factor lies in the range [12.05-14.75] g/inhaler.

##### 4.3.5.14.4 Activity Data

Information was gathered on the amounts of sold inhalers charged with F-gases. Information on the percent of propellant (F-gas) for each type of inhaler was also provided. The two F-gases in inhalers are HFC-134a and HFC-227ea.

Figure 4-40 – Sold Metered Dose inhalers using F-gases as propellant



#### 4.3.5.14.5 Further Improvements

More detailed information should be provided by manufacturers in the future, in order to obtain a better characterization of the inhalers market.

#### 4.3.5.14.6 Uncertainty Analysis

The uncertainty in MDI was assumed as 63 percent, due to yearly changes.

#### 4.3.5.15 Fire Protection

##### 4.3.5.15.1 Overview

The most used equipments for fire protection in Portugal are the streaming (portable) ones. They contain HFC-23 and HFC-227ea gases.

##### 4.3.5.15.2 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)

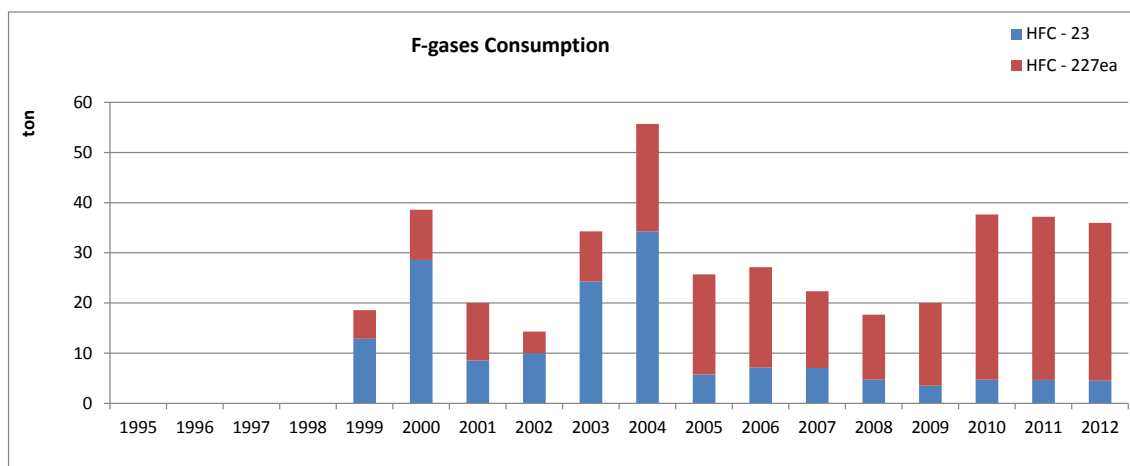
##### 4.3.5.15.3 Emission Factors

It was assumed y equal to 99.99 percent and z equal to 99 percent. Annually, 4 percent of the existing equipments are dismissed.

#### 4.3.5.15.4 Activity Data

Data on amounts of used gases in fire extinguishing equipments was provided by sellers and responsible enterprises for equipments filling for the period 1999-2010 and forecasted for the period 2011-2012 based on gross domestic product. These equipments contain HFC-23 and HFC-227ea gases (see the figure below). The replacement of halons by HFC during 2004 in order to fulfil Regulation (EC) No 2037/2000 is reflected in the consumption increase of HFC-23 and HFC-227-ea. In the 2005-2009 period there is a decrease in consumption values associated to market saturation.

Figure 4-41 – HFC consumption in Fire Extinguishing Equipments by type of gas (ton)



#### 4.3.5.15.5 Uncertainty Assessment

The uncertainty from fire protection equipment data was assumed as 20 percent, given that only one company is importing this kind of equipment to Portugal. The uncertainty in the type of gas, either HFC-23 or HFC-227ea, and differences in their GWP value, amount to an uncertainty of 60 percent. The final uncertainty value was set at 64 percent.

#### 4.3.5.15.6 Further Improvements

Activity data will be updated in next submission based on information provided by sellers and responsible enterprises for equipments filling.

#### 4.3.5.16 *Electrical Equipment Manufacturing*

##### 4.3.5.16.1 Overview

In Portugal, sulphur hexafluoride (SF<sub>6</sub>) is used in the electrical equipment manufacturing sector, as current interruption media in switch-gears and circuit breakers. Due to the scarce number of national electrical equipment manufacturers, activity data and emission factors are reported as “C” (confidential) and we only present emissions values.

#### 4.3.5.16.2 Methodology

It is used a Tier 1 methodology based on SF<sub>6</sub> consumption by manufacturers and on emission factors in line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Emissions are estimated using the following equation:

$$\text{SF}_6 \text{ emission}_{(y)} = \text{EF} * \text{SF}_6 \text{ consumption}_{(y)}$$

where

SF<sub>6</sub> emission<sub>(y)</sub> - annual SF<sub>6</sub> emission in year y (ton/yr);

SF<sub>6</sub> consumption<sub>(y)</sub> – annual SF<sub>6</sub> consumption in year y (ton/yr);

EF – Fraction of SF<sub>6</sub> emitted during electrical equipment manufacturing.

#### 4.3.5.16.3 Emission Factors

Due to confidentiality constraints it was not possible to publish the chosen emission factors, however they are in line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. We assumed that 50% of the manufactured equipments are sealed pressure and the other 50% are closed pressure.

#### 4.3.5.16.4 Activity Data

Activity data on SF<sub>6</sub> consumption in electric equipment manufacturing was obtained from national equipment producers for the period 1995-2012, however due to confidentiality constraints it was not possible to publish the chosen activity data. We assumed that 50% of the manufactured equipments are sealed pressure and the other 50% are closed pressure.

#### 4.3.5.16.5 Uncertainty Assessment

The uncertainty in activity data was set at 10 percent, since SF<sub>6</sub> consumption in electrical equipment manufacturing was obtained directly from manufacturers. It was used a 20% uncertainty for sealed-pressure equipments emission factor and a 30% uncertainty for closed-pressure equipments as advised in Table 8.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### 4.3.5.16.6 Further Improvements

No further improvements are expected.

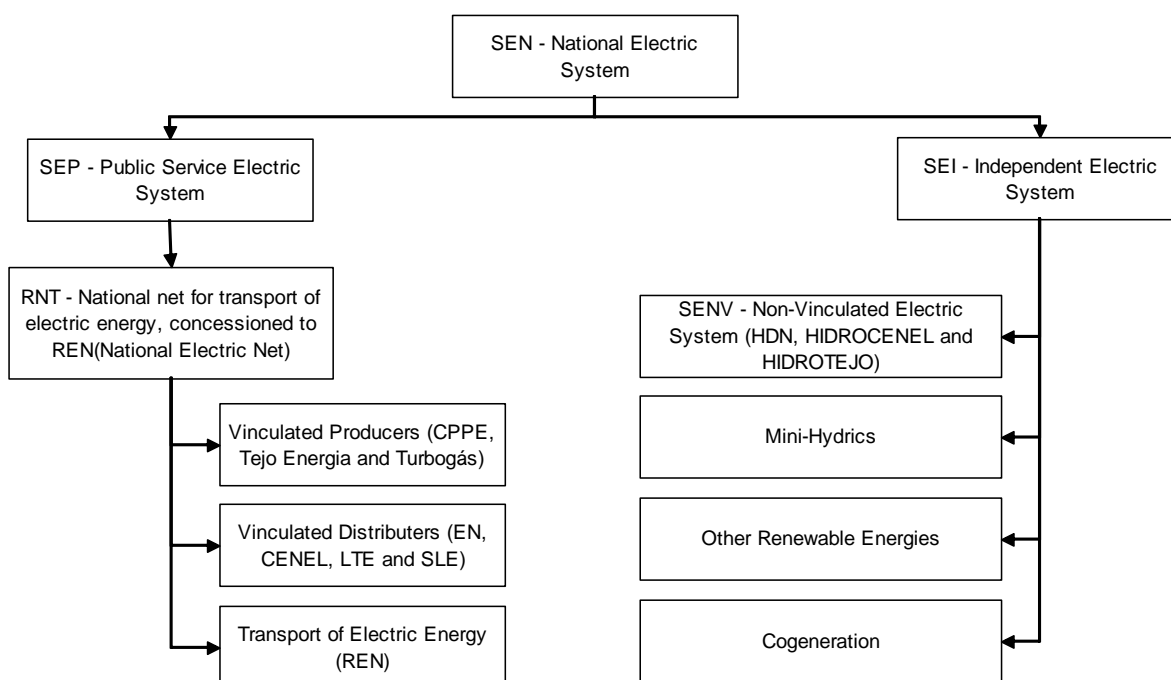
#### 4.3.5.17 *Electrical Equipment Use*

##### 4.3.5.17.1 Overview

In Portugal, sulphur hexafluoride (SF<sub>6</sub>) 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 4-42 - 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 ( $\leq 1$  kV), Medium (>1 kV and  $\leq 45$  kV) and High Voltage (>45 kV and  $\leq 110$  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 4-43 – Map of National Network of Electric Energy Transport



#### 4.3.5.17.2 Methodology

There are different estimates methodologies for:

- REN;
- EDP Distribuição, EDP Produção, Tejoenergia and Turbogás.

##### 4.3.5.17.2.1 REN

In this case, a methodology based on “Correspondent States Principle” was used:

$$P \times V = Z \times n \times R \times T$$

Where “Z” is the compressibility factor that can be obtained from tabled values for Reduced Pressure and Temperature.

$$n_i = \frac{P_i \cdot V}{R \cdot T_i} \cdot \frac{1}{Z_i}$$

$$n_f = \frac{P_f \cdot V}{R \cdot T_f} \cdot \frac{1}{Z_f}$$

$$m = (n_f - n_i) \cdot M$$

Source: REN – Rede Eléctrica Nacional ([www.ren.pt](http://www.ren.pt))

where:

Ti and Pi - Measured Temperature and Pressure at the beginning of reposition of lost SF<sub>6</sub>;

Tf and Pf - Measured Temperature and Pressure at the end of reposition of lost SF<sub>6</sub>;

R - Gases Constant;

V - Compartment volume filled with SF<sub>6</sub> inside the equipment;

Zi - Compressibility Factor at Pressure Pi and Temperature Ti;

Zf - Compressibility Factor at Pressure Pf and Temperature Tf;

ni - Mole number of SF<sub>6</sub> at pressure Pi and Tf before the reposition of gas;

nf - Mole number of SF<sub>6</sub> at pressure Pf and Tf after the reposition of gas;

M - SF<sub>6</sub> molecular mass;

m - SF<sub>6</sub> mass emitted;

There are two alarm situations that require an intervention and reposition of SF<sub>6</sub>:

- Loss of SF<sub>6</sub> slightly above Service Pressure (≈70 percent of Maximum Pressure);
- Loss of SF<sub>6</sub> below Service Pressure (<70 percent of Maximum Pressure) - in this situation the equipment doesn't work at all;

Besides these two situations there is a team that does regular gas repositions (each 15 days) after temperature and pressure measurements on containers. Each intervention is registered in a database and the equipment used is identified.

#### 4.3.5.17.2.2 EDP Distribuição

In EDP Distribuição separate estimates were made for:

- Gas Circuit Breakers;
- Outdoor Gas Insulated Switchgears;
- Gas Insulated Switchgears;
- High and Medium Voltage Sectioning Posts;

Actual emissions of SF<sub>6</sub> from electrical equipment were estimated with a tier T3b, based on data provided by "EDP Distribuição", excluding the details in life-cycle and using a country-specific emission factor. Emissions were determined using the following equation:



$$Emi_{SF_6(t)} = Stock_{SF_6(t)} * (EF/100)$$

where:

$Emi_{SF_6(t)}$  - Equipment use emissions, including leakage emissions, servicing and maintenance;

$Stock_{SF_6(t)}$  - total  $SF_6$  gas in existence at year t in all electrical equipments;

EF – Emission Factor, corresponding to the percentage of  $SF_6$  in stock at year t that is emitted to atmosphere.

#### 4.3.5.17.2.3 EDP Produção, Tejoenergia and Turbogás

The used methodology was identical to the one described in “EDP Distribuição”.

Disposal or retiring units were not included in the inventory as emission sources because, according to industry experts, the collection of gas at end of lifetime is done in a systematic and efficient way. Manufacturing and installation emissions were assumed to be included in emissions from equipment usage.

#### 4.3.5.17.3 Emission Factors

There are different emission factors for:

- REN;
- EDP Distribuição;
- EDP Produção;
- Tejoenergia;
- Turbogás.

##### 4.3.5.17.3.1 REN

The database on  $SF_6$  repositions by equipment was available for the period 2003-2010. For the period 1995-2002 and from 2011 onwards, an average of the estimated loss (0.38 percent) for the period 2003-2010 was considered.

##### 4.3.5.17.3.2 EDP Distribuição

In EDP Distribuição different emission factors were considered for:

- Gas Circuit Breakers:

all circuit breakers are “Closed Pressure” equipments and the emission factor is 2.6 percent/year as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”;

- Outdoor Gas Insulated Switchgears;

all outdoor gas insulated switchgears are “Sealed Pressure” equipments and the emission factor is 0.2 percent/year as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment”;

- Gas Insulated Switchgears;

it is assumed by EDP expert judgment that 27 percent of equipments are “Sealed Pressure” and 73 percent are “Closed Pressure”;

the emission factors are 0.2 percent/year to “Sealed Pressure” as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment” and 2.6 percent/year to “Closed Pressure” as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”;

- High and Medium Voltage Sectioning Posts;

all high and medium voltage sectioning posts are “Sealed Pressure” equipments and the emission factor is 0.2 percent/year as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment”;

#### 4.3.5.17.3.3 EDP Produção

Different emission factors are used for:

- Sealed Pressure Equipments;

emission factor is 0.2 percent/year as proposed on table 8.2 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Sealed Pressure Electrical Equipment”

- Closed Pressure Equipments;

EDP Produção has a database on SF<sub>6</sub> stock amounts in “Closed Pressure” equipments in the period 2000-2010. There is no data related to SF<sub>6</sub> stock in the period 1995-1999 and it is used an average emission factor of 0.93 percent based on 2000-2006 data period.

#### 4.3.5.17.3.4 Tejoenergia and Turbogás

It is assumed by “Tejoenergia” and “Turbogás” expert judgment that all equipments are “Closed Pressure” and that the emission factor is 2.6 percent/year as proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment”.

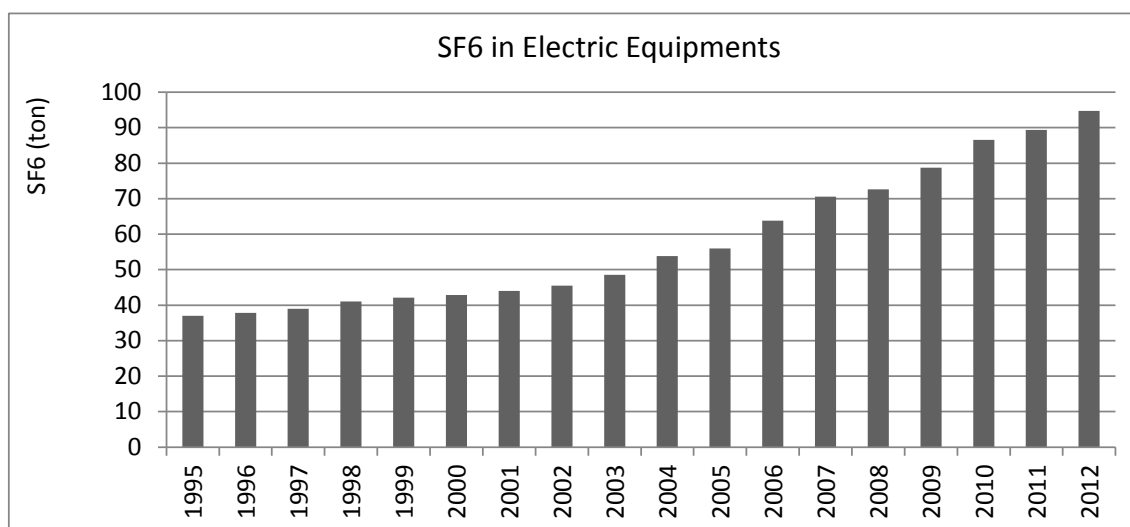
#### 4.3.5.17.4 Activity Data

Although it is not possible to differentiate activity data in this report, the information on the yearly total amount of SF<sub>6</sub> in Electric Equipments is available (see the figure below).

Table 4-35 – Average SF<sub>6</sub> charge for each kind of equipment

Equipment	SF <sub>6</sub> (kg)
Gas Circuit Breaker	1.200
Outdoor Gas Insulated Switchgear	0.720
Gas Insulated Switchgear	0.484

Figure 4-44 - Total SF6 in stock in electric equipments in Portugal



#### 4.3.5.17.5 Uncertainty Assessment

The uncertainty within a range of 12-13 percent in the emission factor was obtained from statistical analysis of the emission factors. The uncertainty in activity data was set between 6-7 percent.

#### 4.3.5.17.6 Further Improvements

No further improvements are expected.

## 5 SOLVENTS AND OTHER PRODUCT USE (CRF 3.)

### 5.1 Overview

Solvents and related compounds are a significant source of emissions of non-methane volatile organic compounds (NMVOC). Emissions of N<sub>2</sub>O from the use of anesthesia are also included in this sector. No emissions of methane are included in this source sector.

Some peculiarities apply to this source sector. In first place not all emissions occur directly to atmosphere when the production or use action takes place, as some solvents remain in product or are conveyed into wastewater. However, because eventually sooner or later these solvent fractions are liberated to atmosphere, all solvent losses may be assumed to contribute to air emissions. On the other hand, emissions of solvent may occur in three phases: during production of products containing solvents, during actual use of products containing solvent and during disposal.

NMVOC emissions estimates must be converted in CO<sub>2</sub> emissions whenever the carbon that is present in organic compounds has fossil fuel origin (originated from feedstocks from petroleum, coal or natural gas), and being assumed that NMVOC compounds are fully oxidized in air to carbon dioxide contributing thence to the atmospheric pool.

Figure 5-1 - NMVOC emissions from solvents and other product use

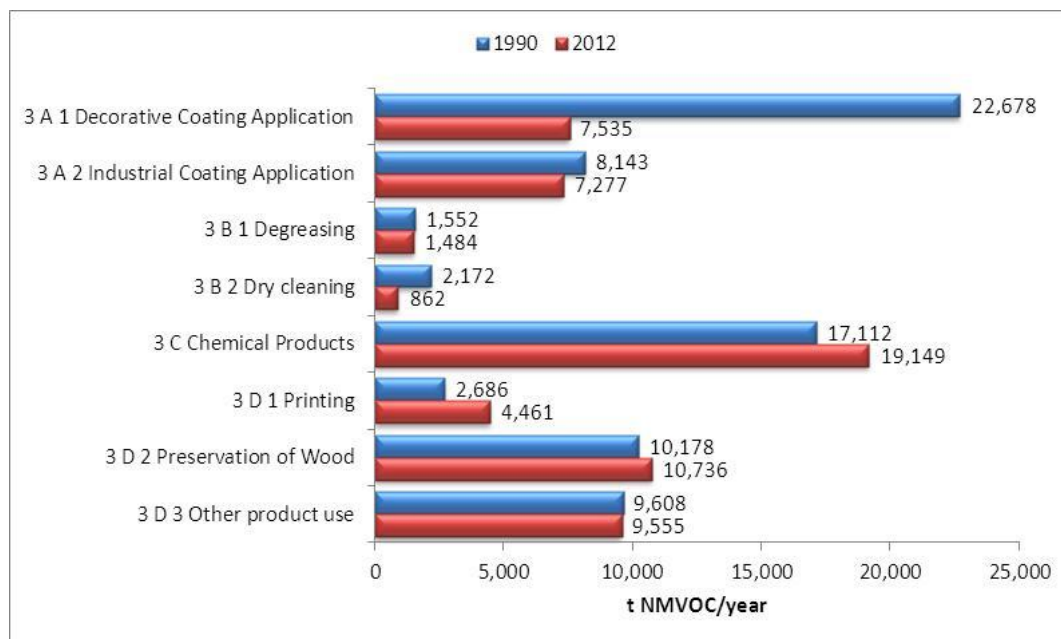
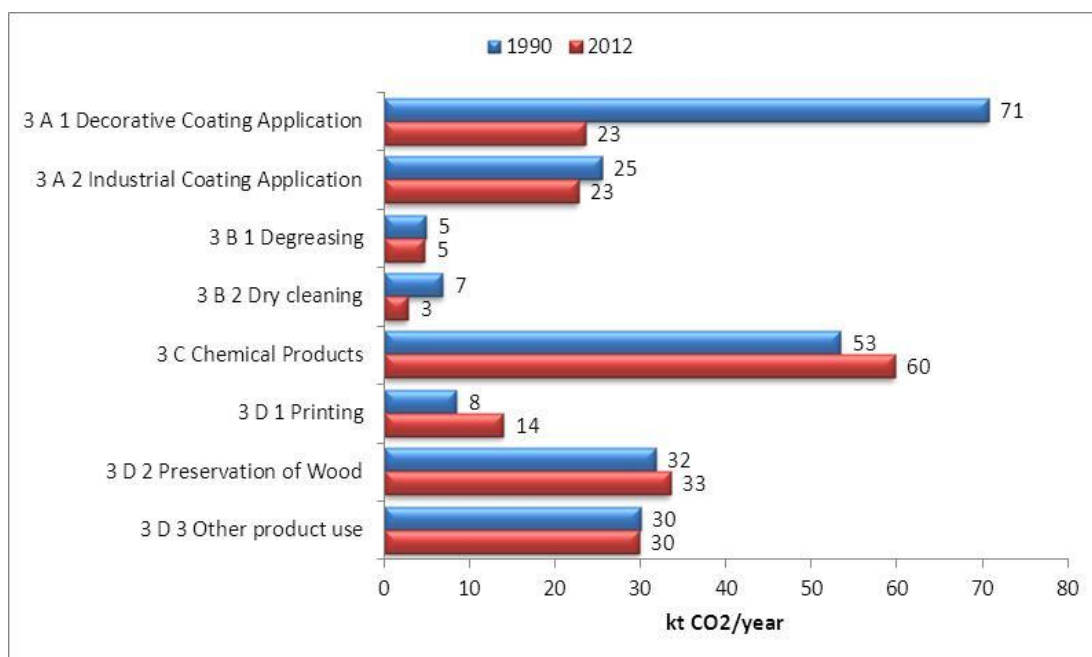


Figure 5-2 – CO<sub>2</sub> emissions from solvents and other product use



## 5.2 Recalculations

Table 5-1 - Recalculations of emissions of ghg from solvent use: differences between submissions 2011 and 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2			CH4			N2O		
	2013	2014	Difference( 1)	2013	2014	Difference (1)	2013	2014	Difference (1)
	subm.	subm.		subm.	subm.		subm.		
	CO2 equivalent (Gg)			CO2 equivalent (Gg)			CO2 equivalent (Gg)		
	(%)			(%)			(%)		
1990									
3. Solvent and Other Product Use	231.04	231.04	0.00				98.58	98.58	0.00
A. Paint Application	96.06	96.06	0.00						
B. Degreasing and Dry Cleaning	11.61	11.61	0.00				NO	NO	
C. Chemical Products, Manufacture and Proces	53.34	53.34	0.00						
D. Other	70.04	70.04	0.00				98.58	98.58	0.00
2011									
3. Solvent and Other Product Use	218.34	196.87	-9.84				48.35	25.62	-47.01
A. Paint Application	66.03	51.36	-22.21						
B. Degreasing and Dry Cleaning	7.68	7.41	-3.53				NO	NO	
C. Chemical Products, Manufacture and Proces	63.39	59.77	-5.71						
D. Other	81.24	78.33	-3.59				48.35	25.62	-47.01

(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.

## 5.3 Category Sectors

### 5.3.1 Paint Application (CRF 3.A)

#### 5.3.1.1 Overview

This sub-source sector covers NMVOC emissions resulting from the use of coating materials – interpreted as the application of a continuous layer in a surface with the objective of protecting

the surface or enhancing its appearance<sup>76</sup> – such as paints, stains, varnishes, enamels and lacquers, either in buildings or artifacts, and either from professional activities or domestic use. Emissions due to the use of inks and textile coloring are not included here. Emissions from paint manufacturing are discussed in sector CRF 3 C.

Emissions from paint use occur after paint is applied as a coating layer, irrespective of the application methodology: spraying (air pressure or electrostatic), spreading by roller or brush, dipping and electro-deposition, and happen from evaporation of solvent during paint cure. All organic compounds that evaporate are considered NMVOC emissions except if they are recovered and treated by any control equipment such as incineration or absorption.

All emissions from paint activity are included here, such as those arising from car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities and domestic use.

The distinction between coating operations in construction and building and domestic use is not very relevant because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

#### 5.3.1.2 Methodology

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(y)}$  – NMVOC emissions resulting from use/application of coating substances during year y (ton/yr);

$Coating_{CONS(a,p,y)}$  – Use of coating substance p in economic activity a during year y (ton coater/yr);

$EF_{(p)}$  – NMVOV emission factor (solvent content) resulting from application of substance p (kg/ton).

For specific sectors more detailed activity data and emissions factors were available a product base methodology was used. This is the case for:

- Cars manufacturing;
- Truck cabin coating;
- Leather finishing.

The product based methodology can be described as following.

$$Emi_{NMVOC(p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

<sup>76</sup> Non continuous applications of coatings is printing industry and is included in other sub-source category. Application of continuous layers for gluing materials, by the use of glues or adhesives is also considered elsewhere.

Where

$Emi_{NMVOC(p,y)}$  – NMVOC emissions resulting the production of product p during year y (t/yr);

$Product_{(p,y)}$  – Production units of product p during year y (cars/yr, truck cabins/yr, kg leather/yr);

$EF_{(p)}$  – NMVOV emission factor for production of product p (kg/car, kg/truck cabin, kg/kg leather)

p – product (cars, truck cabin, leather).

Ultimate CO<sub>2</sub> emissions were calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO<sub>2</sub> emissions are included in the inventory as CO<sub>2</sub>e.

$$U_{CO_2} = NMVOC * 0.85 * (44/12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

#### 5.3.1.3 *Emission Factors*

Emission factors were taken from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatment technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC\ y} = \frac{CS_{t,y}}{100} \times \left(1 - \frac{AT_t}{100}\right) \times EF_{NMVOC\ default}$$

Where:

$EF_{NMVOC(y)}$  – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$  – Control strategy, share of abatment technology t during year y (%);

$AT_{(t)}$  – Efficiency of abatment technology t (%);

t – abatment technology;

$EF_{NMVOC(default)}$  – Default NMVOC emission factor.

In cases where industrial detailed information was not available, Tier 1 emission factors for industrial paint application were used. This emission factor is based on the quantity of coating applied.

Table 5-2 – NMVOC Tier 1 emission factor for industrial application

NFR	NFR Title	Tier 1 EF	EF Unit
3 A 2	Industrial coating application	400	g/kg paint

Source: (EEA/EMEP, 2009)

#### 5.3.1.3.1 Construction and buildings (SNAP 060103)

Table 5-3 – Default emission factor

SNAP	Unit	NMVOC
Construction and buildings	g/kg paint	230

Source: (EEA/EMEP, 2009)

Table 5-4 – Abatement technology

Abatement Technology	Efficiency
Substitution with dispersion/emulsion (2-3 wt-% solvent)	39
Substitution with water-based paints (efficiency 80%)	26
Substitution with high solids paints (efficiency 40-60%)	4
Substitution with dispersion/emulsion and water-based paints	65
Substitution with dispersion/emulsion and high solids paints	43
Substitution with dispersion/emulsion, water-based and high solids paints	70

Source: (EEA/EMEP, 2009)

Table 5-5 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2012
Substitution with dispersion/emulsion (2-3 wt-% solvent)	%	0	0	100	50	0	0
Substitution with water-based paints (efficiency 80%)	%	0	100	0	0	0	0
Substitution with high solids paints (efficiency 40-60%)	%	100	0	0	0	0	0
Substitution with dispersion/emulsion and water-based paints	%	0	0	0	0	0	0
Substitution with dispersion/emulsion and high solids paints	%	0	0	0	0	0	0
Substitution with dispersion/emulsion, water-based and high solids paints	%	0	0	0	50	100	100

Source: (IIASA, 2009)

Table 5-6 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF	g/kg paint applied	221	170	140	105	69	69



### 5.3.1.3.2 Wood (SNAP 060107)

Table 5-7 – Default emission factor

SNAP	Unit	NM VOC
Wood	g/kg paint applied	960

Source: (EEA/EMEP, 2009)

Table 5-8 – Abatement technology

Abatement Technology	Unit	Efficiency
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 35%	%	75
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 75%	%	75
Wood coating-Coated surface-Combination of the above options	%	75
Wood coating-Coated surface-Low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping)	%	0
Wood coating-Coated surface-Medium solids systems (55% solvent content), application process with an efficiency of 75%	%	31
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 35%	%	94
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 75%	%	94
Uncontrolled	%	0

Source: (EEA/EMEP, 2009)

Table 5-9 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2012
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 35%	%	0.0	0.0	0.0	0.0	7.5	7.5
Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 75%	%	0.0	0.0	0.0	0.0	20.3	20.3
Wood coating-Coated surface-Combination of the above options	%	0.0	0.0	0.0	0.0	0.0	0.0
Wood coating-Coated surface-Low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping)	%	38.1	38.1	38.1	38.4	20.0	20.0
Wood coating-Coated surface-Medium solids systems (55% solvent content), application process with an efficiency of 75%	%	0.0	0.0	0.0	0.0	0.0	0.0
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 35%	%	3.8	3.8	3.8	3.8	3.8	3.8
Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 75%	%	44.1	44.1	44.1	44.1	44.1	44.1
Uncontrolled	%	14.0	14.0	14.0	13.7	4.4	4.4

Source: (IIASA, 2009)

Table 5-10 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF	g/kg paint applied	528	528	528	528	328	328
Final EF	t/t	0.5	0.5	0.5	0.5	0.3	0.3
Final EF	wt %	52.8	52.8	52.8	52.8	32.8	32.8

#### 5.3.1.3.3 Manufacture of automobiles (SNAP 060101)

Table 5-11 – Default emission factor

SNAP	Unit	NMVOC
Manufacture of automobiles: Car coating	kg/car	8

Source: (EEA/EMEP, 2009)

Table 5-12 – Abatement technology

Abatement Technology	Unit	Efficiency
Water-based primer; solvent-based	%	10
Solvent-based primer; water-based basecoat	%	40
Water-based primer and basecoat	%	50
Add on: incinerator on drying oven	%	10
Add on: Incinerator on drying oven; activated carbon adsorption on spray booth & thermal incineration	%	40

Source: (EEA/EMEP, 2009)

Table 5-13 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2012
Manufacture of automobiles-Vehicles-Process modification and substitution	% Efficiency of abatement technology mix	0	22.5	45	67.5	90	90

Source: (IIASA, 2009)

Table 5-14 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF Car coating	kg/car	8.0	6.2	4.4	2.6	0.8	0.8

#### 5.3.1.3.4 Truck cabin coating (SNAP 060108)

Table 5-15 – Default emission factor

SNAP	Unit	NMVOC
Industrial coating application: Vehicle refinishing	kg/vehicle	8

Source: (EEA/EMEP, 2009)

Table 5-16 – Abatement technology

Abatement Technology	Unit	Efficiency
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	40
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	%	45
80% two layer - 20% one layer; waterborne primer and basecoat, high solid clear coat, waterborne solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	60
Uncontrolled	%	0

Source: (EEA/EMEP, 2009)

**Table 5-17 – Control strategy**

Technology	Unit	1990	1995	2000	2005	2010	2012
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	0	0	0	0	0	0
50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	%	0	0	0	0	0	0
80% two layer - 20% one layer; waterborne primer and basecoat, high solid clear coat, waterborne solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel	%	0	0	0	0	0	0
Uncontrolled	%	100	100	100	100	100	100

Source: (IIASA, 2009)

**Table 5-18 – Final emission factor**

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0	8.0

#### 5.3.1.3.5 Leather finishing (SNAP 060108)

**Table 5-19 – Default emission factor**

SNAP	Unit	NMVOC
Industrial coating application: leather finishing	g/kg leather	200

Source: (EEA/EMEP, 2009)

**Table 5-20 – Abatement technology**

Abatement Technology	Unit	Efficiency
Use of water based products (30 wt-% solvent content)	%	65
Add on: Thermal oxidation	%	81
Add on: Biofiltration	%	81
Uncontrolled	%	0

Source: (EEA/EMEP, 2009)

**Table 5-21 – Control strategy**

Technology	Unit	1990	1995	2000	2005	2010	2012
Use of water based products (30 wt-% solvent content)	%	0	0	0	10	30	38
Add on: Thermal oxidation	%	0	0	0	0	0	0
Add on: Biofiltration	%	0	0	0	0	5	5
Uncontrolled	%	100	100	100	90	65	57

Source: (IIASA, 2009)

Table 5-22 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF leather finishing	g/kg leather	200.0	200.0	200.0	187.0	152.9	142.5

#### 5.3.1.4 *Activity Data*

The available and reliable information concerning the use of paints is restricted to a small number of activities in Portugal. From IAIT and IAPI industrial surveys, compiled by national statistics, it is only possible to determine consumption of paint in industrial activities, but the remaining, and larger part of consumption, is not known. Therefore total consume of paint and varnish in Portugal had first to be estimated from internal production, importation and exportation according to:

$$\text{Total}_{\text{Cons}(y)} = \text{Production}_{(y)} + \text{Imports}_{(y)} - \text{Exports}_{(y)}$$

where:

$\text{Total}_{\text{Cons}(y)}$  - Consumed paint and varnish in year y (t/yr);

$\text{Production}_{(y)}$  - National Produced paint and varnish in year y (t/yr);

$\text{Imports}_{(y)}$  - Imported paint and varnish in year y (t/yr);

$\text{Exports}_{(y)}$  - Exported paint and varnish in year y (t/yr).

Annual production of paints, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 5-23.

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 5-24.

Total consumption of paints was calculated and the resultant time series is presented in Table 5-25.

Table 5-23 – National production of paints (t)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Produced paints	115 892	117 358	109 426	93 969	101 145	95 328	114 015	124 512	141 700	137 979	142 082	154 210

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Produced paints	154 992	155 081	154 221	149 706	148 908	165 048	161 165	135 826	155 209	133 748	119 692

Table 5-24 – Paint import and export (t)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Imports	7 679	10 340	12 211	14 431	21 986	25 084	27 845	28 980	31 912	32 230	35 434	36 885
Exports	5 336	5 626	5 785	5 415	7 534	8 130	12 854	11 614	14 670	13 622	13 823	16 171

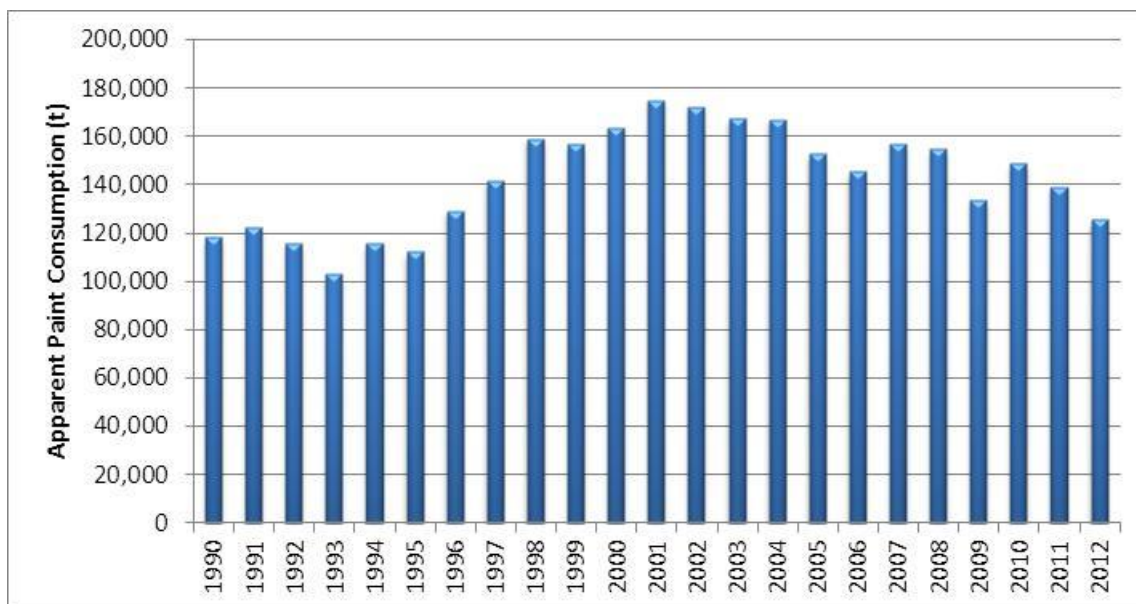
Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Imports	37 990	36 398	38 680	37 097	37 371	35 624	35 883	34 466	33 044	45 556	41 781
Exports	20 545	23 827	25 973	34 089	40 749	43 510	42 435	36 546	39 398	40 338	35 838

Table 5-25 – Estimated paint consumption (t)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Apparent Consumption	118 236	122 073	115 853	102 984	115 596	112 282	129 006	141 878	158 941	156 587	163 694	174 924

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Apparent Consumption	172 437	167 651	166 928	152 714	145 530	157 162	154 612	133 746	148 855	138 965	125 635

Figure 5-3 - Total consumption of paints in Portugal



Finally total consumption of paint was disaggregated by the economic activity where the paint is used. In first place, from IAIT and IAIP industrial surveys, it was possible to determine consumption of coating materials per economic activity but only for the industry sector: results from IAIT and IAPI are presented in Table 5-26. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction<sup>77</sup>.

<sup>77</sup> No further disaggregation by this uses is possible from available statistical information

Table 5-26 - Paint and varnish consumption by snap (t paint)

SNAP	NFR Title	SNAP Title	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
060103	Decorative coating application	Paint application: construction and buildings	10 738	10 326	9 248	8 388	8 760	8 486	9 447	9 225	7 761	7 069	8 399	7 866
060104	Decorative coating application	Paint application: domestic use (except 060107)	91 969	95 902	92 001	79 659	92 249	90 715	102 421	111 519	129 668	125 779	130 608	147 593
060101	Industrial coating application	Paint application: manufacture of automobiles	111	111	111	111	111	249	709	1 142	1 143	1 130	2 595	1 528
060107	Industrial coating application	Paint application: wood	6 508	6 824	5 583	5 917	5 567	4 061	4 813	5 057	4 626	3 849	2 836	3 862
060108	Industrial coating application	Other industrial paint application	8 475	8 475	8 475	8 475	8 475	8 475	11 609	15 400	16 351	19 319	20 891	14 867
060108	Industrial coating application	Other industrial paint application: truck cabin coating	391	391	391	391	391	391	562	523	381	433	631	534
060108	Industrial coating application	Other industrial paint application: leather finishing	154	154	154	154	154	154	154	154	154	137	330	201

SNAP	NFR Title	SNAP Title	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
060103	Decorative coating application	Paint application: construction and buildings	7 524	7 328	8 613	9 242	10 373	10 374	11 120	8 385	9 846	7 390	6 658
060104	Decorative coating application	Paint application: domestic use (except 060107)	147 528	145 161	144 863	129 412	115 964	130 607	123 686	108 092	119 610	114 261	102 550
060101	Industrial coating application	Paint application: manufacture of automobiles	1 528	1 528	1 274	1 232	1 346	1 540	1 441	911	1 212	1 197	1 158
060107	Industrial coating application	Paint application: wood	3 872	3 740	4 333	4 493	5 078	5 257	5 402	4 244	5 018	3 918	3 464
060108	Industrial coating application	Other industrial paint application	12 827	10 787	8 746	9 074	13 489	10 061	13 324	11 952	13 110	12 140	11 748
060108	Industrial coating application	Other industrial paint application: truck cabin coating	534	534	320	363	489	242	158	99	113	111	108
060108	Industrial coating application	Other industrial paint application: leather finishing	152	102	52	130	137	621	923	973	1 159	1 144	1 107

Table 5-27 Final activity data used for paint application emission calculation

NFR	SNAP Title	Unit	1990	1995	2000	2005	2010	2012
3 A 1	Paint application: construction and buildings	t paint	10 738	8 486	8 399	9 242	9 846	6 658
3 A 1	Paint application: domestic use (except 060107)	t paint	91 969	90 715	130 608	129 412	119 610	102 550
3 A 2	Paint application: manufacture of automobiles	n vehicles	134 109	100 170	195 309	146 340	157 552	159 577
3 A 2	Paint application: wood	t paint	6 508	4 061	2 836	4 493	5 018	3 464
3 A 2	Other industrial paint application	t paint	8 475	8 475	20 891	9 074	13 110	11 748
3 A 2	Other industrial paint application: truck cabin coating	n vehicles	9 608	2 557	6 929	6 203	4 396	3 657
3 A 2	Other industrial paint application: leather finishing	t leather	834	534	2 386	8 932	14 854	9 010

Table 5-28 Final NMVOC emission factors data used for paint application emission calculation

NFR	SNAP Title	Unit	1990	1995	2000	2005	2010	2012
3 A 1	Paint application: construction and buildings	g/kg paint applied	220.8	170.2	140.3	104.7	69.0	69.0
3 A 1	Paint application: domestic use (except 060107)	g/kg paint applied	220.8	170.2	140.3	104.7	69.0	69.0
3 A 2	Paint application: manufacture of automobiles	kg/car	8.0	6.2	4.4	2.6	0.8	0.8
3 A 2	Paint application: wood	g/kg paint	527.9	527.9	527.9	527.9	328.1	328.1
3 A 2	Other industrial paint application	g/kg paint	400.0	400.0	400.0	400.0	400.0	400.0
3 A 2	Other industrial paint application: truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0	8.0
3 A 2	Other industrial paint application: leather finishing	g/kg leather	200.0	200.0	200.0	187.0	152.9	142.5



#### 5.3.1.5 *Uncertainty Assessment*

The uncertainty factor of the emission factor for NMVOC and CO<sub>2</sub> was calculated from information obtained from EEA/CORINAIR Guidebook. The uncertainty value for CO<sub>2</sub>/NMVOC emission factor was calculated to be 35.1% for all uses of paint.

The uncertainty associated with the activity data from INE was assumed to be 10%.

An overall uncertainty of 36.5% was calculated for the paint application sector.

#### 5.3.1.6 *Recalculations*

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.1.7 *Further Improvements*

No further improvements are planned for this sector.

### 5.3.2 *Degreasing and Dry Cleaning (CRF 3.B.)*

#### 5.3.2.1 *Overview*

Degreasing refers to operation processes, usually realized within industrial activities, where solvents are used as degreasers to clean products and materials from water insoluble substances (fats), such as oil, grease, wax or tars. This cleaning procedure precedes normally the application of other treatment processes and occurs mainly in metal industry, plastics products manufacturing, rubber<sup>78</sup>, textiles, glass, paper and fiber-glass, etc. Usually solvents used to achieve degreasing are petroleum distillates, chlorinated hydrocarbons, ketones and alcohols, and the cleaning process is usually done in tanks, which may have some form of emissions control (solvent recovery).

In essence dry-cleaning has the same objective to degreasing, seeking to remove, by the aid of solvents, of contamination or dirt from cloths, textile, furs, leather, down leathers, textiles or other objects made of fibers.

#### 5.3.2.2 *Methodology*

Assuming that all solvents consumed during degreasing and dry-cleaning evaporate, NMVOC emission will be equal to the amount of solvents used. If it is considered that annual consumption of solvents in an economic activity is used to replenish the quantity of solvent that was lost, then annual NMVOC emissions may be estimated from the annual consumption of solvent. This methodology overcomes the need of being aware of the portion of solvent that is recovered.

In the case of the dry-cleaning activity it was assumed that either the solvent is lost directly to atmosphere, or if it is conveyed to water or retained in clothes, but it will eventually reach atmosphere by evaporation.

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several sources (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

CO<sub>2</sub> emissions are derived by assuming that 85 percent of the mass emissions of NMVOC is carbon:

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<sup>78</sup> Emissions from degreasing in this industry are included under rubber processing

$$U_{CO_2} = NMVOC * 0.85 * (44/12)$$

where:

$U_{CO_2}$  - Ultimate  $CO_2$  (ton);

NMVOC - Global emissions of NMVOC (ton).

#### 5.3.2.3 *Activity Data*

Statistical information concerning total solvent use, from the National Statistics Institute (INE), was used to estimate VOC emissions. Consumption of solvents, presented in Table 5-29, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

Table 5-29 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	2005	2012
Metal Degreasing	1 552	1 415	1 484	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)<sup>79</sup> consumed in Portugal is used in dry-cleaning<sup>80</sup> activity and that all PER used is imported (no national production). Annual apparent consumption was estimated from INE's statistical databases on external trade from 1990 to 2012 and assumed as equal to solvent use.

Table 5-30 - Annual consumption of PER (Tetra-chloro-ethylene) (t)

Parameter	1990	1995	2000	2005	2010	2012
Imports	2 172	1 155	1 649	944	1 108	874
Exports	0	0	0	24	49	12
Apparent Consumption	2 172	1 155	1 649	920	1 059	862

Source: INE.

#### 5.3.2.4 *Uncertainty Assessment*

The time trend of activity data for metal degreasing is very incomplete and an uncertainty of 100% was considered. Because emissions from PER use in dry cleaning were established from importation of this product the error is mostly due to incorrect allocation of emission, i.e. considering in dry cleaning a fraction of PER emissions that were realized in fact in other industrial activity. The final effect in inventory totals is therefore not significant and an error of

<sup>79</sup> 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.

<sup>80</sup> There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

10% was used (USEPA). The uncertainty of emissions from both sectors are fully considered under activity data.

#### 5.3.2.5 *Recalculations*

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.2.6 *Further Improvements*

No further improvements are planned for this sector.

### 5.3.3 Chemical Products, Manufacture and Processing (CRF 3.C)

#### 5.3.3.1 *Overview*

This source sub-category comprehends several emission sources that are related to industrial processes involving manipulation of polymer. Although emissions for this source result mostly from the use of solvents, which are used as diluters or cleaning agents, some emissions result also from monomers leakage from the polymer, which means that these emissions should in fact be quantified under Production Processes. Nevertheless it was decided to include all those emissions here for simplicity in reporting and because it is not always possible to distinguish the part that is solvent from the part that has resulted from evaporation of monomers or from the degradation process of materials.

#### 5.3.3.2 *Methodology*

Emissions were estimated by the use of emission factors that are multiplied by the quantity of material produced:

$$Emi_{NMVOC} = EF * Activity_{Rate} * 10^{-3}$$

where

$Emi_{NMVOC}$  - annual emission of NMVOC (ton/yr);

$Activity_{Rate}$  - Indicator of activity in the production process. Quantity of product produced per year as a general rule for this emission source sector (ton/yr);

EF - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents with fossil origin, therefore contributing fully to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

#### 5.3.3.3 *Polyester processing (CRF 3.C)*

##### 5.3.3.3.1 *Methodology*

Emissions from polyester processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook **Fonte especificada inválida..** A tier 2 approach was used as activity data and emissions factors were stratified for polyester processing.

Emissions were estimated from the quantity of polyester processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{POYESTER(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from polyester processing (t/yr);

$EF_{NMVOC}$  – NMVOC emission factor for polyester processing (g/kg monomer used);

$Prod_{FOAM(y)}$  – Quantity of monomer used y (t/yr).

#### 5.3.3.3.2 Emission Factors

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). The emissions factor was assumed constant for all covered period.

Table 5-31 – NMVOC foam processing emission factor

SNAP	Unit	NMVOC
Polyester processing	g/kg monomer used	50

Source: (EEA/EMEP, 2009)

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

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

#### 5.3.3.3.3 Activity Data

Data on polyester is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5-32 –Polyester processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2012
Polyester processing	t monomer	5	57	870	405	1 061	1 736

Source: INE

#### 5.3.3.3.4 Uncertainty Assessment

The uncertainty associated with the emission factor from polyester processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 90% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyester processing was calculated to be 91%.

#### 5.3.3.3.5 Recalculations

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.3.3.6 Further Improvements

No further improvements are planned for this sector.

#### 5.3.3.4 Polyvinylchloride processing (CRF 3.C)

##### 5.3.3.4.1 Methodology

Emissions from polyvinylchloride processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). A tier 1 approach was used as specific emissions factors from the EEA/EMEP guidebook were not available for polyvinylchloride processing.

Emissions were estimated from the quantity of polyvinylchloride resin processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RESIN(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from polyvinylchloride processing (t/yr);

$EF_{NMVOC}$  – NMVOC emission factor for polyvinylchloride processing (g/kg resin);

$Prod_{RESIN(y)}$  – Quantity of polyvinylchloride resin (t/yr).

##### 5.3.3.4.2 Emission Factors

The default emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). The emissions factor was assumed constant for all covered period.

Table 5-33 – Tier 1 emission factor for chemical product use

Source category	Unit	NMVOC
Chemical products, manufacture and processing	g/kg product	10

Source: (EEA/EMEP, 2009)

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

$$Emi_{CO2} = Emi_{NMVOC} * 0.85 * (44 / 12)$$

##### 5.3.3.4.3 Activity Data

Data on polyvinylchloride is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5-34 – Polyvinylchloride processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2012
Polyvinylchloride processing	t PVC	95 993	102 618	138 944	74 862	60 512	57 825

Source: INE

#### 5.3.3.4.4 Uncertainty Assessment

The uncertainty associated with the emission factor from polyvinylchloride processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 300% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyvinylchloride processing was calculated to be 300%.

#### 5.3.3.4.5 Recalculation

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.3.4.6 Further Improvements

No further improvements are planned for this sector.

### 5.3.3.5 *Polyurethane and polystyrene foam processing (CRF 3.C)*

#### 5.3.3.5.1 Methodology

Emissions from polyurethane and polystyrene foam processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). A tier 2 approach was used as activity data and emissions factors were stratified for polyurethane and polystyrene foams.

Emissions were estimated from the quantity of foam processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{FOAM(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from foam processing (t/yr);

$EF_{NMVOC}$  – NMVOC emission factor for foam processing (g/kg foam processed);

$Prod_{FOAM(y)}$  – Quantity of foam processed in year y (t/yr).

#### 5.3.3.5.2 Emission Factors

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2009). The emission factor was assumed constant for all covered period.

Table 5-35 – NMVOC foam processing emission factor

SNAP	Unit	NMVOC
Polyurethane foam processing	g/kg foam processed	120
Polystyrene foam processing	g/kg foam processed	60

Source: (EEA/EMEP, 2009)

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

$$Emi_{CO_2} = Emi_{NMVOC} \times 0.85 \times (44 / 12)$$

#### 5.3.3.5.3 Activity Data

Data on polyurethane and polystyrene foam is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5-36 –Foam processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2012
Polyurethane processing	t foam	5 700	6 322	11 704	16 989	10 038	8 736
Polystyrene processing	t foam	11 222	14 454	22 212	16 561	16 995	23 720

Source: INE

#### 5.3.3.5.4 Uncertainty Assessment

The uncertainty associated with the emission factor from polyurethane processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 150% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyurethane processing was calculated to be 150%.

The uncertainty associated with the emission factor from polystyrene foam processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 58% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyurethane processing was calculated to be 59%.

#### 5.3.3.5.5 Recalculations

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.3.5.6 Further Improvements

No further improvements are planned for this sector.

### 5.3.3.6 Rubber processing (CRF 3.C)

#### 5.3.3.6.1 Methodology

Emissions from rubber processing was estimated according with EMEP/CORINAIR Guidebook. Rubber processed for tyre production is not included in this sector.

Statistical information for year 2008 was not yet available, therefore emissions were estimated according with a forecast based on historical emissions from the last five year period.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RUBBER(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from rubber processing (t/yr);

$EF_{NMVOC}$  – NMVOC default emission factor for rubber processing (g/kg rubber produced);;

$Prod_{RUBBER(p,y)}$  – Production of rubber in year y (t/yr).

#### 5.3.3.6.2 Emission Factors

The emission factor used for rubber processing was obtained from EMEP/CORINAIR guidebook. The same emission factor was used for year 1990 to 2008.

Table 5-37 – NMVOC rubber processing emission factor

SNAP	Unit	NMVOC
Rubber processing	g/kg rubber produced	8

Source: EMEP/CORINAIR 2009, 3.C Chemical products, table 3-5, pp18

#### 5.3.3.6.3 Activity Data

Production data of rubber artefacts was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 5-38 –Rubber processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2012
Rubber processed	t rubber	26 871	24 484	29 915	32 818	68 442	70 088

Source: INE

#### 5.3.3.6.4 Uncertainty Assessment

The uncertainty associated with the emission factor for rubber processing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 100% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with polyurethane processing was calculated to be 100%.

#### 5.3.3.6.5 Recalculations

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.3.6.6 Further Improvements

No further improvements are planned for this sector.

#### 5.3.3.7 *Paints, Inks and Glues Manufacturing (CRF 3.C)*

##### 5.3.3.7.1 Methodology

Emissions from paints, inks and glue manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(p,y)} = EF_{NMVOC(y)} \times ProductManuf_{(p,y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(p,y)}$  – NMVOC emissions from manufacturing of product p in year y (t/yr);

$EF_{NMVOC(y)}$  – NMVOC emission factor for production of paints, inks and glue during year y (g/kg product);



ProductManuf<sub>(p,y)</sub> – Quantity of product p manufactured in year y (t/yr);

p – product (paint, ink, glue)

y - year

#### 5.3.3.7.2 Emission Factors

Emission factors were taken from EMEP/CORINAIR guidebook 2009. Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC\ y} = \frac{CS_{t,y}}{100} \times \left(1 - \frac{AT_t}{100}\right) \times EF_{NMVOC\ default}$$

Where:

EF<sub>NMVOC(y)</sub> – NMVOC emission factor in year y (t/yr);

CS<sub>(t,y)</sub> – Control strategy, share of abatement technology t during year y (%);

AT<sub>(t)</sub> – Efficiency of abatement technology t (%);

t – abatement technology;

EF<sub>NMVOC(default)</sub> – Default NMVOC emission factor.

Table 5-39 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Paints, Inks and Glue Manufacturing	g/kg product	11

Table 5-40 – Abatement technology (Source: EMEP/CORINAIR 2009)

Abatement Technology	Unit	Efficiency
Use of good practices	%	27

Table 5-41 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2010	2012
Use of good practices	%	0	0	0	50	100	100
No control	%	100	100	100	50	0	0

Table 5-42 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF	g/kg product	11.0	11.0	11.0	9.5	8.0	8.0

#### 5.3.3.7.3 Activity Data

Production data of paints, inks and glue was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in the following table.

Table 5-43 – Production of paints, inks and glue

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2012
060307	Paints manufacturing	t paint	117 961	96 320	146 854	158 181	169 908	131 982
060308	Inks manufacturing	t ink	3 677	1 166	3 266	2 262	3 485	3 174
060309	Glues manufacturing	t glue	29 666	23 451	79 466	60 524	61 882	37 310

Source: INE

#### 5.3.3.7.4 Uncertainty Assessment

The uncertainty associated with the emission factor for paints, inks and glues manufacturing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 36% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with paints, inks and glues manufacturing was calculated to be 38%.

#### 5.3.3.7.5 Recalculations

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.3.7.6 Further Improvements

No further improvements are planned for this sector.

#### 5.3.3.8 *Manufacture of Tyres (CRF 3.C)*

##### 5.3.3.8.1 Methodology

Emissions from tyre manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the number of tyres produced according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC(y)} \times Tyres_{(y)} \times 10^{-6}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC emissions from manufacturing of tyres during year y (t/yr);

$EF_{NMVOC(y)}$  – NMVOC emission factor for manufacturing of tyres in year y (g/tyre);

$Tyres_{(y)}$  – Number of tyres produced in year y (n./yr);

y - year

#### 5.3.3.8.2 Emission Factors

Emission factors were taken from EMEP/CORINAIR guidebook 2009. Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC\ y} = \frac{CS_{t,y}}{100} \times \left(1 - \frac{AT_t}{100}\right) \times EF_{NMVOC\ default}$$

Where:

$EF_{NMVOC(y)}$  – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$  – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$  – Efficiency of abatement technology t (%);

t – abatement technology;

$EF_{NMVOC(default)}$  – Default NMVOC emission factor.

Table 5-44 – Default emission factor (Source: EMEP/CORINAIR 2009)

SNAP	Unit	NMVOC
Tyre production	g/kg tyre	10

Table 5-45 – Abatement technology (Source: EMEP/CORINAIR 2009)

Abatement Technology	Unit	Efficiency
Process optimisation: Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent)	%	30
New processes: Use of 25% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvents)	%	75

Table 5-46 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2010	2012
Incineration	%	0	22	43	43	43	43
Use of 30% solvent based additives and 70% low solvent additives (100% vulcanized rubber produced)	%	0	29	57	57	57	57
No control	%	100	50	0	0	0	0

Since the final emission factor is expressed in g/kg tyre, a conversion factor was used to obtain emission factor expressed in g/tyre in order to use the activity data provided by INE. A conversion factor of 15kg/tyre was used.

Table 5-47 – Final NMVOC emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2012
Final EF	g/kg tyre	10	7	4	4	4	4
Final EF	g/tyre	150	108	67	67	67	67

#### 5.3.3.8.3 Activity Data

Production data for tyres was available from the IAIT and IAPI industrial surveys from INE until 2010. The values, collected from original INE's database, are reported in the following table. The 2011 values were forecasted based on 1990-2010 values.

Table 5-48 – Production of tyres

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2012
060314	Manufacture of tyres	tyres	4 218 714	5 891 971	11 605 755	14 748 990	15 595 153	16 769 699

Source: INE

#### 5.3.3.8.4 Uncertainty Assessment

The uncertainty associated with the emission factor for manufacture of tyres was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 40% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty associated with paints, inks and glues manufacturing was calculated to be 41%.

#### 5.3.3.8.5 Recalculations

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.3.8.6 Further Improvements

No further improvements are planned for this sector.

### 5.3.4 Other (CRF 3.D.)

#### 5.3.4.1 *Use of N<sub>2</sub>O for Anaesthesia (CRF 3.D.1)*

##### 5.3.4.1.1 Methodology

The N<sub>2</sub>O consumed in Portugal is primarily for medical use as anaesthesia. The new 2006 guidelines propose that emissions be estimated from supply "It is good practice to estimate N<sub>2</sub>O emissions from data of quantity of N<sub>2</sub>O supplied that are obtained from manufacturers and distributors of N<sub>2</sub>O products". There will be a time delay between manufacture, delivery and use but this is probably small in the case of medical applications because hospitals normally receive frequent deliveries to avoid maintaining large stocks. Therefore, it is reasonable to assume that the N<sub>2</sub>O products supplied will be used in one year.

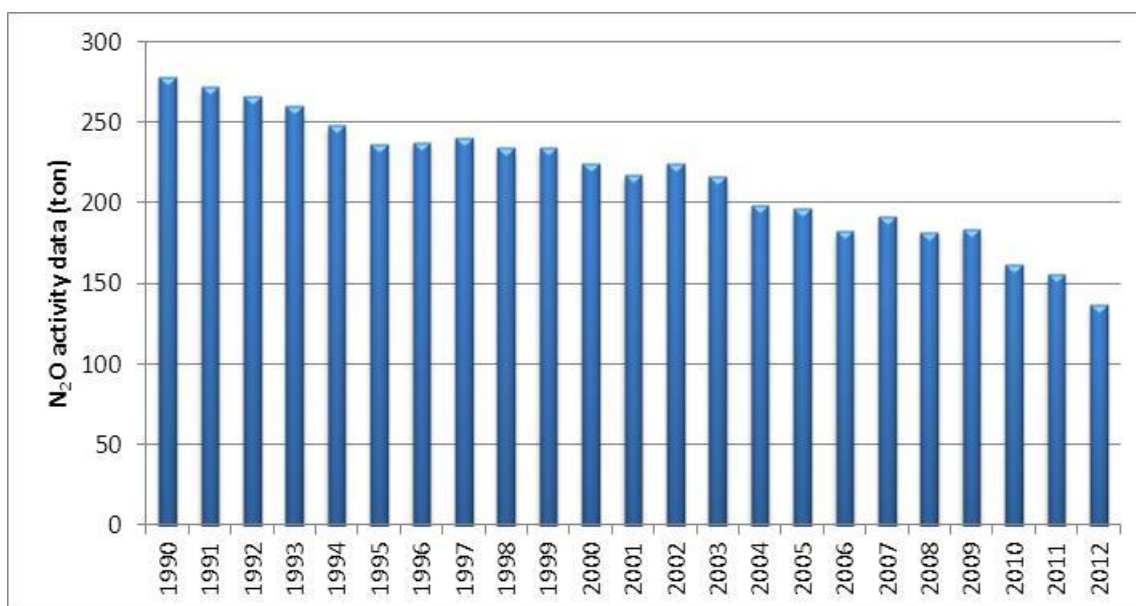
##### 5.3.4.1.2 Emission Factors

It is assumed that none of the administered N<sub>2</sub>O is chemically changed by the body, and all is returned to the atmosphere. It is reasonable to assume an emission factor of 1.0

##### 5.3.4.1.3 Activity Data

Consumption of N<sub>2</sub>O emissions are calculated from data collected from enterprises (1990 to 2012). This set of activity data includes estimatives due to lack of data.

Figure 5.4 – N<sub>2</sub>O activity data (ton)



#### 5.3.4.1.4 Uncertainty Assessment

The uncertainty is associated with the activity data which refers to information collected from the producers/importers and include estimates for the previous years. Values considered are: 1990-2000: 25 per cent; 2001-2007: 10 per cent; 2008-2012: 1 per cent.

#### 5.3.4.1.5 Category-specific QA/QC and verification

No category-specific QA/QC has been made for this category.

#### 5.3.4.1.6 Recalculations

Estimates from this category were done based on statistics obtained from INE in previous submissions which has now been changed for data collect directly from enterprises in order to retrieve a more consistent activity data time trend.

#### 5.3.4.1.7 Further Improvements

No further improvements are under consideration at this time.

#### 5.3.4.2 *Fire Extinguishers (CRF 3.D.2)*

Emissions from this category are not occurring.

#### 5.3.4.3 *N<sub>2</sub>O from Aerosol Cans (CRF 3.D.3)*

Emissions from this category are not occurring.

#### 5.3.4.4 *Other Use of N<sub>2</sub>O (CRF 3.D.4)*

Emissions from this category are not occurring.

#### 5.3.4.5 *Other (CRF 3.D.5)*

##### 5.3.4.5.1 Overview

In this chapter are included emission calculations for different activities, such as:

- printing;
- edible and non edible oil extraction;
- use of glue and adhesives;
- preservation of wood;
- other solvents use;
- use of perfume;
- use of waxes and polishing products;
- use of soaps and detergents;
- use of solvents from biomass.

##### 5.3.4.5.2 Printing (CRF 3.D.5)

###### 5.3.4.5.2.1 Overview

Printing involves the application of an ink to several materials by presses, the most common of which is paper, but also cardboard, wood, plastics and metallic artifacts are subjected to this process. Emissions are very dependent of the printing technology because it (i.e., the type of press equipment) dictates the types of inks and coatings – and its solvent content - that can be used and defines, to a large extent, the emissions and the control techniques that are applicable (USEPA,1985). The following technologies are available:

- lithography: the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellent to ink, by action of a dampener. In offset lithography the image is applied to a rubber-covered blanket cylinder and then transferred onto the substrate. This technique dominates the production of books and pamphlets and has been used increasing in newspapers;
- rotogravure: uses cylindrical image carrier, where the printing area is below the non printing area. The low relive is filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder. Used mostly in packaging, advertising, greeting cards, art books, catalogues, and directories;
- flexography: the image carrier, made of rubber or elastic photopolymers on which the printing areas are above the non printing areas. Used mostly in packaging, advertising newspapers, books, magazines, financial and legal document and directories;
- letterpress: similar to flexography, it uses a relief printing plate, but these plates differ from flexographic plates in that they have a rigid backing and are not

"flexible." Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to non-heatset web offset;

- screen: the ink is passed onto the surface to be printed by forcing it through a porous image carrier (stencil), in which the printing area is open and the non-printing area is sealed off. It is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles;
- plateless: Images printed on paper by laser printers, photo copiers, fax machines, and ink jets

NMVOC emissions from printing result from the evaporation of solvents that are components of the ink or that are added (dilution) just prior to printing activities. Emissions may also result from the use of cleaning products and dampeners. Emissions may occur during drying at air or at ovens (heat set).

#### 5.3.4.5.2.2 Methodology

Emissions from printing industry was estimated according with Tier 1 methodology from EMEP/CORINAIR Guidebook.

$$Emi_{NMVOC(y)} = EF_{(i)} * INK_{CONS(y)} \times 10^{-3}$$

Where

$Emi_{NMVOC(y)}$  – NMVOC emissions resulting from printing activities during year y (t/yr);

$INK_{CONS(y)}$  – Use of printing ink during year y (t/yr);

$EF_{(i)}$  – NMVOC emission factor (solvent content) for ink use (g/kg ink).

Ultimate CO<sub>2</sub> emissions are calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO<sub>2</sub> emissions are included in the inventory.

$$U_{CO_2} = NMVOC * 0.85 * (44 / 12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

#### 5.3.4.5.2.3 Emission Factors

The emission factor used for printing activities was obtained from EMEP/CORINAIR guidebook. The same emission factor was used for the entire period.

Table 5-49 – NMVOC emission factor for printing activities

SNAP	Unit	NMVOC
Printing	g/kg ink	500

Source: EMEP/CORINAIR 2009

#### 5.3.4.5.2.4 Activity Data

Consumption of inks in printing industry according to printing product is available from the INE's statistical database for the period 1990-2010, which is summarized in the following table. The 2012 values were forecasted based on 1990-2010 values.

Table 5-50 – Consumption of inks in printing industry

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2012
060403	Printing Industry	t ink	5 372	5 372	9 290	8 722	9 336	8 921

Source: INE

#### 5.3.4.5.2.5 Uncertainty Assessment

The uncertainty associated with the emission factor for printing was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 207% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty was calculated to be 207%.

#### 5.3.4.5.2.6 Recalculations

Estimates for 2011 were done based on the value of GDP which has now been corrected.

#### 5.3.4.5.2.7 Further Improvements

No further improvements are planned for this sector.

### 5.3.4.5.3 Edible and non edible oil extraction (CRF 3.D.5)

#### 5.3.4.5.3.1 Overview

This sub-source comprehends emissions of NMVOC from extraction of edible and non-edible oils from seeds.

Extraction of oil in Portugal may be made using mechanical processes or solvent based processes. Mechanical processes, using presses, are used to extract first olive oil from olives<sup>81</sup>. Extraction by solvents, usually using hexane and heat, is presently done in extraction from most oil seeds or secondary extraction of olive oil. Solvent recovery, where the oil is separated from the oil-enriched wash solvent and from the steamed out solvent, is an integral part of the production processes although leakages occur continuously leading to the need of solvent stock replenishment. Losses are either made directly to atmosphere through vents or leaks or indirectly through water and residues.

#### 5.3.4.5.3.2 Methodology

Emissions of NMVOC were estimated considering that the annual hexane consumption by the industrial plant, hexane make-up, is due to losses to the air, and hence:

<sup>81</sup> Classified as virgin olive oil



$$Emi_{NMVOC}(y) = MakeUp_{Solvants}(y)$$

where:

$Emi_{NMVOC}(y)$  - Emissions of NMVOC (ton/yr);

$MakeUp_{Solvants}(y)$  - annual consumption of solvent in edible and non-edible oil industry, to replenish losses (ton/yr).

Ultimate CO<sub>2</sub> emissions are calculated assuming that 85 percent of the mass emissions of NMVOC is carbon<sup>82</sup> and is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO<sub>2</sub> emissions are included in the inventory.

$$U_{CO_2} = NMVOC * 0.85 * (44 / 12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

#### 5.3.4.5.3.3 Emission Factors

The national emission factor for NMVOC was calculated as the ratio of the amount of solvents consumed during manufacture processes to the quantities of edible and non edible oil manufactured. However, from the available data from INE, this emission factor could be only estimated from IAIT industrial survey, i.e. from 1989 to 1991, because solvent consumption is not available from IAPI survey. Statistical information used in actual calculations of annual emission factor are presented in Table 5-51, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole covered period.

Table 5-51 – Calculation of the National emission factor for edible and non-edible oils extraction (kg/ton).

Oil Type	Parameter	1989	1990	1991	Average
Edible	Oil refined (ton)	93 401	90 686	107 163	
non-edible		113 749	110 883	113 509	
Total		207 150	201 569	220 672	
Edible	Solvent Use (ton)	2 328	1 763	1 697	
non-edible		1 394	1 257	1 408	
Total		3 722	3 020	3 106	
Edible	Emission Factor NMVOC (kg/ton)	24.9	19.4	15.8	20.1
non-edible		12.3	11.3	12.4	12.0
Total		18.0	15.0	14.1	15.7

<sup>82</sup> From hexane chemical formula

#### 5.3.4.5.3.4 Activity Data

Oil refining data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2010. The 2012 values were forecasted based on 1990-2010 values. Annual values are reported in Table 5-52. Production of olive oil by mechanical pressure does not cause NMVOC emissions.

Table 5-52 - Refining of edible and non-edible oils in Portugal

Parameter	1990	1995	2000	2005	2010	2012
Oil refining	201 569	220 672	184 406	280 430	186 238	187 705

Source: National Statistics Institute (INE)

#### 5.3.4.5.3.5 Uncertainty Analysis

The activity data time trend is reasonably complete and an uncertainty of 10% was considered. The uncertainty of NMVOC/CO<sub>2</sub> emission factor was established by comparison of the emission factors determined from the several available years: 26%.

#### 5.3.4.5.3.6 Recalculations

No recalculations were made.

#### 5.3.4.5.4 Industrial application of glues and adhesives (CRF 3.D.5)

##### 5.3.4.5.4.1 Methodology

$$\text{NMVOC} = \text{Cons}_{\text{Nat}} \times \text{FE}_{\text{Nat}} + \text{Imp} \times \text{FE}_{\text{imp}}$$

where:

NMVOC = Global emissions of NMVOC (ton)

Cons<sub>Nat</sub> = Domestic consumption of glues and adhesives produced in Portugal (ton)

FE<sub>Nat</sub> = Emission factor for glues and adhesives produced in Portugal (kg NMVOC/ton Ink)

Imp = Imported glues and adhesives (ton)

FE<sub>imp</sub> = Emission factor associated with the use of imported glues and adhesives.

$$\text{Cons}_{\text{Nat}} = \text{Prod}_{\text{Nat}} - \text{Exp}$$

where:

Cons<sub>Nat</sub> = Consumed glues and adhesives produced in Portugal (ton)

Prod<sub>Nat</sub> = National production of glues and adhesives (ton)

Exp = Exported glues and adhesives (ton)

#### 5.3.4.5.4.2 Emission Factors

To estimate the emission factor applied for the use of national glues and adhesives, the ratio of the amount of solvents consumed (Table 5-53 from INE) during manufacture processes with the

amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5-54). 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 5-53 - 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 5-54 - National emission factors (kg/ton).

	1989	1990	1991	Average
For production and use of glue and adhesives	190	172	175	179
Only for use of glue and adhesives	170	152	155	159

For non-natural imported glues and adhesives the CORINAIR90 Default Emission Factor was used: 600 kg/ton. It is considered that natural based glue does not contribute to NMVOC emission.

#### 5.3.4.5.4.3 Activity Data

Table 5-55 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	2012
National Production (ton)	36 297	35 769	35 473
Importation (ton)	2 192	2 328	2 260
Exportation (ton)	707	532	620

Source: National Statistics Institute (INE)

#### 5.3.4.5.4.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

#### 5.3.4.5.4.5 Recalculations

No recalculations were made for this source sector.

#### 5.3.4.5.5 Wood Preservation (CRF 3.D.5)

##### 5.3.4.5.5.1 Overview

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts an building and construction materials. It is usually done by impregnation or immersion

of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

#### 5.3.4.5.5.2 Methodology

$$Emi_{NMVOC(y)} = Consumption_{(y)} * FE_{Consumption}$$

where:

$Emi_{NMVOC(y)}$  - Emissions of NMVOC associated to consumption of wood preservation products (ton)

$Consumption_{(y)}$  - Consumption of wood preservation products (ton)

$FE_{Consumption}$  - Emission factor associated to the consumption of wood preservation products.

#### 5.3.4.5.5.3 Emission Factors

CORINAIR90 Emission Factor Handbook proposes three emission factors for VOC emission from wood preservation, depending on the type of product used. The emission factor is 100 kg/ton of product applied for creosote; 900 kg/ton for solvent based products and 0 for water based products. The available data do not discriminate the share of the several types of preservation products, therefore, it was assumed that the main product used in Portugal is creosote.

#### 5.3.4.5.5.4 Activity Data

Table 5-56 - Wood preservation products consumption (ton)

Year	1990	1991	1992–2012
Wood Preservation products Consumption (ton)	2083	2900	2491

Source: National Statistics Institute (INE)

#### 5.3.4.5.5.5 Uncertainty Assessment

The activity data and emission factors have a high level of uncertainty and errors therefore a uncertainty of 100% was assumed in both cases.

#### 5.3.4.5.5.6 Recalculations

No recalculations were made for this source sector.

#### 5.3.4.5.6 Domestic solvent use including fungicides (CRF 3.D.5)

##### 5.3.4.5.6.1 Methodology

This sector addresses emissions from the use of solvent containing products by the public in their homes. This sector does not include the use of decorative paints which is covered by source category 3.A. Paint Application.

NMVOCs are used in a large number of products sold for use by the public. These include:

- Cosmetics and toiletries; Products for the maintenance or improvement of personal appearance, health or hygiene.
- Household products; Products used to maintain or improve the appearance of household durables.
- Construction/Do-It-Yourself; Products used to improve the appearance or the structure of buildings such as adhesives and paint remover.
- Car care products; Products used for improving the appearance of vehicles to maintain vehicles or winter products such as antifreeze.

Pesticides such as garden herbicides and insecticides and household insecticide sprays may be considered as consumer products. Most agrochemicals, however, are produced for agricultural use and fall outside the scope of this section.

Emissions from this sector were calculated using a Tier 1 approach. This approach uses a single emission factor expressed on a person basis which was multiplied by the population to derive emissions from domestic solvent use.

$$NMVOC_i = Population_i \times EF_{NMVOC} / 1000$$

where:

NMVOC<sub>i</sub> - Emissions of NMVOC associated to the use of domestic products containing solvents [t]

Population<sub>i</sub> – inhabitants in year i;

EF<sub>NMVOC</sub> - Emission factor associated with the use of domestic products containing solvents [kg/person/year]

##### 5.3.4.5.6.2 Emission Factors

Emission factor for NMVOC was obtained from EMEP/CORINAIR Guidebook, 2009. This default emission factor has been derived from an assessment of the emission factors presented in GAINS model developed by IIASA.

Table 5-57 – Default emission factor.

Description	Unit	Value
Emission factor for domestic solvent use including fungicides	kg/person/year	1

#### 5.3.4.5.6.3 Activity Data

Table 5-58 - Activity data (inhabitants)

Description	1990	1995	2000	2005	2010	2012
Inhabitants	9 970 441	10 043 180	10 256 658	10 569 592	10 636 979	10 487 289

Source: National Statistics Institute (INE)

#### 5.3.4.5.6.4 Uncertainty Assessment

The uncertainty associated with the emission factor for domestic solvent use was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 125% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty was calculated to be 125%.

#### 5.3.4.5.6.5 Recalculations

No recalculations were made for this source sector.

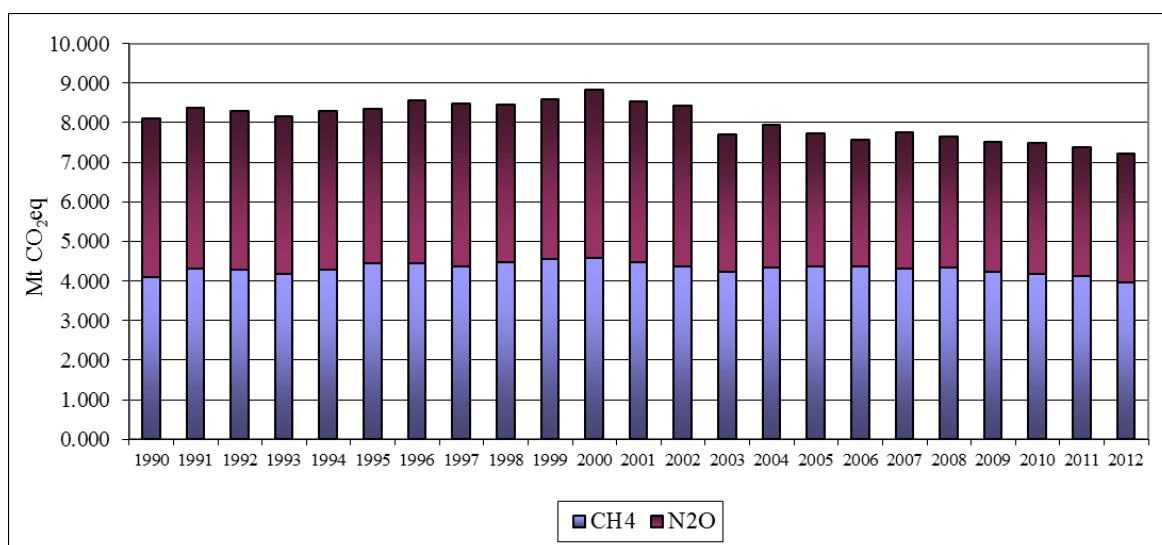
## 6 AGRICULTURE (CRF 4.)

### 6.1 Overview

Agriculture activities generate emissions of GHG from a variety of sources. This section refers to the quantification of: CH<sub>4</sub> emissions from enteric fermentation; CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management; direct and indirect N<sub>2</sub>O emissions from agriculture soils; CH<sub>4</sub> from rice cultivation and CH<sub>4</sub> and N<sub>2</sub>O emissions from field burning of agriculture residues. Also dealt here are the NH<sub>3</sub> emissions from agriculture, which are used as an intermediate step in the quantification of N<sub>2</sub>O 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 CO<sub>2</sub> release and uptake resulting from conversion of agriculture land and grazing land to other uses, conversion of other uses to agriculture land and grazing land, conversion of agriculture land to grazing land and vice versa, and substantial changes in agriculture practices, such as conversion of annual crops to perennial crops and the opposite, are estimated in the inventory but included in chapter Land Use, Land Use Change and Forestry (LULUCF).

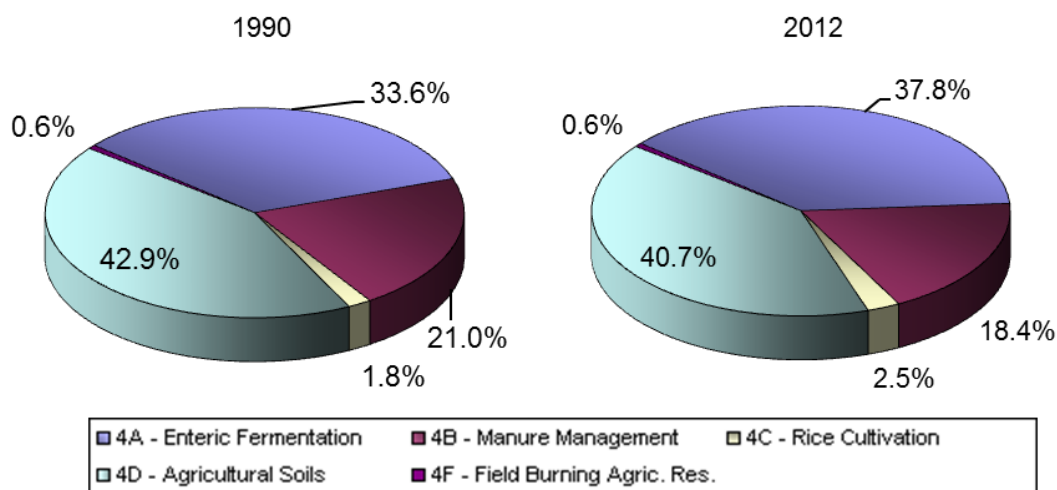
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 13.3 per cent in 1990 to 10.5 per cent in 2012. This decrease in importance is followed by a decrease of 11.02 per cent in the total agriculture emissions from 1990 to 2012: 8.12 Mton of CO<sub>2</sub>eq in 1990 and 7.22 Mton CO<sub>2</sub>eq in 2012 (Figure 6-1). Total GHG emissions show that nitrous oxide emissions have been decreasing in the last years while methane emissions were constant for most of the same time period with a slightly decrease since 2009. Because of these nitrous oxide variations, methane as increase its share on the total emissions from 50.3 per cent in 1990 to 55.0 per cent in 2012.

Figure 6-1 – Total Greenhouse Gas Emissions from Agriculture - trends by GHG



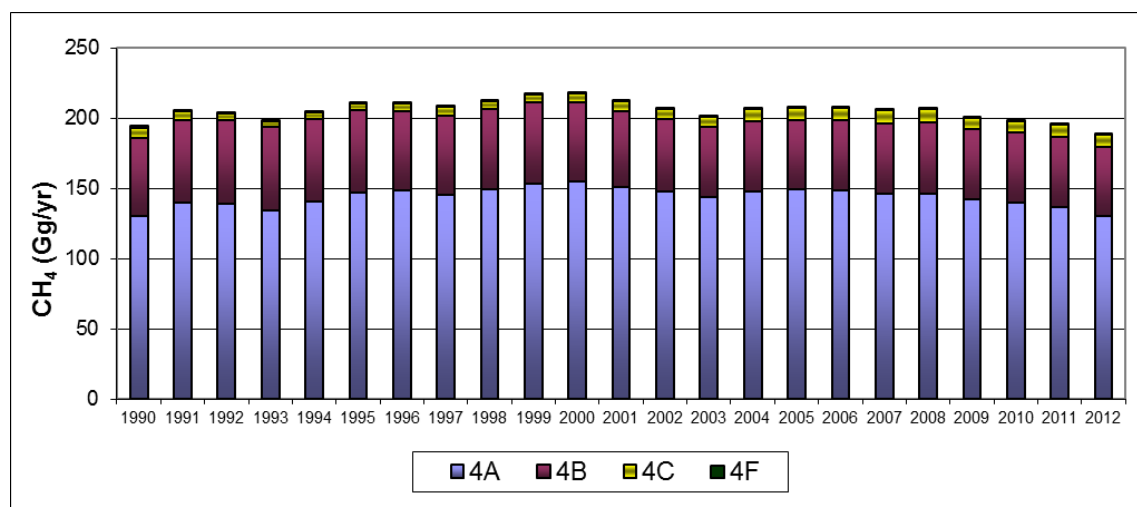
The majority of emissions in 2012 from agriculture are the result of only 3 sub-source sectors (figure below): Agriculture Soils, Enteric Fermentation, and Manure Management (hierarchically listed in order of the most prevalent).

Figure 6-2- Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2012



Emissions of CH<sub>4</sub> from agriculture have decreased 2.8 per cent from 1990 to 2012 (Figure 6-3). Enteric Fermentation was responsible, in 2012, for 68.7 per cent of the sectoral emissions and Manure Management accounted for 26.1 per cent of the sectoral emissions in the same year. The remaining 5.2 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 year.

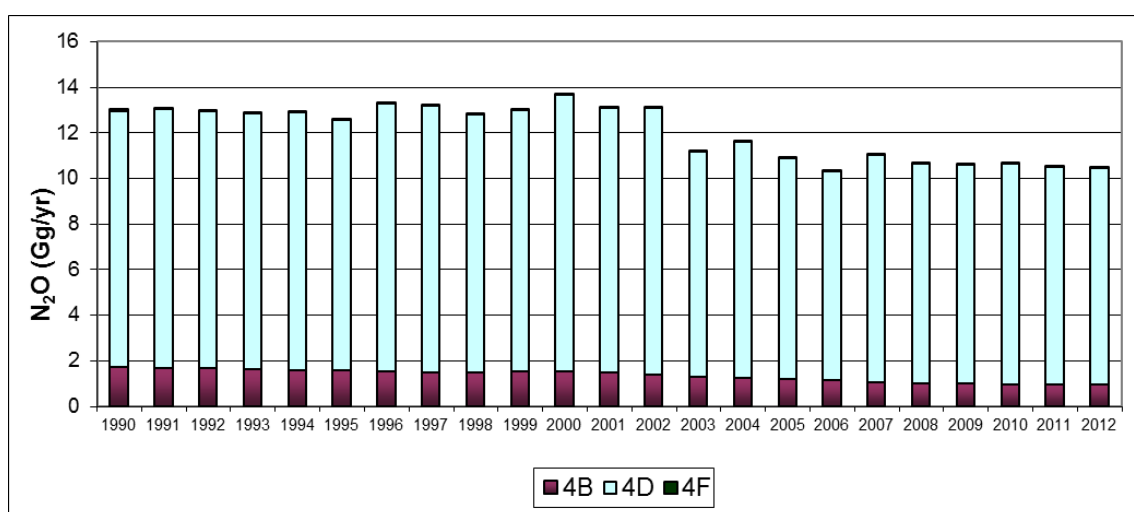
Figure 6-3 - Methane emissions from agriculture





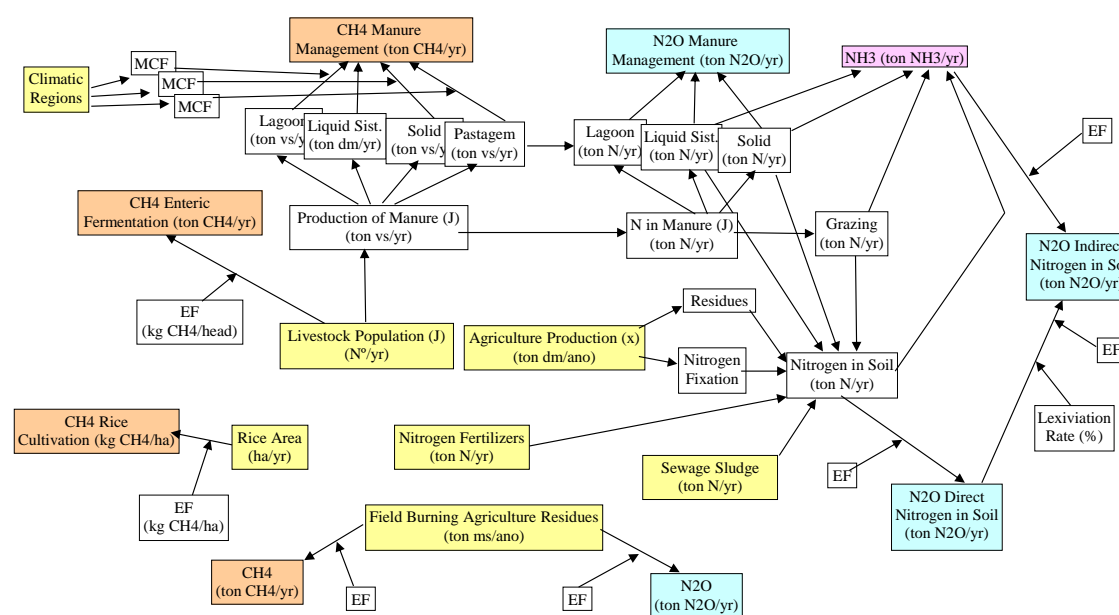
Following the same trend, N<sub>2</sub>O emissions have decreased by 19.4 per cent from 1990 to 2012 (Figure 6-4). The great majority of emissions in 2012 were associated with direct and indirect emissions from agricultural soils (90.4 per cent), manure management is responsible for 9.0 per cent of emissions, while the small remaining fraction results from field burning of agricultural residues (0.6 per cent).

Figure 6-4 - 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 the figure below.

Figure 6-5 - 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.

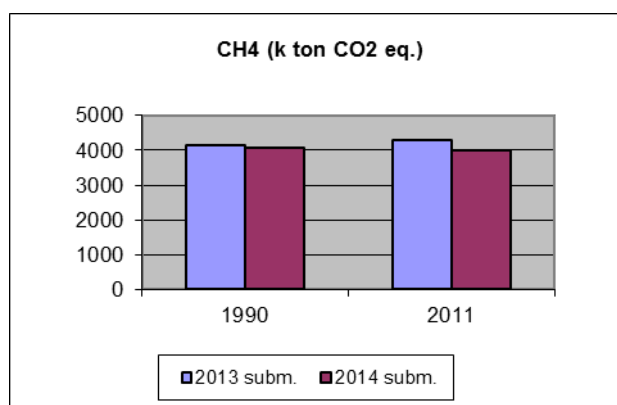
## 6.2 Recalculations

The major changes between submissions result from the following actions:

- improvement of the methodology to estimate methane emissions  $\text{CH}_4$  from dairy cattle enteric fermentation (UNFCCC review recommendation);
- revision of N excretion coefficient for swine sub-categorie "Fattening pigs - 20-50 kg";
- revision of the methodology to estimate methane emissions from rice cultivation (UNFCCC review recommendation);
- revision of crop residues amounts burned in the fields;
- accounting of  $\text{N}_2\text{O}$  emissions from N fixed by Sown Biodiverse Permanent Pastures Rich in Legumes (SBPPRL) (UNFCCC review recommendation);
- revision of 2009 to 2011 values for apparent consumption of synthetic fertilizers updated by INE;
- separate accounting of  $\text{N}_2\text{O}$  emissions from sewage sludge applied to agriculture soils, and reallocation of wastewater handling systems related  $\text{N}_2\text{O}$  emissions, previously reported in the waste sector (CRF 6B) into the agriculture sector (CRF 4D) (UNFCCC review recommendation).

These changes result in the differences between submissions shown in the following figure and table.

Figure 6-6 - Differences between submission 2013 and submission 2014 for  $\text{CH}_4$  and  $\text{N}_2\text{O}$  emissions from agriculture



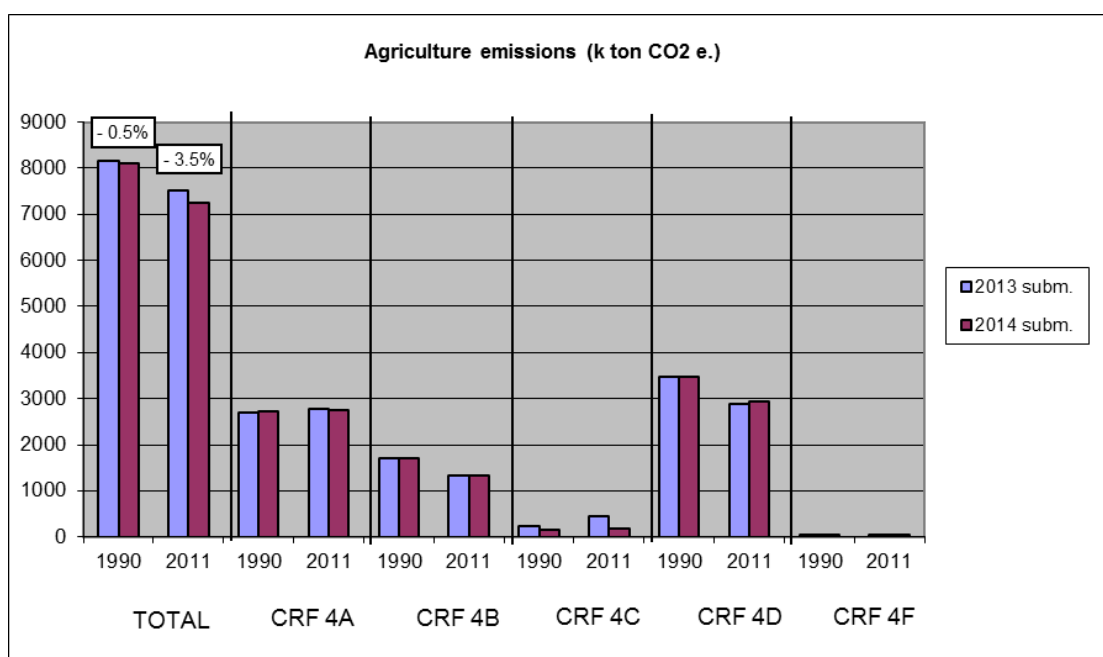
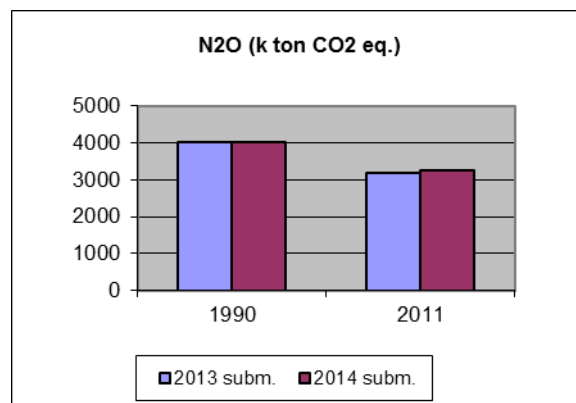


Table 6-1 – Recalculations. Differences between submission 2013 and submission 2014 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2013 subm.	2014 subm.	Difference (t)	2013 subm.	2014 subm.	Difference (t)	2013 subm.	2014 subm.	Difference (t)
	CO <sub>2</sub> equivalent (Gg)			CO <sub>2</sub> equivalent (Gg)			CO <sub>2</sub> equivalent (Gg)		
<b>1990</b>									
<b>4. Agriculture</b>				4 151.22	4 085.99	-1.57	4 008.28	4 032.59	0.61
4.A. Enteric Fermentation				2 709.14	2 729.30	0.74			
4.B. Manure Management				1 184.85	1 179.65	-0.44	525.96	527.03	0.20
4.C. Rice Cultivation				226.76	148.35	-34.58			
4.D. Agricultural Soils				NE,NO	NE,NO		3 460.52	3 484.25	0.69
4.E. Prescribed Burning of Savannas				NO	NO		NO	NO	
4.F. Field Burning of Agricultural Residues				30.46	28.69	-5.81	21.80	21.31	-2.22
4.G. Other				NO	NO		NO	NO	
<b>2011</b>									
<b>4. Agriculture</b>				4 303.81	3 984.43	-7.42	3 201.07	3 256.20	1.72
4.A. Enteric Fermentation				2 784.26	2 742.88	-1.49			
4.B. Manure Management				1 044.45	1 032.06	-1.19	296.30	296.90	0.20
4.C. Rice Cultivation				456.35	184.84	-59.50			
4.D. Agricultural Soils <sup>(2)</sup>				NE,NO	NE,NO		2 889.66	2 941.65	1.80
4.E. Prescribed Burning of Savannas				NO	NO		NO	NO	
4.F. Field Burning of Agricultural Residues				18.75	24.64	31.44	15.11	17.66	16.82
4.G. Other				NO	NO		NO	NO	

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100 per cent x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

## 6.3 Source categories

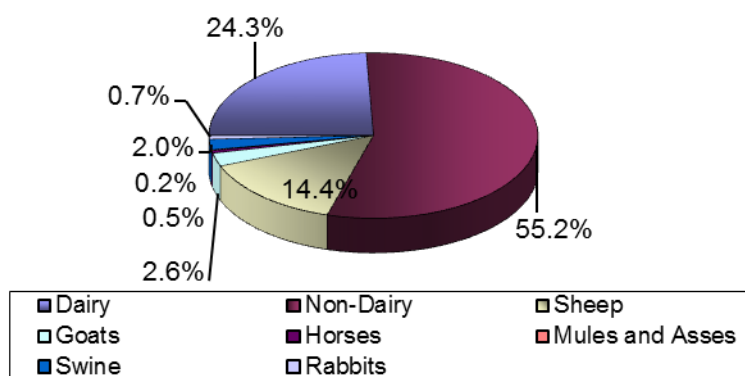
### 6.3.1 CH<sub>4</sub> Emissions from Enteric Fermentation in Domestic Livestock (CRF 4.A.)

#### 6.3.1.1 Overview

Methane emissions from enteric fermentation in animals result from this gas being produced as a by-product during the digestive process of carbohydrates by micro-organisms in the digestive system. This process occurs specially in ruminant animals, due to the activity of specific micro-organisms in their upper digestive tracts, but also in smaller quantities in monogastric animals (swine, equines and rabbits). The estimates in this inventory include only emissions in domestic animals. Emissions from wild animals and semi-domesticated game are not quantified neither there is quantification of emissions from humans or pet animals.

CH<sub>4</sub> emissions from enteric fermentation are a key source, both by level and trend assessment. The share of each animal type is observable in Figure 6-7. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents, according to different years, 24.3 per cent to 29.4 per cent of total CH<sub>4</sub> emissions from Enteric Fermentation, while non-dairy cattle represents about 39.4 to 55.2 per cent of total CH<sub>4</sub> from enteric fermentation. Together, in 2012 cattle was responsible for about 79.5 per cent of total CH<sub>4</sub> emissions from enteric fermentation.

Figure 6-7 - Relative Importance of emissions of CH<sub>4</sub> from Enteric Fermentation per each animal species in 2012



Sheep is also an important source of methane, for which emissions have oscillated between 14.4 per cent and 23.3 per cent of total CH<sub>4</sub> from Enteric Fermentation. Emissions from goats were 2.4 to 4.5 per cent of total enteric fermentation and swine represented 1.9 to 2.9 per cent of emissions. Total emissions of methane for all other species varied between 1.4 and 2.7 per cent, for the same period and have less importance.

#### 6.3.1.2 *Methodology*

Emissions were estimated for each animal type<sup>83</sup> by multiplication of the number of animals by the respective emission factor, in accordance to equation 4.12 of the Good Practice Guidebook (Tier 2 method).

$$Emi_{CH_4 (y)} = \sum_t [EF_{(i,y)} * N_{(i,y)}]$$

where, for each specie:

$Emi_{CH_4}$  - methane emissions from enteric fermentation in year y, kg CH<sub>4</sub>/year;

EF - emission factor for the specific population of animal type i in year y, kg/head/year;

N - the number of animals of type i in year y, head.

#### 6.3.1.3 *Emission Factors*

Emission factors may be seen in Table 6-2, in which is presented the range of values according to time variation, which will be further discussed. In accordance with the unavailability of emissions factors in IPCC (rev 1996) 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 Lamas in Portugal.

The default emission factors proposed by IPCC (revised 1996) (table 4-4) 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.

<sup>83</sup> For most animal types an enhanced characterization of livestock, with subdivision per age, sex and management conditions was used. This is discussed in more detail under activity data.

**Table 6-2 - Emission Factors for Enteric Fermentation (kg CH<sub>4</sub>/head/year)**

<b>Animal type</b>	<b>sub-class</b>	<b>EF (kg CH<sub>4</sub>/hd/yr)</b>	
Dairy-Cattle	Dairy Cows	93.53 – 131.13	T2
non-dairy cattle	Beef calves (<1 yr)	18.3-20.9	T2
	Calves, Males for Replacements (<1 yr)	40.0-45.7	T2
	Calves, Females for Replacements (<1 yr)	34.1-39.0	T2
	Males 1-2 yrs	61.7-70.5	T2
	Beef Females 1-2 yrs	42.4-48.5	T2
	Females for Replacemet 1-2 yrs	48.3-55.1	T2
	Steers (>2 yrs)	76.7-87.5	T2
	Heifers for Beef (>2 yrs)	51.7-59.1	T2
	Heifers for Replacements (>2 yrs)	51.7-59.1	T2
	non-dairy cows	75.9-86.7	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	7.9-9.8	T2
	Other: rams and young males	10.3-12.7	T2
	Lambs	4.4-5.4	T2
Caprines	Does	7.7-8.8	T2
	Other: bucks and young males	4.8-5.6	T2
	kids	2.6-3.1	T2
Equides	Horses	18	T1
	Asses, Mules and hynies	10	T1
Other	Rabbits	3.6	T2

#### 6.3.1.3.1 Determination of tier 2 emission factors

Following the recommendations from previous review processes, a tier 2 analysis was sought for the most significant animal types.

According to the IPCC Good Practice Guidebook and Uncertainty Management (GPG) equation 4.14, at tier 2, the emission factors for enteric fermentation are determined using the equation:

$$EF_{CH_4} = (GE * Y_m * 365 \text{ days/yr}) / (55.65 \text{ MJ/kg CH}_4)$$

where:

$EF_{CH_4}$  - emission factor, kg CH<sub>4</sub>/hd/yr

GE - gross energy intake, MJ/hd/day

$Y_m$  - methane conversion rate, which is the fraction of gross energy in feed that is converted to methane.

#### 6.3.1.3.1.1 Dairy Cattle

For dairy cattle Gross Energy (GE) estimation (IPCC2006) two separate country regions were considered due to differences on feed situation, diet characteristics and milk production. In Portugal Mainland, dairy cows are predominantly stalled with a feed diet based on maize silage (40%) and hay/straw (10%) as raw feed and compound feed (50%). In Azores archipelago dairy cows diet are based on pasture, maize or grass silage and compound feed, being the ratio pasture and, or silage/compound feed about 65/35. Feed digestibility (DE%) of these two different dairy cows feed diets was estimated by experts<sup>84</sup> of the National Institute for Agriculture and Veterinary Research (INIAV) based on available feed tables data: 74% for mainland region and 71% for Azores.

Milk production ( $\text{kg hd}^{-1} \text{d}^{-1}$ ) was estimated dividing the annual production over the number of cows in production<sup>85</sup> and 365 days. Therefore, lactating and non – lactating periods are included in the estimation of the  $\text{CH}_4$  dairy cattle emission factor.

Livestock numbers, annual milk production and fat content of milk are published by National Statistical Institute (INE) disaggregated by region.

The majority of cows used for milk production in Portugal belong to the Frisians race. The average weight of 600 kg for mature Frisian cows was supplied by experts<sup>86</sup> of the General Directorate for Food and Veterinary (DGAV) of Ministry of Agriculture (MAM), based on the analysis of the available national information and international studies.

The fraction of cows giving birth annually, disaggregated by region, was estimated based on available data (1999-2012) of National Animal Registration (SNIRA)<sup>87</sup>. For the period 1990 – 1998 data were completed based on a linear regression developed by the Statistics Unit (DSE) of GPP (MAM).

Table 6-3 presents the time series (1990 - 2012) for the relevant country<sup>88</sup> specific parameters used to estimate  $\text{CH}_4$  dairy cow emissions from enteric fermentation.

<sup>84</sup> Dra Olga Moreira e Eng<sup>a</sup> Teresa Dentinho - Unit of Animal Production and Health

<sup>85</sup> The same time series used in the inventory but not averaged over 3 years.

<sup>86</sup> Dr Vicente de Almeida - Animal Genetic Resources Department ; Dr José Neves – Unit of Animal Identification, Registration and Movement

<sup>87</sup> Provided by Funding Institute for Agriculture and Fisheries (IFAP),

<sup>88</sup> Weighted average

Table 6-3 – Time series of country parameters to estimated methane EF dairy cattle

Year	Average Weight (kg hd <sup>-1</sup> )	Average Milk production (kg hd <sup>-1</sup> d <sup>-1</sup> )	Fat content in milk (%)	Cows giving birth in the year (%)	Cows with predominance of pasture on diet (%)	Feed digestibility DE (%)
1990	600	12.23	3.97	75.03	21	73.36
1991	600	12.16	3.96	75.08	22	73.33
1992	600	12.09	3.95	74.88	21	73.35
1993	600	11.26	3.94	74.84	22	73.35
1994	600	11.84	3.93	74.81	22	73.35
1995	600	12.48	3.92	74.80	22	73.34
1996	600	13.00	3.91	74.78	23	73.33
1997	600	13.19	3.90	74.86	24	73.32
1998	600	13.63	3.88	74.98	25	73.29
1999	600	15.67	3.87	75.22	28	73.23
2000	600	17.16	3.86	75.16	28	73.19
2001	600	17.81	3.83	75.31	30	73.14
2002	600	19.27	3.83	76.93	32	73.09
2003	600	18.54	3.79	75.24	32	73.05
2004	600	18.56	3.84	75.02	32	73.03
2005	600	19.82	3.83	74.94	34	73.01
2006	600	20.10	3.79	75.34	35	72.99
2007	600	20.03	3.84	74.48	35	72.96
2008	600	20.92	3.83	74.09	35	72.95
2009	600	21.44	3.78	73.96	37	72.93
2010	600	21.61	3.78	74.16	38	72.91
2011	600	21.72	3.76	75.65	38	72.88
2012	600	22.40	3.77	76.54	39	72.86

The improvement in breeding conditions and of the technological development of dairy farms caused the increase in milk yield in the overall period, while annual variations show sometimes decreases that are related to unfavorable climacteric conditions such as droughts, as can be seen in the temporary decreases in 1993, 2003 and 2004, and recover periods thereafter.

Table 6-4 shows the time series for the different net energy required (NEm, NEa, NEI, NEp, NEg, NEw) and the results for Gross Energy (Mj d<sup>-1</sup>) and CH<sub>4</sub> emission factor (kg CH<sub>4</sub> hd<sup>-1</sup>yr<sup>-1</sup>) from enteric fermentation dairy cows, which were calculated based on the equations described in IPCC 2006.

A constant methane conversion factor of 6.5% of gross energy intake converted to methane was applied.



Table 6-4 - Methane Emission factors from enteric fermentation - dairy cattle

Year	NEm	NEa	NEg <sup>(1)</sup>	NEI	NEw	NEp	REM	GE (Mj d <sup>-1</sup> )	CH <sub>4</sub> EF (kg CH <sub>4</sub> hd <sup>-1</sup> yr <sup>-1</sup> )
1990	46.80	1.70	0.00	37.44	0.00	3.52	0.54	227.17	96.85
1991	46.80	1.77	0.00	37.22	0.00	3.52	0.54	226.75	96.71
1992	46.80	1.69	0.00	36.90	0.00	3.51	0.54	225.89	96.27
1993	46.80	1.71	0.00	34.33	0.00	3.51	0.54	219.43	93.53
1994	46.80	1.74	0.00	36.03	0.00	3.51	0.54	223.74	95.43
1995	46.80	1.76	0.00	37.94	0.00	3.50	0.54	228.67	97.52
1996	46.80	1.80	0.00	39.49	0.00	3.50	0.54	232.72	99.25
1997	46.80	1.88	0.00	39.97	0.00	3.50	0.54	234.17	99.92
1998	46.80	2.01	0.00	41.23	0.00	3.51	0.54	237.81	101.52
1999	46.80	2.23	0.00	47.35	0.00	3.52	0.54	254.32	108.50
2000	46.80	2.25	0.00	51.77	0.00	3.52	0.54	265.49	113.35
2001	46.80	2.42	0.00	53.56	0.00	3.53	0.54	270.83	115.57
2002	46.80	2.57	0.00	58.05	0.00	3.60	0.54	283.29	120.73
2003	46.80	2.58	0.00	55.58	0.00	3.52	0.54	277.36	118.01
2004	46.80	2.58	0.00	55.92	0.00	3.51	0.54	278.03	118.37
2005	46.80	2.70	0.00	59.61	0.00	3.51	0.54	288.06	122.54
2006	46.80	2.77	0.00	60.09	0.00	3.53	0.54	288.98	123.23
2007	46.80	2.79	0.00	60.33	0.00	3.49	0.54	289.61	123.48
2008	46.80	2.78	0.00	62.90	0.00	3.47	0.54	295.54	126.24
2009	46.80	2.92	0.00	64.08	0.00	3.46	0.54	299.83	127.78
2010	46.80	2.99	0.00	64.50	0.00	3.47	0.54	300.87	128.39
2011	46.80	2.99	0.00	64.65	0.00	3.54	0.54	302.13	128.67
2012	46.80	3.10	0.00	66.64	0.00	3.58	0.54	307.60	131.13

(1) Assumed no gain weight as definition of dairy cows categorie are mature cows.

Country EF estimation are close to default IPCC (2006) emission factors for similars milk production and parameters (table 10.A.1). For the year 2012 estimated the EF is 131.13 (kg CH<sub>4</sub> hd<sup>-1</sup>yr<sup>-1</sup>) for an average milk production of 8 178 (kg hd<sup>-1</sup>yr<sup>-1</sup>) and the default value for a milk productin of 8 400 (kg hd<sup>-1</sup>yr<sup>-1</sup>) is 128 (kg CH<sub>4</sub> hd<sup>-1</sup>yr<sup>-1</sup>).

#### 6.3.1.3.1.2 Non-dairy Cattle

The Ministry of Agriculture (MAM) compiled in 1998, and updated recently (GPPAA<sup>89</sup>, 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:

<sup>89</sup> Presently GPP, Gabinete de Planeamento e Políticas/Planning and Policies Office of Ministry of Agriculture

Table 6-5.- Livestock population by age.

<1 yr	<b>Beef Calfs</b>
	Calfs, Males for Replacements
	Calfs, Females for Replacements
1-2 yr	Males
	Beef Females
	Females for Replacement
>2 yr	Steers
	Heifers for Beef
	Heifers for Replacements
	non-dairy cows

Feed intake estimates for each cattle sub-category was estimated using the energy model of the IPCC Good Practices (IPCC,2000), which is briefly presented here. First, net energy is determined from:

$$\begin{aligned}
 NE_m &= CF_i * (Weight)^{0.75} \\
 NE_a &= C_a * NE_m \\
 NE_w &= 0.10 * NE_m * W_{hour} \\
 NE_g &= 4.18 * \{0.0635 * [0.891 * (Weight * 0.96) * (478/(C_g * MW))]^{0.75} * (WG * 0.92)^{1.097}\} \\
 NE_l &= milk_{Yield} * (1.47 + 0.40 * Fat) \\
 NE_p &= C_{pregnancy} * NE_m
 \end{aligned}$$

Needs of digestible energy, and finally Gross Energy Intake (GE), expressed in energy, and Feed Intake (FI), expressed in dry matter ingested, are estimated from:

$$\begin{aligned}
 NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\
 NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\
 GE &= \{[(NE_m + NE_a + NE_l + NE_w + NE_p)/(NE_{ma}/DE)] + [NE_g/(NE_{ga}/DE)]\} / (DE/100) \\
 FI &= GE / ED
 \end{aligned}$$

where, the following variables are estimated:

NE<sub>m</sub> – net energy required by the animal for maintenance, MJ day<sup>-1</sup>;

NE<sub>a</sub> – net energy for animal activity, MJ day<sup>-1</sup>;

NE<sub>w</sub> – net energy for work, MJ day<sup>-1</sup>;

NE<sub>g</sub> – net energy needed for growth, MJ day<sup>-1</sup>;

NE<sub>l</sub> – net energy for lactation, MJ day<sup>-1</sup>;

NE<sub>p</sub> – net energy required for pregnancy, MJ day<sup>-1</sup>;

GE – gross energy, MJ day<sup>-1</sup>;

FI – Feed Intake,  $\text{kg dm day}^{-1}$ ;

Based on the knowledge of the following parameters:

$\text{NE}_{\text{ma}}/\text{DE}$  - ratio of net energy available in a diet for maintenance to digestible energy consumed;

$\text{NE}_{\text{ga}}/\text{DE}$  - 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,  $\text{kg hd}^{-1}$ ;

MW - the mature body weight of an adult animal, kg;

WG - the daily weight gain,  $\text{kg day}^{-1}$ ;

$\text{Milk}_{\text{Yield}}$  – milk production,  $\text{kg day}^{-1}$ ;

$W_{\text{hour}}$  - hours of work per day;

Fat - fat content of milk, %;

ED - energy density of the feed,  $\text{MJ kg}^{-1} \text{ dm}^{-1}$ ;

$C_{\text{fi}}$  - a coefficient for maintenance, specific of each animal class;

$C_{\text{a}}$  – activity coefficient corresponding to the feeding situation of the animal;

$C_{\text{g}}$  – Coefficient for growth, dependent on the sex;

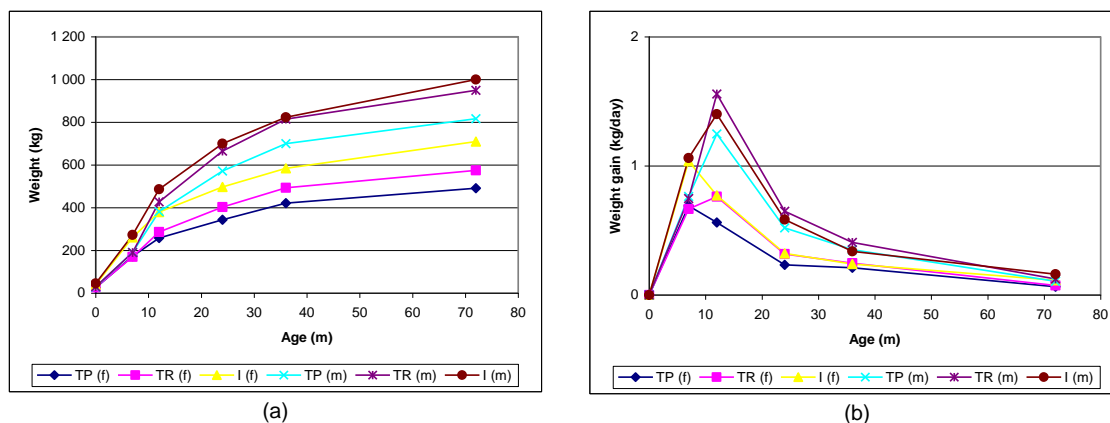
$C_{\text{pregnancy}}$  = pregnancy coefficient.

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 range<sup>90</sup>. The difference between traditional animals on pasture and range depends on the topography conditions, being assumed the range situation for breeds mostly existing in the south plains (“Montados”) and pasture in small grazing plots (“Prados” and “Lameiros”) in central and northern continental Portugal and in the islands.

Given that the database did not have detailed information for all age classes a model had to be derived for each breed from information at birth, 7 months and adult weight. The model, based on information collected from other countries (Jarrige, 1988), considers the following evolution pattern.

<sup>90</sup> 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.

Figure 6-8 – Growth 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 factor<sup>91</sup>. The average values of the parameters and the average values of the values calculated are presented in Table 6-6 though Table 6-9.

Table 6-6 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of individual breed.

sub-class	W (kg)	WG (kg day <sup>-1</sup> )	Cfi	NEm (MJ day <sup>-1</sup> )	Ca <sup>i</sup>	NEa (MJ day <sup>-1</sup> )	Cg	NEg (MJ day <sup>-1</sup> )
Beef calves (<1 yr)	212	0.948	0.322	17.8	0.177	2.8	0.9	8.6
Calfs, Males Rep. (<1 yr)	230	1.139	0.322	19.0	0.177	3.2	1.0	8.9
Calfs, Fem. Rep. (<1 yr)	182	0.757	0.322	15.9	0.177	2.6	0.8	7.9
Males 1-2 yrs	543	0.589	0.322	36.2	0.177	6.3	1.0	8.2
Beef Fem. 1-2 yrs	366	0.295	0.322	26.9	0.177	4.4	0.8	4.7
Females for R. 1-2 yrs	366	0.295	0.322	26.9	0.177	4.4	0.8	4.7
Steers (>2 yrs)	789	0.249	0.322	47.9	0.177	8.4	1.2	3.7
Heifers for Beef (>2 yrs)	462	0.160	0.322	32.1	0.177	5.4	0.8	2.9
Heifers for Rep. (>2 yrs)	462	0.160	0.322	32.1	0.177	5.4	0.8	2.9
non-dairy cows	599	0.000	0.328	39.1	0.177	6.5	0.8	0.0

i) Weighted average for different feeding situations: Stall, Pasture and Grazing large areas.

<sup>91</sup> The preference for this weighting factor other than number of animals results from the fact that the number of declared animals is probably over-estimated for traditional breeds.

Table 6-7 – 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 <sup>-1</sup> )	188
Milk Yield during milking period (kg d <sup>-1</sup> ) <sup>i</sup>	8.00
F (Fat content of Milk) (%)	4.00
NE <sub>i</sub> (MJ day <sup>-1</sup> )	12.8
C <sub>pregnancy</sub>	0.10
NE <sub>p</sub> (MJ day <sup>-1</sup> )	3.60

i) Value considered for non-dairy cows sub class. Milk yield for all other sub classes considered 0 kg d<sup>-1</sup>.

Following recommendations made by the UNFCCC review team during the 2012 incountry review, the milking period for non-dairy cows was changes from 56 days yr<sup>-1</sup> to 188 day y<sup>-1</sup>. For this value we considered an average 1 500 kg milk hd<sup>-1</sup> yr<sup>-1</sup> and a daily production value of 8 kg milk hd<sup>-1</sup> (Jarrige, 1988).

Table 6-8 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of Mature Weight (MW).

MW	kg
Male	930
Female	600

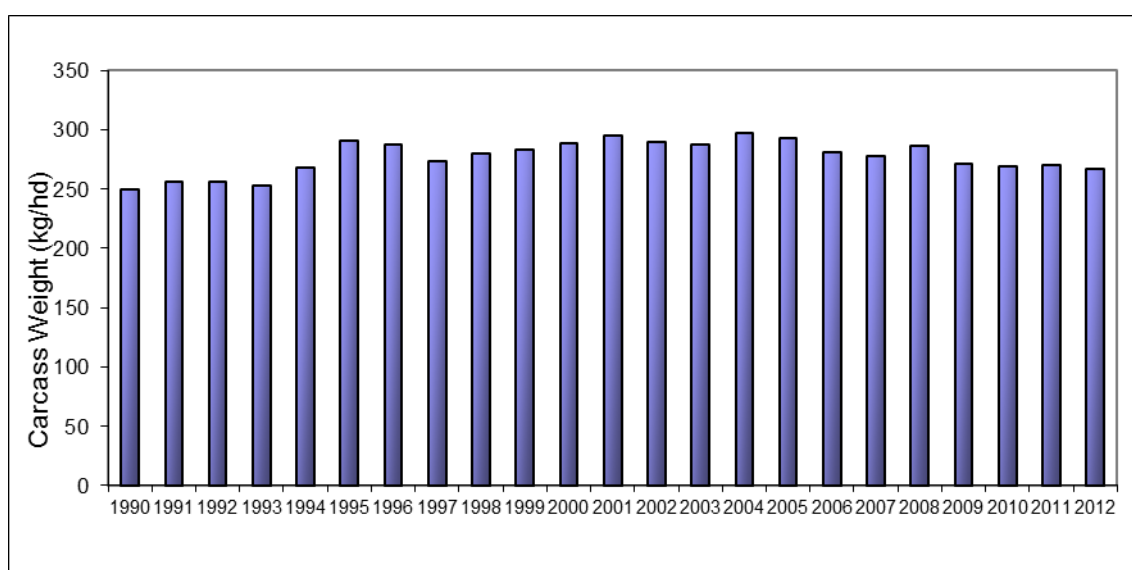
Table 6-9 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Y<sub>m</sub>) and Emission Factor of CH<sub>4</sub> emissions from Enteric Fermentation for non-dairy cattle. Weighted averages from individual breeds.

sub-class	NE (MJ day <sup>-1</sup> )	NE <sub>ma</sub> /DE	NE <sub>ga</sub> /DE	DE (%)	GE (MJ day <sup>-1</sup> )	FI (kg dm <sup>-1</sup> day <sup>-1</sup> )	Y <sub>m</sub>	EF CH <sub>4</sub> (kg hd <sup>-1</sup> y <sup>-1</sup> )
Beef calves (<1 yr)	29.2	0.514	0.308	65	105	5.7	0.06	20
Calves, Males for Rep. (<1 yr)	31.1	0.514	0.308	65	111	6.0	0.06	44
Calves, Females for Rep. (<1 yr)	26.3	0.514	0.308	65	95	5.1	0.06	37
Males 1-2 yrs	50.7	0.495	0.278	60	192	10.4	0.05	67
Beef Fem. 1-2 yrs	36.0	0.495	0.278	60	134	7.2	0.05	46
Females for R. 1-2 yrs	36.0	0.495	0.278	60	134	7.2	0.06	53
Steers (>2 yrs)	60.2	0.495	0.278	60	212	11.5	0.06	84
Heifers for Beef (>2 yrs)	40.3	0.495	0.278	60	143	7.8	0.06	56
Heifers for Rep. (>2 yrs)	40.3	0.495	0.278	60	143	7.8	0.06	56
non-dairy cows	62.5	0.495	0.278	60	210	11.4	0.06	83
Average (1998)	44.3	0.502	0.289	62	156	8.5	0.06	59

These estimates were assumed representative of the situation when the database was compiled, in 1998. The evolution of the average carcass weight at slaughter, Figure 6-9, was used to add a time trend to the estimated quantities, assuming that overall parameters at a given year ( $Par_x$ ) could be approximately related to carcass weight in the same year ( $Cweight_x$ ), from the values of the parameters and weight at base year ( $Par_{base}$  and  $Cweight_{base}$ ) by the power function used for  $NE_m$ . This procedure resulted in an average  $CH_4$  emission factor per animal in 2012, 5.4 per cent higher than the corresponding 1990 value.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 6-9 – Average carcass weight at slaughtering. Total Cattle



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Following recommendations for clarification made by the 2010 review team, the next table shows  $C_{weight}$  values used for estimating  $CH_4$  EF from 1990 to the last inventory year.

Table 6-10 – Determination of the methane emission factor –  $C_{weight}$

Sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Carcass (numbers)	436 055	463 070	443 833	422 377	326 507	325 093	307 741	348 550	282 266	275 244	276 788	248 162
Carcass Weight (t)	108 650	118 676	113 782	106 710	87 367	94 568	88 368	95 210	78 927	77 948	79 818	73 318
Cweight (kg/hd)	249	256	256	253	268	291	287	273	280	283	288	295
Factor (%) <sup>(1)</sup>	91.7	93.7	93.7	92.7	96.8	103.0	102.0	98.3	100.0	101	102.3	104.2

Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carcass (numbers)	284 058	283 612	320 336	314 255	302 520	283 281	306 031	294 226	270 810	270 124	256 927
Carcass Weight (t)	82 286	81 594	95 227	92 185	84 982	78 745	87 508	79 843	72 860	73 047	68 703
Cweight (kg/hd)	290	288	297	293	281	278	286	271	269	270	267
Factor (%) <sup>(1)</sup>	102.7	102.2	104.7	103.7	100.3	99.6	101.7	97.8	97.2	97.5	96.7

**Table 6-11 – Methane emission factor values (kgCH<sub>4</sub>/hd/yr) per animal sub-class for all time series**

Parameter	1990	1991	1992	1992	1994	1995	1996	1997	1998	1999	2000	2001
Beef calfs (<1 yr)	18.3	18.7	18.7	18.5	19.4	20.6	20.4	19.7	20.0	20.2	20.5	20.8
Calfs, Males for Rep.(<1 yr)	40.0	40.9	40.9	40.4	42.2	44.9	44.5	42.9	43.6	44.0	44.6	45.4
Calfs, Females for Rep.(<1 yr)	34.1	34.9	34.9	34.5	36.0	38.3	38.0	36.6	37.2	37.6	38.1	38.8
Males 1-2 yrs	61.7	63.0	63.0	62.4	65.1	69.3	68.6	66.1	67.3	67.9	68.9	70.1
Beef Fem. 1-2 yrs	42.4	43.4	43.4	42.9	44.8	47.7	47.2	45.5	46.3	46.7	47.4	48.2
Females for R. 1-2 yrs	48.3	49.3	49.3	48.8	50.9	54.2	53.7	51.7	52.6	53.1	53.8	54.8
Steers (>2 yrs)	76.7	78.3	78.3	77.5	80.9	86.1	85.3	82.1	83.6	84.4	85.5	87.1
Heifers for Beef (>2 yrs)	51.7	52.8	52.9	52.3	54.6	58.1	57.5	55.4	56.4	56.9	57.7	58.8
Heifers for Rep. (>2 yrs)	51.7	52.8	52.9	52.3	54.6	58.1	57.5	55.4	56.4	56.9	57.7	58.8
non-dairy cows	75.9	77.6	77.6	76.7	80.1	85.3	84.5	81.4	82.8	83.6	84.7	86.3
Average	52.3	53.3	53.0	52.6	55.3	59.5	59.5	57.8	59.1	59.4	60.1	61.0

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Beef calfs (<1 yr)	20.5	20.4	20.9	20.7	20.1	19.9	20.3	19.6	19.4	19.5	19.3
Calfs, Males for Rep.(<1 yr)	44.8	44.6	45.7	45.2	43.8	43.4	44.3	42.6	42.4	42.5	42.2
Calfs, Females for Rep.(<1 yr)	38.2	38.0	39.0	38.6	37.3	37.0	37.8	36.4	36.1	36.3	36.0
Males 1-2 yrs	69.1	68.7	70.5	69.8	67.5	67.0	68.4	65.8	65.4	65.6	65.1
Beef Fem. 1-2 yrs	47.5	47.3	48.5	48.0	46.4	46.1	47.1	45.3	45.0	45.1	44.8
Females for R. 1-2 yrs	54.0	53.7	55.1	54.5	52.8	52.4	53.5	51.4	51.1	51.3	50.9
Steers (>2 yrs)	85.8	85.4	87.5	86.7	83.9	83.2	85.0	81.7	81.2	81.5	80.8
Heifers for Beef (>2 yrs)	57.9	57.6	59.1	58.5	56.6	56.2	57.4	55.2	54.8	55.0	54.5
Heifers for Rep. (>2 yrs)	57.9	57.6	59.1	58.5	56.6	56.2	57.4	55.2	54.8	55.0	54.5
non-dairy cows	85.0	84.6	86.7	85.8	83.1	82.4	84.2	81.0	80.4	80.8	80.1
Average	60.1	59.7	61.1	60.5	58.9	58.8	60.3	58.1	57.7	57.6	56.7

### 6.3.1.3.1.3 *Sheep and Goats*

The same database from MAM that was referenced previously for non dairy cattle includes also information for the twelve<sup>92</sup> native Portuguese breeds of sheep and the five native Portuguese breeds of goats<sup>93</sup>. Three imported breeds of sheep<sup>94</sup> 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.

<sup>92</sup> 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.

<sup>93</sup> Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

<sup>94</sup> Assaf, Ile de France and Merino Precoco.



In a similar mode to that used for cattle, the energy model proposed in the IPCC Good Practices Guidance (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:

$$\begin{aligned} NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\ NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\ GE &= \{[(NE_m + NE_a + NE_l + NE_p)/(NE_{ma}/DE)] + [(NE_g + NE_{wool}) / (NE_{ga}/DE)]\} / (DE/100) \\ FI &= GE / ED \end{aligned}$$

where, the following variables and parameters are estimated:

NE<sub>m</sub> – net energy required by the animal for maintenance, MJ/day;

NE<sub>a</sub> – net energy for animal activity, MJ/day;

NE<sub>g</sub> – net energy needed for growth, MJ/day;

NE<sub>l</sub> – net energy for lactation, MJ/day;

NE<sub>p</sub> – net energy required for pregnancy, MJ/day;

NE<sub>wool</sub> – net energy for wool production, MJ/day;

GE – gross energy, MJ/day;

FI – Feed Intake, kg dm/day;

NE<sub>ma</sub>/DE - ratio of net energy available in a diet for maintenance to digestible energy consumed;

NE<sub>ga</sub>/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<sub>Lamb</sub> – 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<sub>Yield</sub> – milk production for lamb pre-weaning feeding and milk production, kg/year;

Wool<sub>Prod</sub> – Wool production per animal and year, kg;

C<sub>fi</sub> - a coefficient for maintenance, specific of each animal class;

C<sub>a</sub> – activity coefficient corresponding to the feeding situation of the animal;

a, b – parameters dependent on sex of animal, used in the determination of  $a + b \cdot BW$ , the Energy Value of the Weight gain, MJ/kg;

EV<sub>milk</sub> - the energy value for milk, MJ/kg;

EV<sub>wool</sub> - energy value of the wool produced, MJ/kg;

C<sub>pregnancy</sub> = pregnancy coefficient.

An estimate was done individually for each breed and distinctly for ewes, does, lambs (for slaughtering), kids (slaughtering) and males (rams, bucks and young males). Parameters and final energy values were averaged using the number of registered animals as weighting factor and are presented in the next set of tables.

Table 6-12 – 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 <sub>fi</sub>	0.250	0.217	0.254	0.315	0.315	0.315
NE <sub>m</sub> (MJ/day)	6.64	4.30	1.36	3.57	2.97	0.93
C <sub>a</sub> <sup>i</sup>	0.017	0.017	0.017	0.024	0.024	0.024
NE <sub>a</sub> (MJ/day)	1.39	0.93	0.17	0.90	0.68	0.12
WG (kg/day)	-	-	0.196	-	-	0.160
NE <sub>g</sub> (MJ/day)	-	-	1.26	-	-	0.78
Wool (kg/yr)	6.5	3.6	-	-	-	-
NE <sub>wool</sub> (MJ/day)	0.43	0.23	-	-	-	-
C <sub>pregnancy</sub>	-	0.075	-	-	0.066	-
NE <sub>p</sub> (MJ/day)	-	0.32	-	-	0.20	-

i) Sheep - Average for different feeding situations: grazing flat and hilly pasture. Goats – Grazing hilly pasture.

Table 6-13 – 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)	57	442
Milking period (days/yr)	153	234
Milk Production (kg/day)	0.156	1.210
Total Avg. Milk Production (kg/day)	0.210	1.237
EnergyValue of Milk (MJ/kg)	4.60	2.80
NE <sub>i</sub> - Milk Production per day (MJ/day)	0.96	3.47

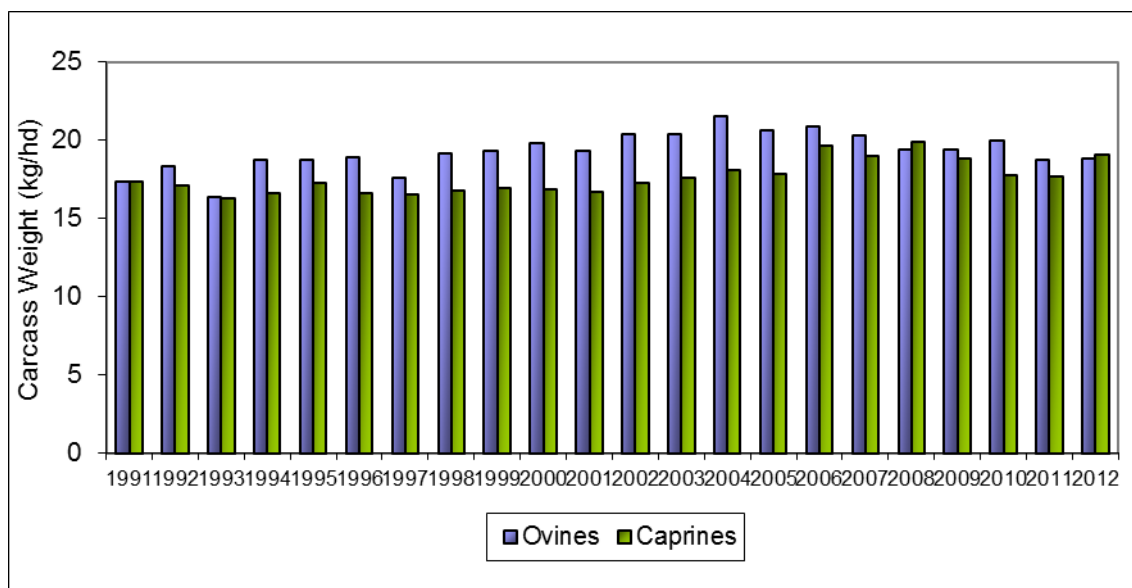
Table 6-14 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Y<sub>m</sub>) and Emission Factor of CH<sub>4</sub> emissions from Enteric Fermentation for sheep and goats. Weighted averages of individual breeds.

Sub-class	Sheep			Goats		
	Ram	Ewe	Lamb	Buck	Doe	Kid
NE <sub>ma</sub> /DE	0.495					
NE <sub>ga</sub> /DE	0.278					
DE (%)	60					
GE (MJ/day)	29.60	22.84	12.67	15.07	24.31	8.19
FI (kg dm/day)	1.60	1.24	0.69	0.82	1.32	0.44
Y <sub>m</sub>	0.06			0.05		
EF (kg CH <sub>4</sub> /hd/yr)	11.6	8.99	5.0	4.94	7.97	2.69

Data on the average carcass weight at slaughter, Figure 6-10, 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<sub>x</sub>) could be approximately related to carcass weight in the same year (Cweight<sub>x</sub>), from the values of the parameters and weight at base year (Par<sub>base</sub> and Cweight<sub>base</sub>). This procedure resulted in the CH<sub>4</sub> emission factors for ovine per animal being 6.47 per cent higher in 2012 than the corresponding values in 1990 and for goats 7.49 per cent higher.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 6-10 – Average carcass weight at slaughtering. Total sheep and total goats



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Following recommendations for clarification made by the 2010 review team, the next table shows  $C_{weight}$  values used for estimating CH<sub>4</sub> EF from 1990 to the last inventory year.

Table 6-15 – Determination of the methane emission factor - Ovises –  $C_{weight}$

Sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Carcass (numbers)	183 478	177 547	141 768	233 548	153 228	145 499	129 211	144 632	100 041	76 177	68 700	74 903
Carcass Weight (t)	3 213	3 075	2 602	3 814	2 875	2 724	2 446	2 547	1 913	1 469	1 363	1 450
Cweight (kg/hd)	17.5	17.3	18.4	16.3	18.8	18.7	18.9	17.6	19.1	19.3	19.8	19.4
Factor (%) <sup>(i)</sup>	91.6	90.6	96.0	85.4	98.1	97.9	99.0	92.1	100.0	100.8	103.8	101.2

Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carcass (numbers)	65 518	49 520	39 963	43 814	46 188	58 906	72 642	76 451	75 807	76 409	80 889
Carcass Weight (t)	1 337	1 011	860	903	965	1 198	1 410	1 484	1 512	1 434	1 523
Cweight (kg/hd)	20.4	20.4	21.5	20.6	20.9	20.3	19.4	19.4	19.9	18.8	18.8
Factor (%) <sup>(i)</sup>	106.7	106.8	112.5	107.8	109.3	106.4	101.5	101.5	104.3	98.1	98.5

**Table 6-16 – Determination of the methane emission factor - Caprines – C<sub>weight</sub>**

Sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Carcass (numbers)	42 687	42 687	53 063	38 729	47 363	45 980	50 121	45 604	38 997	28 457	22 192	16 348
Carcass Weight (t)	740	740	909	632	786	793	833	755	654	483	375	273
C <sub>weight</sub> (kg/hd)	17.3	17.3	17.1	16.3	16.6	17.2	16.6	16.6	16.8	17.0	16.9	16.7
Factor (%) <sup>(1)</sup>	103.4	103.4	102.1	97.3	99.0	102.8	99.1	98.7	100.0	101.2	100.8	99.6

Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carcass (numbers)	14 239	12 102	7 563	3 809	5 755	6 804	6 638	6 789	6 407	10 808	8592
Carcass Weight (t)	246	213	137	68	113	129	132	128	114	191	164
C <sub>weight</sub> (kg/hd)	17.3	17.6	18.1	17.9	19.6	19.0	19.9	18.9	17.8	17.7	19.1
Factor (%) <sup>(1)</sup>	103.0	104.9	108.0	106.5	117.1	113.1	118.6	112.4	106.1	105.4	113.8

**Table 6-17 – Methane emission factor values (kgCH<sub>4</sub>/hd/yr) per animal sub-class for all time series - Ovines**

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ewes	8.3	8.3	8.7	8.0	8.9	8.8	8.9	8.5	9.0	9.0	9.2	9.1
Rams and young males	10.8	10.8	11.3	10.3	11.5	11.5	11.6	10.9	11.6	11.7	12.0	11.8
Lambs	4.6	4.6	4.8	4.4	4.9	4.9	4.9	4.7	5.0	5.0	5.1	5.0
Average	8.5	8.5	8.9	8.2	9.1	9.1	9.2	8.7	9.2	9.3	9.4	9.0

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ewes	9.4	9.4	9.8	9.5	9.6	9.4	9.1	9.1	9.3	8.9	8.9
Rams and young males	12.2	12.2	12.7	12.3	12.4	12.2	11.8	11.8	12.0	11.5	11.5
Lambs	5.2	5.2	5.4	5.3	5.3	5.2	5.0	5.0	5.1	4.9	4.9
Average	9.2	9.1	9.5	9.3	9.4	9.2	8.9	8.9	9.0	8.6	8.7

**Table 6-18 – Methane emission factor values (kgCH<sub>4</sub>/hd/yr) per animal sub-class for all time series - Caprines**

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Does	8.2	8.2	8.1	7.8	7.9	8.1	7.9	7.9	8.0	8.0	8.0	7.9
Bucks and young males	5.1	5.1	5.0	4.8	4.9	5.0	4.9	4.9	4.9	5.0	5.0	4.9
Kids	2.8	2.8	2.7	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Average	7.19	7.14	7.02	6.78	6.87	7.08	6.89	6.87	6.91	6.96	7.01	7.08

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Does	8.2	8.3	8.4	8.4	9.0	8.7	9.1	8.7	8.3	8.3	8.8
Bucks and young males	5.1	5.1	5.2	5.2	5.6	5.4	5.6	5.4	5.2	5.1	5.4
Kids	2.7	2.8	2.8	2.8	3.0	2.9	3.1	2.9	2.8	2.8	3.0
Average	7.37	7.51	7.63	7.53	8.05	7.85	8.16	7.87	7.56	7.53	8.1

#### 6.3.1.3.1.4 Swine and Rabbits

The methodology used by the French I.N.R.A. (INRA, 1984) was used to estimate feed intake for each swine sub-class, according to the following formula:

$$GE = \text{Feed}_{ED} / (DE / 100)$$

where,

GE – gross energy, MJ/day;

Feed<sub>ED</sub> – 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 CH<sub>4</sub> emissions from enteric fermentation were obtained from INRA (1984) for each animal sub-class and are presented in Table 6-19.

Table 6-19 – Parameters used in determination of Gross Energy (GE) ingestion and enteric fermentation methane emission factor by swine and rabbits (all values INRA (1984))

sub-class	Weight (kg)	DE (MJ/day)	DE (% GE)	EF (kg CH <sub>4</sub> /h/y)	Ym	Notes
Swine						
Piglets (<20 kg)	10	6.2	79.4	0.31	0.006	Avg. 22 d. to 20 kg
Fattening Pigs (20-50 kg)	35	23.4	72.6	1.27		Regression
Fattening Pigs (50-80 kg)	65	34.5	72.6	1.87		DE = 17.93*Ln(W)-40.13
Fattening Pigs (80-110 kg)	95	41.3	72.6	2.24		(r <sup>2</sup> - 0.998)
Fattening Pigs (> 110 kg)	120	45.5	72.6	2.47		
Boars (>50 kg)	250	32.4	68.0	1.88		
Sows, pregnant	170	31.4	68.0	1.82		Sow in gestation
Sows, non-pregnant	195	64.9	68.0	3.75		Sow in lactation
Rabbits						
Reproductive Female	-	12.6	56.7	3.63	0.025	per female cage. The Ym is the IPCC default for Horses

#### 6.3.1.3.1.5 Poultry<sup>95</sup>

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):

<sup>95</sup> CH<sub>4</sub> emissions from Enteric Fermentation are not estimated for Poultry. Nevertheless GE is estimated for these animal types for the estimate of CH<sub>4</sub> 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<sub>ME</sub> – Recommended metabolic energy ingestion, MJ/day;

EM/GE - Metabolisability, metabolic energy expressed as a percentage of gross energy, per cent.

Table 6-20 – Parameters used in determination of Gross Energy ingestion by Poultry

Animal Type	Energy Intake (MJ EM/day)	Metabolizability (EM/GE)	GE (MJ/day)	Ym
Broiler	1.02	68.3	1.50	NA
Laying hens, eggs production	1.39	63.5	2.20	NA
Laying hens, reproduction	1.36	63.5	2.15	NA
Cocks	1.71	63.5	2.69	NA
Turkeys	3.23	68.0	4.75	NA
Ducks#	1.46	65.8	2.22	NA

# used as reference for other fowl

It is importante to point out that for poultry there is no methane conversion rate and thus no enteric fermentation emissions. The choice to include the GE methodology for poultry in this chapter was made to maintaing coherency between animal types.

#### 6.3.1.4 Activity Data

Periodic census to agriculture<sup>96</sup> and animal husbandry activities are made every 10 years by the National Statistical Institute (INE) in accordance with UE requirements. The first census was made in 1952/54, followed by exercises in 1968, 1979, 1989, 1999 and 2009. Last census (RA09), considered the survey of all national territory at the same time. Inquiries were done at each individual production unit by direct interview,

The periodic agriculture census is subjected to Quality Control measures by INE. A set of interviews are made to a selected number of production units and the results from the “normal interview” are compared to the results from the “control interview”. Data from 2009 survey was first introduced in the 2012 inventory.

Also, every two years about 40 000 farms (production units) 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.

<sup>96</sup> Referred in Portuguese as Recenseamento Agrícola (RA, 2009). Previous census were referred as Recenseamento Geral da Agricultura (RGA)

Using those data sources, the National Statistics Institute (INE), built consistent time series of annual livestock numbers from 1987 to 2012 for cattle, swine, sheep, goats, horses, mules and donkeys, disaggregated per region<sup>97</sup>, age and sex.

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, 1989 and 1990).

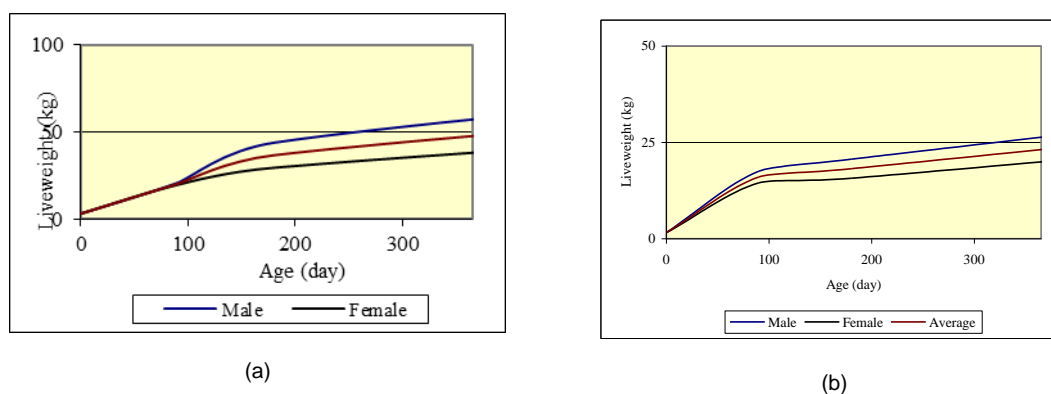
All original figures in statistical database represent stock numbers at a particular time of the year, mostly December and consequently for some species with strong seasonal reproducing periods, such as goats and sheep, these numbers had to be corrected and converted in average annual population. The 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 INE. The number of lambs and kids reported as activity data represents the equivalent annual average of animals, i.e.:

$$\text{lambs/kids (hd)} = \text{Annual Slaughter (hd/yr)} * \text{Age\_Slaughter (days)} / 365$$

The age at which slaughter occurs (Age\_Slaughter) was determined from the inverse function of the growth models<sup>98</sup> for both species, Figure 6-11, using the weight at slaughter that was determined from the information published by INE, which values are presented in Figure 6-12. Resultant average ages vary from 107 to 113 days for lambs and 73 to 102 days for kids.

Figure 6-11 – Growth Model for Sheep (a) and Goats (b)



For both caprine and ovine animals there is a very appreciable variation of number of slaughtering according to months, as may be seen in Figure 6-13 for two subsequent years (GPPAA<sup>99</sup>, 2004). The importance of the periods of Christmas and Easter is evident. From this

<sup>97</sup> 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.

<sup>98</sup> Model set from the information on the breeds existent in Portugal, complemented by information in Jarrige (1988) concerning growth pattern.

<sup>99</sup> Presently GPP, Gabinete de Planeamento e Políticas/Planning and Policies Office of Ministry of Agriculture



data, the population of lambs and kids was estimated for the beginning of each month (day 1), considering that at that moment were alive all animals killed in that same month and in the subsequent months according to the average age when young animals are killed. The ratio of population of young animals in the first of December (reference data for RGA99) to the average annual population, estimated to be 1.17 for sheep and 1.89 for goats, was used to estimate lamb and kids population in the moment of the RGA. The number of animals remaining from the total ovine and caprine numbers after subtraction of number of females (ewes and does) and the number of youngsters (lambs and kids) is reported as “Other Ovines” and “Other Caprines”. These animals are mostly adult males, but also young animals that are kept to reproductive functions and are not slaughtered.

Figure 6-12 – Average carcass weight at slaughtering. Lambs and Kids

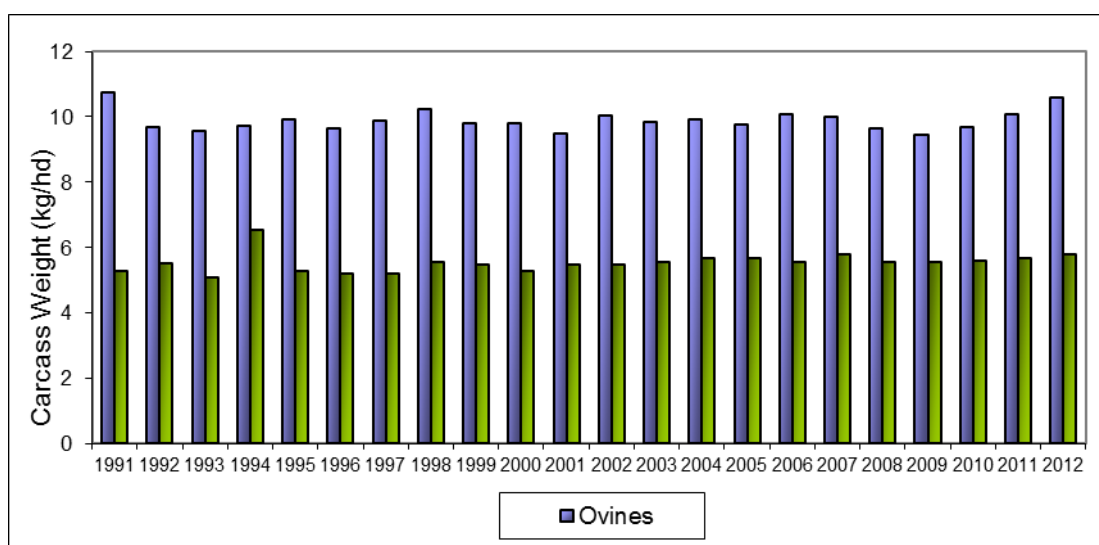
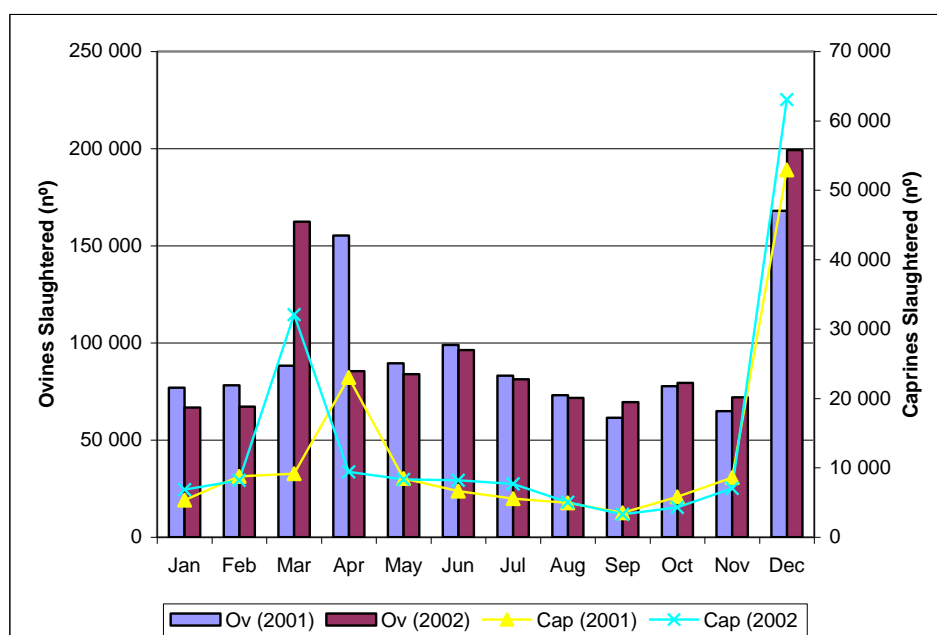


Figure 6-13 – Number of slaughtered young animals in each month for the years 2001 and 2002



**Table 6-21 - Livestock Numbers (Thousands)**

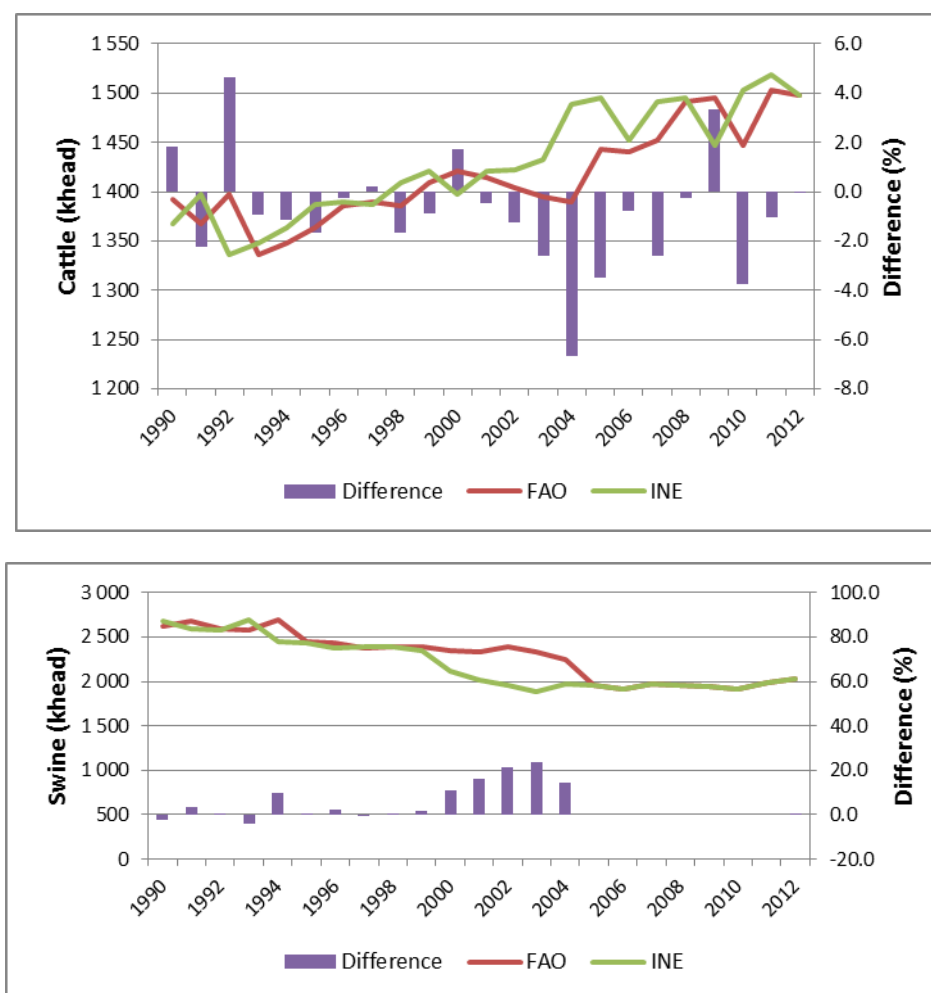
Animal	Sub-class	1990	1995	2000	2005	2010	2011	2012
Dairy-Cattle	Dairy cows	394	383	353	290	255	247	241
Non-dairy cattle	Beef calves (<1 yr)	46	60	67	104	114	120	125
	Calfs M.Rep. (<1 yr)	186	162	144	136	123	128	136
	Calfs F Rep. (<1 yr)	177	158	174	183	171	179	190
	Males 1-2 yrs	112	103	82	81	66	60	55
	Beef Fem. 1-2 yrs	18	22	17	17	20	19	20
	Females rep. 1-2 yrs	111	109	127	135	137	132	131
	Steers (>2 yrs)	38	33	26	25	38	41	44
	Heifers Beef (>2 yrs)	4	10	6	9	12	13	14
	Heifers rep. (>2 yrs)	45	52	67	94	110	111	110
	non-dairy cows	242	273	345	397	438	440	442
Swine	Piglets (<20 kg)	727	726	663	574	597	614	634
	Fatt. Pigs (20-50 kg)	662	660	585	467	448	446	455
	Fatt. Pigs (50-80 kg)	525	525	483	368	360	362	366
	Fatt. Pigs (80-110 kg)	218	198	174	214	244	251	255
	Fatt. Pigs (> 110 kg)	44	44	38	41	36	30	27
	Boars (>50 kg)	26	26	20	12	7	6	5
	Sows, pregnant	210	211	195	191	179	172	166
	Sows, non-pregnant	124	132	124	68	66	66	66
Ovines	Ewes	2 292	2 339	2 410	2 293	1 915	1 811	1735
	Other Ovines	662	817	733	254	217	205	185
	Lambs	307	279	320	302	252	238	242
Caprines	Does	614	517	460	380	356	353	349
	Other Caprines	149	151	129	54	42	39	35
	kids	47	41	33	29	27	27	28
Equides	Horses	33	48	58	52	38	36	36
	Asses and Mules.	118	103	69	40	22	21	21
Poultry	Hens, reproductive	3 421	3 271	2 644	2 480	2 743	2 855	2855
	Hens eggs	7 539	7 745	9 060	7 925	8 763	9 123	9123
	Broilers	18 524	18 813	24 374	18 686	19 474	20 254	20254
	Turkeys	603	827	1 283	1 019	1 114	1 098	1127
	Ducks; Geese;Guinea Fowl	804	804	804	804	804	804	804
Other	Rabbits	475	401	336	289	263	267	267

#### 6.3.1.4.1 Quality Assessment of Livestock Numbers

The decrease in dairy cows is consistent with the increase in productivity and the UE quotas limits (GPPAA<sup>100</sup>, 2004). More detailed information and critical analysis of the trends can be consulted in the Animal Production Yearbooks, published periodically by the Ministry of Agriculture including a detailed analysis of the animal production sector and the causes, both at national and EU level, which explain the trends<sup>101</sup>.

Livestock numbers<sup>102</sup> used in the inventory, as collected from National Statistics, were compared to FAO livestock numbers for years 1990-2012, and results are presented in the Figure 6-14 for cattle, swine and ovine.

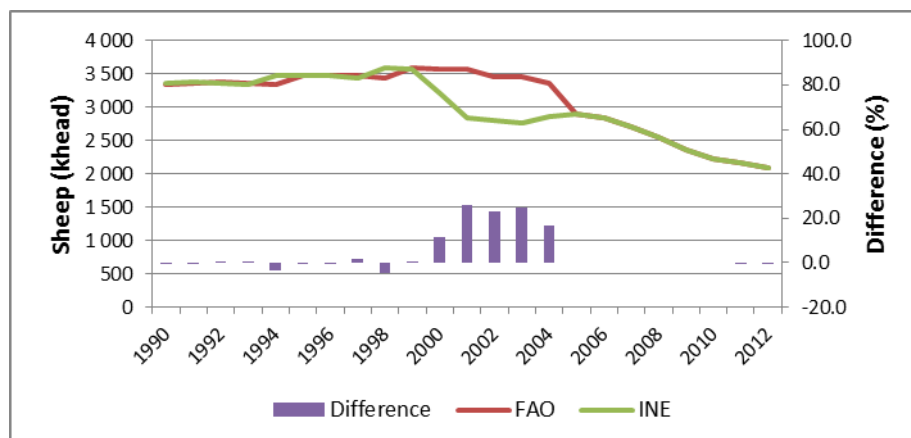
Figure 6-14 – Comparison of Livestock numbers between national statistics and FAO database. Values represent the relative per cent difference to National Statistics



<sup>100</sup> APresently GPP, Gabinete de Planeamento e Políticas/Planning and Policies Office of Ministry of Agriculture

<sup>101</sup> Reports available at (<http://www.gpp.pt/publicacoes.html>)

<sup>102</sup> Annual values, not 3 year averages.



FAO and INE livestock numbers have a good adhesion for all species. For swines and sheeps they are even the same from 2005 onwards. For cattle the values in almost of time serie are the same but one year delayed. FAO livestock number of year  $n$  is equal to INE livestock number for the year  $n-1$ . Only in 2012 values total agree in both dataset. For emission estimations we used in the inventory a three average number so this delay between series is diminished.

The number of horses, mules, asses and turkeys<sup>103</sup> is very different when comparing statistics from FAO and INE, but they have a small importance in the emissions inventory. The population of laying hens, also from National Statistics, include animals producing eggs for consumption as well as eggs used to obtain broilers and to replace other laying and reproductive animals. Poultry numbers include also animals kept in domestic rural houses and not only animals in farms and agro-industrial places. These two facts explain the constant numbers differences reported for birds in National Statistics and those reported in FAO database.

#### 6.3.1.5 *Uncertainty Assessment*

The uncertainty of livestock numbers for cattle is expected to be lower than for other animal types, due to the longer growing period for this specie and also due to the strong control (tagging) that is made on this animals. An almost similar situation may be assumed to the swine population. Herd numbers of sheep and goats are probably less known, mostly because of the strong seasonal character of breeding, because of the younger age at which animals are sacrificed and finally due to the significant importance of auto-consumption. The need to estimate a time-series based on surrogate drivers, and the prevalence of dispersed animals in small farms, naturally causes higher uncertainty values for these animals. Finally, animals that are usually not considered as meat, such as equines, are less controlled and numbers tend to be known with less rigour.

Uncertainty estimates of livestock numbers are based on expert judgment and are presented in table Table 6-22.

<sup>103</sup> While poultry numbers do not affect emissions of CH<sub>4</sub> from Enteric Fermentation they are discussed here to simplify NIR presentation.

Table 6-22 - Uncertainty for livestock population.

Animal Type	U (%)
Dairy - Cattle	10
Non dairy cattle	10
Sheep	10
Goats	10
Pigs	10
Horses	20
Mules and Asses	50
Hens	20
Broilers	20
Turkeys	30
Other	30

The uncertainty of the emission factor was assumed to be 20 per cent for all animals where tier 2 was used and 50 per cent when tier 1 emission factors were used, in accordance with the Good Practice Guidebook (IPCC, 2000).

#### 6.3.1.6 *Category-specific QA/QC and verification*

For this source category QA/QC procedures were focused in the livestock data obtained from INE. Two quality assessments of the livestock numbers were produced:

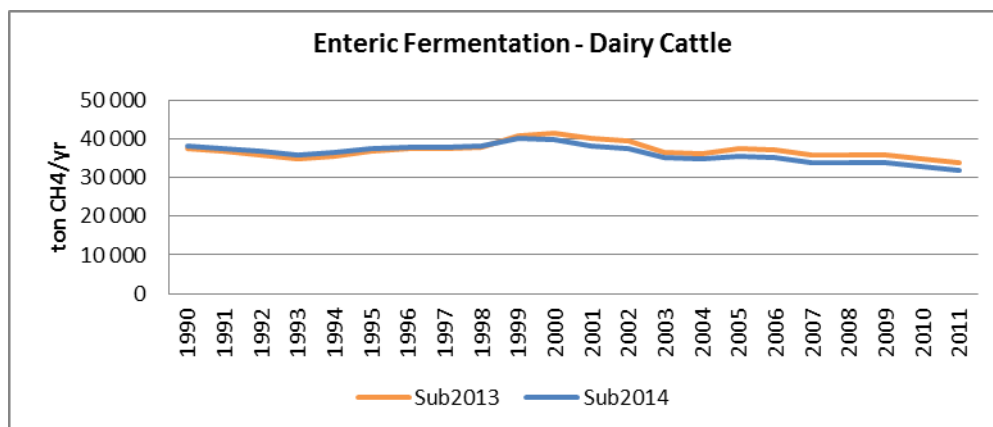
- Comparison between data from RGA 99 (INE) and data from Farm Structure Survey (also from INE) concerning poultry and rabbits;
- Comparison between livestock data obtained from INE and FAO numbers.

The first analysis is described in the Activity Data chapter and the second in the Quality Assessment of Livestock Numbers chapter.

#### 6.3.1.7 *Recalculations*

Given the importance of the category (key category), a significant revision was made following the UNFCCC review recommendation.

The major recalculation made for 4.A concerns the improvement of the methodological level to estimate emissions from enteric fermentation of dairy cattle through country specific parameters enhance. The differences between 2013 submission and this year submission are represented in the figure below.



#### 6.3.1.8 Further Improvements

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

### 6.3.2 CH<sub>4</sub> Emissions from Manure Management (CRF 4.B.)

#### 6.3.2.1 Overview

Methane emissions from manure occur when the organic material it contains, either solid or dung or liquid as urine, decomposes, during storage or treatment, in anaerobic environments by the action of methanogenic bacteria. The quantity that is emitted depends mostly of the existence of anaerobic conditions during storage of manure that promotes the activity of methanogenic microorganisms. Methane formation is therefore particularly important in highly anaerobic Manure Management Systems (MMS) such as anaerobic lagoons, anaerobic digesters, accumulation in tanks in liquid or slurry state or where manure remains for a long time residence on stall floor. Methane emissions resulting from manure deposited directly in soil during grazing and pasture, although in small quantities, are also included in this source category<sup>104</sup>.

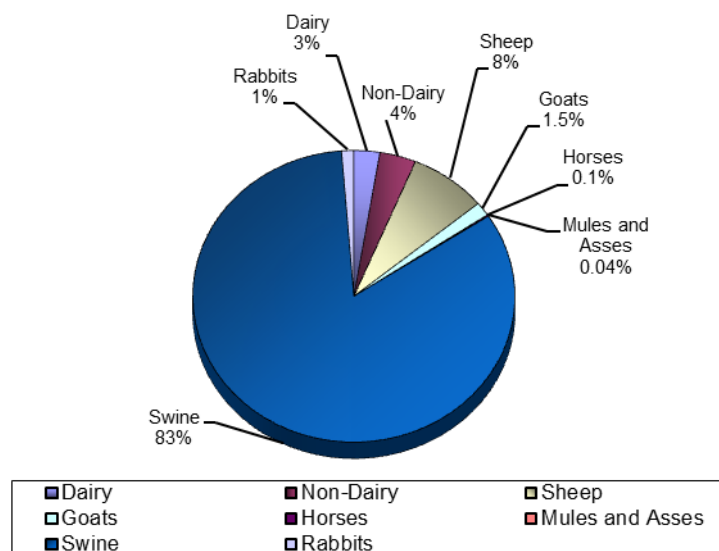
In some systems, such as anaerobic lagoons and digesters, the emitted gas may be collected and burned for energy use or simply flared. In these cases, methane emissions to the atmosphere may be significantly reduced.

Methane emission from Manure Management in Portugal is a key source. According to origin of manure by specie, most emissions result from swine manure, with 83 per cent of emissions in

<sup>104</sup> Nitrous oxide emissions from manure deposited in soil during grazing and pasture are nevertheless included in source category N<sub>2</sub>O from agricultural soil: Animal production, in accordance with UNFCCC reporting guidelines.

2012, as may be seen in Figure 6-15, and according to the Good Practice rule of thumb this specie is the only significant source.

Figure 6-15 - Relative Importance of emissions of CH<sub>4</sub> from Manure Management per each animal species in 2012



### 6.3.2.2 Methodology

Following the 1996 IPCC Revised Guidelines and the Good Practice Guidebook, emission estimates are calculated by the following simple equation (following equation 4.15 of GPG) applied for each animal type and considering emission factors dependent on animal type and climatic conditions. By this procedure both the quantity of manure produced per animal and the storage conditions are included in the determination of the emission factor, and will be discussed thereafter.

$$Emi_{CH_4} = \sum_i \sum_c [EF_{(i,k)} * N_{(i,k)}]$$

where, for each specie:

$Emi_{CH_4}$  = methane emissions from manure management, kg CH<sub>4</sub>/year;

$EF_{(i,k)}$  = emission factor for the specific population of animal type i, living in climate region k, kg/head/year;

$N_{(i,k)}$  = total number of animals of type i, living in climate region k, head.

### 6.3.2.3 Emission Factors

Emissions Factors for each animal type were established according to the tier 2 methodology proposed in GPG (equation 4.17), which considers the use of country specific information concerning the quantity of manure produce per animal and the share of each Manure Management System that is used for each animal type. The equation used for the calculation of the EF for each animal species is therefore:



$$EF_{(i)} = VS_{(i)} * 365 * Bo_{(i)} * 0.67 * \sum_{jk} MCF_{(jk)} * MMS_{(jk)}$$

$EF_{(i)}$  - annual emission factor for a defined livestock animal specie i (kg/year);

$VS_{(i)}$  - Amount of excretion, expressed in Volatile Solids (VS) for an average animal i in the livestock population (kg VS /day);

$Bo_{(i)}$  - Maximum methane production capacity from manure ( $m^3/kg$  VS) for animal specie i.  $0.67 kg/m^3$  is methane density;

$MCF_{(jk)}$  - methane conversion factor for each Manure Management System j and for each climate region k;

$MMS_{(jk)}$  - fraction of total manure from animal specie i handled with Manure Management System j and for each climate region k.

$B_o$  values were set according to IPCC rev 1996. 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:

$$VS = GE * (1kg-dm/18.45 MJ) * (1-DE/100) * (1-Ash/100)$$

where

GE – Daily average gross energy feed intake, MJ/day;

DE – Digestible energy of the feed, per cent;

Ash – mineral content of feed, per cent.

For dairy cattle an urinary energy (0,04GE) was also considered (IPCC2006, eq.10.24) for VS estimation.

The next table presents the parameters that were used for each animal class: Digestibility of feed (DE; Ash content in manure (Ash) and the maximum methane production capacity from manure ( $B_o$ ) for each animal type. VS values change along years as consequence of the change in Gross Energy estimates.

Table 6-23 – Parameters used in the estimate of Volatile Excretion per animal

Animal Class	sub-class	DE (%)	Ash (%)	B <sub>o</sub> (m <sup>3</sup> /kg VS)
Dairy-Cattle	Dairy Cows	73 <sup>»</sup>	8	0.24
non-dairy cattle	Calves (<1 yr)	65	8	0.17
	Other animals	60	8	0.17
Swine	Piglets (<20 kg)	79 <sup>#</sup>	2	0.45
	Fattening Pigs	73 <sup>#</sup>	2	0.45
	Sows and Boars	68 <sup>#</sup>	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 <sup>#</sup>	5 <sup>#</sup>	0.32
	Hens eggs	63 <sup>#</sup>	5 <sup>#</sup>	0.32
	Broilers	68 <sup>\$</sup>	2 <sup>#</sup>	0.32
	Turkeys	68 <sup>#</sup>	3 <sup>#</sup>	0.32
	Ducks, Geese and Guinea Fowl	66 <sup>#</sup>	2 <sup>#</sup>	0.32
Other	Rabbits	57 <sup>#</sup>	3 <sup>#</sup>	0.33 (a)

Note: all values IPCC default, except:

»-Country specific (Table 6-3); # - INRA (1984); \$- McDonald et al (2004); (a) Value assumed equal to horses

Expert guess<sup>105</sup>, based on survey data and field knowledge of technical personnel of the Ministry of Agriculture was used to establish the percent of each Management System in 1990. The same expertise was used to establish a prevailing trend in the period 1990-2010, considering the practices that are becoming more common and some results of legislation and institutional control. Although the exact year at which the situation changes is unknown, a linear evolution between year 1990 and the target year of 2010 was assumed. Since no new data is available for 2012 we assume the 2010 distribution.

The values for the fraction of manure handled in each MMS were revised for the 2010 submission by the Ministry of Agriculture technical personnel<sup>106</sup>. This revision followed recommendation from the expert review team expressed in the 2009 review process. The MMS changes were only made to the 2010 values (1990 remained the same).

The final IEF of methane emissions from Manure Management, expressed in kg CH<sub>4</sub> per animal, that way derived for Portugal, results in considerable differences when in comparison to the default values in the 1996 Revised IPCC Guidelines (IPCC, 1997). The different values are clearly justified by the use of a different share of Management Systems for Manure, which are presented in Table 6-24 and also in Figure 6-16. The country-specific used in Portugal differ from the one proposed in the IPCC default in the following aspects:

<sup>105</sup> Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005.

<sup>106</sup> Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 7, October 2009.

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- swine manure in Portugal is usually treated in anaerobic lagoons, which have the highest MCF among MMS. A small number of explorations still have short retention pits (< 1 month), however due to new legislation constrains higher retention time pits are expected to be adopted in the near future;
  - the management of wastes from dairy cows kept in stall is split among solid storage and short retention time pits;
  - dairy cows in pasture are more common in Portugal than the default assumption in IPCC;
  - non dairy cows with milking calves are usually kept on pasture, but fattening animals are usually grown in confined areas. Solid storage was the prevalent method of treatment for wastes from other cattle in 1990, but has since been losing importance;
  - daily spread and usage as fuel are practically unknown in Portugal;
  - there is a small percentage of traditional swine kept outdoors and foraging in pasture range;
  - some poultry is kept outside, either in small farms or industrial production of country poultry;
  - there are no substantial seasonal variations in the share of management system.

Table 6-24 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990 and 2012(equal to 2010) (%).

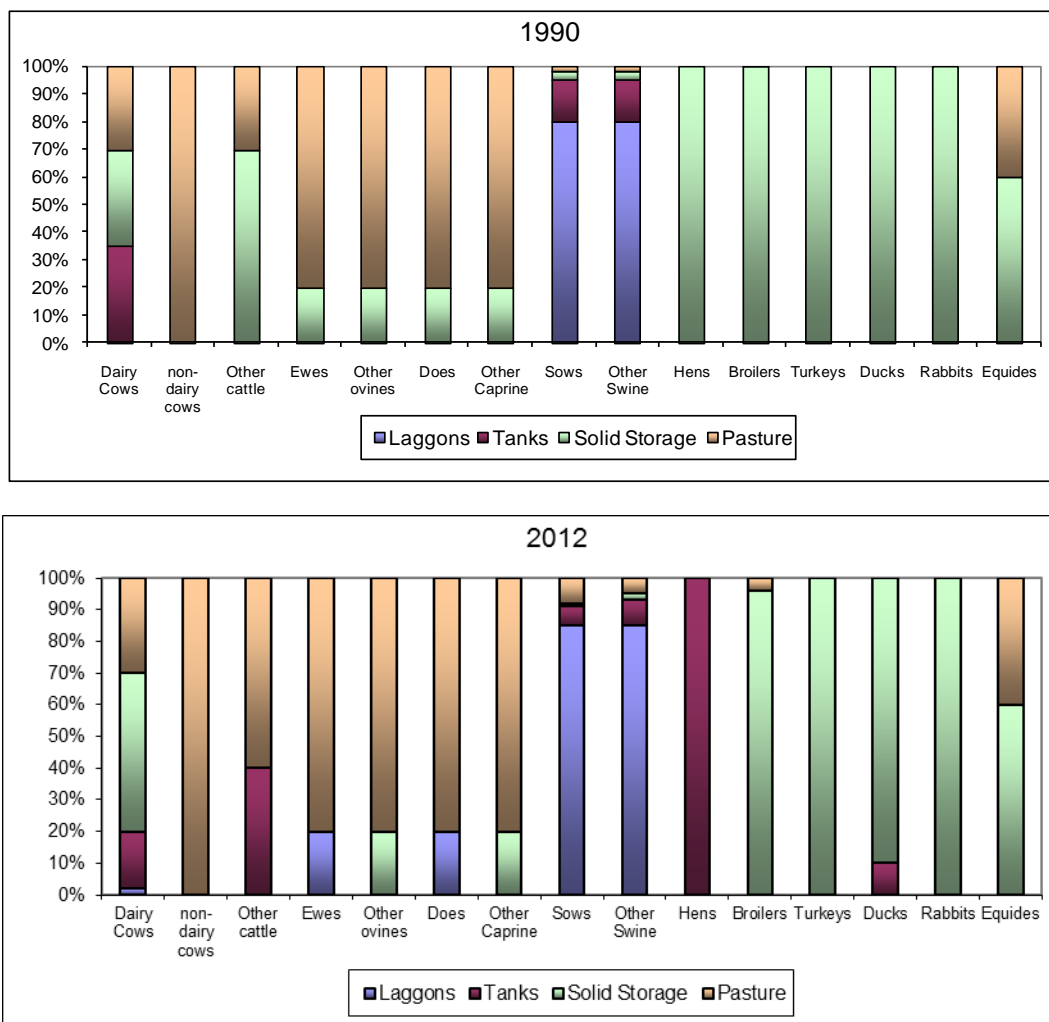
Animal Type	1990					2012				
	Laggons	Tanks	Solid Storage	Pasture	Total	Laggons	Tanks	Solid Storage	Pasture	Total
Dairy Cows	-	35.0	35.0	30.0	100.0	2.0	18.0	50.0	30.0	100.0
Non-dairy cows	-	-	-	100.0	100.0	-	-	-	100.0	100.0
Other cattle	-	-	70.0	30.0	100.0	-	40.0	-	60.0	100.0
Ewes	-	-	20.0	80.0	100.0	20.0	-	-	80.0	100.0
Other ovine	-	-	20.0	80.0	100.0	-	-	20.0	80.0	100.0
Does	-	-	20.0	80.0	100.0	20.0	-	-	80.0	100.0
Other caprine	-	-	20.0	80.0	100.0	-	-	20.0	80.0	100.0
Sows	80.0	15.0	3.0	2.0	100.0	85.0	6.0	1.0	8.0	100.0
Other Swine	80.0	15.0	3.0	2.0	100.0	85.0	8.0	2.0	5.0	100.0
Hens	-	-	100.0	-	100.0	-	100.0	-	-	100.0
Broilers	-	-	99.9	0.1	100.0	-	-	96.0	4.0	100.0
Turkeys	-	-	100.0	-	100.0	-	-	99.9	0.1	100.0
Ducks	-	-	100.0	-	100.0	-	10.0	90.0	-	100.0
Rabbits	-	-	100.0	-	100.0	-	-	100.0	-	100.0
Equides	-	-	60.0	40.0	100.0	-	-	60.0	40.0	100.0

Table 6-25 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type.

Animal Type	Laggon	Tanks	Solid Storage	Pasture
Dairy Cows	0.10	-0.85	0.75	-
non-dairy cows	-	-	-	-
Other cattle	-	2.000	-3.500	1.500
Ewes	1.000	-	-1.000	-
Other ovine	-	-	-	-
Does	1.000	-	-1.000	-
Other caprine	-	-	-	-
Sows	0.250	-0.450	-0.100	0.300
Other Swine	0.250	-0.350	-0.050	0.150
Hens	-	5.000	-5.000	-
Broilers	-	-	-0.195	0.195
Turkeys	-	-	-0.005	0.005
Ducks	-	0.500	-0.500	-
Rabbits	-	-	-	-
Equides	-	-	-	-

Note: values represent the annual increment in the per cent of MMS use. Positive values represent increment in the per cent of the MMS. Negative values represent decrease in use

Figure 6-16 - Percentage of manure handled by each Manure Management System, by animal type in 1990 and 1912 (equal to 2011)



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 unit<sup>107</sup> and for each animal sub-type. Within each *concelho* territorial area a homogenous distribution of animals was assumed;

<sup>107</sup> 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 km<sup>2</sup>. A nut III level territorial unit is defined as a set of *Concelhos*.

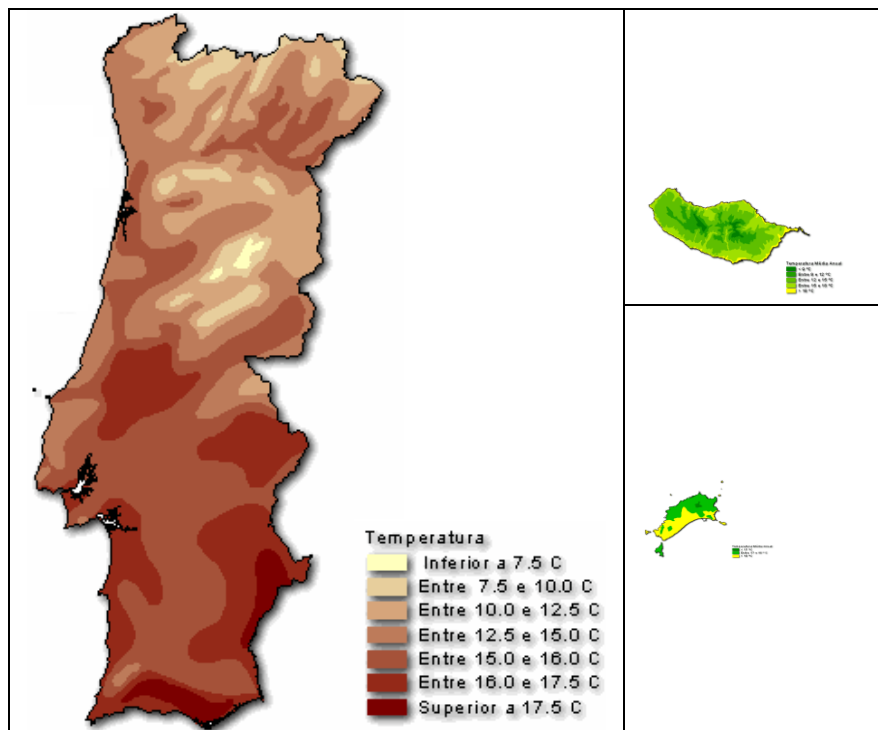
- for each *Concelho* territorial area in mainland Portugal and Madeira archipelago the percentage of land area above and below 15°C was determined using the annual average air temperature map, which is presented in Figure 6-17. All area in Azores islands were considered to be in temperate region;
- livestock numbers per animal type were available at *Concelho* level from two detailed agriculture surveys: RGA89 and RGA99<sup>108</sup>. Data for 1999 was available for all animal types and for 1989 only for dairy cattle, other cattle, ewes, other sheep, female goats and other goats, sows and other swine;
- livestock numbers in each *Concelho* area were allocated to each climate region, for year 1999, according to the land are percentage, and always assuming an homogeneous distribution of animals in the *Concelho* territorial area. Animal numbers were summed at each Administrative Region (Região)<sup>109</sup> for all *Concelhos*, and a per cent of animals in each Region was established, and assumed constant in the period;
- Livestock population in each climate region and by Region was estimated annually from total livestock population in Region and considering the constant share and, finally, the total national livestock population for each region was calculated.

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<sup>108</sup> Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

<sup>109</sup> Região in continental Portugal is equivalent to a NUT I level territorial unit. In Azores and Madeira, Região is equivalent to the whole autonomous region. There are 7 administrative regions in Portugal.

Figure 6-17 – 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 2011, obtained in accordance with the above explained procedure, is presented in Table 6-26.

Table 6-26 – Percentage of livestock population living in climate cool regions in Portugal in years 1990 and 2011.

Animal Type	1990	2012
Dairy Cows	48	38
Other Cattle	43	27
Sheep	29	34
Goats	50	48
Horses	34	41
Mules and Asses	58	73
Swine	22	15
Poultry	41	44
Other	65	65

Methane Conversion Factors are the default ones from IPCC Good Practice Guidance shown in Table 6-27:



Table 6-27 - Methane Conversion Factors (MCF), per cent, for determination of CH<sub>4</sub> emissions from Manure Management

MMS	Temperate	Cool
Laggon	45	39
Tanks <sup>1</sup>	0	0
Solid Storage	1.5	1
Pasture	1.5	1

(1) Combined storage of dung and urine below animal confinements (<1 month)

In the 2010 review an issue concerning the CH<sub>4</sub> IEF for swine was identified by the UNFCCC review team: the IEF for 2008 was considered much higher than the IPCC default for Western Europe. In Portugal the majority of manure from swine is treated in anaerobic lagoons (84.5 per cent) contrary to what IPCC considers as default (0 per cent). This MMS shows the highest CH<sub>4</sub> conversion factor among all management systems which explains the higher IEF for swine in Portugal.

Following the recommendation from the 2013 review we have included the table below with the time series<sup>110</sup> of estimated CH<sub>4</sub> EF (kg/hd/yr) from manure management of all sub classes of non dairy cattle and the default value (IPCC rev.1996, table 4-6) for comparison. The default EF (kg/hd/yr) values presented (1 for cool and 2 for temperate climatic regions) refer to systems where non-dairy manure is usually managed solid and deposited on pastures or range which corresponds to our country's characteristics.

Animal	Sub-class	1990	1995	2000	2005	2010	2011	2012	Average (1990-2012)	Default
Non-dairy cattle	Beef calves (<1 yr)	0.38	0.48	0.45	0.49	0.46	0.47	0.46	0.46	1 - 2
	Calves M.Rep. (<1 yr)	0.96	1.09	1.11	1.15	1.10	1.10	1.09	1.08	
	Calves F Rep. (<1 yr)	0.81	0.92	0.94	0.97	0.91	0.91	0.91	0.91	
	Males 1-2 yrs	1.89	1.92	1.72	1.57	1.25	1.25	1.24	1.66	
	Beef Fem. 1-2 yrs	1.37	1.39	1.26	1.13	0.88	0.89	0.89	1.20	
	Females rep. 1-2 yrs	1.31	1.36	1.22	1.09	0.87	0.87	0.86	1.16	
	Steers (>2 yrs)	1.95	2.12	1.96	1.78	1.42	1.43	1.42	1.84	
	Heifers Beef (>2 yrs)	1.45	1.41	1.28	1.10	0.90	0.92	0.93	1.20	
	Heifers rep. (>2 yrs)	1.44	1.45	1.29	1.16	0.94	0.94	0.93	1.23	
	non-dairy cows	2.08	2.42	2.44	2.52	2.38	2.39	2.37	2.37	

#### 6.3.2.4 Activity Data

In a consistent manner livestock numbers are the same that were used in previous sub-category: CH<sub>4</sub> from enteric fermentation. Although for this source category more species are considered in the emissions estimates, namely birds.

<sup>110</sup> Complete time series is given in annex

#### 6.3.2.5 *Uncertainty Assessment*

Livestock numbers are considered to be the activity data of this source category and the uncertainty values were equal to uncertainty values discussed for CH<sub>4</sub> emissions from Enteric Fermentation, as explained in the previous chapter.

No recommendations exist in the Good Practice Guidebook 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 CH<sub>4</sub> 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 patterns<sup>111</sup>. 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<sub>0</sub> 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

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<sup>111</sup> 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.

per cent in either direction, value that was assumed as representative of uncertainty for this factor.

The individual uncertainty values are presented in next table (using as base value 1990).

Table 6-28 – Uncertainty Values (in per cent) of the Emission Factors of CH<sub>4</sub> emissions from Manure Management

Specie	$\Sigma$ MMS*MCF	VS	Bo	Region	EF
Dairy Cows	43	20	22.9	30	61
Mother cows	62	20	20.6	30	74
Other cattle	42	20	20.6	30	59
Sheep	44	20	15.8	30	59
Goats	44	20	11.8	30	58
Swine	82	20	17.8	30	91
Poultry	54	20	12.5	30	66
Rabbits	54	20	12.5	30	66
Equines	48	20	10.6	30	61

#### 6.3.2.6 *Recalculations*

The only recalculation made for 4.B CH<sub>4</sub> emissions is related with the methodological improvement made for dairy cows CH<sub>4</sub> emissions 4.A, namely the use of a country specific DE (%) value instead of a default one.

#### 6.3.2.7 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

### 6.3.3 CH<sub>4</sub> Emissions from Rice Cultivation (CRF 4.C.)

#### 6.3.3.1 *Overview*

Methane production is enhanced in rice cultivation areas (rice paddies) due to the prevalence of anaerobic conditions which result from flooding and high levels of organic material in soil surface. The methane that is formed in soil underwater escapes to atmosphere as greenhouse gas emission, as visible bobbles or through transport inside plant stems.

#### 6.3.3.2 *Methodology*

Methane emissions from rice production were estimated following the equation 4.41 of GPG, but simplified because there are no appreciable differentiation in Portugal in what concerns water management regimes or any other conditions that are known to affect emissions from this source sector. Original formula was therefore simplified to:

$$E_{\text{RiceCH}_4(y)} = EF * \text{Rice}_{\text{Area}(y)} * 10^{-2}$$

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 ( $\text{g/m}^2/\text{yr}$ );

$\text{Rice}_{\text{Area}(y)}$  - Area under rice cultivation in year y (ha).

#### 6.3.3.3 *Emission Factors*

According to GPG formulation, the final value for the emission factor results from the multiplication of several factors:

$$EF = E_{fc} * SF_w * SF_o * SF_s$$

where

EF - Final emission factor, seasonally integrated and adjusted for management practices ( $\text{g/m}^2/\text{yr}$ );

$E_{fc}$  - Seasonally integrated emission factor for continuously flooded fields without organic amendments ( $\text{g/m}^2/\text{yr}$ );

$SF_w$  - Scaling factor for water management regime and ecosystem hydrologic conditions;

$SF_o$  - Scaling factor reflecting organic amendments (rice straw, manure, compost, wastes), because easily decomposable carbon increase methane formation;

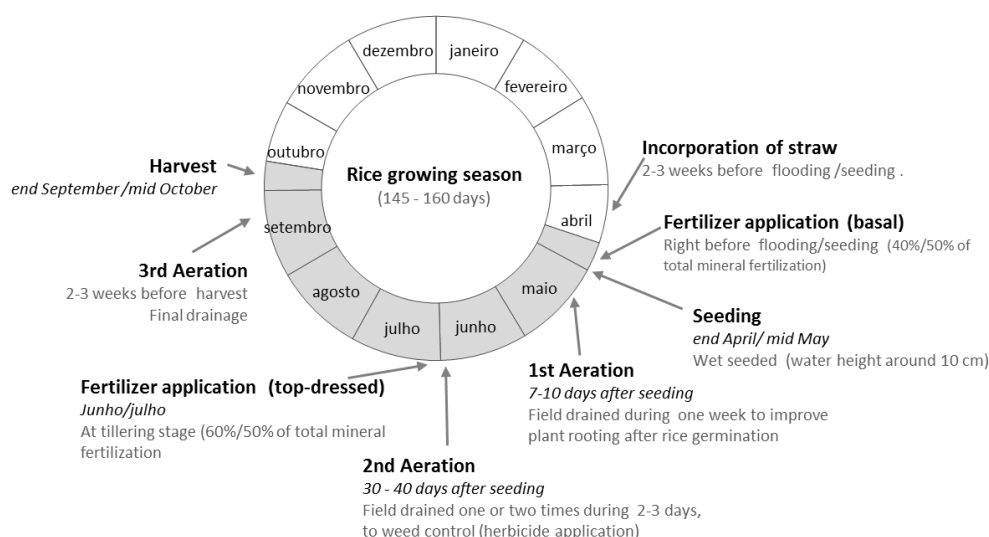
$SF_s$  - Scaling factor for soil type.

The default  $E_{fc}$  proposed in IPCC Good Practice Guidance 20  $\text{g/m}^2/\text{yr}$  is the most appropriate to use in Portugal <sup>112</sup> because a country specific  $E_{fc}$  sufficiently robust was not yet determined.

<sup>112</sup> José Pereira et al.(2013) – “Effects of elevated temperature and atmospheric carbon dioxide concentration on the emissions of methane and nitrous oxide from Portuguese flooded rice fields”. Atmospheric Environment 80, 464-471

Rice cultivation has a long time tradition in Portugal with homogeneous practices in all national territory. In Figure 6-18 are shown the main cultural practices usually done during the rice growing season. The culture is produced in a controlled flooding system with some aeration periods. The first aeration period occurs after rice germination to promote the rooting of the plants. Fields are drained for one week or more (7 to 10 days). The second aeration period (or periods, it could be more than one) is done for weed control and it last only 2 or 3 days. A third and final aeration takes place to create dry conditions for harvest. Water regime is controlled by human activity (water diversion, irrigation and dikes). All areas under rice cultivation are situated close to river banks almost at sea level (lowland). In accordance with IPCC (rev.1996) classification the water management regime for rice cultivation in Portugal is classified as intermittently flooded – single aeration (only one aeration period of more than 3 days, not including final aeration). Considering all the aspects described the value for parameter  $SF_w$  was set as 0.7 based on Table 4-20 of GPG.

Figure 6-18 – Rice cultivation relevant practices for EF estimation



Commonly the major fraction of rice stubbles and straw are burnt in the fields. Nevertheless the practice of incorporating straw into the soil often occurs too with special relevance on rice producing areas inside Natura 2000<sup>113</sup> limits. In these situations the practice of burning crop residues is forbidden<sup>114</sup> for reasons of Conservation of natural habitats and animal species since 2000 until nowadays.

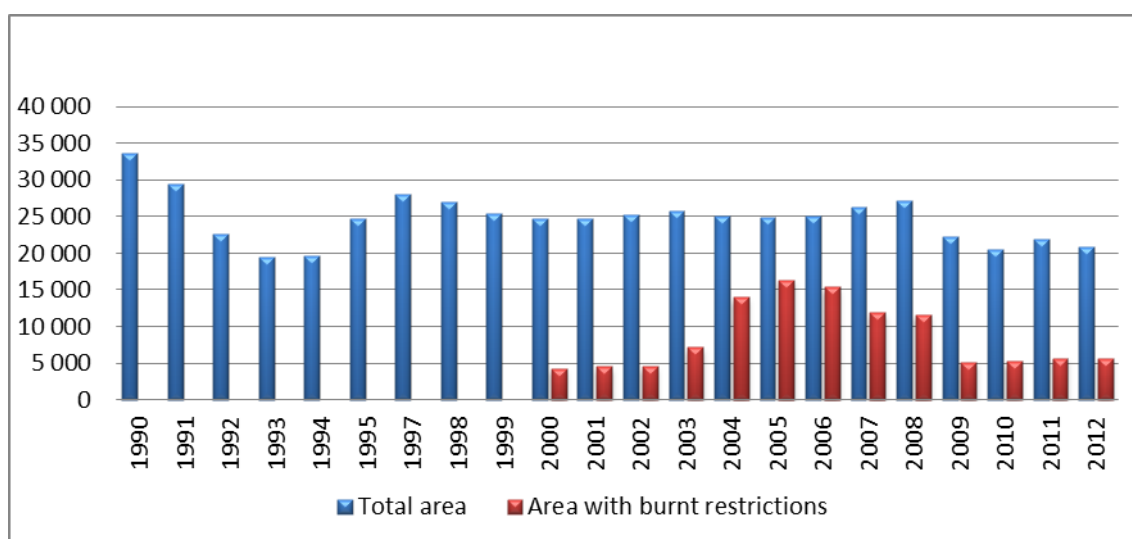
<sup>113</sup> Natura 2000 network includes Special Zones for Conservation (ZPC) established under Habitats Directive (92/43/ CEE) and Special Protection Zones (ZPE) established under Birds Directive (last revision 2009/147/CE). <http://www.icnf.pt/portal/naturaclas/rn2000>

<sup>114</sup> National Laws: DL 140/99 artº 11º (revised by DL 49/2005); RCM 177/2008 artº 21º; RCM 182/2008 artº 8º.

Outside the Natura 2000 network during the time period 2002-2008<sup>115</sup> all rice cultivation areas subjected to “Techniques of Integrated Production and Protection”<sup>116</sup> had the same burnt residues restrictions. Straw were left on ground and incorporated into soil by plowing before next crop season.

Figure 6-19 shows the evolution of rice cultivation areas where the practice of residues burnt is not allowed.

Figure 6-19 **Erro! A origem da referência não foi encontrada.**– Rice cultivation areas (ha) in Portugal



Source: Ministry of Agriculture, GPP 2013

Total quantities of residues per hectare were estimated from rice production and assuming a residue/crop ratio (1.4) and a dry matter content (85 per cent) (table 4.16 IPCC's GPG). Using this information S<sub>Fo</sub>, the scaling factor for organic amendments, was determined using the data in table 4.21 of the GPG. For time series period (1990-2012) the range of values used for S<sub>Fo</sub> were 1.50 - 2.50 corresponding to an amount of organic amendment applied of 2 ton dm/ha and 5 ton dm/ha respectively.

Finally, no information is available to establish the influence of soil type and S<sub>F</sub>s was also set to one.

<sup>115</sup> From 2009 onwards the limitation of residues burnt was removed (Circular / DSPFSV/ 08 from Directorate General of Agriculture and Rural Development -DGADR)

<sup>116</sup> “Modos de protecção e produção integrada” in the original in Portuguese.

Table 6-29 – Emission factor EF used to estimated CH<sub>4</sub> emissions from rice paddies in Portugal

	EF (g CH <sub>4</sub> /m <sup>2</sup> /day)
1990 - 1999	21
2000 - 2003	28
2004 - 2008	35
2009 - 2012	28

#### 6.3.3.4 Activity Data

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 6-19. It is noticeable the existence of significant variations in annual rice paddy areas, expressing annual variations in hydrological conditions. There is only one rice crop per year.

#### 6.3.3.5 Uncertainty Assessment

The uncertainty in the adjusted seasonally integrated emission factor was considered to be 40 per cent, according to the range proposed in table 4.22 of the GPG. For activity data, the standard deviation of inter-annual area under rice cultivation was considered: 34 per cent.

#### 6.3.3.6 Recalculations

The recalculations made for 4.C followed the 2013 review advice “to Portugal reevaluate the methodology of country specific EF estimation as it is out of IPCC range and the highest value among reporting Parties (69.13 g/m<sup>2</sup>)”.

Also in 2013 in the framework of a national research project<sup>117</sup> (José Pereira et al., 2013) a similar recommendation was suggested.

The methodology reevaluation was made in coordination with experts<sup>118</sup> from the Ministry of Agriculture GPP/Policies and Planning Office and INIAV/National Institute for Agriculture and Veterinary Research.

Comparing with previous submission (2013) the main differences introduced in this year submission are related to:

- EF<sub>c</sub> – use of default IPCC value 20 g/m<sup>2</sup>/yr as suggested by national studies. Previously the value used was determined by reference to Schutz (1989);

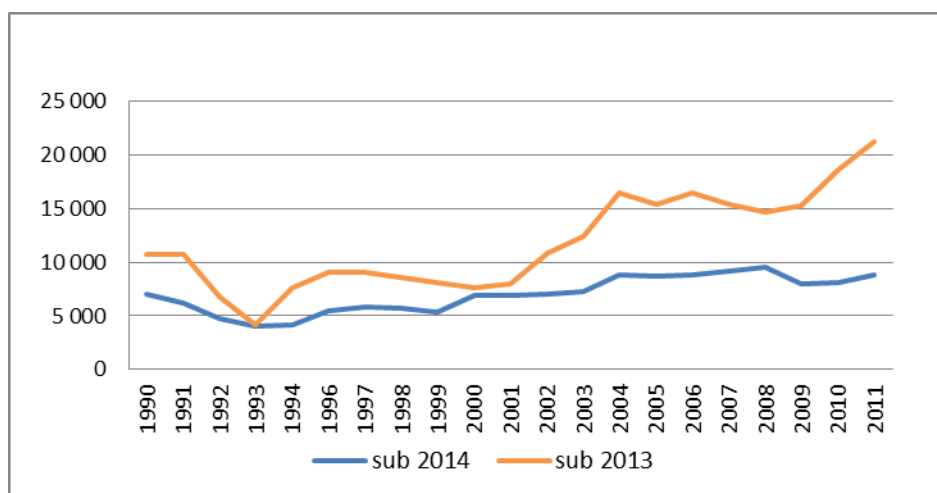
<sup>117</sup> José Pereira et al.(2013) – “Effects of elevated temperature and atmospheric carbon dioxide concentration on the emissions of methane and nitrous oxide from Portuguese flooded rice fields”. Atmospheric Environment 80, 464-471

<sup>118</sup> Eng<sup>o</sup> Adriano Carvalho, Eng<sup>a</sup> Patrícia Queirós, Eng<sup>a</sup> Teresa Avelar from GPP and Eng<sup>a</sup> Corina Carranca, co-author of the study above, from INIAV.

- SFw – use of a scaling factor value of 0.7 in accordance with water management practices in national rice fields and the intermittently flooded IPCC classification. Previously water regime management was incorrectly classified as continuous flooded;
- Revision of rice areas with residues burnt restrictions.

Recalculation results are reflected on the below figure.

Figure 6-20 – Rice cultivation CH<sub>4</sub> emissions estimation (t CH<sub>4</sub>/yr), differences between submission 2013 and this year submission



#### 6.3.3.7 Further Improvements

The establishing of a national integrated emission factor based on collection of data in Portugal would be welcomed but there are no current plans or studies to achieve that goal. The category is no longer identified as priority in the key categories assessment and will not be considered in the 2015 PDM.

### 6.3.4 N<sub>2</sub>O Emissions from Manure Management (CRF 4.B.)

#### 6.3.4.1 Overview

Part of the Nitrogen that is in manure, either in faeces or urine is emitted as N<sub>2</sub>O during management or during storage of manure, before application to soil, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen.

Emissions of N<sub>2</sub>O that occur after manure is deposited in soil, either as a way for disposal or as a fertilizer process, are reported in the category N<sub>2</sub>O from agricultural soils and are discussed later. Following the UNFCCC reporting guidelines, emissions of N<sub>2</sub>O from dung and urine that are deposited directly into soil during grazing, pasture and in paddocks, are also included in category N<sub>2</sub>O from agricultural soils.

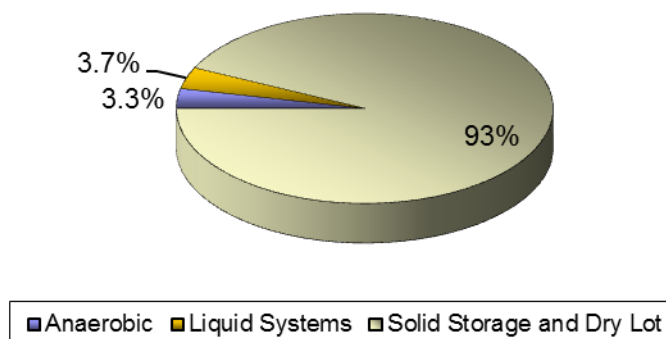
In a short description, this is a biological based process where emission of N<sub>2</sub>O from manure require the previous oxidation of organic nitrogen in ammonia form, which results from bacterial mineralization of organic nitrogen, into nitrites and nitrates (nitrification, a biological process 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 N<sub>2</sub> and nitrous oxide). Although there is no extensive information concerning the factors that affect this process it is believed that N<sub>2</sub>O emissions increase with aeration, at least to finalize the process, and hence increase under opposite conditions that determine methane emissions from solid storage or deposition during grazing and dry lot, which means that are lesser emissions in fully anaerobic systems like liquid systems and anaerobic lagoons.

In terms of the importance of each Manure Management System, observable in Figure 6-21, the great majority of emissions result from solid storage and dry-lot, totalizing on average in the 1990-2012 period 95.2 per cent of total N<sub>2</sub>O emissions from Manure Management. The rest comprehends 2.5 per cent of emissions from anaerobic lagoons and 2.3 per cent of total emissions from liquid systems. In terms of origin by animal type<sup>119</sup>, emissions are dominated by dairy cattle (47.6per cent), poultry (33.4 per cent<sup>120</sup>) which together comprehend about 81.0 per cent of total emissions, as may be seen in Figure 6-22 for the year 2012.

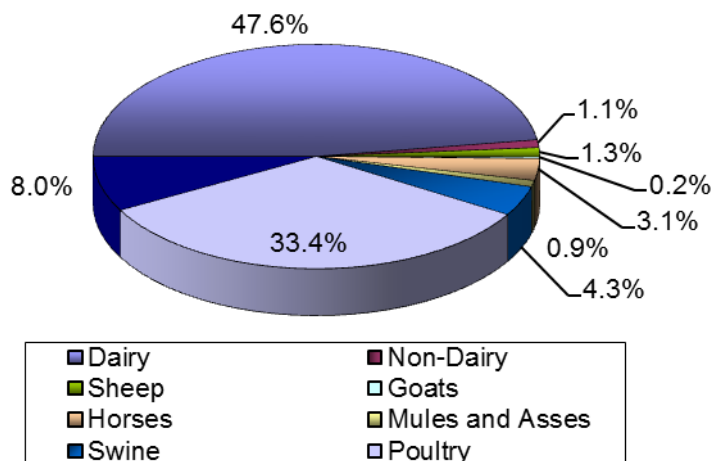
Figure 6-21 – Distribution of total N<sub>2</sub>O emissions from Manure Management per System in year 2012



<sup>119</sup> 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.

<sup>120</sup> According to the IPCC rule of thumb in figure 4.4 of IPCC (2000), although in strict terms sub-categories for this source category are management systems and not animal species.

Figure 6-22 – Distribution of total N<sub>2</sub>O emissions from Manure Management per animal species as origin of manure in year 2012



#### 6.3.4.2 Methodology

Emissions of N<sub>2</sub>O from manure for each Manure Management Systems were estimated from the following formula:

$$EN_{2O(s)} = 44/28 * \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)}$$

where,

$EN_{2O(s)}$  - N<sub>2</sub>O 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;

$EF3_{(s)}$  - N<sub>2</sub>O emission factor for Manure Management System s (kg N<sub>2</sub>O-N/kg N).

This formulation follows the one proposed in GPG (equation 4.18).

The following Manure Management Systems were considered for the calculation of total N<sub>2</sub>O emissions from manure management, in accordance with the expert information received from the Ministry of Agriculture (MAM). The

following table presents the original classes from the MAM and the correspondent classes in CRF table 4.B(b).

Table 6-30– Classification of Manure Management Systems in Portugal

MAMA	GPG Class (Table 4.12)	CRF classification
Water Treatment Plant: Anaerobic Lagoon	Anaerobic Lagoons	Anaerobic Lagoon
Tank	Liquid/slurry or Open pits below animal confinements	Liquid System
Solid Storage: Composting	Solid Storage	Solid Storage and Dry Lot

This same methodology was used to assess Direct N<sub>2</sub>O 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 (6.3.5) “Direct Nitrous Oxide Emissions from agricultural soils”.

Parameters  $N_{(i)}$ ,  $N_{ex(i)}$  and  $MS_{(i,s)}$  will be discussed under “activity data” and  $EF3_{(s)}$  will be discussed as “emission factor”.

#### 6.3.4.3 Emission Factors

N<sub>2</sub>O 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 IPCC rev 1996 emission factors (table 4-22 which were maintained in GPG table 4.12) because there are no country-specific emission factors.

Table 6-31 – N<sub>2</sub>O from Manure Management: Emission factors per Manure Management System

MMS	EF3 (kg N <sub>2</sub> O-N/kg N)
Water Treatment Plant: Anaerobic Lagoon	0.001
Liquid Systems: Tank, Open Pit	0.001
Solid Storage and drylot	0.020
Pasture Range and Paddock	0.020

#### 6.3.4.4 Activity Data

Livestock population numbers used to estimate total nitrogen excretion are the same that were also used to estimate emissions of CH<sub>4</sub> from Enteric Fermentation and CH<sub>4</sub> from Manure Management, and which were already presented in the chapter concerning CH<sub>4</sub> emissions from Enteric Fermentation.

The quantity of nitrogen excreted per head results from expert information provided by the Ministry of Agriculture<sup>121</sup>. 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 (CH<sub>4</sub> emissions from Enteric Fermentation and Manure Management).

The final Nex rates used in the inventory (Table 6-33) were established on the basis of the nitrogen excretion (Nex) rates proposed by the Revised Agriculture Good Practice Code (CBPA – Código de Boas Práticas Agrícolas), and are the same that are published in Annex XII of Portaria<sup>122</sup> n° 259/2012, 8<sup>th</sup> August.

This revision process was conducted in close coordination with the Ministry of Agriculture expert team including the INIAV experts. The following procedures were also considered on the analysis done:

- Compliance of the nitrogen excretion rates from CBPA with the detailed livestock information used in the inventory;
- Resort to expert guess when animal types are not covered in CBPA, by comparing with similar animal types reported in this document.

The following section presents the detailed methodology used for establishing the country/specific nitrogen ratios for dairy-cattle (which vary with milk production). For all other animal the nitrogen rates were determined following the methodology explained above.

#### 6.3.4.4.1 Dairy-Cattle

CBPA defines the nitrogen excretion rate of dairy-cattle as a function of milk production. The base nitrogen value for dairy-cattle is 115 kg N/hd/yr for 7000 kg milk produced/hd/year. For different milk production values the extrapolation procedures defined in CBPA are the following:

- The Nex decreases 10 per cent for every 1000 kg less of milk production;
- The Nex increases 2 per cent for every 1000 kg extra of milk production.

Milk production and Nex are presented in Table 6-32.

<sup>121</sup> Dr<sup>a</sup> Fátima Calouro, director of the Laboratório Químico Agrícola Rebelo da Silva in Lisbon. This laboratory was created in 1886. It performs research in the area of fertilizer use and improvement, as well as soil and plant analysis and fertilizer recommendations. Nowadays the Laboratory is integrated in National Institute for Agriculture and Veterinary Research (INIAV)

<sup>122</sup> Nacional law related with the implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources

Table 6-32 – Milk production values and corresponding Nex of dairy cattle

Year	Milk per Cow (kg/hd/yr)	Nex (kg/hd/yr)
1990	4 464	85.8
1991	4 440	85.6
1992	4 412	85.2
1993	4 111	81.8
1994	4 322	84.2
1995	4 556	86.9
1996	4 747	89.1
1997	4 813	89.8
1998	4 973	91.7
1999	5 718	100.3
2000	6 262	106.5
2001	6 502	109.3
2002	7 032	115.1
2003	6 768	112.3
2004	6 775	112.4
2005	7 233	115.5
2006	7 337	115.8
2007	7 311	115.7
2008	7 634	116.5
2009	7 826	116.9
2010	7 886	117.0
2011	7 929	117.1
2012	8 178	117.3

#### 6.3.4.4.2 Final Nitrogen Excretion - Nex

The following table presents the nitrogen excretion rates applied in the estimation of N<sub>2</sub>O from Manure Management and the IPCC defaults Nex. There is an acceptable agreement between country-specific values and IPCC defaults for all species other than ovines and caprines. For these two categories the nitrogen excretion rate appears to be low, when in comparison to IPCC default, but it has similarities to those used by other parties.

**Table 6-33 – N excretion rate per head and by animal species/category (Nex)**

Animal Class	Animal type	Nexc (kg N/hd/yr)	
		Inventory	IPCC Default
Dairy-cattle	Dairy Cows	117.3	100
non dairy cattle	Beef calves (<1 yr)	25.0	70
	Calfs, Males for Rep. (<1 yr)		
	Calfs, Females for Rep. (<1 yr)		
	Males 1-2 yrs	40.0	
	Beef Fem. 1-2 yrs		
	Females for R. 1-2 yrs		
	Steers (>2 yrs)	41.0	
	Heifers for Beef (>2 yrs)	55.0	
	Heifers for Rep. (>2 yrs)		
	non-dairy cows	80.0	
Swine	Piglets (<20 kg)	0.0	20
	Fat. Pigs (20-50 kg)	9.0	
	Fat Pigs (50-80 kg)	13.0	
	Fat Pigs (80-110 kg)		
	Fat Pigs (> 110 kg)		
	Boars (>50 kg)	18.0	
	Sows, pregnant	20.0	
	Sows, non-pregnant	42.0	
Ovine	Ewes	9.17	
	Other Ovines	6.6	
	Lambs	0.0	
Caprine	Does	7.0	25
	Other Caprines	6.6	
	kids	0.0	
Equides	Horses	44.0	
	Asses, Mules and hynies	22.0	
Poultry	Hens Reproductive	0.6	0.6
	Hens eggs	0.8	
	Broilers	0.45	
	Turkeys	0.48	
	Ducks, Geese and Guinea Fowl	0.48	
Other	Rabbits	9.0	25

Note: The Nex value for dairy-cattle associated with Sub 2014 represents the value for latest year reported in that submission (2012).

Values for piglet (<20kg), lambs and caprine kids, are 0 kg N/hd/yr because the Nex include these animal types with their respective mothers:

- Piglet (<20kg) – included in sows, pregnant and sows, non-pregnant;
- Lambs – included in other ovines;

- 
- Caprine kids – included in other caprines.

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to year 2012, is presented in the table below.

Table 6-34 – Total Nitrogen in Manure produced by livestock in Portugal (ton N/yr)

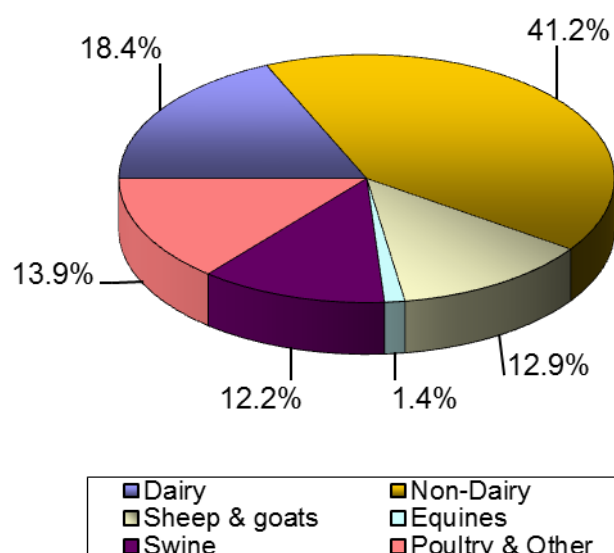
Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Dairy	33 830	33 177	32 457	31 305	32 147	33 262	33 803	34 031	34 364	36 929	37 566	36 101
Non-Dairy	43 438	44 308	43 599	43 602	43 888	45 511	47 217	48 392	49 477	50 316	51 394	52 693
Sheep	25 387	25 805	25 906	26 034	26 472	26 835	27 151	27 003	27 210	27 441	26 939	25 234
Goats	5 279	5 149	4 983	4 824	4 703	4 614	4 535	4 480	4 409	4 301	4 077	3 678
Horses	1 447	1 666	1 750	1 842	1 953	2 094	2 272	2 396	2 485	2 527	2 563	2 582
Mules and Asses	2 599	2 560	2 513	2 499	2 393	2 273	2 104	1 969	1 812	1 658	1 517	1 383
Swine	26 055	27 093	27 064	27 217	26 701	26 132	24 977	24 816	24 653	24 618	23 786	22 485
Poultry	17 095	17 286	17 569	17 864	17 821	17 407	17 071	17 157	18 218	19 757	20 805	20 874
Other	4 273	4 172	4 022	3 872	3 733	3 605	3 452	3 263	3 113	3 041	3 023	2 984
Total	159 402	161 217	159 865	159 058	159 810	161 734	162 583	163 509	165 740	170 588	171 671	168 014

Animal Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Dairy	35 821	33 341	33 064	33 462	32 914	31 817	31 284	30 779	29 840	28 890	28 230
Non-Dairy	53 869	55 201	56 592	58 318	59 523	60 536	61 211	61 741	62 388	62 835	63 410
Sheep	23 315	22 322	22 374	22 701	22 811	22 364	21 455	20 236	18 991	17 962	17 137
Goats	3 327	3 055	3 004	3 016	3 069	3 000	2 908	2 815	2 771	2 727	2 674
Horses	2 596	2 567	2 449	2 273	2 141	2 083	2 009	1 833	1 672	1 584	1 584
Mules and Asses	1 247	1 115	983	880	785	726	645	565	491	462	462
Swine	20 858	19 650	19 285	19 190	19 248	19 183	19 131	19 114	18 836	18 696	18 703
Poultry	20 013	19 113	18 149	17 112	16 203	15 445	15 740	16 938	18 340	19 039	19 053
Other	2 923	2 862	2 754	2 599	2 429	2 290	2 256	2 294	2 369	2 406	2 406
Total	163 969	159 225	158 654	159 552	159 123	157 443	156 640	156 314	155 697	154 600	153 660



The major contributors to total nitrogen from livestock in Portugal in 2012 were non-dairy cattle and dairy cattle, as may be seen in Figure 6-23.

Figure 6-23 – Origin of nitrogen in manure from livestock production in Portugal in 2012, 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 CH<sub>4</sub> emissions from Manure Management<sup>123</sup>.

According to the national share of MMS, it is larger the percentage of cattle in pasture range than according to what is suggested by the IPCC (IPCC,1996 revised) in table B-3 and B-4 (Appendix B in Reference Manual, pag. 4.43 / 4.44) , particularly for non - 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<sub>2</sub>O emissions from manure are larger than if the default MMS from IPCC was applied.

For pigs, the IPCC assumes most manure managed is in tanks while the national information considers Anaerobic Lagoons the most relevant MMS. However IPCC recommends a higher level of solid storage systems than the per cent that it was considered in the national inventory according to the experts of the Portuguese Ministry of Agriculture. There exist a small number of animals kept feeding by grazing in range.

For sheep and goats, there is a different percentage of animals in closed systems and in Pasture, but that does not affect significantly total N<sub>2</sub>O estimates - because EF<sub>3</sub> has equal default value for both MMS - although emissions are allocated to different emission categories.

<sup>123</sup> In the 1996 Revised IPCC Guidelines, however, there is no coherence between the default Manure Management System share proposed to estimate CH<sub>4</sub> from Manure Management (Table B-3/4/6, Apendix B, pgs 4.43/44/46) and that for N<sub>2</sub>O from Manure Management (table 4-21, pg 4.101).

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.

#### 6.3.4.5 *Uncertainty Assessment*

Uncertainty in activity data is the result of the combined uncertainties in livestock number, nitrogen excretion rates and the distribution by each manure management system. The values for uncertainty in livestock numbers are the same that were for sector CH<sub>4</sub> emissions from enteric fermentation. The uncertainty in N-excretion rate was set at 37.5 per cent, considering an intermediate situation between the uncertainty values recommended by GPG for default N-excretion rates (50 per cent) and the lower uncertainty when country-specific values are based on accurate national statistics (25 per cent). Uncertainty in MMS share was determined as the maximum difference in total excretion for each MMS considering the allocation per MMS used in previous submissions (Seixas et al, 1999) and the new revised share of MMS by the Ministry of Agriculture, and the values vary from about 1 per cent for anaerobic lagoons and liquid systems to around 10 per cent for solid systems and pasture. The overall uncertainty values range from 37.5 per cent to 39 per cent.

The uncertainty in N<sub>2</sub>O emission factors was set in accordance with the maximum values proposed in table 4.12 of the Good Practice Handbook (IPCC,2000), 100 per cent for all MMS.

#### 6.3.4.6 *Category-specific QA/QC and verification*

Since this year no major changes were made for this source category QA/QC procedures consisted only on the comparison between inventory Nex values and the corresponding IPCC default (Table 6-33).

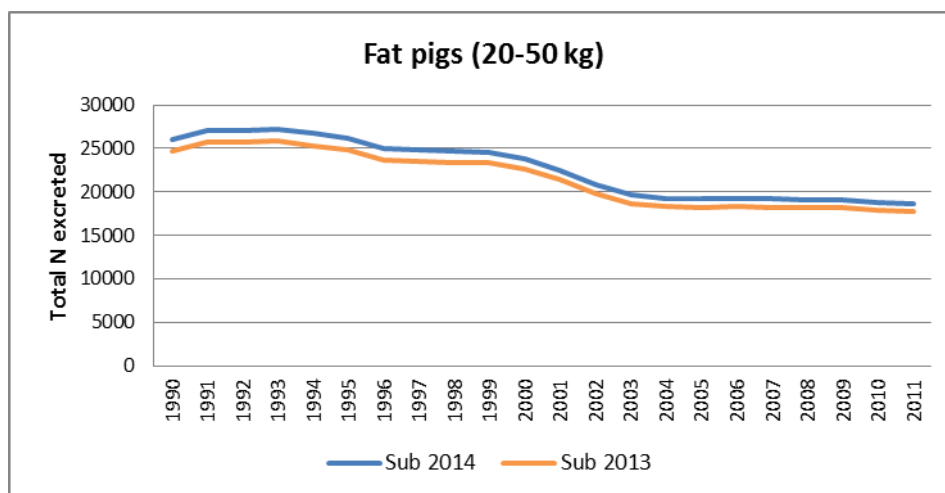
#### 6.3.4.7 *Recalculations*

The only recalculation made for 4.B N<sub>2</sub>O emissions concerns the reevaluation of Nex rate for swine subcategory Fat pigs (20-50 kg). Formerly it was 7.0 kg/hd/yr and now is 9.0 kg/hd/yr. This reevaluation was done in coordination with INIAV experts<sup>124</sup>. The rationale behind this change is:

- On the CBPA the N value presented for non-pregnant sows excretion is 42 kg/hd/yr. This excretion rate for mothers includes the breeding of 20 to 24 piglets until they have 25 to 30 kg. The N excretion value (42 kg/hd/yr) was estimated on basis of a feed diet with a gross protein content of 165 g/kg for sows non-pregnant and 175 g/kg for piglets until 30 kg weight;
- In conclusion, Nex for sows non-pregnant (42 kg/hd/yr) includes N excreted by piglets until 30 kgs weight;
- Therefore the subcategory “fat pigs (20-50 kg)” has a major percentage of animals that have a weight variation between 30 to 50 kg. In this case a Nex value of 9.0 kg/hd/yr is the adequate for this category (for fat pigs categories over 50 kg CBPA N value excretion is 13 kg/hd/yr).

<sup>124</sup> Dr<sup>a</sup> Fátima Calouro, National Institute for Agriculture and Veterinary Research.

Recalculation has been made for all the time series and the differences of total N excreted by swines sub category "Fat pigs (20-50kg)" between last year's submission and this year submission are shown in the next figure.



#### 6.3.4.8 Further Improvements

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

### 6.3.5 Direct N<sub>2</sub>O Emissions from Agricultural Soil (CRF 4.D)

#### 6.3.5.1 Overview

In agricultural soils, emission of N<sub>2</sub>O 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. N<sub>2</sub>O 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 N<sub>2</sub>O, there are no available sound estimate techniques and consequently these were not estimated in this inventory.

Direct emissions of N<sub>2</sub>O resulting from the increase of nitrogen added to cultivated soils due to agricultural activities includes the following sub-categories:

- application of synthetic fertilizers;

- application of animal manure;
- animal manure (droppings) deposited directly by animals on pasture, range and paddock;
- nitrogen fixation by N-fixing crops (leguminous plants);
- nitrogen input from incorporation of crop residues into soils;
- sewage sludge amendments.

Most effort was placed to make estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources:  $N_2O$ ,  $CH_4$  and  $NH_3$ .

$N_2O$  emission from the application of sewage sludge in agriculture soils was estimated for the first time in this submission in order to follow previous UNFCCC review' recommendations

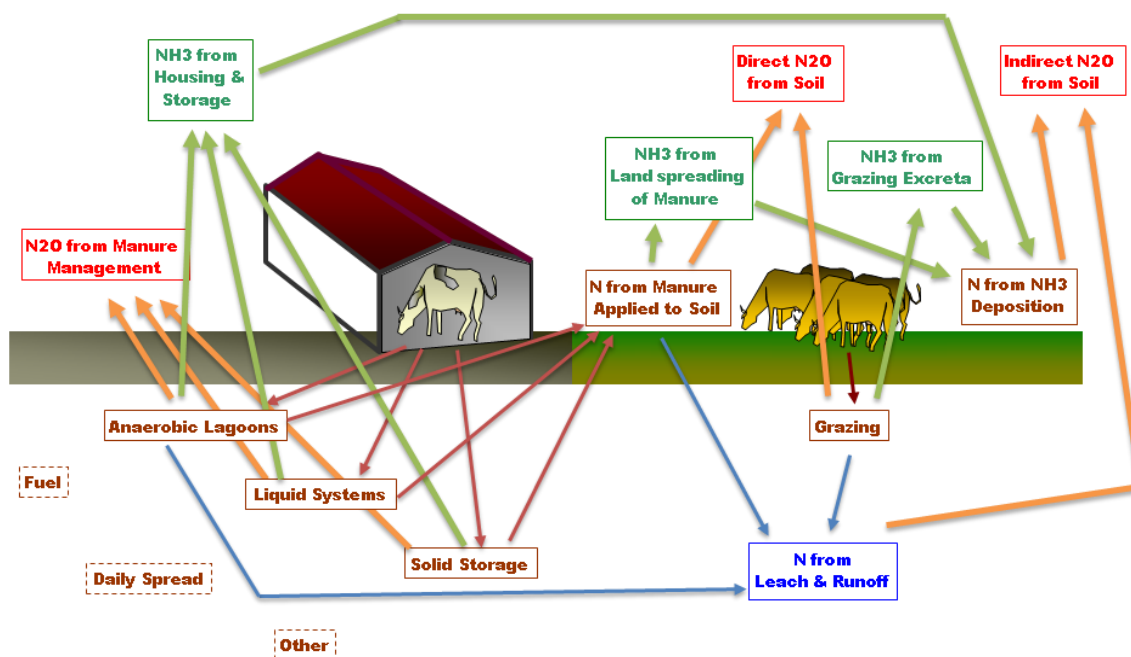
Considering climate conditions, and the long period since when soils have been subjected to agriculture in Portugal, histosols are not present in Portugal and  $N_2O$  emissions from histosols may be reported as not occurring. This is also supported by data available from the European Soil Data Centre (ESDAC, see <http://eusoils.jrc.ec.europa.eu/wrb/>) which show no presence of peat in Portugal. It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

The situation concerning  $N_2O$  emissions from manure is somehow complex because nitrogen originally in manure may give origin to  $N_2O$  emissions that are considered in different IPCC categories:

- emissions of  $N_2O$ , as well of ammonia, during the period that manure is stored in house or any Manure Managed System were already considered under source category  $N_2O$  emissions from Manure Management;
- emissions from nitrogen in manure added to soil as fertilizer is included in source category "direct  $N_2O$  from agricultural soils". In Portugal it was assumed that manure managed as liquid systems and solid storage is fully applied to agricultural soil as a fertilizer, irrespective of the animal species considered, whereas only a percentage of manure handled in anaerobic lagoons is placed in soil.

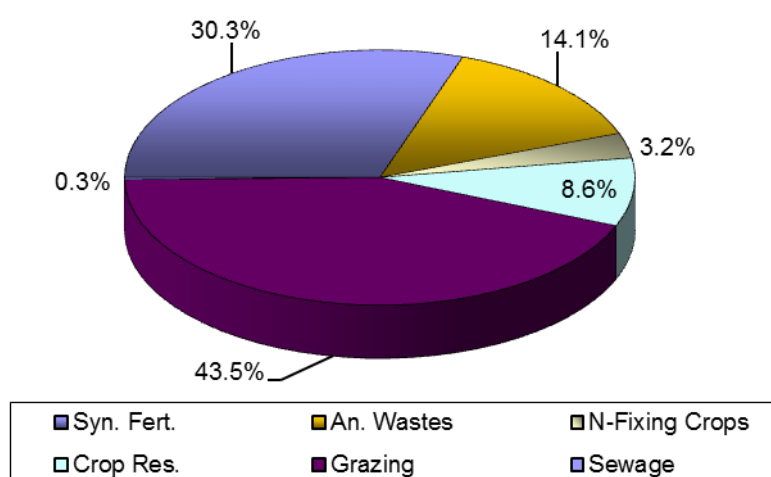
The following figure synthesizes the livestock system in what concerns nitrogen fluxes and direct and indirect  $N_2O$  emissions.

Figure 6-24 – Nitrogen fluxes from livestock system



The comparative importance of the several sub-source activities for 2012 is shown in Figure 6-25, from where it is evident the major contribution from direct deposition (Grazing 43.5 per cent) and synthetic fertilizers (Syn. Fert with 30.3 per cent) which may be considered significant sources in accordance with the IPCC rule of thumb. Manure used as fertilizer (An. Waste) is also an important source, responsible for 14.1 per cent of emissions.

Figure 6-25– Contribution of the various sub-sources to total  $N_2O$  emissions from direct agricultural soil emissions in 2012



### 6.3.5.2 Methodology

#### 6.3.5.2.1 N<sub>2</sub>O emissions from agricultural soils other than animal production

The approach used to estimate N<sub>2</sub>O emissions from agricultural soils other than animal production (emissions of N<sub>2</sub>O in Pasture Range and Paddock) may be better classified as Tier 1a, because the same emission factor was used to all nitrogen sources to soil<sup>125</sup>.

Final N<sub>2</sub>O emissions are estimated with a formulation derived from equation 4.20 of GPG:

$$EN_{2O_{Direct}} = 44/28 * (F_{SN} + F_{AM} + F_{BN} + F_{CR} + F_{SEW}) * EF_1$$

where:

EN<sub>2O<sub>Direct</sub></sub> - Annual emission of N<sub>2</sub>O

F<sub>SN</sub> - Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilizes as NH<sub>3</sub>

F<sub>AM</sub> - Annual amount of animal manure nitrogen intentionally applied to soils adjusted to account for the amount that volatilizes as NH<sub>3</sub>

F<sub>BN</sub> - Amount of nitrogen fixed by N-fixing crops cultivated annually

F<sub>CR</sub> - Amount of nitrogen in crop residues returned to soil annually

F<sub>SEW</sub> - Amount of nitrogen in sludge applied to agriculture soils adjusted to account for the amount that volatilizes as NH<sub>3</sub>

EF<sub>1</sub> - N<sub>2</sub>O emission factor from N input to soil (kg N<sub>2</sub>O-N/kg N input)

F<sub>SN</sub>, the annual amount of synthetic fertilizer nitrogen applied to soil after adjusting to account for the amount that volatilizes, is estimated from:

$$F_{SN} = N_{Fert} * (1 - \text{Frac}_{GASF})$$

where,

N<sub>Fert</sub> - total amount of nitrogen in synthetic fertilizers consumed annually

Frac<sub>GASF</sub> - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH<sub>3</sub> or NO<sub>x</sub>

The amount of nitrogen in animal manure that is used as fertilizer (F<sub>AM</sub>) was estimated from total nitrogen excreted from livestock that is applied to agricultural soils and after subtraction of nitrogen that was volatilized in housing, manure storage and after deposition in soil as fertilizer. The following equation applies:

$$F_{AM} = \sum_i \{ N_{(i)} * N_{ex(i)} * \sum_s [ MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)}) * (1 - EF_{NH3SD(i)}) ] \}$$

<sup>125</sup> However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

where

$F_{AM}$  - total amount of nitrogen in manure from Manure Management System that is applied to soil as fertilizer;

$N_{(i)}$  - Number (head) of individuals from livestock category  $i$  in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category  $i$ ;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  that is managed in Manure Management System  $s$ , except grazing;

$MSSD_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  treated in Manure Management System  $S$  that is used as fertilizer in agriculture soils;

$EF_{NH3(i,s)}$  - Fraction of nitrogen in Manure Management System  $s$  from livestock category  $i$  that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$  - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

This equation is equivalent to equation 4.23 of GPG if one considers that  $Frac_{GASM}$  equals the sum of  $EF_{NH3(i,s)}$  and  $EF_{NH3SD}$  and being aware that  $Frac_{PRP}$  is partly represented by parameter  $MSSD$ . To maintain consistency to the Good Practice methodology, and although emissions of  $N_2O$  from manure handled in Anaerobic Lagoons, Liquid Storage and Solid Storage were already accounted in  $N_2O$  emissions from Manure Management, the subtraction of the nitrogen that is lost that way is not made here.

Estimates of nitrogen fixed by crops follows exactly the Tier1b approach of the GPG (Equation 4.26) which means that crop-specific residue to product ratio and dry matter content are used:

$$F_{BN} = \sum_i \{Crop_{BF(i)} * (1 + Res_{BF}/Crop_{BF(i)}) * Frac_{DM(i)} * Frac_{NCRBF(i)}\}$$

where

$i$  - Crop type

$Crop_{BF(i)}$  - Crop production of nitrogen fixing crops (ton/yr)

$Res_{BF}/Crop_{BF(i)}$  - Residue to crop product mass ratio for nitrogen fixing crop  $i$  (ton/ton)

$Frac_{DM(i)}$  - Fraction of dry matter in the aboveground biomass of crop type  $i$

$Frac_{NCRBF(i)}$  - nitrogen fraction in crop dry biomass (ton/ton)

$F_{CR}$ , 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:

$$F_{CR} = \sum_i \{ [Crop_{(i)} * Res/Crop_{(i)} * Frac_{DM(i)} * Frac_{NCR(i)}] * [1 - Frac_{BURN(i)} - Frac_{FUEL(i)} - Frac_{CNST(i)} - Frac_{FOD(i)}] \}$$

where

i - Crop type

Crop<sub>(i)</sub> - Crop production (ton/yr)

Res/Crop<sub>(i)</sub> - Residue to crop product mass ratio for crop i (ton/ton)

Frac<sub>DM(i)</sub> - Fraction of dry matter in the aboveground biomass of crop type i (assumed to be equal to the fraction in the all plant)

Frac<sub>NCRBF(i)</sub> - nitrogen fraction in crop dry biomass (ton/ton)

Frac<sub>BURN(i)</sub> - fraction of crop residue burned in the field before and after harvest

Frac<sub>FUEL(i)</sub> - fraction of crop residue burned as fuel outside field

Frac<sub>CNST(i)</sub> - fraction of crop residue used for construction

Frac<sub>FOD(i)</sub> - fraction of crop residue used as animal fodder.

Finally F<sub>SEW</sub>, nitrogen in sludge applied to agriculture soils, is calculated deducting the amount of nitrogen that volatilises as NH<sub>3</sub> or NO<sub>x</sub>, as follows:

$$F_{SEW} = SS * NSSF * (1 - \text{Frac}_{GASM})$$

where

SS - quantity of sewage sludge spread on agricultural lands (ton/yr)

NSSF - nitrogen fraction of sewage sludge (percentage of dry solids)

Frac<sub>GASM</sub> – fraction of N volatilised as NH<sub>3</sub>-N.

#### 6.3.5.2.2 Emissions of N<sub>2</sub>O in Pasture Range and Paddock

Emissions of N<sub>2</sub>O 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 N<sub>2</sub>O from Manure Management. Emissions were therefore estimated with the following formula:

$$\text{Emi}_{N_2O} = 44/28 * F_{GR} * EF_3$$

where,

Emi<sub>N<sub>2</sub>O</sub> - N<sub>2</sub>O emissions from manure in Pasture, range and paddock;

EF<sub>3</sub> - N<sub>2</sub>O emission factor (kg N<sub>2</sub>O-N/kg N);

F<sub>GR</sub> - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture. This variable is determined from equation:

$$F_{GR} = \sum_i [N_{(i)} * N_{ex(i)} * MS_{GRAZ(i)}]$$

where:

i - Animal/species category of livestock;



$N_{(i)}$  - Number (head) of individuals from livestock category  $i$  in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category  $i$ ;

$MS_{GRAZ(i)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  that is managed in Pasture Range and Paddock.

In the determination of  $N_2O$  from Pasture Range and Paddock there is no need to account for the amount that volatilizes as  $NH_3$ .

#### 6.3.5.3 *Emission Factors*

$EF_1$ , the emission factor relating N input to soil with  $N_2O$  emissions, was set equal to the IPCC default value of 0.0125 kg  $N_2O$ -N/kg N input (table 4.17 of GPG and table 4.18 of IPCC rev 1996)<sup>126</sup>.

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 IPCC rev. 1996 emission factor (table 4-22) that is also maintained in GPG (table 4.12).

#### 6.3.5.4 *Activity Data*

The estimated quantities of nitrogen added to agricultural soils from each specific source, and that are activity data for determining direct  $N_2O$  emissions, are shown in Table 6-35 and the percent contribution of each one in year 2012 is also represented graphically in Figure 6-26

Total nitrogen added to soil was in 2012 about 17.4 per cent lower than what it was applied in 1990, although for the year 2002, application of nitrogen was 2.1 per cent higher than in base year. The variation in percentage of each specific source along the time serie is shown in figure below.

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<sup>126</sup> Which is the same as stating that 1.25% of nitrogen input to soil is emitted as  $N_2O$

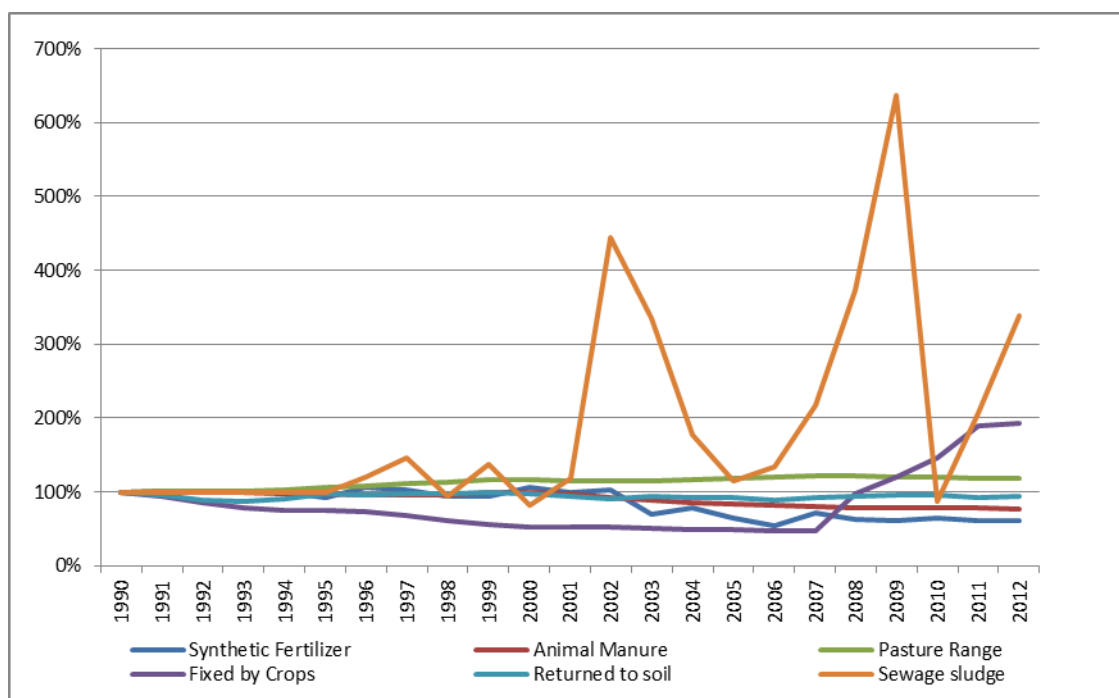


Table 6-35 - Total quantities of Nitrogen Added to Agricultural Soils: activity data for direct N<sub>2</sub>O emissions<sup>127</sup>

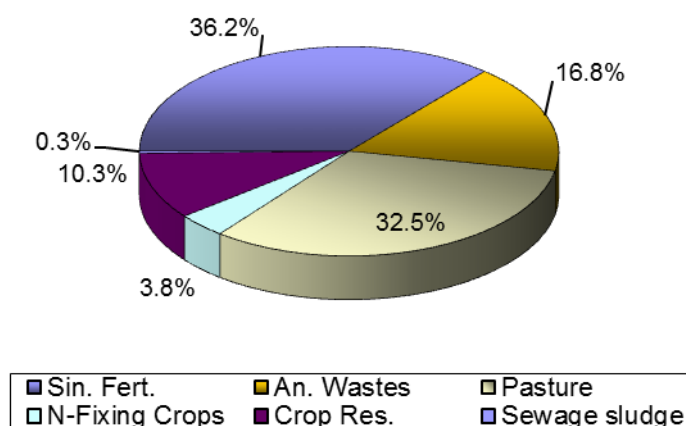
ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Synthetic Fertilizer	149 856	149 856	149 939	151 322	149 721	137 628	158 325	153 963	140 850	139 979	160 265	148 504
Animal Manure	55 696	56 077	55 526	54 971	54 690	54 469	53 691	53 231	53 541	55 361	55 596	53 849
Pasture Range	70 558	71 537	70 941	70 862	72 097	74 444	76 673	78 249	79 909	81 830	82 535	81 602
Fixed by Crops	5 032	4 701	4 272	3 906	3 740	3 780	3 667	3 411	3 043	2 838	2 668	2 640
Crop Residues	27 994	26 582	24 818	24 542	25 464	27 183	26 828	27 249	27 488	27 786	27 138	26 168
Sewage sludge	256	256	256	256	256	256	309	373	241	352	211	302
Total	309 392	309 008	305 751	305 859	305 967	297 759	319 492	316 476	305 072	308 146	328 412	313 065

ton N/yr	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Synthetic Fertilizer	154 529	103 834	118 648	96 793	82 393	106 543	94 485	91 730	96 895	92 707	92 707
Animal Manure	51 790	49 066	47 844	47 062	45 918	44 462	43 953	44 021	43 906	43 609	43 150
Pasture Range	80 864	80 434	81 756	83 817	85 092	85 596	85 453	84 830	84 244	83 561	83 303
Fixed by Crops	2 599	2 591	2 491	2 451	2 397	2 367	4 940	6 018	7 380	9 512	9 737
Crop Residues	25 360	26 418	25 614	25 709	24 845	25 660	26 311	26 735	26 663	25 901	26 437
Sewage sludge	1 136	857	454	293	343	555	953	1 628	223	530	866
Total	316 278	263 202	276 807	256 126	240 988	265 183	256 096	254 961	259 311	255 820	256 199

<sup>127</sup> 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 NH<sub>3</sub> subtraction because, for determining N<sub>2</sub>O from this category, there is no need to account for the amount that volatilizes as NH<sub>3</sub>. For crop residues and N fixated in crops, no ammonia volatilization is considered.

For the last year in the inventory there are two categories that represent the majority of nitrogen added to soil: Synthetic Fertilizers (36.2 per cent) and direct droppings during grazing in Pasture (32.5 per cent) as shown in figure below.

Figure 6-26 – Sources of direct input of Nitrogen to agricultural soil in 2012



#### 6.3.5.4.1 Synthetic Fertilizers

There are no available records of statistical information concerning the annual quantity of nitrogen used to agricultural soils or even available statistical information concerning sales of synthetic fertilizers. However, following the need to respond to other communitaire and international requests, such as the calculation of Agri-environmental Indicators “Nitrogen Balance” and “Fertilizer Consumption” for the EUROSTAT and OECD, the National Statistical Institute, in collaboration with the Laboratório Químico Agrícola Rebelo da Silva<sup>128</sup> and ADP<sup>129</sup>, 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 national production and international market information data:

$$ACFA = Prod + Imports - Exports$$

Where Prod is the annual quantity of nitrogen fertilizers produced (excluding consumption in industry), and is based on the IAPI census<sup>130</sup>. Data of Imports and Exports is also from INE..

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

<sup>128</sup> Laboratório Químico Agrícola Rebelo da Silva is a public laboratory, under the Ministry of Agriculture, and proceeds to soil, plant and fertilizer analysis. Presently integrated in the National Institute for Agriculture and Veterinary Research (INIAV).

<sup>129</sup> ADP, Adubos de Portugal, S.A., is the main producer of fertilizers in Portugal, and responsible for about 75% of fertilizer sales (INE,2004)

<sup>130</sup> Annual census made to the Manufacturing Industry, by INE.

significant influence in the outcome. Another important note is that fertilizers use determined by INE includes fertilizers for agriculture and forestry use.

Because of the limited time period requested by EUROSTAT and OECD 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).

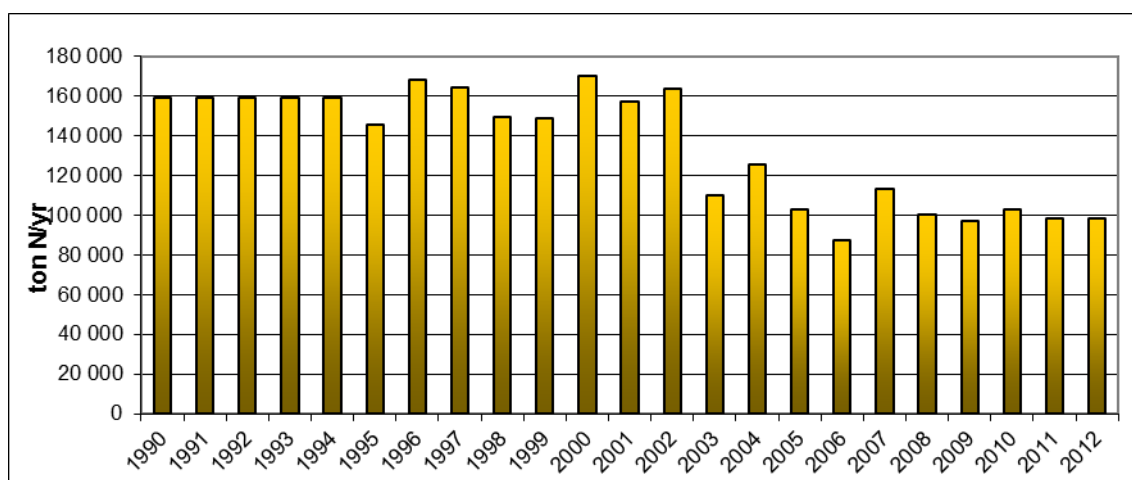
To overcome this limitation, and back-cast the time series to the base year, two regression curves between annual fertilizer use in 1995-2003 and estimated nitrogen fertilizer use considering annual crop production per crop and the rate of nitrogen application proposed by Ministry of Agriculture (2000). 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 Ministry of Agriculture (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 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).

It is also important to explain that INE most up to date information on apparent consumption of fertilizers only goes to the year n-1 (for this inventory exercise - 2011). This is due to time frame incompatibilities: IAPI data availability (begin of n+2) and the need of information for estimating emissions in the inventory (late n+1). Because of this the 2012 apparent consumption of fertilizers was made equal to 2011.

The available time series is presented in Figure6-27. It shows an increasing trend until 2002, being the value of that year 3.1 per cent higher than the value reported for 1990, with a sharp decrease for the next year. Since then there is a slight decrease trend with some yearly fluctuations

Figure6-27 - Use of Nitrogen Fertilizers (ton N/yr) in Portugal, estimated from INE data (1995-2012)  
- Using a simple average value for 1990-1994 and 2012 equal to 2011



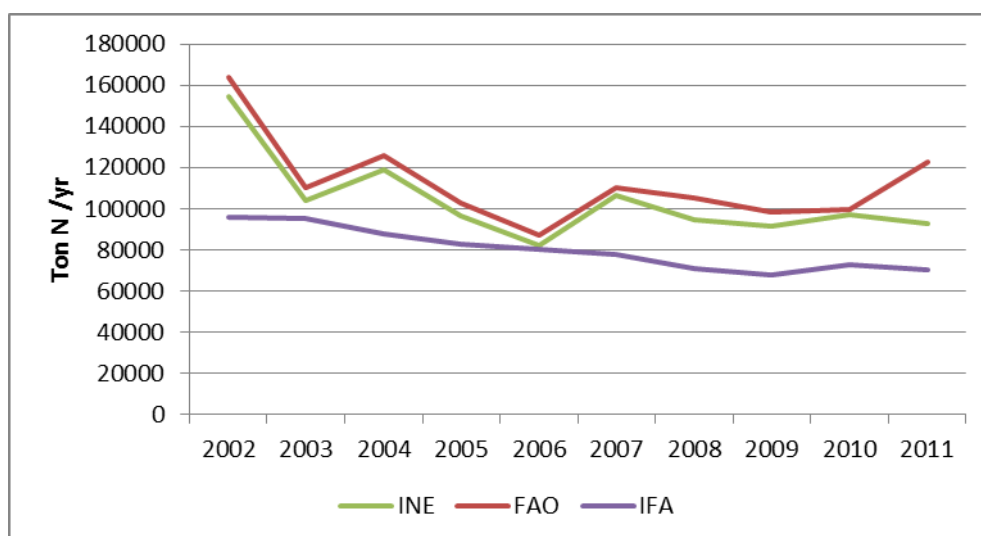
Losses of nitrogen from volatilisation of  $\text{NH}_3$  and  $\text{NO}_x$  were estimated using a time variable and country-specific fraction  $\text{Frac}_{\text{GASF}}$ , which varies between 0.053 and 0.064 kg  $\text{NH}_3\text{-N/kg N}$ , and

which are almost half the default value from table 4-19 of IPCC rev. 1996 (0.1 kg NH<sub>3</sub>-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<sub>3</sub> Emissions from Volatilization in Agriculture Soils (Chapter 6.3.8).

#### 6.3.5.4.1.1 Comparison to FAO and IFA<sup>131</sup> database

A comparison was made between inventory data produced by National Statistical Authority (INE) with FAO (<http://faostat3.fao.org/faostat-gateway/go/to/download/R/RF/E/>) and IFA (<http://www.fertilizer.org/ifa/ifadata/search>) databases for the period 2002 – 2011. For previous years (1990-2001) FAO database archive has remarks in all figures highlighting that they are unofficial. In both database, FAO and IFA, 2011 is the last year available. Comparison results are shown in Figure 6-28.

Figure 6-28 - Use of Nitrogen Fertilizers in Portugal. Comparison inventory (INE), FAO and IFA data (ton N/yr)



FAO and INE series agree quite well. The difference for 2011 is due to a recent INE update to the previous value that should then be transmitted by Eurostat to FAO, what apparently has not been done yet.

IFA data are lower than INE ones because IFA consumption statistics, follow the IFA definition “*relate, to the extent possible, to real consumption*” and not the apparent consumption concept. The restriction access to detailed information about the construction of IFA data set prevented a further understanding of these statistics, namely how “*real consumption*” values were produced. Until this issue is completely clarified we decided to keep INE statistics on apparent consumption to estimate emissions from synthetic fertilizers in a conservative approach.

Nevertheless we underline that both series trends show a decrease in fertilizer consumption.

<sup>131</sup> International Fertilizers Association

#### 6.3.5.4.2 Animal Manure

The quantity of nitrogen in manure that is applied to soil as fertilizer resulting in  $N_2O$  emissions was estimated from the same data that was used to estimate nitrogen excreted in  $N_2O$  from Manure Management and assuming that all the manure that is treated under Solid Storage or Liquid Systems is used as soil fertilizer, i.e.  $MSSD_{(i,s)}$  equals 1 only for Solid Storage and Liquid Systems. Concerning the other Manure Management System, Anaerobic Lagoons, 80 per cent of effluent is added to soil as fertilizer<sup>132</sup>, in accordance with a characterization study made in Portugal (Bicudo & Albuquerque, 1995; LNEC, 1996; GPPAA, 2001)<sup>133</sup>. As explained before, under  $CH_4$  and  $N_2O$  emissions from Manure Management, no other Manure Management Systems exist in Portugal. Quantities applied each year were also presented in Figure 6-26 above, where is shown that manure is the third major source of nitrogen applied to soil. Ammonia volatilisation factors,  $EF_{NH_3(i,s)}$  and  $EF_{NH_3SD}$ , are presented and discussed in more detail in chapter  $NH_3$  Emissions from Agriculture (Chapter 6.3.8) and they result from EMEP/UNECE Guidebook 3rd ed (table 3A in chapter B1050). These volatilization fractions depend only on animal class and not on the specific Manure Management System.

Table 6-36 – Emission factors used for calculation of  $NH_3$  volatilisation emissions from land spreading of manure as fertilizer

Animal Type	Losses after land spreading (kg $NH_3$ -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 Table6-37 and in detail in chapter 6.3.8.

<sup>132</sup> It is not clear if the nitrogen is disposed to soil as fertilizer or only as a final disposal site, and hence better classified as the last step of the treatment process rather than fertilization. For all purposes it was assumed that  $N_2O$  emissions would occur in soil according to similar processes, and included in this source category. The remaining 20% are rejected directly to the water system. GPPAA is now named as GPP, Gabinete de Planeamento e Políticas/Planning and Policies Office of Ministry of Agriculture

<sup>133</sup> According to the same studies the remaining 20% wastewater flow and nitrogen is rejected directly to water systems. This fraction is included in the determination of  $N_2O$  indirect emissions from agricultural soils.

Table6-37 – Emission factors used for calculation of  $\text{NH}_3$  volatilisation from animal droppings during grazing (Pasture Range and Paddock)

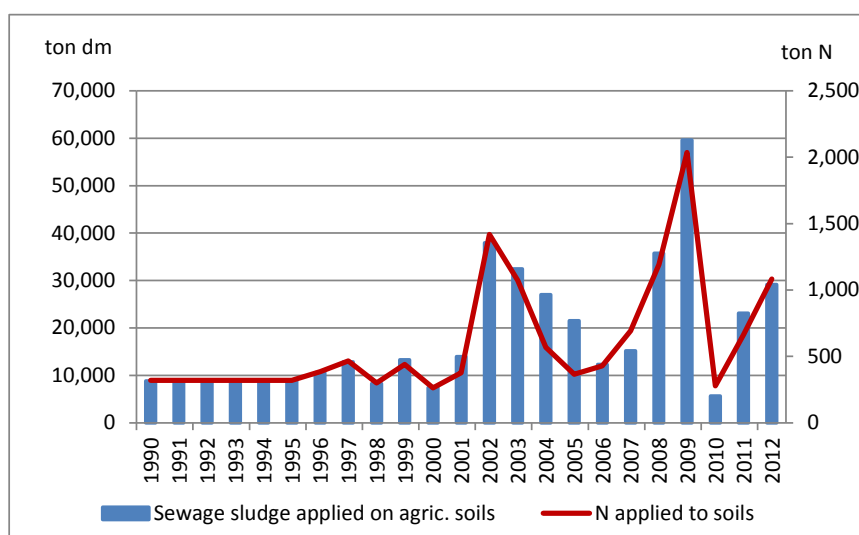
Animal Type	Grazing in Pasture
Dairy Cows	0.08
Other Cattle	0.08
Sheep	0.04
Goats	0.04
Swine	0.08
Equines	0.08

The use of emission factors of ammonia volatilisation from EMEP/UNECE results, therefore, in obtaining a value for  $\text{Frac}_{\text{GASM}}$  that is different and slightly higher than the default value for  $\text{Frac}_{\text{GASM}}$  ( $0.2 \text{ kg N-NH}_3 + \text{N-NO}_x / \text{kg of N excreted}$ , in table 4-19 of IPCC (rev 1996). The resultant implied  $\text{Frac}_{\text{GASM}}$  oscillates between 0.22 to  $0.23 \text{ kg N-NH}_3 + \text{N-NO}_x / \text{kg of N excreted}$ <sup>134</sup>.

#### 6.3.5.4.3 Sewage Sludge

The quantities of sewage sludge applied as soil amendment refer to data reported under the EU Directive 86/278/EEC on sewage sludge. Data for the latest years are considered to have a higher level of certainty and refer to data collected under Decree-Law n.º 276/2009 which establishes the use of sewage sludge on agricultural soils, transposing for the internal legal order the EU Directive no. 86/278/EEC, of 12 June. Data on the agriculture use of sludge under this legal provision is collected by the DRAPs (Regional Directorates for Agriculture and Fisheries), and are annually reported to the APA (Waste Department).

Figure 6-29 – Application of sewage sludge (ton dm/yr) and quantities of N (ton N) applied in agriculture soils



<sup>134</sup> The rates presented in previous tables are expressed in  $\text{kg N-NH}_3 + \text{N-NO}_x / \text{kg of N deposited in soil}$ .



The estimated quantities of N applied in soils from sewage sludge were calculated on the basis of the data on concentrations of Total N reported and deducting the amounts of NH<sub>3</sub>-N volatilised on the basis of the IPCC default for FracGASM (0.2).

Table 6-38 – Quantities of sewage sludge and nitrogen applied in agriculture soils

Direct	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Sewage Sludge applied	ton dm	8 800	8 800	8 800	8 800	8 800	8 800	10 626	12 852	8 283	13 309	7 435	13 971
N content	kg N /kg dm	0.0363	0.0363	0.0363	0.0363	0.0363	0.0363	0.0363	0.0363	0.0363	0.0330	0.0354	0.0270
Total N (before NH <sub>3</sub> vol.)	ton N	319	319	319	319	319	319	386	467	301	440	263	377
<b>Total N</b>	<b>ton N</b>	<b>256</b>	<b>256</b>	<b>256</b>	<b>256</b>	<b>256</b>	<b>256</b>	<b>309</b>	<b>373</b>	<b>241</b>	<b>352</b>	<b>211</b>	<b>302</b>

Direct	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Sewage Sludge applied	ton dm	37 952	32 479	27 006	21 533	12 282	15 154	35 739	59 609	5 647	23 088	29 172
N content	kg N /kg dm	0.0374	0.0330	0.0210	0.0170	0.0349	0.0458	0.0333	0.0341	0.0493	0.0287	0.0371
Total N (before NH <sub>3</sub> vol.)	ton N	1 419	1 072	567	366	429	693	1 191	2 035	278	663	1 082
<b>Total N</b>	<b>ton N</b>	<b>1 136</b>	<b>857</b>	<b>454</b>	<b>293</b>	<b>343</b>	<b>555</b>	<b>953</b>	<b>1 628</b>	<b>223</b>	<b>530</b>	<b>866</b>

Notes:

a) 1990-1994: data refer to 1995.

b) Data submitted until 2007 under Directive no. 86/278/EEC, was considered to refer to wet sludge.

Source: National reports submitted under Directive no. 86/278/EEC.

The calculation of direct N<sub>2</sub>O emissions was based on the IPCC EF default for direct soil emissions (0.0125 kg N<sub>2</sub>O-N/kg N).

#### 6.3.5.4.4 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.

The data series for crops that was considered in the inventory, at National level, is presented in Table 6-39 for leguminous crops and in Table 6-40 for non leguminous crops. For each year a three year average centred in the reporting year was used<sup>135</sup> from 1990 to 2008. From 2009 onwards due to the higher quality of statistics produced since late agriculture census the three year average was left and the annual data crops are used instead. It must be stressed that not only pulses and beans were included in nitrogen fixing crops but all leguminous crops, included a perennial: carob tree (*Ceratonia siliqua*) and sown biodiverse pastures rich in leguminous (SBPRL) since 2008. 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.

<sup>135</sup> For year n the value reported as production crop is the average of n-1, n and n+1.

Table 6-39 –Annual production of Leguminous Crops (metric tons) <sup>136</sup>

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Broad Beans <sup>(</sup>	47 486	45 402	45 285	45 182	44 766	45 050	42 776	40 417	37 390	37 533	36 902	37 108
Beans	31 243	27 426	21 926	17 071	13 553	12 679	11 722	10 756	8 926	7 426	6 106	5 802
Chick-Peas	3 563	3 081	2 583	2 101	1 937	1 899	1 815	1 810	1 478	1 196	965	1 009
Peas Green	5 867	5 867	5 433	5 533	5 867	6 533	7 210	7 417	7 390	6 947	6 974	7 000
Carobs	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green	25 000	25 000	25 000	25 000	32 200	37 433	40 308	33 461	26 844	21 002	18 107	16 679
SBPRL	-	-	-	-	-	-	-	-	-	-	-	-
Other leguminous	77	75	64	63	54	51	54	57	61	59	59	59
Total	133 236	126 850	120 292	114 950	118 377	123 646	123 886	113 917	102 088	94 164	89 113	87 657

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Broad Beans <sup>96</sup>	36 703	37 309	36 848	36 157	35 465	34 773	34 081	33 390	32 698	32 006	5 893
Beans	5 310	4 788	3 881	3 655	3 483	3 501	2 882	2 132	2 042	2 058	1 932
Chick-Peas	1 166	1 317	1 132	899	749	788	752	608	605	680	634
Peas Green	7 000	7 000	7 000	7 000	7 233	7 467	7 833	8 100	8 500	7 490	6 633
Carobs	20 000	20 000	20 000	20 667	20 667	20 667	20 500	21 500	19 4000	31 067	30 653
Beans	5 310	4 788	3 881	3 655	3 483	3 501	2 882	2 132	2 042	2 058	1 932
SBPRL	-	-	-	-	-	-	102 074	145 376	202 713	207 288	291 221
Other leguminous	59	59	59	59	61	62	64	65	64	65	31
Total	75 548	75 261	72 801	72 092	71 141	70 759	171 068	213 303	442 664	282 712	338 929

<sup>136</sup> For SBPRL unit is ton of dry matter. Source: "4. Relatório Final Agro 87.05" Ricardo Carvalho et al

Table 6-40 – Annual Production of non-leguminous Crops (metric tons)

Crop	1990	1995	2000	2005	2012
Wheat	510 519	409 404	286 821	207 992	58 990
Triticale	61 983	63 141	29 849	21 716	17 019
Maize	666 832	738 450	909 279	617 285	848 666
Barley	95 691	73 074	26 085	52 690	21 151
Rye	98 612	51 326	42 088	23 605	14 784
Oats	91 718	65 778	83 605	57 859	30 506
Rice Paddy	156 939	142 842	146 731	143 473	187 028
Sunflower	46 954	34 806	23 242	6 809	9 624
Tomatoes	714 563	877 383	937 512	1 089 729	1 394 417
Tobacco	5 072	5 283	5 895	4 135	122
Tea	170	62	120	121	95
Chicory	2 203	2 644	2 633	2 517	994
Potatoes	1 374 093	1 329 140	833 837	628 439	445 649
Sugar Beet	12 225	46 492	415 982	517 160	18 894
Yams	1 294	1 176	2 100	2 233	1 664
Sugar Cane	3 760	4 000	4 000	4 333	5 721
Sweet Potatoes	27 000	23 667	22 000	23 000	11 995
Maize for Forage	3 398 333	4 633 333	5 000 000	5 020 000	3 242 795
Sorghum for Forage	331 667	346 667	360 000	364 000	388 385
Other Forage	6 300 000	6 866 667	7 200 000	7 220 000	6 077 139
Pumpkins	4 200	9 700	12 000	12 000	46 449
Lettuce	32 000	56 367	66 190	62 014	54 974
Garlic	1 667	1 467	1 400	1 433	3 450
Eggplants	6 667	5 833	5 500	5 667	4 897
Onions	57 200	107 900	62 362	37 482	48 316
Carrots	82 667	128 133	90 898	58 892	100 827
Cauliflower	19 667	26 700	20 378	16 562	14 560
Cabbages <sup>(</sup>	166 667	150 000	209 110	173 956	200 647
Spinach	16 667	14 667	14 000	14 333	9 374
Fresh Fruit including orchards	1 050 252	954 751	1 020 283	1 013 487	876 405
Dry fruit orchards	77 033	53 751	53 496	45 441	30 823
Olives groves	324 038	278 693	246 411	298 137	395 023
Vineyards	1 388 333	1 091 580	1 013 520	1 006 690	839 534

Source: National Statistical Institute

The Nitrogen fixed by crops was estimated from the ratio of residue to crop product mass ( $\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$ ), the fraction of dry matter in product ( $\text{Frac}_{\text{DM}}$ ) and the fraction of dry biomass in the whole plant that is nitrogen ( $\text{Frac}_{\text{NCRBF}}$ ). These parameters were established for each leguminous plant using the default IPCC values (table 4.17 of IPCC 1996 Revised Guidelines which was later replaced by table 4.16 of Good Practice Guidebook when available, and from other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in Table 6-41

Table 6-41 – Parameters considered for determination of N fixed by nitrogen fixing plants

Crop	$\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$	$\text{Frac}_{\text{DM}}$ (%)	$\text{Frac}_{\text{NCRBF}}$ (%)
Broad Beans	1.5	35.0 - 86.5 <sup>1</sup>	2.02
Beans	2.1	85.5	2.62
Chick-Peas	1.5	85.0	2.62
Peas Green	1.5	87.0	1.42
Carobs	1.0	85.0	2.62
Beans Green	1.5	20.0	2.62

<sup>1</sup> Green – dry respectively

For sown biodiverse pastures rich in leguminous the value used for the amount of nitrogen fixed by crop (FBN) refer to a country specific parameter that is 0.026 kg N/ kg dm<sup>137</sup>

Nitrogen added to soil in crop residue was also estimated from  $\text{Res}/\text{Crop}$ ,  $\text{Frac}_{\text{DM}}$  and  $\text{Frac}_{\text{NCR}}$ . Values for estimation of nitrogen in residues from nitrogen fixing plants are the same that were used in the estimate of nitrogen fixed by crops (Table 6-41). The values for other non-leguminous crops were determined from IPCC defaults (IPCC rev 1996 and GP) and other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in next table.

<sup>137</sup> : "4. Relatório Final Agro 87.05" Ricardo Carvalho et al

Table 6-42 - Parameters for determination of N added to soil in crop residue from non-leguminous plants

<b>Crop</b>	<b>Res<sub>BF</sub>/Crop<sub>BF</sub></b>	<b>Frac<sub>DM</sub> (%)</b>	<b>Frac<sub>NCRO</sub> (%)</b>
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
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
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	1.00	15.0	1.50
Dry Fruits	1.00	85.0	1.50
Olive groves	1.00	15.0	1.50
Vineyards	1.00	15.0	1.50

In estimating the parameter FCR the following assumption was also made: - Frac<sub>FUEL</sub>, Frac<sub>CNST</sub> and Frac<sub>FOD</sub> were set to zero for all crops. Use of crop residues as combustible has negligible expression in Portugal and also there is no tradition of its use as a building material. Although some residues are used as animal feeding, particularly, as result of grazing in after harvesting cereal areas, it is not possible to estimate that fraction quantitatively. Using a conservative approach it was decided not to remove this part of nitrogen added to soil: this approach may result however in some doubling counting of nitrogen added to soil in this sub-category and in

nitrogen added to soil from animal production (Pasture Range and Paddock). In a consistent way,  $Frac_{BURN}$  is the same value used in estimate of GHG emissions from field burning of agriculture residues.

#### 6.3.5.5 *Uncertainty Assessment*

The Good Practice Guidebook presents no information concerning the uncertainty in activity data, and therefore, the values were set in the following mode:

- Synthetic Fertilizers: Apart from the time series of the total quantity of nitrogen applied in synthetic fertilizers from INE, that was considered as activity data for the period 1995-2000, other estimates are available or were made for the inventory for the same time period: PNAC studies (Seixas et al, 1999), FAO statistical database and the estimates of nitrogen necessity using the Good Practice Use of Fertilizers (MA, 2000). Comparing the values of nitrogen in synthetic fertilizers from these independent data sources between 1995 and 2000 a maximum uncertainty value of 17 per cent was obtained;
- For nitrogen in animal manure applied to soil and animal production the same uncertainty value that was used for activity data in  $N_2O$  from Manure Management was used and increased, in the case of animal manure applied to soil, by 100 per cent due to the uncertainty in the percentage of manure that ends up in soil;
- An uncertainty error of 25 per cent in crop production was considered in accordance with GPG considerations about overall error for the all source sector;
- Errors due to determination of nitrogen volatilization are difficult to access because of the interconnections with indirect emissions, and were quantified only in source category Indirect  $N_2O$  emissions from Agricultural Soils.

GPG presents a possible variation from one-fifth to 5 times the default emission factor of 1.25 per cent. From that range an uncertainty of 500 per cent was assumed in uncertainty analysis for nitrogen applied as synthetic fertilizers, manure, crop residues and nitrogen fixed by n-fixing crops. Considering that in the cases of nitrogen added to soil from n-fixing crops and crop residues, an additional 100 per cent uncertainty was added to take into account errors in the determination of nitrogen content of crops and residues from production. In the case of animal production a lower uncertainty of 100 per cent was used, following table 4.12 of the GPG.

#### 6.3.5.6 *Category-specific QA/QC and verification*

The QA/QC procedures applied in this source category comprehend a comparison between FAO and IFA data with INE values concerning the use of nitrogen fertilizers in Portugal. This procedure and the corresponding results are explained in the chapter Comparison to FAO and IFA database.

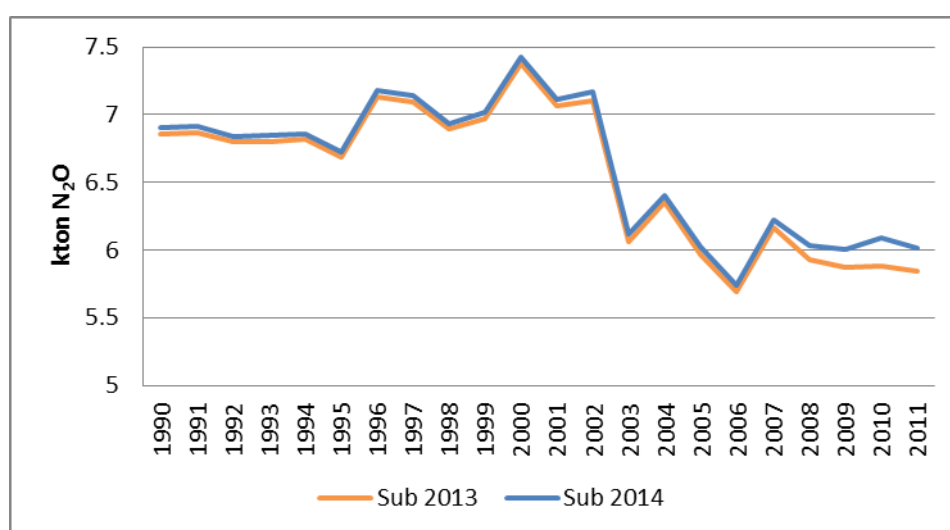
#### 6.3.5.7 *Recalculations*

There were several recalculations to this source category:

- Revision of the apparent consumption of synthetic fertilizers for 2009, 2010 and 2011 using updated INE data;
- Accounting of  $N_2O$  emissions from sewage sludge applied to agriculture soils for the first time in this sector (CRF 4D). Previously was reported in waste sector (CRF 6B);

- Accounting of N<sub>2</sub>O emissions from N fixed by Sown Biodiverse Pastures Rich in Leguminous (SBPRL) for the first time and in consistence with LULUCF and KP reported activity areas in grassland ;
- Recalculations related with the revisions done of Nex coefficient for swine subcategory Fat pigs (20-50 kg) explained in point 6.3.4.7;
- Recalculations related with the reevaluation of rice cultivation practices explained in point 6.3.3.6.

Differences in total direct N<sub>2</sub>O soil emissions, including during grazing, between submission 2013 and this year submission are graphically represented in figure below.



#### 6.3.5.8 Further Improvements

The share of each nitrogen fertilizer, particularly the importance of urea use, is still under consideration by INE and will be used to improve the preliminary estimate that was made by APA and that is temporarily being used in this year report.

Also additional efforts have to be made, together with our sectoral focal points, to revise the methodology for estimating the annual number of kids and lambs.

Data on the quantities of sewage sludge applied as a soil amendment should be checked and further analysed, in order to better understand and explain the significant variations in the available time series.

### 6.3.6 Indirect N<sub>2</sub>O Emissions from Agriculture (CRF 4.D)

#### 6.3.6.1 Overview

Emissions of N<sub>2</sub>O from agriculture are considered indirect emissions from agriculture when they result from nitrogen that was not emitted when was applied the first time into soil but that has first suffered a path through one of two environmental systems:

- the atmospheric system - after volatilisation as ammonia or nitrogen oxides and intermediate transformation in nitric acid and ammonium salts in particulate or aerosol form
- the soil-water system - after leaching and/or runoff as ammonia, nitrite, nitrate or light organic compounds.

Actually  $N_2O$  indirect emissions result from the same microbial process associated to nitrification and denitrification that causes direct emissions. The only difference results from the fact that direct emissions occur solely in agricultural soils whether indirect emissions will occur in whenever conditions are adequate: in agricultural soils, non agricultural soils and even aquatic, Benthic and wetland systems.

Also, all  $NO_x$  and  $NH_3$  emissions from other emissions sources may settle in soil and water and result in similar  $N_2O$  emissions. However, estimates of indirect emissions from these sources are not included in the Portuguese inventory.

Indirect emissions of  $N_2O$  from ammonia and  $NO_x$  volatilisation were estimated from ammonia volatilised whether actual indirect  $N_2O$  emissions occurred in the Portuguese territory or not. In the case of  $N_2O$  indirect emissions from leaching and runoff the geographical characteristics of the territory - where there are no water basins discharging to other countries - cause that all indirect emissions will occur still on the national territory or nearby ocean waters<sup>138</sup>.

Even though this nitrogen flow is evident in Figure 6-24, it's important to stress the fact that indirect emissions of  $N_2O$  from volatilization result from 2 volatilization processes: the first as direct  $NH_3/NO_x$  emission and the second as  $N_2O$  indirect emission. Between these two processes occurs deposition of nitrogen from  $NH_3/NO_x$  direct emissions.

Figure 6-30 shows the percent importance of each sub-source for year 2012, where:

- Syn. Fert. Vol. – Synthetic Fertilizers N volatilization;
- Syn. Fert. Leach - Synthetic Fertilizers N resulting from leaching and runoff;
- An. Was. Vol. – Volatilization of N from Animal Waste (manure) applied to soil as fertilizer;
- An. Was. Leach. - Leaching and runoff of N from Animal Waste (manure) applied to soil as fertilizer
- Graz. Vol. – N volatilization from droppings during Grazing;
- Graz. Leach. – N leached from droppings during Grazing;
- MM. Vol. – Volatilizations of N from Manure Management Systems;
- MM. Leach. – Leaching and runoff of N from Manure Management Systems;
- Sew. Vol. – Volatilization of N from Sewage Sludge applied in soils (minor category);

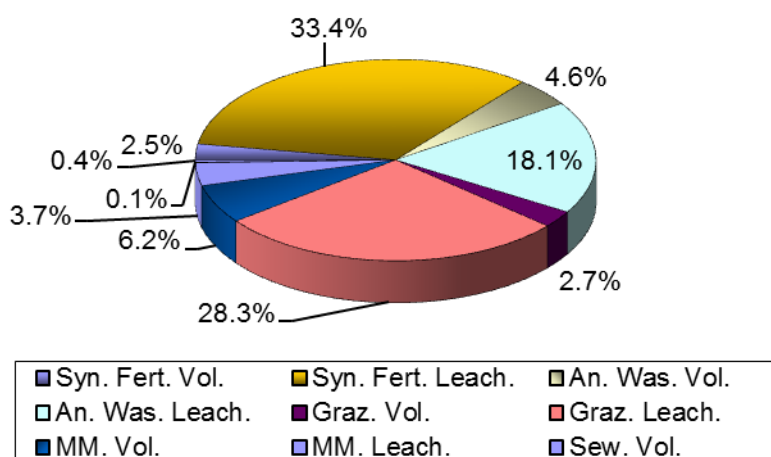
<sup>138</sup> In fact, part of indirect  $N_2O$  emissions from leaching and runoff from agriculture activities in Spain will occur most probably in Portuguese territory. These emissions are not included however in the Portuguese inventory.



- Sew. Leach. – Leaching and runoff of N from Sewage Sludge applied in soils (minor category).

Indirect emissions from runoff and leaching from synthetic fertilizers, animal manure applied to soil and direct droppings during grazing are significant sources of N<sub>2</sub>O indirect emission in this source category.

Figure 6-30 – Relative importance of Indirect emissions of N<sub>2</sub>O from agriculture in year 2012



#### 6.3.6.2 Methodology

Different methodologies were used to estimate Indirect emissions from Agriculture. These methodologies are explained in the following chapters.

##### 6.3.6.2.1 Volatilization

N<sub>2</sub>O<sub>(G)</sub>, Indirect N<sub>2</sub>O emissions from atmospheric deposition of nitrogen that has volatilised as NO<sub>x</sub> and ammonia from nitrogen used in agriculture as an external input<sup>139</sup>, either synthetic or in animal manure. The following equation, that is similar to GPG Tier1a equation, was utilized for N<sub>2</sub>O emissions from volatilisation:

$$N_2O_{(G)} = 44/28 * (SF\_NVol + MMS\_NVol + AM\_NVol + GR\_NVol + SEW\_NVol) * EF_4$$

where

SF\_NVol - Total volatilisation, as ammonia or nitrogen oxides, of the nitrogen from synthetic fertilizers applied to soil (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

MMS\_NVol - Volatilisation of nitrogen from manure in Manure Management Systems (emissions in housing and outside storage) (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

AM\_NVol - Volatilisation of nitrogen from manure applied to soil as fertilizer (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

<sup>139</sup> No indirect N<sub>2</sub>O emissions are estimated from nitrogen leached or removed in runoff from nitrogen fixation by leguminous plants or from nitrogen in crop residues.

GR\_NVol - Volatilisation of nitrogen from animal excreta deposited in soil during grazing in pasture range and paddock (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

SEW\_NVol - Volatilisation of nitrogen from sewage sludge applied on soil (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

EF<sub>4</sub> - Emission factor for N<sub>2</sub>O emissions from atmospheric deposition of nitrogen on soil and water surfaces (kg N<sub>2</sub>O-N/kg NH<sub>3</sub>-N+kg NO<sub>x</sub>-N).

Methodologies for the estimation of ammonia from synthetic fertilizers, manure and animal excreta are explained in chapter NH<sub>3</sub> Emissions from agriculture (6.2.8). It was assumed that volatilisation emissions occur predominantly in ammonia form.

#### 6.3.6.2.2 Leaching and Run-off

Indirect N<sub>2</sub>O 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):

$$N_2O_{(L)} = 44/28 * (N_{Fert} + N_{AM} + N_{GR} + N_{SEW}) * Frac_{LEACH} * EF_5$$

where,

N<sub>Fert</sub> - Annual amount of synthetic fertilizer nitrogen applied to soils (ton N/yr);

N<sub>AM</sub> - Annual amount of animal manure nitrogen intentionally applied to soils (ton N/yr), calculated from:

$$N_{AM} = \sum_i \{ N_{(i)} * Nex_{(i)} * \sum_s [ MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)}) ] \}$$

N<sub>(i)</sub> - Number (head) of individuals from livestock category i in the country;

Nex<sub>(i)</sub> - Annual country average N excretion per head of animal species/category i;

MS<sub>(i,s)</sub> - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

MSSD<sub>(i,s)</sub> - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

EF<sub>NH3(i,s)</sub> - 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<sub>GR</sub> - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture;

N<sub>SEW</sub> - Total annual nitrogen input from sewage sludge applied as soil amendment;

Frac<sub>LEACH</sub> - Fraction of N input that is lost through leaching and runoff

EF<sub>5</sub> - Emission factor for leaching/runoff (Kg N<sub>2</sub>O-N / kg NH<sub>3</sub>-N + NO<sub>x</sub>-N)

Until submission 2007, 80 per cent of the effluent from anaerobic lagoons is used as soil fertilizer whereas the remaining 20 per cent is discharged to the water system. However, during the 2006 inventory review under the UNFCCC and the NIR 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 N<sub>2</sub>O emissions in agriculture, in order to achieve consistency with the GPG.

In the 1996 Revised IPCC Guidelines and the Good Practice Guidance, there is no clear recommendation preventing the removal of direct discharge to water. However, the GPG 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 N<sub>2</sub>O emissions from Leaching and run-off should be estimated from total nitrogen production after removal of fuel, feed and construction, and then the application of the leaching factor.

The 2006 guidelines, used here only as an indicative reference, refer the possibility of subtraction of the fraction of nitrogen in manure that goes directly to the water system, although these guidelines are referring to the specific case of dry lots, where run-off and leaching could contribute directly to the water system without passage by soil. In chapter 10 (N<sub>2</sub>O from Manure Management) emissions from Leaching and Runoff from Manure Management could be estimated according to Equations 10.28 and 10.29, and using the default EF from Leaching and Run-off from agricultural soils.

**EQUATION 10.28**  
**N LOSSES DUE TO LEACHING FROM MANURE MANAGEMENT SYSTEMS**

$$N_{\text{leaching-MMS}} = \sum_S \left[ \sum_T \left[ \left( N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)} \right) \cdot \left( \frac{\text{Frac}_{\text{leachMS}}}{100} \right)_{(T,S)} \right] \right]$$

**EQUATION 10.29**  
**INDIRECT N<sub>2</sub>O EMISSIONS DUE TO LEACHING FROM MANURE MANAGEMENT**

$$N_2O_{L(mm)} = (N_{\text{leaching-MMS}} \cdot EF_5) \cdot \frac{44}{28}$$

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 N<sub>2</sub>O emissions).

**EQUATION 10.34**  
**MANAGED MANURE N AVAILABLE FOR APPLICATION TO MANAGED SOILS, FEED, FUEL OR CONSTRUCTION USES**

$$N_{\text{MMS\_Avb}} = \sum_S \left\{ \sum_T \left[ \left[ \left( N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)} \right) \cdot \left( 1 - \frac{\text{Frac}_{\text{LeachMS}}}{100} \right) \right] + \left[ N_{(T)} \cdot MS_{(T,S)} \cdot N_{\text{beddingMS}} \right] \right] \right\}$$

The procedure that could be more akin to what is happening in reality is the estimate of emissions of N<sub>2</sub>O 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- $N_2O$ /kg N-leached, applied to the quantity of nitrogen discharged<sup>140</sup>. In general terms the emissions of  $N_2O$  from nitrogen discharged directly from Manure Management Systems  $N_2O\_MM_{(L)}$  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 system<sup>141</sup>;

$EF_5$  – Emission factor for leaching/runoff (kg  $N_2O$ -N / kg  $NH_3$ -N +  $NO_x$ -N)

#### 6.3.6.3 Emission Factors

Default IPCC emission factors were used for  $EF_4$  and  $EF_5$  (table 4-23 of the 1996 IPCC and table 4.18 of the GPG):

Table 6-43 – Emission factors for  $N_2O$  indirect emissions from agricultural soil

Emission Factor	kg $N_2O$ -N / 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 ( $EF_4$ ). According to GPG the default value for  $EF_5$  will be probably revised in the near future.

#### 6.3.6.4 Activity Data

Emissions of  $N_2O$  from atmospheric deposition of nitrogen compounds that were volatilised consider 5 components:  $SF\_NVol$  (Synthetic Fertilizers);  $MMS\_NVol$  (Manure Management

<sup>140</sup> Total contribution, not assuming volatilization or leaching rates.

<sup>141</sup> MSSW in the case of Anaerobic Lagoons is equal to 1-MSSD.

Systems); AM\_NVol (Animal Manure applied as fertilizers), GR\_NVol (Grazing), and SEW\_NVol (Sewage Sludge), that are presented in Table 6-44 and each contribution of sub-sources in year 2012 is presented in Figure 6-31

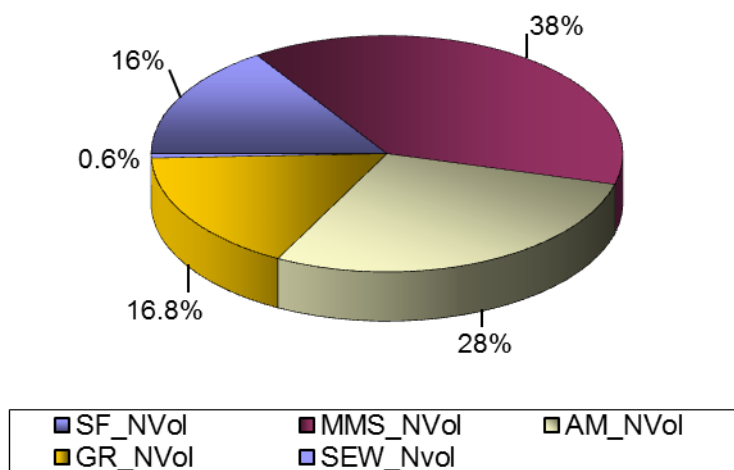
Nitrogen from  $\text{NH}_3$  volatilisation and subsequent deposition from Manure Management Systems was the major contributor to indirect emissions with about 38 per cent of total deposition in 2012. The following most important components are nitrogen in manure applied to soil as fertilizer (28 per cent), nitrogen volatilised from droppings during grazing (16.8 per cent) and nitrogen volatilised from synthetic fertilizers (16 per cent). The less important source is nitrogen volatilised from sewage sludge (0.6 per cent). Total ammonia emissions and deposition have decreased about 18.5 per cent from base year to last year in the inventory.

Table 6-44 – Nitrogen added to soil from Ammonia volatilisation, by emission source/component, which is activity data for Indirect N<sub>2</sub>O emission

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SF_NVol	9 089	9 089	9 006	7 623	9 224	8 187	9 904	10 325	8 453	8 965	9 744	9 007
MMS_NVol	17 323	17 195	17 078	16 954	16 818	16 494	16 368	16 504	17 084	17 178	16 682	17 323
AM_NVol	12 855	12 723	12 586	12 513	12 456	12 262	12 159	12 245	12 713	12 807	12 442	12 855
GR_NVol	4 730	4 683	4 677	4 764	4 942	5 111	5 243	5 369	5 515	5 592	5 583	4 730
SEW_NVol	64	64	64	64	64	64	77	93	60	88	53	75
Total	43 730	44 062	43 671	42 028	43 519	42 467	43 849	44 188	42 631	44 365	45 373	43 789

ton N/yr	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SF_NVol	9 372	6 298	7 196	5 871	4 997	6 462	5 731	5 563	5 877	5 623	5 623
MMS_NVol	16 021	15 196	14 801	14 529	14 180	13 760	13 677	13 820	13 906	13 888	13 783
AM_NVol	12 002	11 373	11 093	10 917	10 651	10 314	10 228	10 301	10 326	10 285	10 190
GR_NVol	5 597	5 603	5 708	5 862	5 958	6 015	6 035	6 024	6 015	5 994	6 001
SEW_NVol	284	214	113	73	86	139	238	407	56	133	216
Total	43 276	38 684	38 912	37 252	35 872	36 690	35 909	36 116	36 180	35 921	35 813

Figure 6-31 – Percent importance of nitrogen added to soil from volatilization of ammonia, by emission source/component in 2012



The fraction of nitrogen input to soil that is lost through leaching and runoff ( $\text{Frac}_{\text{LEACH}}$ ) of nitrogen added to soil was determined as 0.3 kg N/kg N, the default value in IPCC rev 1996. 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 oxide<sup>142</sup>.

The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in Table 6-45 and in, for each component that is considered in lixiviation/runoff estimate: FSN (Synthetic Fertilizers), FAM (Animal Manure), FGR (Grazing), FSEW (Sewage Sludge) and direct discharge to the water system. Nitrogen added to soil in synthetic fertilizers is the major lixiviation/runoff source. From 1990 to 2012 nitrogen deposited into soil has decreased by 20.2 per cent.

<sup>142</sup> Which explains the fact that in CRF table 4Ds2, the “implicit”  $\text{Frac}_{\text{LEACH}}$  is a little higher than the default.

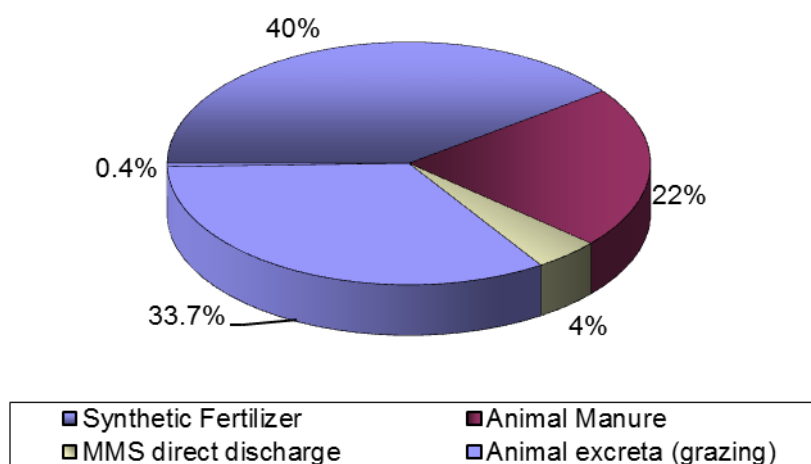
Table 6-45 – Nitrogen lost from soil from lixiviation and runoff (ton N/yr)

Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Synthetic Fertilizer	47 684	47 684	47 684	47 684	47 684	43 745	50 469	49 286	44 791	44 683	51 003	47 253
Animal Manure	20 542	20 680	20 475	20 267	20 161	20 077	19 786	19 617	19 736	20 422	20 521	19 887
MMS direct discharge	3 252	3 443	3 499	3 578	3 575	3 566	3 484	3 523	3 561	3 623	3 580	3 464
Animal excreta (grazing)	21 167	21 461	21 282	21 259	21 629	22 333	23 002	23 475	23 973	24 549	24 760	24 481
Sewage Sludge	96	96	96	96	96	96	116	140	90	132	79	113
Total	92 741	93 364	93 035	92 883	93 144	89 817	96 856	96 041	92 151	93 409	99 943	95 198

Description	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Synthetic Fertilizer	49 170	33 040	37 753	30 799	26 217	33 902	30 065	29 188	30 831	29 499	29 499
Animal Manure	19 138	18 132	17 681	17 394	16 971	16 433	16 254	16 297	16 270	16 168	16 002
MMS direct discharge	3 297	3 178	3 182	3 230	3 287	3 316	3 333	3 347	3 319	3 262	3 235
Animal excreta (grazing)	24 259	24 130	24 527	25 145	25 527	25 679	25 636	25 449	25 273	25 068	24 991
Sewage Sludge	426	322	170	110	129	208	357	611	84	199	325
Total	96 290	78 801	83 313	76 678	72 131	79 537	75 646	74 891	75 777	74 196	74 051



Figure 6-32 – Percent importance of sub-sources of Nitrogen Lost from soil from lixiviation and runoff in 2012



#### 6.3.6.5 *Uncertainty Assessment*

The uncertainty in emission factors was set at an order of magnitude, in accordance with the considerations in GPG (IPCC, 2000). In what concerns the uncertainty associated with activity data an additional 50 per cent error was applied to the uncertainty in activity data reported in N<sub>2</sub>O Direct emissions, in order to incorporate the error of the volatilization and leaching fractions, also in accordance with GPG (IPCC,2000), and the final resultant uncertainty value is 63 per cent.

#### 6.3.6.6 *Recalculations*

The recalculations to this source category are directly related to those detailed in point 6.3.5.7 and are exactly the same. Differences between last year and this year submission are so slight that are not visible in a graphic representation. In a general way the effect of recalculations for indirect emissions, volatilization and leaching resulted in an average increase of 1 per cent.

#### 6.3.6.7 *Further Improvements*

No further improvement is planned for next year other than the related with the detailed ones described in point 6.3.5.8.

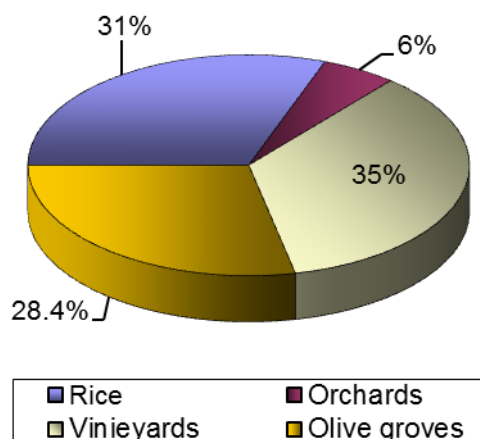
### 6.3.7 **Field Burning of Agriculture Residues (CRF 4.F.)**

#### 6.3.7.1 *Overview*

In-site burning of agricultural residues is still practiced nowadays in Portugal, being however forbidden by law-decree during the Forest Fire Season from May to September. These burning, results in emissions of trace gases as in other combustion processes, including methane, nitrous oxide, carbon monoxide, nitrous oxides and volatile organic compounds. Carbon dioxide is of course also emitted in this process but because it has biomass origin and it is in principle re-absorbed during next growing season, it is not considered in GHG emission inventory.

Considering equivalent carbon dioxide emissions (Figure 6-33), burning of residues from vineyards is the most significant source of this non-key source.

Figure 6-33 – Importance of GHG emissions from field burning of agriculture residues by crop in 2012



#### 6.3.7.2 Methodology

Emissions of in-site burning of agriculture residues were estimated from the following equation:

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

where

$\text{Emission}_{(p, \text{crop}, y)}$  - Emission estimate of pollutant p from field burning of residues from a specific crop in year y (ton/year);

$\text{Crop}_{\text{BURN}(\text{crop}, y)}$  - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{EF}_{(p, \text{crop})}$  - 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 IPCC rev 1996

#### 6.3.7.3 Emission Factors

Except for NMVOC and  $\text{SO}_x$ , emission factors for each specific pollutant are estimated from different equations whether they are carbon containing pollutants ( $\text{CO}_2$ ,  $\text{CH}_4$  and CO) or nitrogen containing pollutants ( $\text{NO}_x$  and  $\text{N}_2\text{O}$ ). This methodology - after IPCC rev 1996 - assumes that some fixed part of carbon and nitrogen that are submitted to burning are emitted as specific compounds.

For carbon containing pollutants the equation is:

$$EF_{(pol,crop)} = C_{Fraction (Crop)} * Frac_{RESOXI (crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

For nitrogen containing compounds the equation is:

$$EF_{(pol,crop)} = C_{Fraction (Crop)} * Frac_{RESOXI (crop)} * NC_{Ratio (crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

where

$EF_{(pol,crop)}$  - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$C_{Fraction (Crop)}$  - Ratio of carbon content in dry biomass matter (kg C/kg dm);

$Frac_{RESOXI (crop)}$  - Fraction or ratio of carbon that it is oxidized during the active burning period (kg C/kg C);

$NC_{Ratio (crop)}$  - Ratio of nitrogen to carbon in crop residue (kg N/kg C);

$ER_{(crop,pol)}$  - Emission ratio, the fraction of total carbon/nitrogen content that it is emitted as pollutant pol (kg C/kg C or kg N/kg N);

$MWC_{(Pol)}$  - Stechiometric correction fraction to convert emissions in carbon/nitrogen units to total molecular weight emissions (kg/kg C or kg/kg N respectively for carbon compounds or nitrogen compounds).

The parameters used to establish emission factors for each crop are presented in next table.

Table 6-46 – 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	0.02
Orchards <sup>143</sup>	0.6	0.9	0.04
Vineyards	0.6	0.9	0.04
Olive groves	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 IPCC rev 1996 and which were still not updated in GPG (Annex 4.A.2).

<sup>143</sup> Comprehending fresh fruit, citrines and dry fruits (nuts)

Table 6-47 – Pollutant specific emission ratios for determination of emissions from field burning of agricultural residues

Pollutant	Emission Ratio (ER)	Units	MWC Ratio
CH <sub>4</sub>	0.5	% Carbon Released from fuel	16/12
N <sub>2</sub> O	0.7		44/28
CO	6.0		28/12
NO <sub>x</sub>	12.1		46/14

Final emission factors for these four pollutants are reproduced in the following table.

Table 6-48 – Final emission factors for field burning of agricultural residues by pollutant and crop (kg/ha) – CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub> and CO

Crop	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO
Rice	6.9 - 22.4	0.2 – 0.6	6.7-21.6	145.1 - 470.2
Fresh Fruits	0.6-0.9	0.03-0.05	1.3-2	11.8-18.5
Citrines	0.3-0.7	0.02-0.04	0.7-1.6	6.5-14.5
Dry fruits	0.3-0.5	0.02-0.03	0.6-1.1	5.5-10.8
Vineyards	1.7-2.5	0.10-0.15	3.7-5.6	34.9-52.5
Olive groves	0.5-0.9	0.03-0.06	1.2-2.1	11.2-19.5

The emission factors for NMVOC are those reproduced in Table 6-49 and were based on EFproposed by AP-42 (USEPA,1992).

Table 6-49 – Final emission factors for field burning of agricultural residues by pollutant and crop (kg/ha) - NMVOC

Crop	NMVOC
Rice	9.0 - 33.5
Fresh Fruits	0.8-1.2
Citrines	0.9-1.9
Dry fruits	0.4-0.9
Vineyards	2.8-4.2
Olive groves	2.1-3.6

Emissions of SO<sub>x</sub> were estimated with EMEP/CORINAIR (2009) emissions factors. These can be seen in the following table:

Table 6-50 – Emission factors for field burning of agricultural residues by pollutant and crop (kg/ton dm) – SO<sub>x</sub>

Crop	SO <sub>x</sub>
Rice	0.3
Fresh Fruits	0.3
Citrines	0.3
Dry fruits	0.3
Vineyards	0.3
Olive groves	0.3

#### 6.3.7.4 Activity data

According to expert information from the MAM (Seixas et al, 2000) only vegetal residues from vineyards, olive groves and orchards are subjected to significant on-site burning. The basic activity data available from INE that was used is area cultivated for each perennial crop. Expert opinion from the MAM (Seixas et al, 2000) was used to establish a fixed percentage of residues annually produced by each permanent crop that is burnt in site (fraction of residues burnt)

Rice is the only annual crop where on field burning residues is usually practised. The fraction of rice residues burnt on field presents annual variations and is determined according to the information received from the agriculture experts from the MAM, namely the annual rice cultivation areas where that specific practice is forbidden (Figure 6-19, chapter 4C – CH<sub>4</sub> emissions from rice cultivation)

Activity data in suitable units is estimated from:

$$\text{Crop}_{\text{BURN (crop,y)}} = \text{Crop}_{\text{AREA(crop,y)}} * \text{Resid}_{\text{PROD (crop)}} * \text{Dm}_{\text{Content(crop)}} * \text{Frac}_{\text{RESBURN (crop)}} * 10^{-4}$$

where

$\text{Crop}_{\text{BURN (crop,y)}}$  - Biomass of residue of a specific crop in year y that is burnt 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 (t/ha);

$\text{Dm}_{\text{Content(crop)}}$  - Dry matter content of crop residues (% dm/live weight);

$\text{Frac}_{\text{RESBURN (crop)}}$  - Fraction of total residues from a specific crop that are burnt in site (%).

Parameters  $\text{Resid}_{\text{PROD}}$ ,  $\text{Dm}_{\text{Content}}$  and  $\text{Frac}_{\text{RESBURN}}$  considered are presented in Table 6-51.

Table 6-51 – Parameters used for the estimation of the quantity of burnt crop residues

Crop	Resid <sub>PROD</sub> <sup>1</sup>	Frac <sub>RESBURN</sub>	DMContent
	t live weight/ha	%	%
Rice	6.5-8.4	29-67	85
Orchards <sup>2</sup>	5.2-6.2	4	50
Vinieyard	4.6-7.0	20	50
Olive grove	0.8-1.4	39	50

1- estimated from crop production assumimng a residue/crop equal to 1.4 for rice and 1 for perennial crops

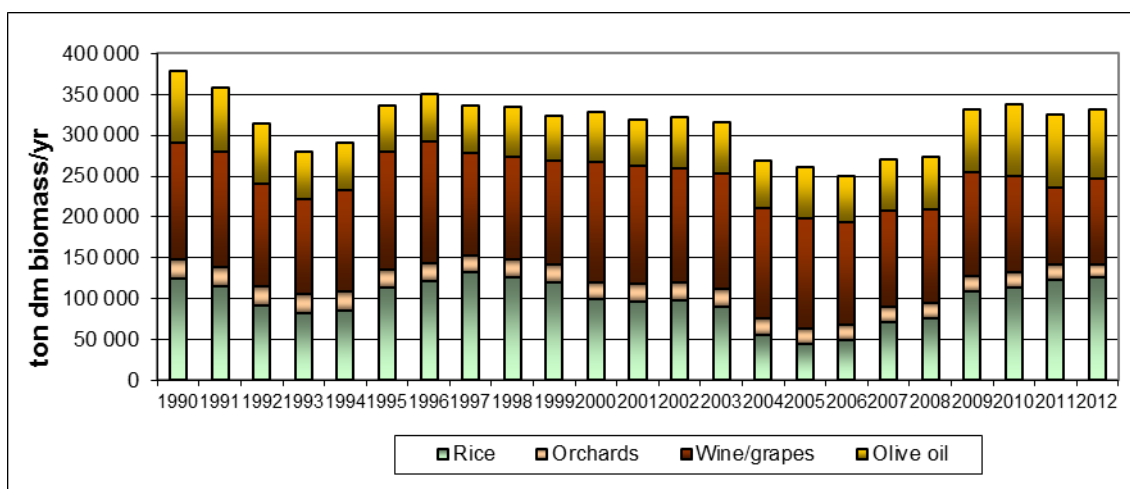
2- average values for fresh fruit, citrines and dry fruit

Table 6-52 – Crop area per crop (ha)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Rice	33 640	29 469	22 595	19 456	19 659	24 685	26 181	27 946	26 956	25 395	24 701	24 670
Orchards	164 147	166 122	168 103	166 840	165 690	164 748	163 844	162 337	161 383	158 792	158 301	156 014
Vineyards	264 359	271 160	264 062	254 528	247 615	241 964	236 654	232 226	226 497	219 442	217 899	217 691
Olive grove	337 189	333 757	338 948	340 579	340 672	333 144	336 621	338 414	347 271	369 032	367 351	361 606
Total	799 335	800 508	793 708	781 403	773 636	764 541	763 300	760 923	762 107	772 661	768 252	759 981

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rice	25 270	25 831	25 053	24 964	25 059	26 210	27 236	28 470	29 120	31 436	31 174
Orchards	153 581	150 956	147 743	144 383	140 623	134 469	131 214	126 750	126 786	127 059	129 803
Vineyards	216 642	213 385	208 956	204 494	199 313	193 988	187 800	181 920	180 079	179 472	179 469
Olive grove	354 040	350 064	347 276	348 426	347 901	347 369	347 140	344 199	343 219	345 683	346 778
Total	749 533	740 236	729 028	722 267	712 896	702 036	693 390	681 339	679 204	683 650	687 224

Figure 6-34 – Estimated total quantities of burnt crop residues per crop



#### 6.3.7.5 Uncertainty Assessment

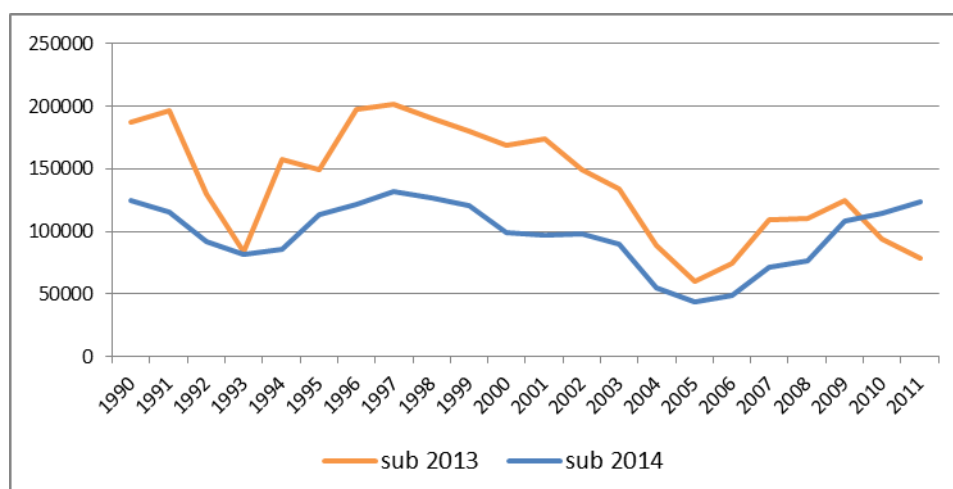
The uncertainty in activity data is higher than the error associated with crop area determination, because there is a higher uncertainty in the percentage of crop areas that are subjected to burning and in which crops field burning is practiced. An uncertainty value of 100 per cent was therefore considered.

The uncertainty range in emission factors was set at 20 per cent in accordance with recommendations from GPG (IPCC, 2000).

#### 6.3.7.6 Recalculations

The main recalculation made for 4.F is related with the methodological reevaluation made for chapter 4C – CH<sub>4</sub> emissions from rice cultivation, namely the revision of crop areas with burnt restrictions and amounts of residues (stubbles and straw) incorporated into the soil (Sfo scaling factor).

Figure 6-35- Amount of rice residues burnt (t dm/yr) differences between submission 2013 and submission 2014





Minor recalculation effects is associated to an adjustment of residues annually produced from each perenial crop (orchards, vineyards and olive grove) that are now estimated in relation with annual crop production.

#### 6.3.7.7 *Further improvements*

No specific improvements are planned

### 6.3.8 NH<sub>3</sub> Emissions from Volatilization in Agriculture Soils

#### 6.3.8.1 *Methodology*

Although emissions of ammonia from nitrogen were already discussed in several chapters, it is explained again here to allow a clearer understanding of this emission source.

Ammonia volatilisation from the application of synthetic fertilizers (SN\_NH<sub>3</sub>) is calculated using the following formula:

$$SN_{NH_3} = N_{Fert} * Fra_{GASF}$$

where,

$N_{Fert}$  - total amount of nitrogen in synthetic fertilizers consumed annually

$Fra_{GASF}$  - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH<sub>3</sub> or NO<sub>x</sub>

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 Guidebook:

- 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<sub>3</sub>) are not differentiated and are estimated according to equation:

$$MMS_{NH_3} = \sum_i [N_{(i)} * Nex_{(i)} * (1 - MS_{GRAZ(i)}) * EF_{NH3(i)}]$$

where

$N_{(i)}$  - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category i;

$EF_{NH3(i)}$  - Fraction of nitrogen from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$MS_{GRAZ(i)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  that is managed in Pasture Range and Paddock;

For the time being the emission factors are only dependent on animal type and not on the manure management system, except in what concerns the differentiation of ammonia volatilisation in grazing.

Emissions from manure collected in Manure Management Systems and that is later deposited in agricultural soil as fertilizer ( $AM\_NH_3$ ) is calculated from:

$$AM\_NH_3 = \sum_t \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

where

$N_{(i)}$  - Number (head) of individuals from livestock category  $i$  in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category  $i$ ;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $T$  that is managed in Manure Management System  $s$ , except grazing;

$MSSD_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  treated in Manure Management System  $S$  that is used as fertilizer in agriculture soils;

$EF_{NH3(i)}$  - Fraction of nitrogen in Manure Management System  $S$  from livestock category  $i$  that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$  - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

Emissions from volatilisation of nitrogen added to soil during grazing ( $GZ\_NH_3$ ) was estimated by:

$$GZ\_NH_3 = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * EF_{NH3(i)}]$$

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.

Emissions from volatilisation of nitrogen added to soil from sewage sludge ( $SEW\_NH_3$ ) was estimated by:

$$\text{SEW\_NH3} = \text{SS} * \text{NSSF} * \text{Frac}_{\text{GASM}} * 17/14$$

where

SS - quantity of sewage sludge spread on agricultural lands (ton/yr)

NSSF - nitrogen fraction of sewage sludge (percentage of dry solids)

Frac<sub>GASM</sub> – fraction of N volatilised as NH<sub>3</sub>-N.

Ammonia emissions from agriculture also result from field burning of residues as it was already presented in chapter 6.3.7.

#### 6.3.8.2 *Emission Factors*

##### 6.3.8.2.1 Ammonia Volatilization from Synthetic Fertilizers

The volatilization ratio from synthetic fertilizers, Frac<sub>GASF</sub>, was determined from an estimate of the share of nitrogen synthetic fertilizers used in Portugal based on statistical information from INE on import, export and national production of each individual nitrogen fertilizer. Albeit some deficiencies still found in the basic information data, it was considered this volatilization ratio to be more suitable to represent the national conditions than to use the default IPCC approach that is recognized to be too high and not representative of the national conditions of fertilization, particularly when the results of the inventory are being used to discuss capes under the European Emissions Ceiling (NEC). The following approach was used:

- Data information concerning national production of nitrogen synthetic fertilizers was available from INE from 1992 till 2000, from the IAPI industrial survey and using PRODCOM product classification. This statistical information has confidential constrains and may not be published in the present report;
- Statistical information about foreign trade is available also from INE concerning importation and exportation of nitrogen fertilizers. Products are classified according to NC codes. The same confidential constrains apply to this data;
- Annual consumption of nitrogen fertilizers per fertilizer type was hence estimated by APA for the years from 1992 to 2000, using the equation below<sup>144</sup>. In Figure 6-36 the share of consumption of each nitrogen fertilizer, as estimated by APA, is presented as an average situation in the 1992-2000 period, where it may be seen that Calcium Ammonium Nitrate is the main fertilizer in use and urea, the fertilizer more prone to nitrogen volatilization, represented about 17 per cent of nitrogen added as fertilizer to soils.

$$\text{Consumption}_{(f)} = \text{Production}_{(f)} + \text{Import}_{(f)} - \text{Export}_{(f)}$$

where,

Consumption<sub>(f)</sub> – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

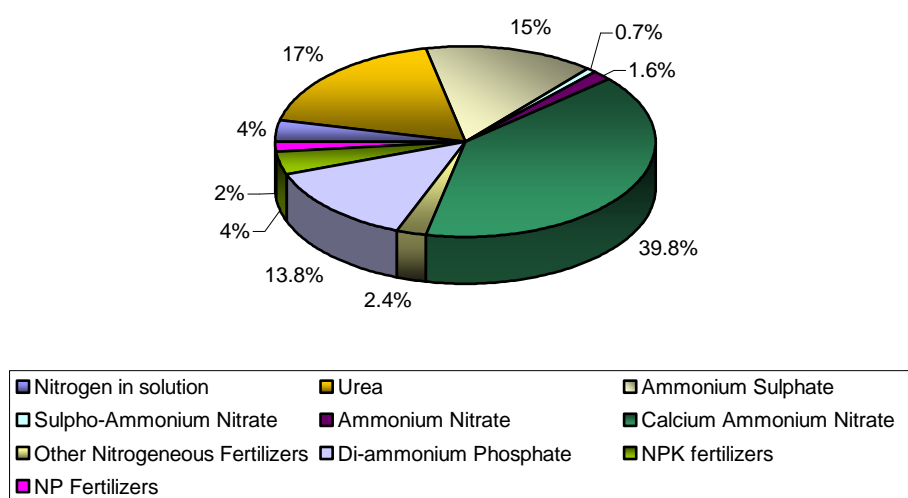
<sup>144</sup> These estimates are only preliminary guesses and are being revised together with INE and the Ministry of Agriculture.

Production<sub>(f)</sub> – Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

Import<sub>(f)</sub> – Annual importation in Portugal of nitrogen fertilizer f (ton N/yr);

Export<sub>(f)</sub> – Annual exportation in Portugal of nitrogen fertilizer f (ton N/yr);

Figure 6-36 – Relative Importance of the use of various nitrogen fertilizers in Portugal, as estimated by APA from production and foreign trade



- product specific volatilization rates from EMEP/CORINAIR (EEA,2003) were used for each nitrogen fertilizer type according to Table 6-53.

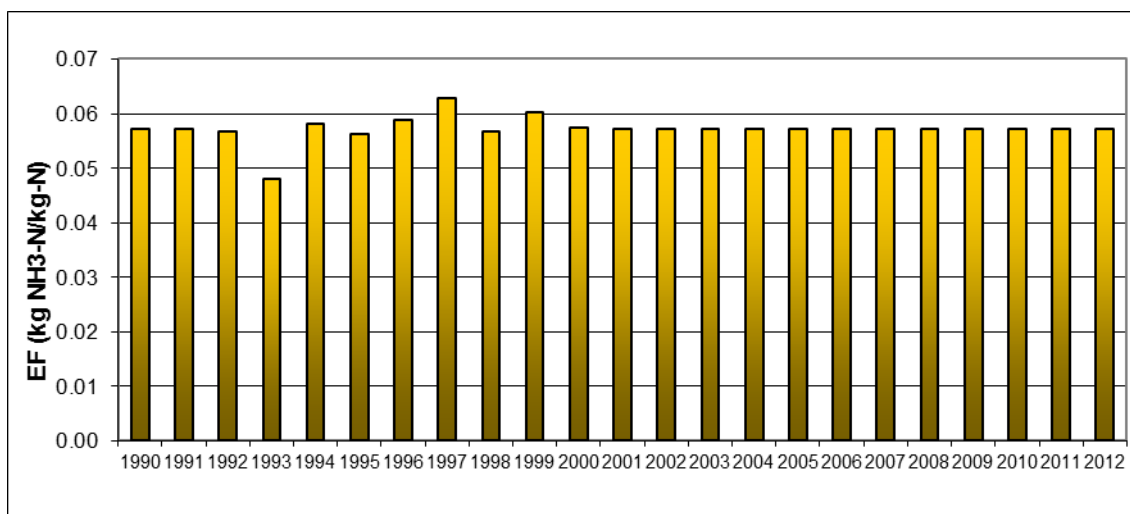
Table 6-53 – Volatilization rates for each nitrogen fertilizer

Acronym	Product	EF (kg NH <sub>3</sub> /kg N)
UAN	Nitrogen in solution	0.08
UREA	Urea	0.15
AS	Ammonium Sulphate	0.08
SAN	Sulpho-Ammonium Nitrate	0.05
AN	Ammonium Nitrate	0.02
CAN	Calcium Ammonium Nitrate	0.02
N	Other Nitr.Fertilizers	0.053
DAP	Di-ammonium Phosphate	0.05
NPK	NPK fertilizers	0.02
NP	NP Fertilizers	0.02

Source: EMEP/CORINAIR file B1010vs4 - Revision of 3rd ed in Jan2003

- finally, the weighted average ammonia volatilization rate was estimated for each year from 1992 to 2000 and the average value in that period applied to 1990, 1991 and extrapolated to 2001-2012. The final volatilization rates appear in Figure 6-37.

Figure 6-37 – Final volatilization rate of ammonia from the application of synthetic fertilizer in agricultural soils



#### 6.3.8.2.2 Ammonia Volatilization from Animal Excreta

The emission factors that were used to estimate ammonia emissions from manure from domestic livestock were already presented in source categories N<sub>2</sub>O emissions from manure management and direct N<sub>2</sub>O emissions from Agricultural Soils and are present again in Table 6-54. These emission factors result from EMEP/UNECE 3rd edition in annex A of chapter B1050 and version 4.0 of chapter B1010 and are not dependent on the Manure Management System that is used. Final emission factors per animal class are presented in next table.

Table 6-54 - Emission factors used for calculation of NH<sub>3</sub> volatilisation from animal housing, land spreading and grazing in pasture (kg N-NH<sub>3</sub>/kg N excreted)

Classe	Housing & Outside Storage	Land spreading of Manure	Grazing in Pasture
Dairy Cows	0.17	0.17	0.08
Other Cattle	0.17	0.17	0.08
Sheep	0.10	0.07	0.04
Goats	0.10	0.07	0.04
Swine	0.22	0.16	0.08
Equines	0.12	0.07	0.08
Poultry	0.22	0.16	-
Hens	0.23	0.15	-
Rabbits	0.22	0.16	-

The use of emission factors from EMEP/UNECE results therefore in values for Frac<sub>GASM</sub> that are different and higher than the default value for Frac<sub>GASM</sub> (0.2 kg N-NH<sub>3</sub> + N-NO<sub>x</sub>/ kg of N excreted, in table 4-19 of IPCC rev 1996).

#### 6.3.8.3 *Ammonia Volatilization from sewage sludge*

The volatilization ratio from sewage sludge, FracGASM, used to estimate ammonia emissions result from IPCC revised 1996 Guideline, table 4-19, page 4.94, and is equal to 0.2 kg NH<sub>3</sub> - N/kg of N applied to soil from sewage sludge.

#### 6.3.8.4 *Activity Data*

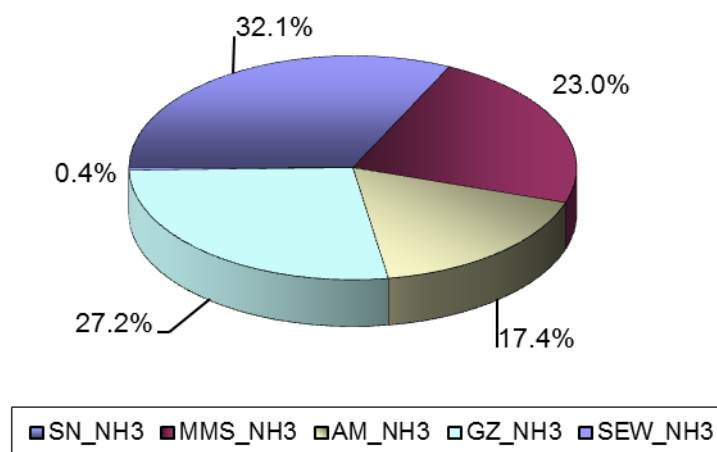
The quantity of nitrogen that is subjected to volatilisation through direct emission is presented in Table 6-55 and in Figure 6-38.

Table 6-55 – Nitrogen subjected to volatilization from each emission source/component, which is activity data for NH<sub>3</sub> emissions

Source	ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Synthetic Fertilizers	SN_NH <sub>3</sub>	158 945	158 945	158 945	158 945	158 945	145 815	168 229	164 288	149 303	148 944	170 009	157 511
M.M.S.	MMS_NH <sub>3</sub>	88 864	89 699	88 943	88 213	87 731	87 309	85 931	85 281	85 852	88 781	89 160	86 437
Animal Manure	AM_NH <sub>3</sub>	68 472	68 932	68 249	67 557	67 203	66 925	65 953	65 390	65 786	68 074	68 403	66 291
Grazing/ Pasture	GZ_NH <sub>3</sub>	70 558	71 537	70 941	70 862	72 097	74 444	76 673	78 249	79 909	81 830	82 535	81 602
Sewage sludge	SEW_NH <sub>3</sub>	319	319	319	319	319	319	386	467	301	440	263	377
Total	-	387 158	389 433	387 397	385 897	386 296	374 813	397 171	393 674	381 151	388 069	410 370	392 217

Source	ton N/yr	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Synthetic Fertilizers	SN_NH <sub>3</sub>	163 902	110 132	125 844	102 663	87 391	113 005	100 216	97 293	102 772	98 329	98 329
M.M.S.	MMS_NH <sub>3</sub>	83 110	78 813	76 920	75 739	74 036	71 852	71 192	71 489	71 458	71 044	70 357
Animal Manure	AM_NH <sub>3</sub>	63 793	60 439	58 937	57 980	56 569	54 776	54 181	54 322	54 232	53 894	53 339
Grazing/ Pasture	GZ_NH <sub>3</sub>	80 864	80 434	81 756	83 817	85 092	85 596	85 453	84 830	84 244	83 561	83 303
Sewage sludge	SEW_NH <sub>3</sub>	1 419	1 072	567	366	429	693	1 191	2 035	278	663	1 082
Total	-	393 088	330 891	344 023	320 565	303 516	325 922	312 234	309 969	312 984	307 491	306 410

Figure 6-38 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation in 2012



For the last inventory year the majority of nitrogen added to soil, that contribute to  $\text{NH}_3$  emissions, resulted from the application of Synthetic Fertilizers (32.1 per cent). Direct droppings during grazing in Pasture (27.2 per cent) and Manure Management System (23.0 per cent) are also two important sources of nitrogen add to soil that is activity data in the determinations of  $\text{NH}_3$  emission.

#### 6.3.8.5 *Recalculations*

Recalculations to this source category:

- Revision of the apparent consumption of synthetic fertilizers for 2009, 2010 and 2011 using updated INE data;
- Reevaluation of Nex rate for swine subcategory Fat pigs (20-50 kg). Formerly it was 7.0 kg/hd/yr and now is 9.0 kg/hd/yr. This reevaluation was done in coordination with INIAV experts<sup>145</sup>.

#### 6.3.8.6 *Further Improvements*

Even though efforts were made to include all data from the RGA 2009 there are areas in which the integration of this data can be improved like the separation of animal types per climate region.

New data from the RGA 2009 (which revised the information for the 2000-2009 time period) showed that the methodology for estimating the number of lambs and kids did not properly adhere to the reality of the country's livestock. An adjustment was made to the methodology to ensure that no incoherencies were included in the emission estimation. Additional efforts have to be made, together with our sectoral focal points, to revise this methodology for estimating the annual number of kids and lambs.

<sup>145</sup> Drª Fátima Calouro, National Institute for Agriculture and Veterinary Research.



Also in RGA 2009 new data was collected by INE concerning the manure management systems used in each livestock exploration. We expect to include this information in the next inventory which will revise the shares of MMS for the 1991-2011 time series.

The importance of the Manure Management System in ammonia emissions needs to be included in the methodology, but that depends on the existence of appropriate emission factors.

It is expected that efforts will continue to ameliorate the volatilisation rates from the application of synthetic fertilizers, following a future better knowledge of the nitrogen fertilizer types used in Portuguese agricultural soils.

## 7 LAND USE, LAND USE CHANGE AND FORESTRY (CRF 5.)

### 7.1 Overview of LULUCF

#### 7.1.1 LULUCF Inventory Framework

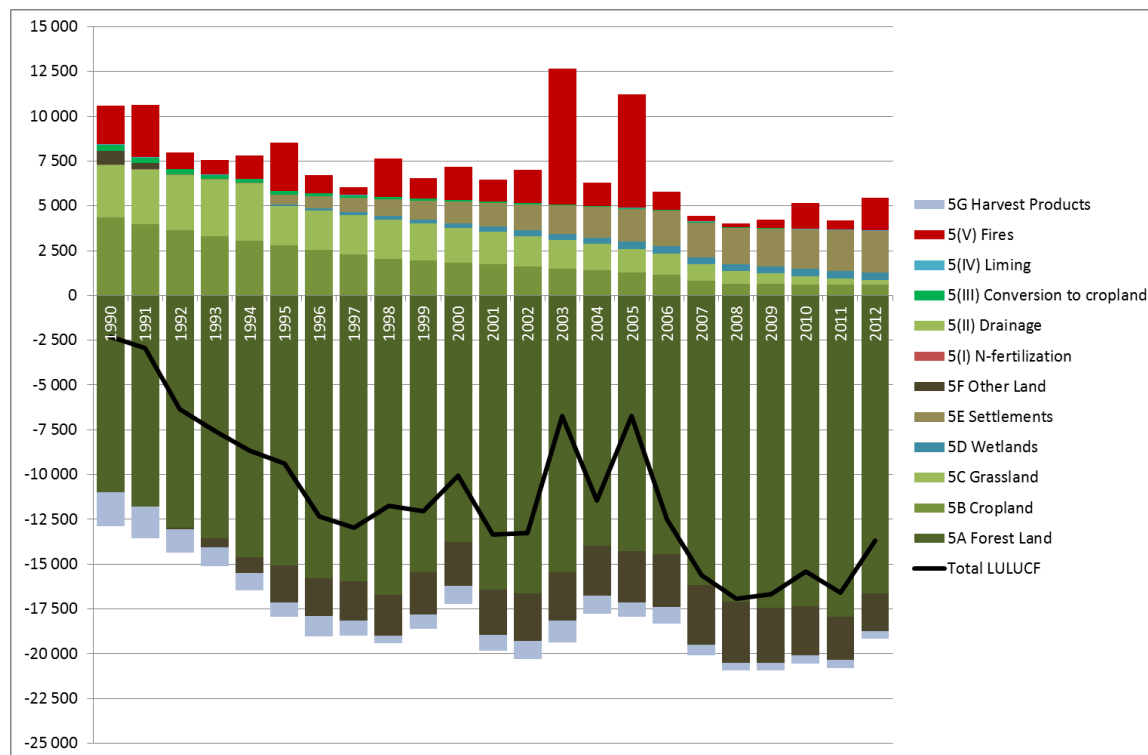
When considered in its entirety, the LULUCF sector is estimated as a net-sink for the whole time series period, as represented in Figure 1.

In 2012 the carbon sink resulting from LULUCF is estimated at 13.45 Mt CO<sub>2</sub>eq. In the period 1990-2012 the average sink increase is 507.35 kt CO<sub>2</sub>eq per year.

The main contributors for this change have been an increase in removals in forest land and in other land and reductions in emissions in cropland and grassland. The trends in other sources and land-uses are much smaller in scale, and it should be noted that fires have a rather erratic behaviour, mostly driven by changes in weather patterns from year to year.

The main drivers for this change have been changes in land-use patterns over time, and the introduction of policies for increasing afforestation, improving the system for the prevention and combat of forest fires (introduced after the big fire seasons of 2003 and 2005) and the introduction of carbon sequestration incentives in agricultural and grassland soils.

Figure 7-1 – Overview of reported emissions and removals in the LULUCF Sector (kt CO<sub>2</sub>eq)

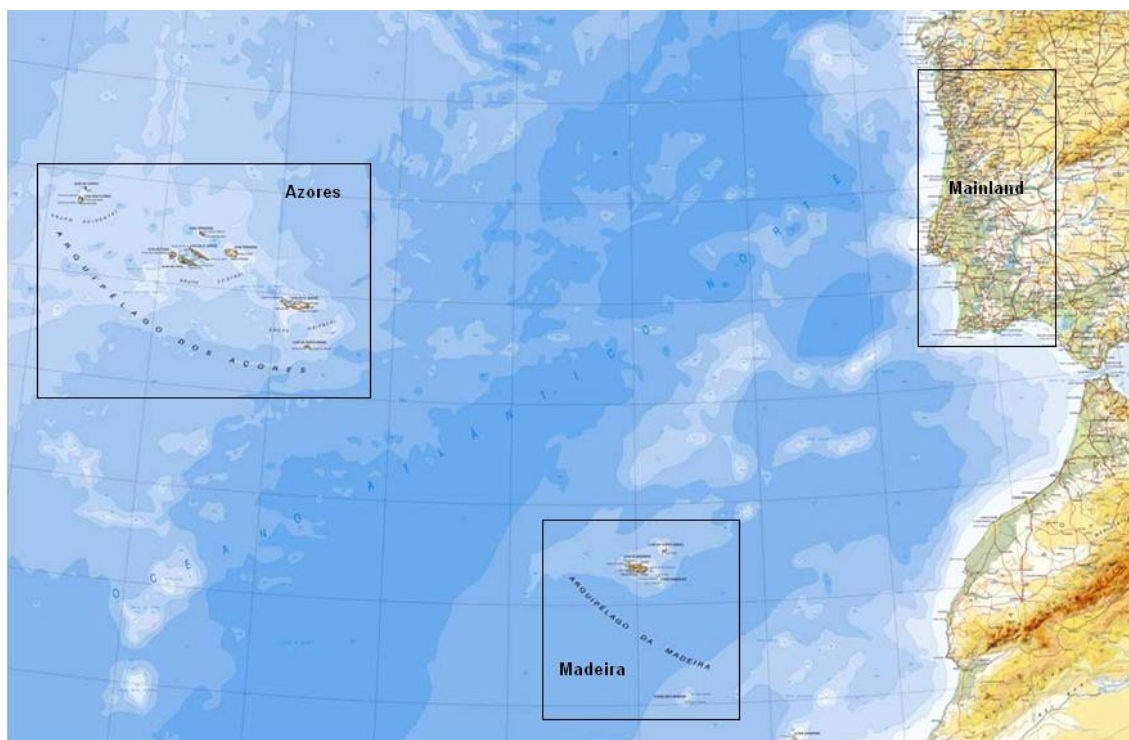


## 7.1.2 Representation of Land-Areas and Land-Use Changes

### 7.1.2.1 *Approaches to Land Representation*

The Portuguese territory is composed of three territorial units (see Figure 7-2): Mainland, the Archipelago of Azores (9 inhabited islands) and the Archipelago of Madeira (2 inhabited islands).

Figure 7-2 – Portuguese Territorial Units



Portugal has 9 239 318 ha, divided by the Mainland with 8 927 540 ha (96.6%), the Archipelago of Azores with 231 676 ha (2.5%) and Archipelago of Madeira with 80 102 ha (0.9%).

Under the Portuguese constitutional law, the Archipelagos of Azores and Madeira are each an Autonomous Region, and as a result of that legal status the information sources (used for activity data) for each region are not exactly the same.

The sections below describe how the data on land-use and land-use change were derived in each of the three regions. The approaches used vary according to territory and time period under consideration from Approach 1 (total land-use area, no data on conversions between land-uses) and Approach 3 (spatially-explicit land-use conversion data), with predominance for the later.

### 7.1.2.2 *Land-Use Data Stratification*

The same land-use stratification is used in all three regions, despite the different sources of land-use data used in each of the regions.

A total of 19 land-use categories were used as shown in Table 7-1.

Table 7-1 – Land-use categories used in the NIR

UNFCCC Category	Land-use Category Name	Description
<b>Forest Land</b>	Pinus pinaster	Forests dominated by maritime pine
	Quercus suber	Forests dominated by cork oak
	Eucalyptus spp.	Forests dominated by eucalypt species
	Quercus rotundifolia	Forests dominated by holm oak
	Quercus spp.	Forests dominated by other oaks
	Other broadleaves	Forests dominated by any other broadleaf species
	Pinus pinea	Forests dominated by umbrella pine
	Other coniferous	Forests dominated by any other coniferous species
<b>Cropland</b>	Rain-fed annual crops	Includes all land cultivated with annual crops without irrigation Includes fallow-land integrated into crop-rotations
	Irrigated annual crops	Includes all land cultivated with annual crops that is under irrigation (except rice) and greenhouses
	Rice paddies	Includes all land prepared for rice cultivation
	Vineyards	Includes all areas used for cultivation of table and/or wine grapes
	Olive groves	Includes all areas used for cultivation of Olea europea <sup>146</sup>
	Other permanent crops	Includes all areas used for cultivation of all other species of woody crops, including fruit orchards <sup>147</sup>
<b>Grassland</b>	All grasslands	Includes all lands covered in permanent herbaceous cover
<b>Wetlands</b>	Wetlands	Includes all lands permanently or temporarily covered in water, such as natural wetlands, water reservoirs and inland natural lagoons, lakes and estuaries
<b>Settlements</b>	Settlements	Includes all artificial territories, including cities and villages, industry, roads and railway, ports and airports
<b>Other Land</b>	Shrubland	Includes all lands covered in woody vegetation that do not meet the forest or permanent crop definitions
	Other land	Includes all lands that do not meet the previous definitions, such as lands covered in rocks, sand dunes, etc.

#### 7.1.2.3 Mainland Portugal

The land-use and land-use change data for Mainland Portugal 1970-2012 was divided into two different time periods: 1970-1995 and 1995-2012.

<sup>146</sup> Olive trees used for the production of olive oil and/or olives. The Wild Olive Tree (sub-species *Olea europea sylvestris*) is reported as Forest Land / Other Broadleaves

<sup>147</sup> Except Sweet Chestnut (*Castanea sativa*), Carob Trees (*Ceratonia siliqua*) and Umbrella Pines (*Pinus pinea*), which are reported to FAO as forest land, even though their main production objective is the respective fruit.

This separation was needed due to the quality of available information, where the period 1995-2012 can be estimated using an approach type 3 (spatially-explicit land-use conversion data), while the data for the period 1970-1995 only allowed for the use of an approach type 1 (total land-use area, no data on conversions between land-uses).

The methodologies used for each of the periods are described below.

#### 7.1.2.3.1 Period 1995-2012

The main information source for this period is the Cartografia de Ocupação de Solo<sup>148</sup> (COS). COS was produced during 2013, based on an earlier version of 2007. COS (2007) was revised and used as a basis to derive COS (1995) and COS (2010), using full aerial photography cover of mainland Portugal.

COS legend was consistent in all 3 maps and totalizes 225 classes. This extensive legend was after converted to the 19 strata described in section 7.1.2.2, which are used as a basis for both UNFCCC and KP reporting. The minimum area considered was 1ha and the minimum width for linear structures and other polygons was 20m. Forest classes considered where forest cover was bigger than 10%. This allows for a representation of forests consistent with the KP Forest Definition of Portugal.

The Final Report of COS further elaborates on the criteria used for land classification and generalization.

Total land-use changes were compiled for the periods 1995-2007 and 2007-2010 by overlapping the respective land-use maps. The results were then annualised by dividing for the period between maps (respectively 12 and 3 years). Land-use changes are assumed to be constant for the period 1995-2007 and 2007-2012 and equal to the annual land-use changes derived in those periods.

Equation 7.1 - Estimation of annual land-use change 1995-2012

$$LUC_{x \rightarrow y[Y_i]} = \frac{LUC_{x \rightarrow y[1995-2007]}}{12}, Y_i = \text{any year in } [1995-2007]$$

$$LUC_{x \rightarrow y[Y_i]} = \frac{LUC_{x \rightarrow y[2007-2010]}}{3}, Y_i = \text{any year in } [2007-2012]$$

Where:

$LUC_{x \rightarrow y[1995-2007]}$  = Total land-use change in the period 1995-2007 (ha/year)

$LUC_{x \rightarrow y[2007-2010]}$  = Total land-use change in the period 2007-2010 (ha/year)

$LUC_{x \rightarrow y[Y_i]}$  = Annual land-use change in Year i (ha)

To guarantee the consistency of the information with KP legend and information from the General Census of Agriculture, one change was made to the original data from COS:

1. The total area for the categories "Rainfed annual crops" and "Grasslands" were recalculated using the respective shares of those land-uses from the General Census of Agriculture.

<sup>148</sup> Land-Use Cartography. COS in the Portuguese acronym

These two categories are very similar and difficult for photo-interpreters to differentiate. The Census, being based on declarations of the actual use of land, was assumed to be more reliable source. However, for consistency the total area of Rainfed + Grasslands from COS was maintained.

The resulting Annual Land-use Change Matrices are presented in Table 7-7 and Table 7-8.

#### 7.1.2.3.2 Period 1970-1995

As mentioned before, the data available from COS is contained to the period 1995-2010. For the period pre-1995, and starting from 1970, the information available is less comparable across sources and land-use classifications and, most importantly, it provides estimates for total land-uses, but not (directly) for land-use changes. Therefore, the approach differed between information source and land-use category.

For “Forest land” the basis for information was the National Forest Inventory from IFN (1974), IFN (1985) and IFN (1995). To maintain time series consistency, the following estimation methodology was used:

1. the total area of forest land (in hectares) from COS(1995) was taken as a starting point for 1995;
2. the trend for total area IFN(1985)-IFN(1995) (in annual % change) was applied retrospectively to estimate total forest area in 1985;
  - a. Allocation to specific forest type in the year 1985 was made using the share of each forest type in IFN(1985)
  - b. Allocation to specific forest type in the years 1986-1994 was made by linear interpolation of the values from 1985 and 1995;
3. The trend for total area IFN (1974)-IFN (1985) (in annual % change) was applied retrospectively to estimate total forest area in 1974;
  - a. Allocation to specific forest type in the year 1974 was made using the share of each forest types in IFN (1974)
  - b. Allocation to specific forest type in the year 1975-1984 was made by linear interpolation of the values from 1974 and 1985;
4. The same trend (in annual % change) was used retrospectively to estimate total forest area in 1970.
  - a. Allocation to specific forest type in the period 1970-1973 was made using the share of each cropland/grassland types in IFN(1974);

For “Cropland” and “Grasslands” the basis for information was the General Census of Agriculture from RGA (1979), RGA (1989) and RGA (1999). To maintain time series consistency, the following estimation methodology was used:

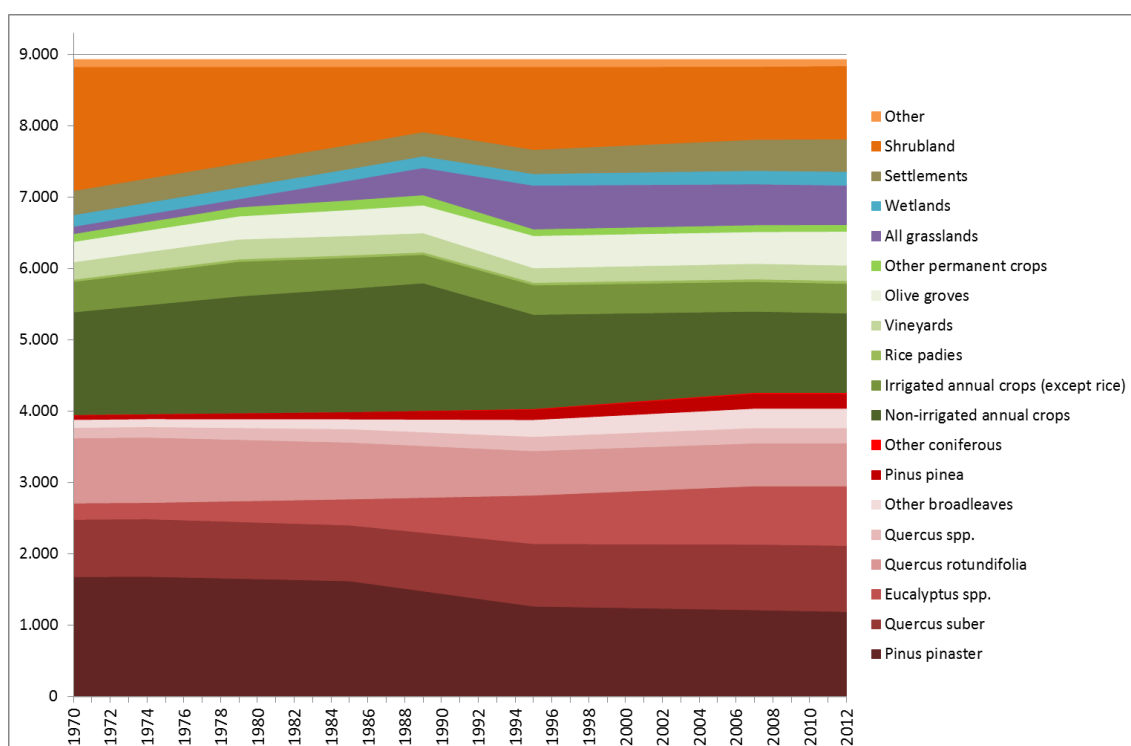
5. the total area of cropland + grassland (in hectares) from COS (1995) was taken as a starting point for 1995;
6. the trend for total area 1989-1999 (in annual % change) was applied retrospectively to estimate total cropland and grassland area in 1989;

- a. Allocation to specific cropland/grassland type in the year 1989 was made using the share of each cropland/grassland types in RGA (1989)
  - b. Allocation to specific cropland/grassland type in the year 1990-1994 was made by linear interpolation of the values from 1989 and 1995;
7. The trend for total area 1979-1989 (in annual % change) was applied retrospectively to estimate total cropland and grassland area in 1979;
  - a. Allocation to specific cropland/grassland type in the year 1979 was made using the share of each cropland/grassland types in RGA (1979)
  - b. Allocation to specific cropland/grassland type in the year 1980-1988 was made by linear interpolation of the values from 1979 and 1989;
8. The same trend (in annual % change) was used retrospectively to estimate total cropland and grassland area in 1970.
  - a. Allocation to specific cropland/grassland type in the period 1970-1979 was made using the share of each cropland/grassland types in RGA (1979);

For “Wetlands”, “Settlements” and “Other Land” no other information source previous to 1995 was found. The following assumption was made: Total area in 1970-1995 = COS area in 1995.

Finally, totals for Mainland Portugal were maintained constant in the period 1970-1995 by adjusting the category “Shrubland”. The results for the full time series 1970-2012 are presented in Figure 7-3.

Figure 7-3 – Changes in Total Land-Use in Mainland Portugal (1000 ha)



As mentioned above, land use changes for the period 1970-1995 cannot be estimated separately for  $X \rightarrow Y$  and  $X \rightarrow Y$ , as the only information available is the total of net-changes in area in each period ( $X \rightarrow Y$  plus  $X \rightarrow Y$ ).

However, as the country's total remains constant over time, the total sum of net-gains in area of a particular set of land-uses needs to be equal to the net-losses in area of all other land-uses. This principle was applied to derive land-use change estimates for all land-uses using Equation 7.2.

Equation 7.2 - Estimation of Land-use Changes, when only net-changes in area are known

$$LUC_{x \rightarrow y, Y_i} = LUC_{x \rightarrow all, Y_i} \times \frac{LUC_{all \rightarrow y, Y_i}}{LUC_{all, Y_i}}$$

Where:

$LUC_{x \rightarrow y, Y_i}$  = Land-use change from land-use x to land-use y in Year i (ha)

$Y_i$  = Any year in the period [1970-1995]

$LUC_{x \rightarrow all, Y_i}$  = Net area loss of land-use type x in Year i (ha)

$LUC_{all \rightarrow y, Y_i}$  = Net area gains of land-use type y in Year i (ha)

$LUC_{all, Y_i}$  = Total land-use changes in Year i (ha)

The resulting annual land-use change matrices for this period are presented in Table 7-2 through to Table 7-6.

Table 7-2 – Annual land-use changes (ha) in the period [1970-1974]

	1970	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Com	Rf crps	Ir crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1970-1974
1974																					
P. pinaster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,147	0	1,147
Q. suber		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	548	0	548
Eucalyptus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	156	0	156
Q. rotundifolia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	622	0	622
O. Quercus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	0	101
O. broadleaves		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0	75
P. pinea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	0	42
O. coniferous		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
Rain-fed crops		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,989	0	21,989
Irrigated crops		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,523	0	6,523
Rice		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	467	0	467
Vineyards		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,725	0	3,725
Olive		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,361	0	4,361
O. permanent		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,695	0	1,695
Grasslands		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,547	0	1,547
Wetlands		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Settlements		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrubland		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. land		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Losses 1970-1974		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43,002	0	43,002



Table 7-3 – Annual land-use changes (ha) in the period [1974-1979]

1979	1974	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Con	Rf crps	lr crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1974-1979
P. pinaster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q. suber		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus	1,138	419		2,142	0	0	0	0	96	0	0	0	0	0	0	0	0	0	8,519	0	12,314
Q. rotundifolia	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. Quercus	330	122	0	622		0	0	0	28	0	0	0	0	0	0	0	0	0	2,474	0	3,576
O. broadleaves	231	85	0	436	0		0	0	20	0	0	0	0	0	0	0	0	0	1,732	0	2,504
P. pinea	320	118	0	602	0	0		0	27	0	0	0	0	0	0	0	0	0	2,393	0	3,460
O. coniferous	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
Rain-fed crops	2,031	748	0	3,826	0	0	0	172		0	0	0	0	0	0	0	0	0	15,212	0	21,989
Irrigated crops	602	222	0	1,135	0	0	0	51	0		0	0	0	0	0	0	0	0	4,512	0	6,523
Rice	43	16	0	81	0	0	0	4	0	0		0	0	0	0	0	0	0	323	0	467
Vineyards	344	127	0	648	0	0	0	29	0	0	0		0	0	0	0	0	0	2,577	0	3,725
Olive	403	148	0	759	0	0	0	34	0	0	0	0		0	0	0	0	0	3,017	0	4,361
O. permanent	157	58	0	295	0	0	0	13	0	0	0	0	0		0	0	0	0	1,172	0	1,695
Grasslands	143	53	0	269	0	0	0	12	0	0	0	0	0	0		0	0	0	1,070	0	1,547
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Settlements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
Shrubland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
O. land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Losses 1975-1979	5,742	2,115	0	10,815	0	0	0	486	0	0	0	0	0	0	0	0	0	0	43,002	0	62,160
				19,158								0				0	0	0	43,002		

Table 7-4 – Annual land-use changes (ha) in the period [1979-1985]

1985	1979	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Con	Rf crps	lr crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1979-1985	Net Gains
P. pinaster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q. suber		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus	985	363		1,855	0	0	0	83	0	1,507	0	147	0	0	0	0	0	0	7,375	0	12,314	21,854
Q. rotundifolia	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. Quercus	286	105	0	539		0	0	24	0	438	0	43	0	0	0	0	0	0	2,141	0	3,576	2,696
O. broadleaves	200	74	0	377	0		0	17	0	306	0	30	0	0	0	0	0	0	1,500	0	2,504	0
P. pinea	277	102	0	521	0	0		23	0	423	0	41	0	0	0	0	0	0	2,072	0	3,460	0
O. coniferous	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rain-fed crops	1,208	445	0	2,275	0	0	0	102		1,849	0	181	0	0	0	0	0	0	9,046	0	15,105	23,316
Irrigated crops	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
Rice	2	1	0	5	0	0	0	0	0	4		0	0	0	0	0	0	0	18	0	30	0
Vineyards	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
Olive	525	193	0	988	0	0	0	44	0	803	0	78		0	0	0	0	0	3,928	0	6,560	0
O. permanent	130	48	0	244	0	0	0	11	0	198	0	19	0		0	0	0	0	970	0	1,620	0
Grasslands	2,130	785	0	4,012	0	0	0	180	0	3,260	0	318	0	0		0	0	0	15,952	0	26,637	26,637
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Settlements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Shrubland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
O. land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Losses 1979-1985	5,742	2,115	0	10,815	0	0	0	486	0	8,788	0	859	0	0	0	0	0	0	43,002	0	71,807	0
				19,158						9,647						0	0	0	43,002			

Table 7-5 – Annual land-use changes (ha) in the period [1985-1989]

1989	1985	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Con	Rf crps	lr crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1985-1989	Net Gains
P. pinaster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q. suber	3,100		0	1,520	0	0	0	0	0	769	0	75	0	0	0	0	0	0	3,903	0	9,367	57,154
Eucalyptus	10,421	0		5,112	0	0	0	0	0	2,584	0	252	0	0	0	0	0	0	13,122	0	31,491	4,323
Q. rotundifolia	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. Quercus	416	0	0	204		0	0	0	0	103	0	10	0	0	0	0	0	0	524	0	1,257	0
O. broadleaves	3,268	0	0	1,603	0		0	0	0	810	0	79	0	0	0	0	0	0	4,114	0	9,874	0
P. pinea	1,390	0	0	682	0	0		0	0	345	0	34	0	0	0	0	0	0	1,751	0	4,201	0
O. coniferous	319	0	0	156	0	0	0		0	79	0	8	0	0	0	0	0	0	402	0	964	0
Rain-fed crops	4,999	0	0	2,452	0	0	0	0		1,239	0	121	0	0	0	0	0	0	6,294	0	15,105	23,316
Irrigated crops	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
Rice	10	0	0	5	0	0	0	0	0	2		0	0	0	0	0	0	0	13	0	30	0
Vineyards	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
Olive	2,171	0	0	1,065	0	0	0	0	0	538	0	53		0	0	0	0	0	2,733	0	6,560	0
O. permanent	536	0	0	263	0	0	0	0	0	133	0	13	0		0	0	0	0	675	0	1,420	0
Grasslands	8,815	0	0	4,324	0	0	0	0	0	2,186	0	214	0	0		0	0	0	11,099	0	26,637	26,637
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Settlements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Shrubland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
O. land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Losses 1985-1989	35,445	0	0	17,387	0	0	0	0	0	8,788	0	859	0	0	0	0	0	0	44,629	0	107,107	0
				52,831						9,647						0	0	0	44,629			

Table 7-6 – Annual land-use changes (ha) in the period [1989-1995]

1995	1989	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Con	Rf crops	Ir crops	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Setfl	Shrub	O. land	Annual Gains 1989-1995	Net Gain																		
P. pinaster		0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57.154	4.323																	
Q. suber	2,216				1,087	0	0	0	0	4,870	0	0	675	0	519	0	0	0	0	0	0																			
Eucalyptus	7,449	0			3,654	0	0	0	0	16,374	0	0	2,269	0	1,746	0	0	0	0	0	0																			
Q. rotundifolia		0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																			
O. Quercus	297	0	0	146			0	0	0	653	0	0	91	0	70	0	0	0	0	0	0																			
O. broadleaves	2,336	0	0	1,146	0			0	0	5,134	0	0	711	0	547	0	0	0	0	0	0																			
P. pinea	994	0	0	487	0	0		0	0	2,185	0	0	303	0	233	0	0	0	0	0	0																			
O. coniferous	228	0	0	112	0	0	0		0	501	0	0	69	0	53	0	0	0	0	0	0																			
Rain-fed crops		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0																			
Irrigated crops	588	0	0	288	0	0	0	0	0	1,293	0	0	179	0	138	0	0	0	0	0	0																			
Rice	16	0	0	8	0	0	0	0	0	35	0		5	0	4	0	0	0	0	0	0																			
Vineyards		0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0																			
Olive	2,476	0	0		1,214	0	0	0	0	5,442	0	0	754		580	0	0	0	0	0	0																			
O. permanent		0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0																			
Grasslands	9,090	0	0		4,459	0	0	0	0	19,981	0	0	2,769		2,130	0	0	0	0	0	0																			
Wetlands		0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0																			
Settlements		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0																			
Shrubland	9,756	0	0		4,786	0	0	0	0	21,446	0	0	2,972	0	2,287	0	0	0	0	0	0																			
O. land		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																			
Annual Losses 1989-1995	35,445	0	0		17,387	0	0	0	0	77,914	0	0	10,797	0	8,307	0	0	0	0	0	0																			
52.831																					97.018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7-7 – Annual land-use changes (ha) in the period [1995-2005]

2007	1995	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Com	Rf crops	Ir crops	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1995-2007	Net Gain
P. pinaster		206	1,154	3	193	415	77	36	1,937	195	0	104	332	37	680	0	38	7,868	122	13,398	48.680	18.872
Q. suber	447		218	473	20	36	70	1	1,103	21	1	14	349	10	2,158	0	4	923	6	5,855		
Eucalyptus	10,578	254		48	26	210	49	9	827	166	0	72	137	47	454	0	36	1,918	19	14,851		
Q. rotundifolia	42	258	91		5	3	10	12	255	3		2	68	12	620	0	10	456		1,846	30.044	-14.062
O. Quercus	315	7	26	0			141	0	2	533	52		13	30	4	45	2	664	10	1,844		
O. broadleaves	1,052	35	147	4	129		3	5	1,670	193	3	51	89	72	149	3	14	997	21	4,635		
P. pinea	175	322	159	489	1	17		2	820	38	2	18	140	58	1,721		5	1,806	0	5,772	30.044	-14.062
O. caniferous	69	0	27		9	7	3		112	7		3	3	1	59		4	170	4	479		
Rain-fed crops	404	107	152	354	51	94	27	1		1,853	63	1,093	526	5,481	3	20	1,164	5	12,490			
Irrigated crops	209	71	177	56	4	34	21	0	3,591		229	619	180	183	666	1	10	106	4	6,161		
Rice		0	0	0		1	0		8	368		1	0	2	10	1	1	0	0	392		
Vineyards	213	40	87	50	34	45	5	1	1,822	521	2		468	146	449	0	2	352	2	4,240		
Olive	76	47	52	78	11	27	2	0	2,870	294	14	169		58	676	0	3	390	2	4,769		
O. permanent	74	2	19	4	7	57	2	0	943	232	3	139	144		178		2	187	0	1,992		
Grasslands	103	526	86	899	14	31	30	4	6,846	777	34	507	493	204		5	42	2,338	330	13,271		
Wetlands	16	81	58	966	9	43	6		272	82	6	8	81	7	326		18	203	9	2,192		
Settlements	1,372	192	676	87	48	172	152	5	2,010	832	4	201	407	150	735	25		1,189	62	8,318		
Shrubland	2,399	56	204	41	177	285	6	27	1,982	215	1	158	1,353	221	2,017	2	95		1,091	10,329		
O. land	146	14	64	5	2	7	7	3	10	2		3	3	1	34	11	4	1,020		1,339	11.668	-11.770
Annual Losses 1995-2007	17,691	2,219	3,397	3,556	741	1,625	471	107	27,610	5,851	361	3,175	5,370	1,740	16,458	53	310	21,752	1,686	114.173	0	
					29,808							44,106			16,458	53	310		23,438			

Table 7-8 – Annual land-use changes (ha) in the period [2005-2012]

2010	2007	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Com	Rf crops	Ir crops	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Setfl	Shrub	O. land	Annual Gains 2007-2010	Net Gain			
P. pinaster		94	1,175	162	58	359	88	41	224	17		18	23	49	189	0	18	1,664	97		4,275	17,962	278		
Q. suber	529		257	310	25	67	107	6	262	6		0	17	0	610		0	273	1		2,472				
Eucalyptus	5,577	217		10	27	196	28	4	122	36	0	31	12	5	154		37	629	53		7,140				
Q. rotundifolia	6	124	170		23	29	58		234	1		0	6	3	321	2	2	93			1,073				
O. Quercus	66	5	22	3		49	0	1	56	4		1	1	1	22	2	2	174	3		410				
O. broadleaves	484	39	185	6	56		3	12	167	9	1	9	20	19	80		18	403	4		1,516				
P. pinea	409	168	99	30		18			19	1		2	14	6	77		4	36			883				
O. caniferous	49	2	11	2	7	48	5		15	3		1		2	18		4	25	1		192				
Rain-fed crops	235	76	146	86	107	102	8	1			477	1	783	702	259	3,288	0	22	694	2				6,990	
Irrigated crops	120	15	74	12	2	35	3			1,847		81	312	73	106	783	2	26	55	0				3,546	
Rice		0								20	819		5			56	0	1	3			905	22,733	827	
Vineyards	49	10	34	35	32	25	0		1,113	339				155	37	297		7	247	5		2,386			
Olive	64	30	117	198	5	17	13	0	3,596	1,312	13	236		146	1,891	4	3	254	9		7,907				
O. permanent	59	2	33	0	4	17	1	7	326	138			69	45		93		3	201			998			
Grasslands	55	134	129	150	3	10	13		3,135	387	1	824	508	280		1	70	1,132	46		6,877				
Wetlands	4	18	10	46	3	32	3	0	71	31	3		57	1	206		202	61	1		750				
Settlements	905	78	745	92	55	161	175	8	699	263	2	79	196	56	632	8			846	45		5,046			
Shrubland	400	51	665	15	26	84	1	105	498	32		54	255	40	2,887	1	61			2,563	7,739	5,046			4,556
O. land	102	5	69	3	1	25	2	1	3	1		1	0		89		7	451			760	8,499			-1,574
Annual Losses 2007-2010	9,114	1,069	3,942	1,158	432	1,275	507	186	12,405	3,879	103	2,426	2,084	11,694	1,010	11,694	19	490	7,241	2,831	61,866	0			
						17,683						21,906				11,694		19	490	10,073					

#### 7.1.2.4 Autonomous Region of Azores

For the Azores, the main sources of information available were:

1. COS (2007) – full wall-to-wall map
2. IFRAA (1987) and IFRAA (2007) – Regional Forest Inventory
3. RGA (1999) and RGA (2009) – General Census of Agriculture

The basis for the estimation of land-use and land-use change in the Azores was COS (2007) combined with growth rates estimated using the IFRAA and RGA, respectively for forest land and cropland and grassland.

For “Forest Land” the following estimation methodology was used:

1. The total area of forest (in hectares) COS (2007) was used directly.
2. For the period 1970-2012 the following assumptions were made:
  - a. total forest area increased (in % annual change) from 1970 to 2012 at the same rate as 1987-2007;
  - b. the share of area per forest type in the period 1970-1987 was considered the same as 1987;
  - c. the share of area per forest type in the period 1987-2007 was interpolated considering the shares of each forest types in 1987 and 2007;
  - d. the share of area per forest type in the period 2007-2012 was considered the same as 2007.

For “Cropland” and “Grassland” the following estimation methodology was used:

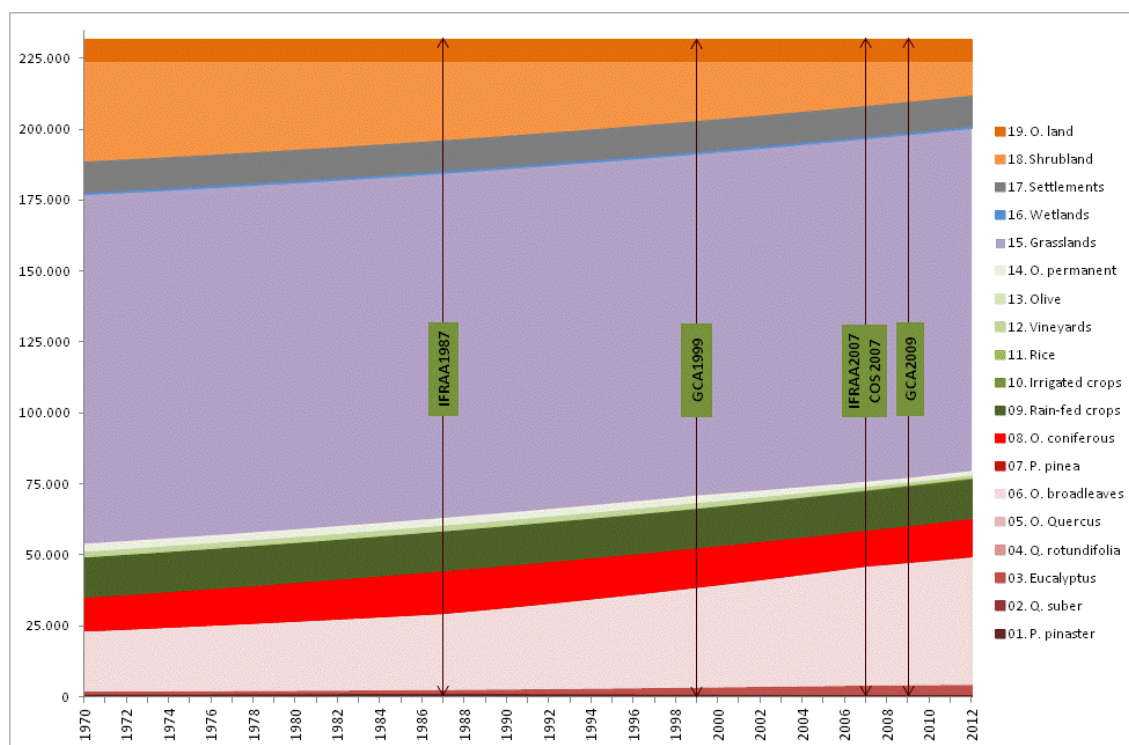
1. The total area of cropland + grassland (in hectares) COS (2007) was used directly.
2. For the period 1970-2012 the following assumptions were made:
  - a. total cropland + grassland area increased (in % annual change) from 1970 to 2012 at the same rate as RGA (1999) and RGA (2009);
  - b. the share of area per cropland or grassland type in the period 1970-1999 was considered the same as RGA (1999);
  - c. the share of area per cropland or grassland type in the period 1999-2009 was interpolated considering the shares of each cropland or grassland types in RGA (1999) and RGA (2009);
  - d. the share of area per cropland or grassland type in the period 2009-2012 was considered the same as RGA (2009).

For “Wetlands”, “Settlements” and “Other Land” the following estimation methodology was used:

1. The total area of wetlands plus settlements plus other land (in hectares) of COS (2007) was used directly.
2. For the period 1970-2012 the following assumptions were made:
  - a. The total area for the Autonomous Region of the Azores was maintained constant in the period 1970-2012 by adjusting the total sum of the categories “Wetland”, “Settlements” and “Other land”;
  - b. The share of each land-use type was considered the same as 2007.

The results for the full time series 1970-2012 for the Azores are presented in Figure 7-4.

Figure 7-4 – Changes in Total Land-Use (1000 ha) in the Azores and Main Information Sources Used



As mentioned above for the case of mainland Portugal, land use changes for the period 1970-2012 cannot be estimated separately from  $X \rightarrow Y$  and  $X \rightarrow Y$ , as the only information available is the total of net-changes in area in each period ( $X \rightarrow Y$  plus  $X \rightarrow Y$ ).

However, as Azore's total remains constant over time, the total sum of net-gains in area of a particular set of land-uses needs to be equal to the net-losses in area of all other land-uses. This principle was applied to derive land-use change estimates for all land-uses using Equation 7.2.

#### 7.1.2.5 *Autonomous Region of Madeira*

For Madeira, the main sources of information available were:

1. CLC (1990) and CLC (2006) – full wall-to-wall map from Corine Land Cover
2. IFRAM (2004) – Regional Forest Inventory
3. RGA (1999) and RGA (2009) – General Census of Agriculture

The basis for the estimation of land-use and land-use change in Madeira was CLC (1990) and CLC (2006) combined with growth rates estimated using the IFRAM and RGA, respectively for forest land and cropland and grassland.

For “Forest Land” the following estimation methodology was used:

1. The total area of forest (in hectares) CLC (1990) and CLC (2006) was used directly:

- a. total forest area increased (in % annual change) from 1970 to 2012 at the same rate as CLC 1990-2006;
2. For the period 1970-2012 the following assumptions were made:
  - a. the share of area per forest type in the period 1970-2012 was considered the same as in IFRAM (2004).

For “Cropland” and “Grassland” the following estimation methodology was used:

1. The total area of cropland + grassland (in hectares) of CLC (1990) and CLC (2006) was used directly.
2. For the period 1970-2012 the following assumptions were made:
  - a. total cropland + grassland area increased (in annual change) from 1970 to 2012 at the same rate as CLC 1990-2006;
  - b. the share of area per cropland or grassland type in the period 1970-1999 was considered the same as in RGA 1999;
  - c. the share of area per cropland or grassland type in the period 1999-2009 was interpolated considering the shares of each cropland or grassland types in RGA (1999) and RGA (2009);
  - d. the share of area per cropland or grassland type in the period 2009-2012 was considered the same as RGA (2009).

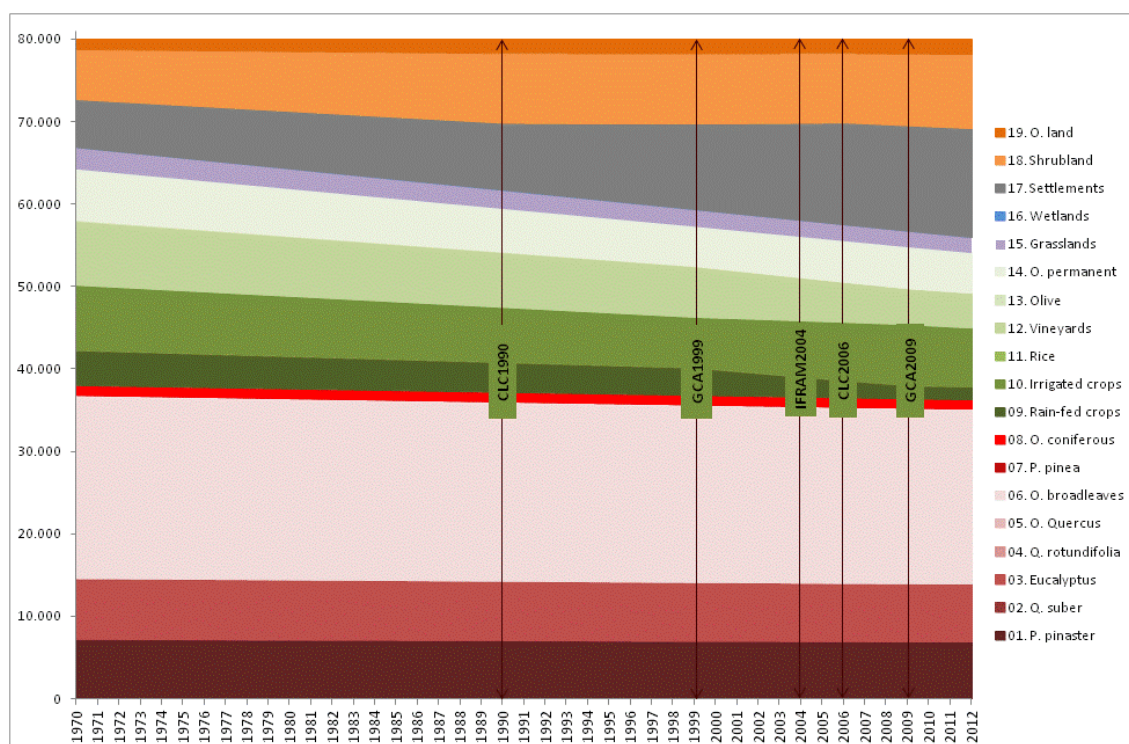
For “Wetlands”, “Settlements” and “Other Land” the following estimation methodology was used:

1. The total area of wetlands + settlements + other land (in hectares) of CLC (1990) and CLC (2006) was used directly;
2. For the period 1970-2012 the following assumptions were made:
  - a. total wetlands + settlements + other land area increased (in annual change) from 1970 to 2012 at the same rate as CLC 1990-2006;
  - b. the share of area per wetlands, settlements or other land type in the period 1970-1990 was considered the same as in CLC (1990);
  - c. the share of area per wetlands, settlements or other land type in the period 1990-2006 was interpolated considering the shares of each wetlands, settlements or other land type in CLC (1990) and CLC (2006);
  - d. the share of area per wetlands, settlements or other land type in the period 2006-2012 was considered the same as CLC (2006).

The results for the full time series 1970-2012 for Madeira are presented in Figure 7-5.



Figure 7-5 – Changes in Total Land-Use in Madeira (1000 ha) and Main Information Sources Used



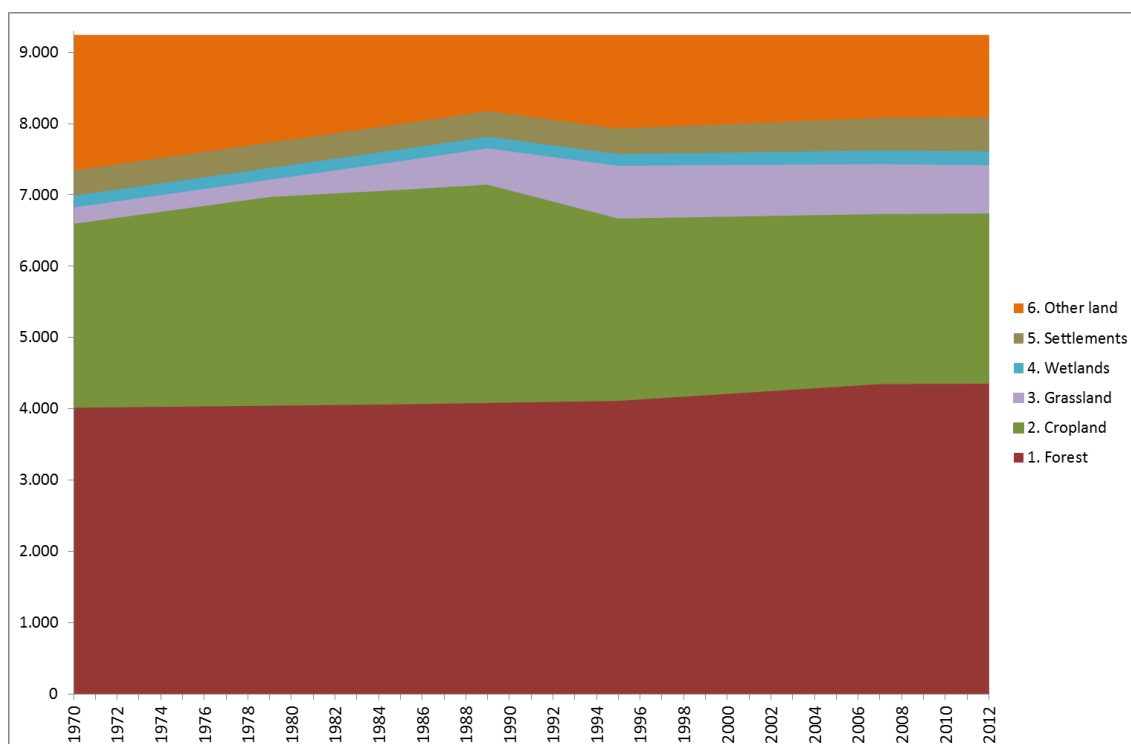
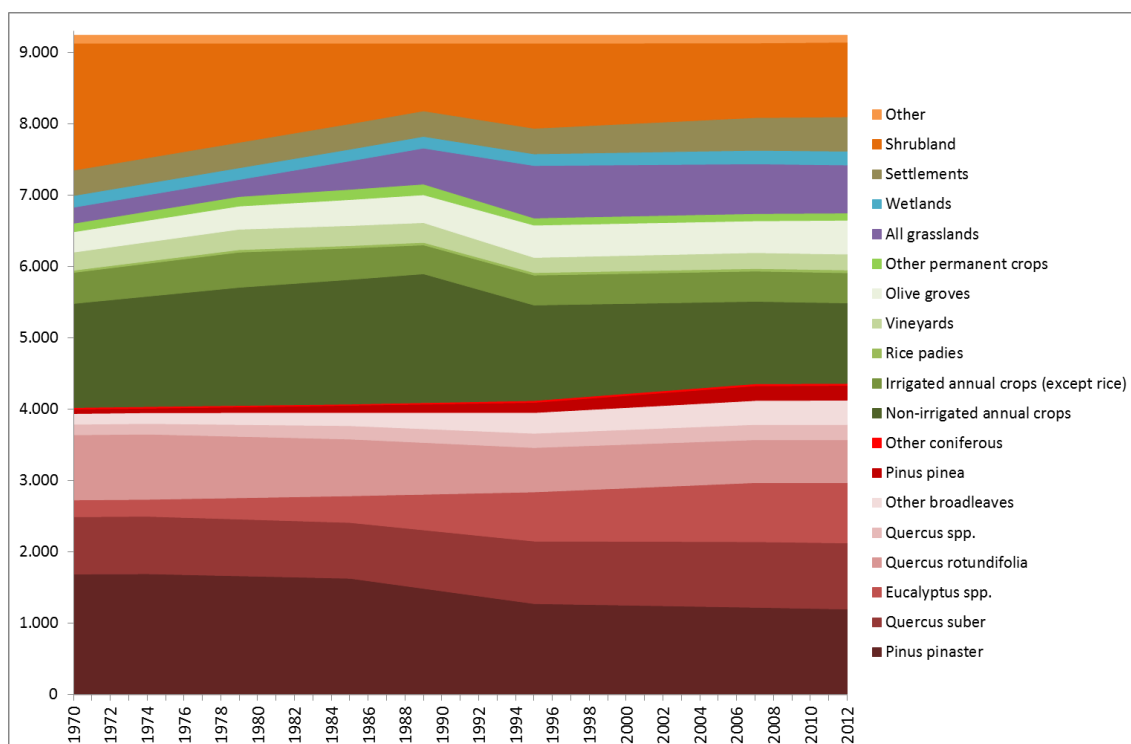
As mentioned above for the case of mainland Portugal, land use changes for the period 1970-2012 cannot be estimated separately from  $X \rightarrow Y$  and  $X \rightarrow Y$ , as the only information available is the total of net-changes in area in each period ( $X \rightarrow Y$  plus  $X \rightarrow Y$ ).

However, as Madeira's total area remains constant over time, the total sum of net-gains in area of a particular set of land-uses needs to be equal to the net-losses in area of all other land-uses. This principle was applied to derive land-use change estimates for all land-uses using Equation 7.2.

#### 7.1.2.6 Overview of Annual Land-Use Estimates for Portugal

The compilation of the estimates for land-use in Portugal, derived from the estimates made for Mainland Portugal, Azores and Madeira is presented in Figure 7-6.

Figure 7-6 – Changes in Total Land-Use (1000 ha) in Portugal



#### 7.1.2.7 Allocation of Land-use and Land-use Change to UNFCCC Reporting Categories

The allocation of each of the 19 land-use categories to each of the UNFCCC reporting categories was described in Table 7-1.

The allocation of land to the sub-categories land remaining land and land X converted to land Y was made using the annual land-use changes described in Table 7-2 through Table 7-8, assuming a 20 year conversion period, as shown in Equation 7.3.

Equation 7.3 – Estimation of Land Conversions for UNFCCC Reporting

$$LC_{y \rightarrow x, RY_i} = \sum_{i=20}^i ALUC_{y \rightarrow x, i}$$

Where:

$LC_{y \rightarrow x, RY_i}$  = Land Y converted to Land X in reporting year i (ha)

$ALUC_{y \rightarrow x, i}$  = Annual Land-use change from Y to X (ha)

The area of “land remaining land” categories was estimated by the difference between the total area of each land use in each year subtracted from the land under that land-use considered in transition, as shown in Equation 7.4.

Equation 7.4 – Estimation of Land Remaining Land for UNFCCC Reporting

$$LRL_{x, RY_i} = TA_{x, RY_i} - LC_{y \rightarrow x, RY_i}$$

Where:

$LRL_{x, RY_i}$  = Land Y remaining Land X in reporting year i (ha)

$TA_{x, RY_i}$  = Total Reported Area of land-use X in reporting year I, as shown in Figure 7-6 (ha)

$LC_{y \rightarrow x, RY_i}$  = Land Y converted to Land X in reporting year i (ha)

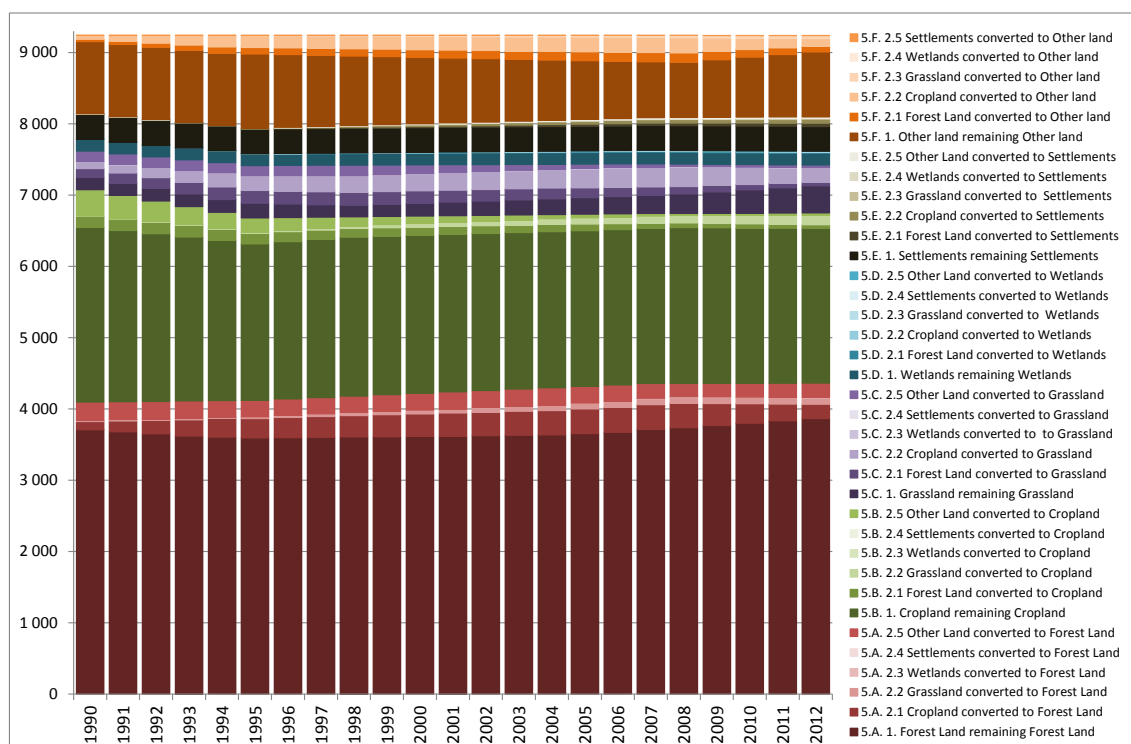
Land conversions within each broad UNFCCC reporting categories (e.g. changes from *Pinus pinaster* to *Eucalyptus sp*) were also estimated and used for estimating emissions and removals, but were reported as “Land remaining Land” (in the previous example, as “forest land remaining forest land”).

Although some lands may be considered as unmanaged (e.g. “shrubland”) the area and emissions estimates include the total of the territory.

The results of this exercise are presented in Figure 7-7.



Figure 7-7 – Total Areas (1000 ha) per UNFCCC Reporting Categories



#### 7.1.2.8 Allocation Land-use and Land-use Change to KP Accounting Categories

The allocation of each of the 19 land-use categories to each of the KP activities was made in a way that responds to the specific activity definitions under the KP LULUCF accounting rules.

For Afforestation and Reforestation all lands converted to forest “since 1990” were considered, as shown in Equation 7.5.

Equation 7.5 – Estimation of KP Areas under Afforestation and Reforestation

$$AR_{RY_i} = \sum_{\substack{1990 \text{ all } y \\ \text{all } x}}^i ALC_{NFLU_y \rightarrow FLU_x, i}$$

Where:

$AR_{RY_i}$  = Area of Afforestation and Reforestation in reporting year i (ha)

$ALC_{NFLU_y \rightarrow FLU_x, i}$  = Annual Land-use change from Non-Forest Land-use Y to Forest Land Use X in reporting year i ( $i \geq 1990$ ) (ha)

Harvested areas under Afforestation and Reforestation (reporting category A.1.2.) were estimated based on the rotation period of the main forest species. The only forest type that was able to complete a full rotation cycle during the Commitment Period was Eucalyptus plantations (first harvesting at 12 years). Therefore the estimates for this category included all areas planted 12 years before the reporting year in question, as shown in Equation 7.6.

Equation 7.6 – Estimation of KP Areas under Afforestation and Reforestation – Harvested during the Commitment Period

$$AR_{H,RY_i} = \sum_{2008}^i ALC_{NFLU_y \rightarrow Eucalyptus, i-12}$$

Where:

$AR_{H,RY_i}$  = Area of Afforestation and Reforestation Harvested in reporting year i (ha)

$ALC_{NFLU_y \rightarrow Eucalyptus, i-12}$  = Annual Land-use change from Non-Forest Land-use Y to Eucalyptus in reporting year i-12 (i ≥ 2008) (ha)

With the exception of the areas described above, all other areas under AR were considered as not-harvested and were reported under category A.1.1.

For Deforestation all lands converted from forest to other land-uses “since 1990” were considered, as shown in Equation 7.7.

Equation 7.7 – Estimation of KP Areas under Deforestation

$$D_{RY_i} = \sum_{1990 \text{ all } y, \text{ all } x}^i ALC_{FLU_y \rightarrow NFLU_x, i}$$

Where:

$D_{RY_i}$  = Area of Deforestation in reporting year i (ha)

$ALC_{FLU_y \rightarrow NFLU_x, i}$  = Annual Land-use change from Forest Land-use Y to Non-Forest Land Use X in reporting year i (i ≥ 1990) (ha)

Forest Management Areas were estimated using the total forest area (all areas are considered managed) in each reporting year deducted from the areas considered under “Afforestation and Reforestation”, as shown in Equation 7.8.

Equation 7.8 – Estimation of KP Areas under Forest Management

$$FM_{RY_i} = TA_{FLU, RY_i} - AR_{RY_i}$$

Where:

$FM_{RY_i}$  = Area under Forest Management in reporting year i (ha)

$TA_{FLU, RY_i}$  = Total Reported Area under Forest Land-Use in reporting year i, as shown in Figure 7-6 (ha)

$AR_{RY_i}$  = Area under Afforestation and Reforestation in reporting year i (ha)

Areas under “Cropland Management” were estimated considering the total area of cropland reported in each year of the Commitment Period, deducted from the areas converted to cropland from forest land during the Commitment Period (reported under deforestation) and added the areas converted from cropland to non-Kyoto activities during the Commitment Period (i.e., conversions to wetlands, settlements or other land), as shown in Equation 7.9.

Equation 7.9 Estimation of KP Areas under Cropland Management

$$CM_{RY_i} = TA_{CL,RY_i} - \sum_{1990 \text{ all } y}^i ALC_{FLU_y \rightarrow CL_x,i} + \sum_{2008 \text{ all } y}^i ALC_{CL_y \rightarrow NR_x,i}$$

Where:

$CM_{RY_i}$  = Area under Cropland Management in reporting year i (ha)

$TA_{CL,RY_i}$  = Total Reported Area under Cropland in reporting year i, as shown in Figure 7-6 (ha)

$ALC_{FLU_y \rightarrow CL_x,i}$  = Annual Land use changes from forest type Y to cropland type X in year i (ha)

$ALC_{CL_y \rightarrow NR_x,i}$  = Annual Land use changes from cropland type Y to Non-KP Activity type X in year i (ha)

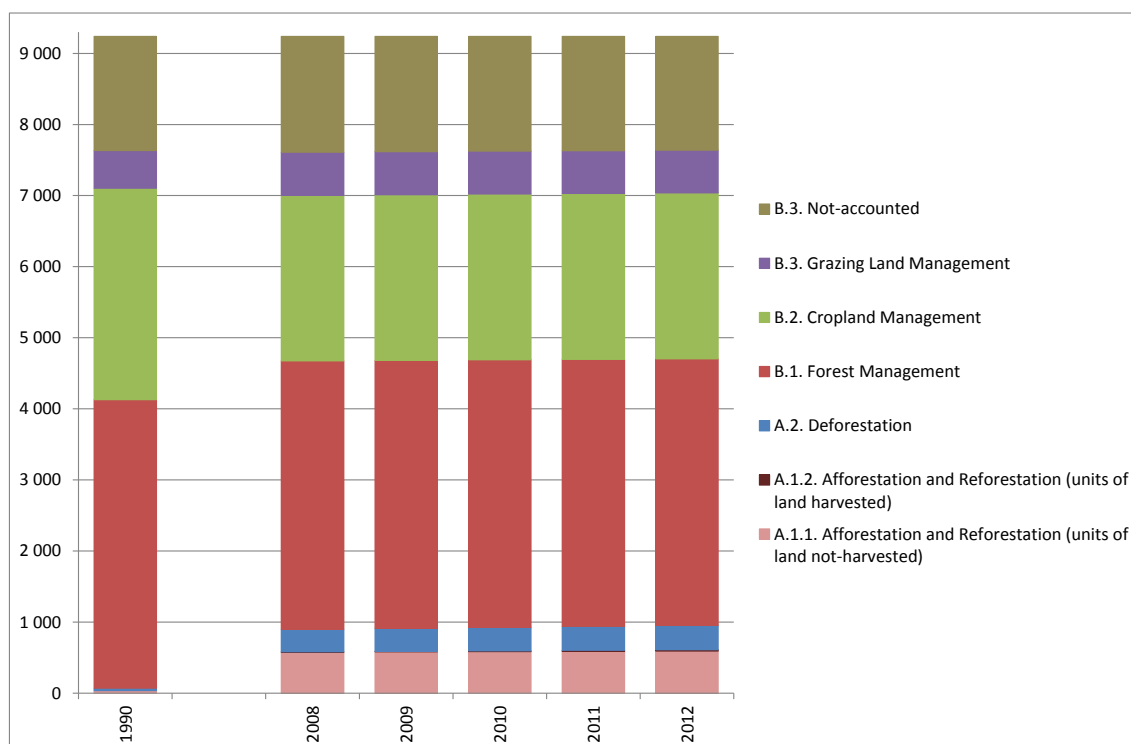
Conversions from cropland to grassland were reported as “Grazing land management”. Conversions between different cropland types were estimated and used in estimating emissions and removals, but the relevant conversion areas were included as “cropland management”.

Estimates for the base year were made considering the area of “Cropland management” in 1990 as the same as the total area of cropland in 1990.

A similar procedure was used to estimate areas under “Grazing land Management”.

A summary of the areas reported under the KP, per activity, is presented in Figure 7-8.

Figure 7-8 – Total Areas (1000 ha) per KP LULUCF Accounting Categories



### 7.1.3 Generic Methodologies Applicable to Multiple Land-Use Categories

#### 7.1.3.1 Biomass Expansion Factors, Root-To-Shoot factors and Carbon Fraction

##### 7.1.3.1.1 Forests

For the main forest species, biomass expansion factors and root-to-shoot factors were derived from NFI5 data using the equations:

$$BEF_f = \frac{AGB_f}{Vol_f} \quad RTS_f = \frac{BGB_f}{AGB_f}$$

Where:

$BEF_f$  = Biomass expansion factor for forest species  $f$  ( $tdm \ m^3$ )

$RTS_f$  = Root-to-shoot factor for forest species  $f$  (*adimensional*)

$AGB_f$  = Total Above Ground Biomass for forest species  $f$  ( $tdm = ton\ of\ dry\ mater$ )

$BGB_f$  = Total Below Ground Biomass for forest species  $f$  ( $tdm = ton\ of\ dry\ mater$ )

$Vol_f$  = Total Volume (under bark) for forest type species  $f$  ( $m^3$ )

The Total Above and Below Ground Biomass used in these estimations were retrieved from the NFI5 final report and the biomass equations used in NFI5 are described in its final report “Anexo Técnico” Section D, pages 182-186 (available in Portuguese only). All equations were parameterized for Portuguese conditions and are thus assumed to correctly represent national conditions.

#### 7.1.3.1.2 Other land uses

For other land-uses no country specific values were found. A series of values from literature were used instead. The main references were the Spanish NIR (submission 2012), for permanent crops, and the Emission Inventory Guidebook of EMEP/EEA (2009), for grasslands, shrubland and other lands.

#### 7.1.3.1.3 Carbon Fraction

The IPCC 2006 guidelines default value of 47% for carbon fraction of biomass was used.

Some other default values from IPCC were used in particular cases, where this was found to be more adequate. This was the case for broadleaves, coniferous and litter.

Table 7-9 summarises the results obtained and the values used in the NIR.

Table 7-9 – Calculated BEF, RTS and Carbon Fraction per Land use Type

Land-use Type	AGB <sub>t</sub> ktdm	BGB <sub>t</sub> ktdm	Vol <sub>t</sub> km <sup>3</sup>	BEF <sub>t</sub> tdm/m <sup>3</sup>	RTS <sub>t</sub> ad	C <sub>f</sub> LB %	C <sub>f</sub> litter %	Notes
Pinus pinaster	40.776	3.977	77.251	0,528	0,098	51%	37%	(1); (2); (3); (5); (6)
Quercus suber	27.049	3.605	21.833	1,239	0,133	48%	37%	(1); (2); (3); (4); (5); (6)
Eucalyptus spp.	24.391	6.066	38.701	0,630	0,249	48%	37%	(1); (2); (3); (5); (6)
Quercus rotundifolia	5.264	3.940	6.605	0,797	0,748	48%	37%	(1); (2); (3); (4); (5); (6)
Quercus spp.	3.415	1.117	3.795	0,900	0,327	48%	37%	(1); (2); (3); (4); (5); (6)
Other broadleaves	4.123	2.068	4.999	0,825	0,502	48%	37%	(1); (2); (3); (4); (5); (6)
Pinus pinea	3.536	191	3.032	1,166	0,054	51%	37%	(1); (2); (3); (5); (6)
Other coniferous	654	67	1229	0,532	0,102	51%	37%	(1); (2); (3); (5); (6)
Rainfed annual crops					1,000	47%	37%	(6); (10)
Irrigated annual crops (except rice)					1,000	47%	37%	(6); (10)
Rice paddies					1,000	47%	37%	(6); (10)
Vineyards	7,117	6,113			0,859	47%	37%	(6); (9)
Olive groves	16,706	2,438			0,146	47%	37%	(6); (9)
Other permanent crops	18,003	3,150			0,175	47%	37%	(6); (9)
All grasslands					1,778	47%	37%	(6); (8)
Wetlands						47%	37%	
Settlements						47%	37%	
Shrubland					0,563	47%	37%	(6); (7)
Other					0,563	47%	37%	(6); (7)

(1) Equations for volume and biomass used by IFN5 are presented in Anexo Técnico, pg 180.  
(2) Total volumes from IFN5 Table 302, pg 42. Values presented = sum of pure, dominant and young stands.  
(3) Total biomass from IFN5 Table 308, pg 46. Values presented = sum of pure, dominant and young stands.  
(4) Estimates of AGB presented do not include leaves.  
(5) Estimates of volume and biomass include small trees (DBH <7,5cm).  
(6) % C default values (51% coniferous; 48% broadleaves; 47% all; 37% litter) from 2006 IPCC Guidelines  
(7) Values from EMEP/EEA emission inventory guidebook 2009, Chapter 11b forest fires, table 3.2 "Scrubland", page 10  
(8) Values from EMEP/EEA emission inventory guidebook 2009, Chapter 11b forest fires, table 3.2 "Grassland (Steppe)", page 10  
(9) Living biomass per ha from NIR Spain 2012, Tabla 7.3.3, page 7.59. Unit values of AGB and BGB on per ha basis  
(10) No values were found in literature for RTS; assumed = 1

#### 7.1.3.2 Mean Annual Increment / Growth Rates

##### 7.1.3.2.1 Forests

Both NFI4 and NFI5 show that Portuguese forests have a high proportion of mixed species forests. Allocation to forest type for reporting purposes has been made by assigning each NFI plot to its dominant species.

For the estimation of Mean Annual Increments for dominated species the following equation was used:

$$MAI_{yf} = MAI_{ff} \times \frac{AVol_{yf}}{AVol_{ff}}$$

Where:

$MAI_{fy}$  = Mean Annual Increment of dominated species y in Forest Type f

$MAI_{ff}$  = Mean Annual Increment of dominant species f in Forest Type f

$AVol_{fy}$  = Average volume per hectare of dominated species y in Forest Type f

$AVol_{ff}$  = Average volume per hectare of dominant species f in Forest Type f

The values for  $MAI_{ff}$  are presented in Table 7-10.

Table 7-10 – Mean Annual Increment per Forest Type (in pure and dominant stands)

Forest species	$MAI_{ff}$ $m^3/ha.y$
Pinus pinaster	5,6
Quercus suber	0,5
Eucalyptus spp.	9,5
Quercus rotundifolia	0,5
Quercus spp.	2,9
Other broadleaves	2,9
Pinus pinea	5,6
Other coniferous	5,0

The average volumes from NFI4 and NFI 5 are presented, respectively, in Table 7-11 and Table 7-12.

Table 7-11 – Average volume per hectare and per tree species by forest type (NFI4/1995)

Mixed forests NFI 4		Forest Type							
average volume $m^3/ha$		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	91,6	1,5	7,3	0,2	8,3	16,1	6,9	0,9
	Quercus suber	0,7	30,5	0,4	4,8	0,5	1,0	8,6	0,3
	Eucalyptus spp.	5,1	0,2	46,9	0,0	1,0	2,6	0,2	0,2
	Quercus rotundifolia	0,1	1,3	0,0	16,0	0,0	0,1	0,0	0,9
	Quercus spp.	1,2	0,2	0,2	0,1	23,3	2,6	0,4	0,8
	Other broadleaves	1,4	0,4	0,4	0,1	5,9	32,9	0,2	2,6
	Pinus pinea	1,0	2,1	0,1	0,1	0,2	0,4	30,4	0,0
	Other coniferous	0,2	0,4	0,0	1,2	0,2	1,0	0,2	24,1
Total		101,1	36,5	55,4	22,5	39,5	56,7	46,8	29,7

Table 7-12 – Average volume per hectare and per tree species by forest type (NFI5/2005)

Mixed forests NFI 5		Forest Type							
average volume m3/ha		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	87,3	1,2	6,7	0,1	10,8	8,2	2,5	1,0
	Quercus suber	0,4	30,5	0,2	3,4	0,2	1,8	6,5	0,1
	Eucalyptus spp.	7,1	0,3	52,3	0,1	1,1	3,4	1,0	0,2
	Quercus rotundifolia	0,0	1,2	0,0	16,0	0,1	0,2	0,1	0,0
	Quercus spp.	1,1	0,1	0,1	0,3	25,3	4,0	0,0	0,8
	Other broadleaves	0,6	0,3	0,2	0,1	3,4	60,7	0,2	1,2
	Pinus pinea	0,2	1,4	0,1	0,0	0,0	0,2	23,3	0,1
	Other coniferous	0,1	0,0	0,0	0,0	0,6	2,0	0,1	49,0
Total		96.8	35.1	59.7	20.0	41.6	80.5	33.6	52.2

Finally, the results of the application of the equation above are presented in Table 7-13 and Table 7-14, respectively for NFI4 and NFI5.

Table 7-13 – Mean Annual Increments per Forest Species and Forest Type (NFI4/1995)

Mixed forests NFI 4		Forest Type							
annual increment m3/ha.year		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	5,6	0,1	0,4	0,0	0,5	1,0	0,4	0,1
	Quercus suber	0,0	0,5	0,0	0,1	0,0	0,0	0,1	0,0
	Eucalyptus spp.	1,0	0,0	9,5	0,0	0,2	0,5	0,0	0,0
	Quercus rotundifolia	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0
	Quercus spp.	0,1	0,0	0,0	0,0	2,9	0,3	0,0	0,1
	Other broadleaves	0,1	0,0	0,0	0,0	0,5	2,9	0,0	0,2
	Pinus pinea	0,2	0,4	0,0	0,0	0,0	0,1	5,6	0,0
	Other coniferous	0,0	0,1	0,0	0,2	0,0	0,2	0,0	5,0

Table 7-14 – Mean Annual Increments per Forest Species and Forest Type (NFI5/2005)

Mixed forests NFI 5		Forest Type							
annual increment m3/ha.year		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	5,6	0,1	0,4	0,0	0,7	0,5	0,2	0,1
	Quercus suber	0,0	0,5	0,0	0,1	0,0	0,0	0,1	0,0
	Eucalyptus spp.	1,3	0,1	9,5	0,0	0,2	0,6	0,2	0,0
	Quercus rotundifolia	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0
	Quercus spp.	0,1	0,0	0,0	0,0	2,9	0,5	0,0	0,1
	Other broadleaves	0,0	0,0	0,0	0,0	0,2	2,9	0,0	0,1
	Pinus pinea	0,1	0,3	0,0	0,0	0,0	0,0	5,6	0,0
	Other coniferous	0,0	0,0	0,0	0,0	0,1	0,2	0,0	5,0

These Mean Annual Increments are referred to the respective inventory year (1995 and 2005) and interpolated for the remaining years, as shown for in Table 7-15.

Table 7-15 – Mean Annual Increments (m<sup>3</sup>/ha.year) used for each Forest Type

Mean Annual Increments for Pinus pinaster		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60
	Quercus suber	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Eucalyptus spp.	1,03	1,06	1,08	1,11	1,14	1,16	1,19	1,21	1,24	1,26	1,29
	Quercus rotundifolia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Quercus spp.	0,14	0,14	0,14	0,14	0,14	0,13	0,13	0,13	0,13	0,13	0,12
	Other broadleaves	0,12	0,11	0,10	0,09	0,08	0,07	0,07	0,06	0,05	0,04	0,03
	Pinus pinea	0,18	0,17	0,15	0,14	0,13	0,11	0,10	0,09	0,08	0,06	0,05
	Other coniferous	0,04	0,04	0,03	0,03	0,03	0,03	0,02	0,02	0,02	0,01	0,01

Mean Annual Increments for Quercus suber		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,08	0,08	0,08	0,08
	Quercus suber	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
	Eucalyptus spp.	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,05	0,05	0,05	0,06
	Quercus rotundifolia	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04
	Quercus spp.	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,01	0,01	0,01	0,01
	Other broadleaves	0,03	0,03	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,01	0,01
	Pinus pinea	0,39	0,38	0,38	0,37	0,37	0,36	0,36	0,35	0,35	0,35	0,34
	Other coniferous	0,07	0,07	0,06	0,05	0,05	0,04	0,03	0,03	0,02	0,01	0,00

Mean Annual Increments for Eucalyptus globulus		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,44	0,44	0,44	0,44	0,44	0,44	0,43	0,43	0,43	0,43	0,43
	Quercus suber	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,00	0,00	0,00	0,00
	Eucalyptus spp.	9,50	9,50	9,50	9,50	9,50	9,50	9,50	9,50	9,50	9,50	9,50
	Quercus rotundifolia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Quercus spp.	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
	Other broadleaves	0,04	0,04	0,03	0,03	0,03	0,02	0,02	0,02	0,02	0,01	0,01
	Pinus pinea	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02
	Other coniferous	0,01	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Mean Annual Increments for Quercus rotundifolia		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Quercus suber	0,08	0,08	0,07	0,07	0,07	0,07	0,06	0,06	0,06	0,06	0,06
	Eucalyptus spp.	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02
	Quercus rotundifolia	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
	Quercus spp.	0,01	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03
	Other broadleaves	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,00	0,00
	Pinus pinea	0,02	0,02	0,02	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01
	Other coniferous	0,24	0,22	0,20	0,17	0,15	0,12	0,10	0,07	0,05	0,03	0,00

Mean Annual Increments for Quercus spp.		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,51	0,52	0,54	0,56	0,58	0,60	0,62	0,64	0,66	0,67	0,69
	Quercus suber	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,00	0,00	0,00
	Eucalyptus spp.	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20
	Quercus rotundifolia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Quercus spp.	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90
	Other broadleaves	0,52	0,49	0,45	0,42	0,38	0,34	0,31	0,27	0,23	0,20	0,16
	Pinus pinea	0,04	0,04	0,03	0,03	0,03	0,02	0,02	0,02	0,01	0,01	0,00
	Other coniferous	0,03	0,04	0,04	0,04	0,04	0,05	0,05	0,05	0,05	0,06	0,06



Mean Annual Increments for Other broadleaves		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,99	0,94	0,89	0,85	0,80	0,76	0,71	0,66	0,62	0,57	0,53
	Quercus suber	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03	0,03
	Eucalyptus spp.	0,53	0,54	0,55	0,56	0,57	0,58	0,59	0,60	0,61	0,62	0,63
	Quercus rotundifolia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01
	Quercus spp.	0,32	0,33	0,35	0,36	0,37	0,39	0,40	0,42	0,43	0,44	0,46
	Other broadleaves	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90	2,90
	Pinus pinea	0,07	0,07	0,06	0,06	0,06	0,06	0,06	0,05	0,05	0,05	0,05
	Other coniferous	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20

Mean Annual Increments for Pinus pinea		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,42	0,39	0,37	0,34	0,32	0,29	0,27	0,24	0,21	0,19	0,16
	Quercus suber	0,14	0,14	0,13	0,13	0,13	0,12	0,12	0,12	0,11	0,11	0,11
	Eucalyptus spp.	0,04	0,05	0,06	0,08	0,09	0,11	0,12	0,13	0,15	0,16	0,18
	Quercus rotundifolia	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Quercus spp.	0,04	0,04	0,04	0,03	0,03	0,02	0,02	0,02	0,01	0,01	0,00
	Other broadleaves	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Pinus pinea	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60	5,60
	Other coniferous	0,03	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,01	0,01	0,01

Mean Annual Increments for Other coniferous		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2011
Dominated species	Pinus pinaster	0,05	0,05	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
	Quercus suber	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Eucalyptus spp.	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,03	0,03	0,03	0,03
	Quercus rotundifolia	0,03	0,03	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,00	0,00
	Quercus spp.	0,10	0,10	0,10	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
	Other broadleaves	0,23	0,21	0,19	0,18	0,16	0,14	0,12	0,11	0,09	0,07	0,06
	Pinus pinea	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,02
	Other coniferous	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00

#### 7.1.3.2.2 Other Land uses

For other land-uses annual living biomass increments were estimated dividing the average standing biomass divided by its conversion period, after which the biomass is assumed to stabilize.

Equation 7.10 - Estimation of Mean Annual Increment in Other Land Uses

$$MAI_l = \frac{AGB_l}{CP_l}$$

Where:

$MAI_l$  = Mean Annual Increment of land-use type l

$AGB_l$  = Average Above Ground Biomass of land-use type l

$CP_l$  = Conversion Period of land-use type l

A similar approach was made to calculate below ground increments of biomass.

The results are presented in Table 7-16.

Table 7-16 – Mean Annual Increments used for Other Land Uses

Mean Annual Increments for Other Land uses	AGB	BGB	transition period considered
Rainfed annual crops	0,31	0,31	1
Irrigated annual crops (except rice)	0,31	0,31	1
Rice padies	0,31	0,31	1
Vineyards	0,17	0,14	20
Olive groves	0,39	0,06	20
Other permanent crops	0,42	0,07	20
All grasslands	0,53	0,94	1
Wetlands	0,00	0,00	1
Settlements	0,00	0,00	1
Shrubland	0,44	0,25	20
Other	0,05	0,03	20

unit: tC/year

### 7.1.3.3 Average Carbon Stocks in Living Biomass per Land-use Type

Average carbon stocks are used for estimating emissions from land-use conversion and fire emissions.

#### 7.1.3.3.1 Forests

In the case of forests, carbon stocks were estimated by converting standing volumes, through the Biomass Expansion Factors, Root-to-shoot ratios and Carbon fraction into total Carbon per unit of land. Carbon stocks were calculated separately for total, above and below ground biomass using Equation 7.11 to Equation 7.13.

Equation 7.11 - Estimation of Total Average Living Biomass in Forests

$$LB_f = \frac{AVol_{yf}}{y} \times BEF_y \times (1 + RTS_y) \times CF_y$$

Equation 7.12 - Estimation of Above Ground Living Biomass in Forests

$$AGB_f = \frac{AVol_{yf}}{y} \times BEF_y \times CF_y$$

Equation 7.13 - Estimation of Below Ground Living Biomass in Forests

$$BGB_f = \frac{AVol_{yf}}{y} \times BEF_y \times RTS_y \times CF_y$$

Where:

$LB_f$  = Average Living Biomass of forest type  $f$  (tC/ha)

$AGB_f$  = Average Above Ground Biomass of forest type  $f$  (tC/ha)

$BGB_f$  = Average Below Ground Biomass of forest type  $f$  (tC/ha)

$AVol_{yf}$  = Average Standing Volume of forest species  $y$  in forest type  $f$  (m<sup>3</sup>/ha)

$BEF_y$  = Biomass Expansion Factor for forest species  $y$

$RTS_y$  = Root-to-Shoot Factor for forest species  $y$

$CF_y$  = Carbon Fraction for forest species  $y$

#### 7.1.3.3.2 Shrubland

For estimating above ground biomass the model proposed by Olson (1963) and adjusted for Portugal by Rosa (2009) was used.

Equation 7.14 - Estimation of Above Ground Living Biomass in Shrubland

$$AGB_s = 18.86 \times (1 - e^{-0.23t}) \times CF_s$$

Where:

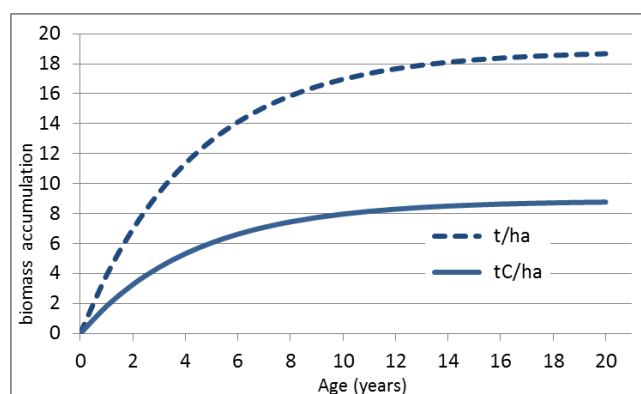
$AGB_s$  = Average Above Ground Biomass of shrubs (tC/ha)

$t$  = time in years

$CF_s$  = Carbon Fraction for shrubs

A 20 years period was assumed for estimating the average above ground biomass. The same value divided by 20 was used as the Mean Annual Increment for shrubland. The application of the equation above is presented in Figure 7-9.

Figure 7-9 – Biomass accumulation in Shrubland in Portugal



Below ground and total living biomass were estimated using the root-to-shoot value presented in section 7.1.3.1.

#### 7.1.3.3.3 Other Land-use Types

For other land-uses no country specific values were found. A series of values from literature were used instead. The main references were the Spanish NIR (submission 2012), for permanent crops, and the Emission Inventory Guidebook of EMEP/EEA (2009), for grasslands, shrubland and other lands.

Table 7-17: Average Carbon Stocks in Living Biomass and Litter per Land Use Type

Average Carbon Stocks per Landuse Type	Above Ground Biomass			Below Ground Biomass			Litter	Notes
	1995 GgC/1.000ha	2005 GgC/1.000ha	2010 GgC/1.000ha	1995 GgC/1.000ha	2005 GgC/1.000ha	2010 GgC/1.000ha	All years GgC/1.000ha	
Pinus pinaster	28,29	26,74	26,74	3,33	3,14	3,14	2,96	(1); (8)
Quercus suber	20,67	20,04	20,04	3,03	2,94	2,94	2,04	(1); (8)
Eucalyptus spp.	16,72	17,97	17,97	3,88	4,20	4,20	1,85	(1); (8)
Quercus rotundifolia	9,47	8,37	8,37	5,03	4,92	4,92	2,04	(1); (8)
Quercus spp.	15,45	15,87	15,87	4,83	4,69	4,69	1,85	(1); (8)
Other broadleaves	20,40	30,79	30,79	7,67	13,34	13,34	1,85	(1); (8)
Pinus pinea	25,40	18,79	18,79	1,96	1,46	1,46	2,41	(1); (8)
Other coniferous	8,70	14,51	14,51	1,62	1,76	1,76	2,96	(1); (8)
Rainfed annual crops	0,31	0,31	0,31	0,31	0,31	0,31	0,33	(4)
Irrigated annual crops (except rice)	0,31	0,31	0,31	0,31	0,31	0,31	0,33	(4)
Rice padies	0,31	0,31	0,31	0,31	0,31	0,31	0,33	(4)
Vineyards	3,34	3,34	3,34	2,87	2,87	2,87	0,33	(5); (6)
Olive groves	7,85	7,85	7,85	1,15	1,15	1,15	0,33	(5); (6)
Other permanent crops	8,46	8,46	8,46	1,48	1,48	1,48	0,33	(5); (6)
All grasslands	0,53	0,53	0,53	0,94	0,94	0,94	0,41	(2)
Wetlands	0,00	0,00	0,00	0,00	0,00	0,00	0,00	(9)
Settlements	0,00	0,00	0,00	0,00	0,00	0,00	0,00	(9)
Shrubland	8,78	8,78	8,78	4,94	4,94	4,94	4,96	(3)
Other	1,05	1,05	1,05	0,59	0,59	0,59	2,07	(7)

(1) Living biomass calculated from NF14 (1995), NF15 (2005) and NF16 (2010). NF16 data will be available in 2013; NIR 2013 assumed = 2005  
(2) Calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Grassland vegetated by perennial grasses", page 6  
(3) Calculated from Rosa 2009 "Estimativa das emissões de gases com efeito de estufa"  
(4) Calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Grassland vegetated by annual grasses and forbs", page 6  
(5) Litter calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Non-forest class", page 6  
(6) Living biomass from NIR Spain 2012, Tabla 7.3.3, page 7.59  
(7) Calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Sparsely vegetated areas", page 6  
(8) Litter values from expert judgement based on Rosa 2009 "Estimativa das emissões de gases com efeito de estufa", Quadro 1, page 19  
(9) No values were found in literature; assumed = 0

#### 7.1.3.4 Litter

Soil emission/sequestration factors were calculated for all possible land-use changes considering the changes in average C Stocks for each land-use, as contained in Table 7-17 and a 20 year conversion period, as shown in Equation 7.15.

Equation 7.15 - Estimation of Litter Emission Factors

$$LEF_{x \rightarrow y} = \frac{ALC_y - ALC_x}{20}$$

Where:

$LEF_{x \rightarrow y}$  = Litter Emission Factor for Land-use Change from x to y (tC/ha/year)

$ALC_y$  = Average Litter Carbon Stock in Land Use y (tC/ha)

$ALC_x$  = Average Litter Carbon Stock in Land Use x (tC/ha)

Table 7-18 – Annual Emission/Sequestration Factors (GgC/1000 ha) for Litter

Changes		TO																		
		Forest land								Cropland						G	W	S	OL	
FROM		Pp	Qs	E spp	Qr	Qspp	Ob	P pinea	OC	Rf	I	R	V	O	Op	G	W	S	Sh	O
Forest land	Pinus pinaster	0,000	-0,046	-0,056	-0,046	-0,056	-0,056	-0,028	0,000	-0,131	-0,131	-0,131	-0,131	-0,131	-0,131	-0,127	-0,148	-0,148	0,100	-0,044
	Quercus suber	0,046	0,000	-0,009	0,000	-0,009	-0,009	0,019	0,046	-0,085	-0,085	-0,085	-0,085	-0,085	-0,085	-0,081	-0,102	-0,102	0,146	0,002
	Eucalyptus spp.	0,056	0,009	0,000	0,009	0,000	0,000	0,028	0,056	-0,076	-0,076	-0,076	-0,076	-0,076	-0,076	-0,072	-0,093	-0,093	0,156	0,011
	Quercus rotundifolia	0,046	0,000	-0,009	0,000	-0,009	-0,009	0,019	0,046	-0,085	-0,085	-0,085	-0,085	-0,085	-0,085	-0,081	-0,102	-0,102	0,146	0,002
	Quercus spp.	0,056	0,009	0,000	0,009	0,000	0,000	0,028	0,056	-0,076	-0,076	-0,076	-0,076	-0,076	-0,076	-0,072	-0,093	-0,093	0,156	0,011
	Other broadleaves	0,056	0,009	0,000	0,009	0,000	0,000	0,028	0,056	-0,076	-0,076	-0,076	-0,076	-0,076	-0,076	-0,072	-0,093	-0,093	0,156	0,011
	Pinus pinea	0,028	-0,019	-0,028	-0,019	-0,028	-0,028	0,000	0,028	-0,104	-0,104	-0,104	-0,104	-0,104	-0,104	-0,100	-0,120	-0,120	0,128	-0,017
	Other coniferous	0,000	-0,046	-0,056	-0,046	-0,056	-0,056	-0,028	0,000	-0,131	-0,131	-0,131	-0,131	-0,131	-0,131	-0,127	-0,148	-0,148	0,100	-0,044
Cropland	Rainfed annual crops	0,131	0,085	0,076	0,085	0,076	0,076	0,104	0,131	0,000	0,000	0,000	0,000	0,000	0,000	0,004	-0,017	-0,017	0,231	0,087
	Irrigated annual crops (except rice)	0,131	0,085	0,076	0,085	0,076	0,076	0,104	0,131	0,000	0,000	0,000	0,000	0,000	0,000	0,004	-0,017	-0,017	0,231	0,087
	Rice padies	0,131	0,085	0,076	0,085	0,076	0,076	0,104	0,131	0,000	0,000	0,000	0,000	0,000	0,000	0,004	-0,017	-0,017	0,231	0,087
	Vineyards	0,131	0,085	0,076	0,085	0,076	0,076	0,104	0,131	0,000	0,000	0,000	0,000	0,000	0,000	0,004	-0,017	-0,017	0,231	0,087
	Olive groves	0,131	0,085	0,076	0,085	0,076	0,076	0,104	0,131	0,000	0,000	0,000	0,000	0,000	0,000	0,004	-0,017	-0,017	0,231	0,087
	Other permanent crops	0,131	0,085	0,076	0,085	0,076	0,076	0,104	0,131	0,000	0,000	0,000	0,000	0,000	0,000	0,004	-0,017	-0,017	0,231	0,087
Grassland	All grasslands	0,127	0,081	0,072	0,081	0,072	0,072	0,100	0,127	-0,004	-0,004	-0,004	-0,004	-0,004	-0,004	0,000	-0,021	-0,021	0,227	0,083
Wetlands	Wetlands	0,148	0,102	0,093	0,102	0,093	0,093	0,120	0,148	0,017	0,017	0,017	0,017	0,017	0,017	0,021	0,000	0,000	0,248	0,104
Settlements	Settlements	0,148	0,102	0,093	0,102	0,093	0,093	0,120	0,148	0,017	0,017	0,017	0,017	0,017	0,017	0,021	0,000	0,000	0,248	0,104
Other Land	Shrubland	-0,100	-0,146	-0,156	-0,146	-0,156	-0,156	-0,128	-0,100	-0,231	-0,231	-0,231	-0,231	-0,231	-0,231	-0,227	-0,248	-0,248	0,000	-0,145
	Other	-0,044	-0,002	-0,011	-0,002	-0,011	-0,011	0,017	0,044	-0,087	-0,087	-0,087	-0,087	-0,087	-0,087	-0,083	-0,104	-0,104	0,145	0,000

#### 7.1.3.5 Soil C Stock Data

Data for soils and soil emission factors is derived from measurements made from three data sets: Measurements made over the ICP Forests grid (1995 and 2005); Project Biosoil (1999); LUCAS soil assessment (2009).

Measurements were made in forest areas over the ICP Forest Sampling Grid in 1995 and repeated for the same plots in 2005. An additional project carried out in 1999 expanded the ICP Forests grid to agriculture and grassland plots. LUCAS was a project conducted by JRC that collected samples throughout Europe. Samples were collected in all sites at 0-20cm depth and some samples were collected also covering the 20-40cm. A summary of the number of plots is presented in Table 7-19.

Table 7-19 – Number of sample plots per land-use and soil depth

No. Plots C(0-20cm) (measured)		Source					No. Plots C(20-40cm) (measured)		Source					Total
		LUCAS	1995/99	2005	Total	Total			LUCAS	1995/99	2005	Total	Total	
Legenda KP		2009	1995/99	2005	Total	Total	Legenda KP		2009	1995/99	2005	Total	Total	
01. Pinus pinaster		54	41	12	53	107	01. Pinus pinaster		0	1	12	13	13	
02. Quercus suber		57	42	37	79	136	02. Quercus suber		0	3	35	38	38	
03. Eucalyptus		46	21	8	29	75	03. Eucalyptus		0		8	8	8	
04. Quercus rotundifolia		30	25	23	48	78	04. Quercus rotundifolia		0		21	21	21	
05. Other quercus		10	4	4	8	18	05. Other quercus		0		4	4	4	
06. Other broadleaves		5	19	17	36	41	06. Other broadleaves		0	1	17	18	18	
07. Pinus pinea + 08. Other coniferous		4	2	1	3	7	07. Pinus pinea + 08. Other coniferous		0	1	1	2	2	
09. Rain-fed crops		78	21		21	99	09. Rain-fed crops		0	21		21	21	
10. Irrigated crops + 11. Rice		22	26		26	48	10. Irrigated crops + 11. Rice		0	25		25	25	
12. Vineyards		22	14		14	36	12. Vineyards		0	14		14	14	
13. Olive		39	12		12	51	13. Olive		0	12		12	12	
14. Other permanent		11	11		11	22	14. Other permanent		0	11		11	11	
15. Grassland		42	18		18	60	15. Grassland		0	15		15	15	
17. Settlements		7				7	17. Settlements		0					
18. Shrubland		36	5	1	6	42	18. Shrubland		0	5	1	6	6	
Total		463	261	103	364	828	Total		0	109	99	208	208	

Given the relatively low number of sampled plots and the lack of land-use history for each of these plots, this information was used to characterize the average carbon stock in each land-use. The summary of results is presented in Table 7-20.

Table 7-20 – Average C Stock measured per land-use and soil depth

Average C (0-20cm) ton/ha (measured)	Source				
	LUCAS	ICP/Biosoil			Total
Legenda KP	2009	1995/99	2005	Average	Average
01. Pinus pinaster	70	73	72	72	71
02. Quercus suber	46	43	40	41	43
03. Eucalyptus	75	41	41	41	62
04. Quercus rotundifolia	41	43	45	44	43
05. Other quercus	58	51	52	52	55
06. Other broadleaves	71	66	63	64	65
07. Pinus pinea + 08. Other coniferous	74	25	64	38	58
09. Rain-fed crops	40	27		27	37
10. Irrigated crops + 11. Rice	39	39		39	39
12. Vineyards	36	24		24	31
13. Olive	49	33		33	45
14. Other permanent	44	26		26	35
15. Grassland	43	30		30	39
17. Settlements	55				55
18. Shrubland	70	52	88	58	68
Média global	52	44	50	46	49

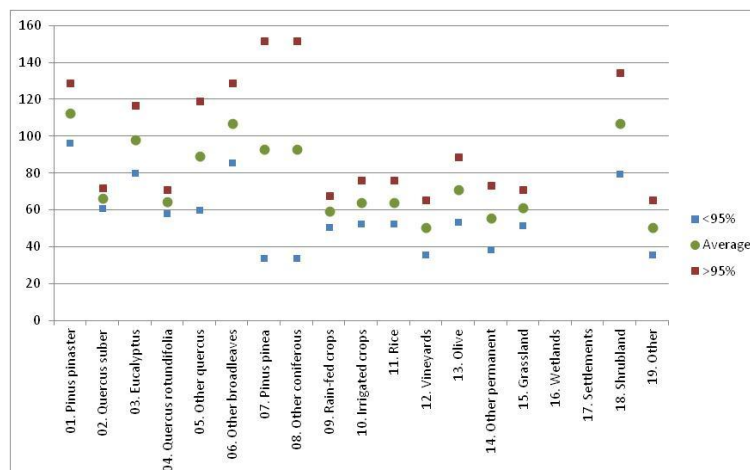
Average C (0-40cm) ton/ha (measured)	Source				
	LUCAS	ICP/Biosoil			
Legenda KP	20-40cm	0-20cm	20-40cm	0-40cm	40/20cm
01. Pinus pinaster		77	45	122	59%
02. Quercus suber		38	15	53	40%
03. Eucalyptus		41	26	67	63%
04. Quercus rotundifolia		44	15	59	35%
05. Other quercus		52	39	91	74%
06. Other broadleaves		60	45	105	75%
07. Pinus pinea + 08. Other coniferous		46	28	74	62%
09. Rain-fed crops		27	19	46	71%
10. Irrigated crops + 11. Rice		37	28	65	74%
12. Vineyards		24	16	40	69%
13. Olive		33	20	53	61%
14. Other permanent		26	16	42	61%
15. Grassland		33	18	51	54%
17. Settlements					
18. Shrubland		58	33	91	58%
Grand Total		41	24	64	58%

For all 208 plots for which both 0-20 cm and 20-40 cm was available the ratio of Carbon between the 2 depths was calculated and used to estimate the missing information for all the plots for which only 0-20 cm samples had been collected. The average C stock per land use is presented in Table 7-21. Figure 7-10 shows graphically the averages per land-use type and the respective 95% confidence interval.

Table 7-21 – Average C Stock 0-40 cm per land-use

Average C (0-40cm) ton/ha (measured + estimated)	Source				
	LUCAS	ICP/Biosoil			Total
Legenda KP	2009	1995/99	2005	Average	Average
01. Pinus pinaster	111	116	110	115	113
02. Quercus suber	73	67	56	62	66
03. Eucalyptus	119	65	67	65	98
04. Quercus rotundifolia	65	68	61	65	65
05. Other quercus	92	81	91	86	89
06. Other broadleaves	113	103	110	106	107
07. Pinus pinea + 08. Other coniferous	117	35	113	61	93
09. Rain-fed crops	63	46		46	59
10. Irrigated crops + 11. Rice	61	67		67	64
12. Vineyards	57	40		40	51
13. Olive	77	53		53	71
14. Other permanent	70	42		42	56
15. Grassland	68	47		47	61
17. Settlements	87				87
18. Shrubland	110	82	137	91	107
Média global	82	71	76	73	78

Figure 7-10 – Average C Stock 0-40 cm per land-use



Each difference in Carbon stocks (19x19 differences) was tested for its significance using a t-test for differences in means from samples of unequal size and unequal variances. An Emission Factor was calculated with Equation 7.16 only where the difference between average C stocks of the respective land-uses was considered significant. The emission factor was considered to be zero in all other cases. An example of how this was processed is presented in Table 7-22.

Table 7-22 – Annual Emission/Sequestration Factors (tC/ha) for Soil Transitions to Pinus pinaster

Data from ICP/Biosoil and LUCAS		Emission Factors based on Significant Differences					All differences	
From	To	minimum confidence interval 95%	Emission Factor	maximum confidence interval 95%	uncertainty ton/ha	uncertainty %	difference in carbon stocks	significance t-Test
01. Pinus pinaster	01. Pinus pinaster						0,0	100,0%
02. Quercus suber	01. Pinus pinaster	1,4	2,3	3,2	0,9	38%	46,1	0,0%
03. Eucalyptus	01. Pinus pinaster						14,2	26,2%
04. Quercus rotundifolia	01. Pinus pinaster	1,5	2,4	3,3	0,9	37%	48,0	0,0%
05. Other quercus	01. Pinus pinaster						23,3	18,9%
06. Other broadleaves	01. Pinus pinaster						5,5	69,7%
07. Pinus pinea	01. Pinus pinaster						19,7	54,9%
08. Other coniferous	01. Pinus pinaster						19,7	54,9%
09. Rain-fed crops	01. Pinus pinaster	1,7	2,7	3,6	0,9	35%	53,3	0,0%
10. Irrigated crops	01. Pinus pinaster	1,4	2,4	3,4	1,0	42%	48,5	0,0%
11. Rice	01. Pinus pinaster	1,4	2,4	3,4	1,0	42%	48,5	0,0%
12. Vineyards	01. Pinus pinaster	2,0	3,1	4,2	1,1	36%	61,9	0,0%
13. Olive	01. Pinus pinaster	0,9	2,1	3,3	1,2	59%	41,4	0,1%
14. Other permanent	01. Pinus pinaster	1,6	2,8	4,0	1,2	42%	56,8	0,0%
15. Grassland	01. Pinus pinaster	1,6	2,6	3,5	1,0	37%	51,3	0,0%
16. Wetlands	01. Pinus pinaster	4,8	5,6	6,5	0,8	15%	112,6	0,0%
17. Settlements	01. Pinus pinaster	4,8	5,6	6,5	0,8	15%	112,6	0,0%
18. Shrubland	01. Pinus pinaster						5,5	73,8%
19. Other	01. Pinus pinaster	2,0	3,1	4,2	1,1	36%	61,9	0,0%

Soil emission/sequestration factors were calculated for all possible land-use changes considering significant changes in average C Stocks for each land-use, as contained in Table 7-21 and a 20 year conversion period, as shown in Equation 7.16.

Equation 7.16 - Estimation of Soil Emission Factors

$$SEF_{x \rightarrow y} = \frac{ASC_y - ASC_x}{20}$$

Where:

$SEF_{x \rightarrow y}$  = Soil Emission Factor for Land-use Change from x to y (tC/ha/year)

$ASC_y$  = Average Soil Carbon Stock in Land Use y (tC/ha)

$ASC_x$  = Average Soil Carbon Stock in Land Use x (tC/ha)

The resulting Soil Emission Factors and the estimates of their uncertainty are presented, respectively, in Table 7-23 and Table 7-24.

Table 7-23 – Estimated Annual Emission/Sequestration Factors (tC/ha) for Soil

Soil Emission Factors			TO																		
			Forest land								Cropland							Grassl.	Wetl.	Setlm.	Other Land
			01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
FROM	Forest land	01. Pinus pinaster		-2,3		-2,4					-2,7	-2,4	-2,4	-3,1	-2,1	-2,8	-2,1	-5,6	-5,6		-3,1
		02. Quercus suber	2,3		1,6			2,0										-3,3	-3,3	2,0	
		03. Eucalyptus		-1,6		-1,7					-2,0	-1,7	-1,7	-2,4	-1,4	-2,1	-1,4	-4,9	-4,9		-2,4
		04. Quercus rotundifolia	2,4		1,7			2,1										-3,2	-3,2	2,1	
		05. Other quercus												-1,9				-4,5	-4,5		-1,9
		06. Other broadleaves		-2,0		-2,1					-2,4	-2,2	-2,2	-2,8	-1,8	-2,6	-1,8	-5,4	-5,4		-2,8
		07. Pinus pinea																-4,6	-4,6		
		08. Other coniferous																-4,6	-4,6		
	Cropland	09. Rain-fed crops	2,7		2,0			2,4										-3,0	-3,0	2,4	
		10. Irrigated crops	2,4		1,7			2,2										-3,2	-3,2	2,1	
		11. Rice	2,4		1,7			2,2										-3,2	-3,2	2,1	
		12. Vineyards	3,1		2,4		1,9	2,8										-2,5	-2,5	2,8	
		13. Olive	2,1		1,4			1,8										-3,6	-3,6	1,8	
		14. Other permanent	2,8		2,1			2,6										-2,8	-2,8	2,6	
	Grassland	15. Grassland	2,6		1,9			2,3										-3,1	-3,1	2,3	
	Wetlands	16. Wetlands	5,6	3,3	4,9	3,2	4,5	5,4	4,6	4,6	3,0	3,2	3,2	2,5	3,6	2,8	3,6			5,4	2,5
	Settlements	17. Settlements	5,6	3,3	4,9	3,2	4,5	5,4	4,6	4,6	3,0	3,2	3,2	2,5	3,6	2,8	3,6			5,4	2,5
	Other Land	18. Shrubland		-2,0		-2,1					-2,4	-2,1	-2,1	-2,8	-1,8	-2,6	-1,8	-5,4	-5,4		-2,8
		19. Other	3,1		2,4		1,9	2,8										-2,5	-2,5	2,8	



Table 7-24 – Estimated Uncertainty of Annual Emission/Sequestration Factors for Soil

Estimated Uncertainty in Soil Emission Factors			TO																		
			Forest land								Cropland						Grassl.	Wetl.	Setlm.	Other Land	
			01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
FROM	Forest land	01. Pinus pinaster		38%		37%					35%	42%	42%	36%	59%	42%	46%	15%	15%		36%
		02. Quercus suber	38%		61%			55%										8%	8%	69%	
		03. Eucalyptus		61%		58%					52%	64%	64%	50%	95%	60%	77%	19%	19%		50%
		04. Quercus rotundifolia	37%		58%			54%										10%	10%	67%	
		05. Other quercus												86%				33%	33%		86%
		06. Other broadleaves		55%		54%					49%	58%	58%	47%	78%	54%	66%	20%	20%		47%
		07. Pinus pinea																64%	64%		
		08. Other coniferous																64%	64%		
	Cropland	09. Rain-fed crops	35%		52%			49%										15%	15%	61%	
		10. Irrigated crops	42%		64%			58%										18%	18%	70%	
		11. Rice	42%		64%			58%										18%	18%	70%	
		12. Vineyards	36%		50%		86%	47%										29%	29%	56%	
		13. Olive	59%		95%			78%										25%	25%	92%	
		14. Other permanent	42%		60%			54%										31%	31%	64%	
	Grassland	15. Grassland	37%		56%			52%										16%	16%	64%	
	Wetlands	16. Wetlands	15%	8%	19%	10%	33%	20%	64%	64%	15%	18%	18%	29%	25%	31%	14%			26%	29%
	Settlements	17. Settlements	15%	8%	19%	10%	33%	20%	64%	64%	15%	18%	18%	29%	25%	31%	14%			26%	29%
	Other Land	18. Shrubland		69%		67%					61%	70%	70%	56%	92%	64%	82%	26%	26%		56%
		19. Other	36%		50%		86%	47%										29%	29%	56%	

#### 7.1.3.6 *Other Dead Organic Matter*

Dead organic matter (other than litter) is considered to be “included elsewhere”.

The two main sources for dead wood are harvesting residues (included and reported as losses in living biomass, that include the emission of the whole tree) and dead trees from fire (included and reported as indirect emissions from fire, that include the emission of the whole tree). Other dead wood sources are considered negligible compared to these two sources or included in harvesting and are not reported separately.

## 7.2 Forest Land (CFR 5.A)

Forest land has stabilised over the last years, despite the increases in afforestation areas. Nevertheless, forests have been a net-sink since 1990, with annual values ranging between -11 Mt CO<sub>2</sub>eq and -18 MtCO<sub>2</sub>eq.

Figure 7-11 – Areas of Forest Land per Reporting Category (1000 ha)

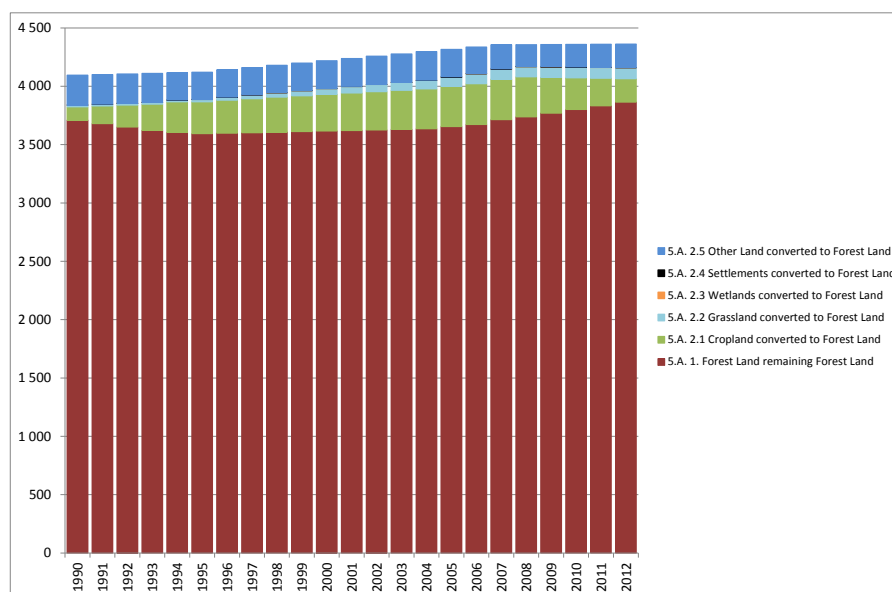
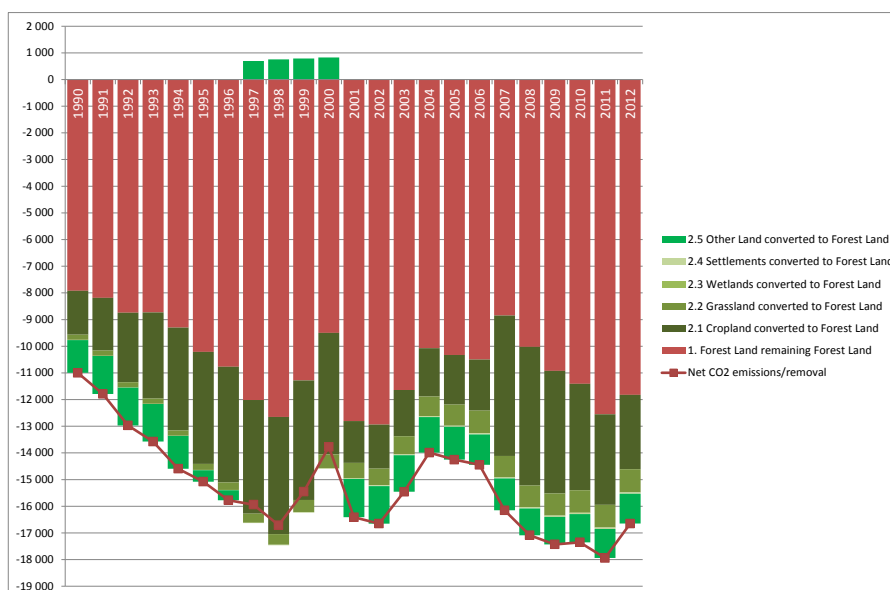


Figure 7-12: Total Emissions and Removals in Forest Land (kt CO<sub>2</sub> eq.)



## 7.2.1 Forest Land Remaining Forest Land

### 7.2.1.1 Area

Area estimates for Forest Land Remaining Forest Land were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

Land-use changes between different forest types (conversion of one type of forest into another or changes in dominant species in mixed forests) have been estimated and included in this category.

### 7.2.1.2 Living Biomass

#### 7.2.1.2.1 Gains in Living Biomass

Gains in living biomass refer to trees only and were estimated using Equation 7.17. Estimates were made for each forest type (8 forest types considered; see Table 7-1). Within each forest type the growth of different forest species was considered, reflecting the large share of mixed forests in Portugal (see Table 7-11 and Table 7-12).

Equation 7.17 – Estimation of Gains in Living Biomass in Forest Land Remaining Forest Land

$$LBG_{RY_i} = \sum_{FT_f} \sum_{FS_y} AFF_{f,RY_i} \times MAI_{yf} \times BEF_y \times (1 + RTS_y) \times CF_y$$

Where:

$LBG_{RY_i}$  = Living Biomass Gains in Reporting Year i

$FT_f$  = Sum for all forest types

$FS_y$  = Sum for all forest species within a forest type

$AFF_{f,RY_i}$  = Area of forest land remaining forest land of type f in reporting year i

$MAI_{yf}$  = Mean Annual Increment of forest species y in forest type f

$BEF_y$  = Biomass Expansion Factor of forest species y

$RTS_y$  = Root-to-Shoot Factor of forest species y

$CF_y$  = Carbon Fraction of forest species y

Gains in living biomass from understory vegetation (non-tree woody vegetation, grasses, ferns, mosses) were not estimated. It is assumed that gains and losses in this vegetation type are equivalent or that any gains or losses are marginal compared to the estimates from trees. This assumption is considered conservative given the annual vegetation cycles (for annual species gains and losses should be equivalent) and management practices (shrubs biomass is reduced as a fire management practice, and removals from lands with growing vegetation tend to offset emissions from lands under shrub vegetation control).

#### 7.2.1.2.2 Losses in Living Biomass

Losses in living biomass refer to harvesting and conversion between different forest types. Losses in living biomass due to forest fires are reported in CRF Table 5(V).

Emissions from harvesting were estimated from domestic industrial wood consumption statistics (collected by INE, the National Statistics Office) for the main forest types with industrial use and allocated to the categories “Pinus pinaster” and “Eucalyptus spp.”. There are no statistics for harvesting from other forest types or wood uses (domestic use of biomass for energy, thinning with no industrial use, and pruning). In those cases, it was assumed that 25% of the mean annual increment was harvested every year, which is believed to be an overestimation of the actual wood harvested for those purposes and, therefore, a conservative estimate.

Eucalyptus plantations are harvested in a rotation period of 12 years, i.e., before the 20 years conversion period<sup>149</sup> is completed. In this case, harvesting was further divided into harvesting in “Forest remaining Forest” and “Land converted to Forest”. The harvesting under lands converted to forest was estimated based on the area planted in year i-12 and assuming a harvest rate of annual increment (in m<sup>3</sup>/ha/year) times 12, the remaining of the industrial consumption of eucalyptus wood was assumed to come from forest land remaining forest land.

Losses in living biomass from understory vegetation (non-tree woody vegetation, grasses, ferns, mosses) were not estimated. It is assumed that gains and losses in this vegetation type are equivalent or that any gains or losses are marginal compared to the estimates from trees. This assumption is considered conservative given the annual vegetation cycles (for annual species gains and losses should be equivalent) and management practices (shrubs biomass is reduced as a fire management practice, and removals from lands with growing vegetation tend to offset emissions from lands under shrub vegetation control).

Equation 7.18: Estimation of losses in living biomass in Forest Land Remaining Forest Land

$$LBL_{RY_i} = LBLH_{RY_i} + LBLFC_{RY_i}$$

<sup>149</sup> Lands are moved from the category “Land converted to Forest” to “Forest Land Remaining Forest Land” 20 years after the afforestation took place.

$$LBLH_{RY_i} = \sum_{FS_y} HARV_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y$$

$$LBLFC_{RY_i} = \sum_{f \rightarrow x} AFC_{f \rightarrow x,RY_i} \times (AGB_f + BGB_f)$$

Where:

$LBL_{RY_i}$  = Living Biomass Losses in Reporting Year i (tC)

$LBLH_{RY_i}$  = Living Biomass Losses from Harvesting in Reporting Year i (tC)

$LBLFC_{RY_i}$  = Living Biomass Losses from Forest Conversion in Reporting Year i (tC)

$FS_y$  = Sum for all forest species

$f \rightarrow x$  = Sum for all conversions between forest types

$HARV_{y,RY_i}$  = Volume of harvesting of forest species y in reporting year i (m<sup>3</sup>)

$AFC_{f \rightarrow x,RY_i}$  = Area of forest land type f converted into type x in reporting year i (ha)

$AGB_f$  = Average Above Ground Biomass of forest type f (tC/ha) (from Table 7-17)

$BGB_f$  = Average Below Ground Biomass of forest type f (tC/ha) (from Table 7-17)

$BEF_y$  = Biomass Expansion Factor of forest species y

$RTS_y$  = Root-to-Shoot Factor of forest species y

$CF_y$  = Carbon Fraction of forest species y

#### 7.2.1.3 *Dead Organic Matter*

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 7.2.1.4 *Mineral Soils*

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 7.2.1.5 *Activity in Forest Management: replacement of harrowing with less disruptive methods for shrub control*

Harrowing is a common practice for shrub encroachment control in natural grasslands under canopy in Portugal. However, such operation is disruptive for the soil and leads to soil organic matter (SOM) loss and, consequently, carbon emissions. Less disruptive methods (eg. forestry mowers) lead to an increase in SOM which was modelled using 145 plots, collected in 2011 and 2012. The difference in SOM between tilled (harrowing management) and no-tilled (mowing management) plots indicates a carbon sequestration factor of **3.41 tCO<sub>2</sub>.ha<sup>-1</sup>.yr<sup>-1</sup>** for a period of 10 years.

Portugal supports this activity through one project carried out by Terraprima and financed by the Portuguese Carbon Fund, where farmers commit to change practices used in shrub control in forest areas. Terraprima and the Portuguese Carbon Fund (PCF) control that the activity is carried out properly.

These areas and the corresponding removals are reported as “forest land remaining forest land” (UNFCCC reporting) and as “forest management”(KP reporting and accounting).

More detail and data on this activity can be found in “ANNEX H: Methodological Note concerning the calculation of carbon sequestration in areas where harrowing was replaced by less disruptive methods for shrub control”.

## **7.2.2 Land Converted to Forest**

### **7.2.2.1 Area**

Area estimates for Land Converted to Forest Land were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

### **7.2.2.2 Living Biomass**

#### **7.2.2.2.1 Gains in Living Biomass**

Equation 7.17 was also used to estimate gains in living biomass for Land converted to Forests, the only difference being the area estimates, which should now refer to “Area converted to forest land of type f in reporting year i”. The remaining parameters were kept unchanged for the two reporting categories.

#### **7.2.2.2.2 Losses in Living Biomass**

Losses in living biomass in Land Converted to Forest were estimated as the sum of emissions from harvesting (assumed to occur in eucalyptus plantations only) and emissions from the destruction of the vegetation of the former land use (as seen in Table 7-17).

Eucalyptus plantations are harvested in a rotation period of 12 years, i.e., before the 20 years conversion period<sup>150</sup> is completed. In this case, harvesting was further divided into harvesting in “Forest remaining Forest” and “Land converted to Forest”. The harvesting under lands converted to forest was estimated based on the area planted in year i-12 and assuming a harvest rate of 100 m<sup>3</sup>/ha, the remaining of the industrial consumption of eucalyptus wood was assumed to come from forest land remaining forest land.

#### **7.2.2.3 Dead Organic matter**

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### **7.2.2.4 Mineral Soils**

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## **7.3 Cropland (CRF 5.B)**

The areas of cropland have been reduced significantly since 1990, mostly for conversion to grasslands, forest land and other land. Throughout the whole period, croplands have been a

<sup>150</sup> Lands are moved from the category “Land converted to Forest” to “Forest Land Remaining Forest Land” 20 years after the afforestation took place.

net-source of emissions, with a clear trend for emission reductions over time, determined mostly by the reduction in area and the introduction of new activities for carbon sequestration.

Figure 7-13 – Areas of Cropland per Reporting Category (1000 ha)

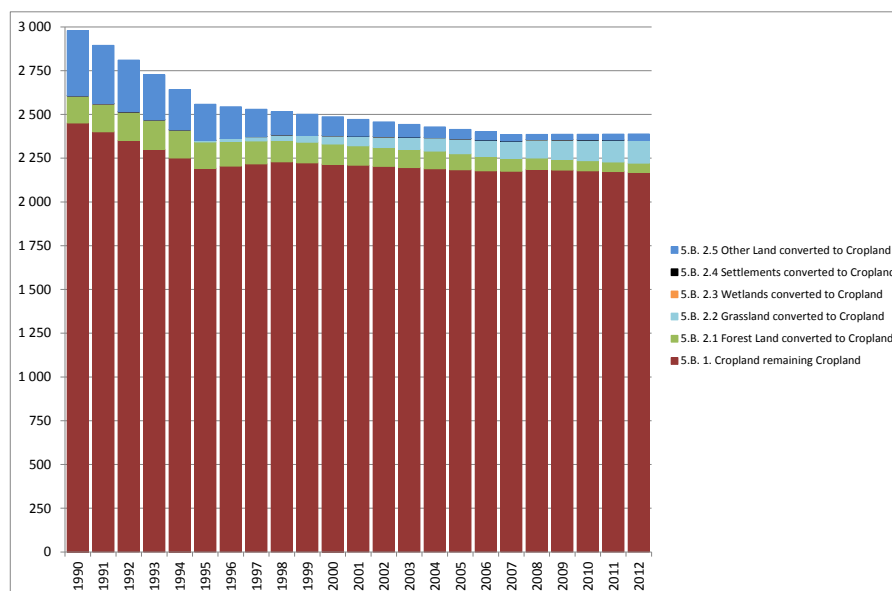
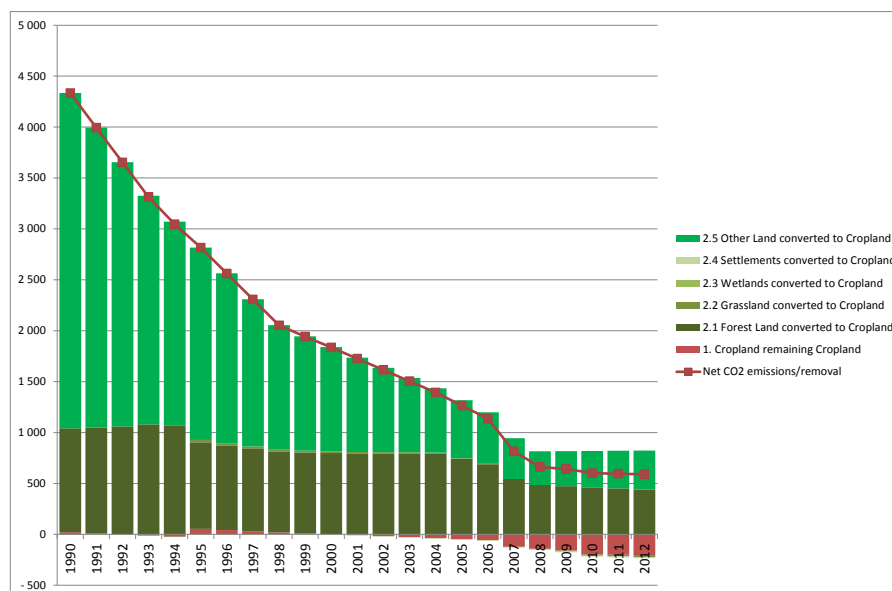


Figure 7-14 – Total Emissions and Removals in Cropland (kt CO<sub>2</sub> eq.)



### 7.3.1 Cropland Remaining Cropland

#### 7.3.1.1 Area

Area estimates for Cropland Remaining Cropland were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

Land-use changes between different cropland types (conversion of one type of cropland into another) have been estimated and included in this category.

### 7.3.1.2 *Living Biomass*

#### 7.3.1.2.1 Gains in Living Biomass

The default assumption of no net-changes in living biomass was used for all cropland categories in that category for over 20 years. Therefore, gains in living biomass in cropland remaining cropland result only from the conversion between cropland types, in particular conversion to perennial crops (vineyards, olive groves, other permanent crops), according to the unit values presented in Table 7-16. All gains are assumed to occur in the year when the land-use change occurs (for annual crops) and over a 20 years period (for perennial crops).

#### 7.3.1.2.2 Losses in Living Biomass

The same default assumption of no net-changes for all cropland categories in that category for over 20 years was applied to losses in living biomass was used. Therefore, losses in living biomass in cropland remaining cropland result only from the conversion between cropland types, in particular conversion from perennial crops (vineyards, olive groves, other permanent crops), according to the unit values presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

#### 7.3.1.3 *Dead Organic Matter*

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 7.3.1.4 *Mineral Soils*

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

Gains in soils from areas under no-tillage were considered separately (see section 7.3.1.5).

#### 7.3.1.5 *Activity in Cropland: No tillage*

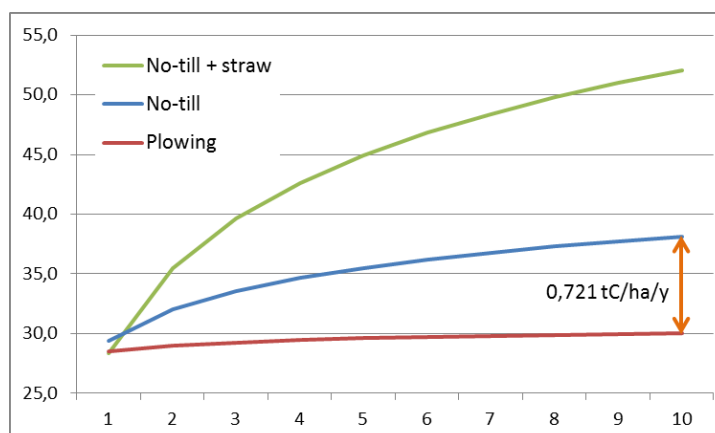
A special activity, taking place usually in lands with rain fed cropland is reported and accounted for under “cropland remaining cropland”: no tillage. This practice eliminates the need for tilling the soils through direct seeding and fertilisation, which results in a significant increase in soil organic matter and, in turn, in increased sequestration.

Portugal supports this activity through agri-environmental incentives of the Rural Development Programme under EU Common Agricultural Policy (CAP), where farmers commit to use only no-till techniques. IFAP is responsible for those contracts with farmers, for controlling that the activity is carried out properly and for the compilation of areas supported by the state. IFAP contracts with farmers are made for a period of 5 years and can be renewed for new 5 years. This information is used as activity data for emissions reporting.

According to research carried out in Portugal by Carvalho et al. (2012), soil organic carbon content increases on average, compared with conventional tilling techniques, by 0,721 tC/ha/year over a 10 years period. This value and transition period has been used for reporting this activity.



Figure 7-15 – Increase in Carbon Stock (tC/ha) in Soils in Conventional vs No-Tillage techniques



Because the sequestration factor was defined as the additional soil C of this activity compared with conventional till, the results of this calculation are then added to the totals of Rainfed Crops, calculated as explained above.

### 7.3.2 Land Converted to Cropland

#### 7.3.2.1 Area

Area estimates for Land Converted to Cropland were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

#### 7.3.2.2 Living Biomass

##### 7.3.2.2.1 Gains in Living Biomass

Gains in living biomass in land converted to cropland result in particular from the conversion to perennial crops (vineyards, olive groves, other permanent crops), according to the unit values and transition periods presented in Table 7-16. All gains are assumed to occur in the year when the land-use change occurs (for annual crops) or over a 20 years period (for perennial crops).

##### 7.3.2.2.2 Losses in Living Biomass

Losses in living biomass in land converted to cropland result from the loss of the vegetation of the previous land use as presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

#### 7.3.2.3 Dead Organic Matter

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 7.3.2.4 Mineral Soils

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## 7.4 Grassland (CRF 5.C)

Contrary to cropland, the areas of grassland have seen an increase since 1990, with most of the area coming from cropland (rain-fed annual crops). The conversion from agriculture to grasslands usually results in an increased sequestration, while the conversions from forest land

and other land result in increased emissions. The net-balance has favoured emissions, although these have been heavily reduced since 1990. More recently the introduction of incentives for biodiverse pastures has allowed for an increase in sequestration rates.

Figure 7-16 – Areas of Grassland per Reporting Category (1000 ha)

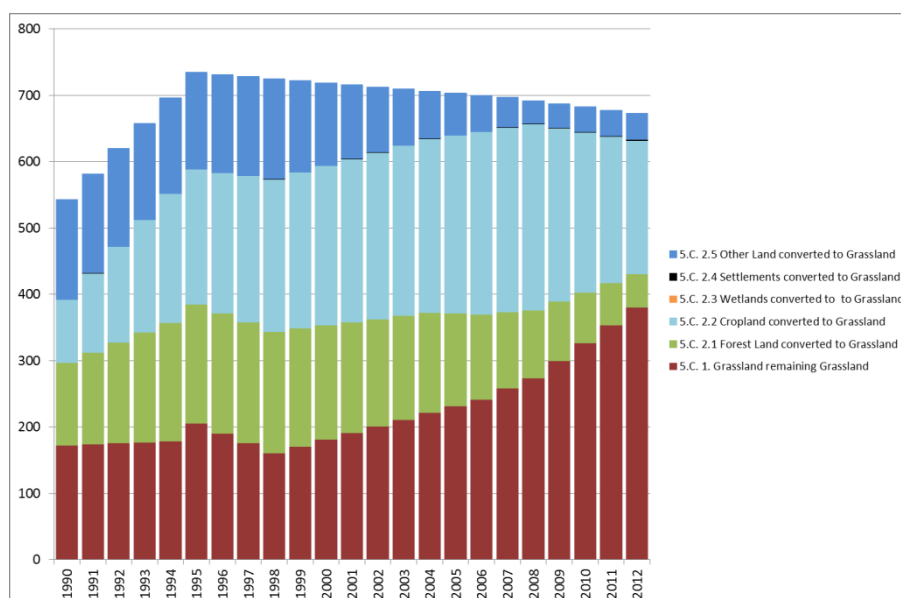
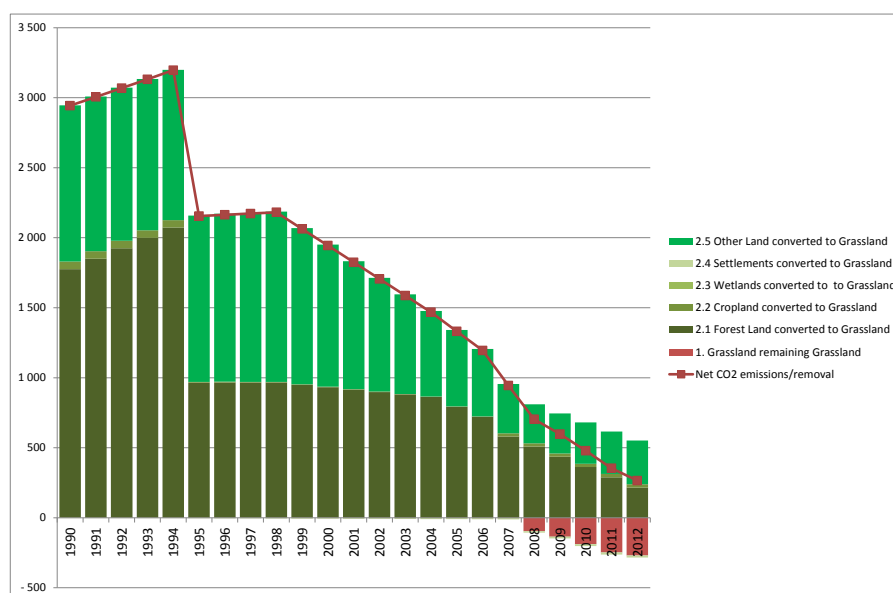


Figure 7-17 – Total Emissions and Removals in Grassland (kt CO<sub>2</sub> eq.)



## 7.4.1 Grassland Remaining Grassland

### 7.4.1.1 Area

Area estimates for Grassland Remaining Grassland were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

#### 7.4.1.2 *Living Biomass*

##### 7.4.1.2.1 Gains in Living Biomass

The default assumption of no net-changes in living biomass was used for all grasslands in that category for over 20 years. Therefore, gains in living biomass in grassland remaining grassland were considered zero.

##### 7.4.1.2.2 Losses in Living Biomass

The same assumption was used for losses in living biomass.

##### 7.4.1.3 *Dead Organic Matter*

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

##### 7.4.1.4 *Mineral Soils*

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

Gains in soils from areas under biodiverse pastures were considered separately (see section 7.4.1.5).

##### 7.4.1.5 *Activity in Grassland: Sown Biodiverse Permanent Pastures Rich in Legumes*

A special activity, taking place in grazed lands is reported and accounted for under “grassland remaining grassland”: SBPPRL sown biodiverse permanent pastures rich in legumes.

Sown biodiverse pastures are based on a diverse mixture of about twenty different species, many of which (approximately 30-50%) are legumes. These grasslands are more productive than the baseline land use system – spontaneous natural pastures. Productivity is accompanied by an increase in soil organic matter (SOM) and correspondent carbon sequestration. Teixeira et al. (2011) analysed the effect from a shift from natural to sown biodiverse pastures, and calculations based on this work estimated a carbon sequestration factor of **6.48 tCO<sub>2</sub>.ha<sup>-1</sup>.yr<sup>-1</sup>** for a period of 10 years.

These pastures are grazed directly by cattle, sheep or goats and result from the seeding with improved and selected seeds.

Portugal supports this activity through the 2 projects carried out by Terraprima and financed by the Portuguese Carbon Fund, where farmers commit to convert conventional pastures or rain-fed crops into SBPPRL. Terraprima and the Portuguese Carbon Fund (PCF) control that the activity is carried out properly.

These areas and the corresponding removals are reported as “grassland remaining grassland” (UNFCCC reporting) and as “grazing land management” (KP reporting and accounting).

More detail and data on this activity can be found in “ANNEX G: Methodological Note concerning the calculation of carbon sequestration in areas with sown biodiverse pastures”.

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## **7.4.2 Land Converted to Grassland**

### **7.4.2.1 *Area***

Area estimates for Land Converted to Grassland were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

### **7.4.2.2 *Living Biomass***

#### **7.4.2.2.1 Gains in Living Biomass**

Gains in living biomass in land converted to grassland result from the accumulation of grassland vegetation, according to the unit value presented in Table 7-16. All gains are assumed to occur in the year when the land-use change occurs.

#### **7.4.2.2.2 Losses in Living Biomass**

Losses in living biomass in land converted to grassland result from the loss of the vegetation of the previous land use as presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

### **7.4.2.3 *Dead Organic Matter***

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### **7.4.2.4 *Mineral Soils***

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## **7.5 Wetlands (CRF 5.D)**

The area of wetlands remaining wetlands has remained fairly constant and the increase in wetland areas is due to the construction of artificial reservoirs, which are included in this land use category. An on-going programme to increase the water storage and hydro-electricity production capacity will likely maintain this trend in the future. As expected under these trends, wetlands are a net-source of emissions, although not a very significant one.

Figure 7-18 – Areas of Wetlands per Reporting Category (1000 ha)

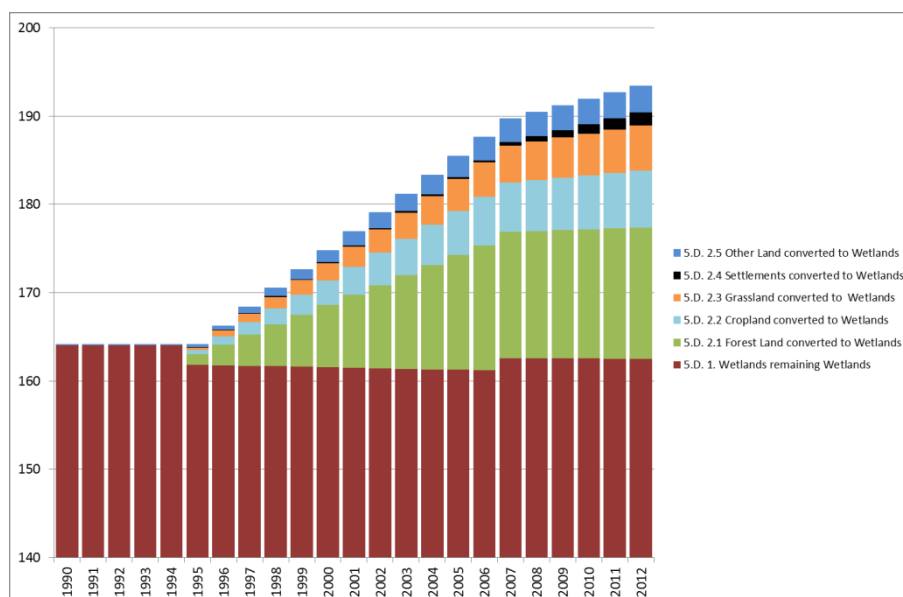
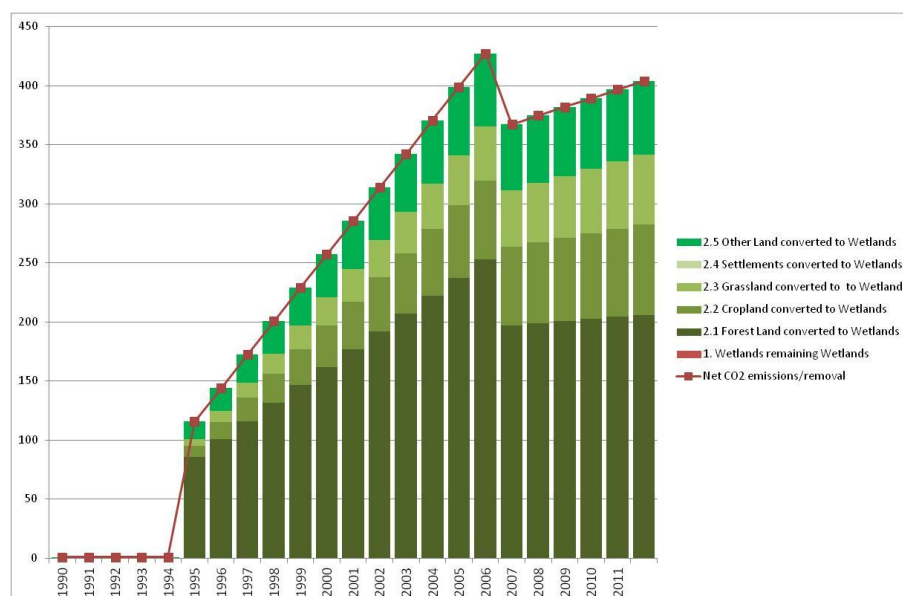


Figure 7-19 – Total Emissions and Removals in Wetlands (kt CO<sub>2</sub> eq.)



### 7.5.1 Wetlands remaining wetlands

Area estimates for Wetlands Remaining Wetlands were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

The default assumption of no net-changes was used for all pools in wetlands in that category for over 20 years. Therefore, all gains and losses in wetlands remaining wetlands were considered zero.

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## **7.5.2 Lands converted to wetlands**

### **7.5.2.1 *Area***

Area estimates for Land Converted to Wetlands were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

### **7.5.2.2 *Living Biomass***

#### **7.5.2.2.1 Gains in Living Biomass**

Gains in living biomass are estimated to be zero, according to the unit value presented in Table 7-16. All gains are assumed to occur in the year when the land-use change occurs.

#### **7.5.2.2.2 Losses in Living Biomass**

Losses in living biomass in land converted to wetlands result from the loss of the vegetation of the previous land use as presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

### **7.5.2.3 *Dead Organic Matter***

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### **7.5.2.4 *Mineral Soils***

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## **7.6 Settlements (CFR 5.E)**

Over the past 2 decades Portugal has witnessed an enormous growth in the building of infrastructure and urban expansion. As a consequence the areas under settlements have increased since 1990. As expected under these trends, settlements are a net-source of emissions, although not a very significant one.

Figure 7-20 – Areas of Settlements per Reporting Category (1000 ha)

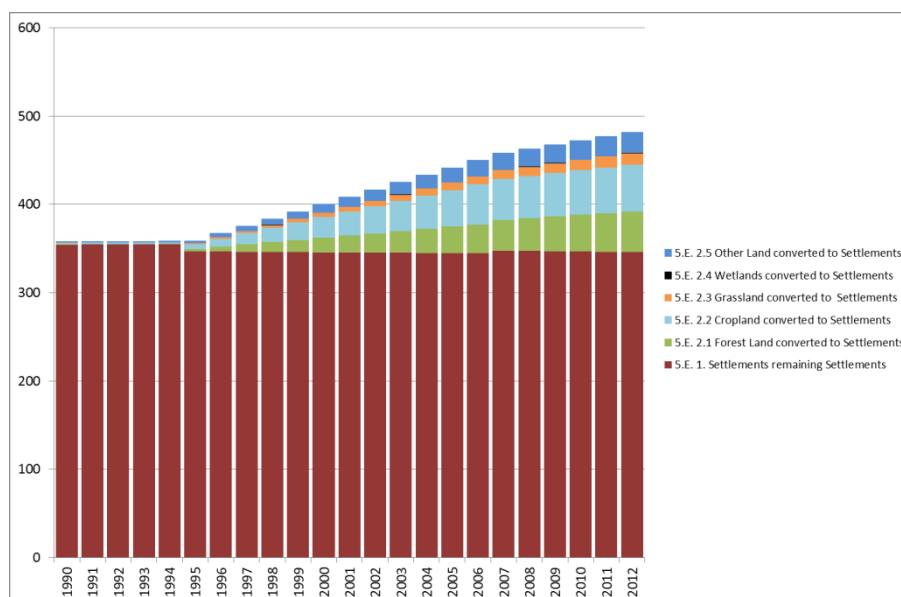
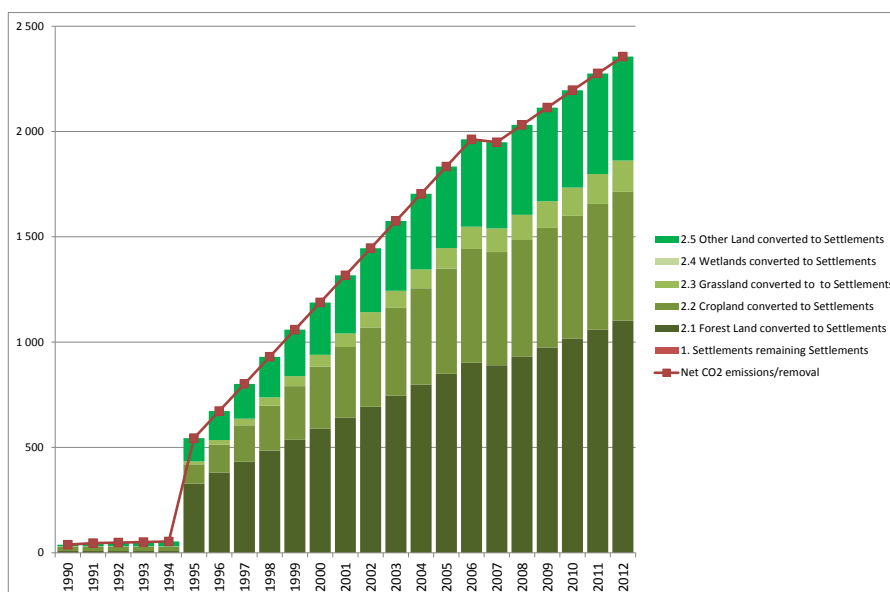


Figure 7-21 – Total Emissions and Removals in Settlements (kt CO<sub>2</sub> eq.)



### 7.6.1 Settlements remaining settlements

Area estimates for Settlements Remaining Settlements were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

The default assumption of no net-changes was used for all pools in settlements in that category for over 20 years. Therefore, all gains and losses in settlements remaining settlements were considered zero.

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## **7.6.2 Lands converted to settlements**

### **7.6.2.1 *Area***

Area estimates for Land Converted to Settlements were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

### **7.6.2.2 *Living Biomass***

#### **7.6.2.2.1 Gains in Living Biomass**

Gains in living biomass are estimated to be zero, according to the unit value presented in Table 7-16. All gains are assumed to occur in the year when the land-use change occurs.

#### **7.6.2.2.2 Losses in Living Biomass**

Losses in living biomass in land converted to settlements result from the loss of the vegetation of the previous land use as presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

### **7.6.2.3 *Dead Organic Matter***

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### **7.6.2.4 *Mineral Soils***

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## **7.7 Other Land (CRF 5.F)**

The category other land is a very dynamic one, with substantial areas of land being converted to other land-uses and vice-versa. In particular the dynamics between other land, forest land and cropland are very high. Increases in Other Land are mostly explained by agriculture abandonment and by degradation of forests to non-forest land, mostly due to recurring forest fires. Despite this high land use dynamics, the higher carbon stocks of other land compared to rain-fed agriculture more than compensate the emissions from the loss of forests, resulting in Other Land being a significant net-sink of 4.6 MtCO<sub>2</sub>eq in 2011.



Figure 7-22 – Areas of Other Land per Reporting Category (1000 ha)

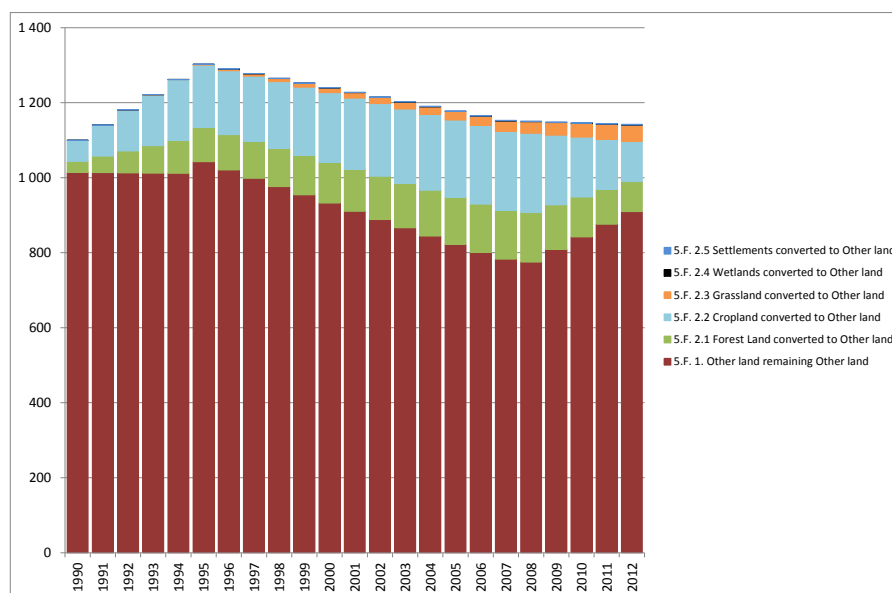
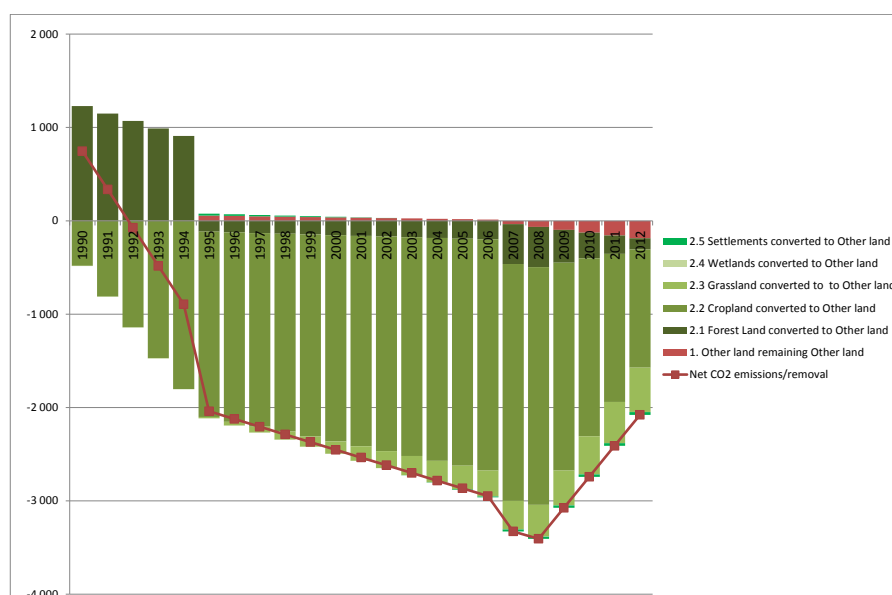


Figure 7-23 – Total Emissions and Removals in Other Land (kt CO<sub>2</sub> eq.)



## 7.7.1 Other land remaining other land

### 7.7.1.1 Area

Area estimates for Other land Remaining Other land were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

Land-use changes between different other land types (conversion of one type of other land into another) have been estimated and included in this category.

#### 7.7.1.2 *Living Biomass*

##### 7.7.1.2.1 Gains in Living Biomass

The default assumption of no net-changes in living biomass was used for all other land categories in that category for over 20 years. Therefore, gains in living biomass in other land remaining other land result only from the conversion between other land types, according to the unit values presented in Table 7-16. All gains are assumed to occur over a 20 years period.

##### 7.7.1.2.2 Losses in Living Biomass

The same default assumption of no net-changes for all other land categories in that category for over 20 years was applied to losses in living biomass. Therefore, losses in living biomass in other land remaining other land result only from the conversion between other land types, according to the unit values presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

##### 7.7.1.3 *Dead Organic Matter*

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

##### 7.7.1.4 *Mineral Soils*

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 7.7.2 *Land converted to other land*

##### 7.7.2.1 *Area*

Area estimates for Land Converted to Other land were made following the methodology outlined in section 7.1.2 - Representation of Land-Areas and Land-Use Changes.

##### 7.7.2.2 *Living Biomass*

###### 7.7.2.2.1 Gains in Living Biomass

Gains in living biomass were estimated using the unit values presented in Table 7-16. All gains are assumed to occur over a 20 years period.

###### 7.7.2.2.2 Losses in Living Biomass

Losses in living biomass in land converted to other land result from the loss of the vegetation of the previous land use as presented in Table 7-17. All losses are assumed to occur in the year when the land use change occurs.

##### 7.7.2.3 *Dead Organic Matter*

The annual emission/sequestration factors of Table 7-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

##### 7.7.2.4 *Mineral Soils*

The annual emission/sequestration factors of Table 7-23 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## 7.8 Harvested Wood Products (CRF 5.G)

Portugal reported in its Submission for Forest Management Reference Level the emissions associated with Harvested Wood Products (HWP) and also includes it in this submission.

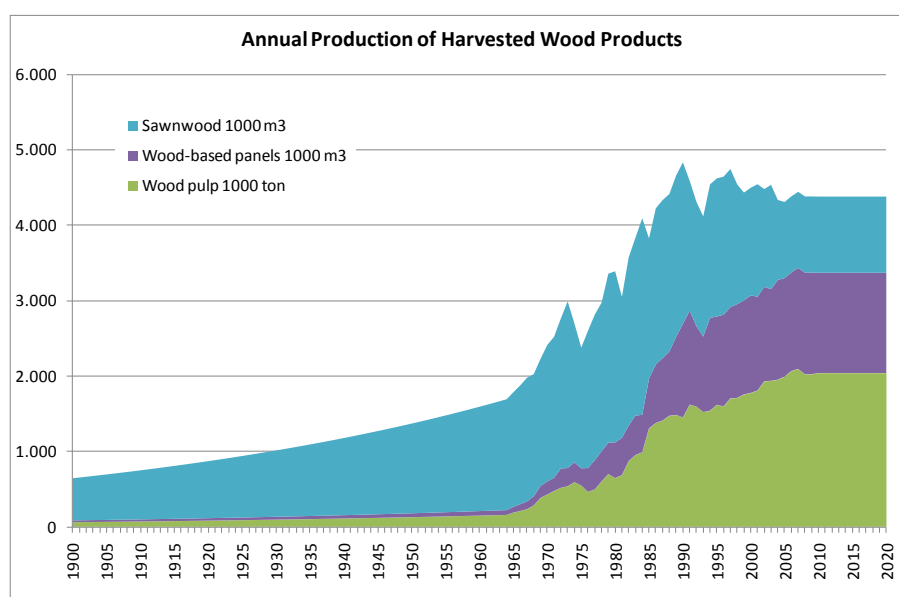
Changes in the Carbon stock in HWP pool were estimated using IPCC methodologies, as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4: Agriculture, Forestry and Other Land-Use; Chapter 12 Harvested Wood Products.

Data for production, imports and exports was derived from UNECE for the period 1964-2009 (last updated July 2010)<sup>151</sup>. Production estimates from 1900-1963 were produced using IPCC equation 12.6. The production of HWP that came from domestic harvest was estimated using equation 12.4.

Product grades considered were wood pulp (UNECE product code 7, half-life of 2 years); wood panels (UNECE product code 6, half-life of 25 years) and sawn wood (UNECE product code 5, half-life 35 years).

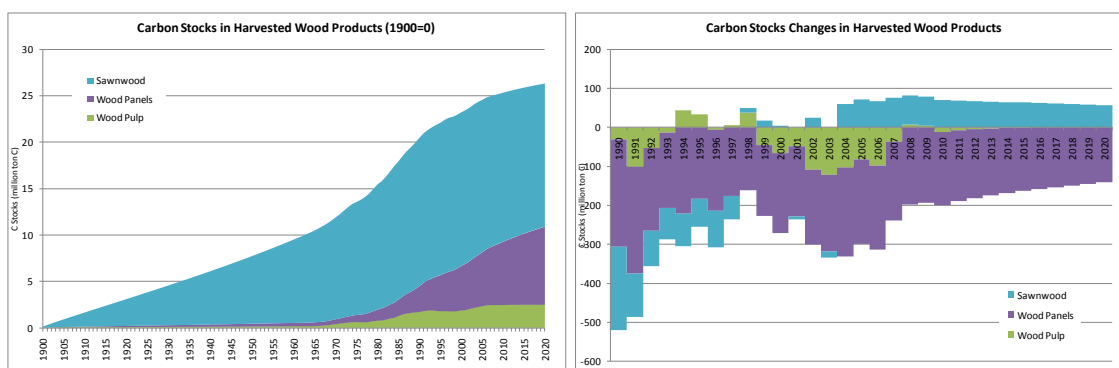
The results of the exercise are presented in Figure 7-25.

Figure 7-24 – Estimated and Reported Annual Production of Harvested Wood Products.



<sup>151</sup> <http://timber.unece.org/fileadmin/DAM/statsdata/flatfile-2010-07.zip>

Figure 7-25 – Evolution of Carbon Stocks and Carbon Stock Changes in Harvested Wood Products



## 7.9 Direct N<sub>2</sub>O Emissions from N-Fertilization of Forest Land(CRF 5(I))

Emissions are quantified together with N fertilization of cropland and grassland and are reported in the Agriculture sector, since it is not possible to distinguish among the fertilizers used in agriculture and in forestry.

## 7.10 Non-CO<sub>2</sub> emissions from Drainage of Soils (CRF 5(II))

The source is considered negligible and is reported as Not Occurring.

## 7.11 N<sub>2</sub>O Emissions from Disturbance Associated with Land-Use Conversion to Cropland (CRF 5(III))

According to IPCC 2003 GPG, it is good practice to estimate emissions/removals from 'land converted to cropland' for a period sufficient for the carbon stock changes to occur following land-use conversion. Since the default inventory period for changes in soil carbon is 20 years, this period of time should be used in area accounting for conversions to cropland.

The equation used was

$$N_2O - N_{conv} = EF_1 \times \Delta C_{LCMineral} \times \frac{1}{C:N \text{ ratio}} \times 10^{-6}$$

Where:

$N_2O - N_{conv}$  = N<sub>2</sub>O emissions as a result of the disturbance associated with land-use conversion of forest land, grassland, or other land to cropland, Gg N<sub>2</sub>O-N.yr<sup>-1</sup>

$EF_1$  = IPCC default emission factor used to calculate emissions from agricultural land caused by added N, whether in the form of mineral fertilizers, manures, or crop residues, kg N<sub>2</sub>O-N.kg<sup>-1</sup> N. (The default value used is 0.0125 kg N<sub>2</sub>O-N.kg<sup>-1</sup> N)

$\Delta C_{LCMineral}$  = C emissions from land LC

## 7.12 CO<sub>2</sub> Emissions from Agricultural Lime Application (CRF 5(IV))

The source is estimated for the first time in this submission on the basis of the information collected directly by APA from the plants producing lime agricultural correctives.

Liming of soils in forest and agriculture land is considered a minor practice in Portugal and information on the application of lime in soils is scarce.

The estimation of this source followed the Tier 1 IPCC guidance and was based on the equation:

$$\text{CO}_2\text{-C Emission} = (M_{\text{Limestone}} \cdot \text{EF}_{\text{Limestone}}) + (M_{\text{Dolomite}} \cdot \text{EF}_{\text{Dolomite}})$$

Where:

$\text{CO}_2\text{-C Emission}$  = annual C emissions from lime application, tonnes C.yr<sup>-1</sup>

$M$  = annual amount of calcic limestone ( $\text{CaCO}_3$ ) or dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ), tonnes.yr<sup>-1</sup>

$\text{EF}$  = emission factor, tonne of C.(tonne of limestone or dolomite)<sup>-1</sup>

The amount of carbonate containing lime applied annually to soils in the country was estimated on the basis of the information collected directly from the national producing limestone and dolomite for agricultural use. Due to the inherent characteristics of these products (low economic value and weight) it was assumed that no imports exist of these materials. The same was considered for exportation, information which was corroborated from the enquiries to the plants.

The IPCC default emission factors of 0.12 for limestone and 0.13 for dolomite were applied, which are equivalent to carbonate carbon contents of the materials (12% for  $\text{CaCO}_3$ , 13% for  $\text{CaMg}(\text{CO}_3)_2$ ).

## 7.13 Emissions from Biomass Burning (CRF 5(V))

Forest Fire Emissions are estimated as the sum of:

- Direct CO<sub>2</sub> emissions, i.e., CO<sub>2</sub> emissions that occur *during the fire*
- Direct non-CO<sub>2</sub> emissions, i.e., CH<sub>4</sub> and N<sub>2</sub>O emissions that occur *during the fire*
- Indirect CO<sub>2</sub> emissions, i.e., CO<sub>2</sub> emissions that occur *after the fire, but as a consequence of the fire*, i.e., from tree mortality caused by wildfires

The following pools and gases included in the estimations of fire emissions are summarised in Table 7-25.

Table 7-25 – Pools and Gases Included in Estimations of Fire Emissions

Land use	GHG →		Direct emissions CO <sub>2</sub>	Direct emissions N <sub>2</sub> O and CH <sub>4</sub>	Indirect emissions CO <sub>2</sub>
	Pool ↓				
Forest	Tree above ground biomass	Yes	Yes	Yes	(dead trees)
Forest	Tree below ground biomass	Considered negligible			Yes (dead trees)
Forest	Shrub below and above ground biomass	Land-remaining-land No gains/losses are considered ⇒ No fire emissions reported	Yes	Land-remaining-land No gains/losses are considered ⇒ No fire emissions reported	
Forest	Litter		Yes		
Agriculture	Above ground biomass		Yes		
Grasslands	Above ground biomass		Yes		
Other land	Above ground biomass		Yes		
Other land	Litter		Yes		

#### 7.13.1 Estimation of Burnt Areas

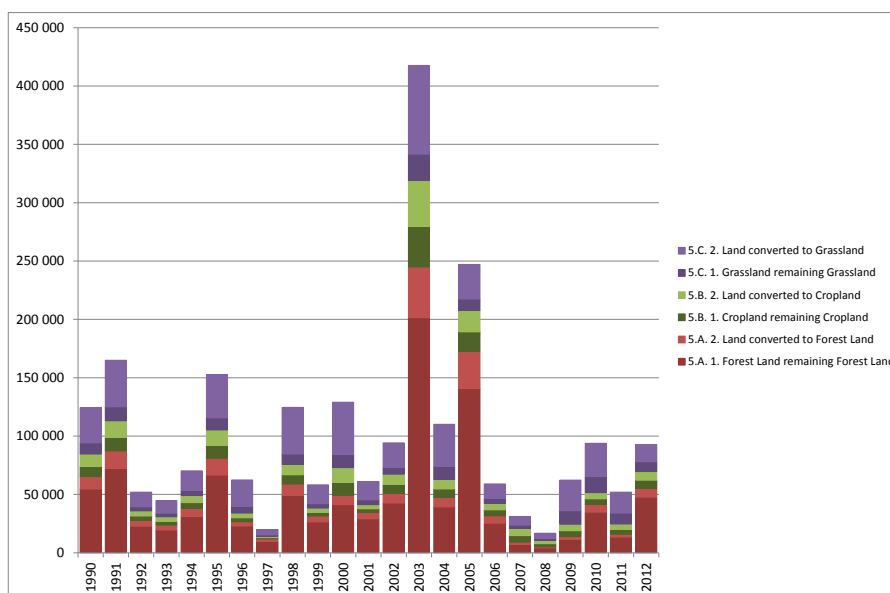
The main sources of burnt areas are the fire reports issued every year by the National Forest Authority, currently the Institute for Nature Conservation and Forestry (ICNF 1990-2012). The reports are derived from satellite imagery and the results cover all burnt areas.

Estimates for burnt area per land use type have been revised by overlapping the annual fire maps with the land-uses observed in 1995, 2005 and 2010 (available from the first phase of NFI6).

Estimates for the Autonomous Region of Madeira were provided by the Secretaria de Recursos Naturais da RAM, and include only broad classes “burnt forest” and “burnt shrubland”. Allocation to forest type was made assuming the same area distribution as reported in total area per forest type.

There are no forest fires in the Autonomous Region of Azores.

Figure 7-26 – Burnt Areas per Reporting Category (ha)



### 7.13.2 Estimation of Biomass Loss due to Fires

The loss of biomass during forest fires was estimated by multiplying the above ground biomass in each land-use with its combustion factor.

According to Rosa (2009) forest fire emissions are much more related to biomass of smaller sizes than to total biomass, as they tend to present much higher combustion factors.

An estimation of the finer particles present in forest was made identifying the following components: leaves, small branches, litter and understory shrubs (woody vegetation under the canopy of species that do not reach 5m at maturity). The basis for this calculation is the biomass values presented in Table 7-17.

As there were no values on combustion factors for these land-use types, a conservative approach was taken and the combustion factor was assumed to be 100%. This assumption considers that 100% of all dead trees (including roots) is oxidised during a fire. This approach is needed as there is no information to adequately characterize gains and losses of this pool. The consequence is an overestimation of emissions in the year of fire, but also an underestimation of emissions in the following years. However, it should be noted that all emissions are reported and the approach is consistent all over the time series (i.e., the system does not consistently bias results in relation to present versus future emissions).

A summary of the values used in estimating biomass loss due to fires is presented in Table 7-26.

Table 7-26 – Combustion Factors per Biomass Component used in the Estimation of Fire Emissions

Land-use Type	Share of AG Tree Biomass		Combustion Factor				
	Leaves %	Small branches %	Leaves %	Small branches %	Litter %	Shrubs %	AG Biomass %
Pinus pinaster	7%	11%	88%	58%	75%	72%	-
Quercus suber	13%	21%	88%	58%	75%	72%	-
Eucalyptus spp.	9%	7%	88%	58%	75%	72%	-
Quercus rotundifolia	16%	27%	88%	58%	75%	72%	-
Quercus spp.	21%	54%	88%	58%	75%	72%	-
Other broadleaves	21%	54%	88%	58%	75%	72%	-
Pinus pinea	5%	8%	88%	58%	75%	72%	-
Other coniferous	8%	12%	88%	58%	75%	72%	-
Rainfed annual crops	-	-	-	-	-	-	100%
Irrigated annual crops	-	-	-	-	-	-	-
Rice padies	-	-	-	-	-	-	-
Vineyards	-	-	-	-	-	-	100%
Olive groves	-	-	-	-	-	-	100%
Other permanent crops	-	-	-	-	-	-	100%
All grasslands	-	-	-	-	-	-	100%

### 7.13.3 Direct CO<sub>2</sub> Emissions from Fires

Direct CO<sub>2</sub> emissions from fires were estimated using Equation 7.19.

Equation 7.19 - Estimation of Direct CO<sub>2</sub> Emissions from Fires

$$E_{CO_2} = BA_x \times BLF_x \times Cf \times CtoCO_2$$

Where:

$E_{CO_2}$  = Emissions of CO<sub>2</sub> (tCO<sub>2</sub>)

$BA_x$  = Burnt area of land-use x (ha)

$BLF_x$  = Biomass Loss due to Fires in Land-use x (tdm/ha)

$C_f$  = Carbon fraction of Dry Matter (%)

$CtoCO_2$  = Stoichiometric conversion from Carbon to CO<sub>2</sub> (44/12 ~ 3,67)

### 7.13.4 Direct CH<sub>4</sub> Emissions from Fires

Direct CH<sub>4</sub> emissions from fires were estimated using Equation 7.20.

Equation 7.20 - Estimation of Direct CH<sub>4</sub> Emissions from Fires

$$E_{CH_4} = BA_x \times BLF_x \times Cf \times C/CH_4 \times CtoCH_4$$

Where:

$E_{CH_4}$  = Emissions of CH<sub>4</sub> (tCH<sub>4</sub>)

$BA_x$  = Burnt area of land-use x (ha)

$BLF_x$  = Biomass Loss due to Fires in Land-use x (tdm/ha)



$C_f$  = Carbon fraction of Dry Matter (%)

$C/CH_4$  = Carbon Lost as  $CH_4$  (IPCC Default = 0,012)

$CtoCH_4$  = Stoichiometric conversion from Carbon to  $CH_4$  (1,33)

#### 7.13.5 Direct $N_2O$ Emissions from Fires

Direct  $N_2O$  emissions from fires were estimated using Equation 7.21.

Equation 7.21 - Estimation of Direct  $N_2O$  Emissions from Fires

$$E_{N_2O} = BA_x \times BLF_x \times C_f \times N/C \times N/N_2O \times NtoN_2O$$

Where:

$E_{N_2O}$  = Emissions of  $N_2O$  (t  $N_2O$ )

$BA_x$  = Burnt area of land-use x (ha)

$BLF_x$  = Biomass Loss due to Fires in Land-use x (tdm/ha)

$C_f$  = Carbon fraction of Dry Matter (%)

$N/C$  = Nitrogen Carbon Ratio (IPCC Default = 0,01)

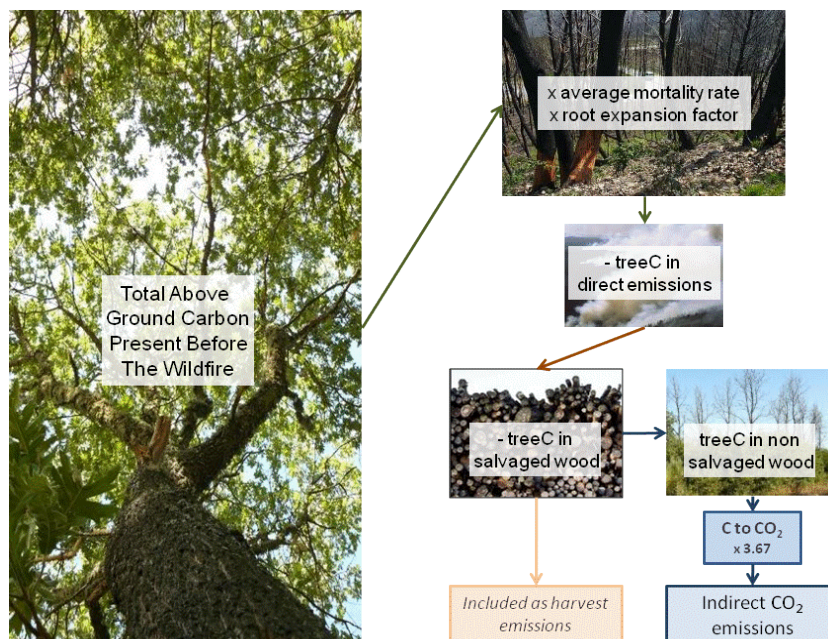
$N/N_2O$  = Nitrogen Lost as  $N_2O$  (IPCC Default = 0,007)

$NtoN_2O$  = Stoichiometric conversion from Nitrogen to  $N_2O$  (3,14)

#### 7.13.6 Indirect $CO_2$ Emissions from Fires

Indirect emissions are defined as those that not released during the forest fire but are attributed to fires, following tree mortality. They are estimated following the flow described in Figure 7-27.

Figure 7-27 – Estimation of Indirect Fire Emissions



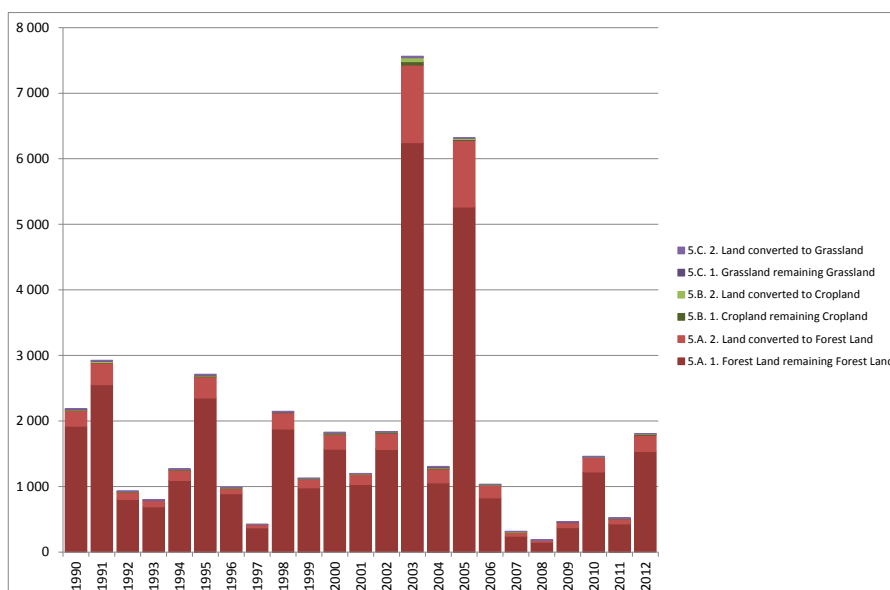
Average Mortality Rates and Salvage Wood were estimated by expert judgement, as presented in Table 7-27.

Table 7-27 – Mortality and Salvage Wood Rates

Land-use Type	Mortality %	Non-salvage %
Pinus pinaster	70%	60%
Quercus suber	30%	60%
Eucalyptus spp.	50%	50%
Quercus rotundifolia	10%	60%
Quercus spp.	30%	60%
Other broadleaves	30%	60%
Pinus pinea	30%	60%
Other coniferous	70%	60%

The results of the estimations are presented in the figure below.

Figure 7-28 – Total Emissions from Biomass Burning per Land-use Category (kt CO<sub>2</sub> eq.)



## 7.14 Uncertainty Assessment

### 7.14.1 Forest land remaining Forest land

The uncertainties of the parameters and activity data for living biomass were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. As a result, the uncertainty estimate was 20% and 19%, in 1990 e 2012 respectively.

### 7.14.2 Land converted to Forest Land

The uncertainties of the parameters and activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. As a result, the uncertainty estimate was 30% (1990) and 18% (2012) for the entire removal by land converted to forest land.

### 7.14.3 Cropland remaining Cropland

Uncertainties of the parameters and the activity data for mineral and organic soils were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty was estimated as 34% (1990) and 29% (2012) for the entire emission from the cropland remaining cropland.

### 7.14.4 Land converted to Cropland

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty was estimated as 51% (1990) and 43% (2012) for the entire emission from the land converted to cropland.

### 7.14.5 Grassland remaining Grassland

Gains in living biomass in grassland remaining grassland were considered zero.

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the

default values described in the GPG-LULUCF. The uncertainty was estimated as 0% (1990) and 58% (2012). In 1990, emissions/removals were considered zero.

#### **7.14.6 Land converted to Grassland**

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty was estimated as 41% (1990) and 43% (2012) for the entire removal from the land converted to grassland.

#### **7.14.7 Wetlands remaining Wetlands**

The default assumption of no net-changes was used for all pools in wetlands in that category for over 20 years. Therefore, all gains and losses in wetlands remaining wetlands were considered zero. So, the uncertainty was estimated as 0% in both years.

#### **7.14.8 Land converted to Wetlands**

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty was estimated as 51% (1990) and 54% (2012) of the total emissions from the land converted to wetlands.

#### **7.14.9 Settlements remaining Settlements**

The default assumption of no net-changes was used for all pools in settlements in that category for over 20 years. Therefore, all gains and losses in settlements remaining settlements were considered zero. So, the uncertainty was estimated as 0% in both years.

#### **7.14.10 Land converted to Settlements**

The uncertainties of the parameters and activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty estimate was 51% (1990) and 50% (2012) for the entire emission from land converted to settlements.

#### **7.14.11 Other land remaining Other land**

Uncertainties of the parameters and the activity data for mineral and organic soils were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty was estimated as 42% (1990) and 41% (2012) for the entire emission from the other land remaining other land.

#### **7.14.12 Land converted to Other land**

The uncertainties of the parameters and the activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the GPG-LULUCF. The uncertainty was estimated as 43% (both exercises) for the entire emission from the land converted to other land.

#### **7.14.13 Direct N<sub>2</sub>O emissions from N fertilization**

The uncertainty estimates of N<sub>2</sub>O emissions from N fertilization were included in agriculture.

#### **7.14.14 N<sub>2</sub>O emissions from disturbance associated with land-use conversion to Cropland**

The uncertainties of parameters were individually assessed on the basis of field studies, expert judgment, or default values described in the GPG-LULUCF, and the uncertainty estimates for the carbon emissions from soil in land converted to cropland were applied to the activity data of

this category. As a result, the uncertainty estimates of N<sub>2</sub>O emissions from disturbance associated with land-use conversion to cropland were 14%.

#### **7.14.15 CO<sub>2</sub> emissions from agricultural lime application**

The uncertainty of CO<sub>2</sub> emissions from this category was assessed and estimated as 9%.

#### **7.14.16 Biomass burning**

The uncertainties for parameters and activity data related to biomass burning were individually assessed on the basis of field studies, expert judgment, or default values described in the GPG-LULUCF. As a result, the uncertainty estimates for the emissions resulting from biomass burning were 37% for CO<sub>2</sub>, 37% for CH<sub>4</sub> and 37% for N<sub>2</sub>O, respectively. The total uncertainty was 90%.

### **7.15 QA/QC**

QA/QC procedures included a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report.

Where applicable cross-checks and consistency checks between data submitted for the UNFCCC and KP reporting were also made.

Particular attention was given to the consistent application of the 20 years conversion period and the “since 1990” in both the UNFCCC and KP reporting.

Issues detected by and recommendations made by the Joint Research Centre were also considered, following the QA/QC procedures implemented by JRC in the compilation of the inventory submission for the EU.

Finally, issues detected by and recommendations made by the Expert Review Teams in previous UNFCCC reviews were also considered and, where possible, corrected.

### **7.16 Recalculations and Data Improvements**

The following recalculations were made and introduced in this submission:

- The replacement of the information on land use and land use changes in Mainland Portugal with data from the Land-Use Cartography of 1995, 2007 and 2010, recently made available from the Direcção Geral do Território (see section 7.1.2.3.2). This improvement had been foreseen in NIR 2013.
- A revision of the soil emission factors, incorporating the LUCAS Data Set and reflecting only statistically significant changes in C Stocks
- A revision on annual burnt areas per land use, using the revised information provided by Instituto de Conservação da Natureza e Florestas released in 2013

Most of the changes in the reported totals of emissions and removals can be attributed to these data source changes. There were no changes in methodologies in relation to the NIR 2013.

Some minor mistakes in the calculation spread sheets were detected and corrected following the QA/QC controls described above. However it should be noted that the impact of these recalculations in the final totals was only marginal.

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### 7.17 Further Developments

Portugal has been doing significant efforts to achieve a higher methodological level, identifying opportunities for improvements towards a full Tier 2 type of information, in order to guarantee a more complete, transparent and accurate reporting of the activities associated with LULUCF sector, namely the coherence with the estimations associated to the activities reported under Articles 3.3 and 3.4 of the Kyoto Protocol.

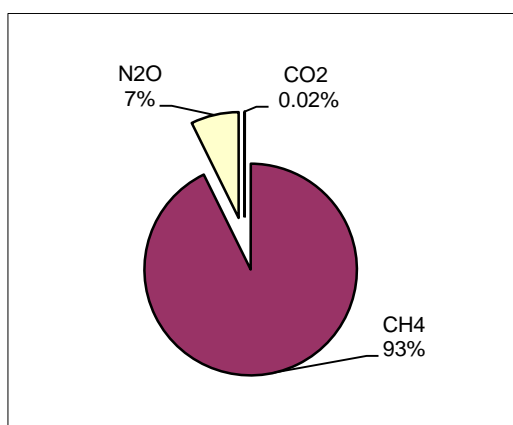
## 8 WASTE (CRF 6.)

### 8.1 Overview

Waste management and treatment of industrial and municipal wastes are sources of GHG emissions. The inventory covers emissions resulting from waste disposal on land, treatment of wastewater and waste incineration.

The most important gas produced is CH<sub>4</sub>, resulting from the anaerobic decomposition of organic waste disposed on land and from handling of wastewater treatment under anaerobic conditions.

Figure 8-1 – Emissions of GHG from waste by gas (2012)



Decomposition of organic waste does not occur instantaneously after disposal on land, but rather over a long period of time, and CH<sub>4</sub> is emitted at a diminishing rate. Different factors affect the generation of CH<sub>4</sub>: Waste disposal practices (degree of control of disposal sites – in general, controlled placement of waste favors anaerobic activity and consequently landfill gas formation, but the gas can be recovered and be either flared or used for energy purposes); Waste composition (quantities of degradable materials is one major element influencing biogas production); and Physical factors (e.g. moisture content and temperature).

Solid waste disposal sites (SWDS), which include both managed landfills and open dump sites, can also produce directly significant amounts of CO<sub>2</sub>. In fact, the decomposition of organic materials originates landfill gas or biogas consisting of approximately 50 per cent CH<sub>4</sub> and 50 per cent CO<sub>2</sub> by volume. However, this carbon dioxide results in its major part from oxidation of biomass materials and does not contribute hence to ultimate CO<sub>2</sub>. Additionally, a much smaller percentage of landfill gas is composed of NMVOC and NH<sub>3</sub>.

The biodegradation of soluble organic matter in wastewater can occur under aerobic or anaerobic conditions. CH<sub>4</sub> emissions result from handling of wastewater and the biomass (sludge) produced under anaerobic conditions. The amount of CH<sub>4</sub> produced depends on the extent of biodegradation occurring under anaerobic versus aerobic conditions. CH<sub>4</sub> produced during deliberate anaerobic wastewater treatment processes can be collected and flared or combusted for energy. Untreated wastewater may originate CH<sub>4</sub> if held under anaerobic circumstances.

CH<sub>4</sub> emissions are affected by:

- Wastewater characteristics. Determines how much organic compounds are degraded. Also the degradable organic content of wastewater determines the CH<sub>4</sub> 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 CH<sub>4</sub> 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 CH<sub>4</sub> generation; systems providing anaerobic conditions will generally produce higher CH<sub>4</sub> emissions than systems having aerobic conditions);
- Temperature (CH<sub>4</sub> generation increases with temperature; CH<sub>4</sub> production occurs with temperatures higher than 15°C; this factor is especially important in uncontrolled systems and warm climates);
- Systems characteristics (other factors affecting CH<sub>4</sub> production are retention time, degree of wastewater treatment, and other site specific conditions).

Wastewater treatment is also potentially a source of NMVOC and N<sub>2</sub>O.

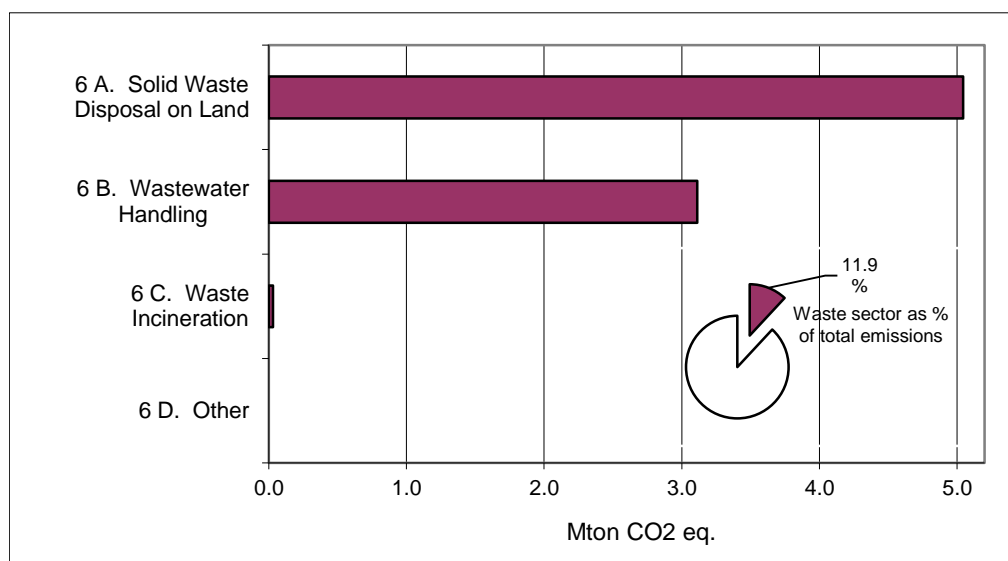
Waste incineration originates emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO, NO<sub>x</sub> and NMVOC. Out of the direct GHG, CH<sub>4</sub> emissions are considered to be the less significant due to combustion conditions in incinerators. According to the IPCC Guidelines (IPCC,1997), only CO<sub>2</sub> 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, CO<sub>2</sub> emissions from waste combustion depends, on the quantities of waste incinerated, the carbon content of the waste, and the fraction of the carbon that is of fossil origin.

Combustion of municipal solid wastes (MSW) in Portugal is made with energy recovery, and thus, according to the IPCC Guidelines, they are accounted for in the energy sector (sub-category 1A(a) Public electricity and heat production). Other waste incineration, such as clinical waste or industrial waste that occurs without energy recovery, 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 generated from waste activities represented in 2012 11.9 per cent of total GHG emissions (excluding LULUCF). The biggest sub-category within the sector refers to waste disposed on land (CRF 6A) – 5 Mt CO<sub>2</sub>e. - corresponding to approx. 62 per cent of the sector's emissions.



Figure 8-2 – Sources of GHG in waste sector (2012)



Waste Water Handling (CRF 6B) contributes to the majority of the remaining emissions, with 38% of the sector emissions. (Industrial WWH 24% and Urban WWH 14%).

Waste incineration without energy recovery (which occur in hospital and industrial units) is accounted in this sector; it represents a minor share of the sector emissions (0.3%).

Waste incineration with energy recovery refers to urban waste that is burnt in Municipal incineration units (waste-to-energy facilities) and reported under Energy sector 1A. These emissions started to occur in 1999 when the two incineration units in Mainland Portugal initiate to operate. Since 2001/02 another incineration unit started to function in Madeira Island.

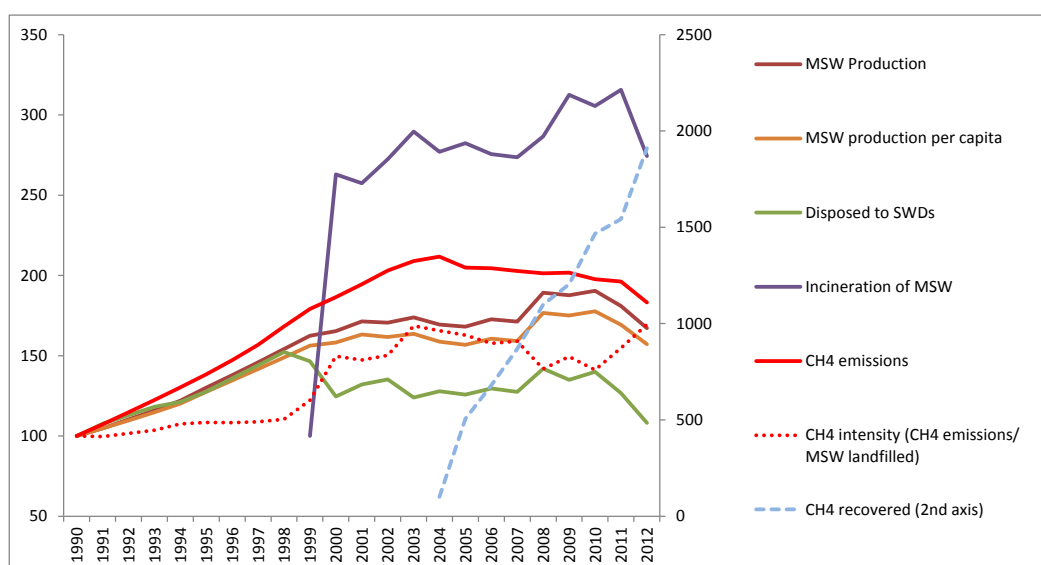
Other waste treatment (CRF 6D) includes emissions from biogas burning without energy recovery. Emissions from biogas combustion with energy recovery are reported in CRF 1A1a.

In the period 1990-2012 GHG emissions from waste activities have increased 37 per cent.

The increase in the sector is strongly related to the growth of waste generation driven by the change in consumption patterns associated with the steady economic growth in particular in the following years after the Portuguese accession to the EU in 1986. Another factor relates to the geographical distribution change of the Portuguese population registered, registering a significant increase of the population living in urban centres since 1960. 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 (Table 8-5).

The growth of the sector emissions is related in majority to the CH<sub>4</sub> emissions generated in Municipal Solid Waste landfilling, representing 32% of the sector emissions in 2012 and having registered a 83% increase since 1990.

Figure 8-3 – CH<sub>4</sub> emissions from Municipal Solid Waste Disposal (Index 1990=100)



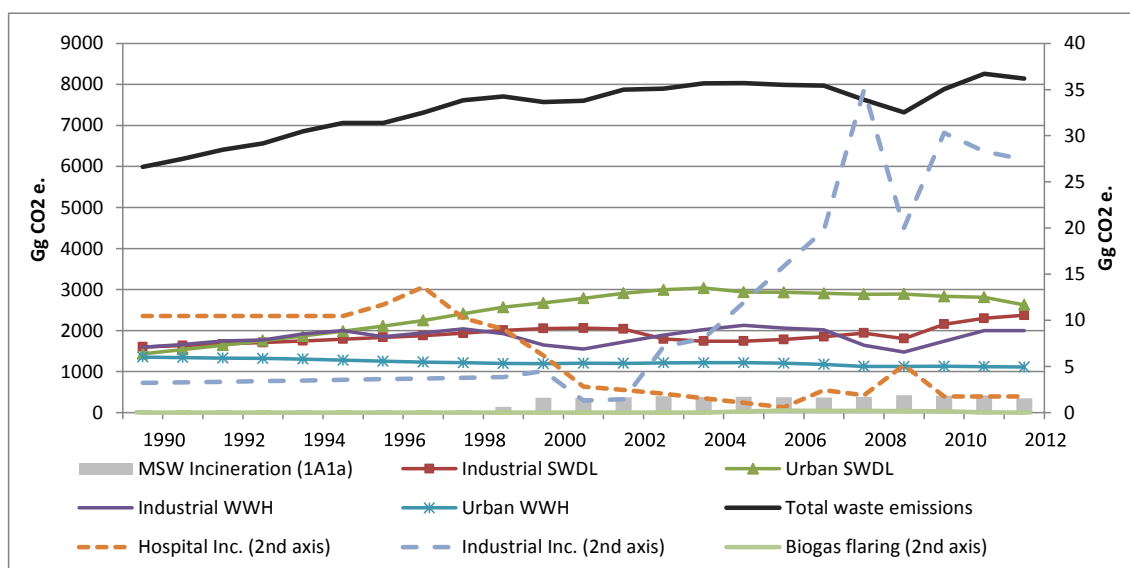
The later increase in CH<sub>4</sub> intensity (as compared to the early waste disposed in land) is due to the degradation process of waste, and the delay that exists between the time biodegradable waste is landfilled and the moment CH<sub>4</sub> is emitted.

In more recent years (from 2004) the rise of the emissions intensity has stabilised or even started to decrease, due to a strong increase in biogas burning that can occur with and without energy recovery. Landfill gas with energy recovery is burned in several units which produce and sell electricity to the grid. Also, the quantities of selectively collected waste, which have more than doubled since 1999, have deviate waste flows from SWDS and incineration units, and contributed to this trend.

The start of operation of two incineration units dedicated to MSW incineration in Portugal Mainland (1999), and another incineration unit the Autonomous Region of Madeira in 2001/02, also contribute to the sectoral trend. The emissions from MSW incineration occur with energy recovery and are therefore accounted in the energy sector (category 1A1a).

Emissions from biogas combustion are also accounted and are reported in the energy sector when there is energy recovery or in the waste sector when biogas is flared (without energy recovery).

Figure 8-4 – Emission trends of GHG from waste by sub-category



## 8.2 Source categories

### 8.2.1 Solid Waste Disposal on Land (CRF 6.A.)

#### 8.2.1.1 CH<sub>4</sub> emissions from Solid Waste Disposal Sites (SWDS)

##### 8.2.1.1.1 Methodology

To better take into account the fact that CH<sub>4</sub> 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 CH<sub>4</sub>/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 CH<sub>4</sub>/Mg waste);

$x$  – year of waste input;

$T$  – current year.

$$\text{CH}_4 \text{ emitted in year } T \text{ (Gg/yr)} = [\text{CH}_4 \text{ generated in year } T - R(T)] * (1 - OX) \quad (2)$$

where:

R(T) - CH<sub>4</sub> recovered in year T (Gg/yr);

OX - oxidation factor (fraction).

CH<sub>4</sub> recovery (R(T)) is the amount of CH<sub>4</sub> generated at SWDS that is recovered and combusted (e.g. flared or used for energy) and not emitted as CH<sub>4</sub> but as CO<sub>2</sub><sup>152</sup>. On the other hand, the CH<sub>4</sub> that is recovered but subsequently vented to atmosphere is not subtracted from emissions.

The Oxidation factor (OX) reflects the portion of CH<sub>4</sub> from SWDS that is oxidised to CO<sub>2</sub> 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 CH<sub>4</sub> is oxidised. Well-managed disposal sites tend to have higher oxidation results than unmanaged dump sites with no cover or where large amounts of CH<sub>4</sub> can escape through cracks in the cover.

The methane generation potential (L<sub>o</sub>) depends upon the composition of waste, waste disposal practices and of the physical characteristics of the SWDS. It is estimated by the formula:

$$L_o = MCF * DOC * DOC_F * F * 16/12$$

where:

MCF - CH<sub>4</sub> correction factor (fraction);

DOC - degradable organic carbon (fraction) (Mg C/Mg waste);

DOC<sub>F</sub> - fraction DOC dissimilated;

F - fraction (volume) of CH<sub>4</sub> in landfill gas.

Methane correction factor (MCF) accounts for the effect of management practices on CH<sub>4</sub> 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.

<sup>152</sup> Although not ultimate CO<sub>2</sub>.

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  $CH_4$  in landfill gas (F) landfill gas is usually considered to be composed dominantly by half of  $CO_2$  and half of  $CH_4$ <sup>153</sup>.

#### 8.2.1.1.2 Activity data and parameters

SWDS include solid municipal waste (household, garden, commercial-services wastes) and industrial wastes.

##### 8.2.1.1.2.1 Municipal waste

###### 8.2.1.1.2.1.1 Quantities of waste landfilled

In 2012, the management of municipal solid waste (MSW) in Portuguese mainland was under the responsibility of 23 entities, known as “systems” (12 multi-municipal and 11 inter-municipal systems). In the Autonomous Region of Azores, municipality authorities are the responsible entities for the management of MSW, and in the Autonomous Region of Madeira, this responsibility is shared between municipalities and the Regional Government.

Since 1999, data on MSW is available for the majority of these systems, including production amounts, final disposal and, to a less extent, waste composition.

For previous years, information on urban waste was not collected on a regular basis, and most information was available from:

- PERSU - “Plano Estratégico dos Resíduos Sólidos Urbanos” (Strategic Plan on Municipal Solid Waste), which was approved by the Government in 1997. This plan includes data from annual municipal registries;
- a study performed by Quercus (1995) – “Caracterização dos Resíduos Sólidos Urbanos e Inventariação dos Locais de Deposição em Portugal” (Characterization of Municipal Solid Waste and Survey of Disposal Sites in Portugal). The study of Quercus (1995) considered open dump sites, managed landfills, composting and incineration units, covering aspects as the quantities of waste treated or landfilled and other characteristics (opening and closure year of operation, waste composition, existence of flaring equipment, etc). Data was based on a survey performed in 1994, which enabled the calculation of per capita generation rates for 1994, based on the amounts of waste collected and the population served by waste collection.

The use of the FOD method requires building a data time series for several decades in the past concerning waste quantities, composition and disposal practices. According to IPCC (2000), it is good practice to estimate historical data if such data are not available, when this is a key source 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  $CH_4$  for 30 years after disposal.

<sup>153</sup> Other gases exist in lesser quantities however.

Before 1994, data on landfill wastes had to be estimated based on expert judgment for waste generation growth rates. For the period 1960-1980 it was considered a per capita waste generation growth rate of 2.5% per year; for the following years (1980-1994) 3% per year. These assumptions were based on scarce information for municipal solid wastes quantities in Portugal mainland, which indicated a tendency of 3% in the period (1980-1985).

Therefore, for the period 1960-1994, municipal solid waste production was estimated for each municipality as follows:

$$[\text{Population (inhabitants)} * \text{Annual amount of municipal waste generated per capita (t/inhabitants/year)}]$$

Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years for the years concerned are: 1960, 1970, 1981, 1991, 2001, and 2011. Data for intermediate years were estimated, by interpolation, for each municipality.

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 or digested:

$$\begin{aligned} \text{Waste disposed to SWDS} = & [\text{Population} * \text{Annual amount of municipal waste generated per capita} * \\ & \text{Percentage of Population served by waste collection}] \\ & - \text{Quantity of incinerated waste} - \text{Quantity of composted/digested waste} \end{aligned}$$

At present the National legislation (Decree-Law no. 178/2006 amended and republished in the Decree-Law no. 73/2011) defines the legal obligations related to the Waste Registry for: waste producers, management waste operators (municipal and non-municipal), waste carriers, integrated schemes for management of specific waste streams, and brokers and waste dealers.

The National entity responsible for the definition, implementation and supervising the waste policies is the APA, I.P./ Waste Department, which is also responsible for the validation and treatment of the information collected via the electronic platform (SIRER/ Integrated System on Electronic Database on Waste).

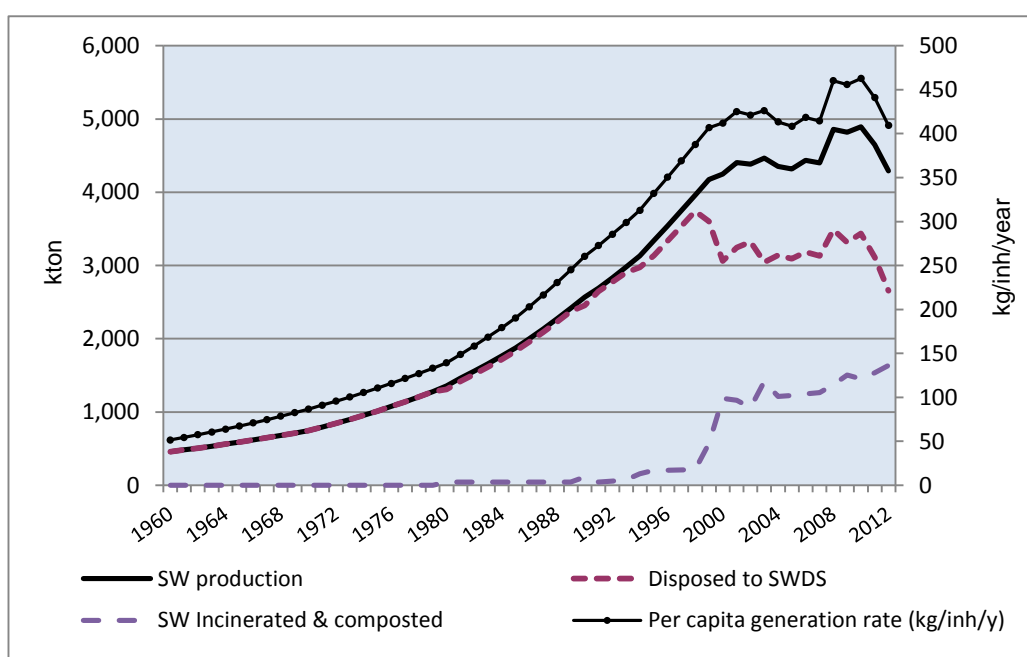
The operators should upload in an electronic registration map (MRRU/ Municipal Waste Registration Form) the information regarding production, transport, trade, recovery and disposal of waste, including the origin of the waste, the quantities generated and treated, the classification and the destiny of the waste.

On the basis of the data collected from the MRRU, the Waste Department within APA, I.P. produces annual information referring to quantities of municipal waste generated in each municipality and their treatment (landfilling, incineration, composting/digestion, recycling). Information on waste composition is also collected (the Ordinance 851/2009 defines the methodology for municipal waste characterization).

Accordingly, for the more recent years (for 1994, and since 1999) the information refers to data effectively collected and reported by the waste management systems, which separates the different treatments: landfilling, incineration, composting/digestion, and material recycling. The inventory excludes the material recycling amounts.

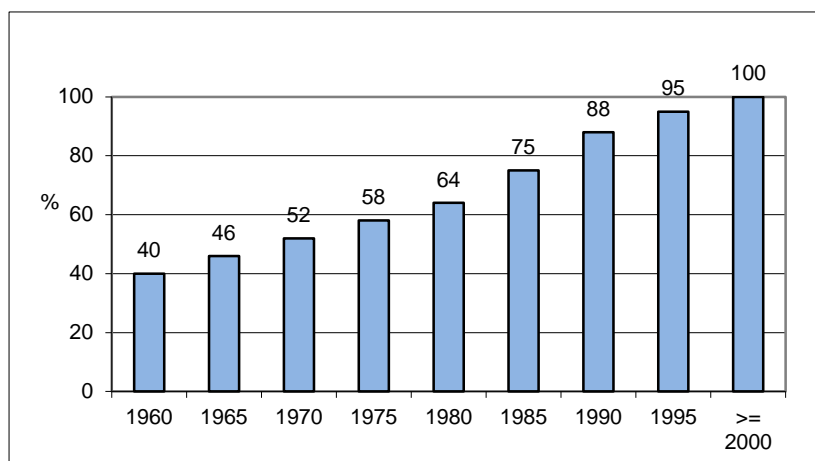
Next figure presents the trends of waste generation per capita, SW generation amounts and quantities incinerated and composted/digested, which include estimates based in the previously mentioned assumptions for the historical time series. As presented in the graph, waste disposed to SWDS reduced since 1999 which corresponds to the beginning of operation of two MSW incineration units.

Figure 8-5 – Municipal waste (excluding material recycling)



Source: APA, include estimates; Quercus study

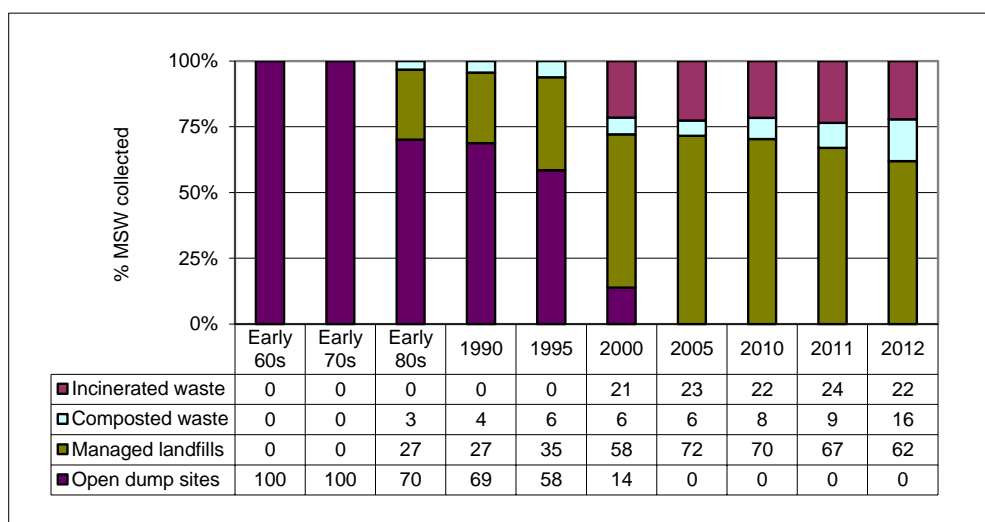
Figure 8-6 - Population served by waste collection systems



Source: APA estimates.

The share of treatment 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 waste disposal on land in favour of incineration, and more recently to organic treatment. 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 2012 this figure fall to 62 per cent, and the percentage of waste incinerated represents 22 per cent).

Figure 8-7 – Waste treatment (% of municipal solid waste without material recycling)



Source: APA estimates; Quercus

#### 8.2.1.1.2.1.2 CH<sub>4</sub> generation potential (Lo)

The parameters used in the calculation are mainly IPCC default values.

Table 8-1 – Parameters used in Lo calculation

Parameter	Explanation	Value considered
MCF	IPCC defaults	Managed landfills = 1.0 Open dump sites = 0.6
DOC	National estimate	Variable on waste composition
DOCF	IPCC default (including lignin C)	0.6
F	IPCC default	0.5

The estimation of Degradable Organic Carbon (DOC), presented in the following table, was based on information on the waste composition from several sources.



Table 8-2 - Composition of waste disposed to SWDS (fermentable fractions)

Fermentable fractions	Early 60s	Early 70s	Early 80s	Early 90s	Mid-90s	2000	2010	2011	2012
Percentage of weight									
Paper and textiles (fraction A)	22.5	22.5	22.5	24.9	25.8	29.0	16.3	15.5	14.9
Non-food fermentable materials (fraction B)	0.0	0.0	0.0	13.4	18.7	17.4	14.3	14.3	14.3
Food waste (fraction C)	59.9	59.9	59.9	42.0	34.8	26.5	42.8	43.0	40.9
Wood or straw (fraction D)	0.0	0.0	0.0	0.2	0.3	0.5	1.5	1.0	1.1
DOC	18.0	18.0	18.0	18.6	18.8	18.7	15.8	15.4	14.8

Notes: Early 60s, 70s and 80s data refer to Fernandes, A Pastor (1982), "RSU do Continente - um Guia para Orientação e Inform. Das Autarquias", LNETI. Early 90s: estimates from interpolation. Mid 90s: data refer to 1994; DGA. 2000 and 2010-2012: APA

#### 8.2.1.1.2.1.3 Other parameters

The value of CH<sub>4</sub> 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 CH<sub>4</sub> for 30 years after disposal.

Data on landfill gas recovered and combusted is flared or used for energy purposes. The first quantities of biogas consumed for energy purposes reported by DGEG (the national energy authority) refer to 2004. This situation is related to the fact that the great majority of landfills have been implemented in the late 90s or the early 2000s. However, flaring (without energy recovery) started before. In order to account with this practice, the APA launched a questionnaire in 2012 with the aim of collecting the total amount of landfill gas combusted either in flaring (without energy recovery) or used for energy purposes. This inquiry is focused on the more recent years (since 2005) in order not to overload the waste systems managers.

As regards the coverage of the APA's questionnaire, it considered all managed SWDS, which totals, in 2011, 34 landfill sites in exploration (receiving waste) in Mainland, plus 3 closed landfill sites which do not receive waste anymore (but burn biogas). Landfill sites in the 2 Autonomous Regions do not burn biogas.

Out of the 37 landfill sites (corresponding to 23 different management entities) considered, 11 landfills reported not to burn biogas. From the 26 sites burning biogas, only data referring to measured data and no extrapolation was done to consider estimates from models.

CH<sub>4</sub> recovered in flares and valorised for energy purposes is estimated on the basis of average biogas flows (continuous measurement) and the n° of hours of burning. The concentration of CH<sub>4</sub> in biogas used in the estimates of the CH<sub>4</sub> quantities refer to monitoring plans (quarterly

measurements) measuring the biogas quality (generally CH<sub>4</sub>, CO<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>S) at the entrance of the flares or the biogas energy recovery system.

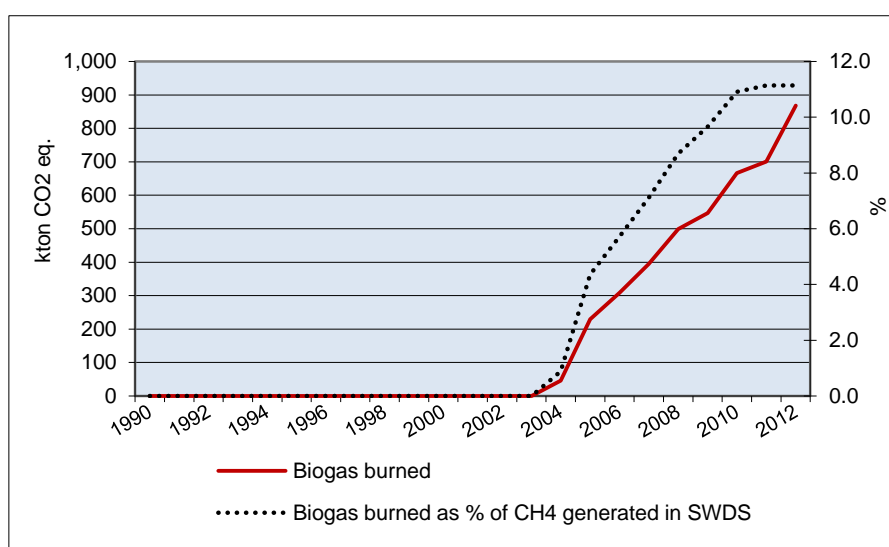
The annual quantities of biogas burnt (in flares and energy recovering units) reported by each landfill (in cubic meters) were converted into CH<sub>4</sub> amounts considering the CH<sub>4</sub> percentages in biogas (based on measurements) reported by management systems.

Table 8-3 –CH<sub>4</sub> in landfill gas

		2004	2005	2006	2007	2008	2009	2010	2011	2012
Average share of CH <sub>4</sub>	%	54	51	53	52	52	52	54	51	52

Source: APA questionnaire.

Figure 8-8 – Quantities of CH<sub>4</sub> combusted (SWDS)



Source: APA questionnaire data (flared and energy recovered quantities); 2004: DGEG data (energy recovery only).

The F value used in the calculation of Lo was based in the IPCC (0.5) default for the whole time series. Data presented in Table 8-3 refer exclusively to landfill sites that burnt biogas for energy purposes or flaring and do not probably represent the whole landfill sites situations. Figures reported in Table 8-3 are weighted averages calculated from data reported by landfills that were used in the calculation of the CH<sub>4</sub> amounts recovered/burnt.

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 CH<sub>4</sub> recovered.

#### 8.2.1.1.2.1.4 Industrial waste

#### 8.2.1.1.2.2 Quantities of waste landfilled

Industrial wastes considered refer only to the fermentable part of industrial waste.

Historical time series are based on 1999 data, which refer to the first set of data available on industrial waste disposal that was collected via an annual registry of industrial declarations received from the regional environment directorates (CCDR).

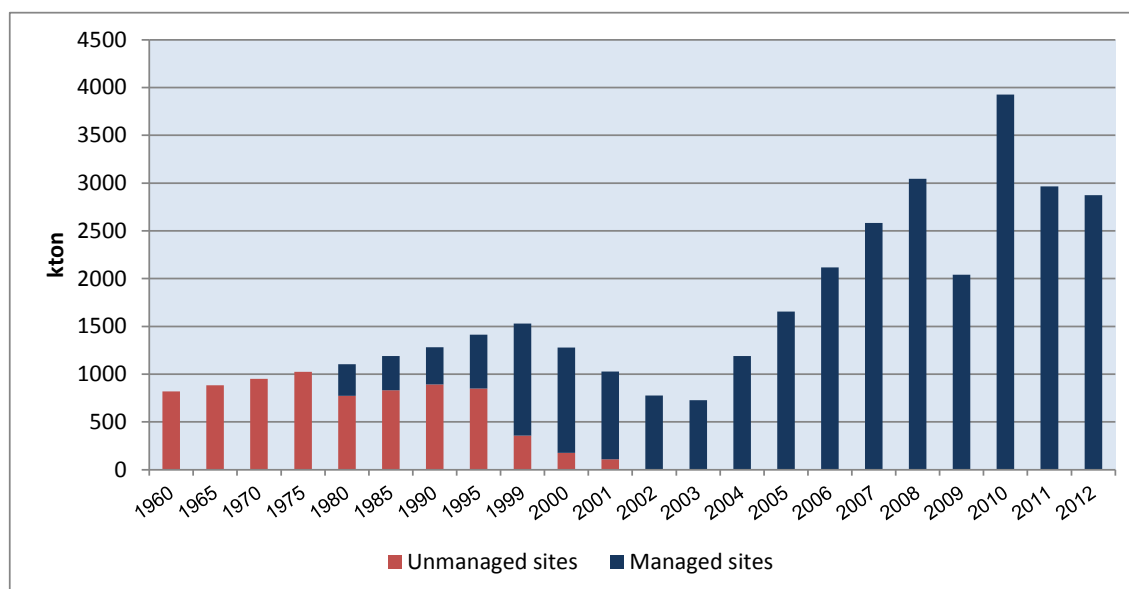
Data for the period 1960-1999 have been estimated based on expert judgment. For the years 1960-1990 a growth rate of 1.5% per year was considered, and for the following years (1990-1998), 2% per year. Data for the years 1999, 2002 and 2003 refer to the annual registries data. The years 2000 and 2001 refer to estimates based on the interpolation of 1999 and 2002 data.

Data from 2008 onwards refer to data collected via an electronic platform (SIRER/ Integrated System on Electronic Database on Waste). After data collection via SIRER and the respective validation at APA, I.P., data is handled by the INE (National Statistical Office) in order to extrapolate the information to the universe of enterprises for each economic branch, due to the different scope required by the national legislation on waste registration and the Waste Statistics Regulation (Regulation (EC) no. 2150/2002).

Data for the years 2011 and 2012 are still under revision by INE and the quantities of industrial waste landfilled have been estimated based on GDP.

All industrial waste was considered to be disposed in SWDS together with municipal waste. However, as there is no available information concerning industrial waste treatment for the earlier years, it was assumed that all estimated waste produced has followed the municipal disposal pattern between uncontrolled and controlled SWDS.

Figure 8-9 – Quantities of fermentable industrial waste disposed to SWDS



Source: APA

The significant fluctuations on the amounts of industrial waste disposed in landfills, as shown in the figure above, results in part from the use of different data sets along the time. There are however other factors, that explain these differences, such as the landfill diversion. The treatment of industrial waste includes landfilling, incineration, export (e.g. dangerous waste),

and recycling. The differences result, at least partially, from the variation of fluxes to other treatments as a consequence of the annual waste market demand.

#### 8.2.1.1.2.2.1 CH<sub>4</sub> generation potential (Lo)

The parameters used in the calculations are basically the same as the ones presented for municipal waste, excepted for DOC. Data for this parameter varies according to the available information on industrial waste composition and includes estimates based on interpolation and average of last available data for missing years. (Table 8-4)

Available data on industrial waste production is based on APA's data which refer to annual registries from industrial units declarations. This information is classified according to the European Waste Catalogue list (EWC) and is disaggregated by type of treatment. From this database a selection was made (by expert judgment) in order to consider the EWC categories referring to organic origin. Each one of these categories was classified according to a group and was assigned with a DOC value, also defined by expert guess.

Until 2003 the inventory considered data from the waste registries at a disaggregated level of 6 digits of the European Waste list Decisions - 2000/532/EC, by treatment/destiny type; no statistical treatment were made to consider the non-responses. Based on these categories, a selection was done in order to consider the categories containing fermentable waste, and each of the categories selected was classified according to a group/DOC value.

Since 2008, data refer to the National Waste Registry that collects data via de web interface for data communication/ SIRER. Data provided by waste operators under this registry are treated subsequently by the INE in order to extrapolate the information to the universe of enterprises for each economic branch. The extrapolation is made however at a more aggregated level.

Data considered for the years 2008 onwards, refer to the EWCSat 4.0 categories that are considered as organic waste. These data are presented in the next table.

Table 8-4 – Industrial organic waste composition and DOC

waste groups	DOC (0..1)	1960-99	1999	2000	2001	2002	2003			
ton										
paper and textiles	0.40		841899			384,713	316,538			
garden waste, park waste or other non-food organic putrescibles	0.17		77,269			208,965	172,135			
food waste	0.15		19,209			56,455	158,286			
wood or straw	0.30		155,142			64,044	14,566			
Fuels	0.00		0			0	0			
Plastic	0.00		115,538			22,190	40,060			
Sludge from natural origin	0.14		236,280			39,759	22,687			
Sludge from non-natural origin or hydrocarbons	0.00		83,191			0	31			
Synthetic fibres	0.00		2,073			0	0			
Non-natural organic substances	0.00		52			1410	2,643			
TOTAL	-	estimates	1,530,654	1279,615	1,028,576	777,537	726,946			
DOC (weighted average)	-	0.262	0.282	0.284	0.285	0.286	0.257			

waste groups (EWC-Stat/Version 4)	DOC (0..1)	2004	2005	2006	2007	2008	2009	2010	2011	2012
ton										
03.2 + 03.3 Sludge from industrial origin	0.14					19,475	47,055	46,228		
05 Health care and biological wastes a)	0.15					5,916	8,852	12,041		
07.2 Paper and cardboard wastes	0.40					93,105	53,202	10,370		
07.5 Wood wastes	0.30					259,655	23,346	9,371		
07.6 Textile wastes a)	0.24					378,817	50,562	930,801		
09.1 Animal waste of food preparation and products	0.15					34,218	47,935	28,703		
09.2 Vegetal waste	0.15					86,763	78,872	182,481		
09.3 Slurry and manure	0.15					0	20	0		
10.1 Household and similar wastes b)	0.172					2,010,405	1,575,144	2,574,925		
10.21 + 10.22 Mixed and undifferentiated materials	0.26					69,460	19,828	25,321		
11 Common sludges	0.14					88,112	134,812	107,268		
TOTAL	-	1,190,742	1,654,538	2,118,334	2,582,130	3,045,927	2,039,630	3,927,509	2,966,341	2,872,330
DOC (weighted average)	-	0.246	0.234	0.222	0.210	0.198	0.178	0.187	0.188	0.188

Total amounts of organic industrial waste and associated DOC values refer to estimates based on interpolation for the years: 2000, 2001 (interpolation of 1999 and 2002 data); 2004-2007 (interpolation of 2003 and 2008 data); data for 2011 and 2012 were estimated based on GDP data for 2011 and 2012, assuming the relation of GDP average for the 2008-2010 and the incinerated quantity average for the same period. DOC values for these years refer to the 2008-2010 average. The amounts of waste incinerated for the previous decades (1960-1998) were calculated considering annual growth rates as explained previously.

DOC values used in the calculations 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.

#### 8.2.1.1.2.2.2 *Other parameters*

Data on quantities of CH<sub>4</sub> recovered and combusted were considered jointly with urban waste, as all industrial waste was considered to be disposed together with urban waste in SWDS.

## 8.2.2 Wastewater Handling (CRF 6.B.)

### 8.2.2.1 *Domestic Wastewater*

The accounting of this category is based on data trends for the public urban wastewater handling systems and types of treatment are compiled by APA (previously INAG/National Institute for Water which was integrated in the APA).

CH<sub>4</sub> emissions from Wastewater Handling (WWH)

#### 8.2.2.1.1.1 *Methodology*

CH<sub>4</sub> emissions from urban wastewater handling were estimated using a methodology adapted from IPCC 1996 Revised Guidelines (IPCC, 1997) and GPG (IPCC, 2000), which follows three basic steps:

##### 8.2.2.1.1.1.1 *1 – Determination of the total amount of organic material originated in each wastewater handling system*

The main factor determining the CH<sub>4</sub> 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<sub>dom</sub> - total domestic/commercial organic waste in kg BOD/yr;

P - population in 1000 persons;

D<sub>dom</sub> - domestic/commercial degradable organic component in kg BOD/1000 persons/yr.

#### 8.2.2.1.1.1.2 2 – Estimation of emission factors

The emission factor for each wastewater and sludge type depends on the maximum CH<sub>4</sub> producing potential of each waste type (B<sub>oi</sub>) and a weighted average of CH<sub>4</sub> conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_{oi} \times \sum_x (WS_{ix} \times MCF_x)$$

where:

EF<sub>i</sub> - emission factor (kg CH<sub>4</sub> /kg DC) for waste type i (e.g., domestic wastewater or sludge, etc);

B<sub>oi</sub> - maximum methane producing capacity (kg CH<sub>4</sub>/kg DC) for waste type i;

WS<sub>ix</sub> - fraction of waste type i treated using wastewater handling system x;

MCF<sub>x</sub> - methane conversion factors of each wastewater system x.

Maximum CH<sub>4</sub> producing capacity (B<sub>o</sub>) is the maximum amount of CH<sub>4</sub> that can be generated from a given quantity of wastewater or sludge.

Methane Conversion Factor (MCF) is an estimate of the fraction of DC that will ultimately degrade anaerobically. The MCF varies between 0 for a completely aerobic system to 1.0 for a completely anaerobic system.

#### 8.2.2.1.1.1.3 3 – Calculation of emissions

Emissions are a function of total organic waste generated and an emission factor characterising the extent of CH<sub>4</sub> generation for each wastewater handling system. CH<sub>4</sub> that is recovered and flared or used for energy should be subtracted from total emissions, as it is not emitted into the atmosphere.

$$M = \sum_i (TOW_i \times EF_i - MR_i)$$

where:

M - Total CH<sub>4</sub> emissions from wastewater and sludge handling in kg CH<sub>4</sub>

TOW<sub>i</sub> - total organic waste for waste type i in kg DC/yr. (Step 1)

EF<sub>i</sub> - emission factor for waste type i in kg CH<sub>4</sub>/kg DC (Step 2)

MR<sub>i</sub> - total amount of methane recovered or flared from wastewater type i in kg CH<sub>4</sub>.

#### 8.2.2.1.1.2 Activity data and parameters

Total organic content of domestic sewage (TOW<sub>dom</sub>) was determined multiplying the total population for each year by a per capita wastewater BOD<sub>5</sub> 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 BOD<sub>5</sub> factor considered was 60 g BOD<sub>5</sub>/cap/day, which is the figure considered in the Council Directive 91/271/CEE, 21<sup>st</sup> Mai, referring to urban waste water treatment.

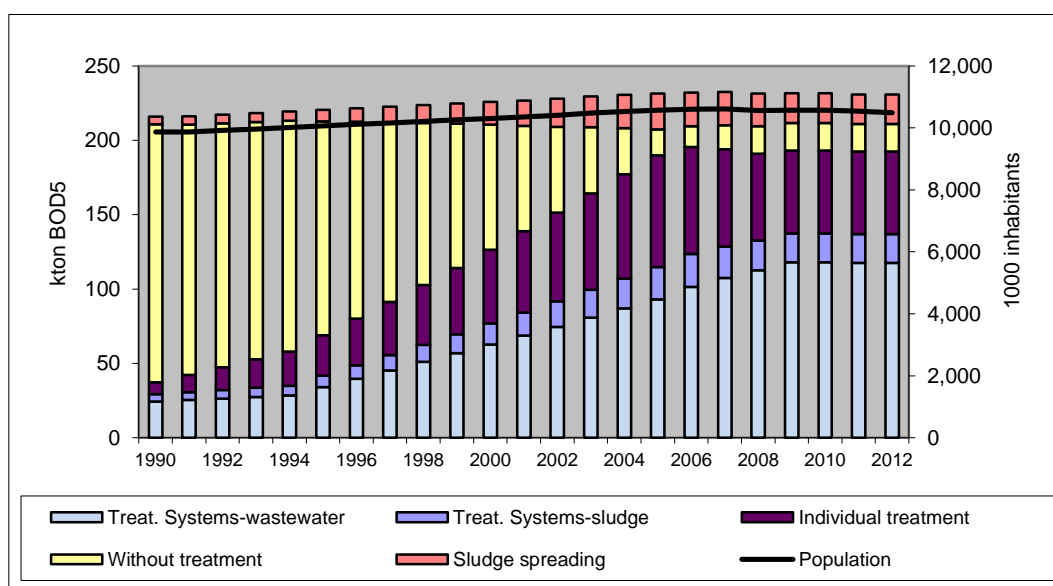
Until 1999, data for wastewater handling systems are based on a compilation study, performed by ex-INAG, of all surveys and inventories done in the past concerning sanitation and wastewater treatment infrastructures. Data from this study refer to 1990, 1994 and 1999. More recent data (from 2005 onwards) is based on a database (INSAAR – Inventário Nacional de Sistemas de Abastecimento e de Águas Residuais/ National survey on water supply and wastewater systems) which was implemented and was managed by ex-INAG. From 2000 to 2004, data used in the calculations are interpolations based on the 1999 and 2005 figures. Data considered since 2010 refer to INSAAR latest available year (2009)..

As a consequence of the restructuration of the National Water Authority, and at present, the “Inventário Nacional de Sistemas de Abastecimento de Água e Águas Residuais (INSAAR)”, the national data base for wastewater treatment systems, is deactivated.

Until further developments, the information to be used in the INERPA will be the information from the River Basin Management Plans. The river basin management plans, according to the Water Framework Directive, DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, of 23 October 2000, establishing a framework for Community action in the field of water policy, must be produced by each Member State every six years, being the next one finalized in 2015.

Total organic waste (TOW in terms of BOD<sub>5</sub> produced) was divided into different fractions (please see next figure), according to the information on wastewater handling types and on assumptions (expert judgment from INAG) concerning the fraction of the organic load treated as a liquid phase (wastewater) and as sludge according to types of wastewater handling systems, and for the % of the organic load retained as non mineralised sludge that is spread in the environment (please see next table).

Figure 8-10 – Wastewater BOD produced according to handling systems (ton BOD<sub>5</sub>) and national population trends



Source: APA (estimates).

Notes: Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with and without anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Lagoons without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Preliminary treatment, Treatment not specified, Lagoon, with anaerobic pond and Imhoff Tanks (100% of organic load).



Treatment systems – sludge: refer to Biodisks with anaerobic sludge digestion, Activated sludge with anaerobic sludge digestion, Percolation beds with anaerobic sludge digestion, Oxidation ponds, Other treatment (37% of organic load) and unspecified treatment.

Individual treatment: refer to wastewater not collected by a public system. It's assumed that the population has a private handling system (private septic tanks).

Without treatment: refer to wastewater collected but not treated, referring to discharges into the ocean, inland waters, soil, and unknown disposal type.

Sludge spreading: refer to the % of the organic load retained as non mineralised sludge in primary treatment (30% of primary organic load generated), and 37% in activated sludge without anaerobic sludge digestion, lagoons without anaerobic pond, Percolation beds without anaerobic sludge digestion, oxidation ponds and other treatment.

Table 8-5 - Percentage of population by wastewater handling system

Wastewater handling systems	1990	1994	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	% population															
<b>Population without sewerage</b>																
1.1- % Pop: without sewerage (latrines)	37.0	23.4	6.4	5.3	4.3	3.2	2.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2- % Pop: individual treatment (private septic tanks)	1.5	8.2	14.8	16.9	19.0	21.2	23.3	25.4	27.5	24.0	23.0	22.0	21.0	21.0	21.0	21.0
<b>Population with sewerage</b>																
2.1- % de Pop: with discharge into the ocean, without treatment	6.5	6.5	6.5	5.6	4.7	3.8	2.8	1.9	1.0	1.0	1.3	1.5	1.2	1.2	1.2	1.2
2.2- % de Pop: with discharge into inland waters, without treatment	36.8	40.8	30.3	25.9	21.5	17.1	12.8	8.4	4.0	3.0	2.5	1.9	1.2	1.2	1.2	1.2
2.3- % de Pop: with discharge into soil, without treatment	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.4- % de Pop: unknown disposal	0.0	0.0	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.0	3.3	4.6	5.6	5.6	5.6	5.6
3- % Pop: with treatment	18.2	21.1	42.0	45.8	49.7	53.5	57.3	61.2	65.0	70.0	70.0	70.0	71.0	71.0	71.0	71.0
3.1- % Pop: collective septic tanks	2.2	2.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	7.0	5.1	3.3	3.0	3.0	3.0	3.0
3.2- % Pop: with preliminary treatment	0.0	0.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	7.0	7.5	8.0	7.6	7.6	7.6	7.6
3.3- % Pop: with primary treatment	5.2	5.2	9.0	8.5	8.0	7.5	7.0	6.5	6.0	3.0	4.4	5.9	1.9	1.9	1.9	1.9
3.4- % Pop: with secondary and tertiary treatment	10.8	13.6	28.0	31.8	35.7	39.5	43.3	47.2	51.0	53.0	52.9	52.9	58.5	58.5	58.5	58.5
3.4.1- Biodisks with anaerobic sludge digestion	1.1	1.4	2.0	1.7	1.4	1.1	0.8	0.5	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
3.4.2- Biodisks without anaerobic sludge digestion	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.7	0.8	0.8	0.6	0.3	0.2	0.2	0.2	0.2
3.4.3- Activated sludge with anaerobic sludge digestion	1.4	2.0	4.6	6.9	9.2	11.5	13.9	16.2	18.5	18.9	18.2	17.5	16.7	16.7	16.7	16.7
3.4.4- Activated sludge without anaerobic sludge digestion	1.4	2.0	4.6	5.8	7.0	8.1	9.3	10.5	11.7	11.9	11.6	11.3	14.0	14.0	14.0	14.0
3.4.5- Laguning, with anaerobic pond	1.7	1.9	3.6	3.0	2.4	1.9	1.3	0.8	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
3.4.6- Laguning, without anaerobic pond	0.6	0.6	1.2	1.9	2.6	3.2	3.9	4.6	5.3	5.5	5.3	5.1	4.4	4.4	4.4	4.4
3.4.7- Percolation beds with anaerobic sludge digestion	3.6	4.6	8.8	8.0	7.1	6.3	5.4	4.6	3.7	3.7	3.4	3.1	2.9	2.9	2.9	2.9
3.4.8- Percolation beds without anaerobic sludge digestion	0.0	0.0	0.0	0.7	1.3	2.0	2.6	3.3	3.9	4.0	3.2	2.4	1.8	1.8	1.8	1.8
3.4.9- Imhoff Tank	0.6	0.3	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.3	1.2	1.0	0.8	0.8	0.8	0.8
3.4.10- Oxidation ponds with anaerobic sludge digestion	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.6	0.6	0.6
3.4.11- Oxidation ponds without anaerobic sludge digestion	0.3	0.4	1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.6	1.5	1.4	1.4	1.4	1.4	1.4
3.4.12- Other treatment with anaerobic sludge digestion	0.0	0.0	0.0	0.4	0.8	1.2	1.5	1.9	2.3	2.3	2.2	2.0	2.5	2.5	2.5	2.5
3.4.13- Other treatment without anaerobic sludge digestion	0.0	0.3	1.6	1.4	1.1	0.9	0.7	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3.4.14- With unspecified treatment	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.7	0.8	1.7	4.7	7.7	12.8	12.8	12.8	12.8

Source: APA

**Parameters: Bo and MCF** - The default IPCC (2000) value for Bo 0.6 kg CH<sub>4</sub>/kg BOD was used for wastewater and sludge. Table 8-6 presents MCF factors used for each wastewater treatment system considered.



Table 8-6 - Wastewater handling systems and associated Methane Conversion Factors (MCF), and fraction of organic load treated as liquid and solid phase

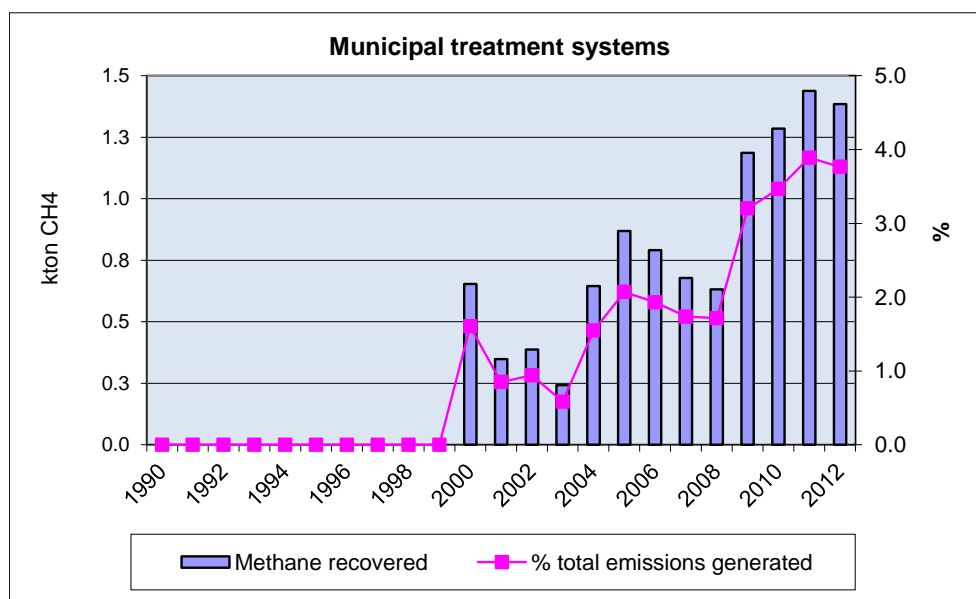
Wastewater handling systems			MCF		Share between liquid phase and solid treatment		Sludge spread in the environment
			Wastewater	Sludge	Wastewater	Sludge	
					(% of organic load)		
Population without sewerage							
1.1-	% Pop: without sewerage (latrines)	a)	0.61	-	-	-	
1.2-	% Pop: individual treatment (private septic tanks)		0.50	-	-	-	
Population with sewerage							
2.1-	% de Pop: with discharge into the ocean, without treatment		0.00	-	-	-	
2.2-	% de Pop: with discharge into inland waters, without treatment	b)	0.30	-	-	-	
2.3-	% de Pop: with discharge into soil, without treatment	b)	0.30	-	-	-	
2.4-	% de Pop: with unknown disposal		0.20	-	-	-	
3-	% Pop: with treatment						
3.1-	% Pop: colective septic tanks		0.50	-	-	-	
3.2-	% Pop: with preliminary treatment		0.00	0.00	-	-	
3.3-	% Pop: with primary treatment		0.00	0.00	70%		30%
3.4-	% Pop: with secondary and tertiary treatment		-	-	-	-	
3.4.1-	Biodisks w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.2-	Biodisks w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.3-	Activated sludge w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.4-	Activated sludge w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.5-	Laguning, w ith anaerobic pond	d)	0.20	0.00	100%	-	
3.4.6-	Laguning, w ithout anaerobic pond		0.00	0.00	63%	-	37%
3.4.7-	Percolation beds w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.8-	Percolation beds w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.9-	Imhoff Tank		0.80	0.00	100%	-	
3.4.10-	Oxidation ponds w ith anaerobic sludge digestion	d)	0.20	0.00	63%	37%	
3.4.11-	Oxidation ponds w ithout anaerobic sludge digestion		0.00	0.00	63%	-	37%
3.4.12-	Other treatment w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.13-	Other treatment w ithout anaerobic sludge digestion		0.00	0.00	63%	-	37%
3.4.14-	With unspecified treatment		0.20	0.00	100%	-	

Notes:

- a) Expert judgment, 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).
- b) 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).
- 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).

Recovery of CH<sub>4</sub>: data on landfill gas flared refer to the amounts of biogas consumed in electrical production in municipal wastewater treatment systems. This information is collected annually by DGEG, together with data on electric energy produced and sold, typology of equipments, etc. The quantities of biogas that are reported in Nm<sup>3</sup> were converted into CH<sub>4</sub> amounts, considering a density of 0.72 kg/m<sup>3</sup> and a percentage of 60% of CH<sub>4</sub> in biogas. This figure is based on the assumption that municipal wastewater treatment uses anaerobic digestion and that the biogas produced has a content of 60 to 70% of CH<sub>4</sub> (Universidade de Coimbra, 2006).

Figure 8-11 - Quantities of CH<sub>4</sub> flared

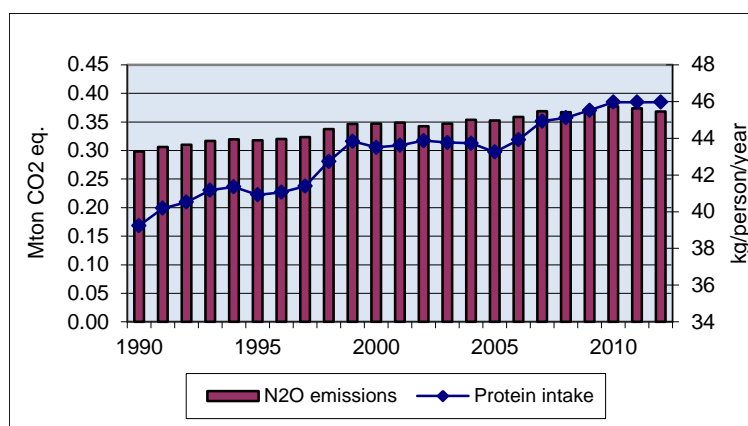


Source: Quantities based on data DGEG data.

#### 8.2.2.1.2 N<sub>2</sub>O 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. N<sub>2</sub>O 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 N<sub>2</sub>O production from human sewage.

Figure 8-12 – N<sub>2</sub>O emissions from human sewage and per capita protein intake



Source: Protein intake: INE data; 2009-2011 data refer estimates. .

#### 8.2.2.1.2.1 Methodology

Emissions of N<sub>2</sub>O 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.

$$N_2O_{(s)} = (\text{Protein} * \text{Frac}_{NPR} * \text{Pop} - \text{FSEW}) * \text{EF} * 44/28$$

where:

$N_2O_{(s)}$  -  $N_2O$  emissions from human sewage (kg  $N_2O$ -N/yr);

Protein - annual per capita protein intake (kg/person/yr);

$\text{Frac}_{NPR}$  - fraction of nitrogen in protein (kg N/kg protein);

Pop - number of inhabitants in country;

FSEW - nitrogen in sewage sludge applied to agriculture soils (please see CRF 4.D chapter)

EF - emissions factor (kg  $N_2O$ -N/kg sewage-N produced);

44/28 is the molecular weight ratio of  $N_2O$  to  $N_2$ .

This approach assumes that N disposal, and thus  $N_2O$  emissions associated with land disposal and domestic wastewater treatment are negligible and all N is discharged directly into aquatic environments. No amount of N is considered to be removed with the sludge and applied in agriculture land or disposed in other forms.

Final disposal of sludge in Portugal comprehends landfill, incineration and agricultural recycling. However, the information available on sludge quantities produced and disposed on land is still scarce and disperse and the existing data refer in majority to estimates. This is the rationale for not accounting separately emissions from land sludge application.

#### 8.2.2.1.2.2 Activity data and parameters

Activity data results of protein intake, according to national data from National Statistical Office (INE) (please see next table), multiplied by total population, from the INE Census for the years 1981, 1991, 2001, and 2011; intermediate years have been estimated by interpolation. Data on annual per capita protein intake refer to the “Balança Alimentar Portuguesa - BAP” which is updated every five years. Latest data available refer to a 2010 enquiry, that considered the 2003-2008 period. Next evaluation is foreseen for 2015 (period 2009-2013). Activity data for the latest years have been estimated by the Excel Forecast function. Other parameters considered for the estimations are based on IPCC (1997) defaults.

Table 8-7 - Data and parameters used calculation of N<sub>2</sub>O emissions from wastewater

Parameter	Year	INE data (kg/person/year)
Annual per capita protein intake	1990	39.2
	1991	40.2
	1992	40.5
	1993	41.2
	1994	41.4
	1995	40.9
	1996	41.1
	1997	41.4
	1998	42.7
	1999	43.8
	2000	43.5
	2001	43.6
	2002	43.9
	2003	43.8
	2004	43.7
	2005	43.3
	2006	43.9
	2007	44.9
	2008	45.1
	2009	45.5
	2010	46.0
	2011	46.0
	2012	46.0
Fraction of nitrogen in protein 1)	16%	(constant)
Emission factor	0.01 kg N <sub>2</sub> O-N/kg N	(constant)

Note:

1) IPCC default

2) INE data: 2009-2012 data refer to estimates.

#### 8.2.2.2 Industrial Wastewater

##### 8.2.2.2.1 CH<sub>4</sub> Emissions from Industrial Wastewater Handling

###### 8.2.2.2.1.1 Methodology

The method to estimate methane emissions from industrial wastewater handling also follows the default methodology proposed in the 1996 IPCC Guidelines (IPCC, 1997) and the Good Practice Guidebook. The following formula is used, combining equations 5.5 and 5.7 in the GP:

$$Emi_{CH_4} = \sum_i \{TOW_{(j)} * \sum_h [WHS_{(j,h)} * MCF_{(h)}] - Rec_{CH_4(j,h)}\}$$

Where,

$Emi_{CH_4}$  – Total methane emissions from industrial wastewater handling, t CH<sub>4</sub>/yr;

$TOW_{(j)}$  – Total Organic wastewater generated from industrial sector j, expressed in COD, t O<sub>2</sub>/yr;

$WHS_{(j,h)}$  – Part of the total organic wastewater generated in industrial sector j that is handled by system h, fraction;

$MCF_{(h)}$  – Methane Conversion Factor, fraction;

$Rec_{CH_4(l,h)}$  – 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.

#### 8.2.2.2.1.2 Activity data

The use of data from specific industrial plants concerning COD concentrations in discharge and its flow could in principle be used to estimate organic wastewater load. Although efforts are being done presently, by the Water Institute in Portugal (INAG) to obtain a reliable survey of industrial discharges, the collected data in the INSAAR system<sup>154</sup> is still not suitable to be used in the inventory of air emissions. Data on sources is scarce, available with difficulty and its representativeness as estimator of load from all units in the sector is undetermined.

After consultation with the experts from INAG, under the works for the Inventory Methodological Development Plan, an alternative approach had to be developed. This approach, which is in line with the recommendations of the IPCC Good Practices, estimates organic wastewater load (TOW) using statistical production data on industries ( $Ind_{PROD}$ , ton product/yr) multiplied by pollution coefficients ( $Pol_{COEF}$ , kg  $O_2$ /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 sectors<sup>155</sup>. The main conclusions from the meeting were:

- The COD in the Cotton fibres processing industries is mainly generated in textile printing and 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 revise 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.

<sup>154</sup> The INSAAR systems is a data collected data implemented by INAG

<sup>155</sup> -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 COD load.

Table 8-8 – Pollution Coefficients to estimate Industrial organic wastewater production

Industry	Unit prod (PU)	Discharge (m3/PU)	CBO5 (kg/PU)	CQO (kg/PU)	in.eq. (kg yr/PU)
Slaughter House	ton	6	18	27	0.881
Slaughter House, swine	ton	6	18	42	0.900
Slaughter House, Poultry	ton	9	6	13	0.269
Meat Packing	ton	10	20	30	0.978
Milk processing	m3	1	1	2	0.044
Cheese	m3 milk	8	13	20	0.651
Other dairy products	m3 milk	5	7	10	0.347
Fruit and vegetables conservation	ton	15	15	27	0.734
Tomato juice	ton	100	19	32	0.930
Fruit Juices	ton	9	45	77	2.216
Fish processing and canning	ton	35	18	35	0.856
Olive oil production	ton olives	1	15	45	0.734
Olive oil processing	ton	6	1	1	0.044
Edible oils	ton	3	13	19	0.612
Margarine	ton	25	3	8	0.161
Grains milling and processing	ton	3	5	9	0.220
Sugar processing	ton	8	2	4	0.093
Yeast	ton	120	600	1 080	29.354
Ethanol	m3	17	328	1 192	16.068
Spirits Distillation	m3	8	95	218	4.628
Wine Cellars	ton grapes	2	5	8	0.220
Beer	m3	5	4	9	0.215
Mineral water and similars	ton	8	6	10	0.294
Wool production	ton	44	89	366	4.354
Wool processing	ton	537	87	347	4.256
Synthetic fibres processing	ton	155	155	268	7.583
Artificial fibres processing	ton	42	30	52	1.468
Cotton fibres processing	ton	317	155	268	7.583
Leather industry	ton	85	85	213	4.159
Cork processing	ton	1	2	8	0.073
Cork granulation	m3	1	83	1 104	4.061
Kraft pulping	ton	140	28	158	1.345
Acid sulphite pulping	ton	270	283	1 050	13.845
Kraft paper	ton	14	1	3	0.034
Wafer board and Strand board	ton	1	14	43	0.695
Chorine and alkalis	ton ClNa	28	0	39	1.336
Inorganic acids	ton	100	0	50	1.712
Cyclic Hydrocarbons	ton	190	285	570	13.943
Aliphatic Hydrocarbons	ton	190	285	570	13.943
Synthetic fertilizers	ton	15	15	38	0.734
Pesticides	ton	4	23	30	1.111
Polymers	ton	15	15	45	0.734
Synthetic rubber	ton	15	15	45	0.734
Artificial fibres production	ton	300	150	450	7.339
Polyester fibres production	ton	348	6	16	0.313
Acrylic fibres production	ton	65	50	121	2.422
Paints, varnishes and lacquers	ton	0	1	9	0.029
Pharmaceutical products	employe	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 2012. 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 which represented 95% of the total wastewater CH<sub>4</sub> emissions in the Initial Report. From a total of 51 industrial sectors 15 represent 95% of the total CH<sub>4</sub> emissions (time period 1990-2004);

- In-depth analysis of the activity data time series for each industrial sector that represented 95% of the total wastewater CH<sub>4</sub> 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 2012;
- Production of paper pulp was available directly from the individual industrial plants, for the all period.

Table 8-9 and Table 8-10 present the building blocks of the activity data time series from the available information. Gaps in mid years were estimated by linear interpolation. In a similar mode, linear extrapolation was used to estimate data for years 1990-1991 and 2001 till 2012, 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 information<sup>156</sup>. The checking of the time series was based on graph plotting of the data, and basically the aim was to detect unexpected sudden changes in the magnitude of the time series from 1991 till 1992, when IAIT was changed to IAPI. In some situations the beginning years when IAPI was started had to be discarded, because a sudden and temporary drop from

<sup>156</sup> 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.

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.

Table 8-9 - Sources of Information used to define the time-series of industrial production (1/2)

Industry	IAIT CAErev1	IAP PRODCOM	Infoline	Note
Slaughter House			1990-2012	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2012	
Slaughter House, Poultry			1990-2012	Broilers, Turkeys, ducks, quails, ostrich, guinea-fowl, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200	-	
Milk processing	3112		1994-2012	
Cheese	3112	15510	-	
Other dairy products	3112		1994-2012	Cream, yogurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2012	
Tomato juice			1994-2012	
Fruit Juices	3131+3132		1994-2012	
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			1993-2012	
Ethanol	313110	159101070; 1592011	-	
Spirits Distillation	3131+3132	1591010-159101070+1592012	-	
Wine Cellars	3131+3132	15930; 15950	2001-2012	
Beer	3133	1596010	-	
Mineral water and similars			1993-2012	

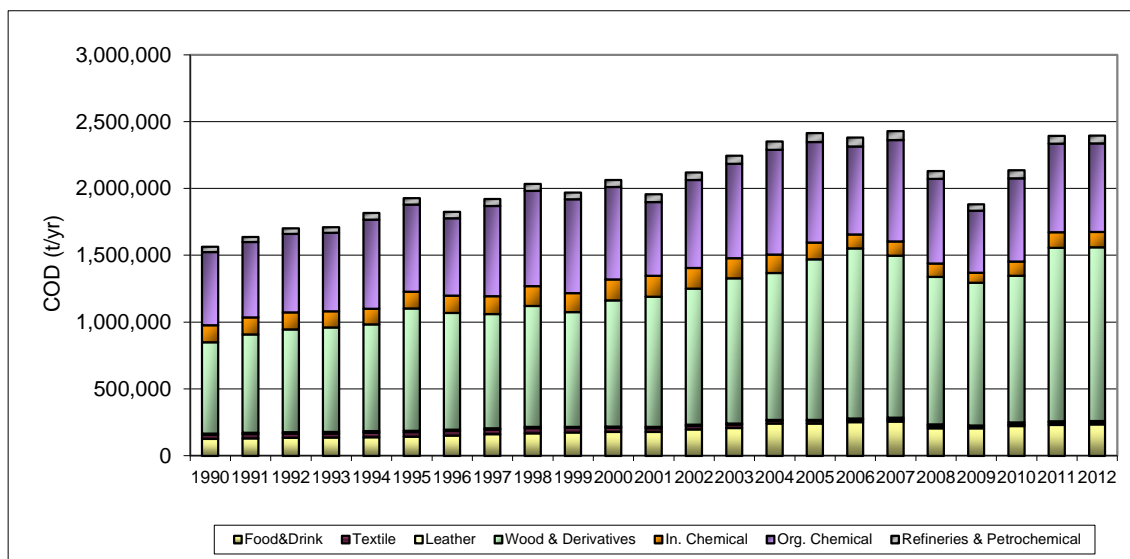


**Table 8-10 - Sources of Information used to define the time-series of industrial production (2/2)**

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	-	
Chorine and alkalis		241301111; 2413015; 2413022	-	
Inorganic acids		2413014-241301453- 241301475- 241301477	-	
Cyclic Hydrocarbons		2414312; 2414314	-	
Aliphatic Hydrocarbons		2414311	-	
Synthetic fertilizers		2415	-	Original units is kg N, kg P2O5 and K2O and were converted to ton of fertilizer
Pesticides	3512	242	-	
Polymers	351312	24160-2416058	-	
Synthetic rubber		2417	-	
Artificial fibres production		2470023; 247003070	-	
Polyester fibres production		247001130; 247001315; 247001350	-	
Acrylic fibres production		247001150	-	
Paints, varnishes and lacquers	3521	24301	-	
Pharmaceutical products			1998-2012	
Soaps		2451131	-	
detergents		2451120/32	-	
Petroleum refining			-	Energy Balance (DGGE): 1990-2012

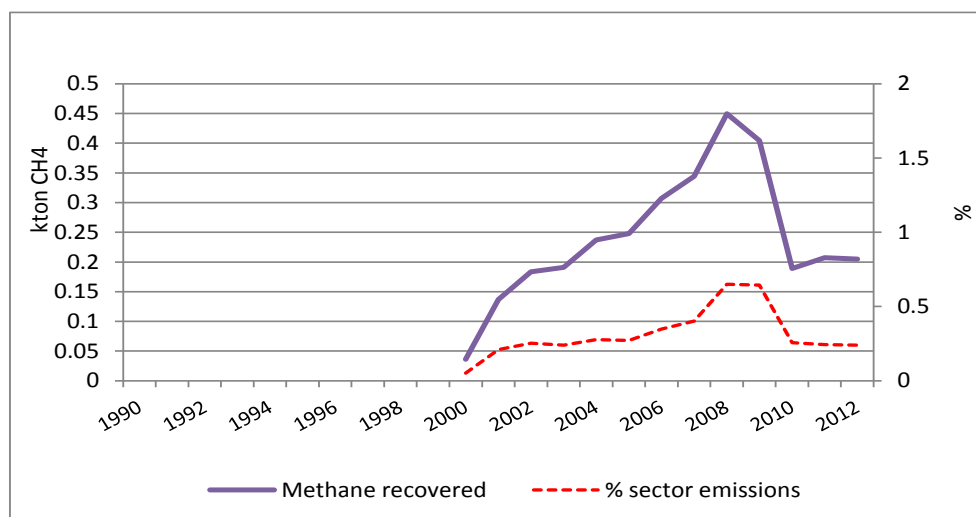
Total wastewater load aggregated per industrial group is presented in Figure 8-13 below, from where it is evident the continuous growth of discharge from 1990 to 2007, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry.

Figure 8-13 - Industrial Wastewater load, expressed in COD, from major groups of industrial activity



Biogas generated in sludge treatment systems is flared for electrical production in cogeneration units. DGEG collects information on the amounts of biogas consumed in an annual inquiry. The quantities of biogas that are reported in Nm<sup>3</sup> were converted into CH<sub>4</sub>, considering a density of 0.72 kg/m<sup>3</sup> and a percentage of 60% of CH<sub>4</sub> in biogas. . This figure is based on the assumption that municipal wastewater treatment uses anaerobic digestion and that the biogas produced has a content of 60 to 70% of CH<sub>4</sub> (Universidade de Coimbra, 2006).

Figure 8-14 – Methane recovery



Source: Quantities based on DGEG data.

### 8.2.2.2.1.3 Emission Factors

#### 8.2.2.2.1.3.1 Wastewater handling systems

As consequence of the fact that there was no available comprehensive information about the existence of each treatment system, the necessary information to determine the per cents for each sector had to be guessed specifically for the inventory using information collected from:

- EPER data. At the time that the inventory was compiled the EPER data was available for 2000 and partially for 2004. Information for the following sectors was available: paper pulp production; crude oil refining; slaughterhouses and meat processing; pig farms; olive oil extraction; fish canning and processing and chemical industry;
- Covenants of Environmental Adaptation. These were voluntary agreements between the Environmental Ministry, other ministries responsible for the permits of specific industrial sectors (Ministry of Economy or the Ministry of Agriculture, Rural Development and Fisheries) and several industrial associations in representation of the industrial units. The agreements were established between March 1997 and February 1998 with the objective to define a time schedule to reach the complete respect of legal constraints concerning the water, air, wastes and noise. The contract involved the elaboration of an *Assessment of the Environmental State*<sup>157</sup> and a *Specific Plan of Elaboration*<sup>158</sup>. 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;
- Information collected from the Environmental Permits attributed to operators of installations covered by the IPPC Directive.

For each specific industrial sector the share of use of each specific treatment system was aggregated according to the following classes:

- There is no treatment of wastewater and the effluent is discharged in the water system or in soil;
- Use of individual Septic Tank;
- Primary treatment only;
- Secondary treatment (aerobic), with deficient management;
- Secondary treatment (aerobic), well managed;
- Secondary treatment (anaerobic), no CH<sub>4</sub> recovery considered;
- Discharge into the sewer system common to the treatment of domestic wastewater system;
- Unknown destiny of effluent, determined as difference to total.

<sup>157</sup> Caracterização da Situação Ambiental, in the original Portuguese nomenclature.

<sup>158</sup> Plano Específico de Adaptação, in the original Portuguese nomenclature.

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 2012.

New information has been collected from the Environmental Permits for this 2013 submission in order to improve the characterization of the wastewater treatment systems for the industrial sectors for which no information was available (unknown treatment). Despite this effort, the information is still incomplete and include considerable error and refer very often to expert assumptions, so this work will continue and should be further developed during this year.

The per cent of total industrial load, expressed in COD, for which the treatment system and final destination of effluents was unknown, varies from 1990 to 2011 between 49% and 33% as presented in the next table.

Table 8-11 - Fraction of industrial wastewater treated using each wastewater handling system (percent of total industrial load expressed as COD)

Wastewater Handling System		1990	1995	2000	2005	2010	2011	2012
No treatment, discharge in river or soil	%	11.6	14.3	10.0	11.7	10.5	12.2	12.2
Primary	%	5.9	5.2	5.3	6.5	1.0	1.0	1.0
Secondary treatment: Aerobic, well managed	%	17.5	14.4	15.0	14.5	25.0	23.0	23.0
Secondary treatment: Aerobic, not well managed	%	2.6	2.3	2.2	2.8	2.5	2.3	2.3
Secondary treatment: Anaerobic, no CH <sub>4</sub> recovery	%	0.0	0.0	0.1	1.1	1.4	1.3	1.3
Septic Tank	%	4.7	6.4	5.8	6.5	6.0	6.9	6.9
Municipal Sewer system, treatment with Municipal Waste Water	%	9.1	12.3	14.2	17.0	18.0	20.1	20.1
Unknown	%	48.6	45.2	47.4	39.9	35.5	33.3	33.1
<b>Total</b>	<b>%</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

#### 8.2.2.2.1.3.2 Methane Production Potential

The parameter  $B_0$ , representing the maximum Methane Production Potential, was assumed constant and common to all sectors and treatment systems, and set to 0.25 kg CH<sub>4</sub>/kg COD, the default value in the Good Practice Guidance from IPCC (2000).

#### 8.2.2.2.1.3.3 Methane Conversion Factor

The GPG (IPCC,2000) is not very comprehensive in what concerns the choice of default MCF values. The new guidelines from IPCC that were recently published (IPCC,2006) present more detailed values, now specific of treatment systems and management conditions, and they were used to establish the new MCF values, as may be seen in the next table.

Table 8-12 - Methane Conversion Factors (MCF) and assumptions

Treatment System	MCF (%)	Explanatory Note
No treatment, discharge in river or soil	10	IPCC (2006). Table 6.8 Sea, river and lake discharge
Primary	0	Assuming that retention time is insufficient to create anaerobic conditions
Secondary treatment: Aerobic, well managed	0	IPCC (2006). Table 6.8 Aerobic Treatment Plant. Well managed
Secondary treatment: Aerobic, not well managed	30	IPCC (2006). Table 6.8 Aerobic Treatment Plant. Not well managed
Secondary treatment: Anaerobic, no CH <sub>4</sub> recovery	80	IPCC (2006). Table 6.8 Anaerobic digester/reactor. CH <sub>4</sub> capture not considered
Septic Tank	50	IPCC (2006). Table 6.3 Septic system

In the case where the industrial effluent was discharged into the unitary municipal treatment system, the MCF was determined from the average situation in Portugal for the domestic wastewater system when there is any form of treatment, either primary, secondary or tertiary. The values follow the evolution in the urban sector that was explained in previous chapters, have decreased from 18% in 1990 to 16% in 2012. In a similar mode, for the unknown situations the average weighted MCF for all situations of treatment of domestic wastewater was used as a best guess. Values also change over time, from 24% in 1990 to 17% in 2012.

#### 8.2.2.2.1.4 Comparison of the Country Specific Methodology and the IPCC defaults

In order to evaluate if Portugal was over-estimating or under-estimating emissions in the base year, the CS Pollutant Coefficients (PC) used in submission 2006 were compared with the Pollutant Coefficients proposed by the IPCC GP (table 5.4 of the Good Practice). For the industrial sectors identified in Portugal, and whenever possible<sup>159</sup>, the comparison of the PC of Cartaxo et al (1985) (named CS) were compared with the equivalent IPCC in the next table<sup>160</sup>:

<sup>159</sup> The level of detail of the IPCC Pollutant Coefficients is not so detailed as the CS data set.

<sup>160</sup> The original IPCC table refers only to wastewater generation rate and COD concentration. The Pollutant Coefficients presented in the table were obtained multiplying the wastewater by the COD concentration. If no recommend value was available in the original table the average value in the range was used.

Table 8-13 – 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	-
Chlorine and alkalis	ton ClNa	39.0	NA	-
Inorganic acids	ton	50.0	NA	-
Cyclic Hydrocarbons	ton	570.0	201.0	0.35
Aliphatic Hydrocarbons	ton	570.0	201.0	0.35
Synthetic fertilizers	ton	37.5	NA	-
Pesticides	ton	30.0	NA	-
Polymers	ton	45.0	2.2	0.05
Synthetic rubber	ton	45.0	2.2	0.05
Artificial fibres production	ton	450.0	2.2	0.00
Polyester fibres production	ton	16.3	2.2	0.14
Acrylic fibres production	ton	121.1	2.2	0.02
Paints, varnishes and lacquers	ton	9.2	30.3	3.29
Pharmaceutical products	employee	13.5	NA	-
Soaps	ton	12.0	2.6	0.21
detergents	ton	1.7	2.6	1.50
Petroleum refining	ton	1.5	0.6	0.40

Departing from the revised COD estimates, new estimates of COD were made using the Pollution Coefficients that are IPCC default (whenever available) and emission estimates rebuilt. The results are presented in the next two figures.

Figure 8-15 - Comparison between COD estimates using CS PC and IPCC defaults.

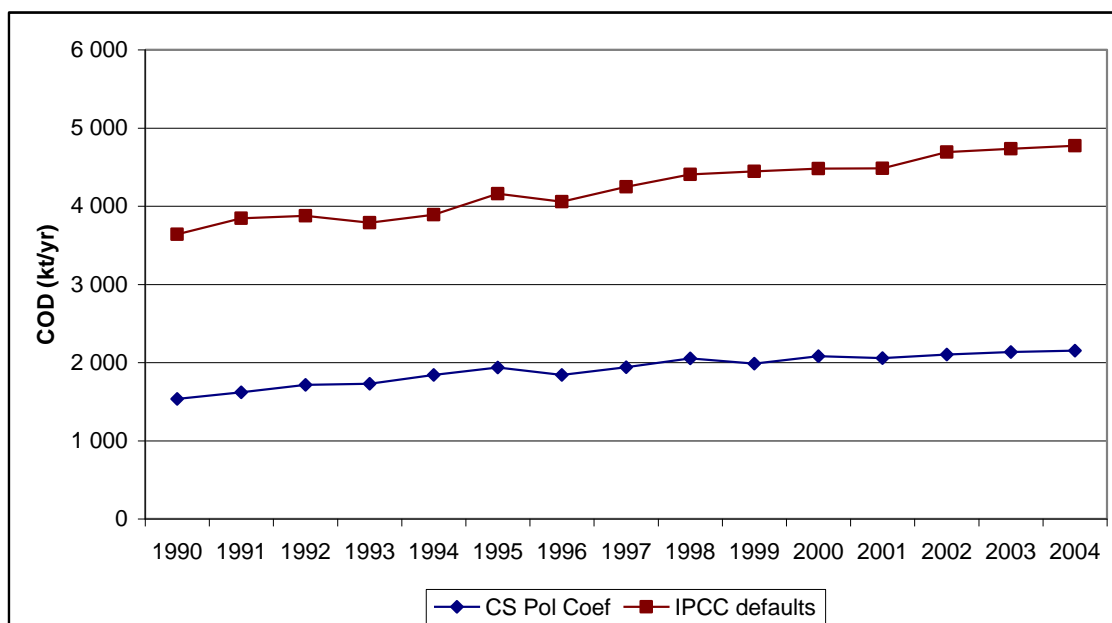
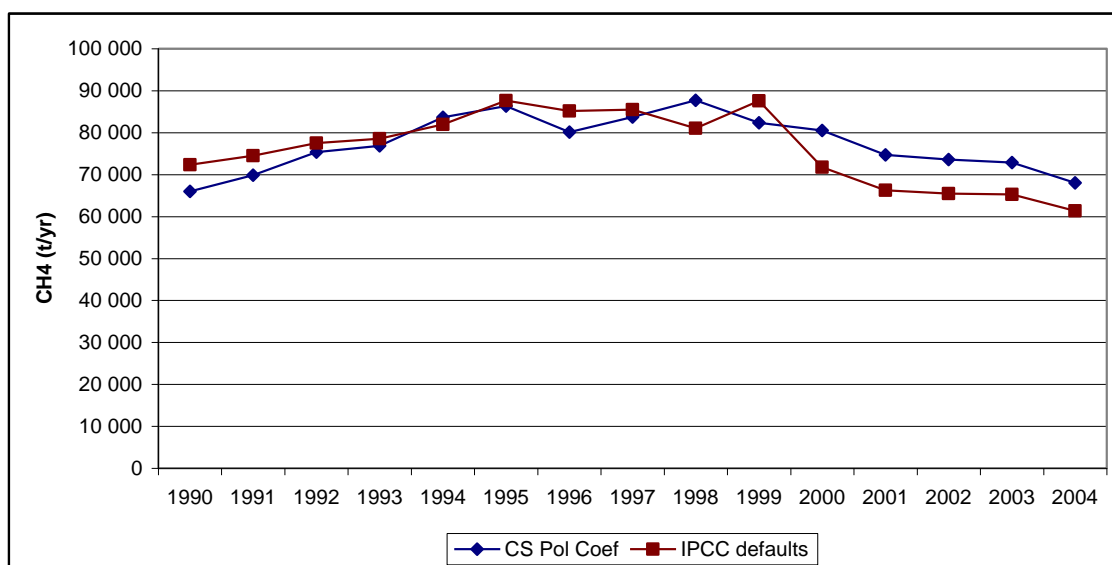


Figure 8-16 - Comparison between CH<sub>4</sub> emission estimates using CS PC and IPCC defaults.



The comparison to IPCC defaults indicates that estimates made by INERPA are probably under-estimating AD and emissions in the base year, and potentially over-estimating emissions in the most recent years. However, total methane emissions are less affected by the choice of Pollutant Coefficients.

#### 8.2.2.2.1.5 Recalculations

Recalculations refer to the revision of activity data on industrial production time series and the revision of treatment types based on the Environmental Permits.

#### 8.2.2.2.1.6 Further Improvements

Information from the Environmental Licensing (European Union's IPPC directive) has been collected for the last submissions in order to improve the characterization of the wastewater treatment systems for the industrial sectors for which no information was available (unknown treatment).

Considering the limitations in the time trend in load and the significant percentage of the unknown situations regarding the treatment types, efforts will continue in order to improve the knowledge of the situation concerning the industrial wastewater handling systems.

#### 8.2.2.2.2 N<sub>2</sub>O Emissions from Industrial Wastewater Handling

##### 8.2.2.2.2.1 Methodology

The IPCC does not propose any methodology to estimate N<sub>2</sub>O 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 N<sub>2</sub>O/yr;

$TLH_{(j)}$  – Total Wastewater Load generated from industrial sector j, expressed in inhabitants-equivalent;

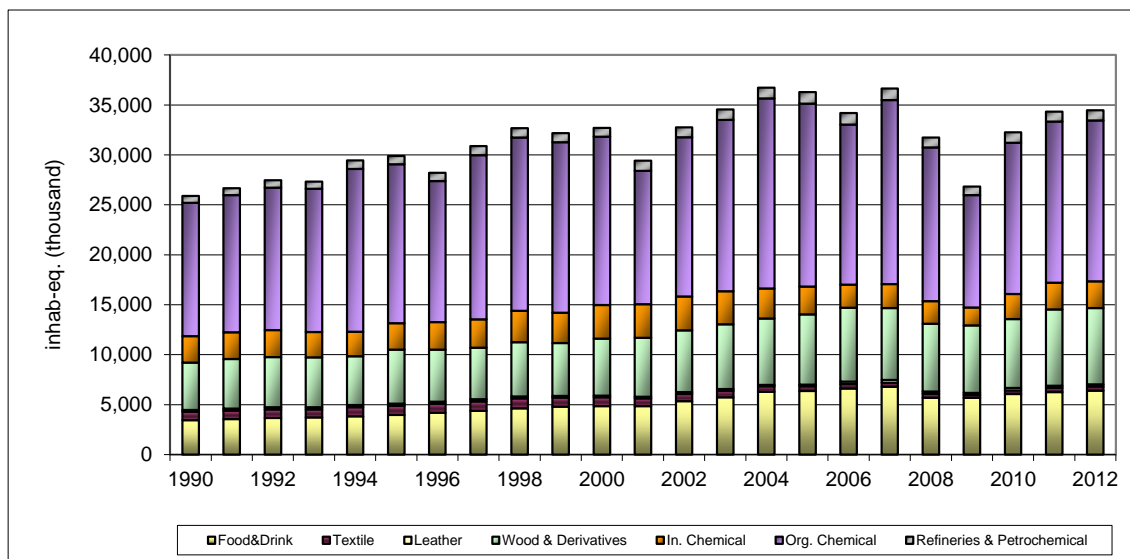
$EF_{N_2O}$  - Emission factor, kg N<sub>2</sub>O/inhab-eq/yr.

##### 8.2.2.2.2.2 Activity Data

The total industrial load, in this case expressed in inhabitants-equivalent was also estimated from data on industrial production and multiplication by pollution coefficients. The methodology was already explained under CH<sub>4</sub> emissions from industrial wastewater management. The evolution of total load, and the contribution from major sectors, are presented in Figure 8-17.



Figure 8-17 - Industrial Wastewater load from major groups of industrial activity



#### 8.2.2.2.2.3 Emission Factors

The emission factor, 0.02 kg N<sub>2</sub>O/kg inhab-eq, is from chapter B9101 from EMEP/CORINAIR (EEA, 2002). As stated before this emission factor is not specific for industrial wastewaters.

#### 8.2.2.2.2.4 Recalculations

No change in methodology was made for this sector and emissions estimates were only changed since last submission as result of the revision of activity data.

#### 8.2.2.2.2.5 Further Improvements

The emission estimates for this sector needs to be improved by the calculation of the total load of nitrogen in industrial effluents, which would allow the use of the methodology proposed by IPCC for domestic wastewater (IPCC, 2000; IPCC, 2006). Nevertheless, the lack of pollution coefficients of comprehensive data on wastewater characteristics may postpone improvements in this sector for the near future.

### 8.2.3 Waste Incineration (CRF 6.C.)

Waste incineration in Portugal includes combustion of municipal, clinical and industrial wastes.

Combustion of municipal solid wastes (MSW) takes place in three modern units where energy is recovered, and thus, according to the IPCC Guidelines, these emissions are accounted for in the energy sector (sub-category 1A(a) Public electricity and heat production). The incineration of other waste, such as clinical or industrial waste that occurs without energy recovery, 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-CO<sub>2</sub> emissions from the biogenic part are accounted under

public electricity and heat production – biomass, and the CO<sub>2</sub> emissions are reported as a memo item from solid biomass use.

#### 8.2.3.1 CO<sub>2</sub> emissions

##### 8.2.3.1.1 Methodology

IPCC Guidelines (IPCC,1997) proposes the following method for ultimate CO<sub>2</sub> emissions estimation from waste incineration, for each waste type (e.g. MSW, hazardous waste, clinical waste, and sewage sludge):

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * CCW_i * FCF_i * EF_i * 44 / 12)$$

where:

i - waste type;

IW<sub>i</sub> - Amount of incinerated waste of type i (Gg/yr);

CCW<sub>i</sub> - Fraction of carbon content in waste of type i;

FCF<sub>i</sub> - Fraction of fossil carbon in waste of type i;

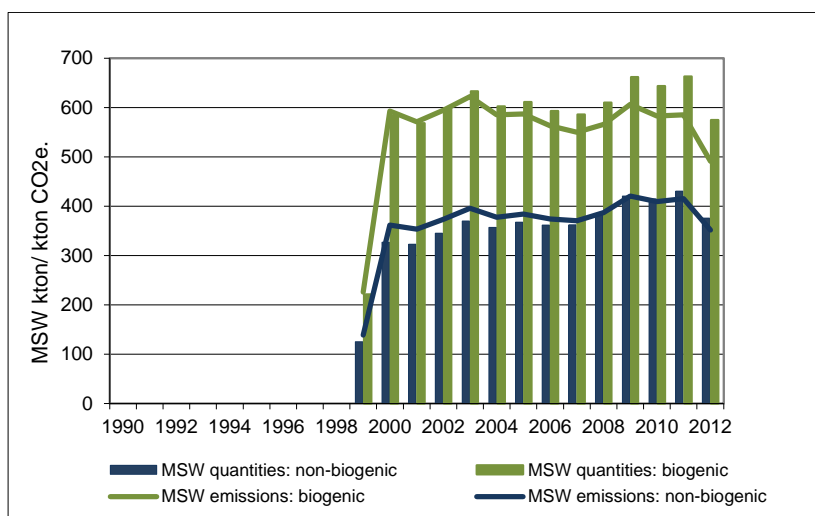
EF<sub>i</sub> - Burn out efficiency of combustion of incinerators for waste of type i (fraction).

##### 8.2.3.1.2 Activity data and parameters

###### 8.2.3.1.2.1 Municipal Solid Waste

In 1999, two new incineration units, Valorsul and Lipor started to operate in an experimental regime, respectively in April and August 1999. Their industrial exploration started at the end of the same year or early January 2000. More recently another unit started operating in one of the Autonomous regions (Madeira Island). These units are dedicated to the combustion of MSW which is composed of domestic/commercial waste.

Figure 8-18 – Incineration of Municipal Solid Waste: quantities incinerated (kton) and related emissions (kt CO<sub>2</sub>e.) (accounted in CRF 1Aa)



Sources: APA

Emissions associated with the components of fossil origin – plastics, synthetic fibers, and synthetic rubber – are accounted for in the net emissions, which include also the non-CO<sub>2</sub> emissions from the combustion of organic materials (e.g. food waste, paper). CO<sub>2</sub> 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<sub>x</sub>, acid gases, dioxins, furans, heavy metals and particulates.

Abatement technologies used include:

- NO<sub>x</sub> reduction system based on the ammonia or urea injection in the combustion chamber;
- semi-dry treatment process, consisting of a reactor, where spray fine droplets of an alkaline reagent (calcium hydroxide) are introduced to neutralise the acid gases;
- activated carbon injection to remove dioxins, furans and heavy metals;
- fabric filter for particulate removal.

GPG refers that it is good practice to assume that the composition of incinerated MSW is the same as the composition of MSW. The fossil C content in MSW was calculated from the weighted average of the C content in plastics and textiles (fossil carbon) and the respective fractions of waste weight. The total C content of MSW, which includes the biogenic and non-biogenic (fossil) components, results from the weighted average of the different waste fractions and the respective total C content. The % of fossil carbon in waste was then obtained dividing the fossil C component by the total C content in MSW.

Information used for the calculation is presented in the next table.

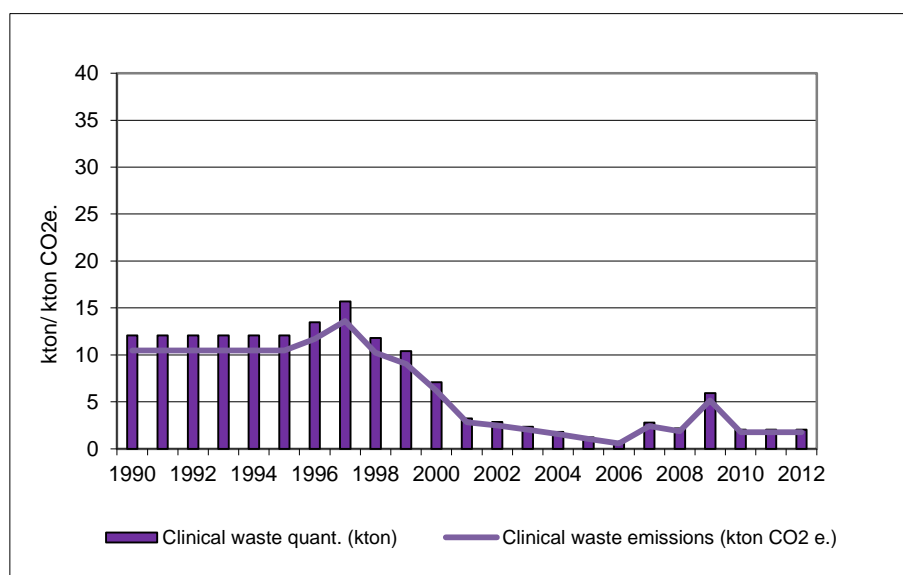
Table 8-14– Base table for MSW C content estimation

	C content		Waste composition (% of weight)						
	Non-biogenic	Total C	1990	1994	1999	2000	2010	2011	2012
Paper/ Card	0	40	21.1	22.7	25.8	26.4	13.7	12.9	12.3
Glass	0	0	4.4	5.1	7.0	7.4	3.7	3.6	4.0
Plastics	85	85	9.2	11.7	11.2	11.1	10.8	10.5	10.2
Metals	0	0	2.8	2.7	2.7	2.75	2.0	1.8	1.6
Food waste	0	15	42.0	34.8	27.9	26.5	42.8	43.0	40.9
Textiles	40	80	3.8	3.1	2.7	2.6	2.6	2.6	2.6
Non-food fermentable materials	0	17	13.4	18.7	17.6	17.4	14.3	14.3	14.3
Wood	0	30	0.2	0.3	0.5	0.5	1.5	1.0	1.1
Other	0	0	3.2	0.8	4.6	5.35	8.7	10.3	13.1
C content in Plastics and Textiles (1)			9.3	11.2	10.6	10.5	10.2	10.0	9.7
Total C of waste (2)			27.9	30.0	29.3	29.2	26.0	25.4	24.6
% non-biogenic C in waste (1)/(2) * 100			33.5	37.3	36.2	35.9	39.2	39.4	39.6

#### 8.2.3.1.2.2 Clinical waste

Data on clinical waste incinerated refers to data declared in registry maps of public and private hospital units, research centres and other units (e.g. piercings, tattoos). 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 clinical waste incinerator is operating since 2004. Other clinical wastes receive alternative treatment or are sent abroad.

Figure 8-19 – Incineration of Clinical Waste: quantities incinerated (kton) and related emissions (kt CO<sub>2</sub>e.)



Sources: APA; DGS.

The existing hospital incinerator suffered two main requalification processes, the most significant occurred in 2004.

The incineration unit includes 2 combustion chambers. At a first stage, the waste is burnt in oxygen deficit conditions at temperatures from 850°C to 950°C. The resulting gases get into a

second combustion chamber or thermal reactor where the gases suffer a new combustion reaching higher temperatures (1100°C – 1200°C) during 2 seconds. These gases are then conducted into a boiler where they are cooled. After that, the gases suffer a dry treatment chemical process, in a contact reactor, through the direct injection of sodium bicarbonate and activated carbon in the gas flux. At the end, the gas is conducted into a ceramic filter where the particulate matter is trapped.

The non-biogenic components fractions are considered to be different for clinical waste and MSW. Data are presented in the two following tables.

Table 8-15 - Parameters considered: clinical waste

	Unit	Clinical waste
C content of waste	%	60 a)
Fraction of fossil carbon in waste	% total C	40 a)

Note:

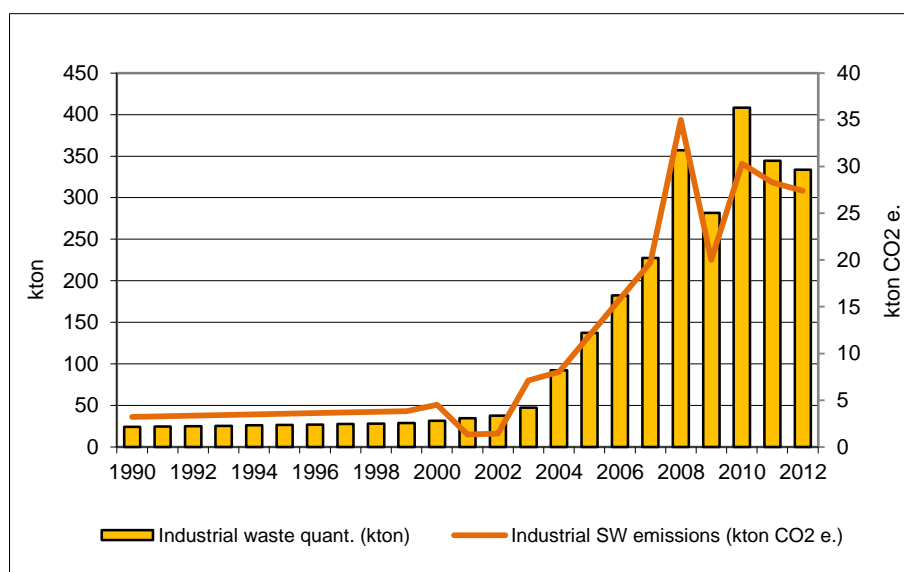
a) IPCC default.

The efficiency of combustion is considered in both situations as 95% (IPCC default).

#### 8.2.3.1.2.3 Industrial waste

Data refer to combustion of industrial solid waste in industrial units collected in APA (previously INR which was integrated in APA). Data for the years 1999, 2002 and 2003 refer to industrial units declarations. Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%. The figures for 2000 and 2001 are interpolated. Data from 2004 onwards refer to data collected under the Waste Registry (Mapa Integrado de Registo de Resíduos (MIRR)) on the framework of SIRER (APA website for the communication between APA and environmental stakeholders). Data provided by the different waste operators and industrials on the amounts of non-urban waste generated are statistical treated by the INE in order to extrapolate the information for the universe of each economic branch.

Figure 8-20– Quantities of combusted industrial waste



Source: APA (include estimates).

Table 8-16- Parameters considered

	Unit	Industrial Solid Waste
C content of waste	%	14-20 a)
Fraction of fossil carbon in waste	% total C	0.3-24 a)
Efficiency of combustion	%	95 b)

Notes:

a) Range of values considered according to the years.

b) IPCC default.

The parameters presented in the previous table (C content and % total C) are national estimates based on the background data on industrial waste production. This information is classified according to the European Waste Catalogue list (EWC) and is disaggregated by treatment type. Each one of the EWC categories were classified according to a group and were assigned with an estimated fraction of C content and a fraction of fossil carbon in waste, which has been defined by expert judgment (please see Table 8-4). The values considered resulted from weighted averages based on quantities reported for each of the EWC categories and the respective assigned C content and fraction of fossil C, and refer to disposal type "incineration".

#### 8.2.3.2 *Non-CO<sub>2</sub> emissions*

##### 8.2.3.2.1 *Methodology*

Emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * EF_i) * 10^{-6}$$

where:

$IW_i$  = Amount of incinerated waste of type i (Gg/yr);

$EF_i$  = Aggregate pollutant emission factor for waste type i (kg pollutant/Gg)

##### 8.2.3.2.2 *Activity data and parameters*

###### 8.2.3.2.2.1 *Municipal waste*

Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR (EEA,2002).

Table 8-17 - Emissions factors of GHG and precursors gases from incineration of MSW

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH <sub>4</sub>	g/GJ	6.500	CORINAIR 94
N <sub>2</sub> O	kg/ton MSW	0.100	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton MSW	0.022	Country measured data
NO <sub>x</sub>	kg/ton MSW	0.724	Country measured data
COVNM	kg/ton MSW	0.020	Corinair 3rd version. Activity 090201. Uncontrolled
CO	kg/ton MSW	0.036	Country measured data

Table 8-18 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: until 2004

Pollutants	Unit	EF	Source
LHV	MJ/kg W	7.82	PROET study
CH <sub>4</sub>	g/GJ	6.5	CORINAIR 94
N <sub>2</sub> O	kg/ton W	0.1	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton W	1.09	AP-42 Uncontrolled
NO <sub>x</sub>	kg/ton W	1.40	2009 guidebook
COVNM	kg/ton W	0.70	2009 guidebook
CO	kg/ton W	1.48	AP-42 Uncontrolled

Table 8-19 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: after 2005

Pollutants	Unit	EF	Source
LHV	MJ/kg W	7.82	PROET study
CH <sub>4</sub>	g/GJ	6.5	CORINAIR 94
N <sub>2</sub> O	kg/ton W	0.1	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton W	0.357	AP-42 Control level: Dry Sorbent Injection/C injection/Fabric Filter
NO <sub>x</sub>	kg/ton W	1.4	2009 guidebook
COVNM	kg/ton W	0.7	2009 guidebook
CO	kg/ton W	1.48	AP-42 Uncontrolled

#### 8.2.3.2.2.2 Industrial waste

Emission factors applied at present refer to “open burning of municipal waste” and were obtained from the international sources US/AP42 or EMEP/CORINAIR (EEA,2002). The figures used in the estimates of this category should be revised in the near future to better reflect the conditions and technologies used by industrial units where incineration occurs.

Table 8-20 - Emissions factors of GHG and precursors gases for Industrial Solid Wastes incineration

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.8	PROET study
CH <sub>4</sub>	g/GJ	6.5	CORINAIR 94
N <sub>2</sub> O	kg/ton MSW	0.1	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton MSW	0.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
NO <sub>x</sub>	kg/ton MSW	3.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
COV	kg/ton MSW	15.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
CO	kg/ton MSW	42.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)

### 8.2.4 CH<sub>4</sub> and N<sub>2</sub>O emissions from landfill gas and other biogas burning (CRF 6.D.)

The capture and burning of landfill gas and biogas (e.g. from sewage sludge) is used for energy purposes or flaring (without energy recovery). The resulting CO<sub>2</sub> from the combustion of landfill gas and biogas of biogenic origin, only needs to be reported as a memo item when there is energy recovery. CH<sub>4</sub> and N<sub>2</sub>O emissions from the combustion of landfill gas and biogas captured need to be estimated and should be included in the energy sector when there is energy recovery, or in the waste sector when is flared.

For practical reasons all information related to the estimates of emissions from biogas combustion (with and without energy recovery) is presented here. However, the emissions related to energy recovery situations are accounted in sector 1A1a, and the emissions resulting from flaring are considered in category 6D.

The inventory considers landfill gas recovery values since 2004. However, in particular flaring (without energy recovery) started before. In order to account with this practice, a questionnaire was launched by APA since the 2012 submission with the aim of collecting the total amount of landfill gas combusted either in flaring (without energy recovery) or used for energy purposes. This inquiry was focused on the more recent years (since 2005) in order not to overload the waste systems managers.

This questionnaire considered all managed SWDS, which totals, in 2012, 34 landfill sites in exploration (receiving waste) in Mainland, plus 3 closed landfill sites which do not receive waste anymore (but burn biogas). Landfill sites in the 2 Autonomous Regions do not burn biogas.

Out of the 37 landfill sites (corresponding to 23 different management entities) considered, 11 landfills reported not to burn biogas. From the 26 sites burning biogas, the data from 1 site has not been considered as the reported burn quantities referred to estimates from LandGem. No extrapolation was done.

CH<sub>4</sub> recovered in flares and valorised for energy purposes is estimated on the basis of average biogas flows (continuous measurement) and the n° of hours of burning. The concentration of CH<sub>4</sub> in biogas used in the estimates of the CH<sub>4</sub> quantities refer to monitoring plans (quarterly measurements) measuring the biogas quality (generally CH<sub>4</sub>, CO<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>S) at the entrance of the flares or the biogas energy recovery system.

#### 8.2.4.1 Methodology

Emissions from the combustion of landfill gas and biogas with and without energy recovery have been estimated using emission factors based on the energy of the biogas consumed (combusted).



#### 8.2.4.2 Activity data and parameters

The quantities of landfill gas and biogas combusted refer to DGEG data (biogas consumed in electrical production) and to the 2013 APA's direct questionnaires sent to the landfill management systems, which were focused on the more recent years (since 2005), and covered both situations with and without energy recovery.

Table 8-21 – Activity data, emission factors and related emissions of biogas combusted

Quantities of landfill gas and biogas combusted		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Electrical production a)	GJ	38,031	28,056	30,216	24,647	146,555	342,822	317,318	536,868	787,149	968,432	1,261,021	1,668,286	2,051,425
Flaring b)	GJ	-	-	-	-	-	266,085	440,544	420,404	416,178	356,085	287,131	60,069	not available
Emission factors														
CO <sub>2</sub>	kg/GJ	52												
CH <sub>4</sub>	g/GJ	1.4												
N <sub>2</sub> O	g/GJ	1.4												
NO <sub>x</sub>	g/GJ	90												
NM/VOC	g/GJ	2.5												
CO	g/GJ	17												
SO <sub>x</sub>	%	0.0016												
Emissions with energy recovery (CRF 1A1a)		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO <sub>2</sub> c)	kton	2.0	1.5	1.6	1.3	7.6	17.8	16.5	27.9	40.9	50.4	65.6	86.8	106.7
CH <sub>4</sub>	ton	0.053	0.039	0.042	0.035	0.205	0.480	0.413	0.815	1.156	1.232	1.604	2.426	3.102
N <sub>2</sub> O	ton	0.053	0.039	0.042	0.035	0.205	0.480	0.413	0.815	1.156	1.232	1.604	2.426	3.102
Emissions without energy recovery (CRF 6D)		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO <sub>2</sub> d)	kton	-	-	-	-	-	-	-	-	-	-	-	-	-
CH <sub>4</sub>	ton	-	-	-	-	-	0.373	0.617	0.589	0.583	0.499	0.402	0.084	0.000
N <sub>2</sub> O	ton	-	-	-	-	-	0.373	0.617	0.589	0.583	0.499	0.402	0.084	0.000

Notes:

- a) Includes landfill biogas and other (e.g. sludge treatment plants) with energy recovery. Data refer mostly to DGEG data.
- b) Data refer to landfill gas flared without energy recovery. Data refer to 2013 APA's questionnaires.
- c) Memorandum item.
- d) According to the guidelines, CO<sub>2</sub> emissions from source categories "Solid waste disposal on land and Waste incineration" should only be included if they derive from non-biological or inorganic waste sources.

## 8.3 Uncertainty Assessment

### 8.3.1 Solid Waste Disposal on Land

#### 8.3.1.1 Municipal Solid Wastes

The uncertainty of activity data for Municipal Solid Wastes is considered high for past years as data was estimated for each year from population and per capita waste production ratio and mostly because of the low accuracy in the backcast establishment of past solid wastes disposal since 1960. The situation changed in more recent years, where data refer to data collected by waste management systems. Different uncertainty values were considered for different periods applying Rule A;  $AD = MSWT \text{ (Total Municipal Solid Waste produced)} * MSWF \text{ (Fraction of MSWT sent to SWDS)}$ , using the proposed values from IPCC 2006. The uncertainties have been calculated separately for quantities deposited in open dump sites and managed landfills, considering a time horizon of 30 years. An uncertainty of 16% was considered as representative of the accuracy of the present time series for quantities disposed in managed SWDS (and 60% for open dump sites that are now closed). As regards the calculation of uncertainty of the emission factor, Rule B was applied, using the default values proposed by GPG for MCF (10% for Managed systems and 60% for unmanaged), DOC (50%), DOCF (30%) and k factor (300%), resulting in a combined EF uncertainty for unmanaged sites of 86% and 62% for managed sites.

#### 8.3.1.2 Industrial Wastes

The activity data for the calculation of emissions from Industrial Waste Production has a lower accuracy than Municipal Solid Wastes, because the time trend since 1960 was established with poor information only collected after 1999. The uncertainty considered for the annual production

of industrial solid wastes was about 64%, value determined by the annual variation of industrial waste quantities disposed on land, and to consider the error in backward forecasts till 1960..

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%),  $DOC_F$  (30%), MCF (10% for Managed systems and 60% for unmanaged) and F (20%) and 300% for k, the methane generation rate constant<sup>161</sup>. An overall error of 62 %, for managed systems and 86 % for unmanaged systems, was therefore obtained and used for both urban and industrial wastes.

### 8.3.2 Wastewater Handling

For urban waste water treatment the activity data, expressed in organic load to wastewater systems, was estimated from population and per capita production and the error associated with both variables needs to be incorporated in the determination of the final uncertainty value. Assuming the default uncertainties proposed in GPG, 5% for human population and 30% for BOD per capita, a final 30.4% error was set for this activity.

Concerning the methane emission factor, the uncertainty of this parameter includes an error in the Maximum Methane Producing Capacity ( $B_o$ ), for which the GPG default of 30% was used, and the error determination in the fraction of water treated anaerobically. For urban water the uncertainty in this last fraction was estimated as 22%, considering the percentage of individual septic tanks and the lack of knowledge of in which conditions they operate.

In the case of industrial waste-water systems the available information is much scarcer. The uncertainty value was estimated for each industrial sector separately for the COD load and the uncertainty in the production activity data:

- the uncertainty in load was estimated for each available coefficient of pollution from the range of COD concentration values presented in the original documentation document (Cartaxo et al, 1985). Uncertainty values range from 11%, for the dairy industry, up to 100%;
- the uncertainty of production data is 20% if data was obtained from National Statistics and 50% if was interpolated.

The uncertainty considering all industrial activities, according to their production, varied between 22 and 24%, according to years.

For industrial wastewater treatment, also the uncertainty in the methane emission factor also changes with time and considers:

- the uncertainty in  $B_o$ , the maximum methane generation potential, is 30% according to the GP;
- the error of the allocation of each specific treatment system, established from the per cent of unknown situations, adds 20% to the error for the known cases;
- the uncertainty in MCF for each specific treatment system, set from the GP, and varying from 10% for Secondary Treatment, well managed, to 50% for the no treatment situation.

<sup>161</sup> The uncertainty for this variable affects nevertheless when emissions occur and not how much and affects emission estimates exponentially.

Finally the error was determined for each industry and propagated accordingly. The final uncertainty varies in time from 29% to 35%.

### **8.3.3 Waste Incineration and Other**

For clinical wastes an uncertainty of 49% was calculated from comparison of annual variation in the quantities reported as incinerated. In a way similar to what was done for determining the uncertainty of production of industrial solid wastes, the uncertainty associated with industrial incineration was calculated from the annual variation of incinerated quantities and the consideration of the shortage of information for historic years, and was estimated as 59%.

The uncertainty of CO<sub>2</sub> emission factors was set as 30% for hospital wastes and 50% for industrial 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<sub>2</sub>O and CH<sub>4</sub> emission factors a 100% uncertainty was considered.

### **8.3.4 Landfill gas and other biogas burning**

CH<sub>4</sub> and N<sub>2</sub>O emissions from biogas flaring reported in category 6D refer to data collected from a direct enquiry to landfill management systems and refer to measured data. The uncertainty value for quantities of biogas flared was set at 1 per cent, which is in accordance to the values considered for LPS data in category 1A1a (biogas burning with energy recovery).

The uncertainty associated with CH<sub>4</sub> and N<sub>2</sub>O emission factors was set to 150 per cent and 1000 per cent, respectively.

## **8.4 QA/QC and verification**

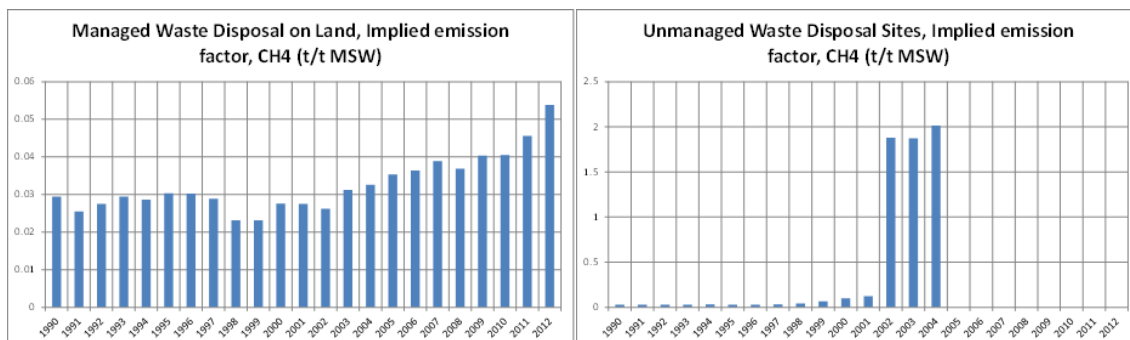
### **8.4.1 Solid Waste Disposal on Land**

#### **8.4.1.1 General QC 1**

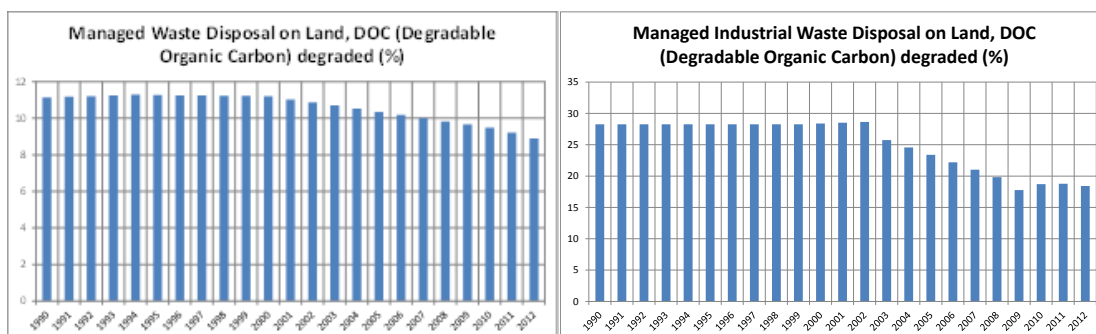
General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and file links;
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

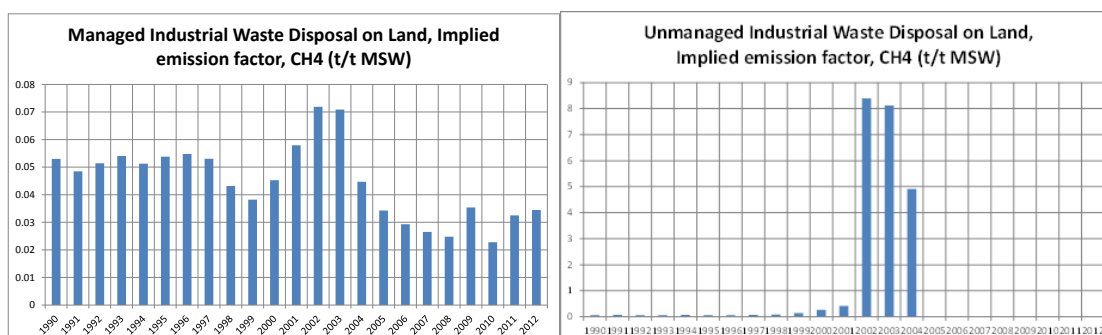
An analysis of emission trends and of IEF was performed to detect unusual trends in order to identify potential underlying problems. The CRF Reporter graph tools have been used for this purpose (2014 CRF v1 outputs).



The IEF of CH<sub>4</sub> for urban SWDL has increased from 0.028 t CH<sub>4</sub>/t MSW in 1990 to 0.047 t CH<sub>4</sub>/t MSW in 2012, representing a 69% increase. This tendency is explained by the increase of MSW disposed to SWDS (approx.. 67% since 1990), associated to the urbanization process and economic development of Portugal, and as a result of the methodology used (FOD method) which accounts for the delay that exists between the time biodegradable waste is landfilled and the moment CH<sub>4</sub> is emitted. CH<sub>4</sub> IEF for unmanaged disposal results from double effect of delayed emissions in time (FOD method) and the closure of uncontrolled land disposal sites in the beginning of the 2000s.



The decreasing tendencies concerning the DOC for urban and industrial waste reflect the deviation of biogenic materials from land disposal, and is related with the the reduction along the time of CH<sub>4</sub> IEF for industrial waste disposed on land. CH<sub>4</sub> IEF for unmanaged disposal results from double effect of delayed emissions in time (FOD method) and the closure of uncontrolled land disposal sites in the beginning of the 2000s.



#### 8.4.1.2 *QC2 procedures*

Activity level parameters were compared with Revised 1996 IPCC Guidelines default values. Data used for the early 90s concerning the MSW generation and disposal rates are consistent with data presented for southern countries. In the most recent years the rates are closer to most industrialized countries, which is in line with the strong economic growth registered in the country during the decade of 1990.

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2010/ FCCC/WEB/SAI/2010), in particular those with similar natural, demographic and economic conditions.

### 8.4.2 Wastewater Handling

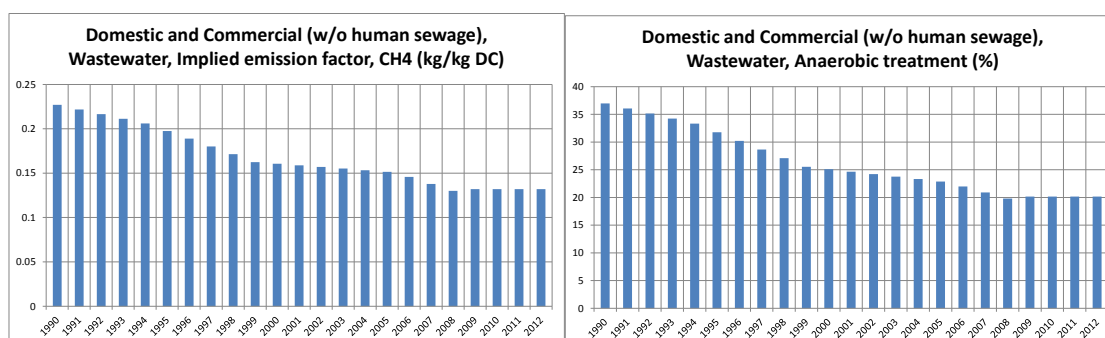
#### 8.4.2.1 *General QC 1*

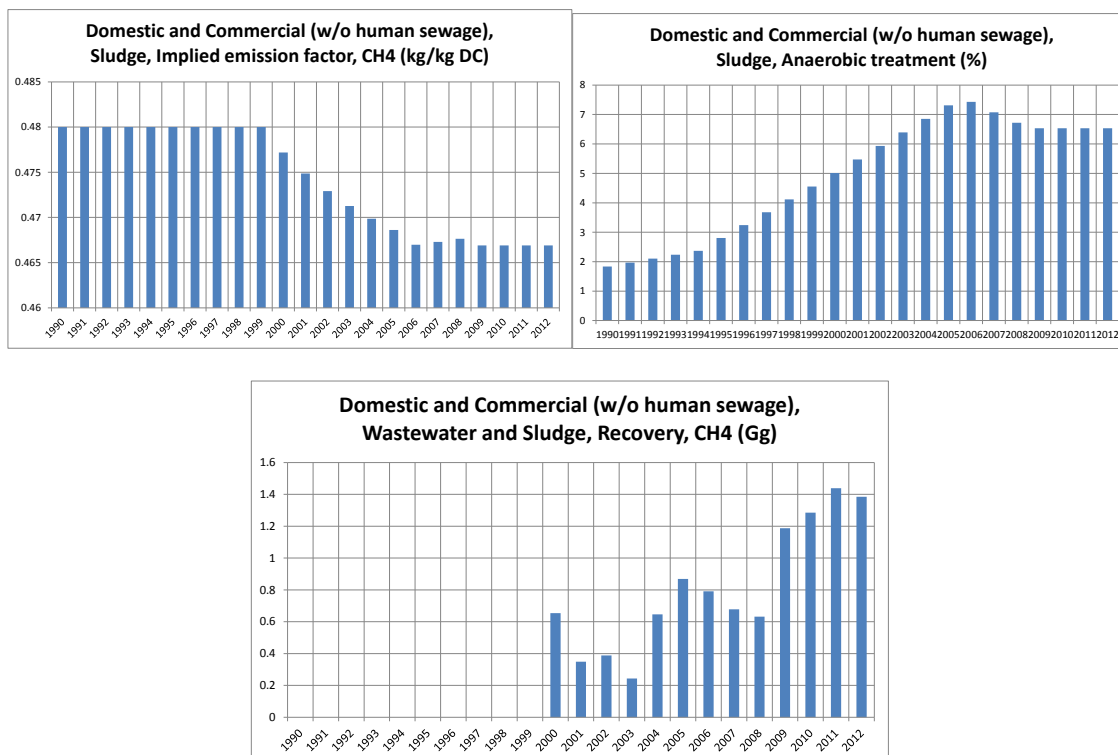
General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and data field relationships
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

An analysis of emission trends and of IEF was performed to detect unusual trends in order to identify potential underlying problems.

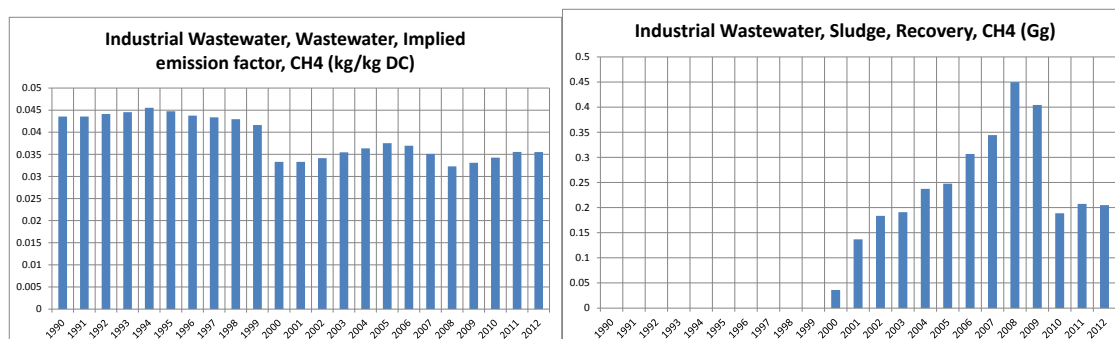
For 6.B.1.b. Domestic and Commercial Waste Water, the IEF of CH<sub>4</sub> has decreased from 0.227 kg/kg DC in 1990 to 0.132 kg/kg DC in 2012, representing a 41.9% reduction, which can be explained by the significant improvements registered in water handling systems since 1990, when a significant share of domestic wastewater were discharged with no treatment (inland and marine waters) or handled in latrines (associated with higher CH<sub>4</sub> production conditions). The situation considerably changed in the late 90s with the implementation of centralised treatment plants and the start (2000) of recovery of biogas which also contributes to the referred decreasing IEF trends.





For 6.B.1.a. Industrial Waste Water, the IEF of CH<sub>4</sub> has decreased from 0.044 kg/kg DC in 1990 to 0.036 kg/kg DC in 2012, which represents a 17.9% reduction. The decrease of CH<sub>4</sub> IEF for Industrial Waste Water is a result of several factors:

- growth of well managed aerobic treatment situations;
- growth of situations corresponding to treatment in Municipal Systems (MCF decreased from 18% (1990) to 16% (2012));
- decrease of Unknown situations for which estimated MCF dropped from 24% (1990) to 17% (2012);
- biogas combustion (with energy recovery): non existing in 1990.



#### 8.4.2.2 *QC2 procedures*

Country-specific emission factors, in particular for industrial wastewater sector, were compared with IPCC default values. Domestic wastewater emissions were also estimated using the IPCC default method.

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2010/ FCCC/WEB/SAI/2010), in particular those with similar natural, demographic and economic conditions. Significant deviations were observed for category 6B (including domestic and industrial wastewater). These differences are however difficult to explain as it implies a deep analysis of the methodologies used by other countries.

### 8.4.3 Waste Incineration and Other

#### 8.4.3.1 General QC 1

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

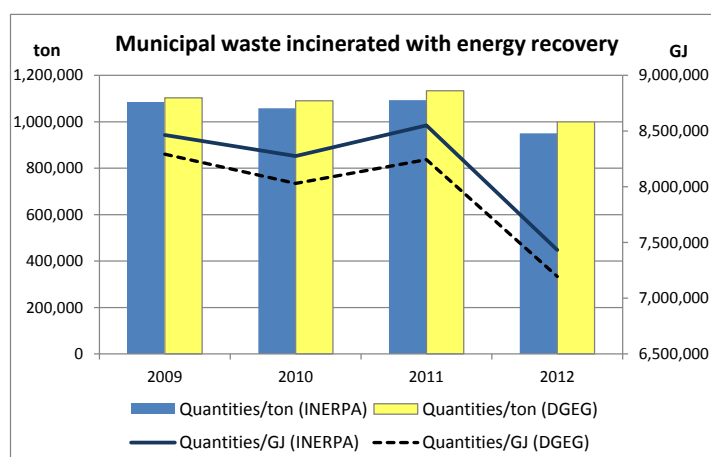
- Checks on data units, calculation procedures, and data field relationships
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

An analysis of emission trends and of IEF was performed to detect unusual trends in order to identify potential underlying problems.

#### 8.4.3.2 QC2 procedures

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2010/ FCCC/WEB/SAI/2010), in particular those with similar natural, demographic and economic conditions.

Following the recommendations from the last UNFCCC reviews, the AD for waste incineration related to energy production used by the inventory was compared with DGEG energy balance available data. As the next figure shows, the amounts considered in the EB and the inventory do not differ significantly (biggest difference refers to 5% in 2012). As regards, the energy content (NCV), the values considered by the EB is lower than the value considered by the inventory.



## 8.5 Recalculations

The changes for this sector refer in majority to CH<sub>4</sub> emissions and result basically from:

- Solid Waste Disposal on Land
  - Municipal waste/ 2006-2011: waste quantities for Açores Islands revised;
  - Industrial waste/ 2011: revision of the quantities incinerated based on the GDP data (data for 2011-12 not available)
- Wastewater systems
  - Domestic and Commercial Waste Water N<sub>2</sub>O emissions from sewage sludge applied to agriculture soils have been accounted separately for the first time, in agriculture sector CRF 4D following a UNFCCC recommendation. Previously no amount of N was considered to be removed with the sludge and applied in agriculture land, and all related emissions were reported in the waste sector (CRF 6B).
  - Industrial wastewater: revision of activity data on industrial production time series and the revision of treatment types. New information has been collected from the Environmental Licensing (European Union's IPPC directive) in order to improve the characterization of the wastewater treatment systems for the industrial sectors for which no information was available (unknown treatment).
- Waste incineration
  - Industrial waste: 2004-2006 data revised on the basis of interpolation of 2003 and 2007.
  - 2011: revision of the quantities incinerated based on the GDP data (data for 2011-12 not available)

Synthesis of changes may be observed in figure and table below.



Figure 8-21 – Differences between 2013 and 2014 submissions (CO<sub>2</sub>eq)

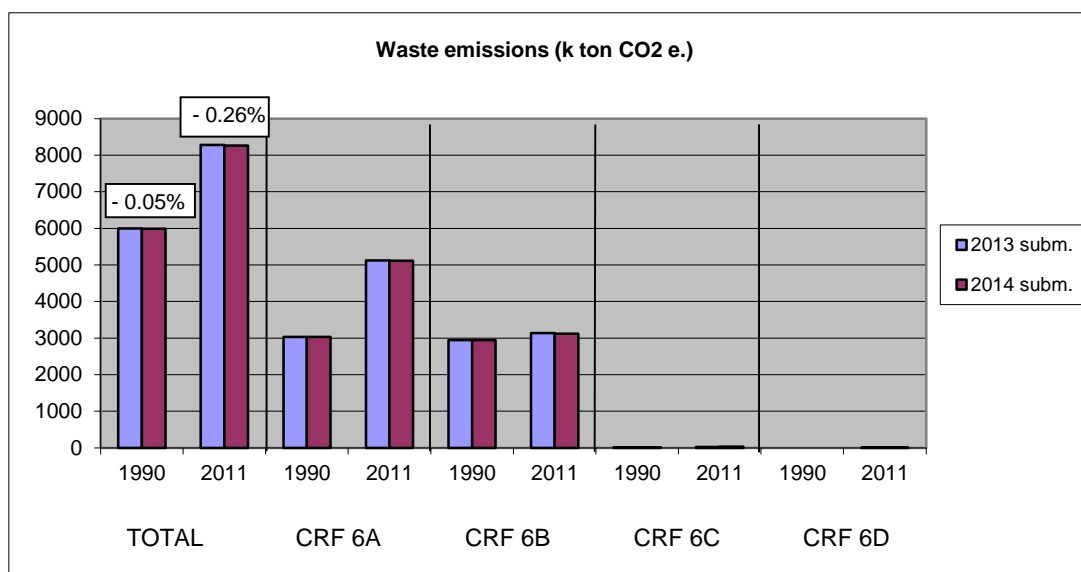


Table 8-22 – Recalculations (differences between 2013 to 2014 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2013 subm.	2014 subm.	Diff. (1)	2013 subm.	2014 subm.	Difference (1)	2013 subm.	2014 subm.	Diff. (1)
	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)
<b>1990</b>									
6. Waste	12.52	12.52	0.00	5,518.81	5,518.81	0.00	463.30	460.26	-0.65
6.A. Solid Waste Disposal on Land	NA	NA		3,032.57	3,032.57	0.00			
6.B. Wastewater Handling				2,486.20	2,486.20	0.00	462.18	459.15	-0.66
6.C. Waste Incineration	12.52	12.52	0.00	0.04	0.04	0.00	1.12	1.12	0.00
6.D. Other	NO	NO		NO	NO		NO	NO	
<b>2011</b>									
6. Waste	13.83	18.94	36.88	7,665.32	7,642.45	-0.30	601.28	597.37	-0.65
6.A. Solid Waste Disposal on Land	NA	NA		5,121.74	5,110.20	-0.23			
6.B. Wastewater Handling				2,543.24	2,531.88	-0.45	591.31	586.59	-0.80
6.C. Waste Incineration	13.83	18.94	36.88	0.34	0.37	8.11	9.94	10.74	8.11
6.D. Other	NO	NO		0.00	0.00	0.00	0.03	0.03	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).

## 8.6 Further Improvements

Continue the work of update and improvement of the assessment of the situation concerning industrial wastewater, having as a basis the information collected from the Environmental Licensing (European Union's IPPC directive).

## 8.7 Background Data Tables

Table 8-23 – National population, waste generation per capita, and municipal waste generation (excluding waste amounts sent to material recycling)

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	51.5	40	457.8	457.8	0.0	0.0	0.0
1961	8,861,388	54.4	41	482.4	482.4	0.0	0.0	0.0
1962	8,833,580	57.5	42	507.8	507.8	0.0	0.0	0.0
1963	8,805,771	60.7	44	534.1	534.1	0.0	0.0	0.0
1964	8,777,962	64.0	45	561.4	561.4	0.0	0.0	0.0
1965	8,750,154	67.4	46	589.6	589.6	0.0	0.0	0.0
1966	8,722,345	70.9	47	618.8	618.8	0.0	0.0	0.0
1967	8,694,536	74.7	48	649.1	649.1	0.0	0.0	0.0
1968	8,666,727	78.5	50	680.4	680.4	0.0	0.0	0.0
1969	8,638,919	82.5	51	712.8	712.8	0.0	0.0	0.0
1970	8,611,110	86.7	52	746.3	746.3	0.0	0.0	0.0
1971	8,722,192	91.1	53	794.5	794.5	0.0	0.0	0.0
1972	8,833,274	95.7	54	845.2	845.2	0.0	0.0	0.0
1973	8,944,357	100.5	56	898.5	898.5	0.0	0.0	0.0
1974	9,055,439	105.4	57	954.5	954.5	0.0	0.0	0.0
1975	9,166,521	110.5	58	1,013.4	1,013.4	0.0	0.0	0.0
1976	9,277,603	115.9	59	1,075.1	1,075.1	0.0	0.0	0.0
1977	9,388,685	121.4	60	1,140.0	1,140.0	0.0	0.0	0.0
1978	9,499,767	127.2	62	1,208.1	1,208.1	0.0	0.0	0.0
1979	9,610,850	133.1	63	1,279.5	1,279.5	0.0	0.0	0.0
1980	9,721,932	139.3	64	1,354.4	949.2	360.5	44.7	0.0
1981	9,833,014	148.7	66	1,462.0	1,021.1	396.2	44.7	0.0
1982	9,836,427	158.4	68	1,558.2	1,088.1	425.4	44.7	0.0
1983	9,839,841	168.6	71	1,658.9	1,158.2	456.0	44.7	0.0
1984	9,843,254	179.3	73	1,764.5	1,231.7	488.1	44.7	0.0
1985	9,846,667	190.4	75	1,875.0	1,308.6	521.7	44.7	0.0
1986	9,850,081	203.2	78	2,001.1	1,396.3	560.1	44.7	0.0
1987	9,853,494	216.5	80	2,133.2	1,488.2	600.3	44.7	0.0
1988	9,856,907	230.5	83	2,271.7	1,584.5	642.5	44.7	0.0
1989	9,860,320	245.1	85	2,416.8	1,685.4	686.7	44.7	0.0
1990	9,863,734	260.4	88	2,568.7	1,764.9	692.1	111.7	0.0
1991	9,867,147	272.7	89	2,690.9	1,731.9	913.5	45.5	0.0
1992	9,916,044	285.5	91	2,831.4	1,821.8	951.7	57.8	0.0
1993	9,964,941	298.9	92	2,978.4	1,915.3	989.4	73.7	0.0
1994	10,013,838	312.8	93	3,132.3	1,839.0	1,137.2	156.2	0.0
1995	10,062,735	332.0	95	3,341.2	1,951.7	1,184.4	205.1	0.0
1996	10,111,632	350.4	96	3,542.8	2,027.8	1,310.3	204.7	0.0
1997	10,160,529	368.9	97	3,748.6	2,007.1	1,531.4	210.1	0.0
1998	10,209,426	387.8	98	3,958.7	1,507.5	2,236.0	215.2	0.0
1999	10,258,323	406.8	99	4,173.3	974.1	2,626.6	226.2	346.4
2000	10,307,220	412.1	100	4,247.9	588.3	2,473.6	274.8	911.1
2001	10,356,117	425.2	100	4,403.1	460.2	2,784.6	266.6	891.7
2002	10,407,463	421.1	100	4,382.7	27.8	3,294.7	116.2	943.9
2003	10,474,685	426.2	100	4,464.6	25.9	3,019.2	416.1	1,003.4
2004	10,529,255	413.3	100	4,351.6	22.3	3,118.9	250.6	959.7
2005	10,569,592	408.4	100	4,316.2	0.0	3,091.0	246.9	978.4
2006	10,599,095	418.4	100	4,434.3	0.0	3,185.6	294.1	954.6
2007	10,617,575	414.3	100	4,399.3	0.0	3,132.5	318.9	947.9
2008	10,563,014	460.1	100	4,860.5	0.0	3,487.5	380.0	993.0
2009	10,573,479	455.8	100	4,819.5	0.0	3,315.7	421.2	1,082.6
2010	10,572,721	462.7	100	4,891.7	0.0	3,438.7	394.6	1,058.4
2011	10,542,398	441.0	100	4,648.8	0.0	3,113.8	441.6	1,093.4
2012	10,487,289	409.4	100	4,293.4	0.0	2,658.0	684.8	950.5

Sources:INE; APA; Quercus Study

Table 8-24 – Fermentable industrial waste disposal

Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills
kton			kton			kton		
1960	819	0	1978	1,071	0	1996	848	594
1961	832	0	1979	1,087	0	1997	810	661
1962	844	0	1980	773	330	1998	594	907
1963	857	0	1981	782	338	1999	358	1,173
1964	870	0	1982	794	343	2000	177	1,102
1965	883	0	1983	806	348	2001	108	921
1966	896	0	1984	818	354	2002	5	773
1967	909	0	1985	830	359	2003	4	723
1968	923	0	1986	842	365	2004	6	1185
1969	937	0	1987	854	370	2005	0	1655
1970	951	0	1988	867	376	2006	0	2118
1971	965	0	1989	880	382	2007	0	2582
1972	980	0	1990	893	388	2008	0	3046
1973	994	0	1991	843	463	2009	0	2040
1974	1,009	0	1992	860	473	2010	0	3928
1975	1,024	0	1993	876	483	2011	0	2966
1976	1,040	0	1994	835	551	2012	0	2872
1977	1,055	0	1995	850	565			

Notes:

Share between open dump and managed landfills based on disposal of municipal solid wastes.

2002 to 2004: disposal on open dump sites refer to disposal on controlled dump sites.

Source: APA (include estimates)

Table 8-25 – Quantities of CH<sub>4</sub> recovered and combusted (SWDS)

	Biogas burned	Biogas burned	Biogas burned as % of CH <sub>4</sub> generated in SWDS
	kton CH <sub>4</sub>	kton CO <sub>2</sub> eq.	%
1990	-	-	-
1991	-	-	-
1992	-	-	-
1993	-	-	-
1994	-	-	-
1995	-	-	-
1996	-	-	-
1997	-	-	-
1998	-	-	-
1999	-	-	-
2000	-	-	-
2001	-	-	-
2002	-	-	-
2003	-	-	-
2004	2.2	45	0.9
2005	10.9	230	4.4
2006	14.7	309	5.7
2007	18.8	395	7.1
2008	23.8	499	8.7
2009	26.0	547	9.7
2010	31.7	667	10.9
2011	33.4	701	11.1
2012	41.3	868	11.1

Source: APA's questionnaires ; 2012 : DGEG data.

Table 8-26 – National population and wastewater BOD produced by handling systems

	Population (1000 inhabitants)	BOD5 produced (kton/year)					
		Total	Treatment systems		Individual treatment	Without treatment	Sludge spreading
			wastewater	sludge			
1990	9,864	216	24	5	8	173	5
1991	9,867	216	25	5	12	168	5
1992	9,916	217	26	6	15	164	6
1993	9,965	218	27	6	19	160	6
1994	10,014	219	29	6	23	155	6
1995	10,063	220	34	8	27	144	8
1996	10,112	221	40	9	31	132	9
1997	10,161	223	45	10	36	121	11
1998	10,209	224	51	12	40	109	12
1999	10,258	225	57	13	44	97	14
2000	10,307	226	63	14	49	84	15
2001	10,356	227	69	16	55	71	17
2002	10,407	228	75	17	60	58	19
2003	10,475	229	81	19	65	45	21
2004	10,529	231	87	20	70	31	22
2005	10,570	231	93	22	75	17	24
2006	10,599	232	101	22	72	14	23
2007	10,618	233	107	21	65	16	22
2008	10,563	231	113	20	58	19	22
2009	10,573	232	118	19	56	19	20
2010	10,573	232	118	19	56	19	20
2011	10,542	231	118	19	55	18	20
2012	10,487	230	118	19	55	18	20

Source: APA (estimates).

Notes:

Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with and without anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Lagoons without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Preliminary treatment, Treatment not specified, Lagoon, with anaerobic pond and Imhoff Tanks (100% of organic load). Treatment systems – sludge: refer to Biodisks with anaerobic sludge digestion, Activated sludge with anaerobic sludge digestion, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (37% of organic load).

Individual treatment: refer to private and collective septic tanks.

Without treatment: refer to discharge into the ocean and inland waters and without sewerage (latrines).

Sludge spreading: refer to the % of the organic load retained as non mineralised sludge in primary treatment (30% of primary organic load generated), and 37% in activated sludge without anaerobic sludge digestion, lagoons without anaerobic pond, Percolation beds without anaerobic sludge digestion, oxidation ponds and other treatment.

Table 8-27 – Quantities of CH<sub>4</sub> combusted from municipal and industrial wastewater handling systems

Year	Municipal treatment systems		Industrial treatment systems	
	kton CH <sub>4</sub> /year	% emissions of total emissions	kton CH <sub>4</sub> /year	% emissions of total emissions
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	0.7	1.60	0.0	0.05
2001	0.3	0.85	0.1	0.21
2002	0.4	0.94	0.2	0.25
2003	0.2	0.59	0.2	0.24
2004	0.6	1.55	0.2	0.28
2005	0.9	2.07	0.2	0.27
2006	0.8	1.93	0.3	0.35
2007	0.7	1.74	0.3	0.40
2008	0.6	1.72	0.4	0.65
2009	1.2	3.20	0.4	0.65
2010	1.3	3.47	0.2	0.26
2011	1.4	3.89	0.2	0.24
2012	1.4	3.77	0.2	0.24

Source: DGEG data

Table 8-28 – Quantities of waste incinerated (accounted CRF 6)

Year	Clinical waste quantities incinerated		Industrial solid waste incinerated	
	Quantities	Emissions	Quantities	Emissions
	kton	kton CO2 e.	kton	kton CO2 e.
1990	12	10	24	3
1991	12	10	24	3
1992	12	10	25	3
1993	12	10	25	3
1994	12	10	26	3
1995	12	10	27	4
1996	13	12	27	4
1997	16	14	28	4
1998	12	10	28	4
1999	10	9	29	4
2000	7	6	32	5
2001	3	3	35	1
2002	3	2	38	1
2003	2	2	47	7
2004	2	2	92	8
2005	1	1	137	12
2006	1	1	182	16
2007	3	2	227	20
2008	2	2	357	35
2009	6	5	282	20
2010	2	2	408	30
2011	2	2	345	28
2012	2	2	334	27

Note: Estimates in italics

Sources: APA (include estimates); DGS

Table 8-29 – MSW waste incinerated (accounted CRF 1A1a)

Year	Quantities incinerated		Emissions	
	Biogenic	Non-biogenic	Biogenic	Non-biogenic
	kton		kton CO2 e.	
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	221	125	226	139
2000	584	327	593	362
2001	568	323	571	353
2002	599	345	595	373
2003	633	370	622	396
2004	602	357	585	378
2005	611	367	587	384
2006	593	362	563	374
2007	586	362	550	370
2008	610	383	566	387
2009	662	421	607	420
2010	644	415	583	410
2011	663	431	585	415
2012	575	376	491	352



Table 8-30 – Comparison between estimates for CH<sub>4</sub> emissions from waste-water handling and IPCC check-method

Year	CH <sub>4</sub> emissions			National CH <sub>4</sub> emissions	
	Check method ton	National estimates ton	% difference %	w without 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	40,117	25.9	40,771	654
2001	54,432	40,639	25.3	40,988	349
2002	54,702	40,827	25.4	41,215	388
2003	55,055	41,262	25.1	41,505	243
2004	55,342	41,100	25.7	41,746	646
2005	55,554	41,061	26.1	41,930	869
2006	55,709	40,159	27.9	40,950	791
2007	55,806	38,340	31.3	39,018	678
2008	55,519	36,192	34.8	36,824	632
2009	55,574	35,890	35.4	37,077	1,187
2010	55,570	35,789	35.6	37,074	1,285
2011	55,411	35,530	35.9	36,968	1,438
2012	55,121	35,390	35.8	36,775	1,385
% variation 1990-2012	6.9	-29.4	-	-26.5	-

## **9 RECALCULATIONS AND IMPROVEMENTS**

This section presents an overview of the recalculations made in the 2014 submission. The recalculations made result mostly from the recommendations issued from last UNFCCC reviews and updates of activity data.

### **9.1 Overview of the UNFCCC Review Process**

The listing below concerns mostly the 2012 review.

No draft ERT Review Report for 2013 was made available to the inventory team until early May 2014. Issues raised in the 2013 review refer to the provisional main findings and recommendations received during the last review.

Table 9-1 Overview of the responses to the UNFCCC review

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
General	Transparency	Since there are documentation lapses in the NIR related to country specific methods, Activity Data and Emission Factors, the ERT recommends that Portugal updates the NIR with the references used and clearly documents justifications for country-specific methodological approaches.	-/2013	Continuous improvement	Under Development	
General	Transparency	The ERT advises Portugal to increase transparency in the NIR regarding the use of EU-ETS data and considerations for time series consistency.	-/2013	Continuous improvement	Under Development	
General	QA/QC and verification	The ERT encourages Portugal to increase QA/QC and verification procedures for sectorial reporting, and consistent reporting in NIR and CRF tables. The ERT also recommends Portugal to increase information in the NIR regarding the QA/QC plan, consistent with information provided during review week.	-/2013	Continuous improvement	Under Development	
General	Recalculations	Portugal is providing limited information regarding to recalculations so it's advised to increase transparency in justifications of recalculations in the NIR.	-/2013	Continuous improvement	Under Development	
General	National system	Portugal should update descriptions of national system in NIR, consistent with the information provided during review week, focusing on general and specific functions in line with Decision 19/CMP1.	-/2013	Continuous improvement	Under Development	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy		The ERT encourages Portugal to continue its efforts to incorporate plant-specific data into its inventory	Previous 2012	Continuous improvement	Under Development	
Energy		Reiterating question from S&A report about CRF 1B2a: The inter-annual changes of CO2 emissions from Refining/storage for 1991-1992, 1993-1997, 1999-2001 and 2002-2003 (ranging from -12.8% to 400.2%) have been identified as outliers. The 2007 value is 1180.2% higher than the 1990 value. The trend is unstable after 1993 and fluctuates. Your response to this was that cracking unit's data should be discussed with refineries. Could you please tell us, did you receive any answers yet?	Previous 2012	From 2005 onwards data is obtained directly from ETS (information verified). Data from 1990-2004 will be revised based on data from refineries.	Under Development	
Energy		The ERT reiterates the recommendation made in previous review reports that Portugal continue to make efforts to improve its estimates of emissions from the use of feedstock's and includes estimates of combustion emissions from feedstock and non-energy use of fuels in the sectorial approach in its next annual submission.	Previous 2012		Under Development	
Energy	1.A.1 Energy Industries	The ERT recommends Portugal to report the emissions resulting from the use of limestone for desulphurization in the industrial processes sector instead of reporting in the combustion sector to able comparability across parties.	-/2013	Emissions from the use of limestone for desulphurization are reported in the 2014 submission in CRF 2A3 (Limestone and Dolomite Use)	Implemented	Sections 3.3.1.1 and 4.3.1.3

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy	1.A.3c Railways	Portugal should revise the Railways Emission Factor of diesel oil fuel to avoid overestimating emissions and to ensure consistency across all sectors by using the same EF for this fuel type.	-/2013	Railways CO2 emission factor for diesel oil fuel was revised and changed from 74,37 kg/Gj to 74,07 kg/Gj. The new EF is the same that is being used by the other mobile sources for this type of fuel to ensure consistency across all sectors	Implemented	Section 3.3.3.3
Energy	Feedstocks and Non-Energy Use of Fuels	Coke, oven coke, coking coal and sub-bituminous coal are misallocated as BKB/patent fuel, other bituminous coal and lignite. Portugal is advised to report emissions under the correct fuel within CRF table 1.A (b) because there is a possible estimation accuracy compromised since the default EF for coke oven coke is higher than that for BKB/patent fuel, while that for sub bituminous coal is lower than for lignite.	-/2013	The problem was corrected: previous quantities misallocated as BKB/patent fuel have been reclassified as coking coal.	Implemented	
Energy	1.B.2 Fugitive emissions (oil)	Fuel used for ammonia production net subtracted from the energy sector could possibly result in double counting. It's advised that Portugal reports it appropriately by revising the methodologies used for reporting non-energy use of fuels and making sure there is no double counting.	-/2013		Under Development	
Energy	1.B.2 Fugitive emissions (oil)	Emissions resulting from the non-energy use fuels and subtracted from the energy sector aren't estimated. It's advised that Portugal reports it appropriately by revising the methodologies used for reporting non-energy use of fuels and making sure there is no double counting.	-/2013	Non-energy use of fuels are being further analyzed.	Under implementation	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy	Road transportation: liquid fuels – CO <sub>2</sub>	Develop country-specific parameters (e.g. hydrogen/carbon ratios and EFs) for gasoline and diesel oil	76/2012		No new developments	
Energy	Stationary combustion, manufacturing industries and construction, and other sectors: liquid fuels – CO <sub>2</sub>	Use the same CO <sub>2</sub> EF for gasoline across all categories where it is combusted	72/2012		Implemented	
Industrial processes		Iron and Steel: The ERT noted that AD for estimating emissions from iron and steel production is mainly based on interpolated or proxy data. The ERT encourages Portugal to make efforts to find appropriate statistical data for the whole time series or to use plant-specific data and report its emission estimates accordingly in its next annual submission.		Portugal made efforts to obtain appropriate statistical data for the time series and used plant-specific data	Implemented	Section 4.3.3.1.2, 4.3.3.1.3 and 4.3.3.1.4.
Industrial processes	Transparency	Provide more detailed information on the methodologies used to estimate emissions for the period 1990–2004, in order to improve the transparency of the reporting, and further describe how time-series consistency is ensured, in the next annual submission	88/2012		Under implementation	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Industrial processes	QA/QC	Update the QA/QC plan for the industrial processes sector and strengthen the sector-specific QA activities in order to enhance the consistency of the information provided	88/2012		Under implementation	
Industrial processes	2. A. 3 Limestone and Dolomite use	CO2 emissions from limestone and dolomite use carbonates in iron and steel industry as flux in blast furnace resulting in CO2 emissions have been included in Energy (1A2), with the assumption that the emission factor of CO2 from blast furnace consumption already includes the carbon from limestone that was liberated from the flux in the blast furnace. In line with the UNFCCC reporting guidelines, the ERT recommends that Portugal should reallocate emissions from energy for the use of limestone and dolomite to be reported under this sub category.	-/2013		Implemented	Section 4.3.1.3.1.
Industrial processes	2.A.7 Glass Production	Data on glass production has been obtained from various sources and provided for the new calculation as a basis for its new carbonate data source. However, since no information on the carbonate data has been provided, but only glass production data, Portugal is advised to ensure consistency and transparency by providing improved information on emission estimates for glass production with the new Activity Data and methodology.	-/2013		Implemented	Section 4.3.1.6.2 and 4.3.1.6.4.

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Industrial processes	2.F.1 Refrigeration and Air Conditioning Equipment	The ERT noted that the two models used to estimate the potential and actual emissions are based on many assumptions; these assumptions are described in the NIR and are based mainly on expert judgment or default values from the IPCC good practice guidance or the 2006 IPCC Guidelines. The ERT also noted that Portugal has compared the results of the models, thereby allowing the Party to verify the assumptions and results. The ERT recommends that Portugal enhance transparency by providing the outcomes of the comparison of the results from the two models in the next annual submission.	-/2013		Under Development	
Agriculture		Nevertheless, the ERT further recommends that Portugal investigate the possibility of obtaining preliminary consumption data (fertilizers) from INE at an earlier date and implement measures to avoid the need for frequent recalculations in the future.	Previous 2012	Meetings with INE ( national Statistics Authority) were done and we were told that there is an intention to revise the methodology to estimate fertilizers consumption soon	Under Development	
Agriculture	Transparency	The 2011 annual review report identified an apparent incompleteness in the reporting of the emissions from agricultural soils due to excluding from the estimates the emissions from the application of sewage sludge as a soil amendment. The ERT recommends that Portugal, for its next annual submission, estimate N <sub>2</sub> O emissions from sewage sludge application to agricultural soils and enhance the relevant explanations in the NIR.	107/2012	Emissions from sewage sludge application in agriculture soils are separately accounted for the first time in the 2014 submission.	Implemented	Sections 6.3.5 and 6.3.6



Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Agriculture	Transparency	Improve the transparency of the NIR by correctly identifying the source of the parameters and EFs from the Revised 1996 IPCC Guidelines and the IPCC good practice guidance.	109/2012	Continuous improvement	Implemented	
Agriculture	Uncertainty	Develop and include country-specific uncertainty values for the AD and EFs, at a minimum for the key categories, and document them fully in the NIR	110/2012	Some improvements have been made. The work on uncertainty analysis and development of country-specific values will continue.	To be further developed	
Agriculture	Recalculations	Improve the transparency of the description of the recalculations performed in the NIR of future annual submissions	111/2012	Continuous improvement	Implemented	
Agriculture	Enteric fermentation – CH <sub>4</sub>	Estimate CH <sub>4</sub> emissions from enteric fermentation for appropriate livestock subcategories for the next annual submission	114/2012	Efforts were done to improve the methodological level for estimation CH <sub>4</sub> emissions from dairy cow enteric fermentation.  Improvements related to some other subcategories are under development	Implemented  under development	Section 6.3.1.3.1.
Agriculture	Enteric fermentation – CH <sub>4</sub>	Enhance the transparency of the description of the methods used in the next annual submission; and enhance the QA/QC activities in order to improve the accuracy of the NIR	115/2012	Continuous improvement	Implemented	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Agriculture	Enteric fermentation – CH <sub>4</sub>	Enhance the transparency of the reporting by providing the additional information required in CRF table 4.A	116/2012	In the 2014 submission an improvement of the methodological level for estimation CH <sub>4</sub> emissions from dairy cow enteric fermentation was done	Implemented	Section 6.3.1.3.1.1
Agriculture	Manure management – CH <sub>4</sub>	Follow the methodological approach provided in the footnote to table 4.10 of the IPCC good practice guidance in order to correctly reflect the practice of anaerobic digestion of swine manure, and document this approach in the NIR of the next annual submission	121/2012	Issue under analysis.	Under development	
Agriculture	Manure management – CH <sub>4</sub>	Provide background information to support the use of the IPCC default values of 45 per cent and 39 per cent for the methane conversion factor for manure treated in anaerobic lagoons in temperate and cool regions, respectively	119/2012	Issue under analysis.	Under development	
Agriculture	Direct soil emissions – N <sub>2</sub> O	Implement QC measures which obviate the need to conduct recalculations of the consumption of mineral N fertilizers  , and identify whether the values derived include all mineral N fertilizers applied to soils, including those applied to forest land	125/2012	Meetings with INE (National Statistics Authority) were done and we were told that there is an intention to revise the methodology to estimate fertilizers consumption soon  It is clearly identified by INE that AD related to consumption of N fertilizers include those applied to agriculture and forest land,	Under development/Implemented	Section 6.3.5.4.1

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Agriculture	Direct soil emissions – N <sub>2</sub> O	Collect AD for sewage sludge application to agricultural soils in order to estimate N <sub>2</sub> O emissions or, if this is not possible, enhance the explanations provided in the NIR	126/2012	Information is presented in the NIR	Implemented	Section 6.3.5.4.3
Agriculture	4.A.1 – dairy cattle	Portugal should implement the correct tier 2 methodology according to the IPCC Good Practice Guidance for Dairy Cattle Emission Factor estimation.	-/2013	In the 2014 submission an improvement of the methodological level for estimation CH <sub>4</sub> emissions from dairy cow enteric fermentation was done	Implemented	Section 6.3.1.3.1.1
Agriculture	4.B.1 – non-dairy cattle	The ERT recommends that Portugal should include the Non-dairy Cattle time series of the country specific Emission Factors for animal categories and compare it with the IPCC default EFs values.	-/2013	Table included in the NIR	Implemented	Section 6.3.2.3
Agriculture	4.C – rice cultivation	Since the estimation the country specific Emission Factor for Rice cultivation is not documented and is out of IPCC range, Portugal is advised to reevaluate the methodology for the EF estimation or provide a correct documented reference for the country specific EF.	-/2013	In the 2014 submission a thorough reevaluation of the methodology for estimation CH <sub>4</sub> emissions from rice cultivation were implemented	Implemented	Section 6.3.3
LULUCF	Transparency	Improve the transparency of the reporting in the next annual submission by providing a clear and detailed description of the methods, AD and parameters used for all pools, as well as the emission sources for each category	140/2012	NIR related chapters have been further developed and thorough explanations have been provided	Implemented	Chapter 7

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
LULUCF	QA/QC	Enhance the QA/QC procedures for the next annual submission	141/2012	BEF have been corrected. Consistency between Convention and KP-LULUCF have been improved (non-tillage activity and biodiverse sowing of pasture activity are now considered in both reportings)	Implemented	Section 7.1.3.1.3
LULUCF	Uncertainty	Conduct an uncertainty analysis for the key categories in the LULUCF sector	142/2012		Under implementation	
LULUCF	Forest land remaining forest land – CO <sub>2</sub>	Use the correct BEF values, reconsider the choice of root-shoot ratio and transparently describe the data sources used in the NIR of the next annual submission	142/2012	BEF values included in NIR	Implemented	Section 7.1.3.1.3
LULUCF	Direct N <sub>2</sub> O emissions from N fertilization of forest land – N <sub>2</sub> O	Disaggregate direct N <sub>2</sub> O emissions from N fertilization of forest land and report the N <sub>2</sub> O emissions from N fertilization of forest land and other land in the appropriate category under the LULUCF sector in the next annual submission	147/2012	No available data to separate forest from agriculture N fertilization. Explanation is given in the NIR.	Not implemented	Section 7.9 and Section 6.3.5.4.1
LULUCF	All categories	Portugal should review and revise quantitative uncertainty estimates for Activity Data in LULUCF to reflect new NF1 6 data source.	-/2013	The information on LULUCF have been changed from IFN6 to COS. The uncertainty estimates will be revised accordingly.	Under implementation	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
LULUCF	5.A Forest Land	Provide further clarification and justification to support the assumption that all living biomass is oxidized during fire events in the next NIR. The current approach reduces residual emission associated with living biomass conversion to dead organic matter.	-/2013		Further explanations to be provided in the 2014 NIR	Section 7.13.2
LULUCF	5.B Cropland	Provide greater detail in terms of duration of no-tillage practice and greater transparency in terms of commitments by farmers. Also provide appropriate cited references used in NIR in reference section and provide specific dates for all census material used.	-/2013		Further explanations to be provided in the 2014 NIR	Section 7.3.1.5
LULUCF	5.C Grasslands	Provide greater detail in terms of specific approach used in determining removals for SBPPRL practice. Ensure cited references are provided in the NIR.	-/2013		Further explanations to be provided in the 2014 NIR	Section 7.4.1.5
LULUCF	5.D Wetlands	Develop estimations for SL/WL to improve overall transparency of reporting all pools associated with LUC.	-/2013	There is no data to support the attribution of a C stock to wetlands or settlements. Annual losses of area are very small and it is not considered cost-effective to develop estimates for those land uses	No developments	
Waste		Recommendation to make efforts to use country-specific parameters in the FOD model for its next annual inventory submission.	Previous 2012	Country parameters are used to the extent of possible	No developments	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Waste		Wastewater handling – CH <sub>4</sub> and N <sub>2</sub> O The ERT recommends that Portugal make efforts to update the country-specific data used in its calculations and verify its assumptions on CH <sub>4</sub> recovery in its next annual inventory submission.	Previous 2012	Continuous improvement	Implemented/ Under Development	
Waste		Improve the information on industrial wastewater.	Previous 2012	Information on industrial wastewater handling systems has been improved on the basis of Environmental Permits. Continuous improvement.	Under implementation	Section 8.2.2.2.1.3.1
Waste	Solid waste disposal on land – CH <sub>4</sub>	Revise the solid waste disposal and DOC estimates for 2000 and 2001 using interpolation techniques for between 1999 and 2002	152/2012		Implemented	Section 8.2.1.1.2.2.1
Waste	Solid waste disposal on land – CH <sub>4</sub>	Use waste composition data from countries with similar national circumstances to derive an appropriate DOC value	155/2012		Implemented	Section 8.2.1.1.2.2.1
Waste	Solid waste disposal on land – CH <sub>4</sub>	Use interpolation techniques to derive data on the amount of waste disposed and the DOC value for the years 2004–2006 where no disposal or composition data are currently available; and make efforts to obtain disposal and DOC data for those years	155/2012		Implemented	Section 8.2.1.1.2.2.1

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Waste	Solid waste disposal on land – CH <sub>4</sub>	Include a full description of the measures taken to address the time-series consistency issues and revise the emission estimates in the NIR of the next annual submission	155/2012		Implemented	Section 8.2.1.1.2.2.1
Waste	Wastewater handling – CH <sub>4</sub> and N <sub>2</sub> O	Enhance the transparency of the reporting by providing information on the source of the assumptions used in the next NIR	157/2012	In continuous improvement.	Under implementation	
Waste	Waste incineration – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Provide an explanation for the inter-annual fluctuations in the time series in the next annual submission	163/2012	Information on data trends and AD data sources are included in the NIR.	Implemented	Sectionr 8.2.3
Waste	Waste incineration – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Address all time-series inconsistency issues related to the AD for waste incineration in the next annual submission	164/2012	Information on data trends and AD data sources are included in the NIR.	Implemented	Section 8.2.3
Waste	Biogas flaring – CH <sub>4</sub> and N <sub>2</sub> O	The ERT noted that the AD for waste incinerators related to energy production are also available in the DGEG energy balance. The ERT encourages Portugal to cross-check this information with the AD used for the waste incineration estimates and explain any discrepancies between the two data sets, as appropriate. Provide additional information in the NIR on the sources of the EFs used, as well as the energy content, in order to enhance the transparency of this section of the NIR	166/2012	AD and energy content (NCV) considered in the inventory and the EB data from DGEG were compared and included in the NIR.	Implemented	Section 8.4.3

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Waste	6.A. Solid waste disposal on land	Portugal should improve documentation and justifications for recalculations because there is a lack of transparency in the recalculations.	-/2013	Rationale and explanations on recalculations are included in the NIR	Implemented	Section 8.5
Waste	6.B. Wastewater handling	Portugal should enhance QA/QC activities because there is inconsistency within the chapter of the NIR regarding the number for the population in all inventory categories.	-/2013	QA/QC procedures have been improved and a summary of the results are included in the NIR	Implemented	Section 8.4
Waste	6.B. Wastewater handling	Since sludge spreading on agricultural soil is not calculated separately, Portugal should obtain the necessary information in order to calculate the emissions and reallocate emissions from sewage sludge spreading on agricultural land in the agriculture sector.	-/2013	Emissions from sludge spreading in agriculture soils are reported in the 2014 submission	Implemented	Section 8.2.2.1.2
KP-LULUCF	National system	Implement the sixth National Forest Inventory in a timely manner, in order to ensure the accurate identification of forest areas under Article 3, paragraph 3, of the Kyoto Protocol	168/2012	<p>The sixth National forest Inventory was implemented for 2013 submission.</p> <p>NIR related chapters included thorough explanations.</p> <p>However, the data source on LULUCF has been changed from IFN6 to COS for the 2014 submission.</p>	Implemented	Chapter 7



Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
KP-LULUCF	Uncertainty	Conduct an uncertainty analysis of the estimates for the KP-LULUCF activities for the next annual submission	170/2012	The information on LULUCF has been changed from IFN6 to COS. The uncertainty estimates will be revised accordingly.	Under revision	
KP-LULUCF	Completeness	Report the N <sub>2</sub> O emissions from N fertilization of afforestation and reforestation, and forest management activities, or include the emissions under the agriculture sector in the next annual submission	171/2012	N <sub>2</sub> O emissions from N fertilizers are included under agriculture sector because there is no available data to separate forest from agriculture N fertilization	Implemented	Section 7.9 and Section 6.3.5.4.1
KP-LULUCF	Activities under Article 3, paragraph 3, of the Kyoto Protocol	The ERT noted that the removals from afforestation and reforestation activities and the emissions from deforestation activities under Article 3, paragraph 3, of the Kyoto Protocol may have been overestimated, owing to: (a) The assumption that the carbon stock in living biomass and soil organic matter in wetlands, settlements and other land is zero; (b) The inappropriate choice and application of default BEF values and the root–shoot ratio from the IPCC good practice guidance for LULUCF. Improve the accuracy of the reporting	173/2012	a) There is no data to support the attribution of a C stock to wetlands or settlements. Annual losses of area are very small and it is not considered cost-effective to develop estimates for those land uses b) BEF have been corrected. Consistency between Convention and KP-LULUCF have been improved (non-tillage activity and biodiverse sowing of pasture activity are now considered in both reportings)	a) No developments b) Implemented	b) BEF values in Section 7.1.3.1.3

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
KP-LULUCF	Activities under Article 3, paragraph 4, of the Kyoto Protocol	The ERT also noted that the removals from afforestation and reforestation activities and the emissions from deforestation activities under Article 3, paragraph 3, of the Kyoto Protocol may have been underestimated, owing to the omission of dead wood in forest land. The ERT recommends that Portugal improve the accuracy of its reporting by addressing this issue, as well as those described in paragraph 173 above. Revise the choice of parameters and describe the reasons for choosing them in the next annual submission	174/2012	Dead wood is considered and reported as Included Elsewhere.	Implemented	Section 7.1.3.6
KP-LULUCF	Cropland management – CO <sub>2</sub>	a) Provide detailed information on the methods and procedures used to derive the value of the soil carbon accumulation rate, including peer-reviewed documents b) Provide information on the identification of non-tillaged land, the reporting and verification system, the QA/QC procedures, and the monitoring and reporting system, and document how these procedures are effectively implemented, in line with the methods and practices described in chapter 4 of the IPCC good practice guidance for LULUCF c) Apply IPCC tier 1 or tier 2 methods by developing land-use, management and input factors based on observations and other data sources, or use the IPCC default factors, and compare the results with those derived from the use of the mean accumulation rate. d) Transparently demonstrate that the non-tillage of cropland did not occur in 1990	178/2012	The LULUCF related chapters have been revised according to the new sources of data, and more detailed explanations provided aiming the improvement of transparency	Implemented/ continuous improvement	Chapters 7 and 10

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
KP-LULUCF	Grazing land management – CO <sub>2</sub>	Transparently describe the practice related to the sowing of pasture in the NIR of the next annual submission	179/2012	The LULUCF related chapters have been revised according to the new sources of data, and more detailed explanations provided aiming the improvement of transparency	Implemented/ continuous improvement	Chapters 7 and 10

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
KP-LULUCF	Grazing land management – CO <sub>2</sub>	<p>a) Provide detailed information in the NIR on the methods and procedures used to identify the pasture sowed, the reporting and verification system, the QA/QC procedures, the post-sowing monitoring and reporting system, and document how these procedures are effectively implemented;</p> <p>b) if the SOM model is used, disaggregate the model according to the different climate and soil conditions, or include climate and soil parameters in the model, and compare the results of the model with results of the IPCC tier 1/tier 2 methods;</p> <p>c) demonstrate that the common practices related to the pasture-sowing project are consistent with the activities conducted under the experiment from which the SOM model was built;</p> <p>d) ensure that the SOM model is applied within five years after the start of the pasture-sowing activities;</p> <p>e) demonstrate that the sowing of pasture occurred after 1990 (i.e. that pasture-sowing activities did not occur in 1990);</p> <p>f) transparently describe the method used in the NIR, especially how the average soil carbon accumulation rate is derived based on the results of the SOM model</p>	182/2012	The LULUCF related chapters have been revised according to the new sources of data, and more detailed explanations provided aiming the improvement of transparency	Implemented/ continuous improvement	Chapters 7 and 10
Cross-cutting issues		The ERT encourages Portugal to develop and include country specific uncertainty values for AD and EFs for key categories and document this in the NIR in its next annual submission.	Previous 2012		Continuous development	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Cross-cutting issues		The ERT recommends that Portugal improve the consistency of the information reported in the CRF and in the NIR in its next submission.	Previous 2012	The QA/QC procedures have implemented in order to increase consistency between NIR and CRF Tables. A responsible person for the review of the final inventory report and a QA/QC coordinator has been designated.	Continuous development	
Information under chapter I.H		The ERT, therefore, reiterates the recommendation in the previous annual review report that Portugal include information on the prioritization of these actions in implementing its commitments under Article 3, paragraph 14, of the Kyoto Protocol	Previous 2012		Implemented	Chapter 14
Uncertainty assessment		The ERT recommends that Portugal revise its estimate of the uncertainty for the LULUCF sector and report thereof in its next annual submission	Previous 2012	9.2 The information on LULUCF has been changed from IFN6 to COS. The uncertainty estimates will be revised accordingly.	9.3 Under revision	
Uncertainty assessment		The ERT also recommends that the Party implement a tier 2 uncertainty analysis in its next annual submission	Previous 2012	Resources constraints does not enable this development	No new developments	

## **9.2 Implications in emissions levels**

The implications of recalculations for emission levels by category and for the national totals by gas are presented in the following tables.

Table 9-2 – Synthesis of recalculations made for the 2014 inventory submission and their implications to the emission level in 1990 and 2011

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
<b>Total National Emissions and Removals</b>			<b>-185.58</b>	<b>-669.90</b>	<b>-0.31</b>	<b>-0.97</b>
<b>1. Energy</b>			<b>-129.29</b>	<b>-237.66</b>	<b>-0.21</b>	<b>-0.34</b>
A. Fuel Combustion Activities (Sectoral Approach)	-	-	-139.60	-168.38	-0.23	-0.24
1.A.1. Energy Industries	-	-	-38.39	0.00	-0.06	-0.06
a. Public Electricity and Heat Production	Reallocation of CO <sub>2</sub> emissions from the use of limestone in the desulphurization occurring in the energy sector (1A1a) to the industrial processes sector (2A3 - Limestone and Dolomite Use).	To follow the UNFCCC review recommendations and to be in accordance with the IPCC Guidelines.	-40.02	0.00	-0.06	-0.06
b. Petroleum Refining			1.63	0.00	0.00	0.00
c. Manufacture of Solid Fuels and Other Energy Industries	-	-	0.00	0.00	0.00	0.00
1.A.2. Manufacturing Industries and Construction			-141.68	-0.23	-0.20	-0.20
a. Iron and Steel	Correction of a compilation error due to a thorough revision of the sector.	Compilation error due to a thorough revision of the sector.	52.92	0.00	0.08	0.08
b. Non-Ferrous Metals			0.00	0.00	0.00	0.00
c. Chemicals	Revision of the 2011 energy balance data	Revision of the 2011 energy balance data	-131.78	-0.01	-0.19	-0.19
d. Pulp, Paper and Print	Revision of the 2011 energy balance data	Revision of the 2011 energy balance data	-1.11	0.00	0.00	0.00
e. Food Processing, Beverages and Tobacco	Revision of the 2011 energy balance data	Revision of the 2011 energy balance data	-13.03	0.00	-0.02	-0.02
f. Other	Revision of the 2011 energy balance data	Revision of the 2011 energy balance data	-48.69	-0.22	-0.07	-0.07
1.A.3. Transport	-	-	-0.72	10.31	0.00	0.01

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
a. Civil Aviation	Update of the 2011 emissions values	Compilation error detected: routine procedure was not correctly applied with implications on the estimative of emissions regarding aircraft movements where information about the aircraft type is not available and is supposed to use averaged airport LTO and cruise emission factors	0.00	10.48	0.00	0.02
b. Road Transportation	-	-	0.00	0.00	0.00	0.00
c. Railways	Railways CO <sub>2</sub> Emission Factor for diesel oil fuel was revised	CO <sub>2</sub> Emission factor for diesel oil fuel was revised in accordance with UNFCCC recommendation	-0.72	-0.17	0.00	0.00
d. Navigation	-	-	0.00	0.00	0.00	0.00
1.A.4. Other Sectors	-	-	-0.52	1.38	0.00	0.00
a. Commercial/Institutional	Revision of the 2011 energy balance data. CH <sub>4</sub> emission factor revision based on COVNM EF from EMEP/EEA air pollutant emission inventory guidebook 2013	Revision of the 2011 energy balance data. CH <sub>4</sub> emission factor revision	-0.39	-1.91	0.00	0.00
b. Residential	Revision of the 2011 energy balance data. CH <sub>4</sub> emission factor revision based on COVNM EF from EMEP/EEA air pollutant emission inventory guidebook 2013	Revision of the 2011 energy balance data. CH <sub>4</sub> emission factor revision	-0.10	3.53	0.00	0.01
c. Agriculture/Forestry/Fisheries	Revision of the 2011 energy balance data.	Revision of the 2011 energy balance data.	-0.03	-0.25	0.00	0.00
1.A.5. Other	-	-	0.00	0.00	0.00	0.00
a. Stationary	-	-	0.00	0.00	0.00	0.00
b. Mobile	-	-	0.00	0.00	0.00	0.00
1.B. Fugitive Emissions from Fuels			10.32	-69.28	0.02	-0.10



CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
1. Solid Fuels			9.44	0.00	0.02	0.00
2. Oil and Natural Gas	CO <sub>2</sub> Emission Factor for Geothermal was revised	Revised data available from regional authority of the Autonomous Region of Azores	0.88	-78.21	0.00	-0.11

<b>2. Industrial Processes</b>			<b>0.00</b>	<b>-124.71</b>	<b>0.00</b>	<b>-0.18</b>
2.A.	Mineral Products		0.00	-106.91	0.00	-0.15
	1. Cement Production		0.00	0.00	0.00	0.00
	2. Lime Production	AD revision based on IAPI.	0.00	-167.10	0.00	-0.24
	3. Limestone and Dolomite Use	a) Limestone and dolomite consumption data revision based on National Statistics data. b) Reallocation of CO <sub>2</sub> emissions from the use of limestone in the desulphurization occurring in the energy sector (1A1a) to the industrial processes sector (2A3 - Limestone and Dolomite Use).	0.00	60.20	0.00	0.09
	4. Soda Ash Production and Use	-	0.00	0.00	0.00	0.00
	5. Asphalt Roofing	-	0.00	0.00	0.00	0.00
	6. Road Paving with Asphalt	Correction of small error in the disaggregation of hot mix asphalt emissions between Drum Mix and Batch Plants.	0.00	-0.01	0.00	0.00
	7. Other (Glass Production)		0.00	0.00	0.00	0.00

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
2.B. Chemical Industry			0.00	1.84	0.00	0.00
1. Ammonia Production			0.00	0.00	0.00	0.00
2. Nitric Acid Production	Correction of N <sub>2</sub> O emission factors based on revised monitoring data.	N <sub>2</sub> O monitoring data update.	0.00	4.51	0.00	0.01
3. Adipic Acid Production			0.00	0.00	0.00	0.00
4. Carbide Production			0.00	0.00	0.00	0.00
5. Other	AD revision based on IAPI.	Revised data available from National Statistics. Previously, 2011 data was estimated based on fuel consumption.	0.00	-2.67	0.00	0.00
2.C. Metal Production			0.00	-21.82	0.00	-0.03
1. Iron and Steel Production	Correction of estimates error.	Error in CO <sub>2</sub> estimates in one of the iron and steel plants.	0.00	-21.82	0.00	-0.03
2. Ferroalloys Production			0.00	0.00	0.00	0.00
3. Aluminum Production			0.00	0.00	0.00	0.00
4. SF <sub>6</sub> Used in Aluminum and Magnesium Foundries			0.00	0.00	0.00	0.00
5. Other			0.00	0.00	0.00	0.00
2.D. Other Production			0.00	0.03	0.00	0.00
1. Pulp and Paper			0.00	0.00	0.00	0.00
2. Food and Drink			0.00	0.03	0.00	0.00
2.E. Production of Halocarbons and SF <sub>6</sub>	-	-	0.00	0.00	0.00	0.00
2.F. Consumption of Halocarbons and SF <sub>6</sub>	AD provisional data revision.	AD provisional data revision.	0.00	2.16	0.00	0.00
2.G. Other	-	-	0.00	0.00	0.00	0.00

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
<b>3. Solvent and Other Product Use</b>			<b>-12.34</b>	<b>-21.60</b>	<b>-0.02</b>	<b>-0.03</b>
A. Paint Application	Estimates for 2011 were done based on the value of GDP which has now been corrected.	New data available	0.00	-14.66	0.00	-0.02
B. Degreasing and Dry Cleaning	Estimates for 2011 were done based on the value of GDP which has now been corrected	New data available	0.00	-0.27	0.00	0.00
C. Chemical Products, Manufacture and Processing	Estimates for 2011 were done based on the value of GDP which has now been corrected	New data available	0.00	-3.62	0.00	-0.01
D. Other	Estimates were done based on statistics obtained from INE in previous submissions which has now been changed for data collect directly from enterprises.	The new is data collected directly from enterprises in order to retrieve a more consistent activity data time trend.	-12.34	-3.04	-0.02	0.00
<b>4. Agriculture</b>			<b>-40.92</b>	<b>-264.25</b>	<b>-0.07</b>	<b>-0.38</b>
4.A. Enteric Fermentation	Improvement of methodological level for Dairy Cattle, including the development of country specific DE value.	Reviews recommendations	20.16	-41.38	0.03	-0.06
4.B. Manure Management	Changing on VS values for dairy cattle in consequence of DE country specific developed. Changing of Nexcreta coefficient for swines category 20-50 kg	Development of DE country specific value	-4.13	-11.79	-0.01	-0.02
4.C. Rice Cultivation	Revision of rice conditions production in Portugal: reclassification of water regime; quantity of organic amendment incorporated; baseline emission factor	Review recommendation 2013 to reevaluation for EF estimation	-78.41	-271.51	-0.13	-0.39

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
4.D. Agricultural Soils	a) Emissions from sewage sludge application in agriculture soils are separately accounted for the first time ; b) Accounting of N <sub>2</sub> O emissions from Sowing Biodiverse Pastures rich in legumes (SBPRL) in line with LULUCF sector; c) update of fertilizers consumption 2009, 2010 and 2011; d) Changing of Nexcreta coefficient for swines category 20-50 kg	a) and b) Review recommendation 2012 ; c) Update done by Statistics National Authority; d) revision under PDM (Methodological Development Plan)	23.72	51.99	0.04	0.08
4.E. Prescribed Burning of Savannas	-	-	0.00	0.00	0.00	0.00
4.F. Field Burning of Agricultural Residues	Revision of crop production residues (rice and permanent crops).	Revision under PDM and QA/QC activities. Revision of rice conditions production	-2.25	8.44	0.00	0.01
4.G. Other	-	-	0.00	0.00	0.00	0.00
<b>5. Land Use, Land-Use Change and Forestry</b>	-	-	<b>-10785.14</b>	<b>-11089.02</b>	<b>-17.75</b>	<b>-16.00</b>
5.A. Forest Land	1) The replacement of the information on land use and land use changes in Mainland Portugal with data from the Land-Use Cartography of 1995, 2007 and 2010, recently made available from the Direção Geral do Território. 2) Revision of the soil emission factors, incorporating the LUCAS Data Set and reflecting only statistically significant	1) Improvements foreseen in the PDM.-and mentioned in the 2013 NIR.	-8469.20	-9828.27	-13.94	-14.18
5.B. Cropland			-1629.18	-3057.78	-2.68	-4.41
5.C. Grassland			-863.23	-722.43	-1.42	-1.04
5.D. Wetlands			0.12	-6.16	0.00	-0.01
5.E. Settlements			6.76	483.55	0.01	0.70
5.F. Other Land			169.58	2042.09	0.28	2.95

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO <sub>2</sub> eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
5.G. Other	changes in C Stocks 3) Revision on annual burnt areas per land use, using the revised information provided by Instituto de Conservação da Natureza e Florestas released in 2013-		0.00	0.00	0.00	0.00
<b>6. Waste</b>	-	-	<b>-3.03</b>	<b>-21.68</b>	<b>0.00</b>	<b>-0.03</b>
6.A. Solid Waste Disposal on Land	-	-	0.00	-11.55	0.00	-0.02
Municipal waste	2011: AD (waste quantities) for Açores Islands revised for 2006-2011.	New data available	0.00	-7.77	0.00	-0.01
Industrial waste	2011: revision of the quantities of industrial waste incinerated based on the GDP data	Data for 2011-2012 not available -	0.00	-3.78	0.00	-0.01
6.B. Waste-water Handling	-	-	-3.03	-16.07	0.00	-0.02
1. Industrial Wastewater	2011: wastewater handling types updated/collected based on information from Environmental Licenses.	Revision under PDM	0.00	-9.96	0.00	-0.01
2. Domestic and Commercial Waste Water	a) 1990 and 2011: Separate accounting of N <sub>2</sub> O emissions from sewage sludge application on agriculture land b) 2011: revision of population data (2008-2011)	a) UNFCCC recommendation b) Update of population data (INE data).	-3.03	-6.11	0.00	-0.01
6.C. Waste Incineration	2011: revision of the quantities of industrial waste incinerated based on the GDP data	Data for 2011-2012 not available -	0.00	5.94	0.00	0.01
6.D. Other	-	-	0.00	0.00	0.00	0.00

CRF Category	Recalculation	Reason for the Recalculation	Emission Impact (Gg CO2eq.)		Impact on Total Emissions without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
Memo Items:						
International Bunkers	-	-	0.00	-10.37	-	-
Aviation	Update of the 2011 emissions values	Compilation correction	0.00	-10.37	-	-
Marine	-	-	0.00	0.00	-	-
CO2 Emissions from Biomass	Revision of the 2011 energy balance data	Revision of the 2011 energy balance data	0.00	-1820.55	-	-

Figure 9-1 Recalculation of total CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission (LULUCF excl.)

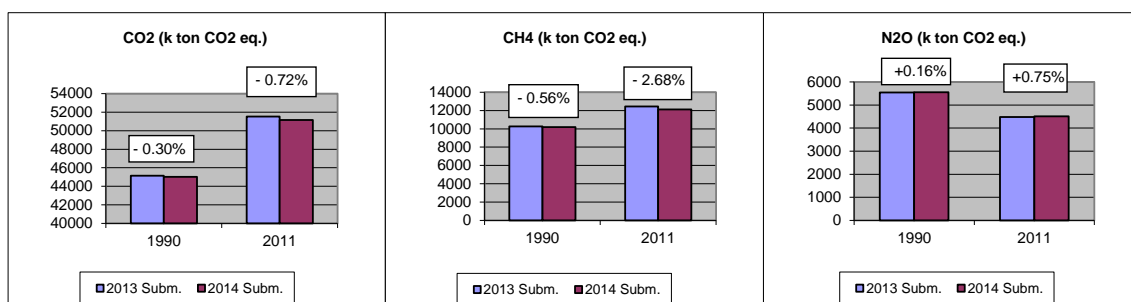


Table 9-3 – Recalculation of total CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission (LULUCF excl.)

Year	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2013 Subm.	2014 Subm.	Difference (%)	2013 Subm.	2014 Subm.	Difference (%)	2013 Subm.	2014 Subm.	Difference (%)
	(kton CO <sub>2</sub> eq.)			(kton CO <sub>2</sub> eq.)			(kton CO <sub>2</sub> eq.)		
1990	45,149	45,013	-0.30	10,260	10,203	-0.56	5,543	5,551	0.16
2011	51,527	51,155	-0.72	12,447	12,113	-2.68	4,479	4,513	0.75

### 9.3 Implications in emissions trends

A slighter difference upwards in the base year (1990: -0.3%) as compared with the reduction in 2011: -0.96%, resulted in a reduction of the growing trend for 1990-2011 from 14.8% % (2013 submission without LULUCF) to 14.1% (2014 submission without LULUCF).

Figure 9-2 – Recalculation of total emission levels (LULUCF excl.)

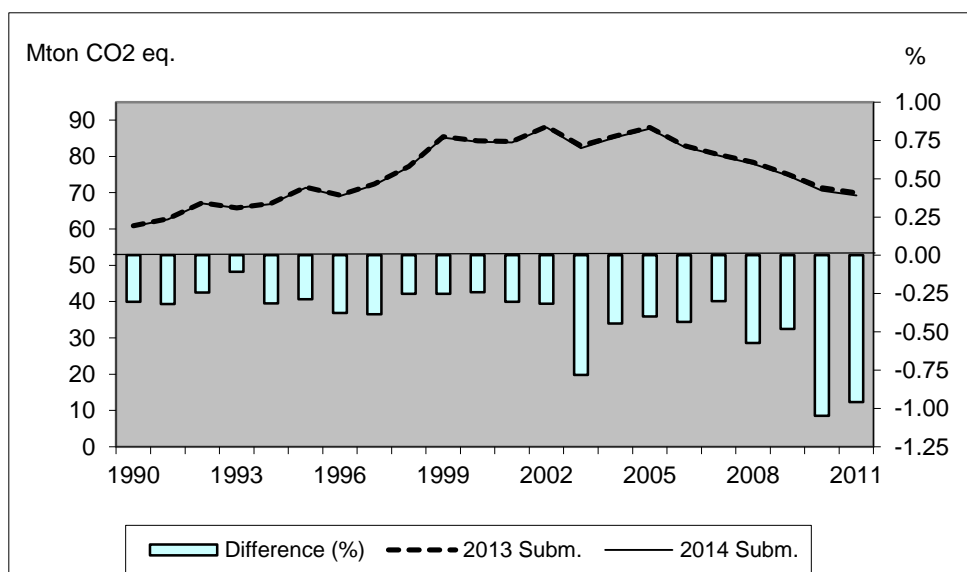


Table 9-4 – Recalculation of total emissions trends (LULUCFs excl.)

Year	2013 Submission (kton CO2 eq.)	2014 Submission (kton CO2 eq.)	Difference (%)
1990	60952	60767	-0.30
1991	62884	62683	-0.32
1992	67269	67105	-0.24
1993	65892	65821	-0.11
1994	67101	66890	-0.31
1995	71604	71399	-0.29
1996	69357	69096	-0.38
1997	72438	72159	-0.38
1998	77302	77107	-0.25
1999	85438	85224	-0.25
2000	84303	84100	-0.24
2001	84127	83872	-0.30
2002	88317	88038	-0.32
2003	82975	82328	-0.78
2004	85680	85299	-0.45
2005	88037	87686	-0.40
2006	83008	82647	-0.43
2007	80510	80269	-0.30
2008	78482	78032	-0.57
2009	75216	74854	-0.48
2010	71382	70634	-1.05
2011	69986	69317	-0.96

## 9.4 Future improvements

Future improvements are defined annually under the MDP which is settled each year in the context of the SNIERPA and which is developed under the responsibility of the APA, in cooperation with the sectorial Focal Points. The MDP pretends to reflect the results of the



various review processes, in particular the UNFCCC reviews, the annual inventory compilation process (all experts and entities involved can make proposals for methodological development), and generally the results of the application procedures of Quality Control and Quality Assurance which have been defined under the Control and Quality Assurance System.

## 10 KP-LULUCF

### 10.1 General Information

#### 10.1.1 Definition of forest and other information

In its Initial Report, Portugal adopted a forest definition according to the following parameters:

- Minimum tree cover: 10%
- Minimum land area: 1 ha
- Minimum tree height: 5 m
- Minimum width: 20 m

Consistent with national definitions and values reported to FAO, agri-forest systems of cork-oak and holm-oak were included as forests whenever the tree cover exceeded 10%.

Consistent with national definitions and values reported to FAO, some woody perennial crops like olive groves, vineyards and fruit production orchards were included as cropland, even if they would reach the forest thresholds mentioned above. However, as Portugal accounts also for Cropland management, any losses of area and biomass from perennial crops are also accounted for under the KP.

These parameters were chosen in the Initial Report for the definition of forest and are within the agreed values in decision 16/CMP.1. Portugal stated in the Initial Report that the threshold value selected for minimum area (1 ha) is higher than the value used for reporting to the FAO, which is 0.5 ha. The value selected corresponds to the most detailed information available from the national mapping of land-use (see section 10.5).

In Portugal all forests are considered managed, as all have anthropogenic activities. Forest management is guided by the rules defined in 2006 in the National Forest Strategy<sup>162</sup> and the Regional Forest Plans.

The Regional forest Plans provide silvicultural models for different ecological situations and for different management objectives; they provide goals for the forest area and the species composition at that level. Minimum silvicultural measures are included in the regional plans and are to be applied by all forest owners. Pending on the size of the forest holding, management plans at local level are mandatory (and approved by the National Forest Authority). Those instruments are designed to increase stands productivity, as in average, and mainly due to the effects of forest fires, the standing volume is considered to be very low and below possibility. The quantification of the expected increase is, however, very difficult and can/will only be assessed by subsequent national forest inventories. In order to improve forest management practices, particularly in areas of fragmented forest holdings, there is also support for a special type of collective management, in forest intervention zones.

Concerning fire prevention, the National Plan for the Protection of Forests Against Fires was approved also in 2006<sup>163</sup> and aims at increasing resilience of forests towards fires, reduce the

<sup>162</sup> National Forest Strategy / Estratégia Florestal Nacional (2006) <http://www.icnf.pt/portal/icnf/docref/enf>

consequences of forest fires, improve fire management and suppression, rehabilitate and recover forest ecosystems and adapt the organization structure. It established a plan of action, measures and goals, and identifies the entities responsible for implementing them.

The existing public support programmes followed the objectives and goals defined on the policy instruments mentioned above. They support measures to prevent forest fires, for instance by establishing fuel breaks and by assuring first intervention teams to forest owners association and local authorities.

#### **10.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol**

Portugal accounts for Article 3.3 activities (mandatory) – Afforestation (A), Reforestation (R) and Deforestation (D), and has elected the following Article 3.4 activities – Forest Management (FM), Cropland Management (CM) and Grassland Management (GM) (FCCC/IRR/2007/PRT).

#### **10.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time**

The definitions for each of these activities were applied consistently over the full time series 1970-2012 and therefore they were also applied consistently for the estimates of emissions and removals in the base year (1990) and the commitment period (2008-2012). This was ensured by defining strict terms of reference for Land-use cartography – COS (for the years 1995, 2007, 2010)<sup>164</sup> that captured the reporting requirements for the Kyoto Protocol.

This instrument developed data for the respective three reference years using the same information protocol and the same teams. Their results are therefore considered consistent over time.

#### **10.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified**

The hierarchy for Article 3.4 activities used since the 2011 submission is the following: Forest Management > Cropland Management > Grazing Land Management.

This classification represents a change to the hierarchical rules originally established (where areas under agro-forestry systems were classified as GM or CM, rather than FM).

## **10.2 Land Related Information**

### **10.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3**

The spatial assessment unit for all land-uses and activities was 1ha, consistent with the methodology of COS.

### **10.2.2 Methodology used to develop the land transition matrix**

The methodology used to develop the land transition matrix is described in section 7.1.2.8.

<sup>163</sup> National Plan for the Protection of Forests Against Fires / Plano Nacional de Defesa da Floresta Contra Incêndios (2006) <http://www.icnf.pt/portal/florestas/dfci/planos-dfci/plano>

<sup>164</sup> The project to develop land use cartography is still ongoing and wasn't used in this submission. However its development was informed by the data needs for UNFCCC and KP reporting purposes.

### 10.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The methodology to identify geographical locations and the information sources that were used are described in section 7.1.2.

## 10.3 Activity-specific information

### 10.3.1 Methods for carbon stock change and GHG emission and removal estimates and Description of the methodologies and the underlying assumptions used

#### 10.3.1.1 *Article 3.3 – Afforestation and deforestation*

The areas estimates for this activity are described in section 7.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.3 - Afforestation and reforestation were the same as those described for:

- land converted to forest land in section 7.2.2 (only for land converted to forest land after 1990);
- GHG emissions from biomass burning in section 7.13

#### 10.3.1.2 *Article 3.3 – Deforestation*

The areas estimates for this activity are described in section 7.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.3 - Deforestation were, depending on land use prior to deforestation, the same as those described for:

- forest land converted to cropland in section 7.3.2 (only for forest land converted to cropland after 1990);
- forest land converted to grassland in section 7.4.2 (only for forest land converted to grassland after 1990);
- forest land converted to wetlands in section 7.5.2 (only for forest land converted to wetlands after 1990);
- forest land converted to settlements in section 7.6.2 (only for forest land converted to settlements after 1990); and
- forest land converted to other land in section 7.7.2 (only for forest land converted to other land after 1990);
- N<sub>2</sub>O emissions from disturbances associated with land-use conversion to cropland in Section 7.11 (only for forest land converted to cropland after 1990)
- GHG emissions from biomass burning in section 7.13

#### 10.3.1.3 *Article 3.4 – Forest Management*

The areas estimates for this activity are described in section 7.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.4 – Forest Management were the same as those described for:

- forest land remaining forest land in section 7.2.1
- land converted to forests in section 7.2.2 (only for land converted to forest land before 1990)
- GHG emissions from biomass burning in section 7.13

#### 10.3.1.4 *Article 3.4 – Cropland Management*

The areas estimates for this activity are described in section 7.1.2.8.

The methods used for estimating emissions and removals in lands under article 3.4 – cropland management were, depending on land use on the previous reporting year, the same as those described for:

- cropland remaining cropland in section 7.3.1;
- land converted to cropland in section 7.3.2 (except land converted to forest land since 1990, which is reported as 3.3 AR);
- cropland converted to wetlands in section 7.5.2. (only for cropland converted to wetlands after 2008);
- cropland converted to settlements in section 7.6.2 (only for cropland converted to settlements after 2008);
- cropland converted to other land in section 7.7.2 (only for cropland converted to other land after 2008);
- areas under no-till in section 7.3.1.5
- N<sub>2</sub>O emissions from disturbances associated with land-use conversion to cropland in section 7.11 (except for forest land converted to cropland after 1990, which is reported under 3.3 D)
- carbon emissions from lime application in section 7.12
- GHG emissions from biomass burning in section 7.13

#### 10.3.1.5 *Article 3.4 – Grassland Management*

The areas estimates for this activity are described in section 7.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.4 – Grassland Management were, depending on land use on the previous reporting year, the same as those described for:

- grassland remaining grassland in section 7.4.1;
- land converted to cropland in section 7.4.2 (except land converted to forest land, which is reported as 3.3 AR);
- cropland converted to wetlands in section 7.5.2. (only for cropland converted to wetlands after 2008);
- cropland converted to settlements in section 7.6.2 (only for cropland converted to settlements after 2008);
- cropland converted to other land in section 7.7.2 (only for cropland converted to other land after 2008);
- areas under biodiverse pastures in section 7.4.1.5
- GHG emissions from biomass burning in section 7.13

#### 10.3.2 *Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4*

As referred before the area of organic soils in Portugal is negligible and therefore the pool is not considered. Otherwise, all pools and gases were considered.

#### 10.3.3 *Information on whether or not indirect and natural GHG emissions and removals have been factored out*

Portugal did not factor out indirect effects of climate change in expected emissions and removals from forest management. This was mostly due to technical difficulties associated with that calculation. However, and in qualitative terms, science on the impacts of climate change impacts in Portugal suggests that the net-effect will most likely result in a reduction of forest productivity.

*“The present capacity of Portuguese forests to store carbon is high. In the future, however, it may not be as high as it could be under present climatic condition due to: (1) decreases or only modest increases in NPP, (2) lower standing biomass due to changes in vegetation and increase in fire frequency and (3) enhanced soil respiration due to warmer winters, thus decreasing the importance of the below ground carbon store”<sup>165</sup>*

#### **10.3.4 Information that demonstrates that activities under Article 3.3 began after 1990 and ended before 31 December of the last year of the commitment period and are directly human-induced**

As explained in section 7.1.2 “Representation of Land-Areas and Land-Use Changes” Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

Only lands afforested since 1990 (i.e. converted from non-forest land to forest land) and deforested since 1990 (i.e. converted from forest to non-forest land) are considered for the purposes of accounting for activities under Article 3.3.

Deforestation is considered as human-induced by definition. Afforestation is a common activity by farmers and forest owners (97% of forest land in Portugal is privately owned) and is carried out with and without public support.

Public support through programmes for afforestation in agriculture lands, i.e. carried out in areas classified for UNFCCC LULUCF reporting as cropland and grassland, and for afforestation in other lands, i.e. carried out in areas classified for UNFCCC LULUCF reporting as other land (mostly shrublands). These programmes are funded by National and EU funds and have been present (although under different names and support levels) since Portugal joined the EU in 1986. Fast-growing species are not eligible for public support and, hence, all afforestation with these species results from direct investment by forest owners.

#### **10.3.5 Information on how harvesting or forest disturbance that is followed by the re-establishment of a forest is distinguished from deforestation**

As explained in section 7.1.2 “Representation of Land-Areas and Land-Use Changes” Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

The main sources of forest disturbance in Portugal are harvesting and forest fires. The usual practice is to reforest those areas after the disturbance event. In the case of forest fires public support for reforestation and re-establishment of forest cover is provided for. These programmes are funded by National and EU funds and have been present (although under different names and support levels) since Portugal joined the EU in 1986.

Some losses of forest cover are obvious deforestation events and are classified as deforestation as soon as they are detected (e.g. conversions to settlements, flooding by a recently constructed water reservoir, conversion to irrigated farmland). In other situations the land use following forest cover loss is less obvious. In those situations land is considered as “temporarily unstocked” for a period of up to 5 years. After such period the land should be confirmed as forest land (i.e., no deforestation has occurred) or non-forest land. In the later

<sup>165</sup> <http://www.siam.fc.ul.pt/SIAMExecutiveSummary.pdf>

case the land is considered deforested and the time series for area of FM is recalculated since the year when the event was first detected.

### 10.3.6 Information that demonstrates that activities under Article 3.4 have occurred since 1990 and are human-induced

As explained in section 7.1.2 “Representation of Land-Areas and Land-Use Changes” Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

All forests are considered managed and agriculture and grazing are, by definition, human induced activities.

### 10.3.7 Anthropogenic greenhouse gas emissions by sources and removals by sinks for each year of the commitment period and the base year (Article 3.4 cropland management and Article 3.4 grazing land management)

The calculation of emissions and removals is explained in section 10.3.1 and include estimations for the year 1990 (base year for Portugal) and all years in the period 2008-2012.

A summary of the reported values is presented in Table 10-1.

Table 10-1: Summary of reported emissions and removals under the KP for the Article 3.4 Activities Cropland Management and Grassland Management

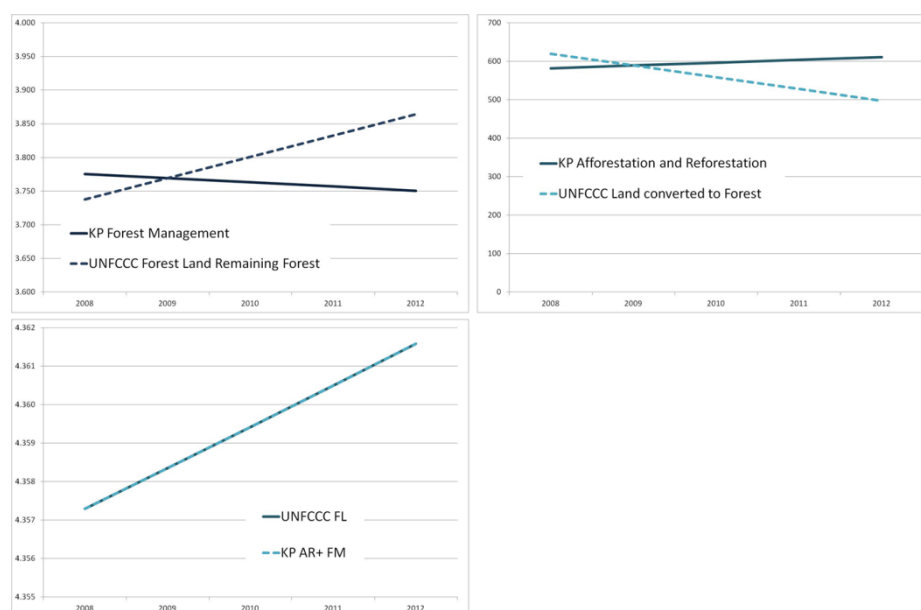
KP Activity		1990	2008	2009	2010	2011	2012
3.4 Cropland Management	5KP-I	3.314	215	212	189	201	213
	5KP-II	373	44	49	52	53	62
3.4 Grassland Management	5KP-I	1.168	191	134	64	-13	-52
	5KP-II	6	1	11	18	14	20

### 10.3.8 Information that demonstrates that emissions and removals resulting from elected Article 3.4 activities are not accounted for as activities under Article 3.3

As explained in section 7.1.2 “Representation of Land-Areas and Land-Use Changes” Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

This time series is used to derive time series for activity data of all activities under the KP. Land is allocated to each activity following the hierarchy of activities described in section 10.1.4. Once allocated to one activity in a particular year, land can not be allocated to another activity in the same year. As part of Portugal's QA/QC procedures, some comparisons between KP and UNFCCC reported areas are made to ensure that no double counting is taking place as illustrated in Figure 10-1.

Figure 10-1: Areas reported under the UNFCCC and KP CRF Tables for forest land



## 10.4 Other Information

### 10.4.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Following the guidance of GPG LULUCF (IPCC, 2003), the assessment of key categories under Articles 3.3 and 3.4 of the Kyoto Protocol was based on the assessment made for the UNFCCC inventory. Accordingly, whenever a category is identified as key in the UNFCCC inventory, the associated activity under the Kyoto Protocol was considered as key in reporting under the Kyoto Protocol, following the guidance from table 5.4.4 GPG LULUCF.

All 3.3 activities and all elected 3.4 activities were identified as key categories.

### 10.4.2 Information relating to Article 6

Portugal has no activities under Article 6.

## 10.5 Further Developments

See section 7.15.



## 11 INFORMATION ON ACCOUNTING KYOTO UNITS

### 11.1 Background Information

This section includes supplementary information required under Article 7, paragraph 1, following the reporting requirements of the Annex of Decision 15/CMP.1.

The standard electronic format (SEF) tables for providing information on ERUs, CERs, tCERs, ICERs, AAUs and RMUs for the year 2013 has been submitted electronically (SEF\_PT\_2014\_1\_12-9-47 9-1-2014.xls) and constitutes Annex D.

### 11.2 Summary of Information Reported in the SEF Tables

The total number of AAU units in the Portuguese registry at the end of the year 2013 was 345,123,957 AAUs, of which 222,828,261 units were in the Party holding account, 4,400,000 units in the entity holding accounts, and 117,895,696 units in the retirement account.

There was 15,762,959 CERs in the registry: 5,578,686 CERs were held in the entity holding accounts and 10,119,578 CERs were held in the retirement account.

The number of ERUs was 4,611,905. The registry did not contain any RMUs, t-CERs or I-CERs. There were no units in the Article 6 issuance and conversion accounts; no units in the Article 3.3 and Article 3.4 issuance or cancellation accounts and no units in the Article 12 afforestation and reforestation accounts.

The total amount of the units in the registry corresponded to 365,498,821 tonnes CO<sub>2</sub>e.

### 11.3 Discrepancies and notifications

There were no discrepant transactions for Portugal in 2013. The RRITL worksheet (PT\_SIAR\_R2-R5.xls) is annexed.

### 11.4 Publicly Accessible Information

The front page of the Registry website displays the link (<http://www.apambiente.pt/index.php?ref=77&subref=873>) where the public information is available. This information is updated on a regular basis.

### 11.5 Calculation of the Commitment Period Reserve (CPR)

The CPR has not been changed. Portuguese assigned amount was fixed in 381 937 527 tonnes CO<sub>2</sub> eq. The calculation of the CPR was based on the assigned amount (90% of the assign amount) and is estimated to be 343 743 774 tonnes of CO<sub>2</sub>e.

### 11.6 KP-LULUCF accounting

Portugal selected accounting of the KP-LULUCF activities at the end of the commitment period. No information on the accounting of these activities is therefore included in the SEF tables.

## **12 CHANGES IN NATIONAL SYSTEM**

Changes to the institutional arrangements since the 2013 submission of the National Inventory report (NIR, 2013) refer to the restructuring of the Ministry for the Environment and Land Use Planning, which previously included Agriculture and Sea, and since August 2013 (Decreto do Presidente da República n.º 97/2013 de 21 de agosto) has encompassed the Energy and now is entitled: Ministry for the Environment, Land Use Planning and Energy (Ministério do Ambiente, do Ordenamento do Território e Energia - MAOTE).

No major impact on the functioning of the national system and the inventory resulted from this rearrangement, since there was no reassignment of institutions or experts acting as Focal Points.

The most relevant and problematic changes refer to new changes occurred within the inventory team, which implied a period of adaptation and learning of the new experts involved in the inventory compilation. Furthermore, the exceptional period that Portugal is facing due to the financial and economic crisis which led to strict financial constraints in Public Administration, is impacting the stability of the resources and availability of background information.

The previously interrupted contract with CAOS Sustentabilidade to support the inventory preparation has been reestablished. Information on the NS is included in the Introduction section of the NIR.

## 13 INFORMATION ON CHANGES IN NATIONAL REGISTRY

The changes to the national registry of Portugal that occurred in 2013 are summarized below:

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a)  Change of name or contact	<p>The contact persons have changed from Mrs. Filomena Boavida and Mrs. Ana Teresa Perez to:</p> <p><b>Mr. Eduardo Santos / Mr. José Paulino</b></p> <p>The email has been changed from <a href="mailto:admin@rple.pt">admin@rple.pt</a> to <a href="mailto:nadmin@rple.pt">nadmin@rple.pt</a></p>
15/CMP.1 annex II.E paragraph 32.(b)  Change regarding cooperation arrangement	No change of the cooperation arrangement occurred during the reported period
15/CMP.1 annex II.E paragraph 32.(c)  Change to database structure or the capacity of national registry	<p>An updated diagram of the database structure is attached as Annex A.</p> <p>Iteration 5 of the national registry released in January 2013 and Iteration 6 of the national registry released in June 2013 introduces changes in the structure of the database.</p> <p>Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan.</p> <p>No change to the capacity of the national registry occurred during the reported period.</p>
15/CMP.1 annex II.E paragraph 32.(d)  Change regarding conformance to technical standards	<p>Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality.</p> <p>However, each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (please see Annex B).</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p>
15/CMP.1 annex II.E paragraph 32.(e)  Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(f)  Change regarding security	No change of security measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(g)  Change to list of publicly available information	The list of publicly available information is available at <a href="http://www.apambiente.pt/index.php?ref=77&amp;subref=873">http://www.apambiente.pt/index.php?ref=77&amp;subref=873</a>
15/CMP.1 annex II.E paragraph 32.(h)  Change of Internet address	No change of the registry internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i)  Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j)  Change regarding test results	<p>Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B.</p> <p>Annex H testing was carried out in February 2014 and the successful test report has been attached.</p>

Reporting Item	Description
The previous Annual Review recommendations	<p>In response to the previous Annual Review recommendations, the Party submitted an addendum to Chapter 14 with information on changes in national registry's of the Annual Inventory Submission for the reporting year 2012.</p> <p>The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. Since the successful certification of the registry on 1 June 2012, Iteration 4 of the registry, introduced in October 2012, added a limited number of new entities, none of them relating to DES entities.</p> <p>A data model was attached which more clearly shows the relevant entities "RECONCILIATIONS", "NOTIFICATIONS", "RESPONSES", "INTERNAL AUDIT LOG" and "MESSAGE LOG." As specified in the DES (Section VII. Data Logging Specifications/E. Message Archive), a copy of messages sent and received is stored in standalone files in one of two managed servers in the hosting environment. For that reason, the Message Archive is not shown in the model. The "MESSAGE LOG" object holds the location of the entire message, for each Message_ID.</p> <p>Since the successful certification of the registry on 1 June 2012, there has been no change in the capacity of the registry or change of its infrastructure.</p> <p>The consolidated EU system of registries successfully completed a full certification procedure in June 2012. Notably, this procedure includes connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES). This included a full Annex H test. All tests were executed successfully and led to successful certification on 1 June 2012.</p> <p>The October 2012 release (version 4.0) was only a minor iteration and changes were limited to EU ETS functionality and had no impact on Kyoto Protocol functions in the registry. The test script previously provided reflects this.</p> <p>However, each major release of the registry is subject to both regression testing and tests related to new functionality. These tests include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production.</p> <p>Regarding the recommendation of correctly displaying public information on the registry website, the front page of the Registry website displays the link (<a href="http://www.apambiente.pt/index.php?ref=77&amp;subref=873">http://www.apambiente.pt/index.php?ref=77&amp;subref=873</a>) where the public information is available. This information is updated on a regular basis.</p>

## **14 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14**

This section provides information on how Portugal is implementing its commitment under the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing countries.

Portugal's contribution to the minimization of the adverse effects of climate change in other Parties, particularly developing countries, is carried out first of all through a strong commitment to implementing the Convention and the Kyoto Protocol.

By working on the implementation of the Protocol, Portugal is minimizing not only the adverse effects of climate change in specific sectors, industries or other Parties, but also any adverse effects due to the reduction of greenhouse gases. This is due to the development of different actions and implementation of different instruments conceived to promote sustainable development and the commitment to support developing countries.

The policies and measures implemented, adopted or foreseen in the National Plan for Climate Change (PNAC), targeting the six GHG of the Kyoto Protocol through its broad portfolio of instruments and wide-ranging coverage of all sectors of the economy, make up a significant effort by the Portuguese Government to address climate change, including the minimization of adverse social, environmental and economic impacts on developing countries of such policies.

The transition to a lower carbon Portuguese economy relies on the contribution of all sectors. Particularly, the Portuguese Energy Strategy relies to a great extent in the diversification of energy sources (including those referring to fossil fuels) and to the increase of exploration of Portugal's endogenous resources (renewable). In some cases, such as measures pertaining to the diversification of primary energy sources (namely shifting to natural gas), there can simultaneously be positive effects on Portugal's emissions reduction and in the economy of fossil fuel exporting countries.

Examples of how this concern is being addressed in some of the policies implemented is shown below:

- EU Emissions Trading System (EU ETS): the EU's main policy mechanism for reducing CO<sub>2</sub> emissions from energy intensive sectors, and enables the creation of additional financial resources for climate change mitigation and adaptation in developing countries through the auction of emission allowances by member states;
- Inclusion of aviation in the EU emission trading scheme which addresses the challenge of reducing emissions from this sector, and enables the creation of additional financial resources for climate change mitigation and adaptation in developing countries through the auction of emission allowances by member states. We would also highlight that there is an exclusion of operators that operate below a certain threshold of flights;
- EU Renewables Directive (Directive 2009/28/EC): sets ambitious targets for each member state for the share of renewable energy generation by 2020 and the proportion of renewable energy in the transport sector (includes biofuels, biogas, hydrogen and electricity from renewables).

Furthermore, the cooperation of Portugal with third countries looks to the integration of the adaptation dimension of climate change in the several sectoral policies and instruments of planning, vulnerabilities and risks associates to climate change. The action of the Portuguese cooperation is developed on the basis of geographical priorities which are centered in the countries of Portuguese official language, in particular the PALOP and Timor East. All these countries are within the group of more vulnerable countries to the variations caused by climate changed either, because they are situated in its majority in Africa, or belong to the set of least developed countries and/or are small insular States.

In recent years the Portuguese Cooperation has been following closely the international negotiations on environmental issues and especially climate change at the United Nations, OECD and CPLP level

Portugal, through the Portuguese Carbon Fund and the collaboration between the Portuguese Environment agency and Instituto Camões have been responsible for approving projects in the field of climate change in partner countries, particularly Portuguese's speaking countries in Africa.

The approach for the approval of projects follows – amongst other criteria - the need for creating capacity to develop measures as well as planning on adaptation to climate change, on one hand, and to maintain the balance between mitigation and adaptation support , on the other.

Most of these countries are LDC's and some (Cape Verde, São Tome e Príncipe and Timor-Leste) are small Island developing states that are quite vulnerable to climate change and therefore adaptation takes on a significantly important role.

We take into account not only the national circumstances of the countries in the project approval process but also the institutional support of the beneficiary country towards the project itself. The process and the actors involved ensures continuity on the main priorities and value added of the Portuguese Development Cooperation as well as the achievement of the commitments made at international level.

Portugal has included an extended description of it cooperation activities in Chapter 6 of its National communication and also in tables 7-9 of the Biannual report.

## 15 List of Acronyms

ABS	Acrylonitrile Butadiene Styrene	Acrido Nitrilo Butadieno Estireno
AC	Air Conditioning	Ar condicionado
ACAP	Portuguese Association of Automobile Business	Associação do Comércio Automóvel de Portugal
ADP	ADP fertilizers (national fertilizer industry)	ADP fertilizantes
AG	Aviation Gasoline	Gasolina de Aviação
AN	Ammonium Nitrate	Nitrato de Amónio
ANA	Airports and Air Navigation	Aeroportos e Navegação Aérea
ANAM	Madeira Island Airports and Air Navigation	Aeroportos e Navegação Aérea da Madeira
ANECRA	National Association of Companies of Automobile Business and Reparation	Associação Nacional das Empresas do Comércio e da Reparação Automóvel
APED	Portuguese Association of Distribution Companies	Associação Portuguesa de Empresas de Distribuição
APIRAC	National Association of Industry of Refrigeration and Air Conditioning	Associação Portuguesa dos Industriais da Refrigeração e Ar Condicionado
APORBET	Portuguese Association of Bituminous Mixes Producers	Associação Portuguesa de Fabricantes de Misturas Betuminosas
AS	Ammonium Sulphate	Sulfato de Amónia
ASN	Ammonium Sulphate Nitrate	Sulfonitrato de Amónia
BAT	Best Available Technologies	-
BOD	Biochemical Oxygen Demand	Carência Bioquímica de Oxigénio
BOF	Basic Oxygen Furnace	-
CAFE	Clean Air For Europe	-
CAN	Calcium Ammonium Nitrate	Nitrato de Cálcio-amónio
CCDR-LVT	Lisbon and Tagus Valley Coordination and Regional Development Commission	Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
CELPA	Portuguese Paper Industry Association	Associação da Indústria Papeleira
CFC	Chlorofluorocarbons	Clorofluorcarbonetos
CH <sub>4</sub>	Methane	Metano
CITEPA	Interprofessional Technical Center of Studies of Atmospheric Pollution	Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique
CKD	Cement Kiln Dust	-
CMN	Calcium Magnesium Nitrate	-
CN	Calcium Nitrate	Nitrato de Cálcio
CO	Carbon Monoxide	Monóxido de Carbono
CO <sub>2</sub>	Carbon Dioxide	Dióxido de Carbono ou anidrido carbónico
CO <sub>2</sub> e	Carbon dioxide equivalente	Dióxido de carbono equivalente
COD	Chemical Oxygen Demand	Carência Química de Oxigénio
CONCAWE	-	-
Concelho	Portuguese territorial unit under the responsibility of a municipal authority	-
CORINAIR	Core Inventory Air Emissions	Inventário de Emissões Atmosféricas
CRF	Common Reporting Format	-



CTCV	Technological Centre for Ceramics and Glass	Centro Tecnológico da Cerâmica e do Vidro
DAP	Di-ammonium phosphate	-
DBH	Diameter at Breast Height	Diâmetro à Altura do Peito (DAP)
DC	Degradable Organic Component	Fracção Orgânica Degradável
DGA	General Directorate of Environment	Direcção Geral do Ambiente
DGADR	General Directorate for Agriculture and Rural Development	Direcção Geral de Agricultura e do Desenvolvimento Rural
DGAE (ex DGE)	General Directorate for Economic Activities	Direcção Geral das Actividades Económicas
DGAV	General Directorate for Food and Veterinary	Direcção geral de Alimentação e Veterinária
DGEG (ex DGGE)	General Directorate for Energy and Geology	Direcção Geral de Energia e Geologia
DGF	General Directorate of Forests	Direcção-Geral das Florestas
DGRF	General Directorate for Forestry Resources	Direcção Geral dos Recursos Florestais
DGTT	General Directorate of Terrestrial Transportation	Direcção Geral dos Transportes Terrestres
Distrito	Portuguese territorial unit comprehending several concelhos but not coincident with a region which is NUT II.	-
DOC	Degradable Organic Carbon	Carbono Orgânico Degradável
DOCF	Degradable Organic Carbon Dissimilated	-
DRAOT	Regional Directorate of Environment and Land Use Planning	Direcção Regional do Ambiente e Ordenamento do Território
EAF	Electric Arc Furnace	Forno Arco Eléctrico
EAPA	European Asphalt Pavement Association	-
EF	Emission Factors	Factores de Emissão
EMEP	Cooperative Programme for Monitoring and Evaluation of the Longrange Transmission of Air Pollutants in Europe	-
EPER	European Pollutant Emission Register	Registo Europeu de Emissões Poluentes
E-PRTR	European Pollutant Release and Transfer Register	-
FAEED	Federal Aviation Administration Aircraft Engine Emission Database	-
FAM	Animal Manure Nitrogen Applied to Soils	-
FAO	Food and Agriculture Organization of the United Nations	-
FCC	Fluidized-bed Catalytic Cracking	Cracking catalítico de leito fluidizado
FCR	Fixation in Crop Residues	-
FCT-UNL	Faculty of Science and Technology of New University of Lisbon	Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
FGR	Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that volatilises as NH <sub>3</sub>	-
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	-
GPP	Planning and Policies Office	Gabinete de Planeamento e Políticas
GPPAA	Agriculture and Food Planning and Policies Office (changed to GPP)	Gabinete de Planeamento e Política Agro-Alimentar
GWP	Global Warming Potential	-
H <sub>2</sub> S	Hydrogen Sulfide	Sulfureto de Hidrogénio
HCFC	Hydrochlorofluorocarbons	-
HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias
HFC	Hydrofluorocarbons	-
APA	Portuguese Environmental Agency	Agência Portuguesa do Ambiente
IAIT	Annual Survey to Manufacturing Industry	Inquérito Anual à Indústria Transformadora
IAPI	Annual Survey to Industrial Production	Inquérito Anual à Produção Industrial
ICAO	International Civil Aviation Organization	
IEF	Implied Emission Factors	Factores de Emissão Implícitos
IEP	Portuguese Road Institute	Instituto de Estradas de Portugal
IFA	International Fertilizer Industry Association	
IFADAP	Institute for Financing and Support of Development of Agriculture and Fisheries	Instituto de Financiamento e Apoio ao Desenvolvimento da Agricultura e das Pescas
IFRAA	Forestry Inventory of the Autonomous Region of Azores	Inventário Florestal da Região Autónoma dos Açores
IFRAM	Forestry Inventory of the Autonomous Region of Madeira	Inventário Florestal da Região Autónoma da Madeira
IMTT (ex. DGV)	Institute for Mobility and Terrestrial Transportation	Instituto da Mobilidade e dos Transportes Terrestres
INAG	National Water Institute	Instituto da Água
INE	National Statistics Institute	Instituto Nacional de Estatística
INIAV	National Institute for Agriculture and Veterinary Research	Instituto Nacional de Investigação Agrária e Veterinária
INR	National Wastes Institute	Instituto Nacional de Resíduos
INRA	National Institute for Agronomic Investigation (France)	Institut National de la Recherche Agronomique (França)
INRB	National Institute of Biological Resources (changed to INIAV)	Instituto Nacional de Recursos Biológicos
IPCC	Intergovernmental Panel on Climate Change	-
IPMA	Portuguese Meteorological Institute	Instituto Português do Mar e da Atmosfera
ISP	Portuguese Insurance Institute	Instituto de Seguros de Portugal
IST-UTL	Technical Superior Institute – Lisbon Technical University	Instituto Superior Técnico – Universidade Técnica de Lisboa
JP	Jet Fuel	-
LCP	Large Combustion Plants (the same as GIC)	o mesmo que GIC
LDPE	Low Density Poly Ethylene	Polietileno de Baixa Densidade (PEBD)
LDV	Light Duty Vehicles	Veículos Ligeiros de Mercadorias

LNG	Liquified Natural Gas	Gás Natural Liquefeito
LOSP	Light Organic Solvent-based Preservatives	-
LQARS	Agriculture Quimical Laboratoy Rebelo da Silva (integrated in INIAV)	Laboratório Químico Agrícola Rebelo da Silva
LPS	Large Point Sources (Corinair definition)	Grandes Fontes Poluidoras
LRTAP	Long-range Transboundary Air Pollution	Poluição Atmosférica Transfronteiras a Longa Distância
LTO	Landing and Take-off	Aterragens e Descolagens
LUCF	Land-use Change and Forestry	Alteração do Uso do Solo e Florestas
LULUCF	Land Use, Land-use Change and Forestry	Uso do Solo, Alteração do Uso do Solo e Florestas
MAC	Mobile Air-conditioning systems	-
MADRP	Ministry of Agriculture, Rural Development and Fisheries (changed to MAMAOT)	Ministério da Agricultura, Desenvolvimento Rural e Pescas (changed to MAMAOT)
MAM	Ministry of Agriculture and Sea	Ministério da Agricultura e do Mar
MAMAOT	Ministry for Agriculture, Sea, Environment and Land Use Planning (changed to MAM)	Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território
MAOT	Ministry of Environment and Land Use Planning (changed to MAMAOT)	Ministério do Ambiente e Ordenamento do Território (changed to MAMAOT)
MCF	Methane Conversion Factor	Factor de Conversão de Metano
MCOTA	Ministry of Urban Affairs, Land Use Planning and Environment (older name of Ministry of Environment)	Ministério das Cidades, Ordenamento do Território e Ambiente (older name of Ministry of Environment)
MDI	Metered Dose Inhalers	-
MEET	Methodologies For Estimating Air Pollutant Emissions From Transport	-
MMS	Manure Management Systems	Sistema de Gestão de Estrumes
MSW	Municipal Solid Wastes	Resíduos Sólidos Municipais
MTBE	Methyl Tertiary Butyl Ether	Metil-Ter-Butil-Éter
Na <sub>2</sub> S	Sodium Sulphide	Sulfureto de Sódio
NaOH	Sodium Hydroxide	Hidróxido de Sódio
NATO	North Atlantic Treaty Organisation	Organização do Tratado do Atlântico Norte
NAV	National Entity responsible for air traffic	Navegação Aérea
NCV	Net Calorific Value	-
NFI	National Forestry Inventories	Inventário Florestal Nacional
NFR	New Format Reporting	-
NH <sub>3</sub>	Ammoniac	Amoníaco
NMVO	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NO <sub>x</sub>	Nitrogen Oxides (NO + NO <sub>2</sub> )	Óxidos de Azoto (NO+NO <sub>2</sub> )
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
PDM	Methodological Development Plan	Plano de Desenvolvimento Metodológico
PEN	National Energetic Program	Plano Energético Nacional
PER	Perchloro-ethylene	Percloroetileno
PERSU	Strategic Plan on Municipal Solid Wastes	Plano Estratégico dos Resíduos Sólidos Urbanos
PETROGAL	Portuguese Petroleum Company	Empresa de Petróleos de Portugal
PFC	Perfluorinated Hidrocarbons	-
PM1	Particles with Aerodynamic Diameter smaller than 1 micrometer	Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro
PM10	Particles with Aerodynamic Diameter smaller than 10 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros
PM2.5	Particles with Aerodynamic Diameter smaller than 2.5 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 2.5 micrómetros
PNAC	National Climate Change Program	Programa Nacional para as Alterações Climáticas
PNPA	National Plan for Environmental Policy	Plano Nacional da Política de Ambiente
PP	Poly Propylene	Polipropileno
PS	Poly Styrene	Poliestireno
PTEN	National Emission Ceilings Program	Programa para os Tectos de Emissão Nacional
PVC	Poly Vinyl Chloride	Cloreto de Polivinil
RA	Agricultural Region	Região Agrária
RCM	Council Minister's Resolution	Resolução do Conselho de Ministros
REN	National Electric System	Rede Eléctrica Nacional
RVP	Reid Vapour Pressure	Pressão de Vapor de Reid
SF6	Sulphur Hexafluoride	Hexafluoreto de Enxofre
SNIERPA	National System of Inventories of Emissions and Remotions of Atmospheric Pollutants	Sistema Nacional de Inventários de Emissões e Remoções de Poluentes Atmosféricos
SOx	Sulphur Oxides	Óxidos de Enxofre
SW	Solid Wastes	Resíduos Sólidos
SWDS	Solid Waste Disposal Sites	Locais para Deposição de Resíduos Sólidos
TANKS	Software designed to estimate air emissions from organic liquids in storage tanks (USEPA, September 27, 2001)	Software criado para a estimativa de emissões atmosféricas a partir de líquidos orgânicos em tanques de armazenamento (USEPA, 27 de Setembro de 2001)
TNT	Trinitrotoluene	Trinitrotolueno
TOE	Tons of oil equivalent	Toneladas Equivalentes de Petróleo (TEP)
TOW	Total Organic Waste	Resíduo Orgânico Total
TRANSGÁS	Portuguese Company of Natural Gas	Sociedade Portuguesa de Gás Natural (Empresa)
TSP	Total Suspended Particles	Partículas Totais em Suspensão
TSS	Triple Super Phosphates	Superfosfatos Triplos

UNECE	United Nations Economic Commission for Europe	-
UNFCCC	United Nations Framework Convention on Climate Change	Convenção Quadro das Nações Unidas para as Alterações Climáticas
USEPA	United States Environmental Protection Agency	Agência de Protecção Ambiental dos Estados Unidos da América
VCM	Vinyl Chloride Monomer	Monómero de Cloreto de Vinilo
VOC	Volatile Organic Compounds	Compostos Orgânicos Voláteis
VRF	Vacuum Residual Fuel Oil	Resíduo de Alto Vácuo
WWH	Wastewater Handling	Tratamento de Águas Residuais
ZA	Agricultural Zone	Zona Agrária

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## ANNEX A: Key Category Analysis

### A.1 Introduction

This chapter provides an analysis of key categories following recommendations of the IPCC Good Practice Guidance (IPCC 2000) and IPCC Good Practice Guidance for LULUCF (IPCC 2003). A key category (source or sink) “is one that is prioritised within the national inventory system because its estimate has a significant influence on a country’s total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.” The aim of defining key categories is the improvement of the inventory’s accuracy. As key categories are the most important sources or removals in terms of their contribution to the absolute level of national emissions, the identification of these categories enables the prioritisation of national efforts and a more efficient use of available resources in order to reach an improvement of national estimates. Information on key categories is also important for the development of policies and measures for emissions reduction.

IPCC Good Practice Guidance (IPCC 2000) purposes several methods for performing key source analysis, which are:

- Tier 1 approach (level and trend assessments);
- Tier 2 approach (level and trend assessments with uncertainty analysis);
- Qualitative approach.

### A.2 Methodology for key source identification: Portuguese inventory

Having as a basis the 2013 Portuguese inventory estimates (1990-2012), 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:

<p>Level Assessment with Uncertainty= Tier 1 Level Assessment • Relative category Uncertainty</p> $LU_{x,t} = L_{x,t} \bullet U_{x,t}$
--

Where,

$LU_{x,t}$  = Level Assessment with Uncertainty

$L_{x,t}$  = calculated as in Tier 1 equation

$U_{x,t}$  = relative category uncertainty in the year t

#### *Tier 2 - Trend assessment*

The trend assessment is based according to the equation:



Trend Assessment with Uncertainty= Tier 1 Trend Assessment • Relative category Uncertainty

$$TU_{x,t} = T_{x,t} \bullet U_{x,t}$$

Where,

$TU_{x,t}$  = Trend Assessment with Uncertainty

$T_{x,t}$  = calculated as in Tier 1 equation

$U_{x,t}$  = relative category uncertainty in the year t

The key categories are those that add up to 90% of the total value of either  $LU_{x,t}$  and  $TU_{x,t}$ .

### A.3 Presentation of results

Key category analysis can be very influenced by the definitions of source categories (extent of the split). If a large category is broken into many subcategories, then these subcategories may not have a significant contribution to the total inventory to be considered as a key source. On the opposite, several non-key sources categories may become key source categories if aggregated into a unique source category.

In a general way, the source and removal categories have been split into (sub) categories that have been estimated using the same methodology and emission factors.

Following the recommendations from the ERT report, LULUCF and Agricultural sectors have been disaggregated according to the IPCC GPG (IPCC 2000 and 2003).

The analysis was based on the application of Tier 2 method with the LULUCF sector and resulted in the identification of 50 key categories.

Table A-1 presents a summary of identified key categories for 1990-2012 using Tier 2 analysis including LULUCF, and the criteria used (level, trend) in the identification.

Three other tables are presented, Tables A-2.1 to A-2.3 for 1990 and 2012 inventory year's level assessment and trend assessment for 1990-2012.

Table A. 1 – Portuguese key categories (1990-2012) based on Tier 2 with LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category Flag	Criteria for Identification	Comments on level assessment	2012 emissions estimate (kton CO <sub>2</sub> eq.)
1A 3 b Road Transportation	All Fuels	CO <sub>2</sub>	✓	Level Trend	All years	16,185.5
1A 1a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	✓	Level Trend	All years	10,886.7
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	✓	Level Trend	2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011	3,038.1
4 A ENTERIC FERMENTATION	Population size	CH <sub>4</sub>	✓	Level	All years	2,727.2
6 A Municipal SWDL	SW Disposal on Land	CH <sub>4</sub>	✓	Level Trend	All years	2,626.1
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	✓	Level	All years	2,550.4
6 A 3 Industrial SWDL	Industrial Waste Disposal on Land	CH <sub>4</sub>	✓	Level Trend	All years	2,418.2
5 E 2 Land converted to Settlements	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	2,355.6
1A 2 f Other	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	All years	2,239.9
1A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	✓	Level Trend	2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	1,997.6
4 D a AGRICULTURAL SOILS, Direct Emissions	Input to soils	N <sub>2</sub> O	✓	Level Trend	All years	1,859.2
6 B 1 Industrial Wastewater	Wastewater	CH <sub>4</sub>	✓	Level Trend	All years	1,786.8
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	1,609.6
1A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	✓	Level	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2010, 2011	1,426.3
4 D b AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N <sub>2</sub> O	✓	Level Trend	All years	1,076.3
4 B MANURE MANAGEMENT	Animal Excretion	CH <sub>4</sub>	✓	Level	All years	1,036.0
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	✓	Trend		988.0
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1999, 2000, 2001, 2002, 2005	899.1
1B 2 a Oil	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	804.0
5 B 2 Land converted to Cropland	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	793.2
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	✓	Level Trend	All years	743.2
1A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	✓	Trend		666.6
1A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	✓	Trend		605.0
5 C 2 Land converted to Grassland	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	535.3
1A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	✓	Level	1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007	435.0
5 D 2 Land converted to Wetlands	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	2006, 2007, 2008, 2009, 2010, 2011, 2012	404.0
1A 3 a i Domestic	Liquid Fuels	CO <sub>2</sub>	✓	Level Trend	1990, 1995, 1996, 1997, 1998, 1999, 2007, 2008, 2009, 2010, 2012	368.0
1B 2 b Natural gas	Gaseous Fuels	CH <sub>4</sub>	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2012	353.1
2 A 2 Lime Production	Production Quantities	CO <sub>2</sub>	✓	Level Trend	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	317.5
2 A 3 Limestone and Dolomite Use	Production Quantities	CO <sub>2</sub>	✓	Level Trend	2008, 2012	237.2
6 B 1 Industrial Wastewater	Wastewater	N <sub>2</sub> O	✓	Level Trend	All years	213.6
1A 4 b Residential	Biomass	CH <sub>4</sub>	✓	Level Trend	All years	193.8
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N <sub>2</sub> O	✓	Level Trend	All years	90.2
5 B 2 Land converted to Cropland	Emissions/Removals	N <sub>2</sub> O	✓	Trend		76.1
1A 1a Public Electricity and Heat Production	Solid Fuels	N <sub>2</sub> O	✓	Level Trend	All years	50.0
1B 2 b Natural gas	Gaseous Fuels	CO <sub>2</sub>	✓	Trend		46.3
2 F 2 Foam Blowing	Consumption	HFC	✓	Trend		45.6
1A 4 b Residential	Biomass	N <sub>2</sub> O	✓	Level Trend	All years	41.0
1A 2 f Other	Solid Fuels	CO <sub>2</sub>	✓	Level Trend	1990, 1991, 1992, 1994	35.2
1A 1a Public Electricity and Heat Production	Biomass	N <sub>2</sub> O	✓	Level Trend	2000, 2003, 2006, 2007, 2008, 2009, 2010, 2011, 2012	26.3
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N <sub>2</sub> O	✓	Level Trend	1999, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	23.4
1A 2 d Pulp, Paper and Print	Biomass	N <sub>2</sub> O	✓	Level Trend	2012	17.7
1A 2 f Other	Gaseous Fuels	N <sub>2</sub> O	✓	Trend		11.8
1A 1a Public Electricity and Heat Production	Other Fuels	N <sub>2</sub> O	✓	Trend		11.7
1A 2 f Other	Biomass	N <sub>2</sub> O	✓	Level Trend	1990, 1991, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010	7.4
1A 4 c Agriculture / Forestry / Fishing	Biomass	N <sub>2</sub> O	✓	Trend		7.3
2 A 6 Road Paving with Asphalt	Production Quantities	CO <sub>2</sub>	✓	Level	All years	2.8
1A 1a Public Electricity and Heat Production	Liquid Fuels	N <sub>2</sub> O	✓	Level Trend	1992	2.2
5 A 2 Land converted to Forest Land	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	-4,606.3
5 A 1 Forest Land remaining Forest Land	Emissions/Removals	CO <sub>2</sub>	✓	Level Trend	All years	-10,439.4
<b>Sub-total with LULUCF</b>		All gases				<b>49,825.0</b>
<b>% of total with LULUCF</b>		All gases				<b>90.1</b>
<b>TOTAL EMISSIONS WITH LULUCF</b>		All gases				<b>55,302.2</b>

Table A. 2 – Tier 2 Level assessment with LULUCF: 1990

Tier 2 Level Assessment (1990)										
IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level Assess.	Combined Uncert.	Level	Share	Cumulative	
			Estimate	Estimate			*	*		
			(kton CO2 eq.)	(kton CO2 eq.)			Uncert.	Uncert.		
			1990	1990		%	%	Total		
4Da AGRICULTURAL SOILS, Direct Emissions	Input to soils	N2O	2140	2140	0.03	500.28	13.65	0.30	0.30	
5A1 Forest Land remaining Forest Land	Emissions/Removals	CO2	-6166	-6166	0.08	36.53	2.87	0.06	0.36	
5B2 Land converted to Cropland	Emissions/Removals	CO2	4313	4313	0.05	45.22	2.49	0.05	0.41	
6A3 Industrial SWDL	Industrial Waste Disposal	CH4	1599	1599	0.02	120.10	2.45	0.05	0.47	
6A Municipal SWDL	SWDisposal on Land	CH4	1433	1433	0.02	124.90	2.28	0.05	0.52	
6B1 Industrial Wastewater	Wastewater	N2O	161	161	0.00	1000.30	2.05	0.04	0.56	
1A4c Agriculture/ Forestry / Fishing	Liquid Fuels	N2O	153	153	0.00	1000.05	1.95	0.04	0.61	
4Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N2O	1342	1342	0.02	113.05	1.94	0.04	0.65	
5A2 Land converted to Forest Land	Emissions/Removals	CO2	-2862	-2862	0.04	35.59	1.30	0.03	0.68	
5C2 Land converted to Grassland	Emissions/Removals	CO2	2943	2943	0.04	31.82	1.19	0.03	0.70	
1A4b Residential	Biomass	N2O	73	73	0.00	1001.80	0.93	0.02	0.72	
4B MANURE MANAGEMENT	Animal Excretion	CH4	1180	1180	0.02	61.42	0.92	0.02	0.74	
1A3b Road Transportation	All Fuels	CO2	9476	9476	0.12	7.07	0.85	0.02	0.76	
4A ENTERIC FERMENTATION	Population size	CH4	2729	2729	0.03	22.36	0.78	0.02	0.78	
6B1 Industrial Wastewater	Wastewater	CH4	1430	1430	0.02	42.54	0.78	0.02	0.79	
1A4b Residential	Biomass	CH4	343	343	0.00	161.55	0.71	0.02	0.81	
6B2 Domestic and Commercial wastewater	Wastewater	CH4	1056	1056	0.01	48.28	0.65	0.01	0.82	
1A1a Public Electricity and Heat Production	Solid Fuels	CO2	7913	7913	0.10	5.10	0.51	0.01	0.84	
1A2f Other	Liquid Fuels	CO2	3345	3345	0.04	11.18	0.48	0.01	0.85	
1A1a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	1000.00	0.46	0.01	0.86	
1A1a Public Electricity and Heat Production	Liquid Fuels	CO2	6405	6405	0.08	5.10	0.42	0.01	0.87	
2A1 Cement Production	Production Quantities	CO2	3176	3176	0.04	10.10	0.41	0.01	0.87	
2A6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	10000.01	0.33	0.01	0.88	
1A3a ii Domestic	Liquid Fuels	CO2	228	228	0.00	100.11	0.29	0.01	0.89	
1A2f Other	Solid Fuels	CO2	1993	1993	0.03	11.18	0.28	0.01	0.89	
1A2f Other	Biomass	N2O	21	21	0.00	1001.80	0.27	0.01	0.90	
2A2 Lime Production	Production Quantities	CO2	197	197	0.00	105.34	0.27	0.01	0.91	
1A4c Agriculture/ Forestry / Fishing	Liquid Fuels	CO2	1661	1661	0.02	11.18	0.24	0.01	0.91	
1A4b Residential	Liquid Fuels	CO2	1660	1660	0.02	11.18	0.24	0.01	0.92	
2B1 Ammonia Production	Production Quantities	CO2	569	569	0.01	31.57	0.23	0.00	0.92	
1A1a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	1000.00	0.20	0.00	0.93	
5B2 Land converted to Cropland	Emissions/Removals	N2O	353	353	0.00	38.75	0.17	0.00	0.93	
1A3d ii National navigation	Liquid Fuels	CO2	260	260	0.00	49.72	0.16	0.00	0.93	
1A2d Pulp, Paper and Print	Biomass	N2O	12	12	0.00	1000.00	0.15	0.00	0.94	
1A4b Residential	Liquid Fuels	N2O	11	11	0.00	1000.05	0.15	0.00	0.94	
1A2f Other	Liquid Fuels	N2O	10	10	0.00	1000.05	0.13	0.00	0.94	
1B2a Oil	Liquid Fuels	CO2	206	206	0.00	50.16	0.13	0.00	0.94	
1A1b Petroleum refining	Liquid Fuels	CO2	1867	1867	0.02	5.10	0.12	0.00	0.95	
1A2e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	821	821	0.01	11.18	0.12	0.00	0.95	
1A1b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1000.00	0.12	0.00	0.95	
6B2 Domestic and Commercial wastewater	Wastewater	N2O	299	299	0.00	30.41	0.12	0.00	0.96	
1A4a Commercial/ Institutional	Liquid Fuels	CO2	749	749	0.01	11.18	0.11	0.00	0.96	
1A2c Chemicals	Liquid Fuels	CO2	1373	1373	0.02	5.83	0.10	0.00	0.96	
4C RICE CULTIVATION	Culture Surface	CH4	148	148	0.00	52.25	0.10	0.00	0.96	
1B1a Coal Mining	Solid Fuels	CH4	74	74	0.00	100.12	0.09	0.00	0.96	
1A2c Chemicals	Liquid Fuels	N2O	6	6	0.00	1000.00	0.08	0.00	0.97	
2B5 Other	Production Quantities	CO2	63	63	0.00	100.50	0.08	0.00	0.97	
5A1 Forest Land remaining Forest Land	Emissions/Removals	CH4	136	136	0.00	45.36	0.08	0.00	0.97	
1A2a Iron and Steel	Solid Fuels	CO2	1058	1058	0.01	5.83	0.08	0.00	0.97	
2C1 Iron and Steel Production	Production Quantities	CO2	170	170	0.00	31.62	0.07	0.00	0.97	
3C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO2	53	53	0.00	100.50	0.07	0.00	0.97	
1A2e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.07	0.00	0.98	
4B MANURE MANAGEMENT	Animal Excretion	N2O	527	527	0.01	10.00	0.07	0.00	0.98	
2B2 Nitric Acid Production	Production Quantities	N2O	518	518	0.01	10.05	0.07	0.00	0.98	
1A2f Other	Solid Fuels	N2O	5	5	0.00	1000.05	0.06	0.00	0.98	
2A7 Other	Production Quantities	CO2	84	84	0.00	54.95	0.06	0.00	0.98	
1A2d Pulp, Paper and Print	Liquid Fuels	CO2	746	746	0.01	5.83	0.06	0.00	0.98	
1B2a Oil	Liquid Fuels	CH4	38	38	0.00	100.08	0.05	0.00	0.98	
2A3 Limestone and Dolomite Use	Production Quantities	CO2	33	33	0.00	105.02	0.04	0.00	0.98	
1A3b Road Transportation	All Fuels	CH4	85	85	0.00	40.31	0.04	0.00	0.99	
1A3b Road Transportation	All Fuels	N2O	67	67	0.00	50.25	0.04	0.00	0.99	
3A PAINT APPLICATION	Paint application	CO2	96	96	0.00	32.81	0.04	0.00	0.99	
4F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	29	29	0.00	101.98	0.04	0.00	0.99	
1B2c Venting and flaring	Liquid Fuels	CO2	52	52	0.00	50.09	0.03	0.00	0.99	
1A4a Commercial/ Institutional	Liquid Fuels	N2O	2	2	0.00	1000.05	0.03	0.00	0.99	
1A2e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.03	0.00	0.99	
4F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	21	21	0.00	101.98	0.03	0.00	0.99	
3D OTHER	Other Use of Chemicals	N2O	86	86	0.00	25.00	0.03	0.00	0.99	
1A2a Iron and Steel	Solid Fuels	N2O	2	2	0.00	1000.00	0.03	0.00	0.99	
1A3d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1001.22	0.03	0.00	0.99	
1A3a ii Domestic	Liquid Fuels	N2O	2	2	0.00	1004.99	0.03	0.00	0.99	
5E2 Land converted to Settlements	Emissions/Removals	CO2	38	38	0.00	51.22	0.02	0.00	0.99	
1A2d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1000.00	0.02	0.00	0.99	
3D OTHER	Other Use of Chemicals	CO2	70	70	0.00	25.00	0.02	0.00	0.99	
1A2d Pulp, Paper and Print	Biomass	CH4	10	10	0.00	150.03	0.02	0.00	0.99	
1A2c Chemicals	Biomass	N2O	1	1	0.00	1000.00	0.02	0.00	1.00	
5A1 Forest Land remaining Forest Land	Emissions/Removals	N2O	28	28	0.00	45.36	0.02	0.00	1.00	
1A3c Railways	Liquid Fuels	CO2	175	175	0.00	7.07	0.02	0.00	1.00	
5B1 Cropland remaining Cropland	Emissions/Removals	CO2	34	34	0.00	33.43	0.01	0.00	1.00	
1A5 Other	Liquid Fuels	CO2	95	95	0.00	11.18	0.01	0.00	1.00	
1B1a Coal Mining	Solid Fuels	CO2	10	10	0.00	100.12	0.01	0.00	1.00	
1A2a Iron and Steel	Liquid Fuels	CO2	167	167	0.00	5.83	0.01	0.00	1.00	
2B5 Other	Production Quantities	CH4	8	8	0.00	100.50	0.01	0.00	1.00	
1A5 Other	Liquid Fuels	N2O	1	1	0.00	1000.05	0.01	0.00	1.00	
6C WASTE INCINERATION	Waste Incinerated	CO2	13	13	0.00	50.25	0.01	0.00	1.00	

Table A. 3 – Tier 2 Level assessment with LULUCF: 2012

Tier 2 Level Assessment (2012)										
IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Combined	Level	Share	Cumulative	
			Estimate	Estimate						Assess.
			(kton CO2 eq.) 1990	(kton CO2 eq.) 2012		%	%	%		
4Da AGRICULTURAL SOILS, Direct Emissions	Input to soils	N2O	2140	1859	0.02	500.28	10.45	0.25	0.25	
5A 1 Forest Land remaining Forest Land	Emissions/Removals	CO2	-6166	-10439	0.12	32.23	3.78	0.09	0.34	
6A 3 Industrial SWDL	Industrial Waste Disposal	CH4	1599	2418	0.03	89.49	2.43	0.06	0.40	
6B 1 Industrial Wastewater	Wastewater	N2O	161	214	0.00	1000.21	2.40	0.06	0.45	
5A 2 Land converted to Forest Land	Emissions/Removals	CO2	-2862	-4606	0.05	42.81	2.22	0.05	0.51	
6A Municipal SWDL	SWDisposal on Land	CH4	1433	2626	0.03	64.20	1.89	0.04	0.55	
4Db AGRICULTURAL SOILS, Indirect Emissions	Input to soils	N2O	1342	1076	0.01	113.05	1.37	0.03	0.58	
5E2 Land converted to Settlements	Emissions/Removals	CO2	38	2356	0.03	50.01	1.32	0.03	0.61	
1A 3b Road Transportation	All Fuels	CO2	9476	16186	0.18	7.07	1.29	0.03	0.64	
1A 4c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	153	90	0.00	1000.05	1.01	0.02	0.67	
2F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	1610	0.02	49.51	0.90	0.02	0.69	
4B MANUREMANAGEMENT	Animal Excretion	CH4	1180	1036	0.01	61.42	0.72	0.02	0.71	
4A ENTERIC FERMENTATION	Population size	CH4	2729	2727	0.03	22.36	0.69	0.02	0.72	
6B 1 Industrial Wastewater	Wastewater	CH4	1430	1787	0.02	31.39	0.63	0.01	0.74	
1A 1a Public Electricity and Heat Production	Solid Fuels	CO2	7913	10887	0.12	5.10	0.62	0.01	0.75	
1B 2b Natural gas	Gaseous Fuels	CH4	0	353	0.00	150.33	0.60	0.01	0.77	
1A 1a Public Electricity and Heat Production	Solid Fuels	N2O	36	50	0.00	1000.00	0.56	0.01	0.78	
1A 4b Residential	Biomass	N2O	73	41	0.00	1001.80	0.46	0.01	0.79	
1B 2a Oil	Liquid Fuels	CO2	206	804	0.01	50.16	0.45	0.01	0.80	
6B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	743	0.01	48.28	0.40	0.01	0.81	
2A 2 Lime Production	Production Quantities	CO2	197	318	0.00	105.34	0.38	0.01	0.82	
1A 4b Residential	Biomass	CH4	343	194	0.00	161.55	0.35	0.01	0.83	
5B 2 Land converted to Cropland	Emissions/Removals	CO2	4313	793	0.01	39.32	0.35	0.01	0.84	
2A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	10000.01	0.32	0.01	0.84	
1A 1a Public Electricity and Heat Production	Biomass	N2O	0	26	0.00	1000.00	0.30	0.01	0.85	
2A 1 Cement Production	Production Quantities	CO2	3176	2550	0.03	10.10	0.29	0.01	0.86	
1A 2f Other	Liquid Fuels	CO2	3345	2240	0.03	11.18	0.28	0.01	0.87	
2A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	237	0.00	105.02	0.28	0.01	0.87	
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	23	0.00	1000.00	0.26	0.01	0.88	
1A 2f Other	Gaseous Fuels	CO2	0	1998	0.02	11.18	0.25	0.01	0.88	
5D 2 Land converted to Wetlands	Emissions/Removals	CO2	1	404	0.00	54.02	0.25	0.01	0.89	
5C 2 Land converted to Grassland	Emissions/Removals	CO2	2943	535	0.01	38.98	0.23	0.01	0.90	
1A 2d Pulp, Paper and Print	Biomass	N2O	12	18	0.00	1000.00	0.20	0.00	0.90	
1A 3a ii Domestic	Liquid Fuels	CO2	228	368	0.00	47.53	0.20	0.00	0.90	
1A 4b Residential	Liquid Fuels	CO2	1660	1426	0.02	11.18	0.18	0.00	0.91	
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3038	0.03	5.10	0.17	0.00	0.91	
5C 1 Grassland remaining Grassland	Emissions/Removals	CO2	0	-270	0.00	43.64	0.13	0.00	0.92	
1A 2f Other	Gaseous Fuels	N2O	0	12	0.00	1000.05	0.13	0.00	0.92	
1A 1a Public Electricity and Heat Production	Other Fuels	N2O	0	12	0.00	1000.00	0.13	0.00	0.92	
6B 2 Domestic and Commercial wastewater	Wastewater	N2O	299	368	0.00	30.41	0.13	0.00	0.93	
1A 3d ii National navigation	Liquid Fuels	CO2	260	225	0.00	49.72	0.13	0.00	0.93	
1A 4c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1661	988	0.01	11.18	0.12	0.00	0.93	
1A 4b Residential	Liquid Fuels	N2O	11	10	0.00	1000.05	0.11	0.00	0.93	
4C RICECULTIVATION	Cult ure Surface	CH4	148	183	0.00	52.25	0.11	0.00	0.94	
1A 1b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1000.00	0.10	0.00	0.94	
2A 7 Other	Production Quantities	CO2	84	155	0.00	54.95	0.10	0.00	0.94	
1A 3b Road Transportation	All Fuels	N2O	67	159	0.00	50.25	0.09	0.00	0.94	
2F 2 Foam Blowing	Consumption	HFC	0	46	0.00	174.14	0.09	0.00	0.95	
1A 1b Petroleum refining	Liquid Fuels	CO2	1867	1550	0.02	5.10	0.09	0.00	0.95	
2B 5 Other	Production Quantities	CO2	63	75	0.00	100.50	0.08	0.00	0.95	
1A 4a Commercial / Institutional	Gaseous Fuels	CO2	0	667	0.01	11.18	0.08	0.00	0.95	
1A 2f Other	Biomass	N2O	21	7	0.00	1001.80	0.08	0.00	0.95	
1A 4c Agriculture / Forestry / Fishing	Biomass	N2O	0	7	0.00	1001.80	0.08	0.00	0.96	
1B 2b Natural gas	Gaseous Fuels	CO2	0	46	0.00	150.33	0.08	0.00	0.96	
1A 4b Residential	Gaseous Fuels	CO2	0	605	0.01	11.18	0.08	0.00	0.96	
1A 2d Pulp, Paper and Print	Gaseous Fuels	N2O	0	6	0.00	1000.00	0.07	0.00	0.96	
1A 2f Other	Other Fuels	N2O	0	6	0.00	1000.05	0.07	0.00	0.96	
3C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO2	53	60	0.00	100.50	0.07	0.00	0.96	
5A 1 Forest Land remaining Forest Land	Emissions/Removals	CH4	136	126	0.00	45.36	0.06	0.00	0.97	
1A 2f Other	Liquid Fuels	N2O	10	6	0.00	1000.05	0.06	0.00	0.97	
1B 2c Venting and flaring	Liquid Fuels	CO2	52	107	0.00	50.09	0.06	0.00	0.97	
5B 1 Cropland remaining Cropland	Emissions/Removals	CO2	34	-190	0.00	27.77	0.06	0.00	0.97	
1A 4a Commercial / Institutional	Gaseous Fuels	N2O	0	5	0.00	1000.05	0.06	0.00	0.97	
1A 2e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	449	0.01	11.18	0.06	0.00	0.97	
1A 4a Commercial / Institutional	Liquid Fuels	CO2	749	435	0.00	11.18	0.05	0.00	0.97	
1A 2d Pulp, Paper and Print	Gaseous Fuels	CO2	0	815	0.01	5.83	0.05	0.00	0.98	
1A 2e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	821	424	0.00	11.18	0.05	0.00	0.98	
1A 4b Residential	Gaseous Fuels	N2O	0	5	0.00	1000.05	0.05	0.00	0.98	
1A 1b Petroleum refining	Gaseous Fuels	N2O	0	5	0.00	1000.00	0.05	0.00	0.98	
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO2	6405	899	0.01	5.10	0.05	0.00	0.98	
1B 2a Oil	Liquid Fuels	CH4	38	41	0.00	100.08	0.05	0.00	0.98	
1A 2c Chemicals	Gaseous Fuels	N2O	0	4	0.00	1000.00	0.04	0.00	0.98	
1A 2e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	3	0.00	1000.05	0.04	0.00	0.98	
1A 3a ii Domestic	Liquid Fuels	N2O	2	3	0.00	1001.12	0.04	0.00	0.98	
1A 1b Petroleum refining	Gaseous Fuels	CO2	0	595	0.01	5.10	0.03	0.00	0.98	
4B MANUREMANAGEMENT	Animal Excretion	N2O	527	293	0.00	10.00	0.03	0.00	0.99	
1A 2c Chemicals	Gaseous Fuels	CO2	0	477	0.01	5.83	0.03	0.00	0.99	
4F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	29	25	0.00	101.98	0.03	0.00	0.99	
1A 2f Other	Other Fuels	CO2	12	204	0.00	11.18	0.03	0.00	0.99	
1A 1a Public Electricity and Heat Production	Liquid Fuels	N2O	15	2	0.00	1000.00	0.02	0.00	0.99	
5B 2 Land converted to Cropland	Emissions/Removals	N2O	353	76	0.00	27.73	0.02	0.00	0.99	
1A 2c Chemicals	Liquid Fuels	CO2	1373	347	0.00	5.83	0.02	0.00	0.99	
1A 4a Commercial / Institutional	Biomass	N2O	0	2	0.00	1001.80	0.02	0.00	0.99	
1A 2c Chemicals	Liquid Fuels	N2O	6	2	0.00	1000.00	0.02	0.00	0.99	
1A 2d Pulp, Paper and Print	Biomass	CH4	10	12	0.00	150.03	0.02	0.00	0.99	
4F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	21	18	0.00	101.98	0.02	0.00	0.99	
2C 1 Iron and Steel Production	Production Quantities	CO2	170	58	0.00	31.62	0.02	0.00	0.99	
1A 3d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1001.22	0.02	0.00	0.99	
1A 1a Public Electricity and Heat Production	Other Fuels	CO2	0	322	0.00	5.10	0.02	0.00	0.99	
1A 4a Commercial / Institutional	Liquid Fuels	N2O	2	2	0.00	1000.05	0.02	0.00	0.99	
3A PAINT APPLICATION	Paint application	CO2	96	46	0.00	32.81	0.02	0.00	0.99	
1A 2e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	1	0.00	1000.05	0.01	0.00	0.99	
2A 7 Other	Production Quantities	CH4	5	16	0.00	75.66	0.01	0.00	0.99	
5A 1 Forest Land remaining Forest Land	Emissions/Removals	N2O	28	25	0.00	45.36	0.01	0.00	0.99	
1A 2d Pulp, Paper and Print	Liquid Fuels	CO2	746	188	0.00	5.83	0.01	0.00	1.00	

Table A. 4 – Tier 2 Trend assessment with LULUCF: 1990-2012

Tier 2 Trend Assessment (1990-2012)								
IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO <sub>2</sub> eq.)	Current year Estimate (kton CO <sub>2</sub> eq.)	Trend Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * %
			1990	2012				Cumulative Total
5A 1 Forest Land remaining Forest Land	Emissions/Removals	CO <sub>2</sub>	-6166	-10439	0.11	32.23	3.59	0.10
5B 2 Land converted to Cropland	Emissions/Removals	CO <sub>2</sub>	4313	793	0.06	39.32	2.47	0.07
5E 2 Land converted to Settlements	Emissions/Removals	CO <sub>2</sub>	38	2356	0.04	50.01	2.22	0.06
5A 2 Land converted to Forest Land	Emissions/Removals	CO <sub>2</sub>	-2862	-4606	0.05	42.81	2.22	0.06
5C 2 Land converted to Grassland	Emissions/Removals	CO <sub>2</sub>	2943	535	0.04	38.98	1.68	0.05
4 D a AGRICULTURAL SOILS. Direct Emissions	Input to soils	N <sub>2</sub> O	2140	1859	0.00	500.28	1.58	0.04
6 A Municipal SWDL	SW Disposal on Land	CH <sub>4</sub>	1433	2626	0.02	64.20	1.56	0.04
6 A 3 Industrial SWDL	Industrial Waste Disposal on	CH <sub>4</sub>	1599	2418	0.02	89.49	1.55	0.04
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	1610	0.03	49.51	1.52	0.04
6 B 1 Industrial Wastewater	Wastewater	N <sub>2</sub> O	161	214	0.00	1000.21	1.18	0.03
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N <sub>2</sub> O	153	90	0.00	1000.05	1.05	0.03
1B 2 b Natural gas	Gaseous Fuels	CH <sub>4</sub>	0	353	0.01	150.33	1.01	0.03
1A 3 b Road Transportation	All Fuels	CO <sub>2</sub>	9476	16186	0.14	7.07	0.98	0.03
1B 2 a Oil	Liquid Fuels	CO <sub>2</sub>	206	804	0.01	50.16	0.58	0.02
1A 4 b Residential	Biomass	N <sub>2</sub> O	73	41	0.00	1001.80	0.53	0.01
1A 1 a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	6405	899	0.10	5.10	0.50	0.01
1A 1 a Public Electricity and Heat Production	Biomass	N <sub>2</sub> O	0	26	0.00	1000.00	0.50	0.01
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	N <sub>2</sub> O	0	23	0.00	1000.00	0.45	0.01
1A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	0	1998	0.04	11.18	0.43	0.01
4 D b AGRICULTURAL SOILS. Indirect Emissions	Input to soils	N <sub>2</sub> O	1342	1076	0.00	13.05	0.42	0.01
5D 2 Land converted to Wetlands	Emissions/Removals	CO <sub>2</sub>	1	404	0.01	54.02	0.42	0.01
2 A 3 Limestone and Dolomite Use	Production Quantities	CO <sub>2</sub>	33	237	0.00	105.02	0.41	0.01
1A 4 b Residential	Biomass	CH <sub>4</sub>	343	194	0.00	161.55	0.40	0.01
1A 2 f Other	Solid Fuels	CO <sub>2</sub>	1993	35	0.04	11.18	0.40	0.01
1A 1 a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	7913	10887	0.07	5.10	0.33	0.01
2 B 1 Ammonia Production	Production Quantities	CO <sub>2</sub>	569	0	0.01	31.57	0.32	0.01
1A 1 a Public Electricity and Heat Production	Solid Fuels	N <sub>2</sub> O	36	50	0.00	1000.00	0.30	0.01
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	0	3038	0.06	5.10	0.30	0.01
2 A 2 Lime Production	Production Quantities	CO <sub>2</sub>	197	318	0.00	105.34	0.26	0.01
6 B 1 Industrial Wastewater	Wastewater	CH <sub>4</sub>	1430	1787	0.01	31.39	0.26	0.01
1A 2 f Other	Biomass	N <sub>2</sub> O	21	7	0.00	1001.80	0.24	0.01
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	1056	743	0.00	48.28	0.24	0.01
1A 1 a Public Electricity and Heat Production	Liquid Fuels	N <sub>2</sub> O	15	2	0.00	1000.00	0.24	0.01
1A 2 f Other	Gaseous Fuels	N <sub>2</sub> O	0	12	0.00	1000.05	0.22	0.01
1A 1 a Public Electricity and Heat Production	Other Fuels	N <sub>2</sub> O	0	12	0.00	1000.00	0.22	0.01
1A 2 f Other	Liquid Fuels	CO <sub>2</sub>	3345	2240	0.02	11.18	0.20	0.01
2 F 2 Foam Blowing	Consumption	HFC	0	46	0.00	174.14	0.15	0.00
1A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	0	667	0.01	11.18	0.14	0.00
1A 4 c Agriculture / Forestry / Fishing	Biomass	N <sub>2</sub> O	0	7	0.00	1001.80	0.14	0.00
1A 3 a ii Domestic	Liquid Fuels	CO <sub>2</sub>	228	368	0.00	47.53	0.14	0.00
5B 2 Land converted to Cropland	Emissions/Removals	N <sub>2</sub> O	353	76	0.00	27.73	0.14	0.00
1B 2 b Natural gas	Gaseous Fuels	CO <sub>2</sub>	0	46	0.00	150.33	0.13	0.00
1A 2 d Pulp, Paper and Print	Biomass	N <sub>2</sub> O	12	18	0.00	1000.00	0.13	0.00
1A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	0	605	0.01	11.18	0.13	0.00
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	1661	988	0.01	11.18	0.12	0.00
1A 2 d Pulp, Paper and Print	Gaseous Fuels	N <sub>2</sub> O	0	6	0.00	1000.00	0.12	0.00
1B 1 a Coal Mining	Solid Fuels	CH <sub>4</sub>	74	8	0.00	100.12	0.12	0.00
1A 2 f Other	Other Fuels	N <sub>2</sub> O	0	6	0.00	1000.05	0.11	0.00
1A 2 a Iron and Steel	Solid Fuels	CO <sub>2</sub>	1058	21	0.02	5.83	0.11	0.00
1A 2 c Chemicals	Liquid Fuels	CO <sub>2</sub>	1373	347	0.02	5.83	0.11	0.00
1A 4 a Commercial / Institutional	Gaseous Fuels	N <sub>2</sub> O	0	5	0.00	1000.05	0.10	0.00
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO <sub>2</sub>	0	449	0.01	11.18	0.10	0.00
4 B MANURE MANAGEMENT	Animal Excretion	CH <sub>4</sub>	1180	1036	0.00	61.42	0.09	0.00
1A 3 b Road Transportation	All Fuels	N <sub>2</sub> O	67	159	0.00	50.25	0.09	0.00
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO <sub>2</sub>	0	815	0.02	5.83	0.09	0.00
1A 4 b Residential	Gaseous Fuels	N <sub>2</sub> O	0	5	0.00	1000.05	0.09	0.00
1A 1 b Petroleum refining	Gaseous Fuels	N <sub>2</sub> O	0	5	0.00	1000.00	0.09	0.00
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	3176	2550	0.01	10.10	0.09	0.00
1A 2 e Food Processing, Beverages and Tobacco	Biomass	N <sub>2</sub> O	5	1	0.00	1001.80	0.09	0.00
1A 2 f Other	Solid Fuels	N <sub>2</sub> O	5	0	0.00	1000.05	0.08	0.00
1A 2 c Chemicals	Liquid Fuels	N <sub>2</sub> O	6	2	0.00	1000.00	0.08	0.00
2 B 2 Nitric Acid Production	Production Quantities	N <sub>2</sub> O	518	66	0.01	10.05	0.08	0.00
1A 2 f Other	Liquid Fuels	N <sub>2</sub> O	10	6	0.00	1000.05	0.08	0.00
2 A 7 Other	Production Quantities	CO <sub>2</sub>	84	155	0.00	54.95	0.08	0.00
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO <sub>2</sub>	821	424	0.01	11.18	0.08	0.00
1A 2 c Chemicals	Gaseous Fuels	N <sub>2</sub> O	0	4	0.00	1000.00	0.07	0.00
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N <sub>2</sub> O	0	3	0.00	1000.05	0.07	0.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO <sub>2</sub>	3	3	0.00	10000.01	0.06	0.00
4 A ENTERIC FERMENTATION	Population size	CH <sub>4</sub>	2729	2727	0.00	22.36	0.06	0.00
2 C 1 Iron and Steel Production	Production Quantities	CO <sub>2</sub>	170	58	0.00	31.62	0.06	0.00
1A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	749	435	0.01	11.18	0.06	0.00
1A 1 b Petroleum refining	Gaseous Fuels	CO <sub>2</sub>	0	595	0.01	5.10	0.06	0.00
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO <sub>2</sub>	746	188	0.01	5.83	0.06	0.00
1B 2 c Venting and flaring	Liquid Fuels	CO <sub>2</sub>	52	107	0.00	50.09	0.05	0.00
1A 2 c Chemicals	Gaseous Fuels	CO <sub>2</sub>	0	477	0.01	5.83	0.05	0.00
6 B 2 Domestic and Commercial wastewater	Wastewater	N <sub>2</sub> O	299	368	0.00	30.41	0.05	0.00
4 C RICE CULTIVATION	Culture Surface	CH <sub>4</sub>	148	183	0.00	52.25	0.04	0.00
1A 3 b Road Transportation	All Fuels	CH <sub>4</sub>	85	26	0.00	40.31	0.04	0.00
1A 2 f Other	Other Fuels	CO <sub>2</sub>	12	204	0.00	11.18	0.04	0.00
4 B MANURE MANAGEMENT	Animal Excretion	N <sub>2</sub> O	527	293	0.00	10.00	0.04	0.00
1A 4 a Commercial / Institutional	Biomass	N <sub>2</sub> O	0	2	0.00	1001.80	0.04	0.00
1A 2 a Iron and Steel	Solid Fuels	N <sub>2</sub> O	2	0	0.00	1000.00	0.04	0.00
1A 1 a Public Electricity and Heat Production	Other Fuels	CO <sub>2</sub>	0	322	0.01	5.10	0.03	0.00
1A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	1660	1426	0.00	11.18	0.03	0.00
2 B 5 Other	Production Quantities	CO <sub>2</sub>	63	75	0.00	100.50	0.03	0.00
3 A PAINT APPLICATION	Paint application	CO <sub>2</sub>	96	46	0.00	32.81	0.03	0.00
1A 3 a ii Domestic	Liquid Fuels	N <sub>2</sub> O	2	3	0.00	1001.12	0.03	0.00
1A 2 c Chemicals	Biomass	N <sub>2</sub> O	1	0	0.00	1000.00	0.02	0.00
1A 2 d Pulp, Paper and Print	Liquid Fuels	N <sub>2</sub> O	2	0	0.00	1000.00	0.02	0.00
1A 1 b Petroleum refining	Liquid Fuels	CO <sub>2</sub>	1867	1550	0.00	5.10	0.02	0.00
1A 4 b Residential	Liquid Fuels	N <sub>2</sub> O	11	10	0.00	1000.05	0.02	0.00
1A 3 d ii National navigation	Liquid Fuels	CO <sub>2</sub>	260	225	0.00	49.72	0.02	0.00
1A 3 c Railways	Liquid Fuels	CO <sub>2</sub>	175	33	0.00	7.07	0.02	0.00
6 C WASTE INCINERATION	Waste Incinerated	N <sub>2</sub> O	1	10	0.00	100.12	0.02	0.00
3 C CHEMICAL PRODUCTS, MANUFACTURE AND	Chemical manufacture and	CO <sub>2</sub>	53	60	0.00	100.50	0.02	0.00
1A 2 a Iron and Steel	Liquid Fuels	CO <sub>2</sub>	167	4	0.00	5.83	0.02	0.00
5B 1 Cropland remaining Cropland	Emissions/Removals	CO <sub>2</sub>	34	-190	0.00	27.77	0.02	0.00
2 A 7 Other	Production Quantities	CH <sub>4</sub>	5	16	0.00	75.66	0.02	0.00
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N <sub>2</sub> O	2	1	0.00	1000.05	0.02	0.00
1B 1 a Coal Mining	Solid Fuels	CO <sub>2</sub>	10	1	0.00	100.12	0.02	0.00

## ANNEX B: Uncertainty Analysis Methodology

### B1 Introduction

Uncertainty in the inventory of emissions and removals of GHG result from the natural variability of emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameter due to errors in original monitoring data, reference studies and expert judgment.

Uncertainty values were defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

The uncertainty analysis was performed only for the direct GHG: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC and SF<sub>6</sub>, considering all emissions in CO<sub>2</sub>e. 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 AP42<sup>166</sup>;
- comparison of several sources of information. For example, comparison to international sources such as FAO, IEA;
- inter-annual un expected variations of activity data;
- statistical variation in the determination of country-specific emission factors, for different units or different years.

The actual uncertainty values that were used for each activity source is reported in following chapters for each source.

### **Error propagation**

Two different rules were used in error propagation (IPCC,2000):

Rule A: For the case when the quantities are to be combined by addition, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms;

$$U_{Total} = \left\{ \sum_i [U_i * x_i]^2 \right\}^{0.5}$$

$$\sum_i [x_i]$$

Where:

<sup>166</sup> 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 %



$U_{\text{total}}$  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:

$$U_{\text{Total}} = [\sum_i U_i^2]^{0.5}$$

Where:

$U_{\text{total}}$  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 table<sup>167</sup>**

The uncertainty was estimated in a consistent way for all years from 1990 to 2011. However, the table presents information only for 2011 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: CO<sub>2</sub> ; CH<sub>4</sub> ; N<sub>2</sub>O and F G (F gases). Emissions are reported for F gases (HFC, PFC and SF<sub>6</sub>) after conversion to CO<sub>2</sub>eq using the appropriate GWP factor. Removals and emissions of the LULUCF sector, except fires, are reported as CO<sub>2</sub>, 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 values<sup>168</sup>. All emissions, irrespective of the gas, are reported as CO<sub>2</sub>e (Column C of table 6.1 in GP (IPCC,2000));

<sup>167</sup> Tables provided in excel annex

<sup>168</sup> Note: all calculation is done with absolute values.



- 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% net confidence interval divided by the mean and expressed as percentage. Detailed presentation of the assumptions and determination of individual values are discussed in main text (Column E of table 6.1 in GP (IPCC,2000));
- EF Uncertainty: the uncertainty value attributed to the implied emission factor, per cent. The determination of this value from basic parameters is discussed in main text. (Column F of table 6.1 in GP (IPCC,2000));
- Combined Uncertainty: derived from the uncertainties of AD and EF and using propagation rule B. (Column G of table 6.1 in GP (IPCC,2000));
- Combined uncertainty as per cent of total national emissions in current year: represents the importance of the uncertainty of each specific individual category to the overall uncertainty in the current year. The addition of the squares of all the entries in column H and after taking the square root (Rule A) is an estimate of the percentage uncertainty in total national emissions in the current year. (Column H of table 6.1 in GP (IPCC,2000));
- type A sensitivity: The per cent difference in emissions for this individual category following a 1% increase in both the base year and current year, expressing the sensitivity in trend to a uncertainty systematic in nature (Column I of table 6.1 in GP (IPCC,2000));
- type B sensitivity: The per cent difference in emissions for this individual category following a 1% increase in the current year only, expressing the sensitivity in trend to a uncertainty due to random error in emission estimate (i.e. error not correlated between years). (Column J of table 6.1 in GP (IPCC,2000));
- Uncertainty in trend from the uncertainty in EF: In all cases type A sensitivity (correlation) was used to estimate uncertainty in EF. (Column K of table 6.1 in GP (IPCC,2000));
- Uncertainty in trend from the uncertainty in AD: In all cases type B sensitivity (no correlation) was used to estimate uncertainty in AD. (Column L of table 6.1 in GP (IPCC,2000));
- Uncertainty into the trend in total national emissions. is an estimate of the uncertainty introduced into the trend in national emissions by the source category in question, derived from the data in columns K and L using Rule B. Total uncertainty in trend is calculated from the entries above using the error propagation equation, summing the squares of all the entries in column M and taking the square root.(Column M of table 6.1 in GP (IPCC,2000)).

### B3 Tier 1 Uncertainty Estimates: 2012

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensisitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	CO2	6,405.4	899.1	1	5	5	0.08	-0.09	0.02	-0.44	0.02	0.44
	Public Electricity and Heat Production	S	1A1a	CO2	7,913.3	10,886.7	1	5	5	1.00	0.06	0.19	0.29	0.26	0.39
	Public Electricity and Heat Production	G	1A1a	CO2	0.0	3,038.1	1	5	5	0.28	0.05	0.05	0.26	0.07	0.27
	Public Electricity and Heat Production	O	1A1a	CO2	0.0	321.5	1	5	5	0.03	0.01	0.01	0.03	0.01	0.03
	Petroleum refining	L	1A1b	CO2	1,866.8	1,549.7	1	5	5	0.14	0.00	0.03	-0.02	0.04	0.04
	Petroleum refining	G	1A1b	CO2	0.0	594.9	1	5	5	0.05	0.01	0.01	0.05	0.01	0.05
	Iron and Steel	L	1A2a	CO2	166.8	4.0	5	5	7	0.00	0.00	0.00	-0.01	0.00	0.01
	Iron and Steel	S	1A2a	CO2	1,057.7	21.3	5	5	7	0.00	-0.02	0.00	-0.08	0.00	0.08
	Iron and Steel	G	1A2a	CO2	0.0	115.0	3	4	5	0.01	0.00	0.00	0.01	0.01	0.01
	Iron and Steel	B	1A2a	CO2	0.0	0.2	60	5	60	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	CO2	1,373.3	347.0	3	4	5	0.03	-0.02	0.01	-0.06	0.02	0.06
	Chemicals	S	1A2c	CO2	39.7	47.3	5	5	7	0.01	0.00	0.00	0.00	0.01	0.01
	Chemicals	G	1A2c	CO2	0.0	477.3	5	5	7	0.06	0.01	0.01	0.04	0.06	0.07
	Chemicals	O	1A2c	CO2	62.8	49.4	5	5	7	0.01	0.00	0.00	0.00	0.01	0.01
	Pulp, Paper and Print	L	1A2d	CO2	745.9	187.6	3	5	5	0.02	-0.01	0.00	-0.04	0.01	0.04
	Pulp, Paper and Print	G	1A2d	CO2	0.0	815.4	3	4	5	0.07	0.01	0.01	0.05	0.06	0.08
	Food Processing, Beverages and Tobacco	L	1A2e	CO2	821.0	424.1	10	5	11	0.09	-0.01	0.01	-0.03	0.10	0.11

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					A	B	C	D	E	F	G	H	I	J	K
Fuel Combustion	Food Processing, Beverages and Tobacco	G	1A2e	CO2	0.0	449.5	10	5	11	0.09	0.01	0.01	0.04	0.11	0.12
	Other	L	1A2f	CO2	3,345.0	2,239.9	3	3	4	0.16	-0.02	0.04	-0.05	0.14	0.15
	Other	S	1A2f	CO2	1,992.5	35.2	3	4	5	0.00	-0.03	0.00	-0.13	0.00	0.13
	Other	G	1A2f	CO2	0.0	1,997.6	4	3	5	0.17	0.03	0.03	0.09	0.19	0.21
	Other	O	1A2f	CO2	12.1	203.8	3	5	6	0.02	0.00	0.00	0.02	0.01	0.02
	Civil Aviation. Domestic	L	1A3aii	CO2	228.0	368.0	47	5	48	0.32	0.00	0.01	0.01	0.42	0.42
	..International	L	1A3ai	CO2	1,461.1	2,720.0	47	5	48	2.34	0.02	0.05	0.11	3.11	3.11
	Road Transportation		1A3b	CO2	9,475.8	16,185.5	5	5	7	2.07	0.12	0.28	0.62	1.96	2.05
	Railways	L	1A3c	CO2	175.2	32.9	5	5	7	0.00	0.00	0.00	-0.01	0.00	0.01
	Navigation. Domestic	L	1A3dii	CO2	259.9	225.1	49	5	50	0.20	0.00	0.00	0.00	0.27	0.27
	..International	L	1A3di	CO2	1,386.0	2,084.6	49	5	50	1.87	0.01	0.04	0.07	2.49	2.49
	Commercial / Institutional	L	1A4a	CO2	748.6	435.0	10	5	11	0.09	0.00	0.01	-0.02	0.11	0.11
	Commercial / Institutional	G	1A4a	CO2	0.0	666.6	10	5	11	0.13	0.01	0.01	0.06	0.16	0.17
	Residential	L	1A4b	CO2	1,660.3	1,426.3	10	5	11	0.29	0.00	0.02	-0.01	0.34	0.35
	Residential	G	1A4b	CO2	0.0	605.0	10	5	11	0.12	0.01	0.01	0.05	0.15	0.16
	Agriculture / Forestry / Fishing	L	1A4c	CO2	1,661.4	988.0	65	4	66	1.17	-0.01	0.02	-0.04	1.56	1.56
	Agriculture / Forestry / Fishing	G	1A4c	CO2	0.0	29.0	10	5	11	0.01	0.00	0.00	0.00	0.01	0.01
	Other Combustion	L	1A5	CO2	95.1	48.3	5	5	7	0.01	0.00	0.00	0.00	0.01	0.01
Fugitive Emissions	Solid fuels		1B1	CO2	9.7	1.0	5	100	100	0.00	0.00	0.00	-0.01	0.00	0.01

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
from Fuels															
	Oil and natural gas		1B2	CO2	13.4	84.0	3	86	86	0.13	0.00	0.00	0.10	0.01	0.10
Industrial Processes	Mineral Products		2A	CO2	3,493.4	3,263.0	12	12	17	1.01	0.00	0.06	-0.01	0.96	0.96
	Chemical Industry		2B	CO2	632.7	74.6	9	88	88	0.12	-0.01	0.00	-0.79	0.02	0.79
	Metal Production		2C	CO2	90.0	57.9	10	30	32	0.03	0.00	0.00	-0.01	0.01	0.02
	Other Production		2D	CO2	0.4	0.3	100	0	100	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Paint Application		3A	CO2	96.1	46.2	8	7	10	0.01	0.00	0.00	-0.01	0.01	0.01
	Degreasing And Dry Cleaning		3B	CO2	11.6	7.3	7	0	7	0.00	0.00	0.00	0.00	0.00	0.00
	Chemical Products, Manufacture And Processing		3C	CO2	53.3	59.7	5	26	26	0.03	0.00	0.00	0.00	0.01	0.01
	Other		3D	CO2	70.0	77.1	6	1,912	1,912	2.67	0.00	0.00	0.36	0.01	0.36
Waste	Waste Incineration		6C	CO2	2.4	16.7	59	50	77	0.02	0.00	0.00	0.01	0.02	0.03
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	CH4	1.4	0.6	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	S	1A1a	CH4	1.3	1.7	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	G	1A1a	CH4	0.0	1.1	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Public Electricity and Heat Production	B	1A1a	CH4	0.0	2.4	1	146	146	0.01	0.00	0.00	0.01	0.00	0.01
	Public Electricity and Heat Production	O	1A1a	CH4	0.0	0.4	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Petroleum refining	L	1A1b	CH4	1.6	1.4	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
Fuel Combustion	Petroleum refining	G	1A1b	CH4	0.0	0.0	1	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	L	1A2a	CH4	0.1	0.0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	S	1A2a	CH4	0.4	0.0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	G	1A2a	CH4	0.0	0.0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Iron and Steel	B	1A2a	CH4	0.0	0.0	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	CH4	1.4	0.4	3	122	123	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	S	1A2c	CH4	0.0	0.0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	G	1A2c	CH4	0.0	0.3	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	B	1A2c	CH4	0.3	0.0	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	O	1A2c	CH4	0.0	0.0	5	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	L	1A2d	CH4	3.3	4.4	3	149	149	0.01	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	G	1A2d	CH4	0.0	1.7	3	132	132	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	B	1A2d	CH4	10.1	12.4	5	139	140	0.03	0.00	0.00	0.01	0.00	0.01
	Food Processing, Beverages and Tobacco	L	1A2e	CH4	0.7	0.4	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	G	1A2e	CH4	0.0	0.2	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Food Processing, Beverages and Tobacco	B	1A2e	CH4	1.3	0.1	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Other	L	1A2f	CH4	2.7	6.2	3	118	118	0.01	0.00	0.00	0.01	0.00	0.01
	Other	S	1A2f	CH4	4.1	0.0	2	124	124	0.00	0.00	0.00	-0.01	0.00	0.01
	Other	G	1A2f	CH4	0.0	1.4	4	102	102	0.00	0.00	0.00	0.00	0.00	0.00

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
Fuel Combustion	Other	B	1A2f	CH4	2.5	2.1	34	87	93	0.00	0.00	0.00	0.00	0.00	0.00
	Other	O	1A2f	CH4	0.0	0.6	3	149	149	0.00	0.00	0.00	0.00	0.00	0.00
	Civil Aviation. Domestic	L	1A3aii	CH4	0.9	0.3	47	100	111	0.00	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3ai	CH4	2.6	1.6	47	100	111	0.00	0.00	0.00	0.00	0.00	0.00
	Road Transportation		1A3b	CH4	85.4	25.7	5	40	40	0.02	0.00	0.00	-0.04	0.00	0.04
	Railways	L	1A3c	CH4	0.3	0.0	5	40	40	0.00	0.00	0.00	0.00	0.00	0.00
	Navigation. Domestic	L	1A3dii	CH4	0.1	0.1	49	100	112	0.00	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3di	CH4	0.5	0.7	49	100	112	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	L	1A4a	CH4	0.5	0.3	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	G	1A4a	CH4	0.0	0.3	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Commercial / Institutional	B	1A4a	CH4	0.0	0.5	60	150	162	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	L	1A4b	CH4	0.8	0.6	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	G	1A4b	CH4	0.0	0.6	10	150	150	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	B	1A4b	CH4	343.5	193.8	60	150	162	0.57	0.00	0.00	-0.34	0.28	0.44
	Agriculture / Forestry / Fishing	L	1A4c	CH4	3.1	1.8	75	36	83	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	G	1A4c	CH4	0.0	0.0	10	149	150	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry / Fishing	B	1A4c	CH4	0.0	0.1	85	39	93	0.00	0.00	0.00	0.00	0.00	0.00
	Other Combustion	L	1A5	CH4	0.0	0.0	5	40	40	0.00	0.00	0.00	0.00	0.00	0.00
Fugitive	Solid fuels		1B1	CH4	74.4	7.7	5	100	100	0.01	0.00	0.00	-0.11	0.00	0.11

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
Emissions from Fuels															
	Oil and natural gas		1B2	CH4	0.0	353.1	5	150	150	0.96	0.01	0.01	0.91	0.04	0.91
Industrial Processes	Mineral Products		2A	CH4	5.7	16.9	9	70	71	0.02	0.00	0.00	0.01	0.00	0.01
	Chemical Industry		2B	CH4	8.3	8.4	7	71	71	0.01	0.00	0.00	0.00	0.00	0.00
	Metal Production		2C	CH4	4.6	13.3	10	20	22	0.01	0.00	0.00	0.00	0.00	0.00
Agriculture	Enteric Fermentation		4A	CH4	2,729.3	2,727.2	6	12	14	0.68	0.00	0.05	0.03	0.41	0.41
	Manure Management		4B	CH4	1,179.7	1,036.0	8	76	76	1.43	0.00	0.02	-0.10	0.21	0.23
	Rice Cultivation		4C	CH4	148.4	183.3	34	40	52	0.17	0.00	0.00	0.03	0.15	0.15
	Field Burning Of Agricultural Wastes		4F	CH4	28.7	25.1	100	20	102	0.05	0.00	0.00	0.00	0.06	0.06
Waste	Urban Solid Waste Disposal On Land		6A	CH4	1,433.2	2,626.1	17	53	56	2.65	0.02	0.04	1.16	1.05	1.56
	Industrial Solid Waste Disposal On Land		6A	CH4	1,599.3	2,418.2	58	57	82	3.57	0.02	0.04	0.88	3.41	3.53
	Industrial Wastewater		6B	CH4	1,429.8	1,786.8	21	24	31	1.01	0.01	0.03	0.18	0.89	0.91
	Domestic and Commercial wastewater		6B	CH4	1,056.4	743.2	30	38	48	0.65	0.00	0.01	-0.16	0.55	0.57
	Waste Incineration		6C	CH4	0.0	0.4	59	100	116	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Combustion	Public Electricity and Heat Production	L	1A1a	N2O	15.3	2.2	1	999	999	0.04	0.00	0.00	-0.21	0.00	0.21
	Public Electricity and Heat Production	S	1A1a	N2O	36.2	50.0	1	1,000	1,000	0.90	0.00	0.00	0.27	0.00	0.27
	Public Electricity and Heat Production	G	1A1a	N2O	0.0	23.4	1	1,000	1,000	0.42	0.00	0.00	0.40	0.00	0.40
	Public Electricity and Heat Production	B	1A1a	N2O	0.0	26.3	1	964	964	0.46	0.00	0.00	0.43	0.00	0.43

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
Fuel Combustion	Public Electricity and Heat Production	O	1A1a	N2O	0.0	11.7	1	1,000	1,000	0.21	0.00	0.00	0.20	0.00	0.20
	Petroleum refining	L	1A1b	N2O	9.1	9.2	1	1,000	1,000	0.17	0.00	0.00	0.01	0.00	0.01
	Petroleum refining	G	1A1b	N2O	0.0	4.6	1	1,000	1,000	0.08	0.00	0.00	0.08	0.00	0.08
	Iron and Steel	L	1A2a	N2O	0.4	0.0	5	972	972	0.00	0.00	0.00	-0.01	0.00	0.01
	Iron and Steel	S	1A2a	N2O	2.1	0.0	5	1,000	1,000	0.00	0.00	0.00	-0.03	0.00	0.03
	Iron and Steel	G	1A2a	N2O	0.0	0.5	3	751	751	0.01	0.00	0.00	0.01	0.00	0.01
	Iron and Steel	B	1A2a	N2O	0.0	0.0	60	1,000	1,002	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	L	1A2c	N2O	6.5	1.9	3	844	844	0.03	0.00	0.00	-0.06	0.00	0.06
	Chemicals	S	1A2c	N2O	0.1	0.1	5	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	G	1A2c	N2O	0.0	3.7	5	1,000	1,000	0.07	0.00	0.00	0.06	0.00	0.06
	Chemicals	B	1A2c	N2O	1.4	0.0	60	1,000	1,002	0.00	0.00	0.00	-0.02	0.00	0.02
	Chemicals	O	1A2c	N2O	0.4	0.3	5	1,000	1,000	0.01	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and Print	L	1A2d	N2O	1.8	0.5	3	880	880	0.01	0.00	0.00	-0.02	0.00	0.02
	Pulp, Paper and Print	G	1A2d	N2O	0.0	6.3	3	708	708	0.08	0.00	0.00	0.08	0.00	0.08
	Pulp, Paper and Print	B	1A2d	N2O	11.5	17.7	13	813	813	0.26	0.00	0.00	0.09	0.01	0.09
	Food Processing, Beverages and Tobacco	L	1A2e	N2O	2.3	1.3	10	1,000	1,000	0.02	0.00	0.00	-0.01	0.00	0.01
	Food Processing, Beverages and Tobacco	G	1A2e	N2O	0.0	3.5	10	1,000	1,000	0.06	0.00	0.00	0.06	0.00	0.06
	Food Processing, Beverages and Tobacco	B	1A2e	N2O	5.3	0.6	60	1,000	1,002	0.01	0.00	0.00	-0.08	0.00	0.08
	Other	L	1A2f	N2O	10.4	5.7	3	545	545	0.06	0.00	0.00	-0.04	0.00	0.04



Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
Fuel Combustion	Other	S	1A2f	N2O	4.6	0.1	2	812	812	0.00	0.00	0.00	-0.06	0.00	0.06
	Other	G	1A2f	N2O	0.0	11.8	4	536	536	0.11	0.00	0.00	0.11	0.00	0.11
	Other	B	1A2f	N2O	20.9	7.4	34	584	585	0.08	0.00	0.00	-0.12	0.01	0.12
	Other	O	1A2f	N2O	0.0	6.0	3	988	988	0.11	0.00	0.00	0.10	0.00	0.10
	Civil Aviation. Domestic	L	1A3aii	N2O	2.0	3.2	47	1,000	1,001	0.06	0.00	0.00	0.02	0.00	0.02
	..International	L	1A3ai	N2O	12.8	23.9	47	1,000	1,001	0.43	0.00	0.00	0.20	0.03	0.20
	Road Transportation		1A3b	N2O	66.9	159.4	5	50	50	0.14	0.00	0.00	0.08	0.02	0.08
	Railways	L	1A3c	N2O	11.5	2.2	5	50	50	0.00	0.00	0.00	-0.01	0.00	0.01
	Navigation. Domestic	L	1A3dii	N2O	2.1	1.8	49	1,000	1,001	0.03	0.00	0.00	0.00	0.00	0.00
	..International	L	1A3di	N2O	11.2	16.8	49	1,000	1,001	0.30	0.00	0.00	0.11	0.02	0.11
	Commercial / Institutional	L	1A4a	N2O	2.4	1.6	10	1,000	1,000	0.03	0.00	0.00	-0.01	0.00	0.01
	Commercial / Institutional	G	1A4a	N2O	0.0	5.2	10	1,000	1,000	0.09	0.00	0.00	0.09	0.00	0.09
	Commercial / Institutional	B	1A4a	N2O	0.0	2.0	60	1,000	1,002	0.04	0.00	0.00	0.03	0.00	0.03
	Residential	L	1A4b	N2O	11.5	9.8	10	1,000	1,000	0.18	0.00	0.00	-0.02	0.00	0.02
	Residential	G	1A4b	N2O	0.0	4.7	10	1,000	1,000	0.09	0.00	0.00	0.08	0.00	0.08
	Residential	B	1A4b	N2O	72.7	41.0	60	1,000	1,002	0.74	0.00	0.00	-0.47	0.06	0.48
	Agriculture / Forestry / Fishing	L	1A4c	N2O	153.2	90.2	92	52	105	0.17	0.00	0.00	-0.05	0.20	0.21
	Agriculture / Forestry / Fishing	G	1A4c	N2O	0.0	0.1	10	990	990	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture / Forestry /	B	1A4c	N2O	0.0	7.3	93	50	105	0.01	0.00	0.00	0.01	0.02	0.02

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
					Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					C	D	E	F	G	H	I	J	K	L	M
	Fishing														
	Other Combustion	L	1A5	N2O	0.8	0.4	5	50	50	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry		2B	N2O	517.9	66.0	1	10	10	0.01	-0.01	0.00	-0.07	0.00	0.07
Solvent And Other Product Use	Other		3D	N2O	86.2	42.4	1	0	1	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Manure Management		4B	N2O	527.0	293.3	36	93	100	0.53	0.00	0.01	-0.33	0.26	0.42
	Agricultural Soils		4D	N2O	3,484.2	2,940.7	19	178	179	9.50	-0.01	0.05	-1.08	1.38	1.75
	Field Burning Of Agricultural Wastes		4F	N2O	21.3	18.0	100	20	102	0.03	0.00	0.00	0.00	0.04	0.04
Waste	Industrial Wastewater		6B	N2O	160.5	213.6	21	1,000	1,000	3.86	0.00	0.00	1.06	0.11	1.06
	Domestic and Commercial wastewater		6B	N2O	298.6	368.3	30	0	30	0.20	0.00	0.01	0.00	0.27	0.27
	Waste Incineration		6C	N2O	0.7	10.3	59	100	116	0.02	0.00	0.00	0.02	0.01	0.02
LULUCF	Forest Land		5A	CO2	-9,028.1	-15,045.7	23	12	26	7.03	-0.11	-0.26	-1.38	-8.25	8.37
	Cropland		5B	CO2	4,334.4	590.2	31	44	54	0.57	-0.06	0.01	-2.65	0.44	2.68
	Grassland		5C	CO2	2,943.0	265.7	47	77	90	0.43	-0.04	0.00	-3.30	0.30	3.31
	Wetlands		5D	CO2	0.8	404.0	35	41	54	0.39	0.01	0.01	0.28	0.35	0.45
	Other Land		5E	CO2	38.1	2,355.6	33	38	50	2.13	0.04	0.04	1.49	1.87	2.40
LULUCF	Forest Land		5A	CH4	746.2	-2,079.1	20	29	35	1.32	-0.05	-0.04	-1.37	-1.02	1.71
	Cropland		5B	CH4	158.4	147.8	28	35	45	0.12	0.00	0.00	0.00	0.10	0.10
	Grassland		5C	CH4	18.2	17.3	28	35	45	0.01	0.00	0.00	0.00	0.01	0.01

Category	Individual Category	Fuel	IPCC Source Category	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Combined Unc.	Combined unc. as % of total emissions in year t	Type A sensitivity	Type B sensisitivity	Uncertainty in trend in total emissions introduced by EF unc.	Uncertainty in trend in total emissions introduced by AD unc.	Uncertainty introduced into the trend in total national emissions
				Wetlands		5D	CH4	7.0	4.1	28	35	45	0.00	0.00	0.00
	Grassland		5C	N2O	32.2	30.0	28	35	45	0.02	0.00	0.00	0.00	0.02	0.02
	Wetlands		5D	N2O	4.8	3.7	27	33	42	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land		5E	N2O	1.4	0.8	28	35	45	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons and Sulphur Hexafluoride		2F	F Gases	33.4	1712.6	18	43	47	1.45	0.03	0.03	1.24	0.73	1.44

## ANNEX C: Energy Balance Sheet for 2012

BALANÇO ENERGÉTICO tep		Hulha e Antracite Estrangeira	Antracite Nacional	Coque	Total de Carvão	Petróleo Bruto	Refugos e Produtos Intermédios	GPL	Gasolinas	Petróleos	Jets	Gasóleo	Fuelóleo	Nafta	Coque de Petróleo	Total de Petróleo Energético	Lubrificantes	Asfaltos	Parafinas	Solventes	Propileno	Total de Petróleo Não Energético	Total de Petróleo	Gás Natural
2012 (provisório)		1	2	3	4 = 1+3	5	6	7	8	9	10	11	12	13	14	15 = 5+14	16	17	18	19	20	21= 16+20	22= 15+21	23
IMPORTAÇÕES	1.	3 097 663		746	3 098 409	11 367 748	393 840	473 725	167 656	966	184 771	905 512	222 887	275 626	373 912	14 366 643	38 569	175 307	6 975	947		221 798	14 588 441	3 938 768
PRODUÇÃO DOMÉSTICA	2.																							
VARIACÃO DE "STOCKS"	3.	98 130		131	98 261	4 087	- 59 452	4 098	- 27 878	- 2 312	- 10 394	34 043	59 209	- 14 614	57 175	43 962	- 2 180	- 3 611	232	1 568	- 625	- 4 116	39 846	- 11 540
SAÍDAS	4.	85 140			85 140			85 121	944 231		966 881	406 376	1 928 815	610 440		4 941 850	127 836	78 366	8 453	13 950	85 979	314 583	5 256 434	
Exportações	4.1	85 140			85 140			85 110	944 231		43 743	356 615	1 375 263	610 440		3 415 402	127 435	78 366	8 453	13 950	85 979	314 183	3 729 585	
Transportes Marítimos Internacionais	4.2											49 760	553 553			603 313	401					401	603 714	
Aviação Internacional	4.3									923 135						923 135							923 135	
CONSUMO DE ENERGIA PRIMÁRIA	5.	2 914 393		615	2 915 008	11 363 661	453 292	384 506	- 748 697	3 278	- 771 716	465 093	- 1 765 137	- 320 200	316 737	9 380 831	- 87 087	100 552	- 1 710	- 14 571	- 85 354	- 88 669	9 292 161	3 950 308
PARA NOVAS FORMAS DE ENERGIA	6.	2 891 583			2 891 583	11 363 661	242 173	- 242 812	- 1 959 176	- 703	- 935 022	- 4 229 235	- 2 125 152	- 1 261 479		852 255	- 135 316	- 151 733	- 13 174	- 18 406	- 85 354	- 398 742	453 513	2 218 616
Briquetes	6.1																							
Coque	6.2																							
Produtos de Petróleo	6.3					11 363 661	170 782	- 242 812	- 1 959 176	- 703	- 935 022	- 4 254 363	- 2 618 252	- 1 280 288		243 827	- 135 316	- 151 733	- 13 174	- 18 406	- 85 354	- 398 742	- 154 915	
Gás de Cidade	6.4																							
Petroquímica	6.5													18 809		18 809							18 809	
Electricidade	6.6	2 891 583			2 891 583							24 743	224 336			249 079							249 079	936 018
Cogeração	6.7						71 391					385	268 764			340 540							340 540	1 282 598
Produção de Electricidade	6.7.1											34	39 552			39 586							39 586	
Refinação de Petróleo	6.7.2						71 391						76 503			117 894							117 894	268 311
Gás de Cidade	6.7.3																							
Agricultura	6.7.4																							7 232
Alimentação, bebidas e tabaco	6.7.5											25	40 939			40 964							40 964	69 154
Têxteis	6.7.6											157	22 998			23 155							23 155	117 959
Papel e Artigos de Papel	6.7.7											10	28 894			28 904							28 904	385 720
Químicas e Plásticos	6.7.8											20	24 430			24 450							24 450	217 300
Cerâmicas	6.7.9											2	3 768			3 770							3 770	42 932
Vidro e Artigos de Vidro	6.7.10																							
Cimento	6.7.11																							2 999
Metalmúrgicas	6.7.12																							
Siderurgia	6.7.13																							
Vestuário, Calçado e Curtumes	6.7.14																							8 194
Madeira e Artigos de Madeira	6.7.15											131	23 637			23 768							23 768	
Borracha	6.7.16																							15 761
Metálo-eleto-mecânicas	6.7.17											6	259			265							265	1 302
Outras Industrias Transformadoras	6.7.18																							2 422
Indústrias Extractivas	6.7.19												3 497			3 497							3 497	71 693
Serviços	6.7.20												4 287			4 287							4 287	71 606

BALANÇO ENERGÉTICO tep	Hulha e Antracite Estrangeira	Antracite Nacional	Coque	Total de Carvão	Petróleo Bruto	Refugos e Produtos Intermédios	GPL	Gasolinas	Petróleos	Jets	Gasóleo	Fuelóleo	Nafta	Coque de Petróleo	Total de Petróleo Energético	Lubrificantes	Asfaltos	Parafinas	Solventes	Propileno	Total de Petróleo Não Energético	Total de Petróleo	Gás Natural
2012 (provisório)	1	2	3	4 = 1a 3	5	6	7	8	9	10	11	12	13	14	15 = 5 a 14	16	17	18	19	20	21 = 16 a 20	22 = 15 + 21	23
<b>CONSUMO DO SECTOR ENERGÉTICO</b>	7.					211 119	2 678	479	- 47	1 253	4 394	185 807	2 025		<b>407 708</b>	3 116	- 129	235	- 119		<b>3 103</b>	<b>410 811</b>	<b>175 539</b>
Consumo Próprio da Refinação	7.1					209 221	1 035				3 040	182 692			395 988	62					62	396 050	156 944
Perdas da Refinação	7.2					1 898	1 643	479	- 47	1 253	1 353	3 115	2 025		11 719	828	- 129	235	- 119		815	12 534	
Coquerie e outras não especificadas	7.3																						
Centrais Eléctricas	7.4															2 223					2 223	2 223	
Bombagem Hidroeléctrica	7.5																						
Gás de Cidade	7.6																						
Extracção de Carvão, Petróleo e GN	7.7															3					3	3	
Perdas de Transporte e Distribuição	7.8										1				1						1	1	18 595
<b>CONSUMO COMO MATÉRIA PRIMA</b>							11 934						954 572		966 506							966 506	
<b>DISPONÍVEL PARA CONSUMO FINAL</b>	8.	22 810		615	<b>23 425</b>		612 706	1 210 000	4 028	162 053	4 689 934	174 208	- 15 318	316 737	<b>7 154 362</b>	45 113	252 414	11 229	3 954		<b>306 970</b>	<b>7 461 331</b>	<b>1 556 153</b>
<b>ACERTOS</b>	9.	4 049		264	4 313		- 16 387	22 707	2 712	25 559	- 5 270	- 39 740	- 15 318	3 309	- 22 414	- 658	2 550	49	- 96		- 3 895	- 26 310	26 491
<b>CONSUMO FINAL</b>	10.	18 761		351	<b>19 112</b>		629 093	1 187 293	1 316	136 494	4 695 204	213 948		313 428	<b>7 176 776</b>	45 771	249 864	11 180	4 050		<b>310 865</b>	<b>7 487 641</b>	<b>1 529 662</b>
<b>AGRICULTURA E PISCAS</b>	10.1						6 393	543	804		327 600	3 470			<b>338 810</b>	320					<b>320</b>	<b>339 130</b>	5 162
Agricultura	10.1.1						6 388	444	804		240 836	1 119			249 591	51					51	249 642	5 109
Pescas	10.1.2						5	99			86 764	2 351			89 219	269					269	89 488	53
<b>INDÚSTRIAS EXTRATIVAS</b>	10.2						1 115	4			29 679	724			<b>31 522</b>	1 425					<b>1 425</b>	<b>32 947</b>	<b>5 168</b>
<b>INDÚSTRIAS TRANSFORMADORAS</b>	10.3	18 761		351	<b>19 112</b>		65 553	420	23		77 687	85 432		313 428	<b>542 543</b>	11 041		11 164	3 479		<b>25 684</b>	<b>568 227</b>	<b>1 022 532</b>
Alimentação, bebidas e tabaco	10.3.1						22 983		4		23 958	51 020			97 965	232					232	98 197	123 153
Têxteis	10.3.2						3 021				320	7 037			10 378	761					761	11 139	104 485
Papel e Artigos de Papel	10.3.3						1 956		6		3 700	14 696			20 358	601					601	20 959	79 670
Químicas e Plásticos	10.3.4	11 366		351	11 717		4 592		5		1 881	8 428			14 906	3 920		8 101	3 442		15 463	30 369	128 596
Cerâmicas	10.3.5						3 996		4		2 114	11		9 518	15 643	110					110	15 753	212 458
Vidro e Artigos de Vidro	10.3.6						342				1 195				1 537	171					171	1 708	198 555
Cimento	10.3.7	1 997			1 997		1 065				13 421	1 681		303 910	320 077	219					219	320 296	29 328
Metalmúrgicas	10.3.8						2 861				647				3 508	57					57	3 565	12 327
Siderurgia	10.3.9	5 398			5 398		61				1 327				1 388	455					455	1 843	49 488
Vestuário, Calçado e Curtumes	10.3.10						3 044				440	1 520			5 004	12					12	5 016	11 758
Madeira e Artigos de Madeira	10.3.11						1 445				5 254	53			6 752	282		2 397			2 679	9 431	8 959
Borracha	10.3.12						111		1			160			272	1 619		552			2 171	2 443	3 975
Metálo-eleto-mecânicas	10.3.13						18 070	420	3		4 303	64			22 860	1 827					1 827	24 687	49 045
Outras Industrias Transformadoras	10.3.14						2 006				19 127	762			21 895	775		114	37		926	22 821	10 735
<b>CONSTRUÇÃO E OBRAS PÚBLICAS</b>	10.4						9 527	95	1		92 248	22 565			<b>124 436</b>	1 708	249 864		61		<b>251 633</b>	<b>376 069</b>	<b>12 247</b>
<b>TRANSPORTES</b>	10.5						34 311	1 186 230		120 191	4 024 238	81 426			<b>5 446 396</b>	30 616					<b>30 616</b>	<b>5 477 012</b>	<b>12 018</b>
Aviação Nacionais	10.5.1							2 667		120 191					122 858	9					9	122 867	
Transportes Marítimos Nacionais	10.5.2							3			39 321	81 426			120 750	175					175	120 925	
Caminho de Ferro	10.5.3										11 498				11 498	3					3	11 501	
Rodoviários	10.5.5						34 311	1 183 560			3 973 419				5 191 290	30 429					30 429	5 221 719	12 018
<b>SETOR DOMÉSTICO</b>	10.6						466 291		441		65 183				<b>531 915</b>							<b>531 915</b>	<b>258 890</b>
<b>SERVIÇOS</b>	10.7						45 903	1	47	16 303	78 569	20 331			<b>161 154</b>	661		16	510		<b>1 187</b>	<b>162 341</b>	<b>213 645</b>

BALANÇO ENERGÉTICO tep		Gás de Cidade	Gás de Coque	Gás de Alto Forno	Alcatrão	Gases Inconde. de Petroquímica	Hidrogénio	Gases o Outros Derivados	Hidro- eletricidade	Eólica	Foto- voltaica	Geo- térmica	Termo- eletricidade	Total de Eletricidade	Calor	Resíduos Industriais	Solar Térmico	Lenhas e Resíduos Vegetais	Resíduos Sólidos Urbanos	Licores Sulfúricos	Outros Renováveis	Biogás	Biocombustí- veis	Renováveis Sem Eletricidade	TOTAL GERAL
2012 (provisório)		24	25	26	27	28	29	30 = 24 a 29	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46 = 39 a 45	47 = 44 + 22 + 23 + 30 + 36 + 37 + 38 + 44 + 45
IMPORTAÇÕES	1.													925 876				35 741					9 273	45 014	22 596 508
PRODUÇÃO DOMÉSTICA	2.								572 781	882 341	33 767	12 596		1 501 485		160 346	67 349	1 604 327	171 865	921 059	105 674	56 413	275 607	3 202 294	4 864 125
VARIAÇÃO DE "STOCKS"	3.																						- 3 740	- 3 740	122 827
SAÍDAS	4.													246 906				275 410					6	275 416	5 863 896
Exportações	4.1													246 906				275 410					6	275 416	4 337 047
Transportes Marítimos Internacionais	4.2																							603 714	
Aviação Internacional	4.3																							923 135	
CONSUMO DE ENERGIA PRIMÁRIA	5.								572 781	882 341	33 767	12 596		2 180 455		160 346	67 349	1 364 658	171 865	921 059	105 674	56 413	288 614	2 975 632	21 473 910
PARA NOVAS FORMAS DE ENERGIA	6.												-2 507 215	-2 507 214	-1 596 798	11 786		440 753	171 865	921 059		56 413	285 555	1 875 645	3 347 131
Briquetes	6.1																								
Coque	6.2																								
Produtos de Petróleo	6.3															- 183							285 555	285 555	130 457
Gás de Cidade	6.4																								
Petroquímica	6.5					- 18 809		- 18 809																	
Electricidade	6.6												-1 855 897	-1 855 897		183		290 676	171 865			52 924	515 465	2 736 431	
Cogeração	6.7					18 809		18 809					- 651 317	- 651 317	-1 596 798	11 786		150 077		921 059	3 489		1 074 625	480 243	
Produção de Electricidade	6.7.1												- 15 543	- 15 543	- 1020									22 023	
Refinação de Petróleo	6.7.2												- 88 621	- 88 621	- 270 719									56 868	
Gás de Cidade	6.7.3																								
Agricultura	6.7.4												- 2 944	- 2 944	- 2 554							449	449	2 183	
Alimentação, bebidas e tabaco	6.7.5												- 27 384	- 27 384	- 54 131									28 613	
Têxteis	6.7.6												- 55 542	- 55 542	- 41 157									44 415	
Papel e Artigos de Papel	6.7.7												- 304 549	- 304 549	- 950 122			131 576		921 059			1 052 635	212 588	
Químicas e Plásticos	6.7.8					18 809		18 809					- 62 517	- 62 517	- 160 545	7 712								45 209	
Cerâmicas	6.7.9												- 15 323	- 15 323	- 20 995									9 384	
Vidro e Artigos de Vidro	6.7.10																								
Cimento	6.7.11												- 12 12	- 12 12	- 941									846	
Metalúrgicas	6.7.12																								
Siderurgia	6.7.13																								
Vestuário, Calçado e Curtumes	6.7.14												- 2 831	- 2 831	- 2 622									2 741	
Madeira e Artigos de Madeira	6.7.15												- 11 720	- 11 720	- 15 840			18 501					18 501	14 709	
Borracha	6.7.16												- 4 230	- 4 230	- 10 891	4 074								4 714	
Metal-eleto-mecânicas	6.7.17												- 726	- 726	- 178									663	
Outras Industrias Transformadoras	6.7.18												- 1260	- 1260	- 1088							1457	1 457	1531	
Indústrias Extractivas	6.7.19												- 26 528	- 26 528	- 34 894									13 768	
Serviços	6.7.20												- 28 387	- 28 387	- 29 101							1583	1 583	9 988	

BALANÇO ENERGÉTICO tep	Gás de Cidade	Gás de Coque	Gás de Alto Forno	Alcatrão	Gases Inconde. de Petroquímica	Hidrogénio	Gases o Outros Derivados	Hidro- eletricidade	Eólica	Foto- voltaica	Geo- térmica	Termo- eletricidade	Total de Eletricidade	Calor	Resíduos Industriais	Solar Térmico	Lenhas e Resíduos Vegetais	Resíduos Sólidos Urbanos	Licores Sulfúricos	Outros Renováveis	Biogás	Biocombustiv- eis	Renováveis Sem Eletricidade	TOTAL GERAL
2012 (provisório)	24	25	26	27	28	29	30 = 24 a 29	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46 = 39 a 45	47 = 42+23+30+ 36+37+38+46
<b>CONSUMO DO SECTOR ENERGÉTICO</b>	7.												712 251	270 719										1 569 320
Consumo Próprio da Refinação	7.1												56 768	270 719										880 481
Perdas da Refinação	7.2																							12 534
Coquerie e outras não especificadas	7.3												5											5
Centrais Eléctricas	7.4												133 938											136 161
Bombagem Hidroeléctrica	7.5												114 477											114 477
Gás de Cidade	7.6																							
Extracção de Carvão, Petróleo e GN	7.7												582											585
Perdas de Transporte e Distribuição	7.8												406 481											425 077
<b>CONSUMO COMO MATÉRIA PRIMA</b>																								966 506
<b>DISPONÍVEL PARA CONSUMO FINAL</b>	8.												3 975 418	1 326 079	148 560	67 349	923 905			105 674		3 059	1 099 987	15 590 953
ACERTOS	9.												- 146									- 1 139	- 1 139	3 209
<b>CONSUMO FINAL</b>	10.												3 975 564	1 326 079	148 560	67 349	923 905			105 674		4 198	1 101 126	15 587 744
<b>AGRICULTURA E PISCAS</b>	10.1												86 248	2 554								19	19	433 113
Agricultura	10.1.1												79 189	2 554								15	15	336 509
Pescas	10.1.2												7 059									4	4	96 604
<b>INDÚSTRIAS EXTRATIVAS</b>	10.2												48 713	34 894								17	17	121 739
<b>INDÚSTRIAS TRANSFORMADORAS</b>	10.3												1 213 389	1 259 530	148 560		160 790			104 119		1	264 910	4 496 260
Alimentação, bebidas e tabaco	10.3.1												150 472	54 131			10 101					1	10 102	436 055
Têxteis	10.3.2												79 328	41 157			689						689	236 798
Papel e Artigos de Papel	10.3.3												243 696	950 122	111		51 405			2 622			54 027	1 348 585
Químicas e Plásticos	10.3.4												180 118	160 545			596						596	511 941
Cerâmicas	10.3.5												33 647	20 995			25 013						25 013	307 866
Vidro e Artigos de Vidro	10.3.6												37 922											238 185
Cimento	10.3.7												67 734	941	148 449		16 875			101 497			118 372	687 117
Metalúrgicas	10.3.8												18 230				70						70	34 192
Siderurgia	10.3.9												106 785											163 514
Vestuário, Calçado e Curtumes	10.3.10												24 254	2 622			590						590	44 240
Madeira e Artigos de Madeira	10.3.11												46 969	15 840			50 935						50 935	132 134
Borracha	10.3.12												17 060	10 891			693						693	35 062
Metalo-eleto-mecânicas	10.3.13												141 811	178			141						141	215 862
Outras Indústrias Transformadoras	10.3.14												65 363	2 108			3 682						3 682	104 709
<b>CONSTRUÇÃO E OBRAS PÚBLICAS</b>	10.4												39 661									15	15	427 992
<b>TRANSPORTES</b>	10.5												33 256									4 146	4 146	5 526 432
Aviação Nacionais	10.5.1																							122 867
Transportes Marítimos Nacionais	10.5.2																							120 925
Caminho de Ferro	10.5.3												33 256											44 757
Rodoviários	10.5.5																					4 146	4 146	5 237 883
<b>SETOR DOMÉSTICO</b>	10.6												1 109 228			27 799	729 203						757 002	2 657 035
<b>SERVIÇOS</b>	10.7												1 445 069	29 101		39 550	33 912			1 555			75 017	1 925 173

ANNEX D: Standard Electronic Format (SEF) tables 2013

Table 1

Party Portugal  
Submission year 2014  
Reported year 2013  
Commitment period 1

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	261304611	NO	NO	NO	NO	NO
Entity holding accounts	4400000	985549	NO	3338620	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	NO	NO	NO
Retirement account	99251257	412799	NO	7688901	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	364955868	1398348	NO	11027521	NO	NO



Table 2a

Party Portugal  
Submission year 2014  
Reported year 2013  
Commitment period 1

Table 2 (a). Annual internal transactions

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Article 6 issuance and conversion												
Party-verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Article 3.3 and 3.4 issuance or cancellation												
3.3 Afforestation and reforestation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland management			NO				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired ICERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							NO	NO	NO	64695	NO	NO
Sub-total		NO	NO				NO	NO	NO	64695	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Retirement	18644439	4154835	NO	2430677	NO	NO

Party Portugal  
Submission year 2014  
Reported year 2013  
Commitment period 1

Add registry Delete registry

Table 2 (b). Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Transfers and acquisitions												
GB	NO	688829	NO	631563	NO	NO	NO	3729	NO	NO	NO	NO
JP	NO	NO	NO	134477	NO	NO	NO	NO	NO	NO	NO	NO
ES	NO	NO	NO	366769	NO	NO	NO	688829	NO	108354	NO	NO
EU	NO	4300770	NO	2814442	NO	NO	19831911	1127653	NO	746684	NO	NO
CDM	NO	NO	NO	734133	NO	NO	NO	NO	NO	NO	NO	NO
SE	NO	NO	NO	615423	NO	NO	NO	NO	NO	NO	NO	NO
CH	NO	NO	NO	293669	NO	NO	NO	NO	NO	NO	NO	NO
RU	NO	44169	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	NO	5033768	NO	5590476	NO	NO	19831911	1820211	NO	855038	NO	NO

Additional information

Independently verified ERUs								NO				
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Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	NO	5033768	NO	5590476	NO	NO	19831911	1820211	NO	919733	NO	NO
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Table 3

Party Portugal  
 Submission year 2014  
 Reported year 2013  
 Commitment period 1

Table 3. Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Temporary CERs (tCERs)</b>								
Expired in retirement and replacement accounts	NO							
Replacement of expired tCERs			NO	NO	NO	NO	NO	
Expired in holding accounts	NO							
Cancellation of tCERs expired in holding accounts	NO							
<b>Long-term CERs (ICERs)</b>								
Expired in retirement and replacement accounts		NO						
Replacement of expired ICERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of ICERs expired in holding accounts		NO						
Subject to replacement for reversal of storage		NO						
Replacement for reversal of storage			NO	NO	NO	NO		NO
Subject to replacement for non-submission of certification report		NO						
Replacement for non-submission of certification report			NO	NO	NO	NO		NO
<b>Total</b>			NO	NO	NO	NO	NO	NO

Table 4

Party                      Portugal  
Submission year        2014  
Reported year          2013  
Commitment period    1

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	222828261	NO	NO	NO	NO	NO
Entity holding accounts	4400000	44271	NO	5578686	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	64695	NO	NO
Retirement account	117895696	4567634	NO	10119578	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	345123957	4611905	NO	15762959	NO	NO

Party
Submission year
Reported year
Commitment period

Portugal
2014
2013
1

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Issuance pursuant to Article 3.7 and 3.8	3.82E+08											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	3.82E+08	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	3503501	NO	NO	1533397	NO	NO	7917857	NO	NO	288000	NO	NO
Year 2 (2009)	28019395	NO	NO	3627324	NO	NO	27039815	NO	NO	604981	NO	NO
Year 3 (2010)	6349425	5000	NO	5398909	NO	NO	13067978	NO	NO	2947341	NO	NO
Year 4 (2011)	5540053	600714	NO	6791635	NO	NO	11805985	192915	NO	4095757	NO	NO
Year 5 (2012)	1822960	3166342	NO	3289158	NO	NO	2385358	2180793	NO	1676823	NO	NO
Year 6 (2013)	NO	5033768	NO	5590476	NO	NO	19831911	1820211	NO	919733	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	45235334	8805824	NO	26230899	NO	NO	82048904	4193919	NO	10532635	NO	NO
Total	4.27E+08	8805824	NO	26230899	NO	NO	82048904	4193919	NO	10532635	NO	NO

Table 5 (b). Summary information on replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Previous CPs			NO	NO	NO	NO	NO	NO
Year 1 (2008)		NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)		NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)		NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)		NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO

Table 5 (c). Summary information on retirement

Year	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	27923069	NO	NO	1985373	NO	NO
Year 3 (2010)	26779644	NO	NO	1527532	NO	NO
Year 4 (2011)	22565716	319988	NO	1278345	NO	NO
Year 5 (2012)	21982828	92811	NO	2897651	NO	NO
Year 6 (2013)	18644439	4154835	NO	2430677	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	1.18E+08	4567634	NO	10119578	NO	NO

Party Portugal  
Submission year 2014  
Reported year 2013  
Commitment period 1

Add transaction

Delete transaction

No corrective transaction

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

Add transaction

Delete transaction

No corrective transaction

Table 6 (b). Memo item: Corrective transactions relating to replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

Add transaction

Delete transaction

No corrective transaction

Table 6 (c). Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

**ANNEX E: Database Structure of the Consolidated European Registries (CSEUR)**

File attached.

## **ANNEX F: Changes Regarding Test Results (CSEUR)**

File attached.



## **ANNEX G: Methodological Note concerning the calculation of carbon sequestration in areas with sown biodiverse pastures**

Ricardo Teixeira<sup>1</sup>, Tiago Domingos<sup>2</sup>, Tatiana Valada<sup>2</sup>, Helena Martins<sup>2</sup>, Fátima Calouro<sup>3</sup>

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<sup>2</sup> *IN+, Center for Innovation, Technology and Policy Research, Environment and Energy Scientific Area, Mechanical Engineering Department, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal*

<sup>3</sup> *National Institute for Agrarian and Veterinary Research, Environment and Natural Resources Unit, Tapada da Ajuda, Apartado 3228, 1301-903 Lisboa, Portugal*

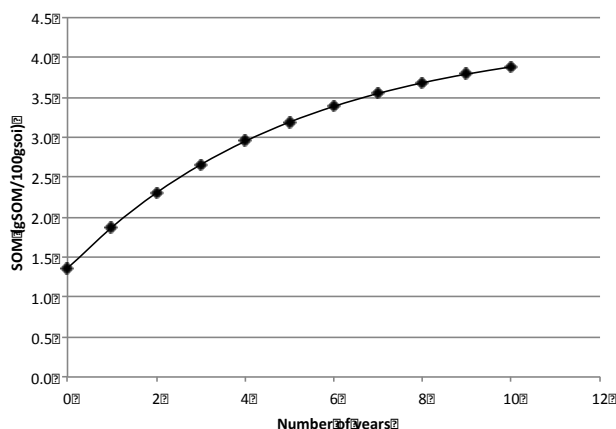
### **Summary**

Sown biodiverse pastures are based on a diverse mixture of about twenty different species, many of which (approximately 30-50%) are legumes. These grasslands are more productive than the baseline land use system – spontaneous natural pastures. Productivity is accompanied by an increase in soil organic matter (SOM) and correspondent carbon sequestration. Teixeira et al. (2011) analysed the effect from a shift from natural to sown biodiverse pastures, and calculations based on this work estimated a carbon sequestration factor of **6.48 tCO<sub>2</sub>.ha<sup>-1</sup>.yr<sup>-1</sup>** for a period of 10 years.

### **Methodology**

The method here employed is based on the SOM dynamic model developed by Teixeira et al. (2011). The authors developed a model for SOM dynamics in natural and sown biodiverse pastures. The mass balance of SOM was calculated as the difference between input and mineralization. The model was calibrated using five years (2001-2005) of soil analyses from eight farms in Portugal. SOM samples were collected in each location from adjacent plots of both pasture types. The model was initialized with the average SOM concentration for pastures in Alentejo, 1.35 gSOM/100gsoil. This value was obtained through soil analyses undertaken in 1999 by the Laboratory of Agronomic Chemistry (LQARS) and constitutes a representative value of the region where sown biodiverse pastures are dominant. A simulation of SOM concentration up to 10 years after sowing biodiverse pastures is presented in Figure 1. These data reveal that sowing biodiverse pastures increase SOM concentration by 2.53 gSOM/100gsoil after 10 years.

Figure 1: 10 years model for SOM levels in sown biodiverse pastures



SOM concentrations were converted into soil organic carbon (SOC) by a factor of 0.58 (gSOC/gSOM). Soil carbon (in mass) was converted to the equivalent carbon dioxide sequestered by plants using a factor of 44/12, which is the ratio between the molecular weight of CO<sub>2</sub> and the atomic weight of carbon.

Finally, estimates of bulk density (BD) at the corresponding sampling depth (10 cm topsoil) were then employed to further convert volumes of soil containing SOC into area. BD was calculated from mineral bulk density (MBD) using the equation below (Adams, 1973). An average MBD for grasslands in Portugal of 1.56 gcm<sup>-3</sup> was extracted from the LUCAS database (<http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/data/database>). BD changes each year since it is a function of SOM concentration, which varies as presented in previous figure.

$$BD = \frac{100}{\frac{SOM}{0.244 \text{ g.cm}^{-3}} + \frac{100 - SOM}{MBD}}$$

## Results

Assuming the SOM dynamic model from Figure 1, the calculation procedure explained yields the yearly carbon sequestration factors presented on Table 1 for the first 10 years after sowing biodiverse pastures. The equivalent 10-year average is **6.48 tCO<sub>2</sub>.ha<sup>-1</sup>.yr<sup>-1</sup>**.

Table 1 – Carbon sequestration factor, by year after sown biodiverse pastures sowing

(tCO <sub>2</sub> .ha <sup>-1</sup> .yr <sup>-1</sup> )	Year after sowing									
	1	2	3	4	5	6	7	8	9	10
Carbon sequestration factor	14.70	11.54	9.15	7.30	5.86	4.72	3.82	3.10	2.53	2.06

## References

Adams, W.A., 1973. The effect of organic matter and true densities of some uncultivated podzolic soils. *Journal of Soil Science* 24: 10-17.

Teixeira, R., Domingos, T., Costa, A., Oliveira, R., Farropas, L., Calouro, F., Barradas, A.M., Carneiro, J.P., 2011. Soil Organic Matter Dynamics in Portuguese Natural and Sown Rainfed Grassland. *Ecological Modelling* 222: 993-1001.

## **ANNEX H: Methodological Note concerning the calculation of carbon sequestration in areas where harrowing was replaced by less disruptive methods for shrub control**

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### **Summary**

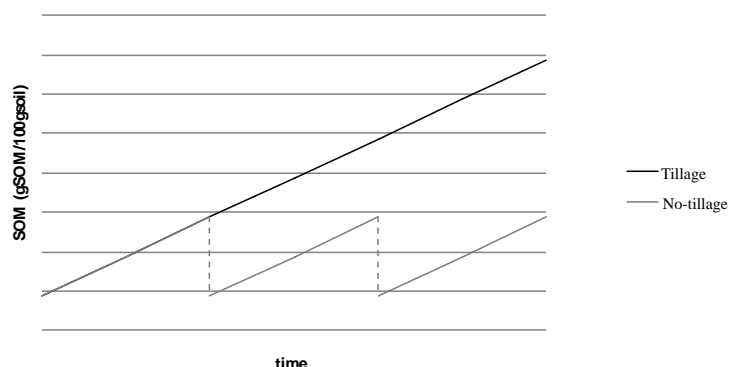
Harrowing is a common practice for shrub encroachment control in natural grasslands under canopy in Portugal. However, such operation is disruptive for the soil and leads to soil organic matter (SOM) loss and, consequently, carbon emissions. Less disruptive methods (eg. forestry mowers) lead to an increase in SOM which was modelled using 145 plots, collected in 2011 and 2012. The difference in SOM between tilled (harrowing management) and no-tilled (mowing management) plots indicates a carbon sequestration factor of **3.41 tCO<sub>2</sub>.ha<sup>-1</sup>.yr<sup>-1</sup>**.

### **Methodology**

A regular grid protocol was set and soil samples from 145 plots distributed in tilled and non-tilled areas in the south of Portugal were collected and analysed for their content in organic carbon (Valada, 2014). For each sample, information was gathered regarding the year of the last harrowing event (YSLM variable). For the plots under current no-tillage there wasn't always information about the year of the last harrowing event. This was estimated to have occurred 5 (YSLM5), 7 (YSLM7) and 9 (YSLM9) years before the last known event.

Without tillage management, the accumulation of SOM follows an exponential distribution that reaches saturation (Teixeira et al, 2011). It is assumed that the plots sampled are far from the saturation levels and, as such, SOM accumulation is approximately linear. For the no-tillage data sub-set one could assume that SOM would increase at a constant rate, as presented in the conceptual representation in Figure 1. In the presence of tillage management, it is here assumed that, when tillage takes place, SOM drops to its original levels. Although a decrease in SOM level is expected after a tillage event, the final level is not known. Here, the same slope for the two sub-sets of data was assumed.

Figure 1: Schematic representation of SOM evolution according to the management system



The influence of tillage/no tillage techniques for shrub control on SOM concentration while controlling for the effects of other variables was assessed with a multivariate linear regression approach. A stepwise regression procedure was conducted for model selection.

## Results

According to Table 1, the multivariate linear model obtained is statistically significant and 55% of the variance in SOM is explained by the independent variables (Valada, 2014).

The difference in SOM concentration due to the management technique is estimated from the  $\beta_1$  coefficient (in units of  $\text{gSOM}/100\text{gsoil} \cdot \text{yr}^{-1}$ ). The 95% CI for the modelled  $\beta_1$  (SOM variation) values are presented in Table 2. The correspondent p-values vary from 0.00 to 0.01. The distinction between YSLM5, 7 or 9 is not of particular relevance to the results. The increase in SOM is higher for 2011 data.

Table 1: Multivariate analysis results (95% CI)

Parameter	2011	2012
<b>Independent variables</b>	Aspect, forest type, herbaceous cover, potassium, topography	Herbaceous cover, aspect, potassium
<b>R-squared</b>	40 – 42% (p-value = 0)	53 – 55% (p-value = 0)
<b>Predicted versus observed data</b>	observed $\approx$ 0.45 predicted	
<b>Homoscedasticity of the residuals</b>	No pattern in the representation of residuals versus fitted values	
<b>Omitted-variable test</b>	Results vary	There are omitted variables
<b>Multicollinearity of independent variables</b>	No multicollinearity problems	
<b>Normality of residuals</b>	Although a graphical assessment shows a roughly normal distribution, the Shapiro-Wilk test indicates non-normality of residues	

Table 2: Higher and lower  $\Delta\text{SOM}$  obtained from the linear regression approach (95% CI), considering the average of the sampling years

Years from last intervention	$\Delta\text{SOM} ((\text{gSOM}/100\text{gsoil}) \cdot \text{yr}^{-1})$					
	2011			2012		
	Low	Average	High	Low	Average	High
YSLM5	0.03	0.08	0.14	0.01	0.05	0.09
YSLM7	0.03	0.08	0.13	0.02	0.05	0.08
YSLM9	0.03	0.07	0.11	0.02	0.05	0.07

The lowest value for  $\beta_1$ ,  $0.059 \text{ (gSOM/100gsoil).yr}^{-1}$  was chosen for being the most conservative. This value was then converted into soil carbon by a factor of 0.58 (gSOC/gSOM). The carbon content per area was estimated using the conservative HWSDB-based bulk density  $1.35 \text{ gsoilcm}^{-3}$  (Fisher et al., 2008; Teixeira et al., 2011) and a sampling depth of 20 cm. The conversion to carbon dioxide with a factor  $^{44}_{12}$  gives a carbon sequestration factor of **3.41  $\text{tCO}_2\text{.ha}^{-1}\text{.yr}^{-1}$**  for a period of 10 years.

## References

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