



**PORTUGUESE NATIONAL INVENTORY REPORT  
ON GREENHOUSE GASES, 1990 - 2013**

**SUBMITTED UNDER THE UNITED NATIONS FRAMEWORK  
CONVENTION ON CLIMATE CHANGE**

Amadora

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APA/DRES – APA/ Departamento de Resíduos

APA/DRH – APA/ Departamento de Recursos Hídricos

DGAE - Direcção Geral das Actividades Económicas

DGEG – Direcção Geral de Energia e Geologia

Direcção Regional do Ambiente – Madeira

Direcção Regional do Ambiente – Açores

EDP – Energias de Portugal

Gabinete de Estratégia e Estudos/ Ministério da Economia

GPP - Gabinete de Planeamento, Políticas e Administração Geral/ Ministério da Agricultura e do Mar

ICNF – Instituto da Conservação da Natureza e das Florestas

IFAP - Instituto de Financiamento da Agricultura e Pescas

IGP - Instituto Geográfico Português

INE - Instituto Nacional de Estatística

INIAV – Instituto Nacional de Investigação Agrária e Veterinária

IST - Instituto Superior Técnico

REN – Redes Energéticas Nacionais

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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.

This report aims to comply with the above-mentioned international commitments under the UNFCCC and the European Commission (EU), taking into account the Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention agreed by the Conference of the Parties at its nineteenth session (decision 24/CP.19), and set out in document FCCC/CP/2013/10/Add.3 <sup>1</sup>, and the requirements of Article 5 and 7 of the Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting (MMR) greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change, providing elements of the Portuguese National Inventory Report (NIR) necessary for the preparation of the Community greenhouse gas inventory report.

According to Decision 13/CP.20 of the Conference of the Parties to the UNFCCC, CRF Reporter version 5.0.0 was not functioning in order to enable Annex I Parties to submit their CRF tables for the year 2015. In the same Decision, the Conference of the Parties reiterated that Annex I Parties in 2015 may submit their CRF tables after 15/April, but no longer than the corresponding delay in the CRF Reporter availability. "Functioning" software means that the data on the greenhouse emissions/removals are reported accurately both in terms of reporting format tables and XML format. CRF reporter version 5.10 still contains issues in the reporting format tables and XML format in relation to Kyoto Protocol requirements, and it is therefore not yet functioning to allow submission of all the information required under Kyoto Protocol.

Recalling the Conference of Parties invitation to submit as soon as practically possible, and considering that CRF reporter 5.10 allows sufficiently accurate reporting under the UNFCCC (even if minor inconsistencies may still exist in the reporting tables, as per the Release Note accompanying CRF Reporter 5.10), the present report is the official submission for the year 2015 under the UNFCCC.

The present report is not an official submission under the Kyoto Protocol, even though some of the information included may relate to the requirements under the Kyoto Protocol.

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<sup>1</sup> <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2>

This submission includes the following parts:

- 1 – The National Inventory Report (the present report), which includes the description of methodologies, the underlying data, the parameters, and the emission factors used in the Portuguese inventory;
- 2 – CRF (Common Reporting Format) data tables for the period 1990-2013, which were compiled with the new CRF Reporter software (version 5.8.14);
- 3 – SEF (Standard Electronic Tables) for the reporting of Kyoto units in the national registry in 31.12.2014 and transfers of units during 2014.

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## EXECUTIVE SUMMARY

- Portuguese total greenhouse gas emissions were 65.3 Mt CO<sub>2</sub> equivalent (CO<sub>2</sub>-e) in 2013, representing a 2.8 per cent decrease since 2012.
- The largest contributor to the Portuguese emissions is the Energy sector (68 per cent of total emissions in 2013), with the transport activities and the energy industries representing, respectively, 24 and 23 per cent of total emissions.
- Portuguese total emissions have increased 8 per cent since 1990.
- Emissions from the Energy and Waste sectors showed a slight reduction from 2012.
- The LULUCF sector is estimated as a sink in 2013 with - 9.4 Mt CO<sub>2</sub>-e, and the Portuguese net emissions were 55.9 Mt CO<sub>2</sub>-e in 2013.

### ES.1 Background information

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 to respond to Article 5 and 7 of the Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting (MMR) greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC.

The GHG emission inventory is the official annual accounting of all anthropogenic (human-induced) emissions and removals of greenhouse gases in Portugal. The inventory measures Portugal's progress against obligations under the United Nations Framework Convention on Climate Change (Climate Change Convention), the Kyoto Protocol and the European Union agreements (Effort Sharing Decision/ Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020).

This report presents a description of the methods, assumptions and background data used in the preparation of the 2015 national inventory submission of GHG. The period covered is 1990-2013.

The 2006 IPCC Guidelines (2006, IPCC) have been applied as far as possible.

The greenhouse gases covered refer to emissions and removals of the carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF<sub>6</sub>) and nitrogen trifluoride (NF<sub>3</sub>). The indirect greenhouse gases, carbon monoxide (CO), sulphur dioxide (SO<sub>2</sub>), oxides of nitrogen (NO<sub>x</sub>) and non-methane volatile organic compounds (NMVOCs) are also included.

The information is reported under the five large sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste.

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 2013, i.e., the inventory is internally consistent.

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 (not included in this submission due to the fact that CRF reporter version 5.10 is not yet functioning to allow the submission of this information), 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 the Environment, Land Use Planning and Energy (*Ministério do Ambiente, do Ordenamento do Território e Energia* - MAOTE), 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 first established through Council of Ministers Resolution 68/2005, of 17 March.

A new legal national arrangement has been adopted in 2015 (Resolução do Conselho de Ministros n.º 20/2015) in order to take into account the recent developments at international level relating to the UNFCCC and the Kyoto Protocol, and the new monitoring and reporting requirements provided at the EU level by Regulation (EU) 525/2013 of the European Parliament and of the Council of 21 May 2013,

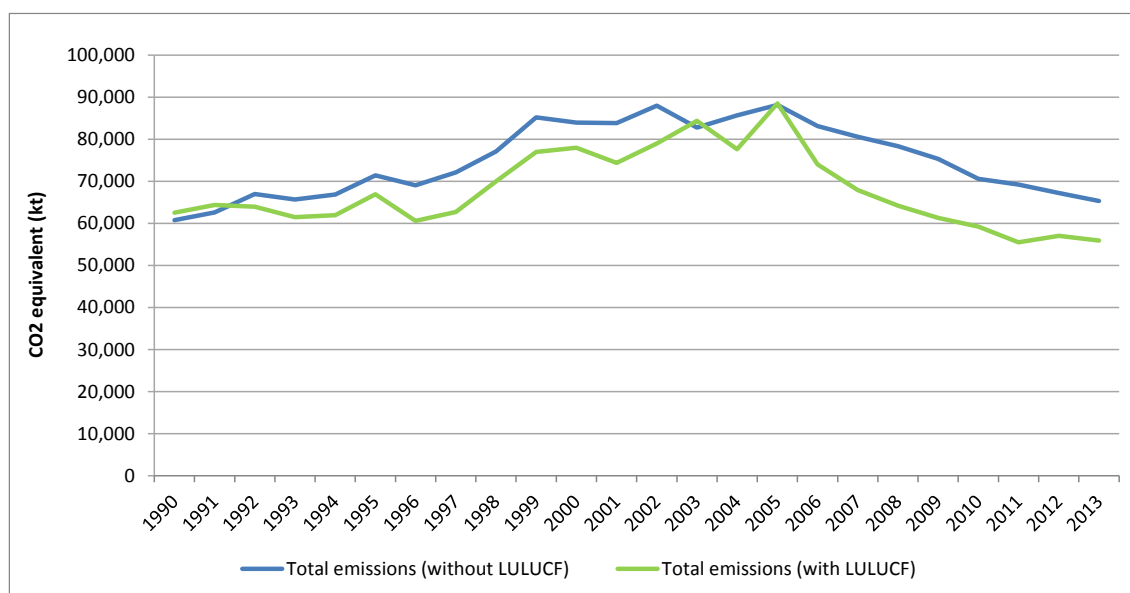
## **ES.2 Summary of national emissions and removal related trends**

### **ES.2.1 Greenhouse Gas Inventory – UNFCCC**

In 2013, total Portuguese GHG emissions, including indirect CO<sub>2</sub>, without land-use, land-use change and forestry (LULUCF) were estimated at about 65.3 Mt CO<sub>2</sub>e, representing an increase of 7.55 per cent compared to 1990 levels and a decrease of 2.8% compared to the previous year (2012).

Throughout this report, emissions values are presented in CO<sub>2</sub> equivalent using IPCC AR4 GWP values. The reference to “total emissions” along the report is meant to refer to “total emissions without LULUCF, including CO<sub>2</sub> indirect emissions”.

Figure 0.1- GHG emissions



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, the large investment in renewable energy sources 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.

Since 2011 there has been a decline in the final energy consumption 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 European economic and financial crisis. This tendency was also verified in 2013, with a contraction in final energy consumption (-2.7%). However, the primary energy consumption grew by 1% in 2013. This apparent contradiction results from the increase in the energy sector with a growth of the production of refineries and petrochemical sector.

The level of emissions show significant inter-annual variations, which are mostly occurring in the power sector and are related to the pronounced fluctuations of hydroelectric power generation that is highly affected by annual variations in precipitation.

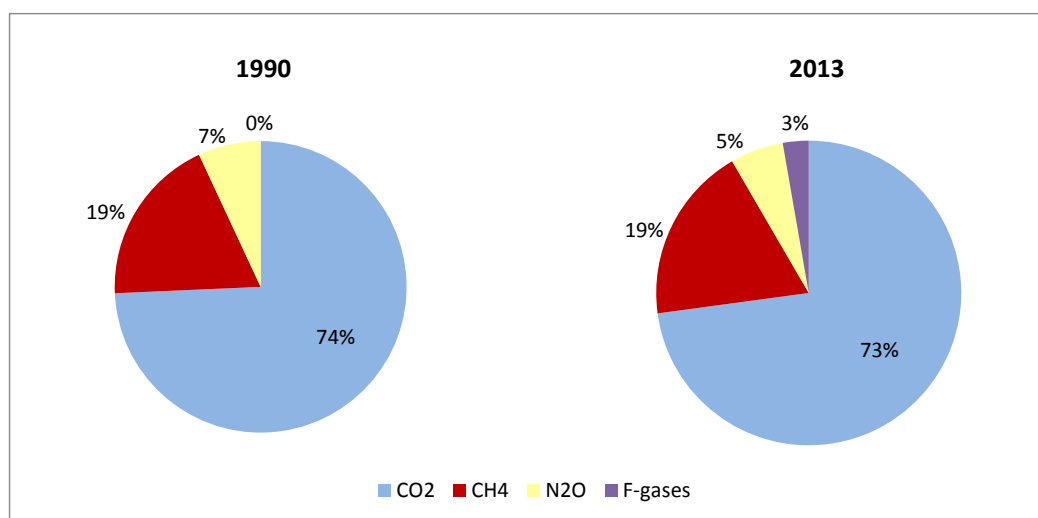


The national emissions decreased from 2012 to 2013 approximately 3% (~ 2 Mt CO<sub>2</sub> e.). This reduction results from the decrease in category “energy industries” and is related to the lower use of coal (-9%) and NG (-70%) in thermal energy production, which is largely explained by the increase in hydropower production in 2013 due to a very favorable year in terms of water availability (high index hydro (HPI = 1.17)). Domestic energy production has been growing in recent years as a result of a greater contribution from renewable energy sources, such as case of hydro and wind power. In 2013 the domestic production of energy rose 17% compared to 2012, with an increase in hydroelectric production and wind of 123% and 17%, respectively.

The analysis of the consumption of different energy sources in 2013, shows that Oil remains the main primary energy supply (44%), followed by Renewables (25%) and Natural Gas (17%).

The figure below illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2013, being evident CO<sub>2</sub> as the primary GHG, accounting for about 73% of Portuguese emissions on a carbon equivalent basis in 2013 (LULUCF excluded). The second most important gas is CH<sub>4</sub>, followed by N<sub>2</sub>O, representing, respectively, 19% and 5% of total emissions in 2013. Portugal has chosen 1995 as the base year for fluorinated gases. In 2013 these gases represented about 3% of total GHG emissions. NF<sub>3</sub> emissions are non-occurring in Portugal.

Figure 0.2 –GHG emissions by gas



Over the 1990-2013 period, CH<sub>4</sub> is the gas having registered the biggest increase (8%) and N<sub>2</sub>O decreased by about 13%.

Table 0.1 –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 w without net CO <sub>2</sub> from LULUCF	44,896	46,537	50,767	49,432	50,091	54,105	51,478	54,317	58,833	66,531	65,355	65,062
CO <sub>2</sub> emissions with net CO <sub>2</sub> from LULUCF	45,933	47,527	47,153	44,688	44,615	48,847	42,511	44,444	51,114	57,772	58,741	55,092
CH <sub>4</sub> emissions without CH <sub>4</sub> from LULUCF	11,339	11,594	11,785	11,813	12,248	12,602	12,567	12,763	13,210	13,426	13,291	13,562
CH <sub>4</sub> emissions with CH <sub>4</sub> from LULUCF	11,544	11,871	11,873	11,888	12,369	12,859	12,664	12,802	13,415	13,532	13,476	13,672
N <sub>2</sub> O emissions w without N <sub>2</sub> O from LULUCF	4,190	4,161	4,142	4,128	4,179	4,369	4,598	4,603	4,582	4,673	4,649	4,487
N <sub>2</sub> O emissions with N <sub>2</sub> O from LULUCF	4,731	4,694	4,625	4,591	4,637	4,846	5,046	5,039	5,042	5,113	5,098	4,920
HFCs	NE,NA,NO	NE,NA,NO	NE,NA,NO	NE,NA,NO	NE,NA,NO	31	49	71	101	186	288	374
PFCs	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF <sub>6</sub>	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	15	15	17	17	18	18	20
NF <sub>3</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>Total (without LULUCF)</b>	<b>60,426</b>	<b>62,292</b>	<b>66,694</b>	<b>65,373</b>	<b>66,518</b>	<b>71,122</b>	<b>68,708</b>	<b>71,771</b>	<b>76,743</b>	<b>84,834</b>	<b>83,602</b>	<b>83,505</b>
<b>Total (with LULUCF)</b>	<b>62,208</b>	<b>64,093</b>	<b>63,651</b>	<b>61,166</b>	<b>61,620</b>	<b>66,597</b>	<b>60,286</b>	<b>62,373</b>	<b>69,689</b>	<b>76,622</b>	<b>77,622</b>	<b>74,079</b>
<b>Total (without LULUCF, with indirect)</b>	<b>60,724</b>	<b>62,587</b>	<b>66,991</b>	<b>65,662</b>	<b>66,817</b>	<b>71,416</b>	<b>69,013</b>	<b>72,090</b>	<b>77,063</b>	<b>85,159</b>	<b>83,932</b>	<b>83,801</b>
<b>Total (with LULUCF, with indirect)</b>	<b>62,507</b>	<b>64,388</b>	<b>63,949</b>	<b>61,456</b>	<b>61,919</b>	<b>66,891</b>	<b>60,591</b>	<b>62,692</b>	<b>70,009</b>	<b>76,947</b>	<b>77,952</b>	<b>74,376</b>

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change 1990-2013
CO <sub>2</sub> equivalent (Gg)													
CO <sub>2</sub> emissions w without net CO <sub>2</sub> from LULUCF	68,805.94	63,647	66,291	68,816	64,251	61,566	59,486	56,724	52,204	50,919	49,146	47,408	5.6
CO <sub>2</sub> emissions with net CO <sub>2</sub> from LULUCF	59,254.32	63,981	57,625	68,124	54,646	48,472	44,989	42,340	40,298	36,820	38,449	37,500	-18.4
CH <sub>4</sub> emissions without CH <sub>4</sub> from LULUCF	13,811.33	14,022	13,992	13,997	13,518	13,343	13,130	13,077	12,771	12,823	12,477	12,213	7.7
CH <sub>4</sub> emissions with CH <sub>4</sub> from LULUCF	13,983.21	14,739	14,130	14,555	13,621	13,384	13,151	13,134	12,922	12,884	12,651	12,366	7.1
N <sub>2</sub> O emissions w without N <sub>2</sub> O from LULUCF	4,532.16	4,196	4,357	4,208	4,067	4,255	4,134	3,804	3,804	3,542	3,543	3,667	-12.5
N <sub>2</sub> O emissions with N <sub>2</sub> O from LULUCF	4,971.13	4,720	4,782	4,690	4,462	4,620	4,474	4,151	4,167	3,891	3,911	4,033	-14.8
HFCs	484.32	618	733	841	955	1,105	1,267	1,380	1,508	1,612	1,737	1,728	
PFCs	NO	NO	NO	0	0	0	0	0	0	0	0	0	
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
SF <sub>6</sub>	19.84	26	35	35	37	46	45	50	52	49	53	55	
NF <sub>3</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
<b>Total (without LULUCF)</b>	<b>87,654</b>	<b>82,509</b>	<b>85,408</b>	<b>87,898</b>	<b>82,827</b>	<b>80,315</b>	<b>78,061</b>	<b>75,035</b>	<b>70,339</b>	<b>68,944</b>	<b>66,956</b>	<b>65,071</b>	7.7
<b>Total (with LULUCF)</b>	<b>78,713</b>	<b>84,085</b>	<b>77,306</b>	<b>88,246</b>	<b>73,721</b>	<b>67,628</b>	<b>63,925</b>	<b>61,055</b>	<b>58,948</b>	<b>55,255</b>	<b>56,801</b>	<b>55,682</b>	-10.5
<b>Total (without LULUCF, with indirect)</b>	<b>87,937</b>	<b>82,786</b>	<b>85,684</b>	<b>88,167</b>	<b>83,097</b>	<b>80,588</b>	<b>78,324</b>	<b>75,276</b>	<b>70,589</b>	<b>69,183</b>	<b>67,189</b>	<b>65,308</b>	7.5
<b>Total (with LULUCF, with indirect)</b>	<b>78,996</b>	<b>84,361</b>	<b>77,582</b>	<b>88,515</b>	<b>73,990</b>	<b>67,901</b>	<b>64,188</b>	<b>61,296</b>	<b>59,197</b>	<b>55,494</b>	<b>57,034</b>	<b>55,918</b>	-10.5

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

### ES.2.1 KP-LULUCF activities

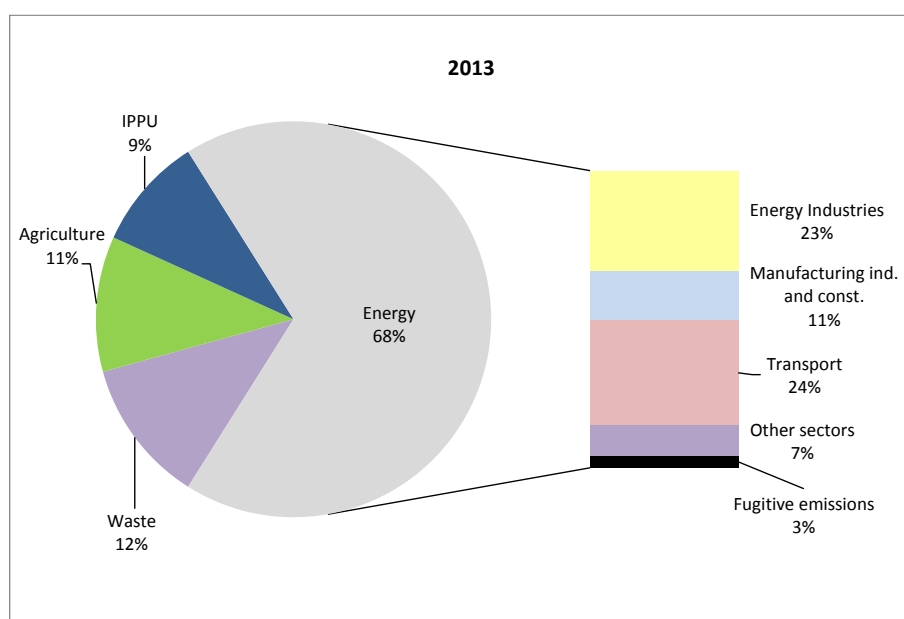
Not included in the 2015 submission due to the fact that CRF reporter version 5.10 is not yet functioning to allow the submission of all the information required under Kyoto Protocol.

## 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 five large IPCC categories: Energy, Industrial Processes and Product Uses (IPPU), Agriculture, LULUCF, and Waste.

Figure 0.3 -GHG emissions in Portugal by sector: 2013

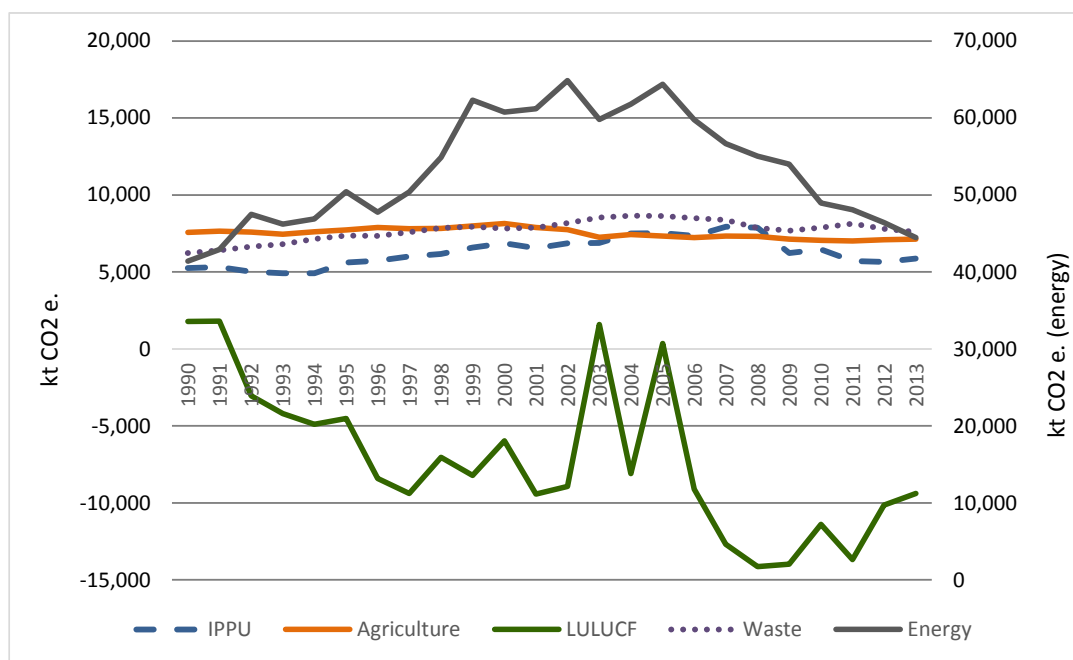


Energy is by far the most important sector, accounting for 68 per cent of total emissions in 2013, and presenting an increase of 8 per cent over the 1990-2013 period. Energy industries and transport are the two most important sources representing, respectively, around 23% and 24% of total emissions. Within the energy industries, public electricity and heat production represents alone 19% of the total emissions. This reflects the country's 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 has changed in the most recent years, where we can observe stagnation and decrease of these trends.

Mobile sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2013 the emissions of transportation sources increased 54 per cent, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel from 1990 to the early 2000s, reflecting the increase in family income and the strong investment in the road infrastructure of the country in the 1990s decade. Indirectly the increase in road traffic activity also augments the emissions from fossil fuel storage, handling and distribution. As previously said, the situation seems to have stabilized in the early 2000s and then started to decline since 2005.

Still within the energy sector, the category “other sectors”, which include the residential and commercial activities, also registered a significant increase of emissions in the 1990-2005 period (with almost 55 per cent rise), but this tendency has decelerated (5.5 per cent decrease in the 1990-2013 period), due to the implementation energy conservation measures, but in the most recent years also to the stagnation of the economic growth and recession.

Figure 0.4 –GHG emissions and removals by sector



Agriculture was, in the period analyzed, one of the most significant sources of GHG emissions, and was responsible for 11 per cent of the Portuguese emissions in 2013, corresponding to a decrease of 6 per cent since 1990. This fact is associated for instance with the reduction of the livestock production of certain categories of animals (e.g. sheep), the extensification of cattle production and the decrease of fertilizer consumption.

Waste represented approximately 12 per cent of Portuguese emissions in 2013, recording an increase of approximately 22 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 and product use represented 9 per cent of the Portuguese emissions in 2013, and have grown 12 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, other uses of carbonates, lime production, and glass production.

Estimates of emissions and sinks from land use change and forestry category show that this category has changed from being a net emitter in 1990 (1.8 Mt CO<sub>2</sub> eq.) to a carbon sink in 1992. This situation was again reverted in the years 2003 and 2005 due to the severe forest wildfires events registered in these years. In 2013 this sector represents a sequester of -9.4 Mt CO<sub>2</sub>e.

Figure 0.5 – GHGs emissions percentage change (1990-2013) by IPCC category (LULUCF excluded)

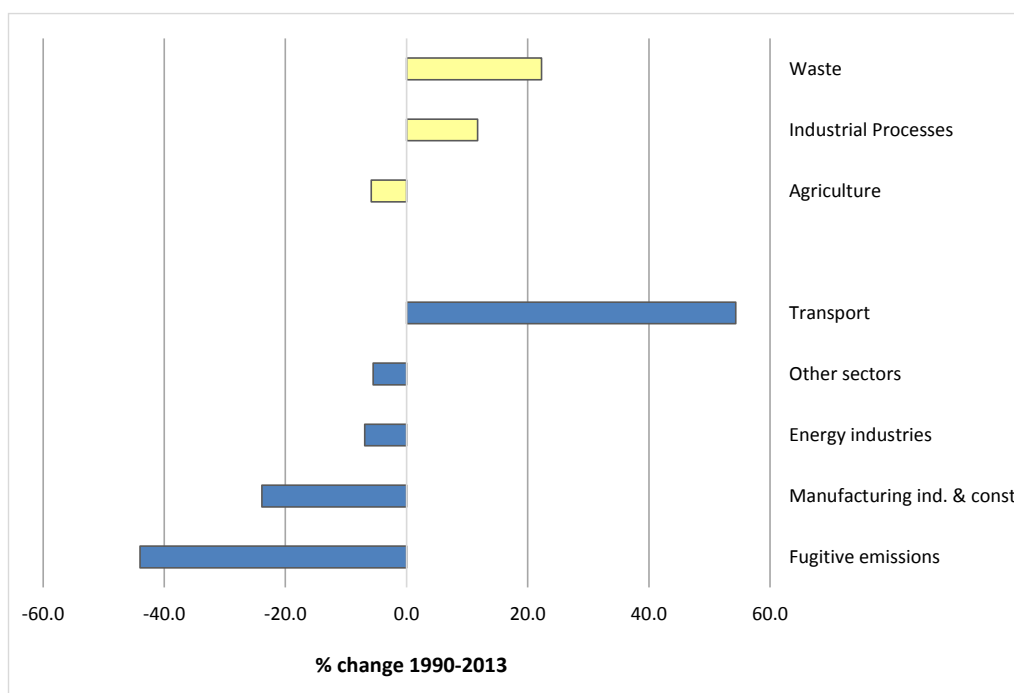


Table 0.2 –GHG emissions and removals by sector

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	41,388	42926.617	47,468	46,213	46,871	50,409	47,753	50,381	54,873	62,326	60,770	61,194
2. Industrial processes and product use	5,246	5310.0357	5,009	4,912	4,906	5,616	5,737	6,009	6,176	6,583	6,861	6,544
3. Agriculture	7,573	7652.3079	7,580	7,442	7,606	7,734	7,888	7,801	7,831	7,993	8,144	7,894
4. Land use, land-use change and forestry(5)	1,783	1800.5981	-3,042	-4,206	-4,898	-4,524	-8,422	-9,398	-7,055	-8,212	-5,980	-9,426
5. Waste	6,218	6403.0718	6,637	6,806	7,135	7,363	7,330	7,580	7,864	7,932	7,826	7,872
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

GHGs SOURCE AND SINK CATEGORIES	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change 1990-2013
CO <sub>2</sub> equivalent (Gg)													
1. Energy	64,875.35	59,825.67	61,808.24	64,396.11	59,765.01	56,677.89	55,040.97	53,987.86	48,936.23	48,075.74	46,426.27	44,473.76	7.5
2. Industrial processes and product use	6,856.97	6,889.53	7,506.62	7,526.80	7,332.13	7,929.42	7,869.03	6,222.34	6,466.69	5,712.97	5,656.36	5,862.26	11.7
3. Agriculture	7,746.19	7,256.51	7,436.92	7,335.53	7,232.15	7,325.25	7,303.42	7,139.72	7,058.06	7,017.07	7,081.92	7,132.85	-5.8
4. Land use, land-use change and forestry(5)	-8,940.76	1,575.47	-8,101.78	347.63	-9,106.55	-12,687.26	-14,135.53	-13,979.37	-11,391.37	-13,688.90	-10,154.88	-9,389.57	-626.7
5. Waste	8,175.08	8,537.52	8,656.31	8,639.73	8,497.90	8,382.38	7,847.16	7,684.90	7,878.01	8,138.36	7,791.37	7,602.59	22.3
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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

### ES.3.1 KP-LULUCF activities

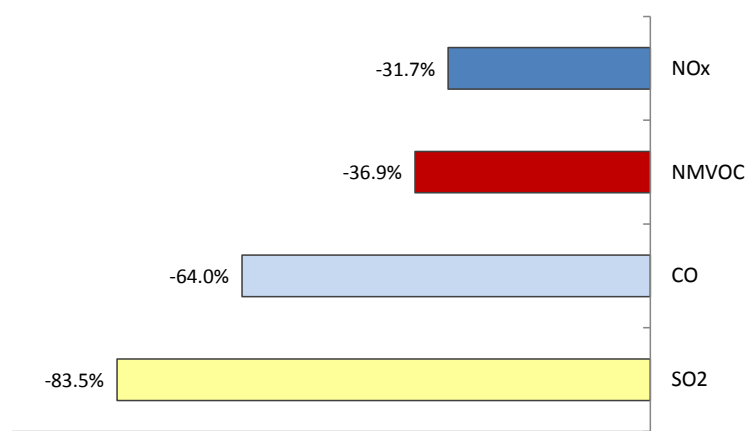
Not included in the 2015 submission due to the fact that CRF reporter version 5.10 is not yet functioning to allow the submission of all the information required under Kyoto Protocol.

## ES.4 Other information

### 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 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 0.6 –Indirect GHG and SO<sub>x</sub> emissions: 1990-2013 variation



In 2013, all these gases emissions have decreased from 1990 levels: SO<sub>x</sub> -84 per cent, CO -64 per cent, NMVOC -37 per cent and NO<sub>x</sub> -32. per cent per cent per cent.

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 Industrial processes and Product use sector.

Within energy, transportation is responsible for the major share of NO<sub>x</sub>, emissions, approx. 47 per cent of 2013 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 stabilized 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 (-13 per cent reduction in the 1990-2013); and CO and NMVOC emissions also register reductions in the 1990-2013 period (more than -80 per cent).

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 46 per cent of the 2013 totals.

SO<sub>x</sub> emissions are mainly generated in the energy industry sector (approximately 36 per cent of total emissions in 2013) and combustion in manufacturing industries (approximately 34 per cent of total emissions in 2013), 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 1990-2013 shows in fact a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries and manufacturing industries -91 per cent and -77 per cent. Since 2007, SO<sub>x</sub> emissions from the energy industries registered a significant reduction (approximately -82 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 0.3 – Indirect GHG and SOx emissions: 1990-2013

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	
	(Gg)												
CO	822	836	875	856	837	827	815	777	765	737	687	605	
NOx	245	256	275	266	266	276	264	263	270	278	274	273	
NM VOC	275	281	284	275	276	271	273	273	273	267	256	246	
SO2	323	314	376	320	295	331	273	288	335	302	263	249	

Gas emissions	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change
	(Gg)												1990-2013
CO	587	550	521	480	446	420	398	372	360	337	306	296	-64.0
NOx	279	256	261	267	245	240	213	202	188	179	167	167	-31.7
NM VOC	244	231	225	215	208	205	196	185	185	179	173	174	-36.9
SO2	249	190	192	194	169	162	113	78	70	64	59	53	-83.5

## **PART I: ANNUAL INVENTORY SUBMISSION**

## 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 – hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF<sub>6</sub>), and nitrogen trifluoride (NF<sub>3</sub>) - do not deplete stratospheric ozone but are potent greenhouse gases. These latter substances are considered by the UNFCCC and accounted for in national greenhouse gas inventories.

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.

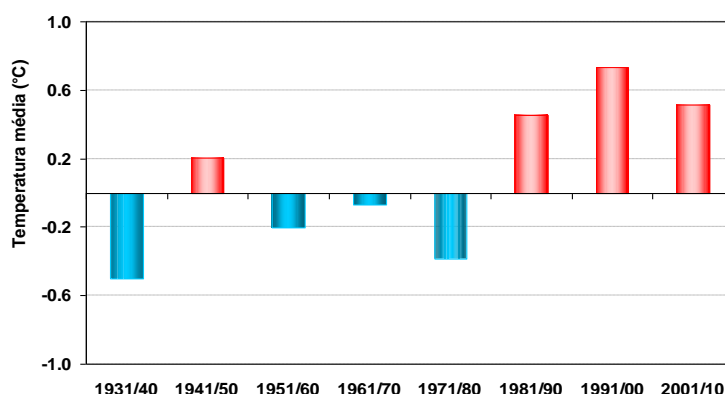
An increase in global temperatures can result in a cascade of environmental effects, including the rise of sea level and changes in the amount and pattern of precipitation. These changes may increase the frequency and intensity of extreme weather events, such as floods, droughts, heat waves, hurricanes, 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



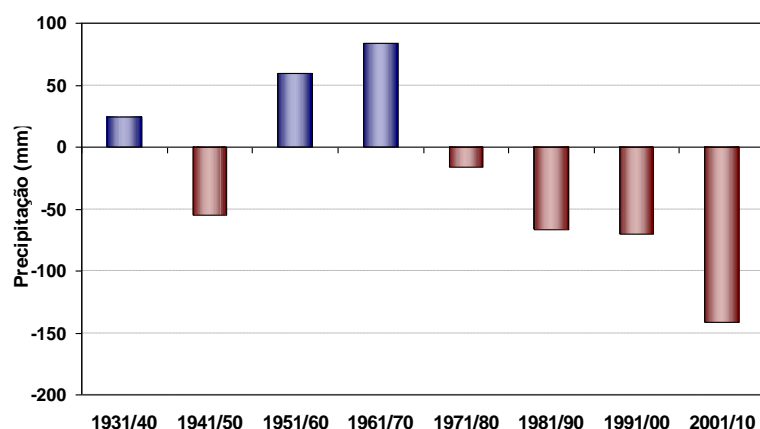
Source: IPMA, 2013

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 and 2014 greenhouse gas emission inventory in September 2013 and 2014.

#### **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), sulphur hexafluoride (SF<sub>6</sub>), and nitrogen trifluoride (NF<sub>3</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 2013.

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. 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.

The former GWP considered (*IPCC Second Assessment Report (SAR)* (IPCC 1996)), have been replaced by the values proposed by the *IPCC Fourth Assessment Report (AR4)* (IPCC 2007), as required as required by the revised UNFCCC reporting guidelines.

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

GHG	SAR	AR4
CO <sub>2</sub>	1	1
CH <sub>4</sub>	21	25
N <sub>2</sub> O	310	298
HFC-23	11 700	14800
HFC-32	650	675
HFC-43-10mee	1 300	1640
HFC-125	2 800	3500
HFC-134 <sup>a</sup>	1 300	1430
HFC-152 <sup>a</sup>	140	124
HFC-143 <sup>a</sup>	3 800	4470
HFC-227ea	2 900	3220
HFC-236fa	6 300	9810
CF <sub>4</sub>	6 500	7390
C <sub>2</sub> F <sub>6</sub>	9 200	12200
C <sub>4</sub> F <sub>10</sub>	7000	8860
C <sub>6</sub> F <sub>14</sub>	7400	9300
SF <sub>6</sub>	23 900	22800
NF <sub>3</sub>	NA	17200

## 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, 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,

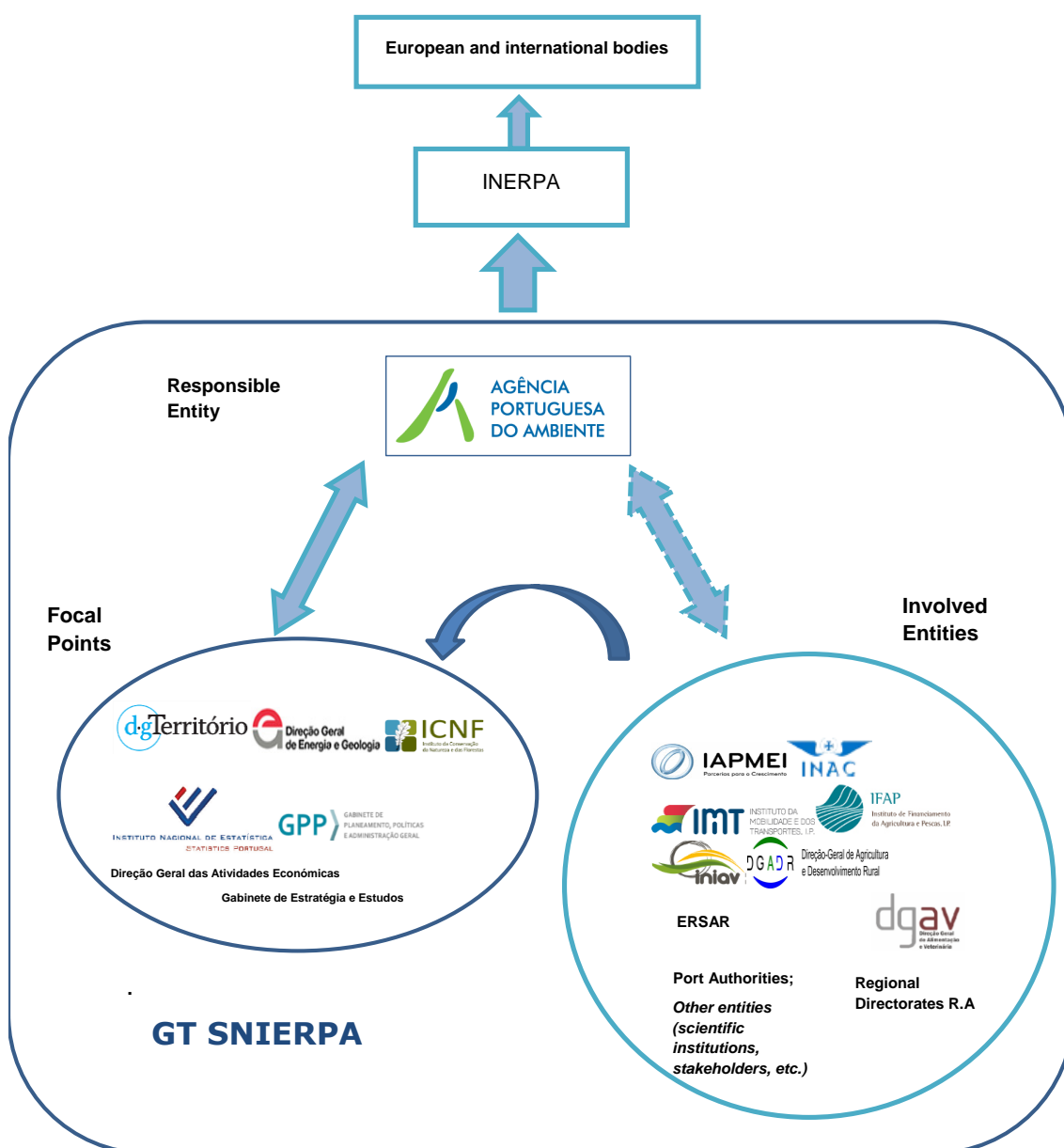
The system was established in 2005 through a Council of Ministers Resolution 68/2005, of 17 March, which defined the entities relevant for its implementation, based on the principle of institutional cooperation. This clear allocation of responsibilities is essential to ensure the inventory takes place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

A new legal national arrangement has been adopted in 2015 (Resolução do Conselho de Ministros n.º 20/2015) in order to take into account the recent developments at international level relating to the UNFCCC and the Kyoto Protocol, and the new monitoring and reporting

requirements provided at the EU level by Regulation (EU) 525/2013 of the European Parliament and of the Council of 21 May 2013, on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC, and the Commission Implementing Regulation (EU) 749/2014 of 30 June 2014 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) No 525/2013 of the European Parliament and of the Council, and the requirements under the CLRTAP and the NECD.

Next figure presents the main entities that make part of the national system.

Figure 1.3 – Main bodies of national system (SNIERPA)



Changes to the institutional arrangements since the 2014 submission refer to an update and enlargement of the number of institutions that make part of the National system and the reassignment of experts acting as Focal Points.

For the sake of efficiency, the Portuguese national system includes 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.

### 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 sectorial 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 1.2 - 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>	-

### 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.

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

## 1.3 Inventory Preparation Process

### 1.3.1 Responsibility

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

The designated representative is:

Agência Portuguesa do Ambiente

Departamento de Alterações Climáticas (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.

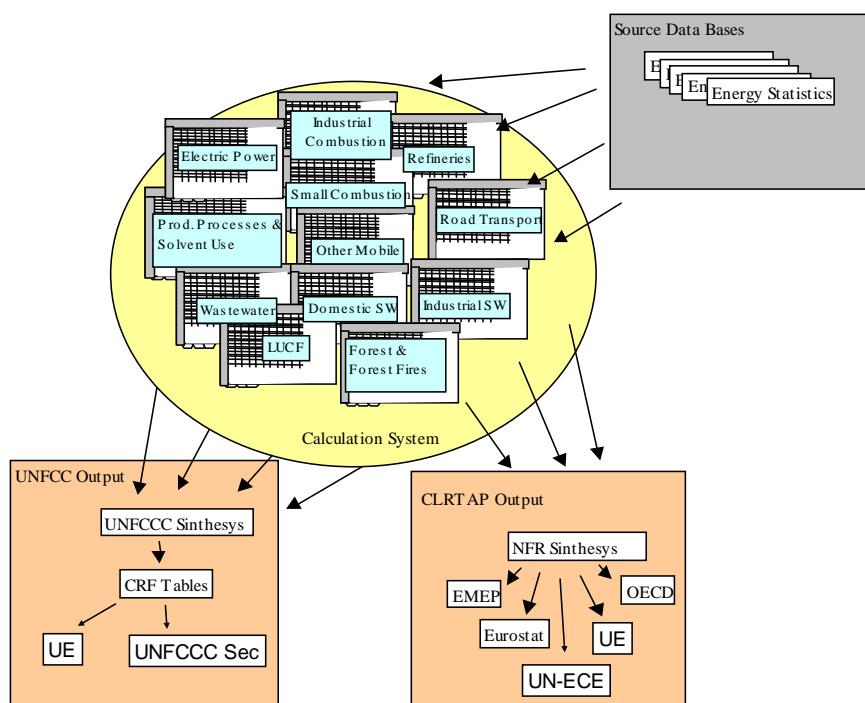
The information received from the several data suppliers is stored in its original format (paper or magnetic). A copy of this information is converted into the working workbooks, where data is further processed, linkage made and calculations performed, maintaining hence the integrity of the original 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 1.4 – 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.

## 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, adopted at the Conference of the Parties (COP), by decision 24/CP.19 (available online at <<http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>>.).

The UNFCCC adopted the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) as the standard methodological approach for Annex I countries inventories.

The Portuguese 2015 submission presents several methodological changes as compared to the previous submission in order include these new Guidance and to implement the

recommendations from the previous UNFCCC reviews (please check Responses to the UNFCCC reviews and information on recalculations).

### **1.5 Brief description of key source categories**

Under revision/development. To be provided in 2016 submission.

### **1.6 Information on QA/QC**

For this submission, the application of QA/QC procedures was done by the inventory staff and refer mainly to CQ1 procedures. These consisted in particular in basic checks on the accuracy of the outputs of the new CRF Reporter, cross-checks among categories and the comparison with the results of calculation sheets, as well as a check with estimates from other years. This work will continue in order to have a complete final reporting of the CRF Tables and a final NIR.

### **1.7 General uncertainty assessment**

Under revision/development. To be provided in 2016 submission.

### **1.8 Overview of the completeness**

The inventory covers the 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>). NF<sub>3</sub> emissions do not occur in Portugal.

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.



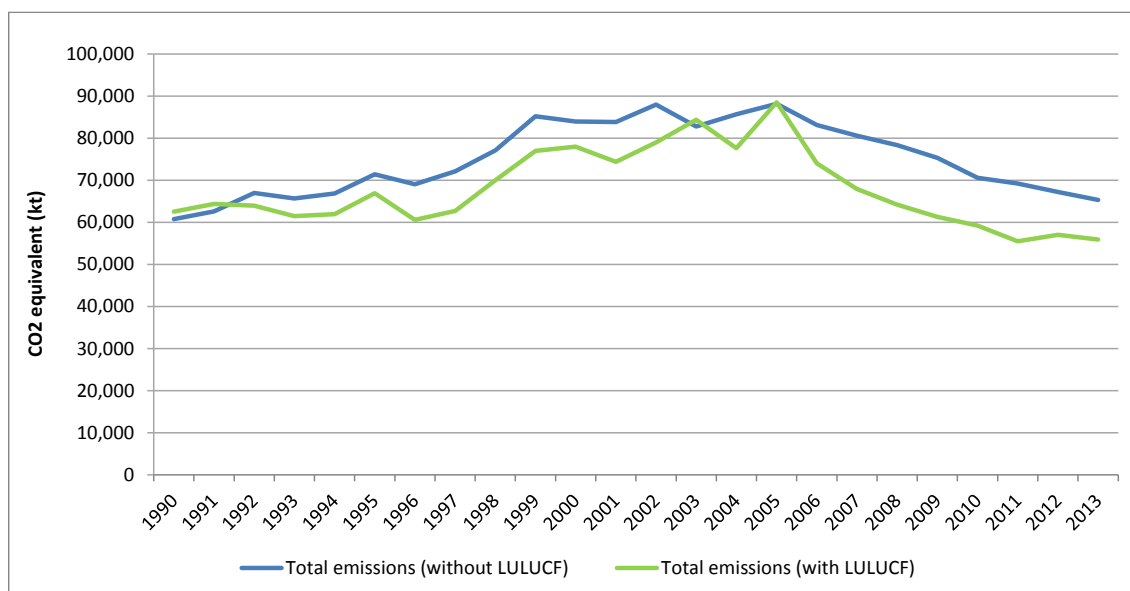
## 2 TRENDS IN PORTUGUESE GHG EMISSIONS

### 2.1 Trends of Total Emissions

In 2013, total Portuguese GHG emissions, including indirect CO<sub>2</sub>, without land-use, land-use change and forestry (LULUCF) were estimated at about 65.3 Mt CO<sub>2</sub>e, representing an increase of 7.55 per cent compared to 1990 levels and a decrease of 2.8% compared to the previous year (2012).

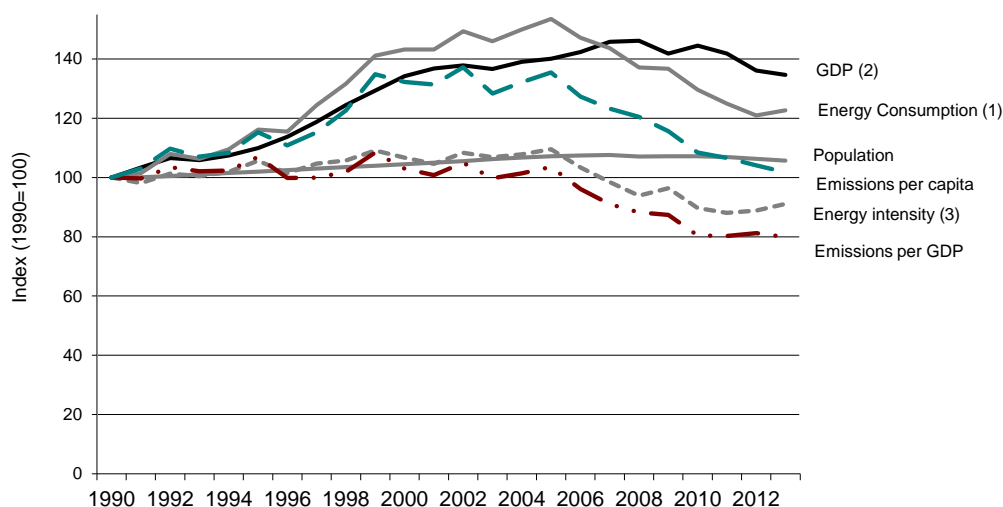
Throughout this report, emissions values are presented in CO<sub>2</sub> equivalent using IPCC AR4 GWP values. The reference to “total emissions” along the report is meant to refer to “total emissions without LULUCF, including CO<sub>2</sub> indirect emissions”.

Figure 2.1- GHG emissions



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, the large investment in renewable energy sources and to the more recent situation of stagnation or later recession of the Portuguese economy.

Figure 2.2 – GHG emissions per capita, per unit of GDP and energy consumption



Notes:

(1) Primary Energy Consumption; (2) GDP at 2011 prices; (3) Energy Consumption per GDP.

Sources: INE, DGEG.

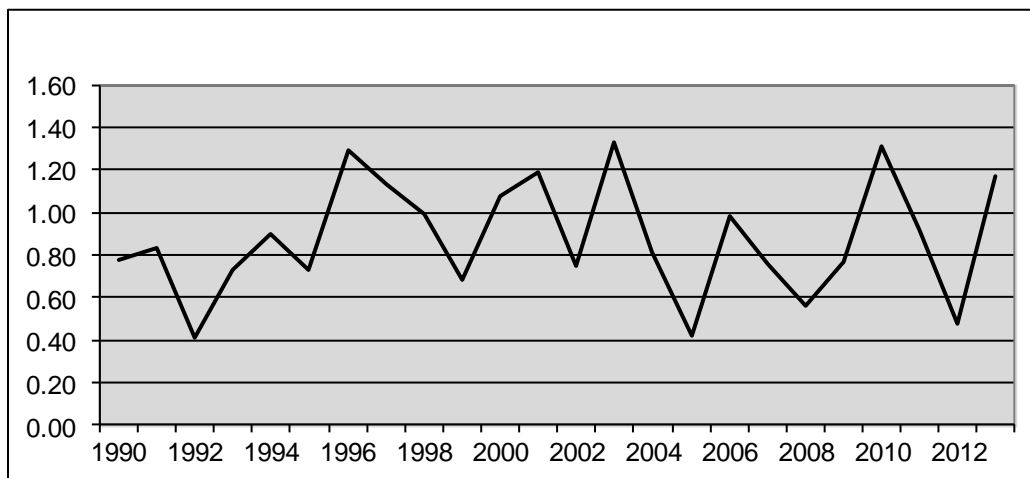
The trends registered in the most recent years reflect, to a certain extent, the decoupling of emissions growth from the economic activity. The decrease of carbon intensity (GHG emissions per GDP unit) observed in the more recent years (see previous figure), is in part related to the implementation of some important measures that had a positive effect in the emissions levels, such as the expansion of renewable energy in electricity production, 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. 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.

Since 2011 there has been a decline in the final energy consumption 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 European economic and financial crisis. This tendency was also verified in 2013, with a contraction in final energy consumption (-2.7%). However, the primary energy consumption grew by 1% in 2013. This apparent contradiction results from the increase in the energy sector with a growth of the production of refineries and petrochemical sector.

The level of emissions show significant inter-annual variations, which are mostly occurring in the power sector and are related to the pronounced fluctuations of hydroelectric power generation that is highly affected by annual variations in precipitation.

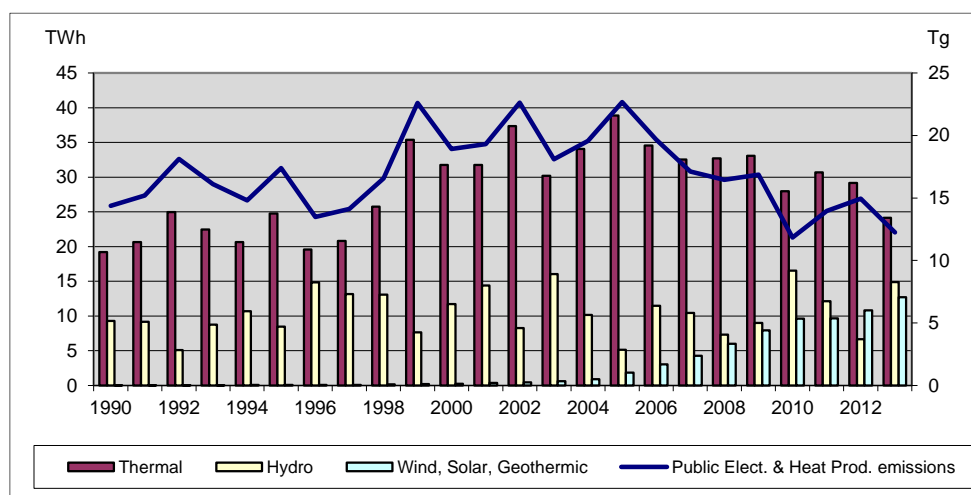
Figure 2.3 –Hydraulic index



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

The national emissions decreased from 2012 to 2013 approximately 3% (~ 2 Mt CO<sub>2</sub> e.). This reduction results from the decrease in category “energy industries” and is related to the lower use of coal (-9%) and NG (-70%) in thermal energy production, which is largely explained by the increase in hydropower production in 2013 due to a very favorable year in terms of water availability (high index hydro (HPI = 1.17)). Domestic energy production has been growing in recent years as a result of a greater contribution from renewable energy sources, such as case of hydro and wind power. In 2013 the domestic production of energy rose 17% compared to 2012, with an increase in hydroelectric production and wind of 123% and 17%, respectively.

Figure 2.4 – Gross electric power production and emissions from electricity and heat generation

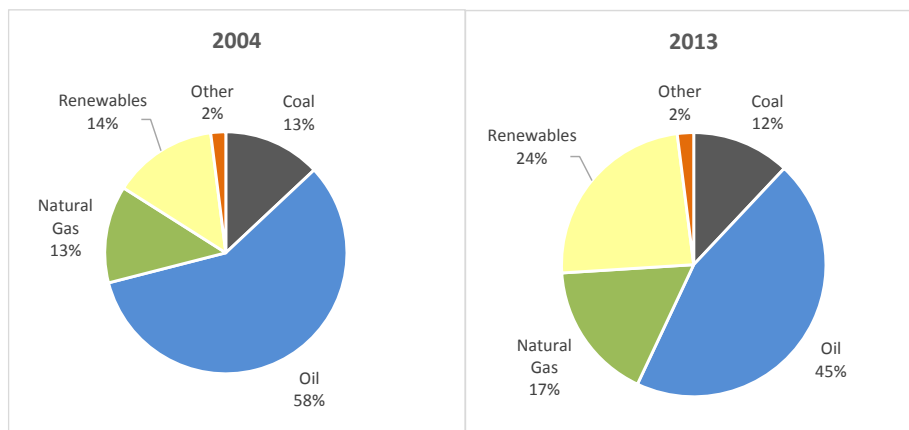


Source: DGGE.

The analysis of the consumption of different energy sources in 2013, shows that Oil remains the main primary energy supply (44%), followed by Renewables (25%) and Natural Gas (17%). Nevertheless the weight of Oil has declined in recent years (58% vs. 45% in 2004 in 2013),

whereas the importance of Renewables (14% in 2004 vs. 24% in 2013) and natural gas (14% in 2004 vs. 17% in 2013) increased considerably.

Figure 2.5 – Primary energy consumption by energy source

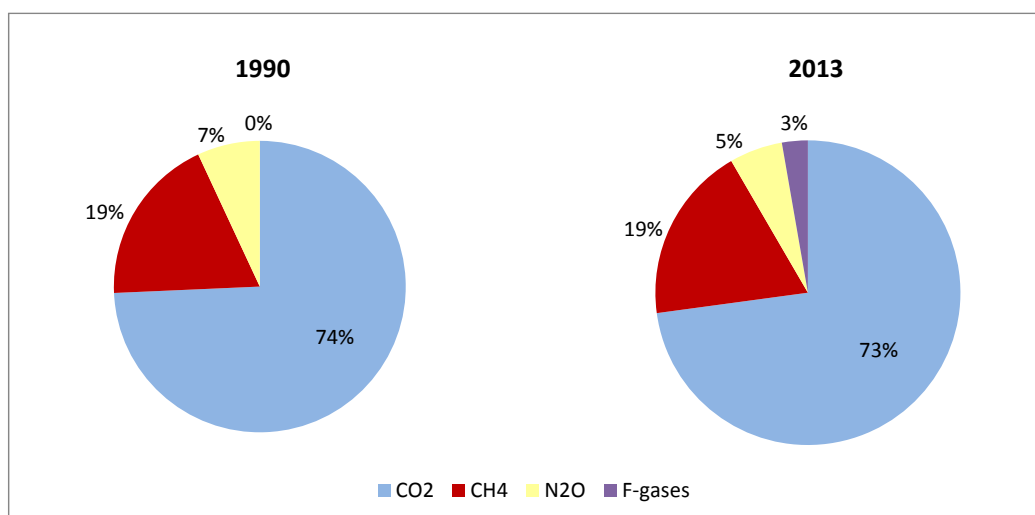


Source: DGGE.

## 2.2 Emissions by Gas

The figure below illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2013, being evident CO<sub>2</sub> as the primary GHG, accounting for about 73% of Portuguese emissions on a carbon equivalent basis in 2013 (LULUCF excluded). The second most important gas is CH<sub>4</sub>, followed by N<sub>2</sub>O, representing, respectively, 19% and 5% of total emissions in 2013. Portugal has chosen 1995 as the base year for fluorinated gases. In 2013 these gases represented about 3% of total GHG emissions. NF<sub>3</sub> emissions are non-occurring in Portugal.

Figure 2.6 –GHG emissions by gas



Over the 1990-2013 period, CH<sub>4</sub> is the gas having registered the biggest increase (8%) and N<sub>2</sub>O decreased by about 13%.

Figure 2.7 – Change of GHG emissions by gas over the period 1990-2013

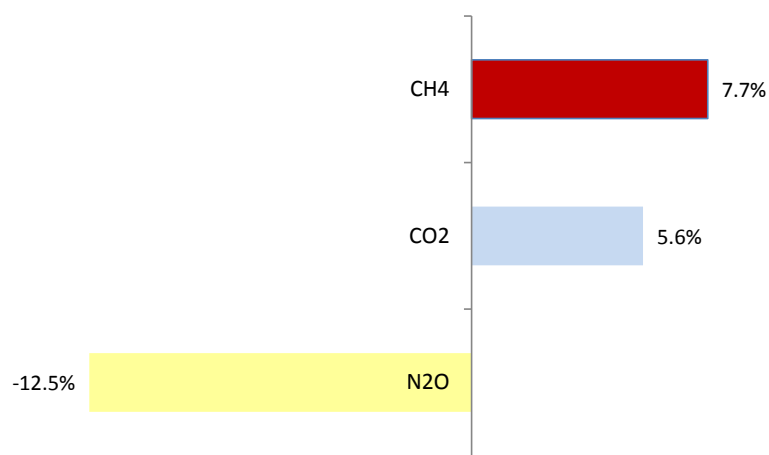


Table 2.1 –GHG emissions and removals in Portugal by gas

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 w without net CO <sub>2</sub> from LULUCF	44,896	46,537	50,767	49,432	50,091	54,105	51,478	54,317	58,833	66,531	65,355	65,062
CO <sub>2</sub> emissions w with net CO <sub>2</sub> from LULUCF	45,933	47,527	47,153	44,688	44,615	48,847	42,511	44,444	51,114	57,772	58,741	55,092
CH <sub>4</sub> emissions w without CH <sub>4</sub> from LULUCF	11,339	11,594	11,785	11,813	12,248	12,602	12,567	12,763	13,210	13,426	13,291	13,562
CH <sub>4</sub> emissions w with CH <sub>4</sub> from LULUCF	11,544	11,871	11,873	11,888	12,369	12,859	12,664	12,802	13,415	13,532	13,476	13,672
N <sub>2</sub> O emissions w without N <sub>2</sub> O from LULUCF	4,190	4,161	4,142	4,128	4,179	4,369	4,598	4,603	4,582	4,673	4,649	4,487
N <sub>2</sub> O emissions w with N <sub>2</sub> O from LULUCF	4,731	4,694	4,625	4,591	4,637	4,846	5,046	5,039	5,042	5,113	5,098	4,920
HFCs	NE,NA,NO	NE,NA,NO	NE,NA,NO	NE,NA,NO	NE,NA,NO	31	49	71	101	186	288	374
PFCs	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF <sub>6</sub>	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	15	15	17	17	18	18	20
NF <sub>3</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>Total (without LULUCF)</b>	<b>60,426</b>	<b>62,292</b>	<b>66,694</b>	<b>65,373</b>	<b>66,518</b>	<b>71,122</b>	<b>68,708</b>	<b>71,771</b>	<b>76,743</b>	<b>84,834</b>	<b>83,602</b>	<b>83,505</b>
<b>Total (with LULUCF)</b>	<b>62,208</b>	<b>64,093</b>	<b>63,651</b>	<b>61,166</b>	<b>61,620</b>	<b>66,597</b>	<b>60,286</b>	<b>62,373</b>	<b>69,689</b>	<b>76,622</b>	<b>77,622</b>	<b>74,079</b>
<b>Total (without LULUCF, with indirect)</b>	<b>60,724</b>	<b>62,587</b>	<b>66,991</b>	<b>65,662</b>	<b>66,817</b>	<b>71,416</b>	<b>69,013</b>	<b>72,090</b>	<b>77,063</b>	<b>85,159</b>	<b>83,932</b>	<b>83,801</b>
<b>Total (with LULUCF, with indirect)</b>	<b>62,507</b>	<b>64,388</b>	<b>63,949</b>	<b>61,456</b>	<b>61,919</b>	<b>66,891</b>	<b>60,591</b>	<b>62,692</b>	<b>70,009</b>	<b>76,947</b>	<b>77,952</b>	<b>74,376</b>

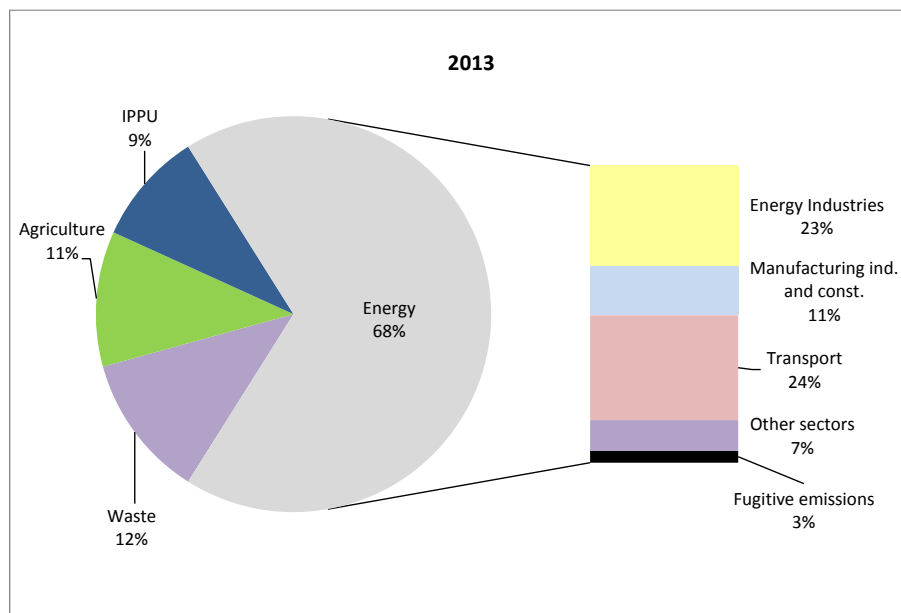
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change 1990-2013
CO <sub>2</sub> equivalent (Gg)													
CO <sub>2</sub> emissions w without net CO <sub>2</sub> from LULUCF	68,805.94	63,647	66,291	68,816	64,251	61,566	59,486	56,724	52,204	50,919	49,146	47,408	5.6
CO <sub>2</sub> emissions w with net CO <sub>2</sub> from LULUCF	59,254.32	63,981	57,625	68,124	54,646	48,472	44,989	42,340	40,298	36,820	38,449	37,500	-18.4
CH <sub>4</sub> emissions w without CH <sub>4</sub> from LULUCF	13,811.33	14,022	13,992	13,997	13,518	13,343	13,130	13,077	12,771	12,823	12,477	12,213	7.7
CH <sub>4</sub> emissions w with CH <sub>4</sub> from LULUCF	13,983.21	14,739	14,130	14,555	13,621	13,384	13,151	13,134	12,922	12,884	12,651	12,366	7.1
N <sub>2</sub> O emissions w without N <sub>2</sub> O from LULUCF	4,532.16	4,196	4,357	4,208	4,067	4,255	4,134	3,804	3,804	3,542	3,543	3,667	-12.5
N <sub>2</sub> O emissions w with N <sub>2</sub> O from LULUCF	4,971.13	4,720	4,782	4,690	4,462	4,620	4,474	4,151	4,167	3,891	3,911	4,033	-14.8
HFCs	484.32	618	733	841	955	1,105	1,267	1,380	1,508	1,612	1,737	1,728	
PFCs	NO	NO	NO	0	0	0	0	0	0	0	0	0	
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
SF <sub>6</sub>	19.84	26	35	35	37	46	45	50	52	49	53	55	
NF <sub>3</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
<b>Total (without LULUCF)</b>	<b>87,654</b>	<b>82,509</b>	<b>85,408</b>	<b>87,898</b>	<b>82,827</b>	<b>80,315</b>	<b>78,061</b>	<b>75,035</b>	<b>70,339</b>	<b>68,944</b>	<b>66,956</b>	<b>65,071</b>	7.7
<b>Total (with LULUCF)</b>	<b>78,713</b>	<b>84,085</b>	<b>77,306</b>	<b>88,246</b>	<b>73,721</b>	<b>67,628</b>	<b>63,925</b>	<b>61,055</b>	<b>58,948</b>	<b>55,255</b>	<b>56,801</b>	<b>55,682</b>	-10.5
<b>Total (without LULUCF, with indirect)</b>	<b>87,937</b>	<b>82,786</b>	<b>85,684</b>	<b>88,167</b>	<b>83,097</b>	<b>80,588</b>	<b>78,324</b>	<b>75,276</b>	<b>70,589</b>	<b>69,183</b>	<b>67,189</b>	<b>65,308</b>	7.5
<b>Total (with LULUCF, with indirect)</b>	<b>78,996</b>	<b>84,361</b>	<b>77,582</b>	<b>88,515</b>	<b>73,990</b>	<b>67,901</b>	<b>64,188</b>	<b>61,296</b>	<b>59,197</b>	<b>55,494</b>	<b>57,034</b>	<b>55,918</b>	-10.5

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

## 2.3 Emissions by Sector

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into five large IPCC categories: Energy, Industrial Processes and Product Uses (IPPU), Agriculture, LULUCF, and Waste.

Figure 2.8 -GHG emissions in Portugal by sector: 2013

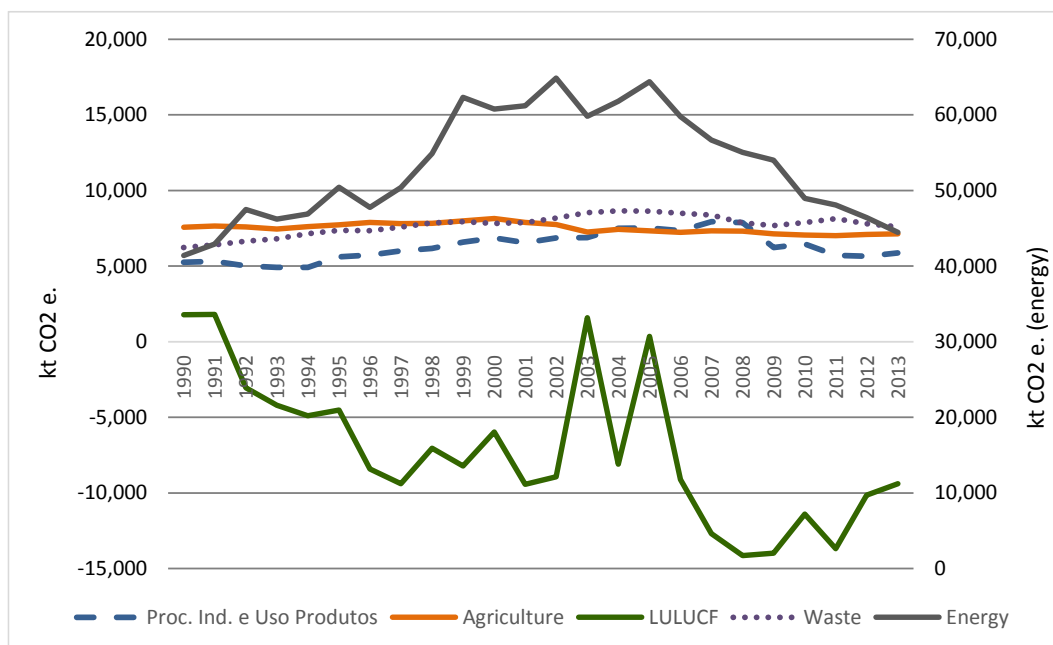


Energy is by far the most important sector, accounting for 68 per cent of total emissions in 2013, and presenting an increase of 8 per cent over the 1990-2013 period. Energy industries and transport are the two most important sources representing, respectively, around 23% and 24% of total emissions. Within the energy industries, public electricity and heat production represents alone 19% of the total emissions. This reflects the country's 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 has changed in the most recent years, where we can observe stagnation and decrease of these trends.

Mobile sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2013 the emissions of transportation sources increased 54 per cent, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel from 1990 to the early 2000s, reflecting the increase in family income and the strong investment in the road infrastructure of the country in the 1990s decade. Indirectly the increase in road traffic activity also augments the emissions from fossil fuel storage, handling and distribution. As previously said, the situation seems to have stabilized in the early 2000s and then started to decline since 2005.

Still within the energy sector, the category "other sectors", which include the residential and commercial activities, also registered a significant increase of emissions in the 1990-2005 period (with almost 55 per cent rise), but this tendency has decelerated (5.5 per cent decrease in the 1990-2013 period), due to the implementation energy conservation measures, but in the most recent years also to the stagnation of the economic growth and recession.

Figure 2.9 –GHG emissions and removals by sector



Agriculture was, in the period analyzed, one of the most significant sources of GHG emissions, and was responsible for 11 per cent of the Portuguese emissions in 2013, corresponding to a decrease of 6 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, in a certain extent associated to the conversion of arable crops to pastures.

Waste represented approximately 12 per cent of Portuguese emissions in 2013, recording an increase of approximately 22 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 9 per cent of the Portuguese emissions in 2013, and have grown 12 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.

Estimates of emissions and sinks from land use change and forestry category show that this category has changed from being a net emitter in 1990 (1.8 Mt CO<sub>2</sub> eq.) to a carbon sink in 1992. This situation was again reverted in the years 2003 and 2005 due to the severe forest wildfires events registered in these years. In 2013 this sector represents a sequester of -9.4 Mt CO<sub>2</sub>e..



Figure 2.10 – GHGs emissions percentage change (1990-2013) by IPCC category (LULUCF excluded)

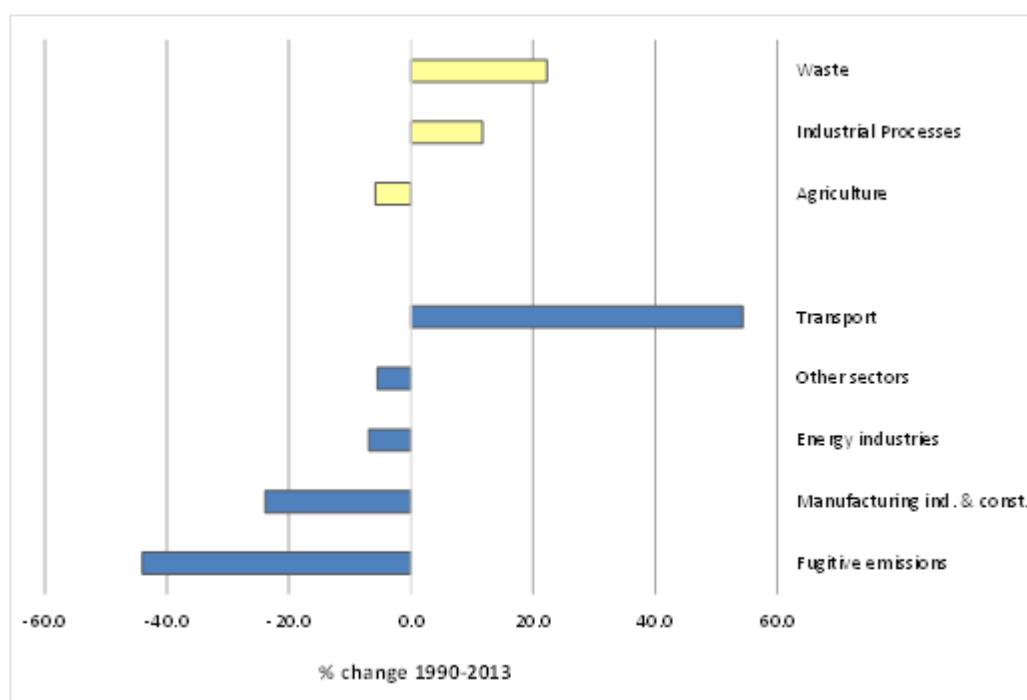


Table 2.2 –GHG emissions and removals by sector

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	41,388	42,926.617	47,468	46,213	46,871	50,409	47,753	50,381	54,873	62,326	60,770	61,194
2. Industrial processes and product use	5,246	53,10,0357	5,009	4,912	4,906	5,616	5,737	6,009	6,176	6,583	6,861	6,544
3. Agriculture	7,573	7652.3079	7,580	7,442	7,606	7,734	7,888	7,801	7,831	7,993	8,144	7,894
4. Land use, land-use change and forestry(5)	1,783	1800.5981	-3,042	-4,206	-4,898	-4,524	-8,422	-9,398	-7,055	-8,212	-5,980	-9,426
5. Waste	6,218	6403.0718	6,637	6,806	7,135	7,363	7,330	7,580	7,884	7,932	7,826	7,872
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

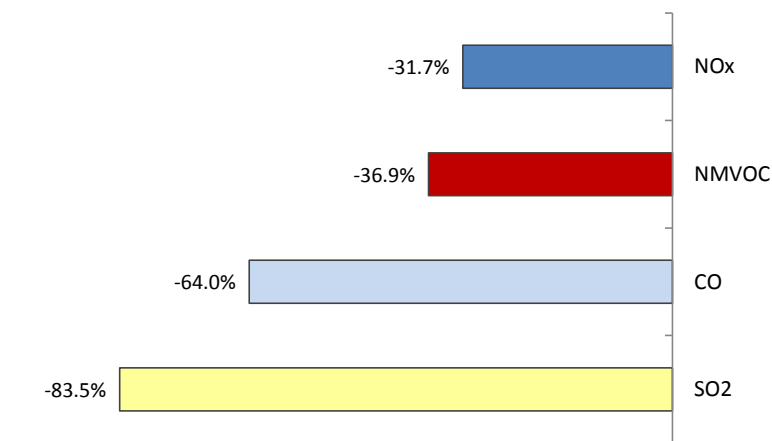
GHGs SOURCE AND SINK CATEGORIES	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change 1990-2013
CO <sub>2</sub> equivalent (Gg)													
1. Energy	64,875.35	59,825.67	61,808.24	64,396.11	59,765.01	56,677.89	55,040.97	53,987.86	48,936.23	48,075.74	46,426.27	44,473.76	7.5
2. Industrial processes and product use	6,856.97	6,889.53	7,506.62	7,526.80	7,332.13	7,929.42	7,869.03	6,222.34	6,466.69	5,712.97	5,656.36	5,862.26	11.7
3. Agriculture	7,746.19	7,256.51	7,436.92	7,335.53	7,232.15	7,325.25	7,303.42	7,139.72	7,058.06	7,017.07	7,081.92	7,132.85	-5.8
4. Land use, land-use change and forestry(5)	-8,940.76	1,575.47	-8,101.78	347.63	-9,106.55	-12,687.26	-14,135.53	-13,979.37	-11,391.37	-13,688.90	-10,154.88	-9,389.57	-626.7
5. Waste	8,175.08	8,537.52	8,656.31	8,639.73	8,497.90	8,382.38	7,847.16	7,684.90	7,878.01	8,138.36	7,791.37	7,602.69	22.3
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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

## 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 2.11 –Indirect GHG and SO<sub>x</sub> emissions: 1990-2013 variation



In 2013, all these gases emissions have decreased from 1990 levels: SO<sub>x</sub> -84 per cent, CO -64 per cent, NMVOC -37 per cent and NO<sub>x</sub> -32. per cent per cent per cent.

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 Industrial processes and Product use sector.

Within energy, transportation is responsible for the major share of NO<sub>x</sub>, emissions, approx. 47 per cent of 2013 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 stabilized 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 (-13 per cent reduction in the 1990-2013); and CO and NMVOC emissions also register reductions in the 1990-2013 period (more than -80 per cent).

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 46 per cent of the 2013 totals.

SO<sub>x</sub> emissions are mainly generated in the energy industry sector (approximately 36 per cent of total emissions in 2013) and combustion in manufacturing industries (approximately 34 per cent of total emissions in 2013), 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 1990-2013 shows in fact a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries and manufacturing industries -91 per cent and -77 per cent. Since 2007, SO<sub>x</sub> emissions from the energy industries registered a significant reduction (approximately -82 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: 1990-2013

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	
	(Gg)												
CO	822	836	875	856	837	827	815	777	765	737	687	605	
NOx	245	256	275	266	266	276	264	263	270	278	274	273	
NM VOC	275	281	284	275	276	271	273	273	273	267	256	246	
SO2	323	314	376	320	295	331	273	288	335	302	263	249	

Gas emissions	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change
	(Gg)												1990-2013
CO	587	550	521	480	446	420	398	372	360	337	306	296	-64.0
NOx	279	256	261	267	245	240	213	202	188	179	167	167	-31.7
NM VOC	244	231	225	215	208	205	196	185	185	179	173	174	-36.9
SO2	249	190	192	194	169	162	113	78	70	64	59	53	-83.5

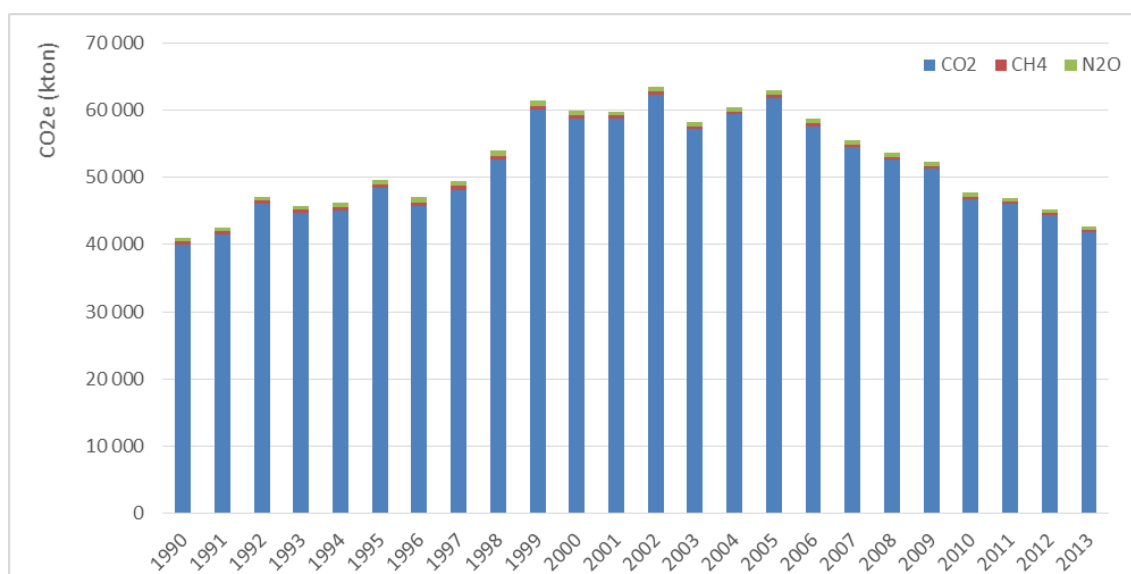
### 3 ENERGY (CRF 1.)

#### 3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting in 2013 for 68.1 per cent of total emissions of CO<sub>2</sub>e excluding LULUCF and including indirect CO<sub>2</sub>. Total emissions from this sector have increased 7.5 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.

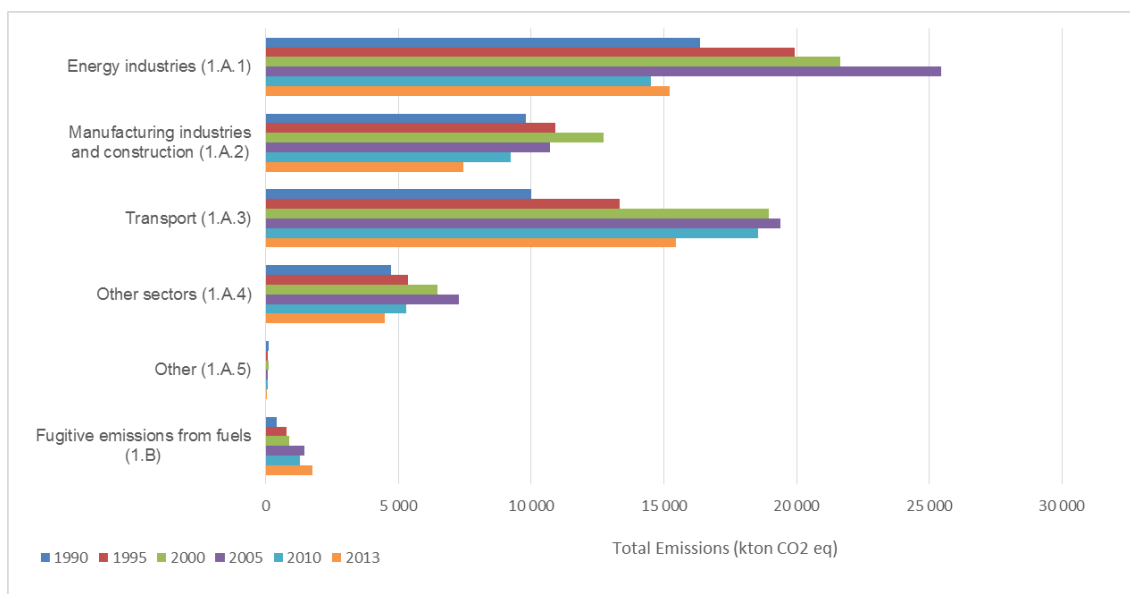
The relative importance of total CO<sub>2</sub>e emissions from the Energy sector has decreased, from 68.2 per cent in 1990 to 68.1 per cent in 2013. By far the most important gas emitted by this sector in 2013 is CO<sub>2</sub>, with 97.7 per cent of sector emissions expressed in CO<sub>2</sub>e.

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 2005, and the decrease in emission for all sector from 2005 to 2013 (except for 1B).

Figure 3-2 – Importance of CO<sub>2</sub>e emissions from sub-sectors in Energy sector in selected years – 1990, 1995, 2000, 2005, 2010 and 2013.



### 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, 23.9 per cent and 19.5 per cent of total GHG emissions excluding LULUCF in year 2013. 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 11.5 per cent of total emissions in 2012. GHG emissions from Refining of Petroleum Products is another relevant source with 3.9 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 the full time trend in Figure 3.3. 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 – 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 98.0 per cent of GHG emissions in 2013. CH<sub>4</sub> and N<sub>2</sub>O are minor sources, respectively 0.8 per cent and 1.2 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>2</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 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.

<sup>2</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.



### 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 3-4 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 88.5 per cent of 1B total emissions in 2013, emissions occurring as CH<sub>4</sub> represent 11.4 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 3-5.

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

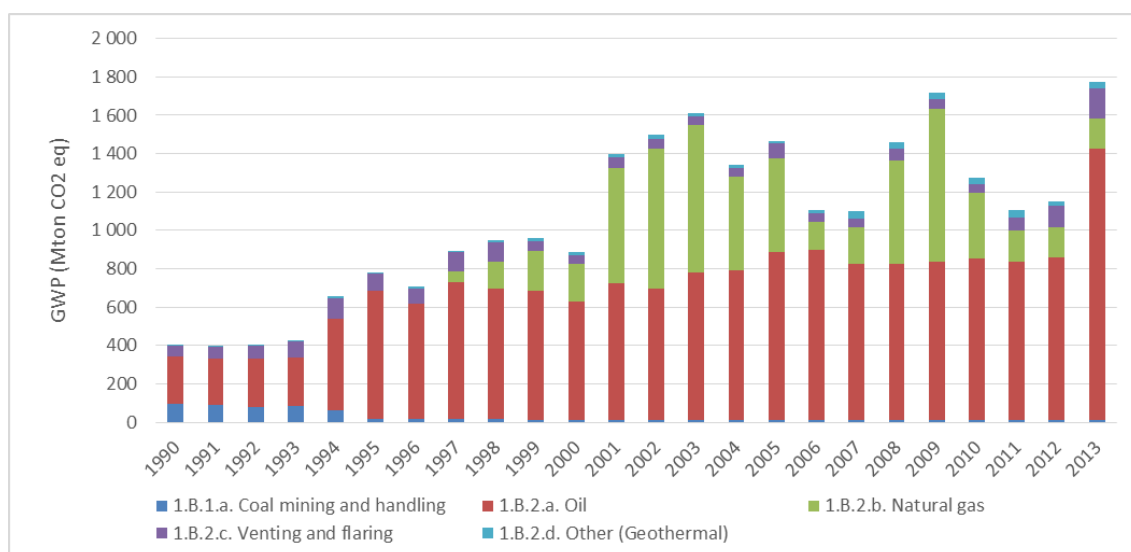
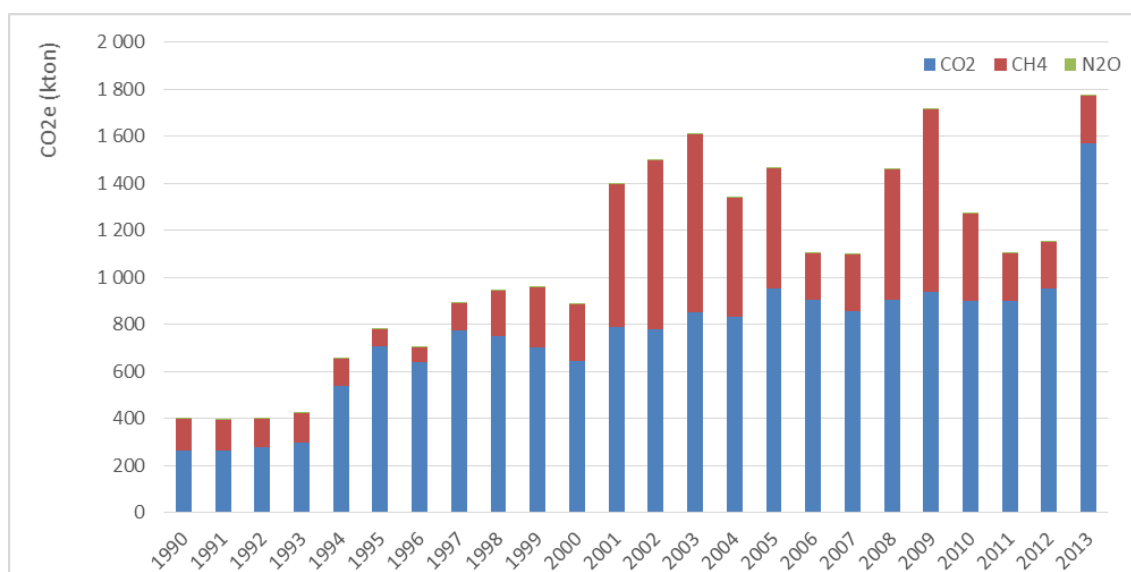


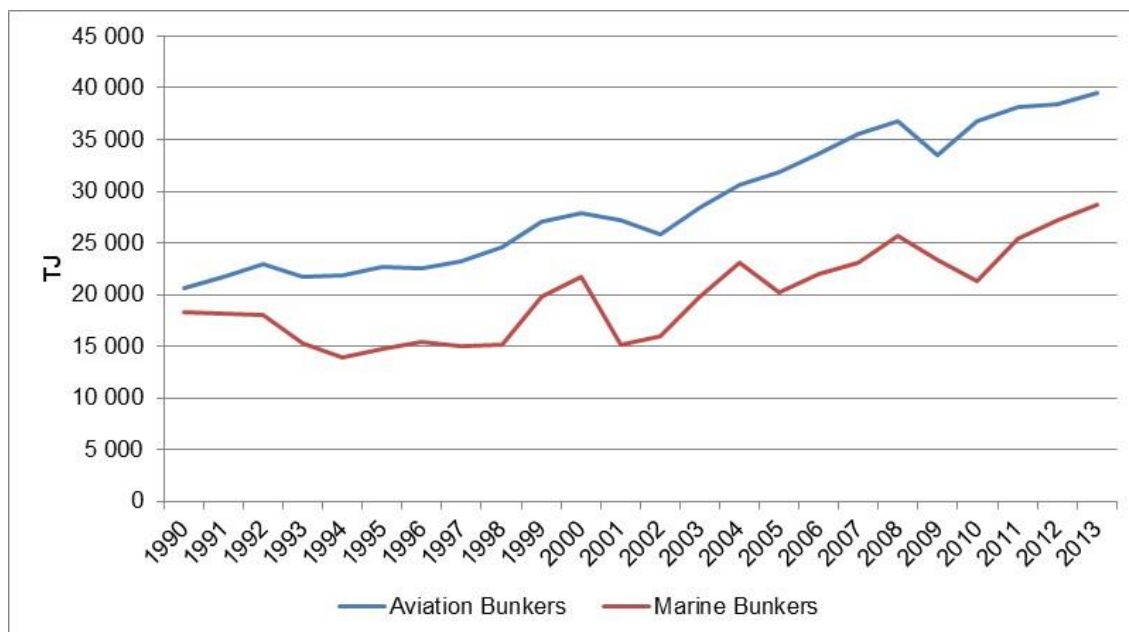
Figure 3-5 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>e, by GHG



## 3.2 International Bunker Fuels

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

Figure 3-6 – International navigation and aviation bunkers



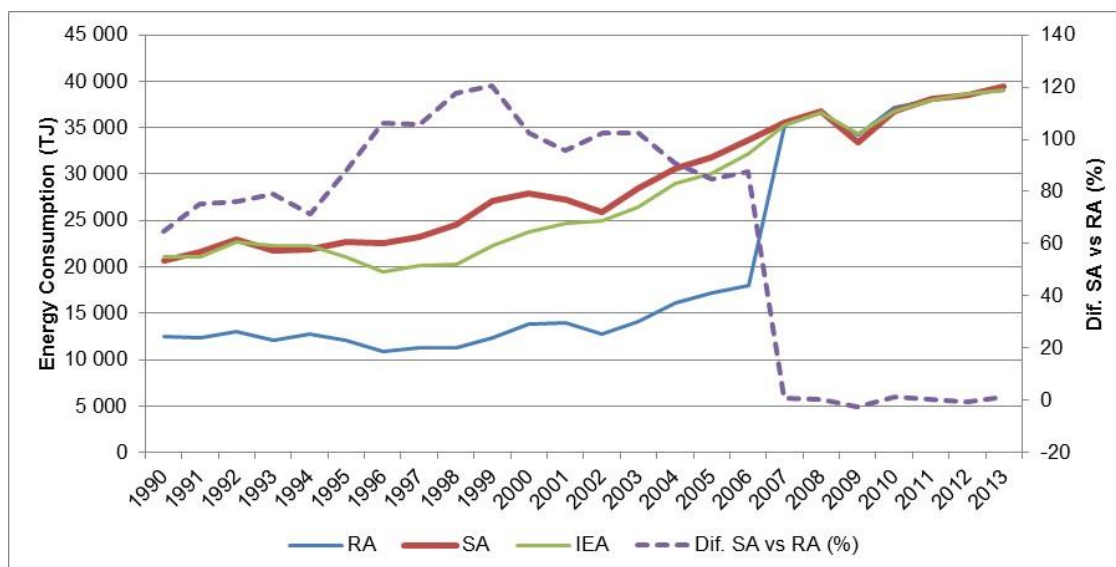
### 3.2.1 International aviation bunkers

The majority of jet fuel is used for international aviation. In 2013 the quantity of jet fuel for international aviation was about 89% 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.

Until 2006, the international aviation energy consumption data from the IEA differ to some extent from the DGEG fuel balance. This discrepancy results from a data treatment made by the IEA after receiving the information from the DGEG.

Figure 3-7 – International aviation bunkers

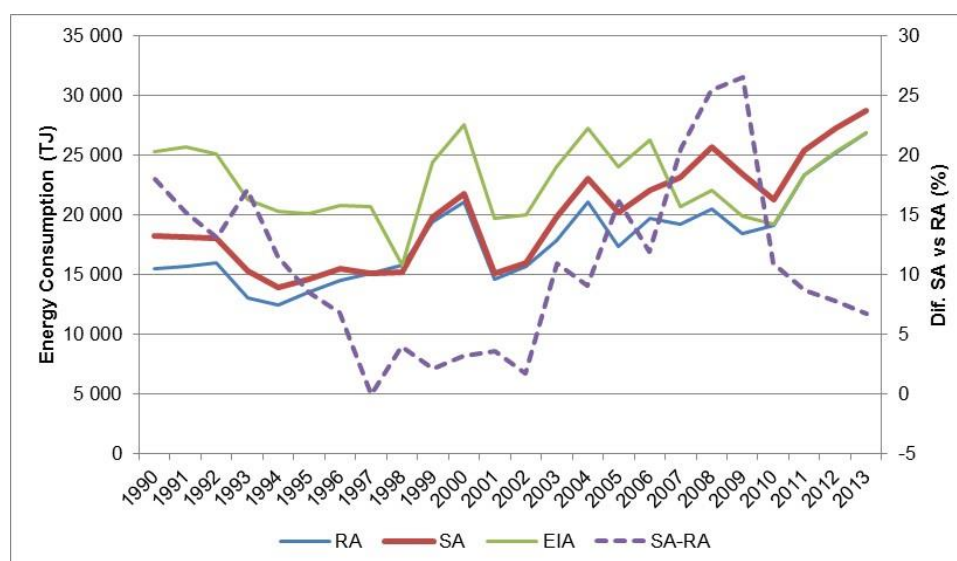


### 3.2.2 International marine bunkers

In 2013 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 3-8 – International marine bunkers



### 3.3 Category Sources

#### 3.3.1 Energy Industries (CRF 1.A.1.)

##### 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>3</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>4</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>3</sup> TER – Termoelétrica do Carregado

<sup>4</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

Power Plant	Location	Start	Situation	Fuel***	Power	Technology	Treatment of Gas Effluents****	Stack Height (m)	Comments
Tapada do Outeiro	Gondomar	1959	Deactivated (2003)	LIG + FO	150/100/47* MWe	Boiler + Steam Turbine.	ESP	60 (x3)	Lignite use stopped in 1997
Portgen (new Tapada do Outeiro)	Gondomar	1998	Working	NG + GO + LPG	990 (3x330) MWe	Combined Cycle.	DLE (only for one group)	60 (x3)	-
Soporgen	Lavos	2001	Working	NG	67 (44+23) MWe	Co-generation. Combined Cycle	DLE	50 (x2)	-
Energim	Alhambra	2002	Working	NG	43.7 MWe	Co-generation. Combined Cycle	-	31 (x1)	-
Mortágua	Mortágua	1999	Working	WW + NG + GO	30 MWe	Boiler + Steam Turbine.	ESP	-	-
Pêgo	Abrantes	1993	Working	HC + FO + GO + LPG	628 MWe	Boiler + Steam Turbine.	ESP + LNOX + WFGD + SCR	225 (x1)	WFGD after 2008 SCR after 2008
Pêgo (Elecgás)	Abrantes	2010	Working	NG + GO	800 MWe	Combined Cycle	DLE	80 (x2)	
Carregado	Alenquer	1968	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.

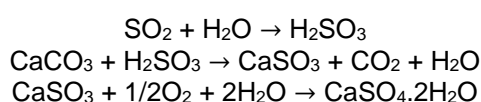
There has also been a change in the production structure since 1990, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase in the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was Orimulsion, that 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);

NMVOC - 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>NMVOC</sub> - Carbon content in NMVOC (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:

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

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

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>3</sub>Cons<sub>(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	Fac <sub>ox</sub> <sup>(ii)</sup> 0..1	FossilC %	CH <sub>4</sub> <sup>(i)</sup> g/GJ	N <sub>2</sub> O <sup>(i)</sup> g/GJ
Lignite	101.0	0.980	100	1.0	1.5
Hard Coal	92.0 <sup>(ii)</sup>	0.980	100	0.7 <sup>(ii)</sup>	1.4 <sup>(ii)</sup>
Fuel-oil	77.4	0.990	100	0.8	0.3
Orimulsion	77.0	0.990	100	3.0	0.6
Natural Gas	56.1	0.995	100	1.0	1.0 – 3.0
LPG	63.1	0.995	100	1.0	0.1
Biomass	112.0	1.000	0	11.0	7.0
Diesel	74.1	0.990	100	3.0	0.6

(i) IPCC (2006); (ii) IPCC (1997);

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

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	92.7 - 95.2	0.991 - 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>5</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	3.0	0.6
Azores	Diesel oil	74.1	0.990	100	3.0	0.6
Madeira	Fuel-oil	77.4	0.990	100	3.0	0.6
Madeira	Diesel oil	74.1	0.990	100	3.0	0.6
Madeira	LPG	63.1	0.995	100	1.0	0.1

(i) IPCC (2006); (ii) IPCC (1997)

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	0.1
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	1.0

(i) IPCC (2006); (ii) EEA (2002); (iii) EEA (2002) NG EF corrected to LPG

<sup>5</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>6</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>7</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>6</sup> The *Auto-controlo* program is a legal obligation for major emitters.

<sup>7</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.

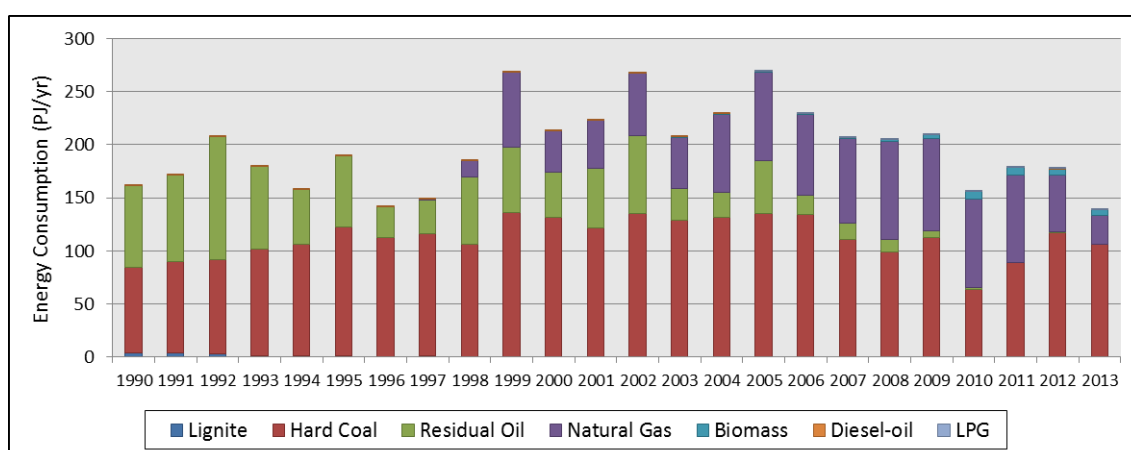
Table 3-7 – Low Heating Value per fuel type

Fuel	LHV/NCV	
Lignite	16.42 (15.57 - 17.02)	MJ/kg
Hard Coal	25.78 (24.51 - 27.23)	MJ/kg
Fuel-oil	40.24 (39.42 - 41.15)	MJ/kg
Orimulsion	28.00	MJ/kg
Diesel oil	43.30	MJ/kg
Natural Gas	38.3 (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 3-9.

Figure 3-9 – Trends of fuel consumption per fuel type



Not visible in the graph is the increase in biomass consumption (wood waste) from 1999 to 2013 (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 2013 due to Barreiro power plant deactivation. Also visible in the last four years it's the increase of energy consumption from Hard Coal, in 2013 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.

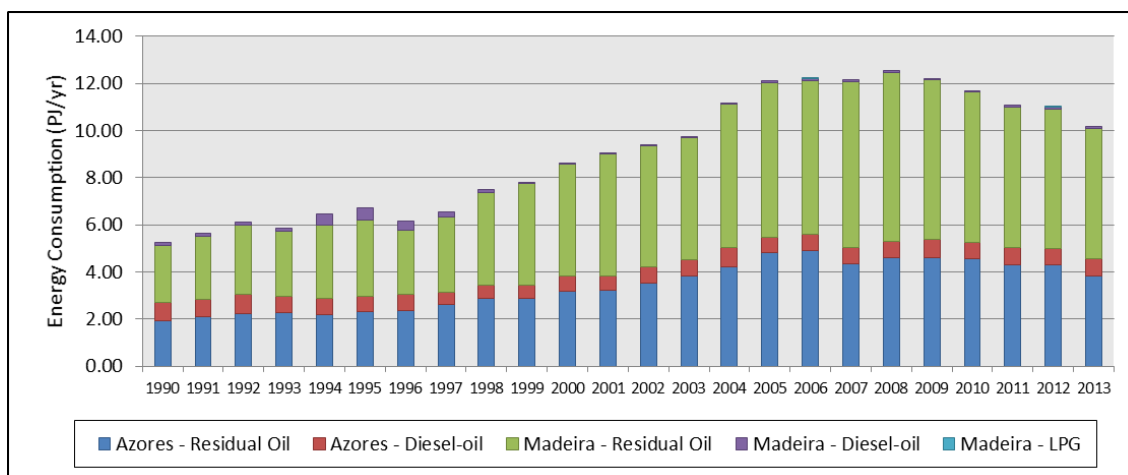
#### 3.3.1.1.4.3 Energy Plants in Azores and Madeira Autonomous Regions

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 3-10 – 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

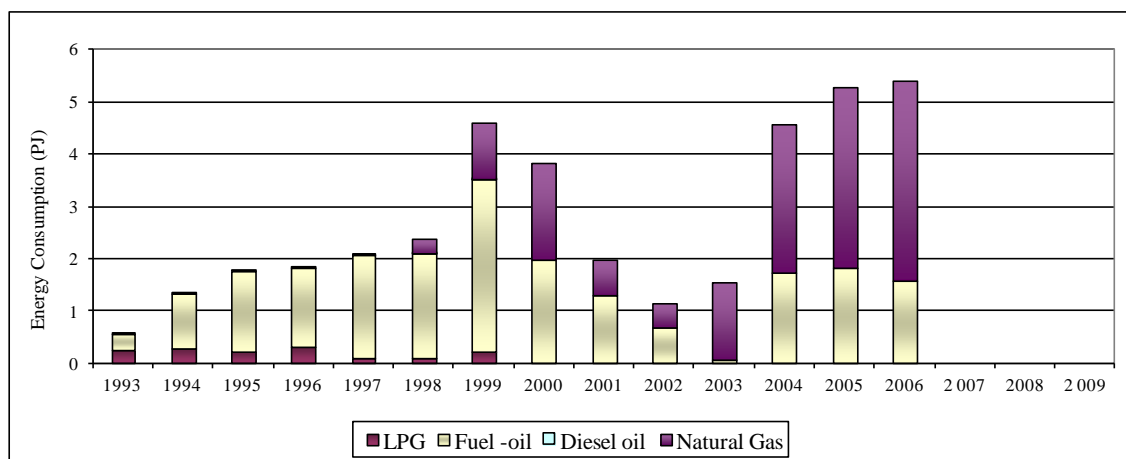
Region	Fuel type	LHV/NCV (MJ/kg)
Azores	Residual fuel oil	40.17
	Diesel oil	43.30
Madeira	Residual fuel oil	40.17
	Diesel oil	43.30
	LPG	47.28

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 3-11.

Figure 3-11 – 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> )

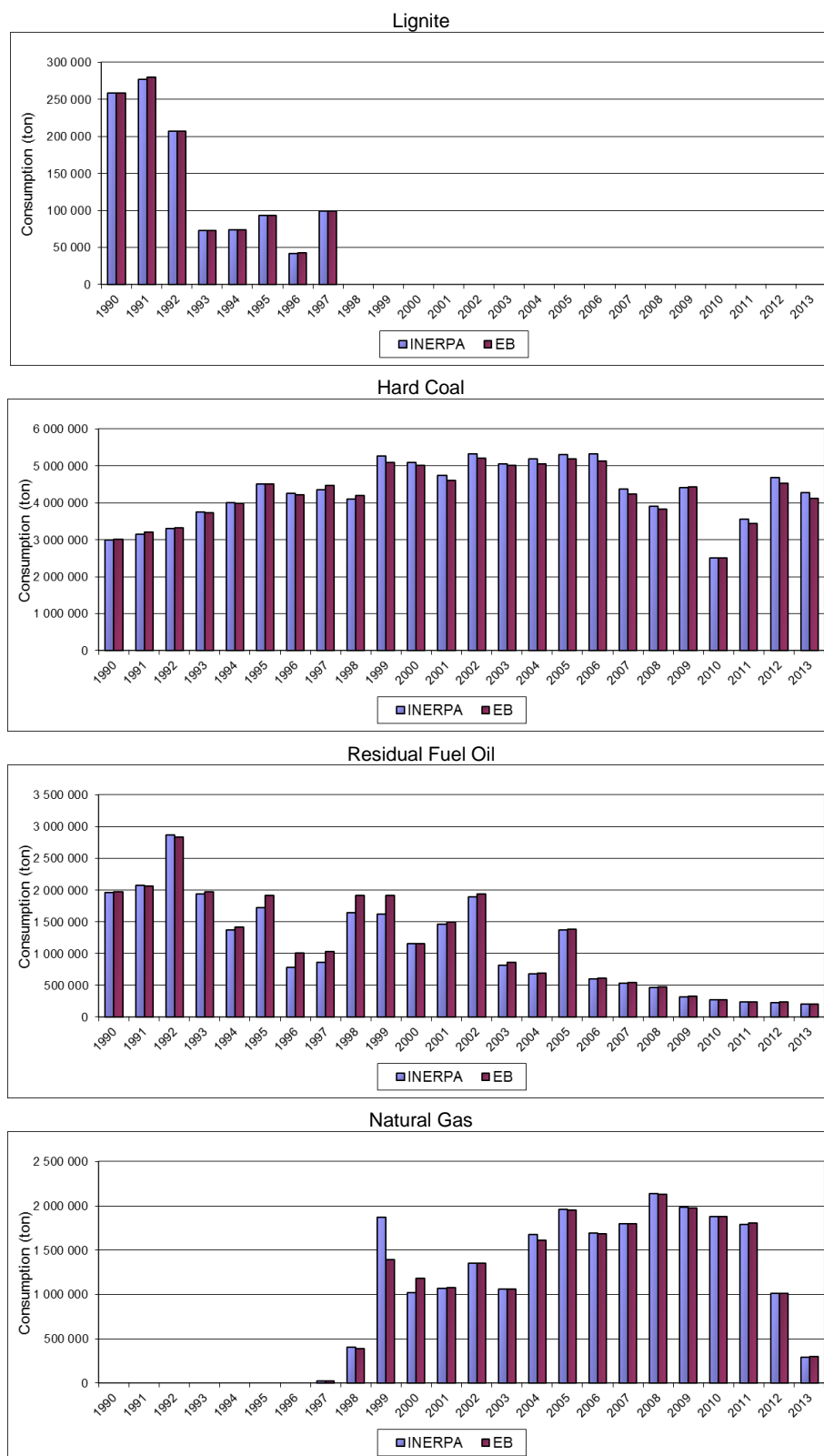
Source: The same as for the fuel consumption

#### 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.



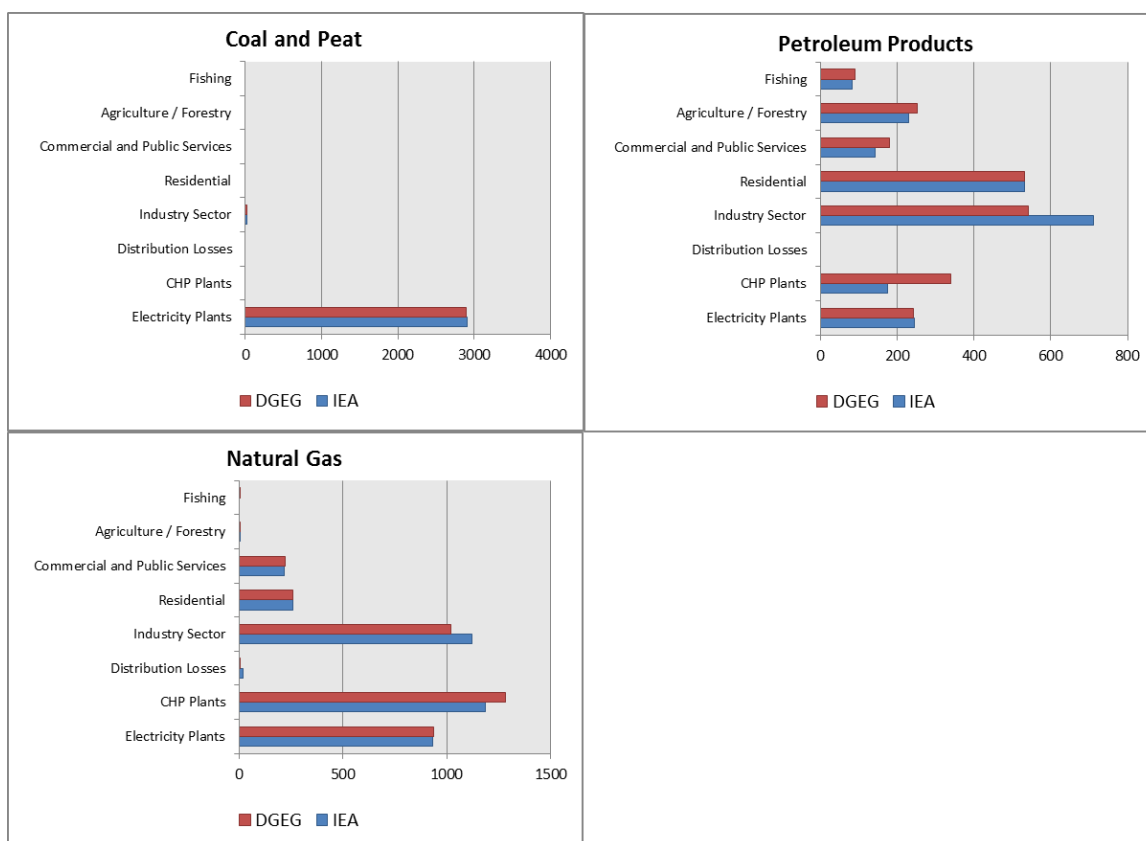
Figure 3-12 – Comparison of total fuel consumption in large power plants, between values used in the inventory (INERPA) and in the Energy Balance



### 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 3-13 – Comparison of fuel consumption between DGEG energy balance and IEA energy statistics



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

#### 3.3.1.1.5 Uncertainty Assessment

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

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

The uncertainty associated with the 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 collected from different information sources. There were also made general checks to the emission compilation spreadsheets from which resulted several small corrections to reported emission.

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

#### 3.3.1.1.7 Recalculations

No recalculations were made.

#### 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>8</sup> has set to streamline data collection for the inventories and for the EU-ETS<sup>9</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 (dessulphurization). This refinery unit has also units for the production of oils, lubricants and aromatics (Benzene, Hexane, toluene, xylene, etc). Sines refinery, installed in 1978 in southern Portugal, has also extensive transformation of crude products after atmospheric and vacuum distillation, which are subjected to Fluid Catalytic Cracking (FCC), platforming, hydrocracking, alquilation and asphalts blowing. The nowadays closed refinery at Lisbon performed mostly cracking. Refinery gas from this unit was used as combustible gas for domestic, service and industry use in Lisbon city.

Following the UNFCCC source categories classification, only emissions resulting from combustion in boilers and furnaces are included in this source sector. Process fugitive emissions, including combustion emissions realized in the FCC unit are included in CRF 1.B.2.a.4.

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.

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:

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<sup>8</sup> European Commission.

<sup>9</sup> European CO<sub>2</sub> trading scheme.

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

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

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

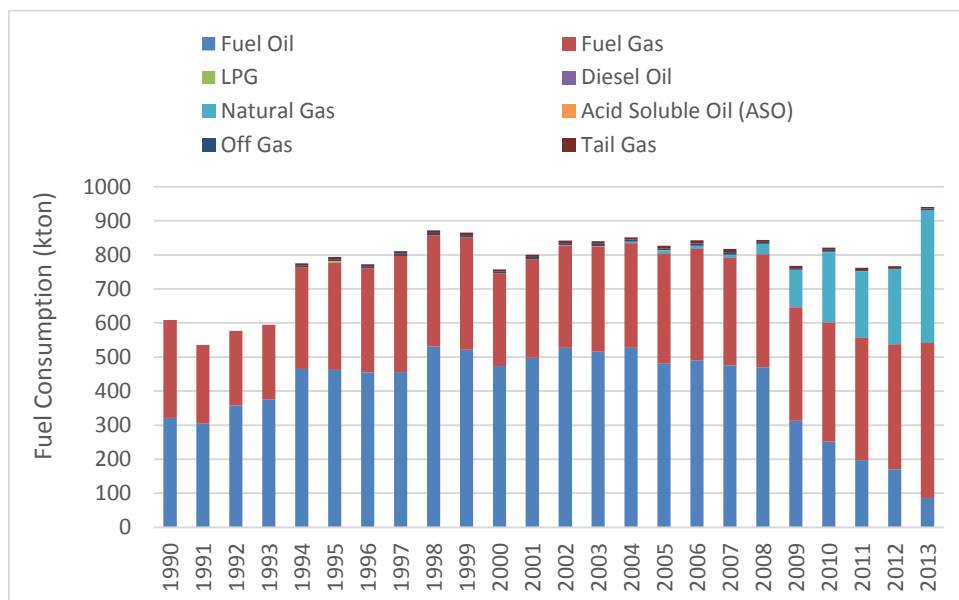
In 1990 there were three oil refining plants in Portugal: Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed and only two units remain now in operation.

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.

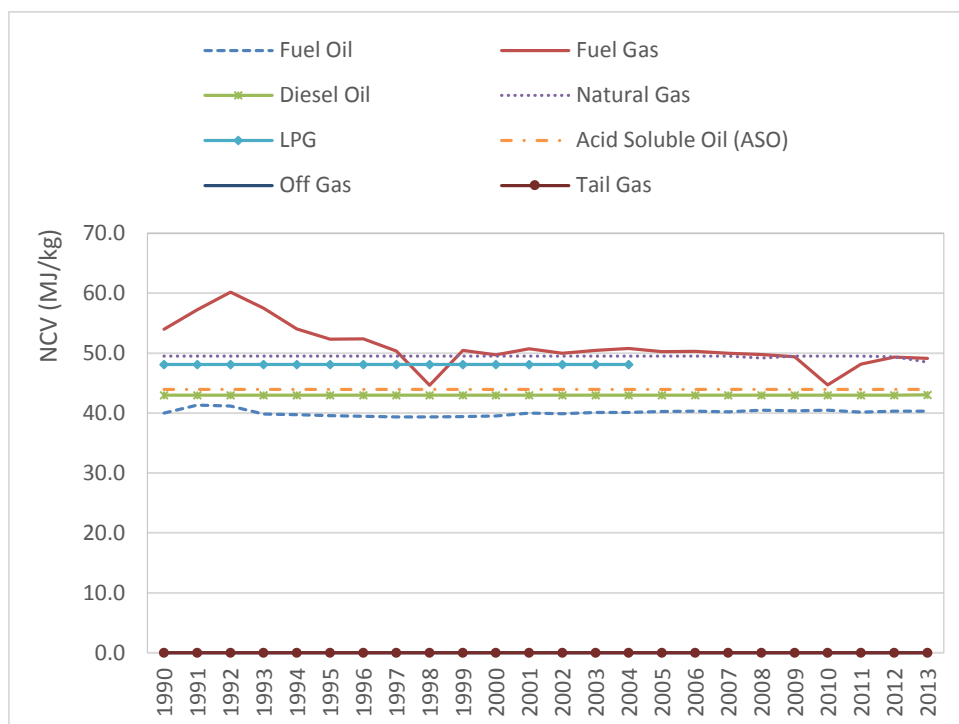
The quantities of fuel consumption from 1990 to 2004 were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in the next figure. Since 2005 data source is EU-ETS. The use of natural gas is becoming more relevant since 2008. In one of the refineries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

Figure 3-14 – 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 3-15 – 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.

### 3.3.2 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>10</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);

<sup>10</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).



FossilCO<sub>2(y)</sub> - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

EF<sub>CO<sub>2</sub></sub> – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

C<sub>Fossil</sub> - Percentage of carbon from fossil origin in fuel f (%);

Fac<sub>OX(f)</sub> – Oxidation factor for fuel f (ratio 0..1);

Energy<sub>Cons(u,f,y)</sub> - 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:

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

where:

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

EF<sub>(p,f,s,t)</sub> - 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<sub>(f,s,t)</sub> - 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<sub>(p)</sub> - Total emissions of pollutant p (ton/yr except CO<sub>2</sub> in kton);

EF<sub>(p)</sub> - 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>11</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;
- 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 2006-2013.

Table 3-11 – Incorporation rate of biodiesel (% toe/toe)

	1990-2005	2006	2007	2008	2009	2010	2011	2012	2013
Incorporation rate	0	1.33	2.50	2.43	4.34	6.42	6.42	6.66	6.49

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).

<sup>11</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.

#### 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

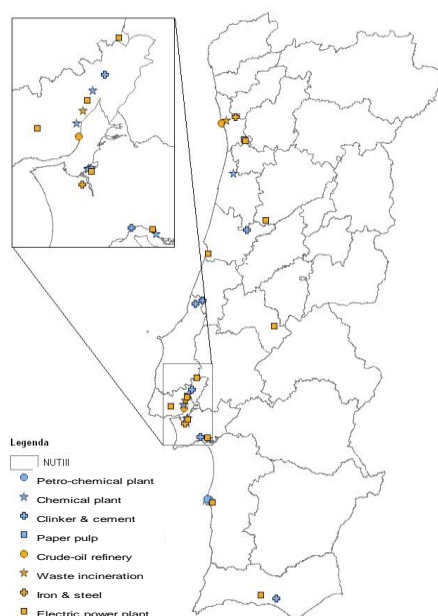
Data on fuel consumption for LPS were obtained from several sources:

- 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 3-16 – Distribution of Large Point Sources in continental Portugal<sup>12</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 3-17 and in the following formula set:

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

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  $\text{Nkm}^3/\text{yr}$ );

<sup>12</sup> This map includes also LPS that are accounted as process emissions (CRF 2).

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

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

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

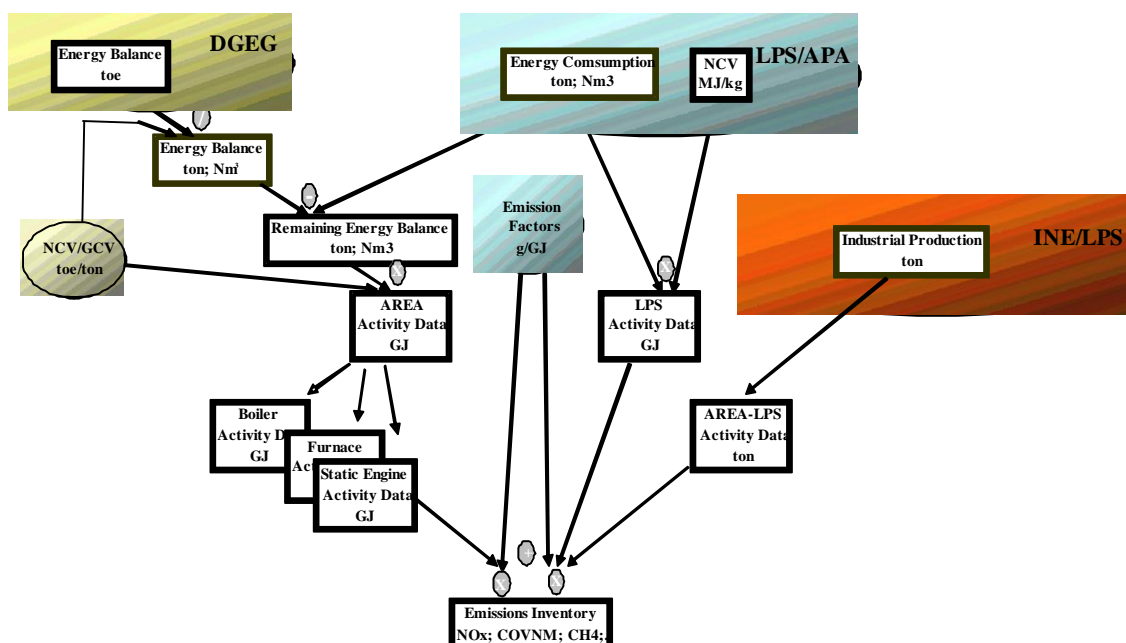
$Frac_{Equi(s,f)}$  – Fraction of consumption of fuel  $f$  in sector  $s$  that is used in equipment  $e$  (0..1);

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

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

$LHV_{AREA(f,s,e)}$  - Low Heating Value/ Net Calorific Value used in the Inventory for fuel  $f$  in equipment  $e$  for area sources (combustion in non LPS) (MJ/kg or MJ/ $Nm^3$ )<sup>13</sup>.

Figure 3-17 – General procedure for emissions estimate



Characterization of the combustion equipments was also taken from LPS sources, as well as some characteristics of the fuels. For the non LPS sources, or the remaining energy consumed that are accounted in the energy balances, there is no detailed information about in which equipment combustion takes place, apart from division between co-generation and non co-generation. Hence separation of fuel consumption among boilers, furnaces and engines was

<sup>13</sup> In most cases similar values to Energy Balance are used

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 2013 is presented in annex to the NIR.

Table 3-12 – Structure of the Portuguese Energy Balance. Sectoral categories

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

Table 3-13 – Structure of the Portuguese Energy Balance. Fuel categories

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

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

**Table 3-14 – Definition of Sectors in accordance with Economic Activity Classes**

Sub sector	EAC (1977)
Agriculture	111, 112, 113, 121, 122
Fisheries	130
Extractive Industry	220, 230, 290
Food processing, beverages and tobacco	311, 312, 313
Textile	321
Paper and paper pulp	341
Chemical and Plastic Industry	351, 352, 356
Ceramic	361, 3691
Glass	362
Cement	369 except 3691
Metallurgy	271, 272 except Iron 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 3-15 – 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 3-16 – Fuel consumption in the Iron and Steel Industry (GJ) (1/2)

Year	Steam Coal	Coke	LPG	Gasoline	Kerosene	Gas Oil	Biodiesel	Residual Oil	Natural Gas
1990	0	5 924 464	267 043	1 674	1 343	46 507	0	1 556 327	0
1991	0	4 929 998	277 793	1 100	1 631	30 249	0	475 008	0
1992	0	6 969 872	329 390	1 728	1 349	33 169	0	652 660	0
1993	0	7 213 502	401 813	1 049	1 788	38 054	0	1 379 123	0
1994	0	7 181 467	433 263	1 807	2 891	32 894	0	1 144 085	0
1995	0	7 015 624	448 733	1 463	2 916	31 708	0	1 328 397	0
1996	0	6 994 473	445 760	2 253	2 811	35 071	0	1 407 903	0
1997	0	6 966 758	257 124	235	3 295	11 459	0	1 397 035	198 634
1998	0	6 156 677	253 539	142	3 158	13 742	0	1 109 521	650 209
1999	0	6 554 761	220 907	177	2 927	13 956	0	1 275 827	698 155
2000	0	6 898 592	289 016	151	586	15 775	0	1 426 004	904 922
2001	0	1 582 713	347 834	3 404	0	16 185	0	1 296 929	958 775
2002	0	0	121 203	164	0	19 385	0	743 708	501 802
2003	0	0	3 567	46	0	28 116	0	645 604	804 587
2004	0	0	5 646	0	0	33 069	0	669 789	257 846
2005	0	0	4 751	0	0	32 860	0	716 823	443 129
2006	0	0	5 762	0	0	36 695	421	1 036 345	566 082
2007	266 699	0	5 336	0	0	44 543	971	671 225	870 797
2008	264 313	0	1 764	0	0	33 619	707	40 965	915 471
2009	153 279	0	1 588	0	84	34 446	1 301	0	644 915
2010	165 085	0	2 514	0	126	33 654	1 950	0	855 719
2011	182 335	0	2 734	0	0	38 902	2 284	0	932 096
2012	226 003	0	2 690	0	0	52 513	2 914	0	1 049 876
2013	250 622	0	3 792	0	0	58 648	3 047	0	1 079 920



Table 3-17 – Fuel consumption in the Iron and Steel Industry (GJ) (2/2)

Year	Coke oven gas	Blast furnace gas	Tar	Other
1990	418 816	1 460 387	341 000	40 348
1991	786 887	1 244 462	357 845	1 210
1992	902 551	2 079 874	388 263	0
1993	934 802	2 158 502	311 278	0
1994	899 612	1 981 945	227 791	0
1995	654 721	1 343 038	272 878	7 318
1996	872 538	1 306 474	198 643	5 608
1997	1 306 582	1 585 069	300 377	8 282
1998	1 330 096	1 396 770	251 115	7 196
1999	1 354 069	1 453 276	281 529	8 401
2000	1 447 382	1 746 675	333 420	10 255
2001	1 242 508	1 547 215	333 420	10 255
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	0	0	0	0
2008	0	0	0	0
2009	0	0	0	0
2010	0	0	0	0
2011	0	0	0	0
2012	0	0	0	0
2013	0	0	0	0

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 change has also caused substantial changes in the contribution of fuels, with the disappearance of coke oven gas and blast furnace gas, and the increase in the use of natural gas, that not only was used to replace the other by product gases, but also partially the use of LPG and residual fuel oil.

Figure 3-18 – Total Energy Consumption in the Iron and Steel Industry

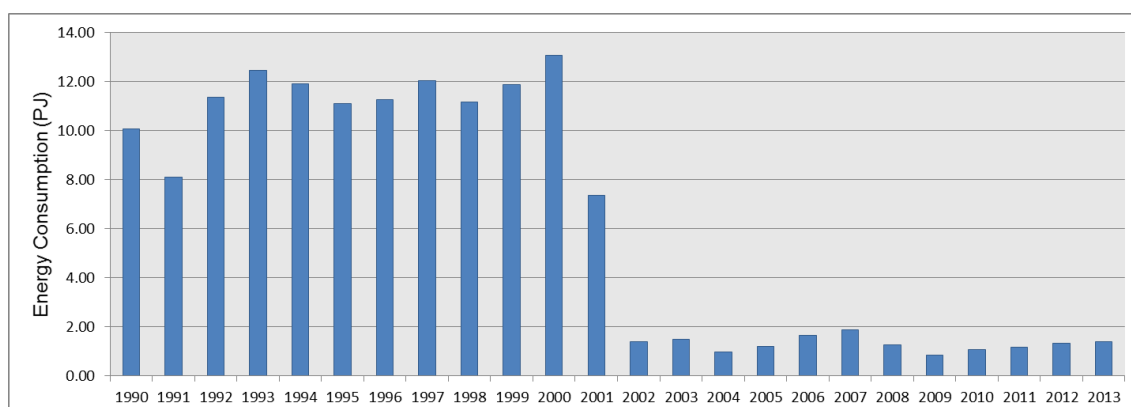
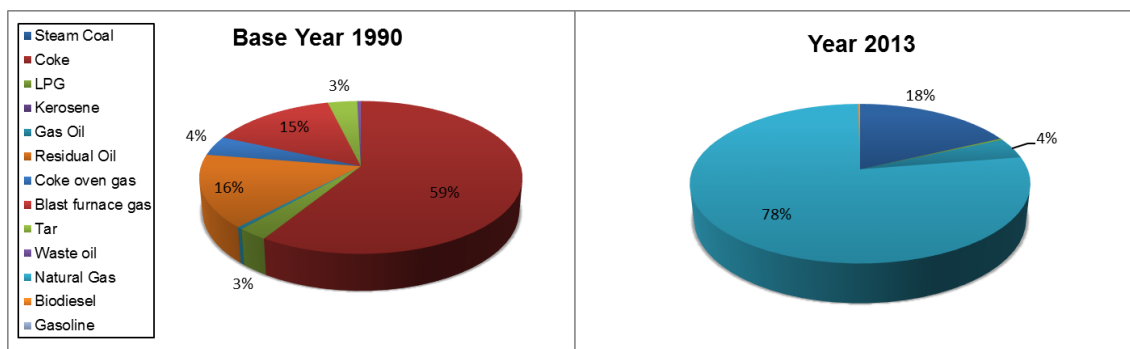


Figure 3-19 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2013



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 3-18 – 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 3-19 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ)**

<b>Year</b>	<b>Steam Coal</b>	<b>Coal Coke</b>	<b>LPG</b>	<b>Kerosene</b>	<b>Gas Oil</b>	<b>Residual Oil</b>	<b>Natural Gas</b>	<b>Wood</b>	<b>Biodiesel</b>
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	522 261	126	1 037
2012	0	0	119 783	0	12 642	0	516 107	0	902
2013	0	0	106 051	0	11 354	0	707 151	0	788

Table 3-20 – 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
2013	0	11 354	788

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. Since 2009 the consumption of natural gas has been increasing, and this fuel is in 2013 responsible for 84% of the consumption

Figure 3-20 – Total Energy Consumption in the Metallurgy Industry

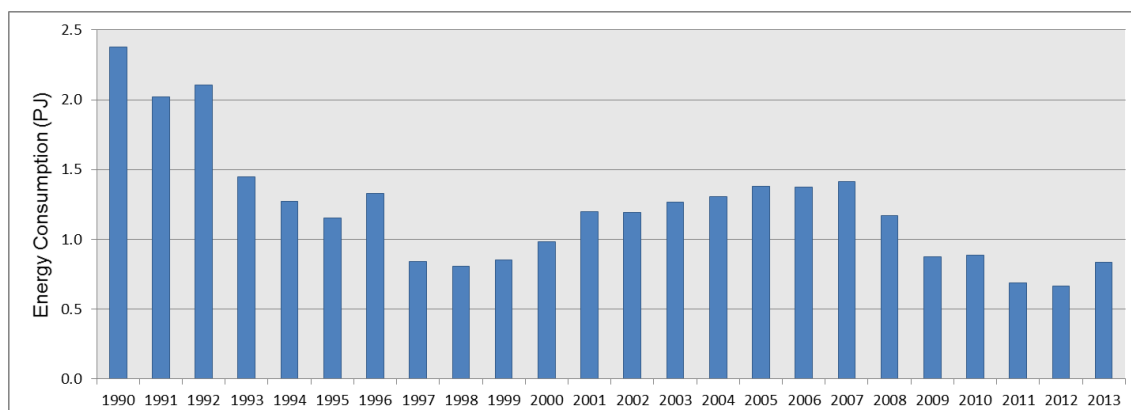
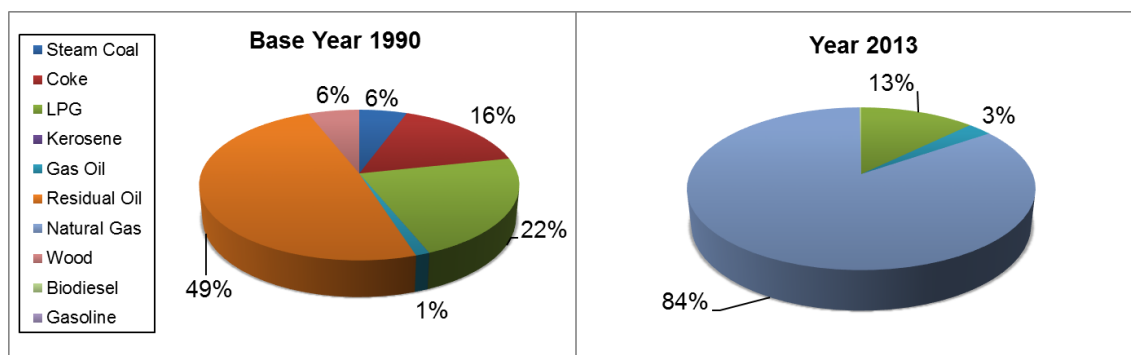


Figure 3-21 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2013



### 3.3.2.2.1.2.3 Chemical and Plastics Industry

Table 3-21 – 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>14</sup>	Gasoline	Flare Gas <sup>15</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>14</sup> Several streams of intermediate gaseous products and tail gases that are used as energy source

<sup>15</sup> Several streams of intermediate gaseous products and tail gases that are used as energy source

Table 3-22 - 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	7 958 616	4 393	6 853 637	2 241
2012	475 871	14 696	192 818	209	36 514	1 866 414	8 774 171	4 393	4 090 846	2 471
2013	496 512	32 448	92 597	84	45 669	868 450	9 051 323	4 393	6 964 579	8 772

Table 3-23 - 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
2013	0	47 898	134 772	8 772

Table 3-24 - 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
2013	369 281

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>16</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 3-22. The consumption of coke time series presents an anomalous value in 2000. When questioned about this, the energy balance team at DGEG could not justify the inconsistent value.

<sup>16</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 3-22 – Total Energy Consumption in the Chemical and Plastic Industry

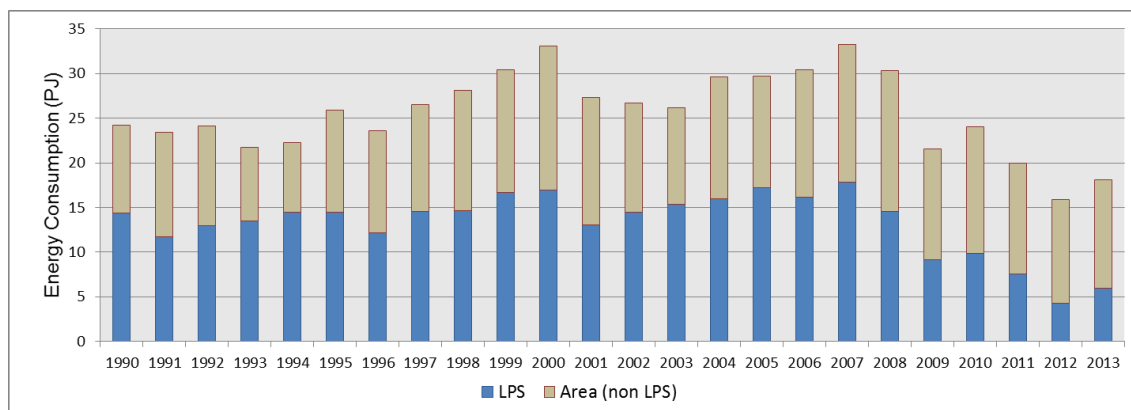
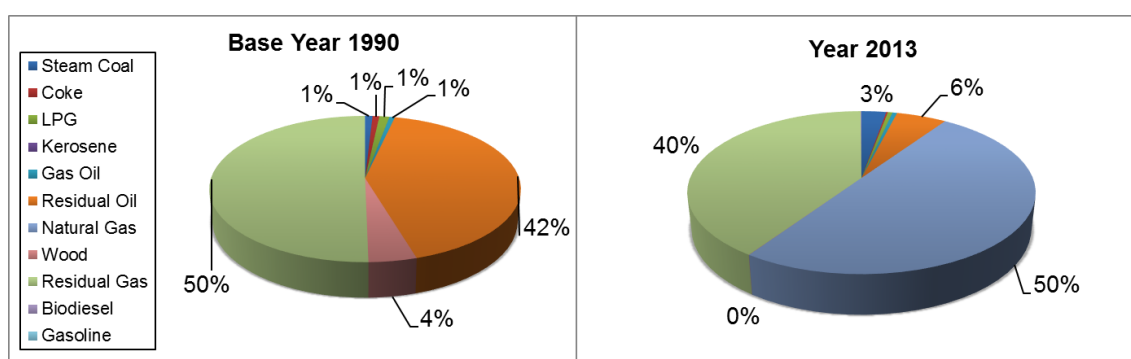


Figure 3-23 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2013



### 3.3.2.2.1.2.4 Paper and Paper Pulp Industry

Table 3-25 – 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 3-26 - 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>17</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	14 940 987	7 046 835	35 921 898	5 061
2012	81 893	251	72 470	2 243 532	14 525 191	8 236 715	37 011 268	5 161
2013	67 784	377	67 147	1 761 626	14 942 441	6 672 518	39 127 798	4 658

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal from 1990 to 2013 (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>17</sup> Wood waste includes methanol, NCG, tall-oil, biogas and gasified biomass.

Table 3-27 - 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	72 165	0	5 161
2013	0	67 101	0	4 658

Figure 3-24 – Total Energy Consumption in the Paper and Paper Pulp Industry

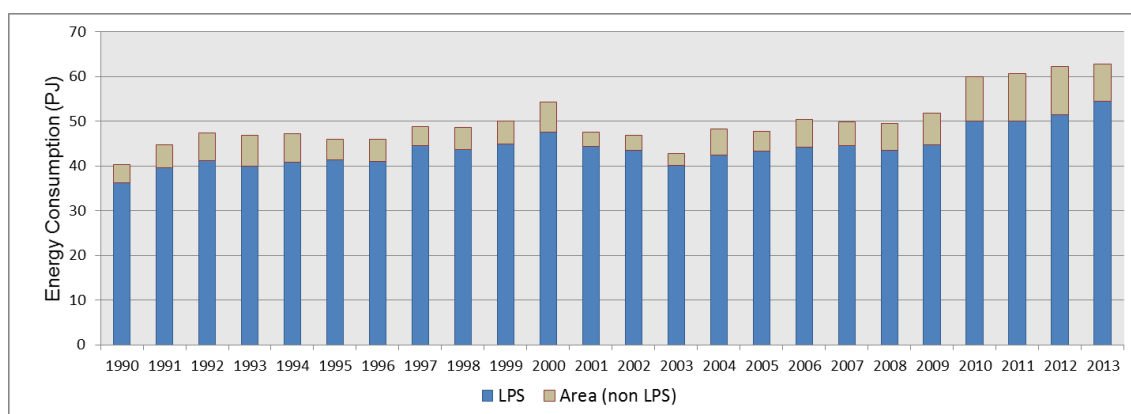
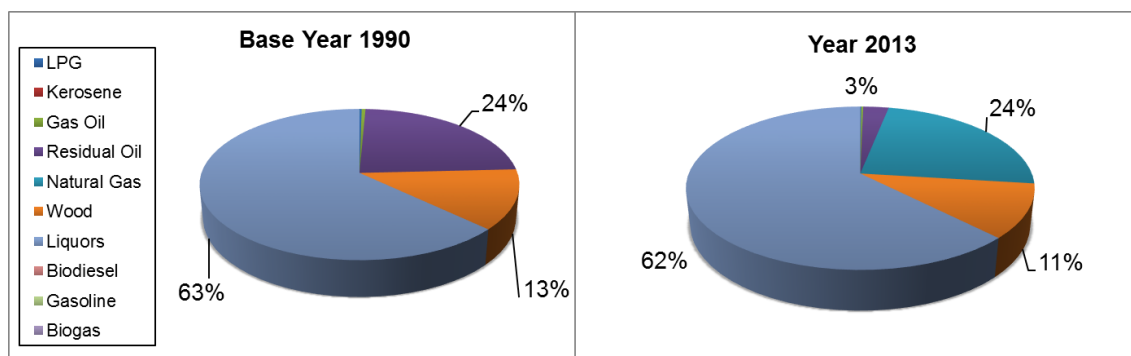


Figure 3-25 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2013



### 3.3.2.2.1.2.5 Food Processing, Beverages and Tobacco Industries

Table 3-28 – 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 3-29 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

Year	Steam Coal	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas	Wood	Biodiesel
1990	12 416	906 272	13 318	545 639	8 902 333	0	3 981 464	0
1991	6 641	1 043 157	6 716	590 698	9 657 033	0	3 911 799	0
1992	432	1 147 678	7 586	683 319	9 558 680	0	3 852 887	0
1993	0	1 217 112	7 662	688 426	9 014 368	0	3 775 816	0
1994	0	1 363 652	6 223	728 505	8 945 629	0	3 775 858	0
1995	0	1 462 813	5 078	735 940	9 399 512	0	3 775 858	0
1996	0	1 626 766	2 130	798 673	9 403 558	0	4 006 695	0
1997	0	1 965 948	4 595	747 839	11 124	3 872	4 006 695	0
1998	0	1 944 223	5 540	720 126	11 360	393 125	4 015 170	0
1999	0	1 899 755	6 938	813 351	10 595	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	7 537 580	422 385	31 649
2012	0	962 872	167	469 520	3 850 073	7 829 735	422 385	32 554
2013	0	990 547	84	447 363	2 336 404	9 182 992	435 607	30 282

Table 3-30 – 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	1 290	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
2013	0	447 363	17 043	30 282

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

Figure 3-26 – Total Energy Consumption in the Food Processing, Beverages and Tobacco Industry

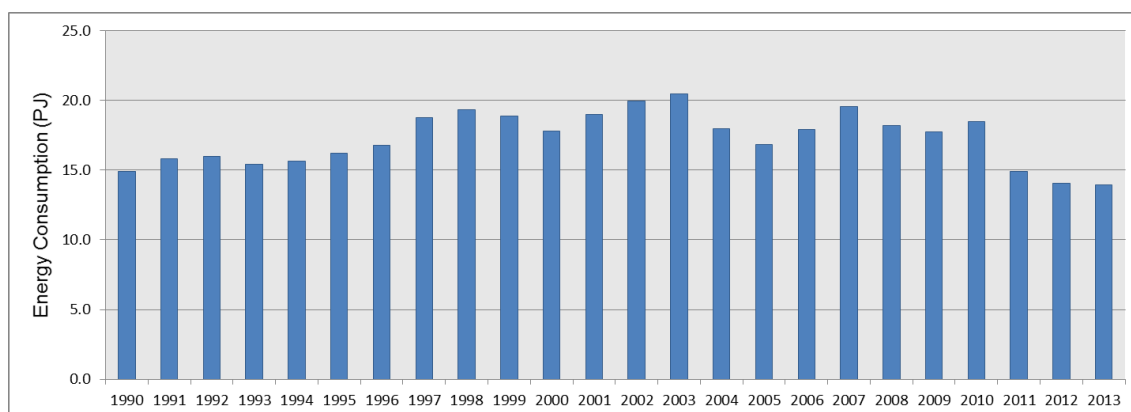
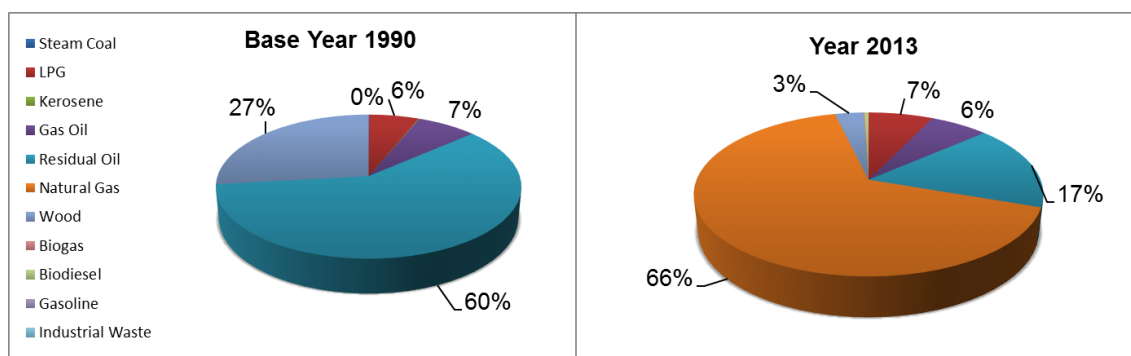


Figure 3-27 - Fuel consumption per fuel type in the Food Processing, Beverages and Tobacco Industries in 1990 and 2013



### 3.3.2.2.1.2.6 Textile Industry

Table 3-31 – 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 3-32 – 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	8 039 451	28 828	375
2012	126 524	0	9 579	1 257 484	9 464 387	17 657	386
2013	115 806	0	6 698	344 568	9 868 036	17 657	357

Table 3-33 – 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	9 579	386
2013	0	6 698	357

Figure 3-28 – Total Energy Consumption in the Textile Industry

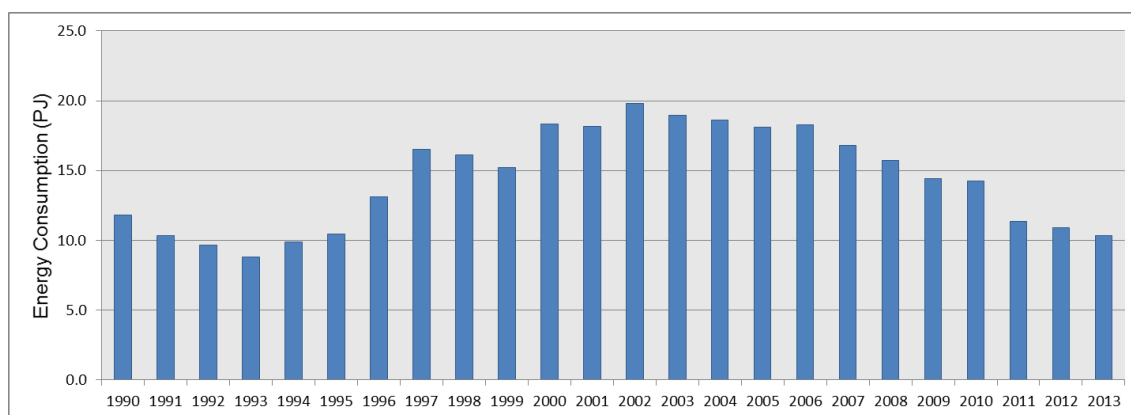
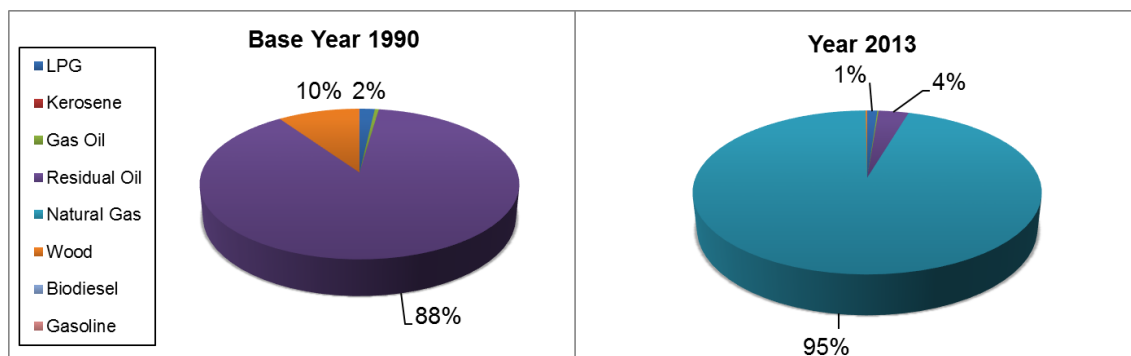




Figure 3-29 – Fuel consumption per fuel type in Textile Industry in 1990 and 2013



### 3.3.2.2.1.2.7 Ceramic Industry

Table 3-34 – 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 3-35 - 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	11 910 316	763 515	3 755
2012	0	398 660	167 429	167	41 347	158 216	10 471 438	1 046 569	2 949
2013	0	366 911	138 080	209	35 177	43 668	9 250 232	678 494	2 441

Table 3-36 – 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
2013	0	35 177	2 441

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 3-30 – Total Energy Consumption in the Ceramic Industry

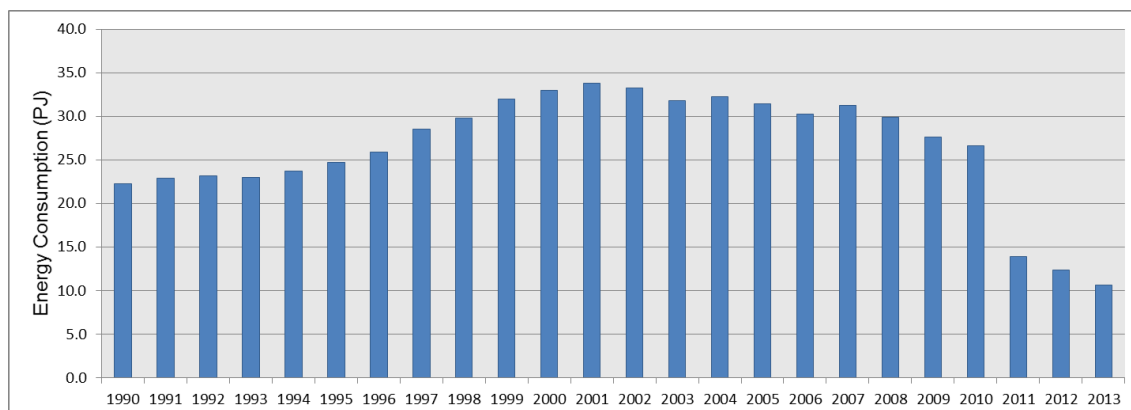
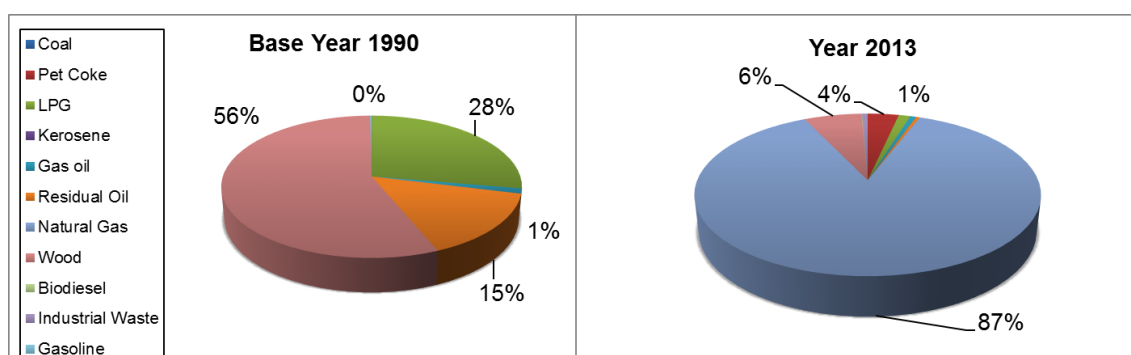


Figure 3-31 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2013



### 3.3.2.2.1.2.8 Glass Industry

Table 3-37 – 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 3-38 – 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	7 621 986	0	1 668
2012	7 877	0	15 223	0	23 702	0	8 259 840	0	1 667
2013	8 871	0	6 574	0	20 479	0	8 365 822	0	1 396

Table 3-39 – 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
2013	0	19 776	1 396

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 3-32 – Total Energy Consumption in the Glass Industry

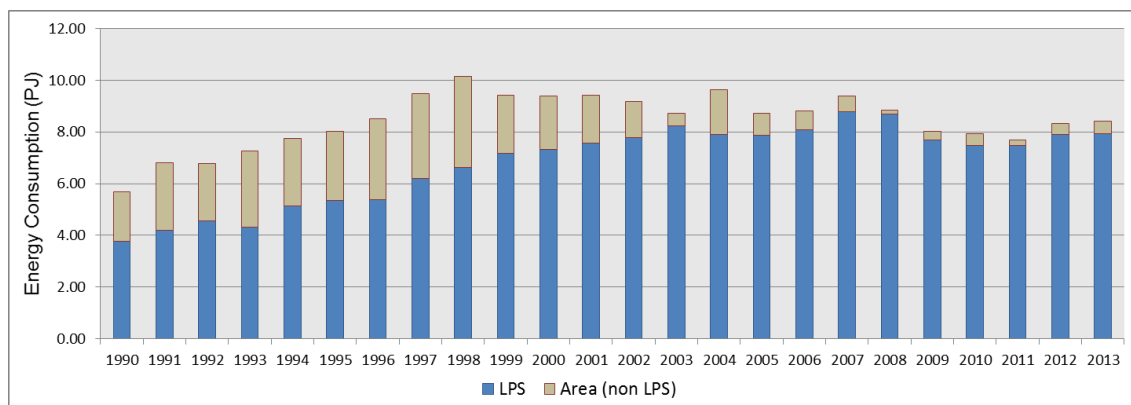
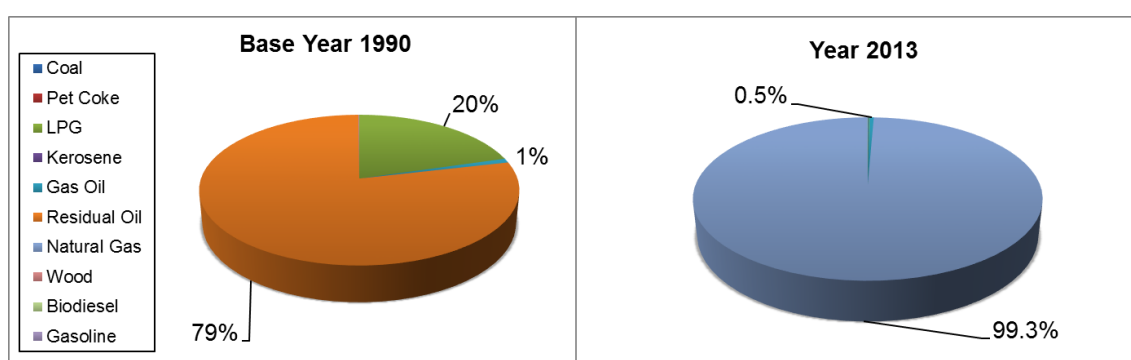


Figure 3-33 – Fuel consumption per fuel type in Glass Industry in 1990 and 2013



#### 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 3-40 – 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 3-34 – Total Energy Consumption in the Cement Industry

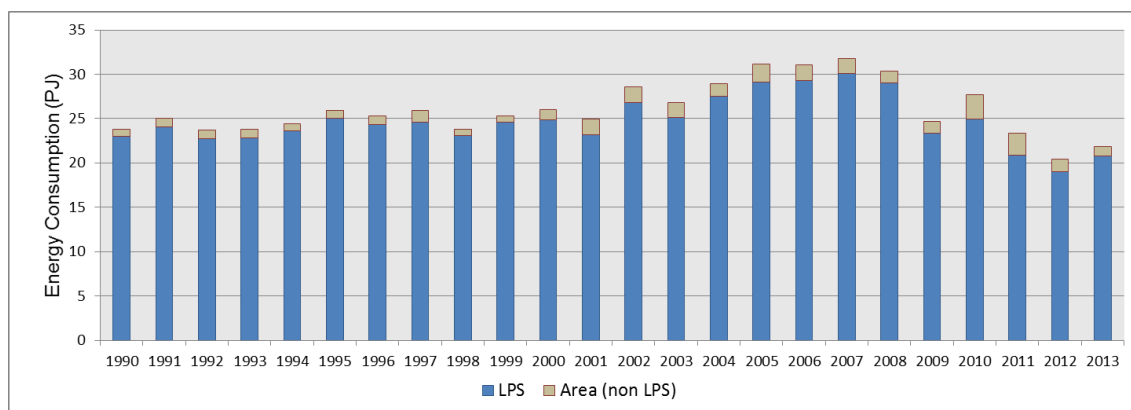
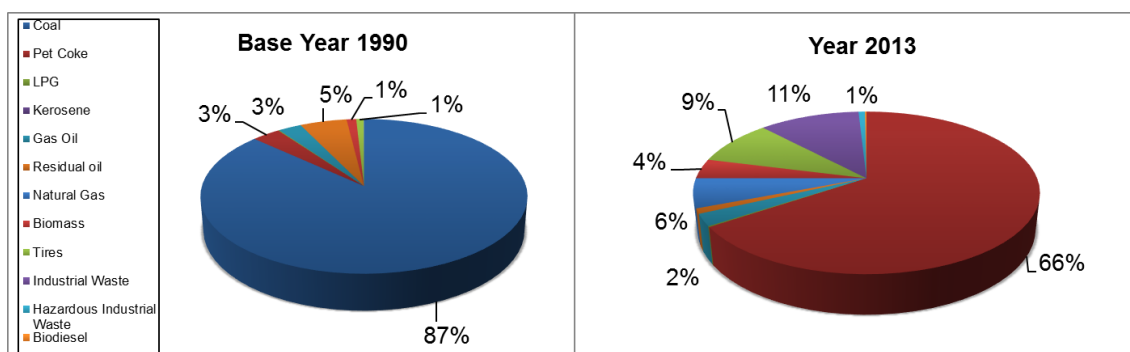




Figure 3-35 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2013



### 3.3.2.2.1.2.10 Clothing, Shoes and Leather Industries

Table 3-41 – 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 3-42 – 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	1 392 163	0	270 921	0
1993	206 219	7	24 420	1 826 146	0	265 523	0
1994	222 108	0	25 347	1 336 452	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	765 598	24 686	549
2012	127 445	0	8 620	63 638	853 521	36 360	591
2013	116 308	0	35 495	45 510	838 239	36 360	2 437

Table 3-43 – 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
2013	0	35 495	2 437

Figure 3-36 – Total Energy Consumption in the Clothing, Shoes and Leather Industries

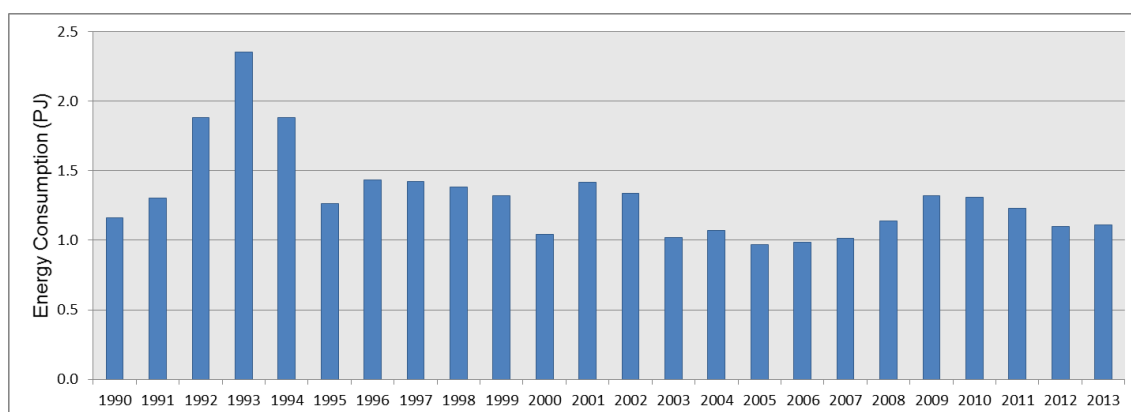
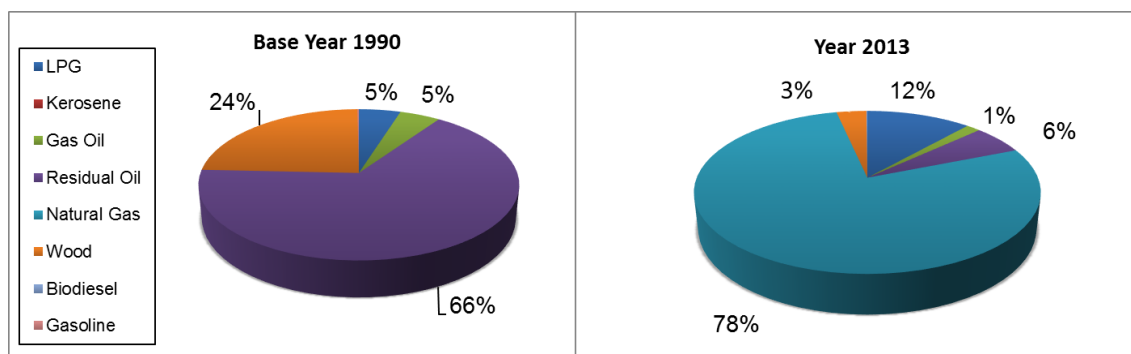


Figure 3-37 - Fuel consumption per fuel type in the Clothing, Shoes and Leather Industries in 1990 and 2013



### 3.3.2.2.1.2.11 Wood Industry

Table 3-44 – 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 3-45 – 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	393 350	2 558 452	7 791
2012	60 499	0	105 721	387 817	375 095	2 160 084	7 007
2013	58 908	0	92 407	413 272	460 255	1 801 213	5 981

Table 3-46 – 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
2013	0	92 407	5 981

Although total consumption of energy from combustion has not changed much from 1990 to 2013, there is not a constant trend along periods, but instead oscillations along the period. The share of fuels has been maintained fairly constant, dominated by the use of residual fuel oil and biomass, and the introduction of natural gas was less important than for other sectors.

Figure 3-38 – Total Energy Consumption in the Wood Industry

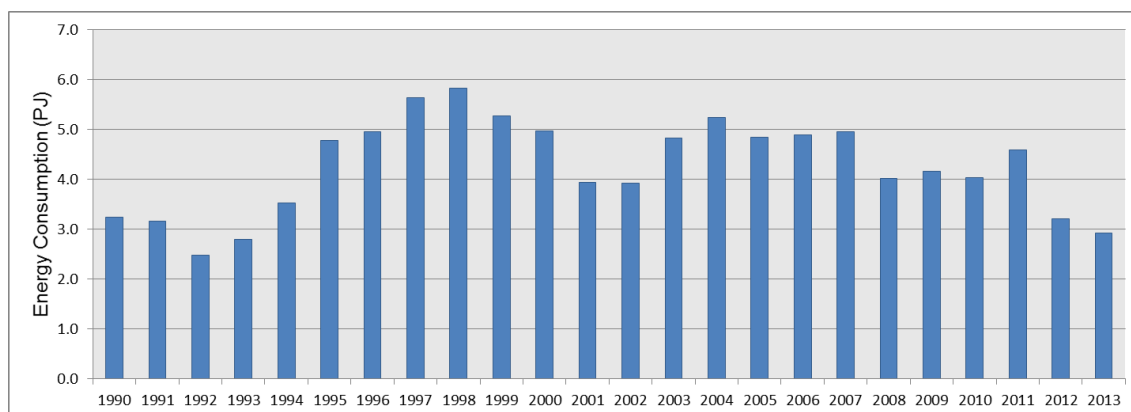
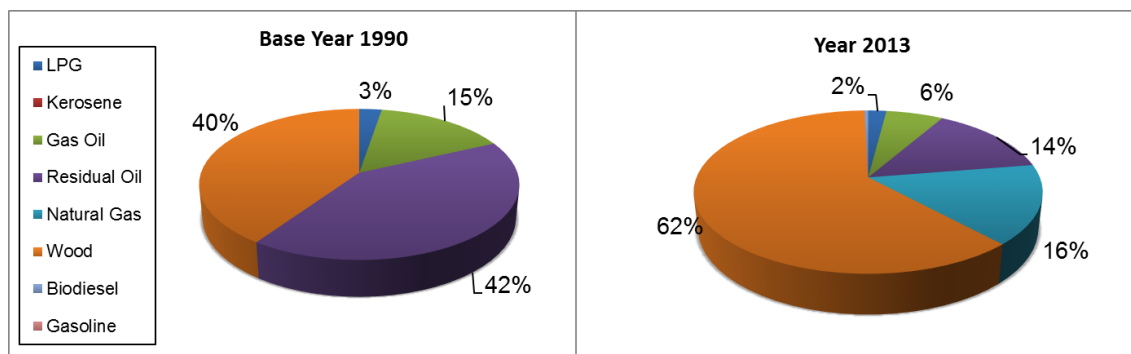


Figure 3-39 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2013



### 3.3.2.2.1.2 Rubber Industry

Table 3-47 – 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 3-48 – 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	0
2007	11 932	42	3 131	11 430	475 620	0	99 394
2008	6 113	0	3 122	17 919	681 025	0	105 632
2009	3 140	42	1 957	21 352	672 819	0	118 318
2010	4 145	42	0	20 682	733 695	0	59 620
2011	4 731	0	0	9 001	774 181	28 996	91 606
2012	4 647	42	0	6 699	826 307	26 151	170 569
2013	4 940	0	0	1 465	858 378	26 151	144 443



Table 3-49 – 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
2013	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 3-40 – Total Energy Consumption in the Rubber Industry

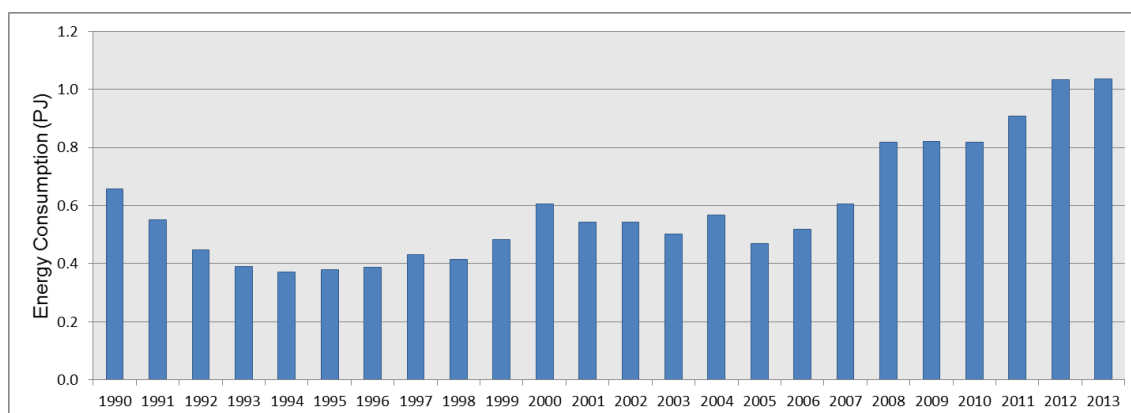
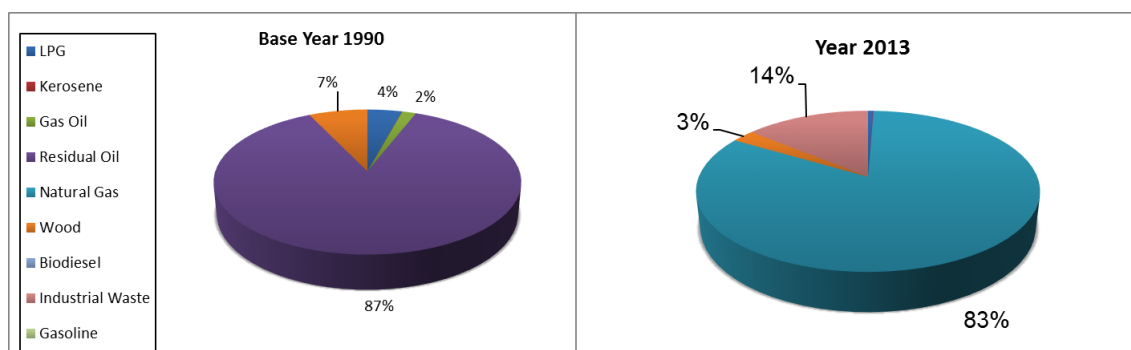


Figure 3-41 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2013



### 3.3.2.2.1.2.13 Manufacturing of Machines and Metallic Equipments Industry

Table 3-50 – 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 3-51– 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	2 167 464	5 021	4 742
2012	757 763	126	84 386	13 523	2 107 928	1 715	5 754
2013	692 449	84	98 939	4 815	2 260 160	1 715	6 713

Table 3-52 – 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	84 386	5 754
2013	1 298	98 939	6 713

Figure 3-42 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry

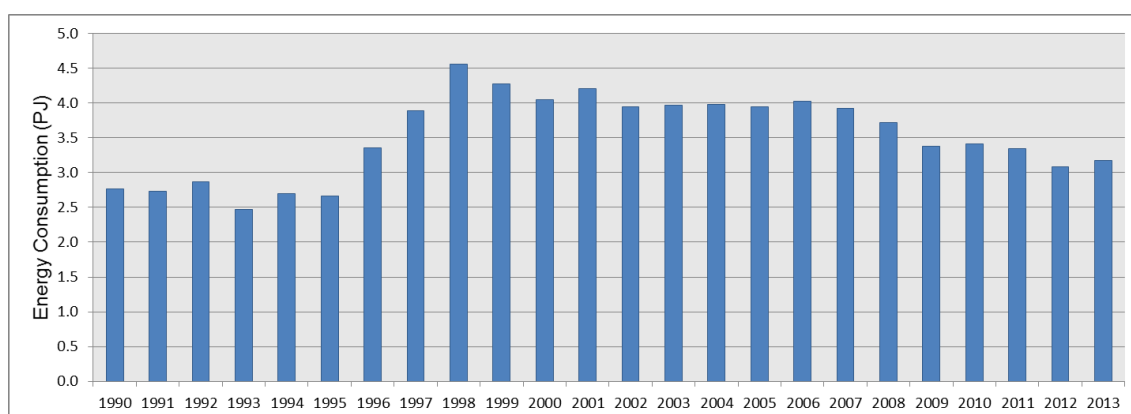
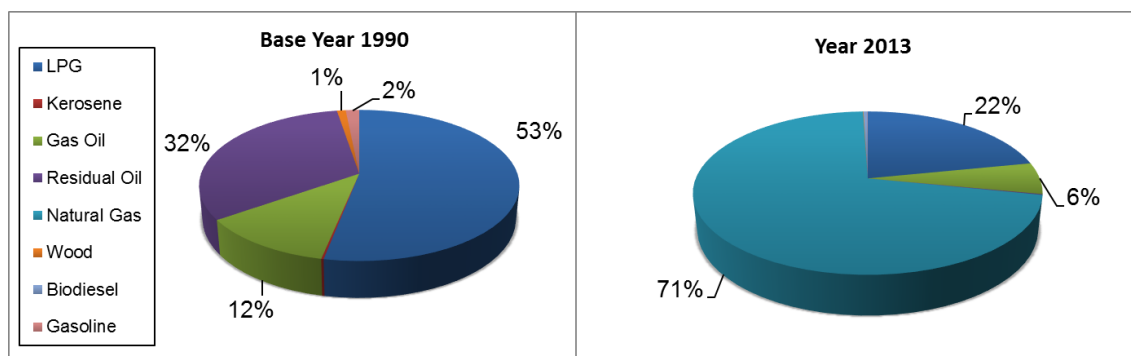


Figure 3-43 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2013



#### 3.3.2.2.1.2.14 Other Transformation Industry

Table 3-53 – 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 3-54 – 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	-19 560	79 004	0	379 282	34 979	-536
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	500 113	144 854	28 514
2012	0	84 070	0	373 702	31 903	0	697 395	8 954	26 509
2013	0	77 455	0	340 523	47 561	0	383 427	15 774	23 557

Table 3-55 – 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	-19 560	0	-536
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	373 702	44 742	26 509
2013	0	340 523	41 855	23 557

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

Figure 3-44 – Total Energy Consumption in Other Transformation Industry

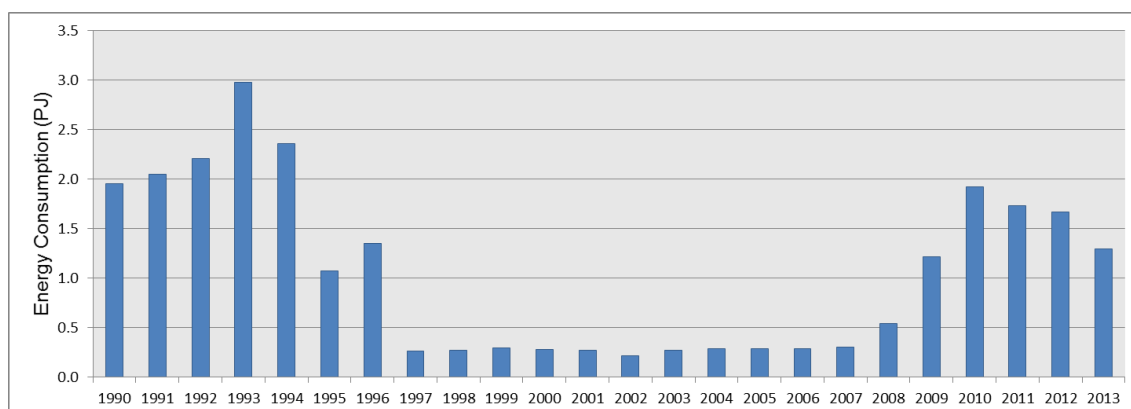
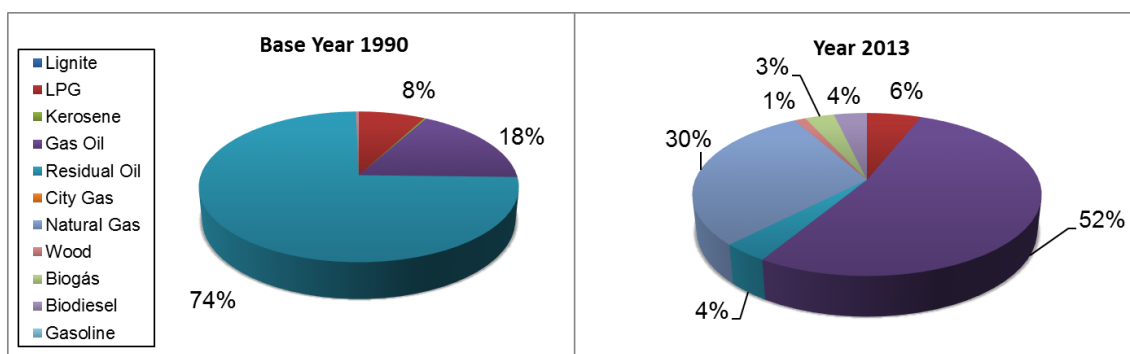


Figure 3-45 – Fuel consumption per fuel type in Other Transformation Industry in 1990 and 2013



### 3.3.2.2.1.2.15 Extractive Industry

Table 3-56 – 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 3-57 – Fuel consumption in the Extractive Industry – Boilers and Furnaces (GJ)

Year	Lignite	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biodiesel
1990	2 402	77 429	0	1 929	496 778	119 777	0	0
1991	2 608	78 386	0	14	537 249	269 792	0	0
1992	1 904	77 081	17	1 274	612 710	169 204	0	0
1993	1 184	86 266	24	605	640 432	87 648	0	0
1994	412	103 715	8	625	481 293	54 018	0	0
1995	0	106 523	0	625	497 405	53 492	0	0
1996	0	127 644	0	202	598 901	57 225	0	0
1997	0	188 025	0	553	940 789	134 366	0	0
1998	0	205 347	0	520	838 773	112 400	0	0
1999	0	197 600	6	213	844 300	87 417	10 869	0
2000	0	176 933	28 632	0	1 054 333	103 471	14 990	0
2001	0	215 503	0	4	1 005 478	150 538	447 558	0
2002	0	142 695	7 249	0	947 979	120 050	57 584	0
2003	0	105 275	4 767	0	1 014 418	89 687	50 472	0
2004	0	67 561	2 941	0	1 011 786	0	862 317	0
2005	0	72 128	2 881	0	971 618	435 410	287 341	0
2006	0	73 804	2 506	0	899 914	140 793	276 841	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	286 712	55 179
2012	0	47 980	0	0	589 668	30 441	216 374	41 513
2013	0	55 296	0	0	553 671	37 757	184 219	37 593

Table 3-58– Fuel consumption in the Extractive Industry – Static Engines (GJ)

Year	Gasoline	Gas Oil	Biodiesel
1990	16 254	466 146	0
1991	15 832	505 626	0
1992	10 443	547 043	0
1993	8 644	544 413	0
1994	6 429	462 454	0
1995	2 037	495 098	0
1996	3 128	596 232	0
1997	5 733	937 636	0
1998	19 912	835 859	0
1999	30 264	842 952	0
2000	20 681	756 662	0
2001	82 161	1 005 478	0
2002	38 785	901 089	0
2003	25 153	900 097	0
2004	57 520	898 758	0
2005	22 469	880 964	0
2006	20 217	827 984	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	55 179
2012	84	589 668	41 513
2013	0	553 671	37 593

Figure 3-46 – Total Energy Consumption in the Extractive Industry

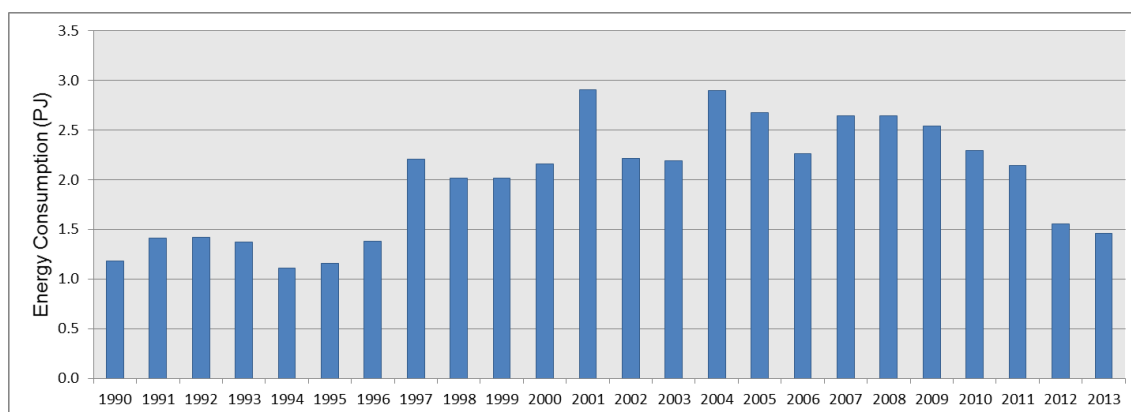
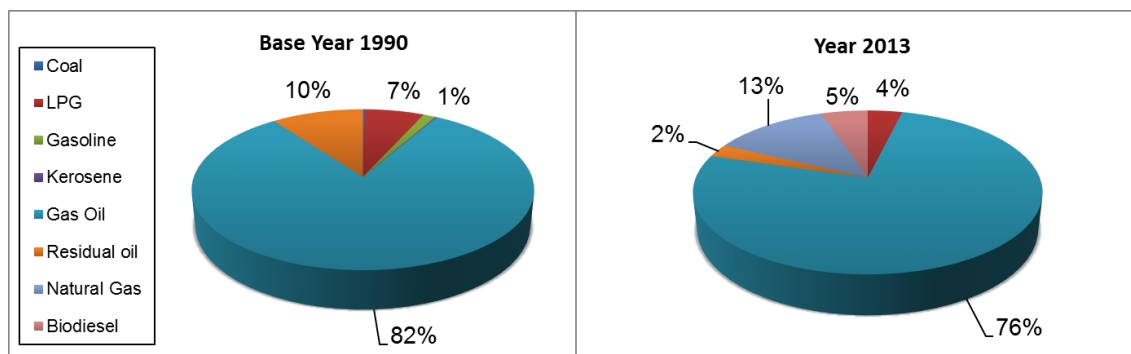


Figure 3-47– Fuel consumption per fuel type in the Extractive Industry in 1990 and 2013



### 3.3.2.2.1.2.16 Construction and Building Industry

Table 3-59 – 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 3-60 – 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	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	1 253 753	357 657
2012	359 777	3 824	42	3 537 355	1 086 618	1 061 160	249 509
2013	326 030	0	42	2 679 697	537 500	1 291 734	183 752

Figure 3-48 – Total Energy Consumption in the Construction and Building Industry

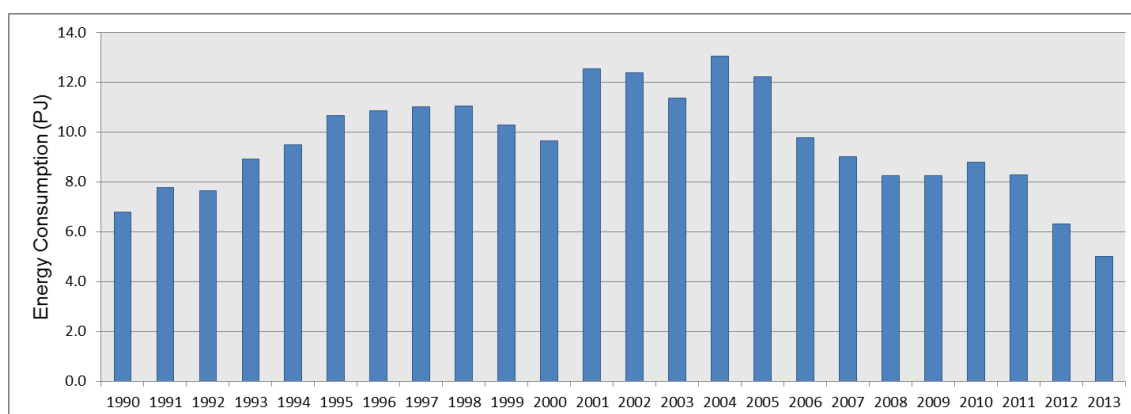
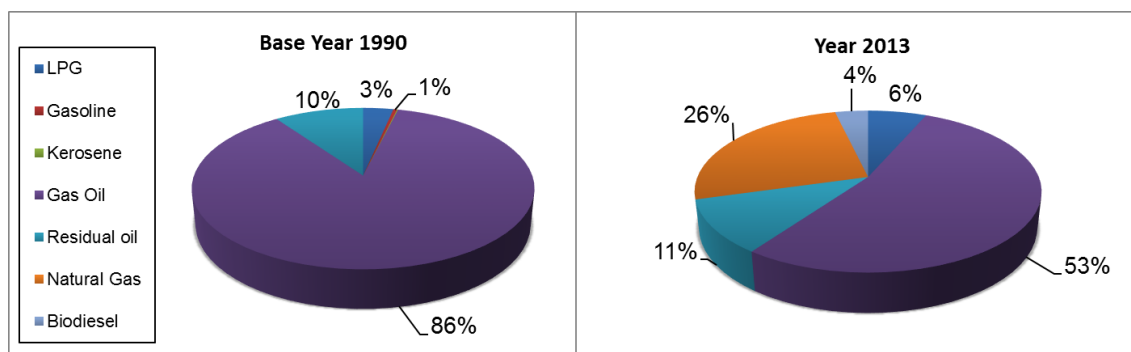


Figure 3-49 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2012

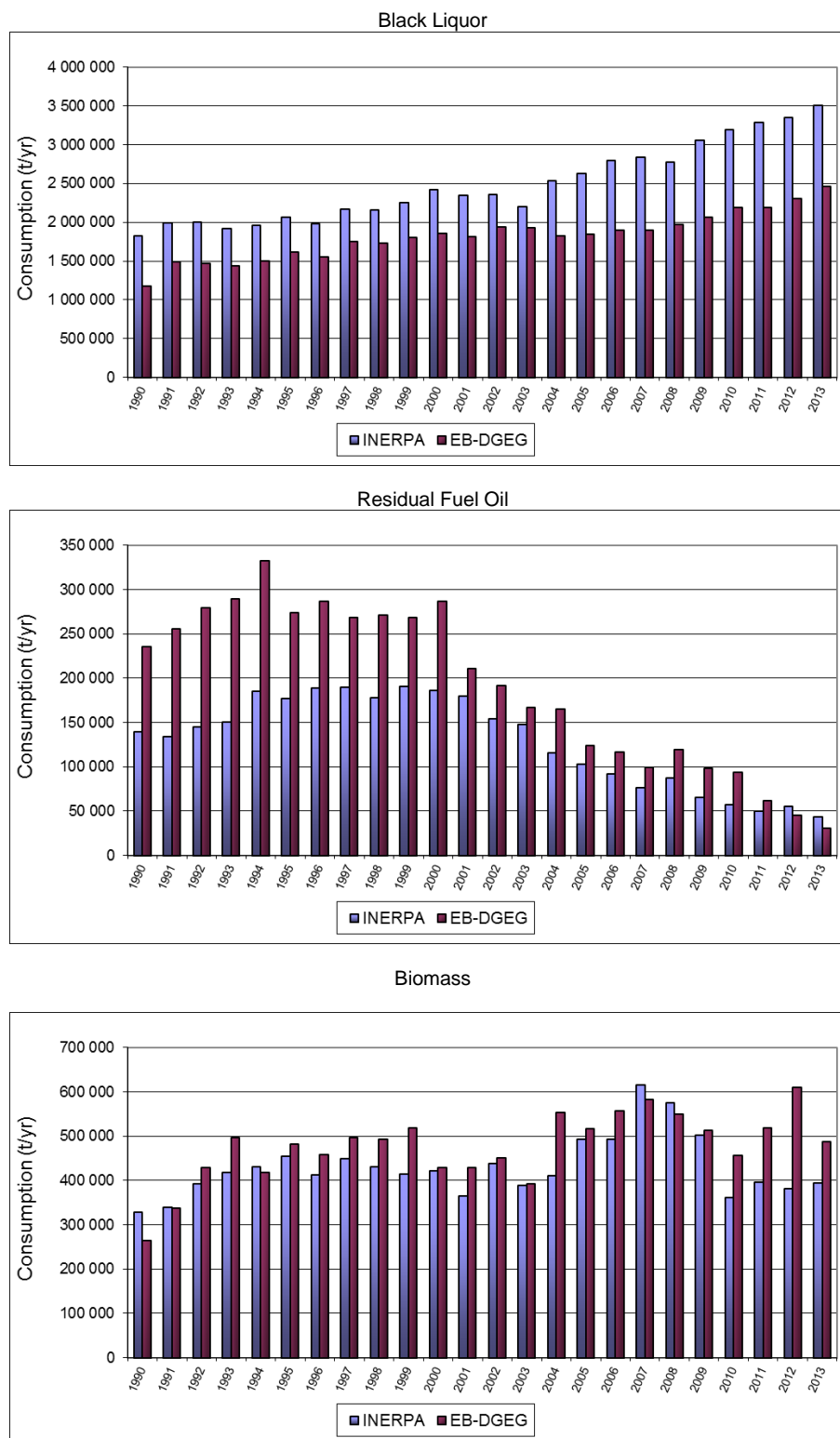


### 3.3.2.2.1.3 Comparison of LPS data vs. Energy Balance

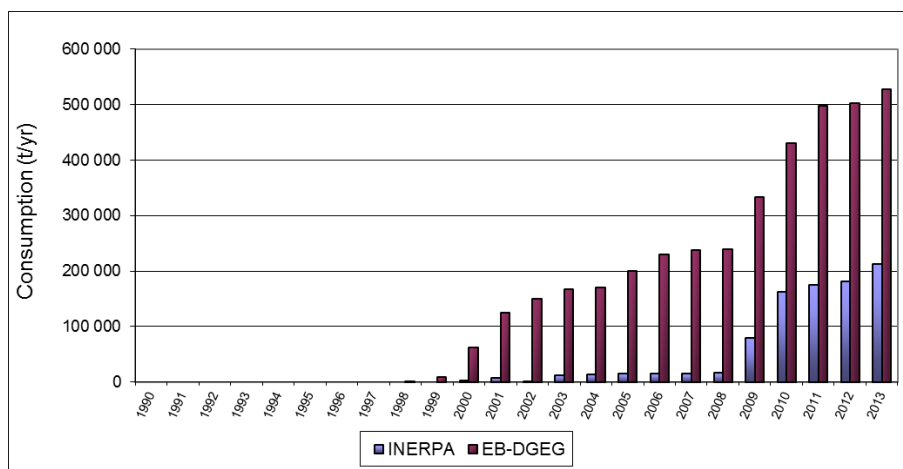
Total consumption in LPS per sector was compared with the correspondent value in the energy balance for the most important fuels, in order to verify the applicability of the methodology in use, which mixes a top-down approach (EB) with a bottom-up approach (LPS data). The following figures present the 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 3-50 – Comparison of total LPS consumption in Paper Pulp units with the reported consumption in the EB for the sector “Paper pulp and paper production”

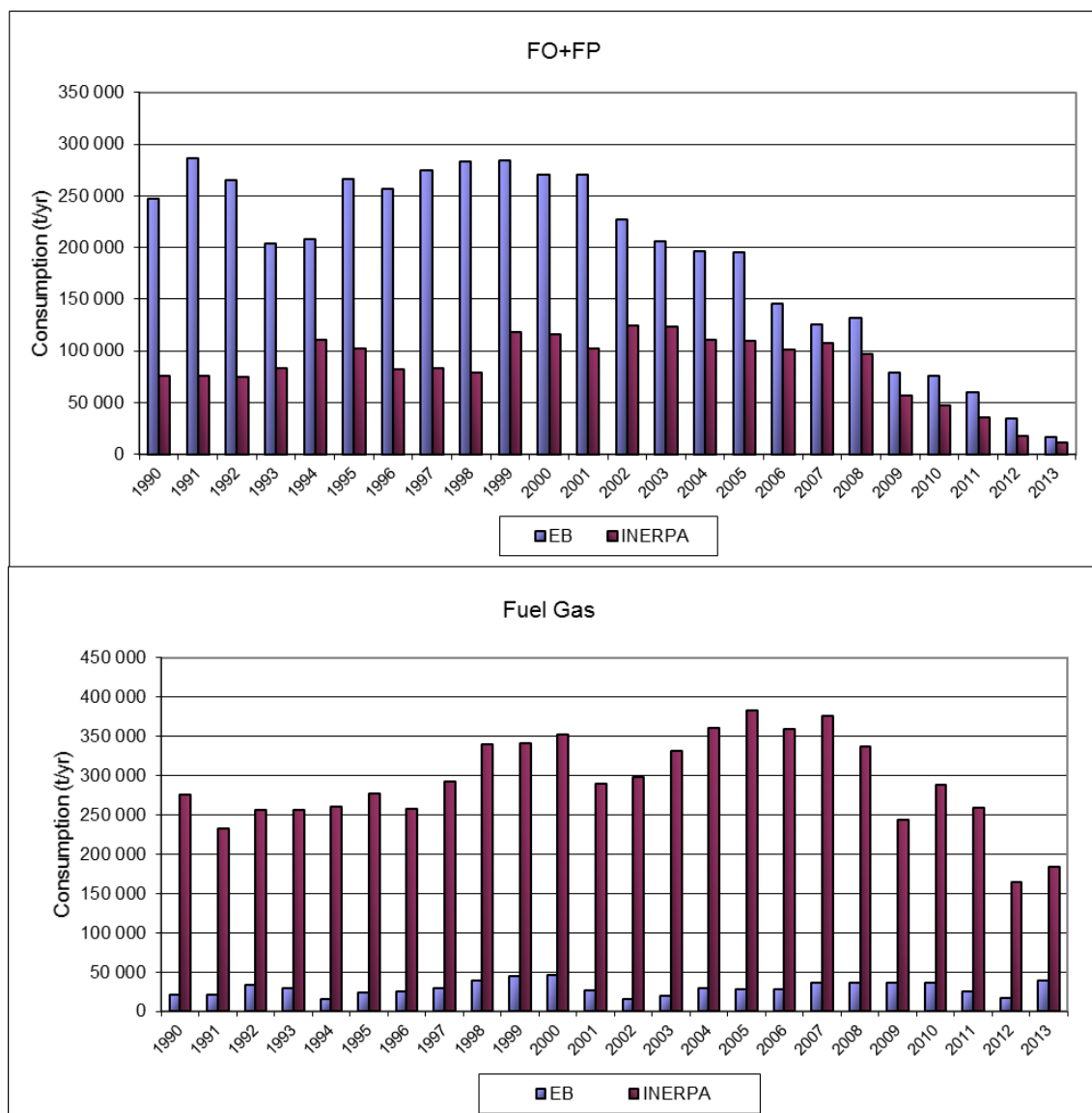


### Natural Gas



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 3-51 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector “Chemical and Plastics”<sup>18</sup>



For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil<sup>19</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.

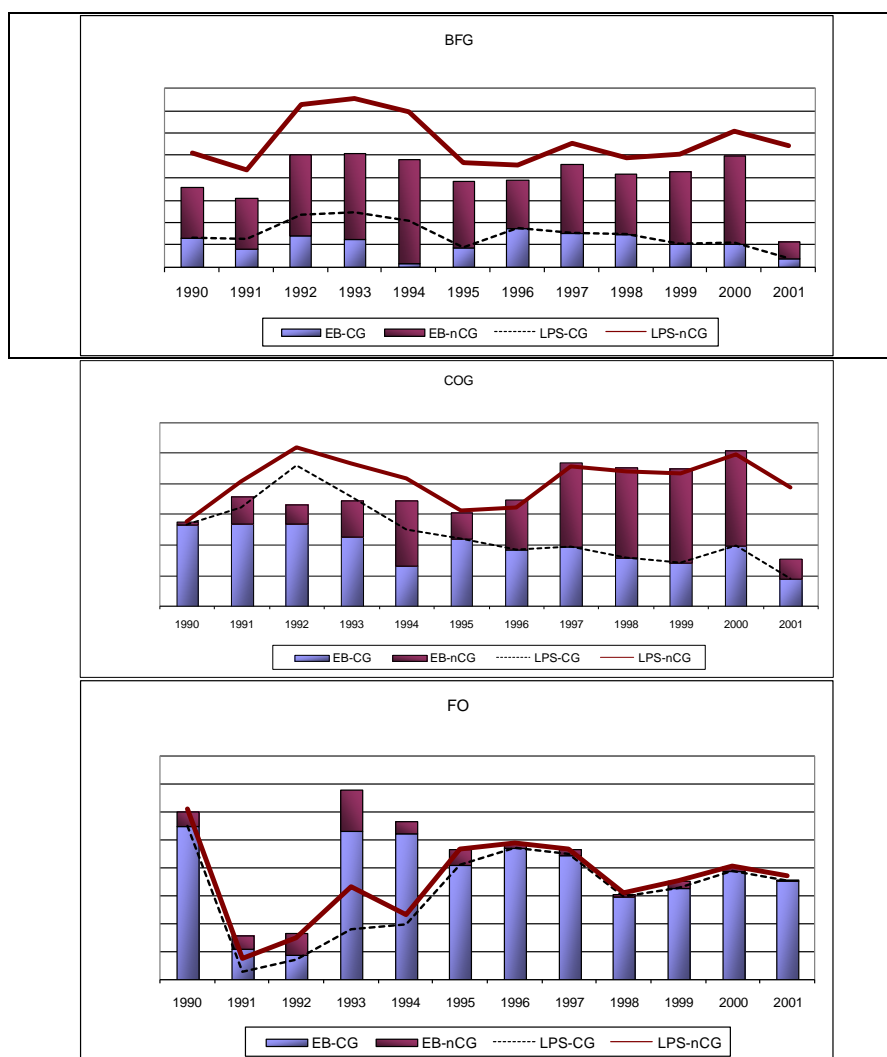
<sup>18</sup> Units in the vertical axis are not indicated due to confidentiality issues.

<sup>19</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.



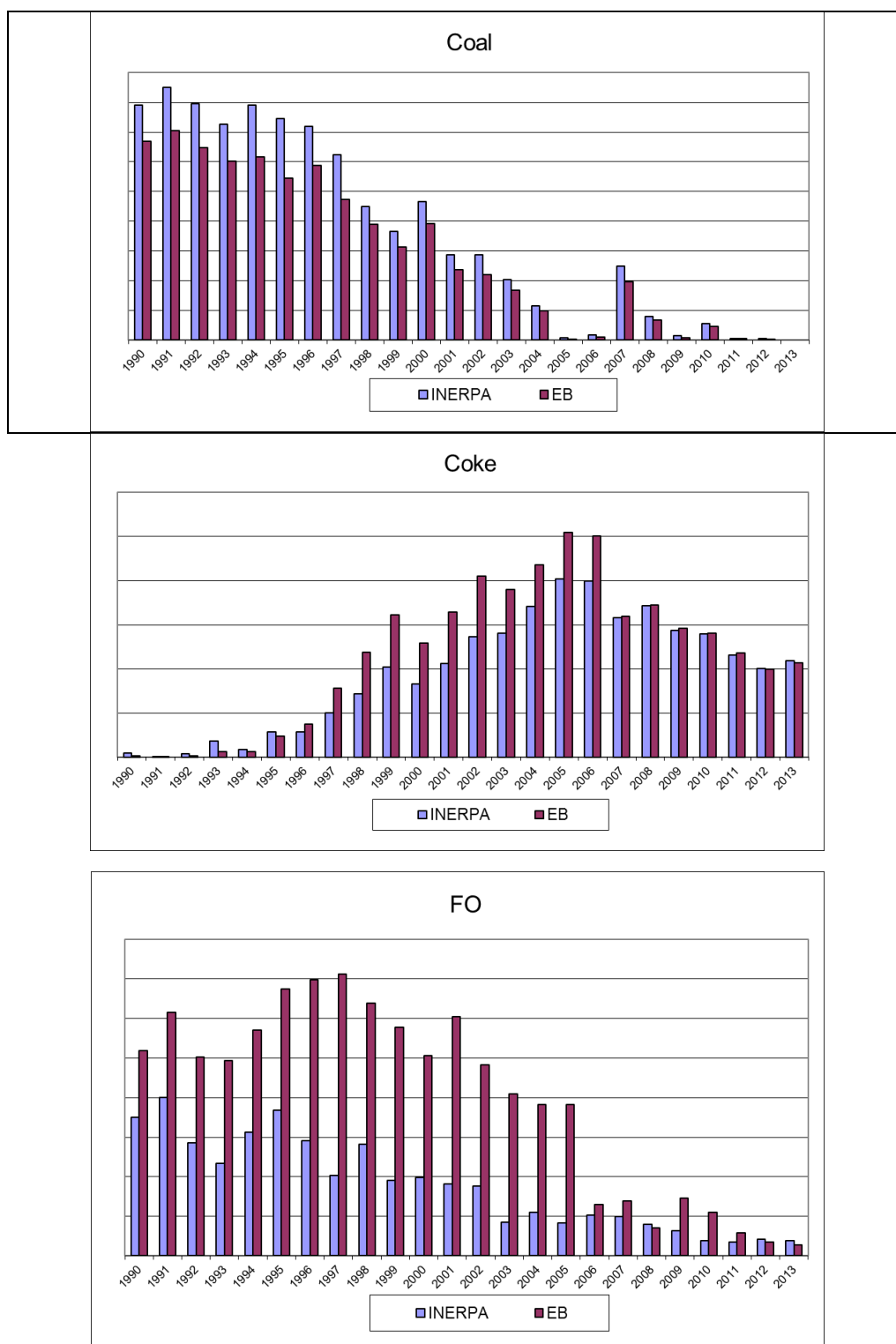
The match for the iron and steel industry show a good consistency, except for intermediate years, and for the slightly higher consumption of Blast Furnace Gas. This last difference may result from the use of different LHV values.

Figure 3-52 – Comparison of total LPS consumption in the only Integrated Iron and Steel Plant with the reported consumption in the EB for the sector “Iron and Steel”<sup>20</sup> (1990-2001)



<sup>20</sup> Units in the vertical axis are not indicated due to confidentiality issues.

Figure 3-53 – Comparison of total LPS consumption in Cement Plant with the reported consumption in the EB for the sector “Cement and Lime” (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 3-61. 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.

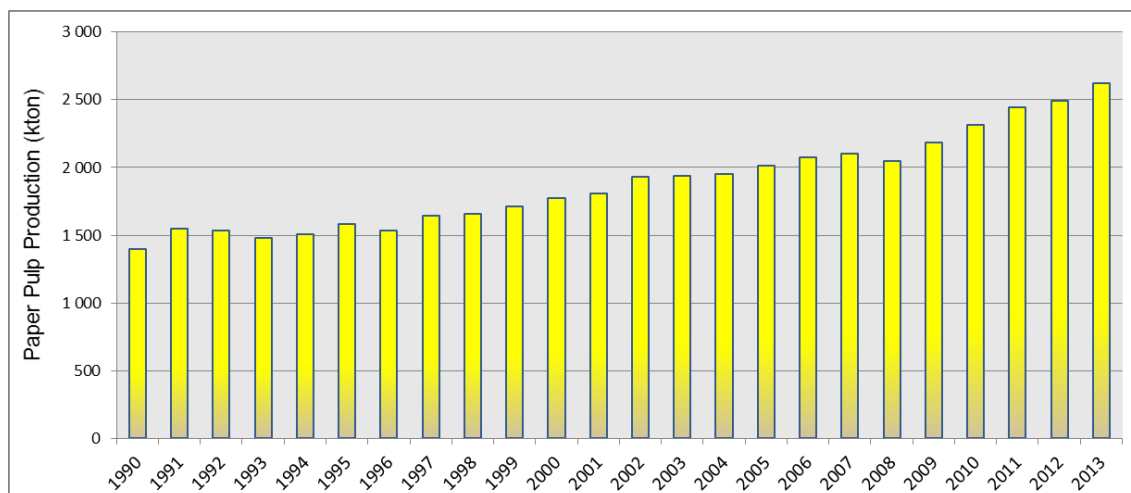
Even though different sources were used the ultimate data source was the same: the industrial plants.

Table 3-61 – 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	2013
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	2 620

Figure 3-54 – Total paper pulp production: Kraft and sulphide paper pulp



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

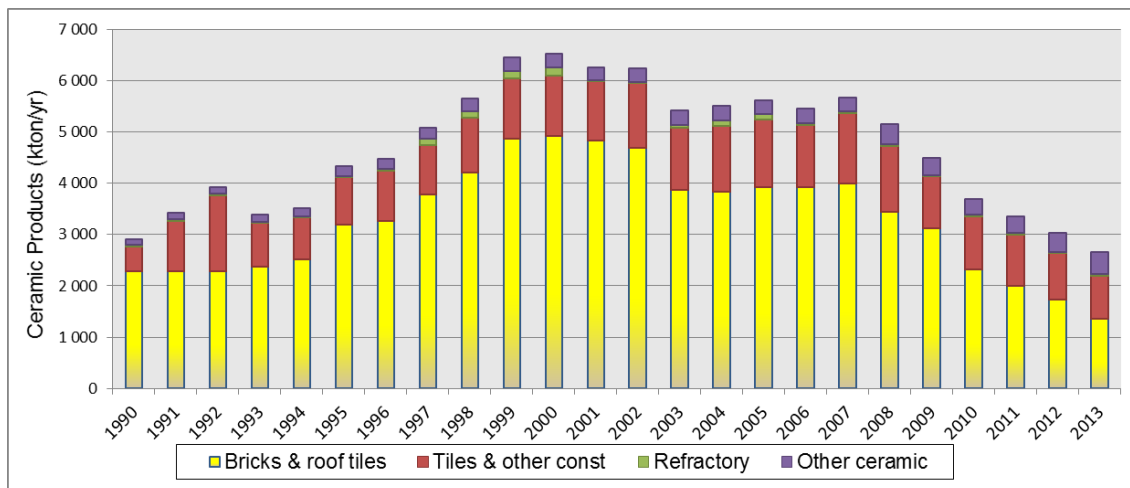
Data on annual manufacturing of ceramic products is available from 1990 to 2013 from INE statistical database. The time series for total production is shown in Table 3-62 and Figure 3-55, according to type of ceramic.

Table 3-62 – 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	2013
Bricks & roof tiles	4 697	3 873	3 831	3 923	3 917	3 993	3 453	3 122	2 321	1 995	1 731	1 360
Tiles & other const	1 253	1 221	1 289	1 327	1 224	1 377	1 276	1 013	1 043	1 009	902	841
Refractory	30	49	103	100	39	40	35	32	25	26	27	27
Other ceramic	258	282	290	278	277	270	399	339	310	323	372	428

Figure 3-55 – Ceramic Production according to type of ceramic



The production values for container glass and lead crystal glass are presented in Figure 3-56 and in Table 3-63, and they were established from the INE statistical databases and information received from Technology Centre for Ceramics and Glass (CTCV). More detailed discussion of the origins of data sources should be consulted in chapter 4.2.A.5. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 3-56 - Glass production by glass type (excluding flat glass production)

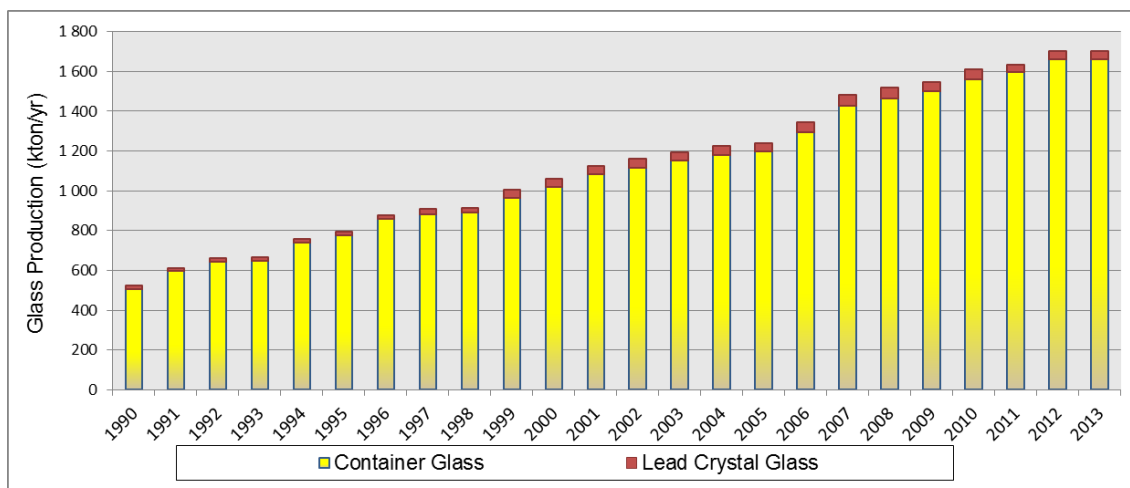


Table 3-63- Glass production by glass type (kton/yr) excluding flat glass production

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	2013
Container Glass	1 117	1 150	1 180	1 197	1 294	1 426	1 464	1 500	1 558	1 596	1 663	1 660
Lead Crystal Glass	42	44	46	45	49	55	54	46	52	39	38	42

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);
- 2006 and 1996 IPCC Guidelines (IPCC,2006; 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 3-64 – 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	98.3	0.980	100	10.0	1.5
	Brown Coal/Lignite	S	105	101.0	0.980	100	10.0	1.5
	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	0.9	4.0
	City Gas	G	308	57.6	0.995	100	1.0	0.1
	Coke Oven Gas	S	304	44.4	0.995	100	1.0	0.1
	Blast Furnace Gas	S	305	260.0	0.995	100	1.0	0.1
	Fuel Gas, Hydrogen	G	399	63.1	0.995	100	0.9	4.0
	Biomass Wood	B	111	112.0	1.000	0	11.0	7.0
	Kerosene	L	206	71.9	0.990	100	3.0	0.6
	Diesel Oil	L	204	74.1	0.990	100	3.0	0.6
	Residual Oil	L	203	77.4	0.990	100	3.0	0.6
	Natural Gas	G	301	56.1	0.995	100	1.0	1.0
	Biodiesel	B	223	70.8	1.000	0	3.0	0.6
Static Engines	Gasoline	L	208	69.3	0.990	100	3.0	0.6
	Gas Oil	L	204	74.1	0.990	100	3.0	0.6
	Biogas	B	309	54.6	1.000	0	1.0	0.1
	Biodiesel	B	223	70.8	1.000	0	3.0	0.6

(i) IPCC (2006); (ii) EEA (2002); (iii) AP-42

Table 3-65 –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 3-66 – 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	3.0	0.6
Gas Oil	L	204	43.31	74.1	0.990	100	3.0	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	1.0	0.1
Natural Gas	G	301	45.97	56.1	0.995	100	1.0	0.1

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 3-67 – Emission factors for use in LPS units in the Iron and steel Industry (from 1990 to 2001, except CO and NMVOC from Sinter Production)

Fuel		CO <sub>2</sub>			CH <sub>4</sub> (g/GJ)	N <sub>2</sub> O (g/GJ)	CO (g/GJ)	NMVOC (g/GJ)
		kg/GJ	Oxidation Factor (ratio)	% C fossil				
Coke oven gas	S	41.0	0.995	100	2.5	1.4	17	2.5
Blast furnace gas	S	297.7	0.995	100	2.5	1.4	17	2.5
Residual oil	L	77.4	0.990	100	3.0	0.6	15	3.0
Tar	L	80.7	0.990	100	3.0	0.6	15	3.0
LPG	L	63.1	0.995	100	4.0	1.4	17	4.0
Waste oils	O	77.4	0.990	100	3.0	0.6	15	3.0

Table 3-68 – CO and NMVOC emission factors for use in Sinter Production (from 1990 to 2001)

Operation	CO (kg/ton Sinter)	NMVOC (kg/ton Sinter)
Sinter Production	30	0.1

Table 3-69 – Emission factors for use in LPS units in the Iron and steel Industry (from 2002 onwards)

Fuel		CO <sub>2</sub>			CH <sub>4</sub> (g/GJ)	N <sub>2</sub> O (g/GJ)	CO (g/GJ)	NMVOC (g/GJ)
		kg/GJ	Oxidation Factor (ratio)	% C fossil				
Natural gas	G	56.6	0.995	100	CRF 2.C.1	0.6	CRF 2.C.1	CRF 2.C.1
Gasoil	L	74.1	0.990	100	CRF 2.C.1	0.6	CRF 2.C.1	CRF 2.C.1
Residual oil	L	78.9	0.993	100	CRF 2.C.1	0.6	CRF 2.C.1	CRF 2.C.1
LPG	L	63.1	0.995	100	CRF 2.C.1	0.1	CRF 2.C.1	CRF 2.C.1

Table 3-70 – Emission factors for use in Area emissions in the Iron and steel Industry

Fuel		CO <sub>2</sub>			CH <sub>4</sub> (g/GJ)	N <sub>2</sub> O (g/GJ)	CO (g/GJ)	NMVOC (g/GJ)
		kg/GJ	Oxidation Factor (ratio)	% C fossil				
Coal	S	96.1	0.980	100	2.4	0.7	150.0	190.0
Coke	S	102.0	0.980	100	2.4	0.7	160.0	12.0
LPG	L	63.1	0.995	100	1.4	1.4	17.0	2.5
Gasoline	L	73.7	0.990	100	0.1	0.6	12.0	1.0
Kerosene	L	71.9	0.990	100	0.1	0.6	12.0	1.0
Gasoil	L	74.1	0.990	100	0.1	0.6	12.0	1.0
Residual oil	L	77.4	0.990	100	3.0	0.6	15.0	3.0
Natural gas	G	56.1	0.995	100	1.4	1.4	13.0	5.0
Coke oven gas	S	46.5	0.995	100	2.5	1.4	17.0	2.5
Blast furnace gas	S	102.5	0.995	100	2.5	1.4	17.0	2.5

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
	LPG	L	303	62.8	0	1.4	1.4
Recovery Boilers	Residual Oil	L	203	76.6	0	3.0	0.6
	Natural Gas	G	301	55.8	0	-	1.4
	Gas Oil	L	204	73.3	0	-	0.6
	Bisulfite Liquor	B	215	73.3	100	30.0	0.6
	Black Liquor	B	215	73.3	100	-	0.6
	Methanol	B	111	62.8	100	-	1.4
Flare	LPG	L	303	62.8	0	1.4	1.4
Lime Kiln	Gasified Biomass	B	111	109.6	100	-	4.3
	Residual Oil	L	203	76.6	0	-	0.6
	Natural Gas	G	301	55.8	0	-	1.4
	Gas Oil	L	204	73.3	0	-	0.6
	NCG	B	111	55.8	100	-	1.4
	Tall-oil	B	111	73.3	100	-	0.6
Static Engine	Gas Oil	L	204	73.3	0	9.9	0.6
Gas Turbine	Natural Gas	G	301	55.8	0	1.4	1.4

(i) The 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**

No recalculations were made.

#### **3.3.2.7 Further Improvements**

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

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

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

##### 3.3.3.1.1 Overview

In 2013 emissions from Civil Aviation in Portugal amounted to 3,159 Gg CO<sub>2</sub> eq, from which 335 Gg CO<sub>2</sub> eq are from domestic flights and 2,823 Gg CO<sub>2</sub> eq 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.

Table 3.77 – Estimated emissions from Civil Aviation (Gg CO<sub>2</sub> eq)

Source Category/Pollutant	1990	1995	2000	2005	2010	2011	2012	2013
<b>Domestic Aviation</b>	<b>231.6</b>	<b>219.1</b>	<b>320.0</b>	<b>389.2</b>	<b>400.9</b>	<b>369.1</b>	<b>372.4</b>	<b>335.3</b>
CO <sub>2</sub>	228.6	216.2	316.6	385.3	397.1	365.6	368.9	332.2
CH <sub>4</sub>	1.1	1.0	0.8	0.7	0.5	0.4	0.4	0.3
N <sub>2</sub> O	1.9	1.8	2.7	3.2	3.3	3.1	3.1	2.8
<b>International Aviation*</b>	<b>1480.3</b>	<b>1631.0</b>	<b>2001.4</b>	<b>2277.6</b>	<b>2634.6</b>	<b>2730.4</b>	<b>2751.9</b>	<b>2823.3</b>
CO <sub>2</sub>	1464.8	1614.2	1982.3	2256.8	2610.7	2705.8	2727.0	2797.9
CH <sub>4</sub>	3.1	3.2	2.4	1.8	1.9	1.9	2.0	1.9
N <sub>2</sub> O	12.3	13.6	16.7	19.0	22.0	22.8	23.0	23.6

\*Memo item. Emissions not included in national totals.

For the elaboration of the greenhouse gases emissions inventory which is reported to the EU<sup>21</sup> and to the UNFCCC, emissions from flights to and from the autonomous regions of Azores and Madeira islands are included in national totals.

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

<sup>21</sup> Decision 2004/280/CE

Table 3.78 – IPCC 2006 source categories

Source Category	Coverage
1 A 3 a Domestic Aviation	Emissions from civil domestic passenger and freight traffic that departs and arrives in the same country (commercial, private, agriculture, etc.), including take-offs and landings for these flight stages.
1 D 1 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 5 b Mobile (aviation component)	Emissions from military aviation.

### 3.3.3.1.2 Methodology

The methodology that is used in the inventory to estimate emissions from jet fuel is a Tier 3 according with IPCC 2006. 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 according with IPCC 2006 which is based primarily in energy statistics.

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

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

Emission<sub>LTO</sub> (p,d,a,s,y) – Emissions of pollutant p from origin/destiny d in airport a performed by aircraft s during year y (ton/yr);

Emission<sub>Arrival</sub>(p,d,a,s,y), Emission<sub>Departure</sub>(p,d,a,s,y) – Arrival and departure emissions of pollutant p from, respectively, origin and destiny d in airport a performed by aircraft s during year y (ton/yr);

N<sub>arrival</sub>, N<sub>departure</sub> – Number of arrival and departure movements performed in year y, by aircraft s in airport s from origin/destiny d.

EF<sub>Arrival</sub>(p,s) – Sum of approach and taxi-in emission factor for pollutant p and aircraft s (kg/movement);

EF<sub>Departure</sub>(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.

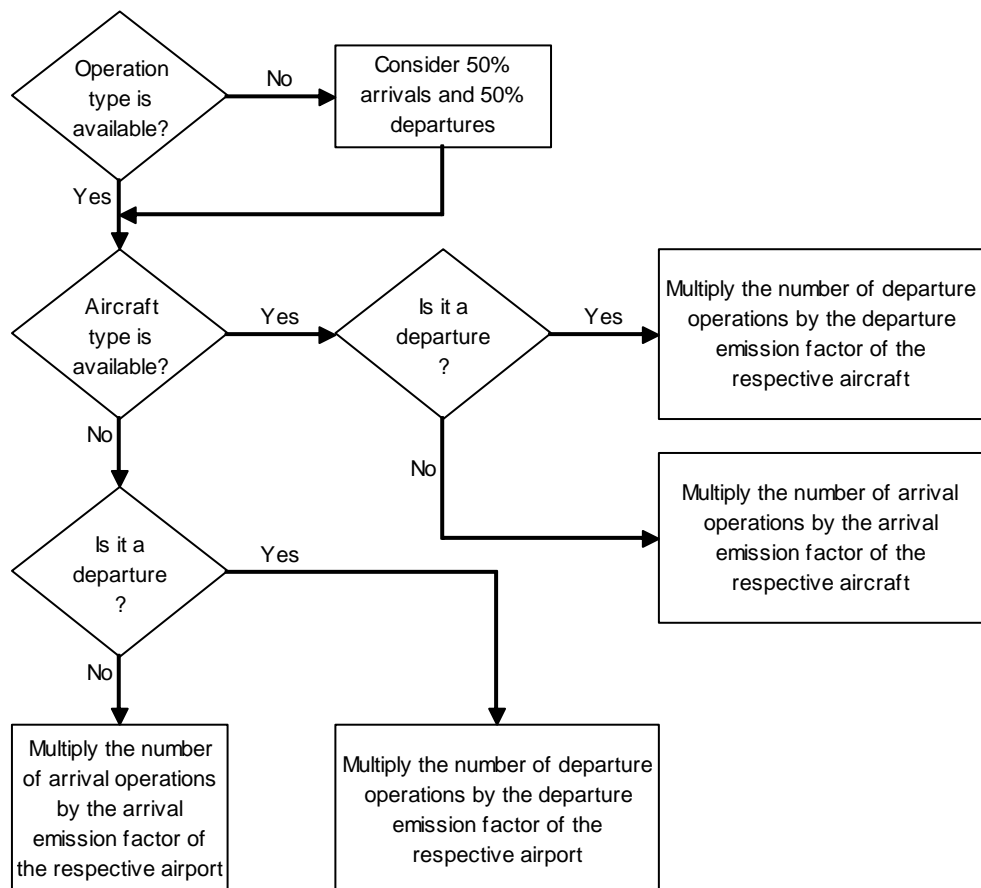
However the aircraft type is not always available. For these cases the approach is based on an airport specific emission factor as follows:

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

Figure 3.57 outlines the process whereby LTO emissions are estimated.



Figure 3.57 – Decision tree for LTO emission calculation



#### 3.3.3.1.2.2 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  $y$ ;

$EF_{cruise}(p,d,a,s,t,y)$  – 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 3.79 - 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 3.80 – Airport based LTO emission factors (kg/movement).

Airport	Operation	Parameter	1990	1995	2000	2005	2010	2011	2012	2013
Lisboa (LIS)	Take-off	Fuel Consumption	670.2	608.9	567.4	452.6	451.6	443.6	450.9	447.0
		VOC	16.4	14.9	15.2	9.3	2.8	2.6	2.5	2.4
		CO	37.1	33.7	35.4	21.5	13.8	13.0	12.4	12.2
		NOx	26.3	23.9	23.6	16.2	15.9	15.8	16.4	16.1
		PM <sub>10</sub>	6.2	5.6	5.2	4.2	4.2	4.1	4.2	4.2
	Landing	Fuel Consumption	291.0	264.4	240.2	204.2	206.6	201.3	202.1	201.0
		VOC	7.0	6.4	6.0	4.4	1.5	1.4	1.3	1.3
		CO	17.8	16.2	16.3	11.1	7.0	6.7	6.4	6.2
		NOx	4.9	4.4	4.3	3.3	3.4	3.3	3.3	3.3
		PM <sub>10</sub>	3.1	2.8	2.6	2.2	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	342.9
		VOC	8.2	7.5	6.5	4.1	3.3	2.8	2.9	3.0
		CO	26.3	23.9	23.0	13.7	12.8	12.0	11.2	11.4
		NOx	19.1	17.3	15.0	11.9	14.7	12.7	11.7	11.6
		PM <sub>10</sub>	4.9	4.5	3.7	3.5	4.0	3.5	3.4	3.2
	Landing	Fuel Consumption	236.2	214.6	181.3	172.9	191.7	165.5	167.3	156.8
		VOC	3.7	3.3	2.9	2.2	1.6	1.3	1.5	1.4
		CO	12.7	11.5	11.1	7.2	6.3	5.9	5.9	5.7
		NOx	3.8	3.5	3.0	2.6	3.2	2.6	2.6	2.5
		PM <sub>10</sub>	2.5	2.3	1.9	1.9	2.1	1.8	1.8	1.7
Faro (FAO)	Take-off	Fuel Consumption	514.8	467.7	443.6	348.7	339.1	262.5	276.9	274.3
		VOC	5.3	4.8	4.9	3.0	2.4	2.0	2.3	2.2
		CO	19.2	17.4	17.2	12.2	11.0	8.9	9.2	9.0
		NOx	17.4	15.8	16.0	11.0	10.0	7.6	8.0	8.0
		PM <sub>10</sub>	4.8	4.3	4.1	3.2	3.1	2.4	2.6	2.5
	Landing	Fuel Consumption	231.8	210.6	198.9	158.2	161.1	126.2	133.2	134.9
		VOC	2.7	2.5	2.5	1.7	1.4	1.3	1.4	1.4
		CO	10.0	9.1	9.0	6.5	5.9	5.2	5.2	5.1
		NOx	3.5	3.2	3.1	2.3	2.4	1.8	1.9	2.0
		PM <sub>10</sub>	2.5	2.3	2.1	1.7	1.7	1.4	1.4	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 3.81 – 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
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 3.82 – 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
B11	British Aerospace (BAC) One Eleven / BAC One Eleven	L JeK	L2J	B11	B11



Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
B12	British Aerospace (BAC) One Eleven 200	L JeK	L2J	B12	B11
BES	Beechcraft 1900/1900C	L JeK	L2T	BE1	BE1
B200	Beech 200 Super King Air	L JeK	L2T	BE20	BE20
B350	Beech Super King Air 350	L JeK	L2T	BE30	B350
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 / BAC One Eleven	L JeK	L2J	B11	B11
BE1	Beechcraft 1900/1900C/1900D	L JeK	L2T	BE1	BE1
BE10	Beech King Air 100	L JeK	L2T	BE10	B350
BE18	Beech 18	L AvG	L2P	BE18	DHO
BE19	Beech 19 Sport	L AvG	L1P	BE19	DHO
BE2	Beechcraft twin piston engines	L AvG	L2P	BE55	DHO
BE20	Beech Huron	L JeK	L2T	BE20	BE20
BE30	Beech Super King Air 300	L JeK	L2T	BE30	B350

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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 / 80	L JeK	L2T	DH8	DH8
DH3	De Havilland Canada DHC-8-300 Dash 8 / 80	L JeK	L2T	DH8	DH8
DH4	De Havilland Canada DHC-8-400 Dash 80	L JeK	L2T	DH8	DH8
DHB	De Havilland Canada DHC-2 Beaver / Turbo Beaver	L AvG	L1P	DHB	DHO
DHP	De Havilland Canada DHC-2 Beaver	L AvG	L1P	DHB	DHO
DHS	De Havilland Canada DHC-3 Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DHO	De Havilland Canada DHC-3 Otter / Turbo Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DR40	Robin DN-400	L AvG	L1P	C150	DHO
EMB	Embraer EMB.110 Bandeirante	L JeK	L2T	EMB	EMB
EM2	Embraer EMB.120 Brasília	L JeK	L2T	EM2	NA
E121	Embraer 121 Xingu	L JeK	L2T	E121	B350
ER3	Embraer RJ135	L JeK	L2J	ERJ	ERJ
ER4	Embraer RJ145 Amazon	L JeK	L2J	ERJ	ERJ
E70	Embraer 170	L JeK	L2J	EMJ	FRJ
E3CF	Boeing Sentry	L JeK	L4J	E3CF	NA
EM2	Embraer EMB.120 Brasília	L JeK	L2T	EM2	NA
EMB	Embraer EMB.110 Bandeirante	L JeK	L2T	EMB	EMB
EMJ	Embraer 170/190	L JeK	L2J	EMJ	FRJ
ERJ	Embraer RJ135 / RJ140 / RJ145	L JeK	L2J	ERJ	ERJ
100	Fokker 100	L JeK	L2J	100	100
F16	Lockheed F-16 Fighting Falcon	L JeK	L1J	F16	NA
F27	Fairchild FH.227	L JeK	L2T	FK7	NA
F28	Fokker F.28 Fellowship 3000	L JeK	L2J	F24	F28
F2TH	Dassault Falcon 2000	L JeK	L2J	F2TH	NA
F406	Cessna F406 Caravan 2	L JeK	L2T	F406	F406
F50	Fokker 50	L JeK	L2T	F50	F50
F70	Fokker 70	L JeK	L2J	F70	NA
F900	Dassault Falcon 900	L JeK	L3J	F900	F50
FA10	Dassault Falcon 10	L JeK	L2J	FA10	S20
FA20	Dassault Falcon 20	L JeK	L2J	FA20	S20
FA50	Dassault Falcon 50	L JeK	L3J	FA50	F50
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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 <del>Gulfstream II / III / IV / V</del>	L JeK	L2J	GLF3	NA
GRS	Gulfstream Aerospace G-159 <del>Gulfstream I</del>	L JeK	L2T	GRS	NA
H25	British Aerospace (Hawker Siddeley) <del>HS-125</del>	L JeK	L2J	H25	S20
H25	British Aerospace (Hawker Siddeley) <del>HS-125</del>	L JeK	L2J	H25	S20
H25B	British Aerospace (Hawker Siddeley) <del>HS-125</del>	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 / <del>200 / 250 Tristar pax</del>	L JeK	L3J	L10	D10
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
L1F	Lockheed L-1011 Tristar Freighter	L JeK	L3J	L10	D10
L29	Aero (2) L-29 Delfin	L JeK	L1J	F16	NA
L4T	LET 410	L JeK	L2T	L4T	NA
LJ31	Learjet 31	L JeK	L2J	LJ31	S20
LJ35	Learjet 35	L JeK	L2J	LJ35	S20
LJ40	Learjet 40	L JeK	L2J	LJ35	S20
LJ45	Learjet 45	L JeK	L2J	LJ35	S20
LJ60	Learjet 60	L JeK	L2J	LJ35	S20
LOE	Lockheed L-188 Electra pax	L JeK	L4T	LOE	NA
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
LOH	Lockheed L-182 / 282 / 382 (L-100) <del>Hercules</del>	L JeK	L4T	C130	LOH
LOM	Lockheed L-188 Electra Mixed <del>Configuration</del>	L JeK	L4T	LOM	NA

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
PUMA	Aerospatile 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
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

Code	Aircraft Name	Fuel Type	Description	LTO Representative	Cruise Representative
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 3.83 – Fuel dependent emission factors

Pollutant	Aviation Gasoline	Jet Fuel
LHV (MJ/kg)	44.0	43.0
CO <sub>2</sub> (t/TJ) <sup>22</sup>	69.3	70.8
N <sub>2</sub> O (kg/TJ)	2.00	2.00

Source: IPCC 2006; 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 2013 was provided by the *Instituto Nacional de Aviação Civil* (INAC). This database is being improved and the coverage of it is increasing as new airports (mostly regional and local airports) are connected to the movements' database from INAC.

Table 3.84 – LTO per airport

Region	Airport Code	1990	1995	2000	2005	2010	2011	2012	2013
Mainland	LIS	30 862	34 932	56 073	68 168	73 783	74 031	80 091	74 378
	OPO	11 574	13 348	23 280	25 910	28 502	30 839	31 964	30 131
	FAO	11 252	13 067	18 243	20 397	22 359	22 426	22 081	21 896
	TOTAL	53 688	61 347	97 596	114 475	124 643	127 295	134 136	126 405

<sup>22</sup> The CO<sub>2</sub> emission factor takes into account an oxidation factor of 0.99.



Region	Airport Code	1990	1995	2000	2005	2010	2011	2012	2013
Islands	FNC	6 475	9 460	12 040	15 952	12 697	12 263	12 591	12 198
	TER	3 801	4 049	4 501	4 875	4 988	4 955	5 180	4 676
	PDL	2 954	3 382	4 134	7 196	8 182	7 867	8 457	7 608
	PXO	2 403	4 243	3 788	3 688	2 325	2 165	2 058	1 703
	HOR	1 237	1 542	1 756	2 964	2 919	2 772	2 695	2 353
	SMA	634	893	1 557	1 649	1 275	1 333	1 113	922
	FLW	281	357	552	1 101	1 136	1 116	1 088	846
	TOTAL	17 785	23 924	28 327	37 425	33 521	32 470	33 180	30 305

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.

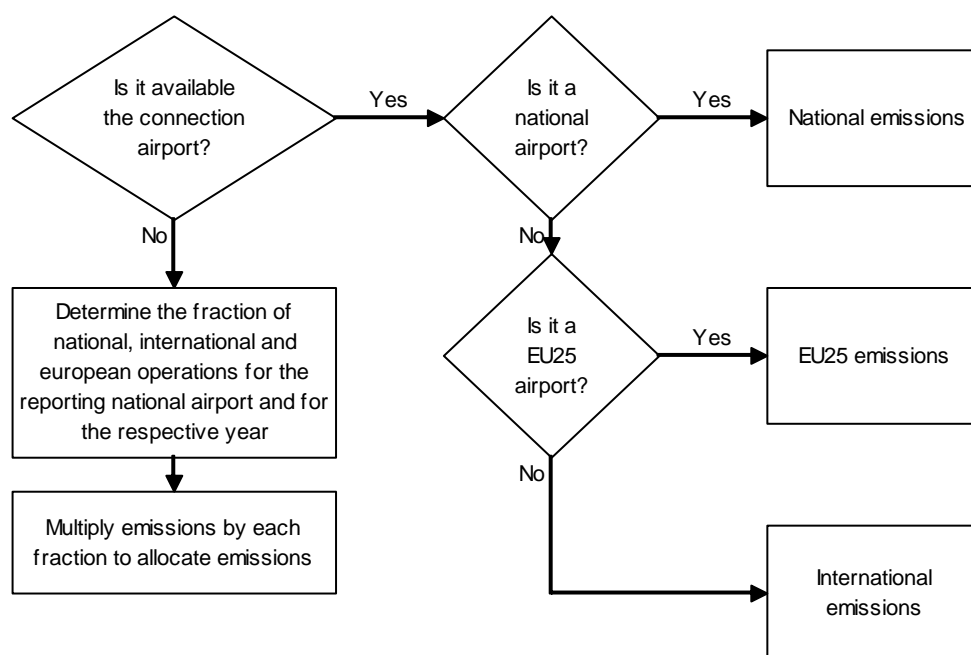


Figure 3.58 – Decision tree for distinction between domestic and international emissions.

### 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.

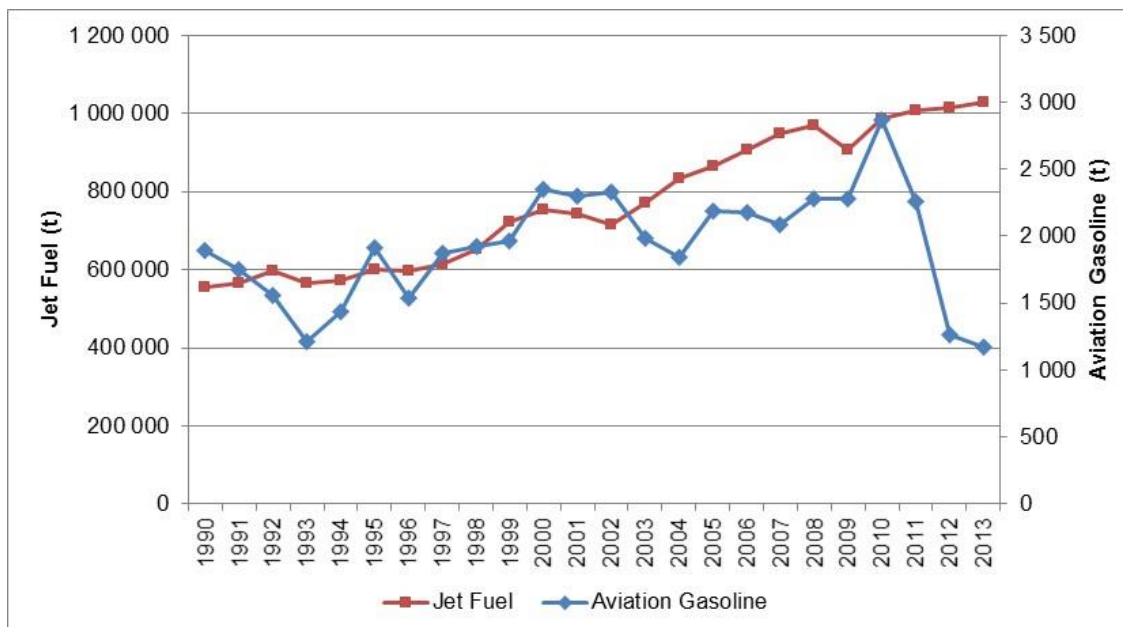


Figure 3.59 – Total Fuel consumption of aviation gasoline and jet fuel (Source: DGEG)

### 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 3.85 – Aviation activity level uncertainty.

Source	Parameter	Unit	1990	1995	2000	2005	2010	2011	2012	2013
All	Uglobal	%	74	72	35	36	35	35	35	36
Cruise	Ucruise	%	99	99	47	49	48	47	48	48
LTO	Ucto	%	100	100	48	49	48	47	48	48

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

Recalculations for this source category comprise:

- revision of 2007 and 2009 energy balance data for Jet fuel;
- CO<sub>2</sub> fuel dependent emission factor revision for Jet fuel and Aviation gasoline based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

### 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 14,846 Gg CO<sub>2</sub> eq. in 2013, representing an increase of 59.1% when compared to 9,330 Gg CO<sub>2</sub> eq. estimated for 1990.

Emissions of N<sub>2</sub>O have increased by a factor of 2.2 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 3.86 – Estimated emissions from road transport (Gg CO<sub>2</sub> eq)

Source Category/Pollutant	1990	1995	2000	2005	2010	2011	2012	2013
<b>Road Transportation</b>	<b>9329.6</b>	<b>12699.9</b>	<b>18297.2</b>	<b>18711.3</b>	<b>17856.2</b>	<b>16588.0</b>	<b>15075.8</b>	<b>14846.3</b>
CO <sub>2</sub> Fossil	9163.8	12285.3	18002.6	18447.4	17649.5	16398.9	14903.7	14681.5
CO <sub>2</sub> Biomass*	0.0	0.0	0.0	0.0	929.5	872.3	825.5	793.4
CH <sub>4</sub>	101.5	109.0	94.6	62.1	39.6	34.8	30.2	28.9
N <sub>2</sub> O	64.3	305.6	200.0	201.7	167.1	154.4	141.9	135.9

\*Information item. Emissions not included in national totals.

#### 3.3.3.2.2 Methodology

Emissions from road transportation are estimated using the COPERT IV (version 11.1 – December 2014). 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 road transportation include non-combustive CO<sub>2</sub> emissions from urea-based catalytic converters which were estimated using the COPERT IV. In 2013, emissions from urea-based catalytic converters represented 0.0008% of the total CO<sub>2</sub> emissions from road transport.

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.

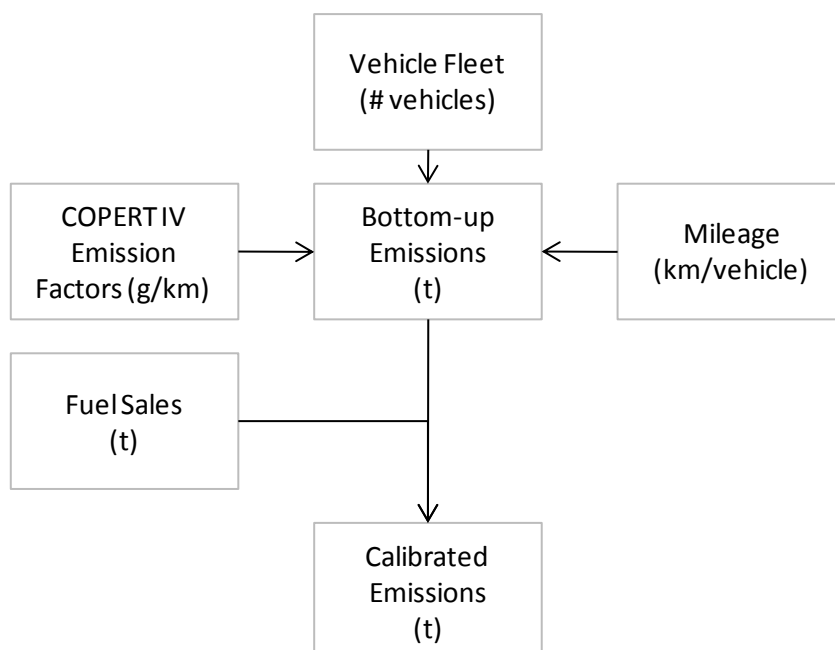


Figure 3.60 – General scheme of methodology applied for road transport emissions estimates (Passenger cars, light duty vehicles and motorcycles)

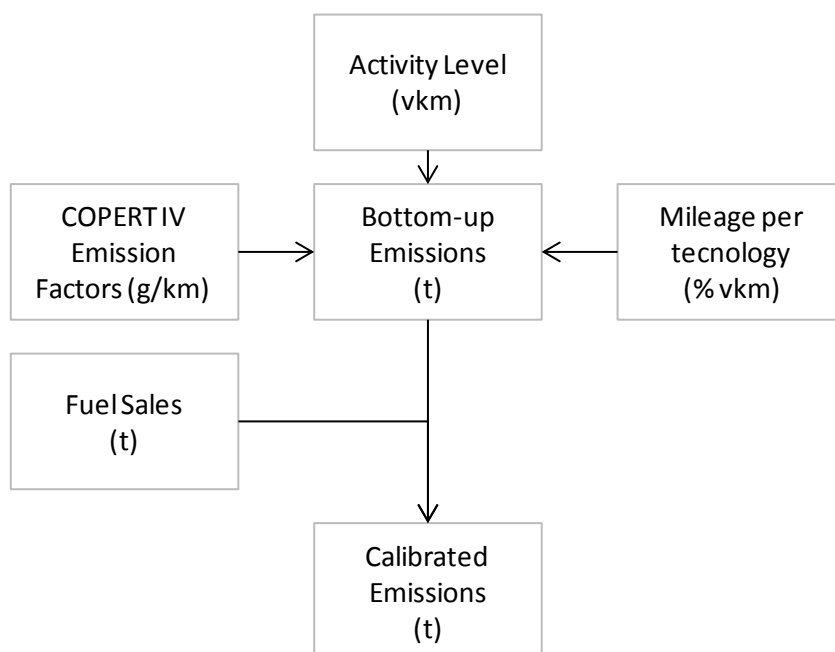


Figure 3.61 – General scheme of methodology applied for road transport emissions estimates (Heavy duty vehicles, buses and coaches)

### 3.3.3.2.2.1 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:

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

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

Where,

$T(c,a,y1)$  = number of vehicles of class c, with age a, using fuel f in year y1;

$S(c,y2)$  = sales of vehicles of class c, using fuel f in year y2;

$A(c,y1-y2)$  = age of vehicles of class c, using fuel f in year y1.

The 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 3.87 – 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 3.88 – Km per year per vehicle type

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2011	2012	2013
Passenger Cars	Gasoline <1,4 l	PRE ECE	5 145	3 720	0	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	7 731	5 637	3 989	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/02	9 316	7 268	5 098	3 454	0	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/03	10 457	9 009	6 941	4 895	3 454	0	0	0
Passenger Cars	Gasoline <1,4 l	ECE 15/04	11 021	10 655	9 478	7 561	5 523	5 170	4 852	4 553
Passenger Cars	Gasoline <1,4 l	Improved Conventional	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline <1,4 l	Open Loop	0	0	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	7 018	6 579	6 144
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	0	0	11 036	10 541	9 134	8 754	8 352	7 932
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	10 982	10 252	9 996	9 701	9 368
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	11 059	10 949	10 863	10 744	10 588
Passenger Cars	Gasoline <1,4 l	PC Euro 5 (post 2005)	0	0	0	0	11 059	11 057	11 048	11 032
Passenger Cars	Gasoline <1,4 l	PC Euro 6	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	6 277	4 721	0	0	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	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	11 401	9 112	6 237	4 544	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	12 332	10 969	8 515	5 888	4 544	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	12 877	12 584	11 621	9 591	6 917	6 432	5 997	5 611
Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop	0	0	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	8 703	8 127	7 546
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	0	0	12 880	12 430	11 172	10 779	10 338	9 852
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	12 803	12 173	11 951	11 683	11 364
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	12 937	12 758	12 671	12 560	12 422
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 (post 2005)	0	0	0	0	12 937	12 932	12 917	12 898
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6	0	0	0	0	0	0	0	0



Sector	Subsector	Technology	1990	1995	2000	2005	2010	2011	2012	2013
Passenger Cars	Gasoline >2,0 l	PRE ECE	6 686	5 485	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	9 082	7 059	5 670	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/02	10 921	8 664	6 640	5 272	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/03	12 190	10 208	7 997	6 197	5 272	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/04	13 288	12 723	11 154	8 992	7 027	6 712	6 435	6 184
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	0	13 331	12 735	11 050	8 816	8 377	7 952	7 544
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	0	0	13 312	12 549	10 726	10 283	9 830	9 376
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13 211	12 109	11 762	11 376	10 959
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 171	13 039	12 862	12 638
Passenger Cars	Gasoline >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	13 355	13 351	13 340	13 318
Passenger Cars	Gasoline >2,0 l	PC Euro 6	0	0	0	0	0	0	0	0
Passenger Cars	Diesel <2,0 l	Conventional	18 516	18 089	16 360	14 000	11 863	11 513	11 194	10 910
Passenger Cars	Diesel <2,0 l	PC Euro 1 - 91/441/EEC	0	19 198	18 445	16 380	13 803	13 325	12 872	12 447
Passenger Cars	Diesel <2,0 l	PC Euro 2 - 94/12/EEC	0	0	19 196	18 299	16 092	15 566	15 038	14 515
Passenger Cars	Diesel <2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	19 127	17 943	17 543	17 095	16 608
Passenger Cars	Diesel <2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	19 241	19 031	18 870	18 649	18 369
Passenger Cars	Diesel <2,0 l	PC Euro 5 (post 2005)	0	0	0	0	19 241	19 237	19 221	19 191
Passenger Cars	Diesel <2,0 l	PC Euro 6	0	0	0	0	0	0	0	0
Passenger Cars	Diesel >2,0 l	Conventional	18 690	17 521	15 735	13 871	12 317	12 066	11 848	11 661
Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	0	20 428	19 808	17 394	14 327	13 820	13 365	12 960
Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	0	0	20 433	19 762	17 201	16 546	15 895	15 267
Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	20 381	19 230	18 759	18 212	17 603
Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	20 446	20 333	20 216	20 032	19 770
Passenger Cars	Diesel >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	20 446	20 445	20 440	20 426
Passenger Cars	Diesel >2,0 l	PC Euro 6	0	0	0	0	0	0	0	0

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2011	2012	2013
Passenger Cars	LPG	Conventional	13 109	12 455	10 806	8 689	6 816	6 501	6 210	5 947
Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	0	13 294	12 546	10 769	85 51	8 125	7 716	7 327
Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	0	0	13 295	12 442	10 554	10 106	9 652	9 197
Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13 166	11 942	11 572	11 166	10 735
Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 330	13 279	13 185	13 044
Passenger Cars	LPG	PC Euro 5 (post 2005)	0	0	0	0	13 355	13 345	13 305	13 223
Passenger Cars	LPG	PC Euro 6	0	0	0	0	0	0	0	0
Passenger Cars	2-Stroke	Conventional	0	0	0	0	0	13 355	13 351	13 341
Passenger Cars	Hybrid Gasoline <1,4	PC Euro 4 - 98/69/EC Stage2005	10 228	9 879	9 134	9 121	10 174	10 620	10 797	10 876
Passenger Cars	Hybrid Gasoline 1,4 -	PC Euro 4 - 98/69/EC Stage2005	0	0	12 937	12 914	12 843	12 866	12 866	12 859
Passenger Cars	Hybrid Gasoline >2,0	PC Euro 4 - 98/69/EC Stage2005	0	0	13 355	13 242	13 191	13 194	13 199	13 201
Light Duty Vehicles	Gasoline <3,5t	Conventional	10 433	8 828	6 292	4 092	2 460	1 342	1 287	1 237
Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	0	13 331	12 735	11 050	8 816	8 377	7 952	7 544
Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	0	0	13 312	12 549	10 726	10 283	9 830	9 376
Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	13 211	12 109	11 762	11 376	10 959
Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	13 355	13 171	13 039	12 862	12 638
Light Duty Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards	0	0	0	0	13 355	13 351	13 340	13 318
Light Duty Vehicles	Gasoline <3,5t	LD Euro 6	0	0	0	0	0	0	0	0
Light Duty Vehicles	Diesel <3,5 t	Conventional	17 571	16 481	13 978	11 295	9 067	8 696	8 367	8 077
Light Duty Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	0	20 733	19 497	16 114	12 248	11 569	10 935	10 346
Light Duty Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	0	0	20 741	19 246	15 618	14 799	13 999	13 224
Light Duty Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	20 649	18 597	17 910	17 173	16 392
Light Duty Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	0	20 491	20 218	19 834	19 344
Light Duty Vehicles	Diesel <3,5 t	LD Euro 5 - 2008 Standards	0	0	0	0	0	20 800	20 785	20 740
Light Duty Vehicles	Diesel <3,5 t	LD Euro 6	0	0	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 3.89 – Assumed vehicle speeds by driving mode and vehicle type.

Driving Mode	Vehicle Type	Assumed Speed (km/h)	Source
Highway	Passenger Car	124	Lemondé, 2000
	Light Duty Vehicles	124	Lemondé, 2000
	Heavy Duty Vehicles	103	LNEC, 2002
	Coaches	103	LNEC, 2002
	Motorcycles	124	Lemondé, 2000
Rural	Passenger Car	61	LNEC, 2002
	Light Duty Vehicles	61	LNEC, 2002
	Heavy Duty Vehicles	56	LNEC, 2002
	Coaches	56	LNEC, 2002
	Mopeds	40	Maximum Legal Value
	Motorcycles	61	LNEC, 2002
Urban	Passenger Car	24.9	Gois et al., 2005
	Light Duty Vehicles	24.9	Gois et al., 2005
	Heavy Duty Vehicles	24.9	Gois et al., 2005
	Buses	14.8	Carris, 2005
	Coaches	24.9	Gois et al., 2005
	Mopeds	24.9	Gois et al., 2005
	Motorcycles	24.9	Gois et al., 2005

### 3.3.3.2.2.5 Fuel consumption

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

$$FC_{(f,y)} = \sum_m \sum_c \sum_t [vkm_{(c,t,m,f,y)} \times FC_{(c,t,m,f)}] \times 10^{-6}$$

where,

$FC_{(f,y)}$  = fuel consumption of fuel type f by all vehicles in year y (km/y) using bottom-up approach;

$vkm_{(c,t,m,f,y)}$  = total kilometres driven by vehicles of class c, with technology t, under driving mode m using fuel f in year y (km/y);

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

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

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

m=driving mode: highway, rural, urban

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

y = civil year.

### 3.3.3.2.2.6 Adjustment of bottom-up and top-down approaches

Fuel adjustments are necessary so that the sum of estimated fuel consumption equals the total fuel sales from the DGEG. Fuel consumption estimates were corrected with the following factor for car type c, technology t, fuel f, driving mode d and year y.

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

Correction factors are later applied to the first approach fuel consumption and emissions. This correction guarantees that emission estimates are in accordance with the good practices (IPCC, 2000; IPCC, 1996). Although emissions were derived from estimate of vehicle kilometres travelled and from fuel consumption per kilometre (bottom-up approach), they were corrected for total national fuel sales (top-down correction).

### 3.3.3.2.2.7 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 3.90 – National specific LHV

Fuel	LHV (GJ/ton)
Gasoline	44.00
Diesel	42.60
Liquefied Petroleum Gases	46.00
Compressed Natural Gases	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 3.91 - CO<sub>2</sub> emission factors

Fuel	EF <sub>CO2</sub> (kg CO <sub>2</sub> /GJ) <sup>23</sup>
Gasoline	68.61
Diesel	73.33
Liquefied Petroleum Gases	62.75
Compressed Natural Gases	55.82

Source: IPCC, 2006

Emissions factors for CH<sub>4</sub> and N<sub>2</sub>O, expressed in g/km, were determined using COPERT IV (version 11.1 – December 2014).

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.

<sup>23</sup> The CO<sub>2</sub> emission factors takes into account an oxidation factor of 0.990 for Gasoline and Diesel, and 0.995 for LPG and CNG

European technology standards were determined according with the vehicle built year as present in table below.

Table 3.92 – 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>(24)</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>24</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 3.93 – Sulphur content in gasoline and diesel (%)

Fuel	1990-1999	2000-2004	2005-2008	2009-2013
Gasoline	0.100	0.015	0.005	0.001

Fuel	1990-1994	1995	1996-1999	2000-2004	2005-2008	2009-2013
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 3.94 – 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 3.95 – Reid Vapour Pressure (kPa)

Month	1990 to 1995	1996 to 1999	2000 to 2013
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 3.96 – 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, 2013)

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, 2013).

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 3.97), emission factors from biodiesel use were assumed to be the same as for diesel.

**Table 3.97 – National biodiesel blends with diesel (%v/v)**

2006	2007	2008	2009	2010	2011	2012	2013
1.6	3.0	2.9	5,1	7,4	7,4	7,7	7,5

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 3.98 – Road transportation emission factors (kg/GJ)

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010	2013
CO <sub>2</sub> (kg/Gj)	Passenger Cars	Gasoline	68.61	68.61	68.61	68.61	68.61	68.61
		Diesel	73.33	73.33	73.33	73.33	73.33	73.33
		LPG	62.75	62.75	62.75	62.75	62.75	62.75
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	73.33	73.33	73.33	73.33	73.33	73.33
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-
	Heavy Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	73.33	73.33	73.33	73.33	0.07	73.33
		LPG	-	-	-	-	-	-
		CNG	-	-	55.82	55.82	55.82	55.82
		Biodiesel	-	-	-	-	-	-
	Motorcycles	Gasoline	68.61	68.61	68.61	68.61	68.61	68.61
		Diesel	-	-	-	-	-	-
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-
CH <sub>4</sub> (kg/Gj)	Passenger Cars	Gasoline	0.044	0.036	0.026	0.019	0.014	0.011
		Diesel	0.006	0.005	0.003	0.002	0.001	0.001
		LPG	0.021	0.022	0.020	0.018	0.015	0.013
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.0009	0.0006
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-
		Diesel	0.004	0.004	0.003	0.002	0.001	0.001
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.0010	0.0007
	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	0.145	0.100	0.074	0.058
		Diesel	-	-	-	-	-	-
		LPG	-	-	-	-	-	-
		CNG	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010	2013
N <sub>2</sub> O (kg/Gj)	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	0.003
		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 3.99 – Road transportation distance based implied emission factor (MJ/km; g/km)

Pollutant	Fuel	Vehicle Type	1990	1995	2000	2005	2010	2013
Energy Consumption (Mj/km)	Diesel	Passenger Cars	2.69	2.61	2.67	2.57	2.52	2.51
		Light Duty Vehicles	3.62	3.52	3.37	3.30	3.26	3.24
		Heavy Vehicles	9.99	9.86	11.62	11.61	11.24	11.67
	Gasoline	Passenger Cars	2.73	2.68	2.65	2.58	2.56	2.56
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	1.10	1.10	1.08	0.97	0.90	0.89
		Motorcycles	1.72	1.75	1.76	1.66	1.60	1.55
	CNG	Heavy Vehicles	-	-	21.57	21.62	21.51	21.51
	LPG	Passenger Cars	2.60	2.63	2.64	2.60	2.58	2.57
		Light Duty Vehicles	-	-	-	-	-	-
CO <sub>2</sub> (g/km)	Diesel	Passenger Cars	197.21	191.09	195.87	188.45	185.10	184.10
		Light Duty Vehicles	265.39	258.38	247.25	241.63	239.13	237.32
		Heavy Vehicles	732.76	723.32	852.32	850.96	824.08	856.09
	Gasoline	Passenger Cars	187.20	183.81	182.12	177.32	175.54	175.46
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	75.47	75.47	73.77	66.25	61.92	60.82
		Motorcycles	118.11	120.20	120.58	114.02	109.68	106.64
	CNG	Heavy Vehicles	-	-	1204.27	1206.97	1200.90	1200.90
	LPG	Passenger Cars	163.30	165.34	165.88	163.35	161.91	161.48
		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	0.002
		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	0.028
		Light Duty Vehicles	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-
		Mopeds	0.219	0.219	0.199	0.106	0.045	0.028
		Motorcycles	0.192	0.192	0.188	0.159	0.131	0.106
	CNG	Heavy Vehicles	-	-	2.05	2.11	1.98	1.98
	LPG	Passenger Cars	0.054	0.058	0.053	0.046	0.040	0.033
		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	-	-	0.002	0.002	0.002	0.002
	LPG	Passenger Cars	0.000	0.010	0.012	0.012	0.011	0.008
		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 2013 was based in data available from ACAP, *Instituto de Seguros de Portugal* (ISP) and INE.

Table 3.100 – Vehicle fleet synthesis

Vehicle Type	1990	1995	2000	2005	2010	2011	2012	2013
Passenger Cars	1 616 142	2 702 220	3 743 313	4 185 544	4 191 284	4 107 557	3 953 000	3 803 360
Light Duty Vehicles	449 918	545 091	684 953	751 144	718 869	697 109	661 532	628 816
Mopeds	834 675	682 031	529 387	330 528	283 369	278 805	278 252	277 354
Motorcycles	66 129	92 239	144 595	157 055	215 987	215 538	222 557	231 095

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 stabilized 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.

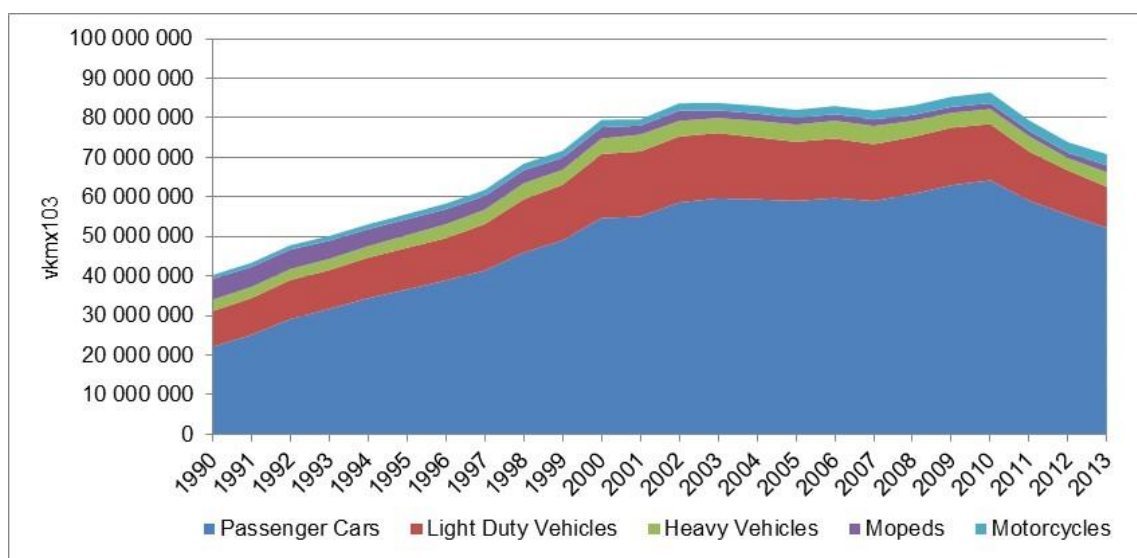


Figure 3.62 – Kilometers travelled by vehicle type (vkmx10<sup>3</sup>)

### 3.3.3.2.4.3 Fuel Consumption

Fuel consumption from road transport sector is available from the revised energy balances from DGE and is presented in the following figure and ANNEX E.

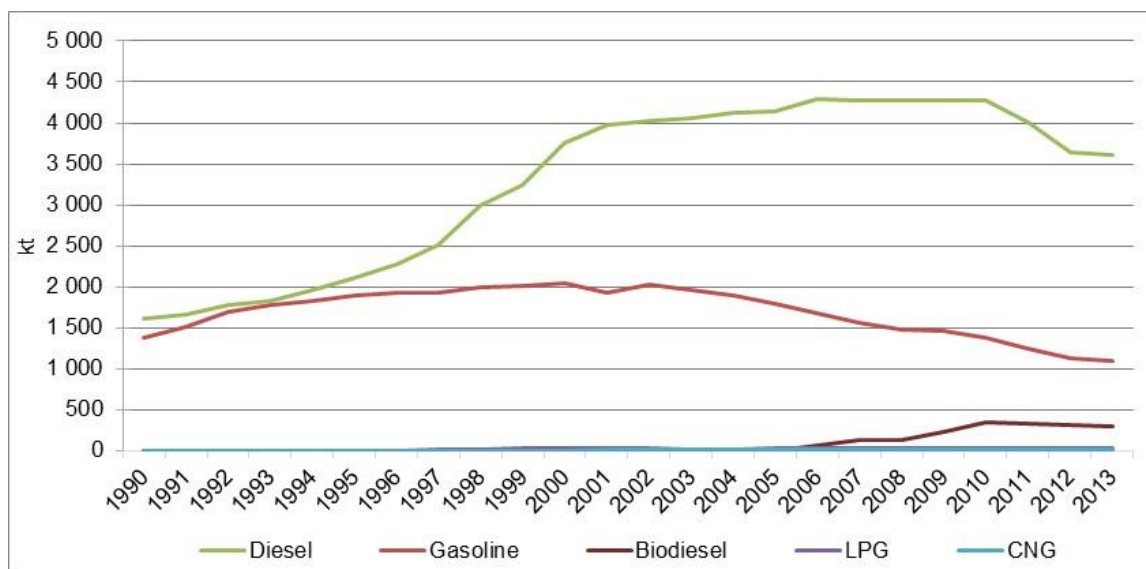


Figure 3.63 – Fuel consumption from road transport sector (kt)

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 2013 the estimated fuel consumption compared to sales are: Gasoline -2%; Diesel 5%; LPG -81%; CNG -98%. 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

Emissions were estimated using the new version of COPERT IV (version 11 - December 2014) and due to improved methodology and updated emission factors, results in the following changes:

- updated emission factors of regulated and non-regulated pollutants for Euro 5/V and Euro 6/VI vehicles, including N<sub>2</sub>O;

- revisions and updates, where necessary, of N<sub>2</sub>O emission factors for pre Euro 5/V technologies;
- a CO<sub>2</sub> correction methodology based on type-approval data for Euro 4-6 gasoline and diesel passenger cars has been introduced;
- CH<sub>4</sub> emission factors for gasoline passenger cars have been updated;
- emission factors for CNG vehicles of Euro 4-6 technologies have been introduced.

Recalculations for this source category also comprise:

- CO<sub>2</sub> fuel emission factor revision for Diesel, Gasoline and LPG based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

### 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.

Table 3.101 – Estimated emissions from Railways (Gg CO<sub>2</sub> eq)

Source Category/Pollutant	1990	1995	2000	2005	2010	2011	2012	2013
<b>Railways</b>	<b>195.94</b>	<b>190.65</b>	<b>149.89</b>	<b>90.98</b>	<b>52.19</b>	<b>45.61</b>	<b>37.10</b>	<b>33.52</b>
CO <sub>2</sub> Fossil	175.31	170.58	134.11	81.41	46.36	40.52	32.95	29.77
CO <sub>2</sub> Biomass*	0.00	0.00	0.00	0.00	3.21	2.81	2.38	2.09
CH <sub>4</sub>	0.25	0.24	0.19	0.12	0.07	0.06	0.05	0.05
N <sub>2</sub> O	20.38	19.83	15.59	9.46	5.76	5.03	4.10	3.70

\*Information item. Emissions not included in national totals.

#### 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:

$$\text{FossilCO}_2(y) = \sum_f [\text{EF}_{\text{CO}_2(f)} * \text{FacOX}(f) * \text{C}_{\text{Fossil}(f)} * \text{Cons}_{\text{Fuel}(f,y)} * \text{LHV}(f)] * 10^{-5}$$

where

FossilCO<sub>2</sub>(y) - Emissions of carbon dioxide to atmosphere from combustion of fossil fuel f (ton);

EF<sub>CO<sub>2</sub>(f)</sub> – Total carbon content of fuel expressed in total CO<sub>2</sub> emissions (kgCO<sub>2</sub>/GJ);

C<sub>Fossil</sub> - Percentage of carbon from fossil origin in fuel f (%);

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

$Cons_{Fuel(f,y)}$  - Consumption of fuel f in year y (ton/yr);

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

For all other pollutants the following formula was used:

$$Emission_{(p,y)} = \sum_f [EF_{(f,p)} * Cons_{Fuel(f,y)}] * 10^{-3}$$

where

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

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

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

### 3.3.3.3.3 Emission Factors

Emission factors were set from available proposed emission factors in IPCC 2006 Guidelines.

Table 3.102 - Low Heating Value (LHV) - Railways

Fuel		NAPFUE	LHV	
			Value	Unit
Coal	S	102	30.95	MJ/kg
Coke	S	108	29.40	MJ/kg
Diesel-oil	L	204	42.60	MJ/kg
Biodiesel	B	223	37.00	MJ/kg

Source: DGEG

Table 3.103 - Oxidation factor and Percentage of carbon from fossil origin in fuels - Railways

Fuel	Oxidation factor		% C fossil	
	Value	Unit	Value	Unit
Coal	0.980	Ratio	100	%
Coke	0.990	Ratio	100	%
Diesel-oil	0.990	Ratio	100	%
Biodiesel	1.000	Ratio	0	%

Table 3.104 - Emission factors for Greenhouse gases in Railways

Fuel	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Coal	96.1	kg/Gj	IPCC 2006	2.0	g/Gj	IPCC 2006	1.5	g/Gj	IPCC 2006
Coke	96.1	kg/Gj	IPCC 2006	2.0	g/Gj	IPCC 2006	1.5	g/Gj	IPCC 2006
Diesel-oil	74.1	kg/Gj	IPCC 2006	4.15	g/Gj	IPCC 2006	28.6	g/Gj	IPCC 2006
Biodiesel	74.1	kg/Gj	IPCC 2006	4.15	g/Gj	IPCC 2006	28.6	g/Gj	IPCC 2006

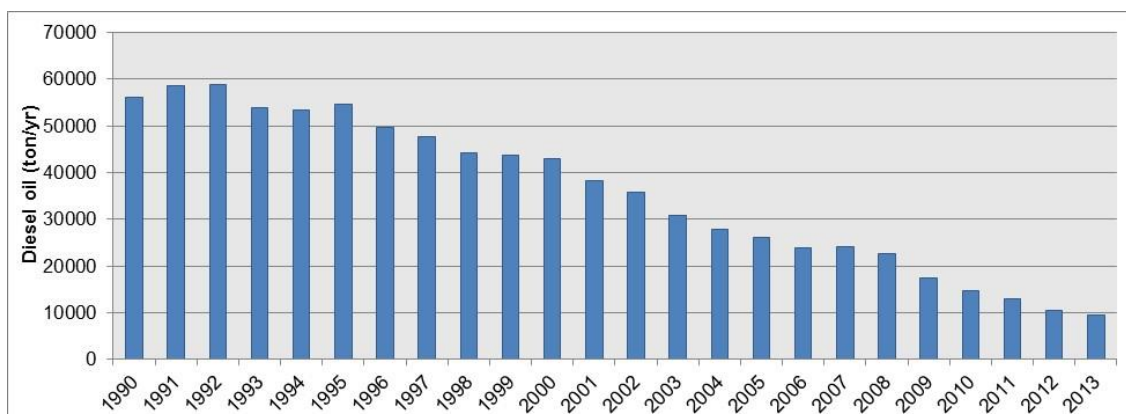
### 3.3.3.3.4 Activity Data

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2013 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>25</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 3.64.

Figure 3.64 - 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.

#### 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 are mostly due to the revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for all fuels based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### 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.

<sup>25</sup> Gas oil represents no less than 93 per cent of total annual use of combustible energy.

Table 3.105 – Estimated emissions from Water-Borne Navigation (Gg CO<sub>2</sub> eq)

Source Category/Pollutant	1990	1995	2000	2005	2010	2011	2012	2013
<b>Domestic Water-Borne Navigation</b>	<b>262.5</b>	<b>227.3</b>	<b>201.4</b>	<b>209.2</b>	<b>229.2</b>	<b>203.6</b>	<b>227.4</b>	<b>249.5</b>
CO <sub>2</sub>	259.9	225.0	199.4	207.1	226.9	201.5	225.1	247.0
CH <sub>4</sub>	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.6
N <sub>2</sub> O	2.0	1.8	1.6	1.6	1.8	1.6	1.8	1.9
<b>International Water-Borne Navigation*</b>	<b>1400.1</b>	<b>1118.9</b>	<b>1667.1</b>	<b>1553.2</b>	<b>1634.6</b>	<b>1952.0</b>	<b>2097.4</b>	<b>2210.2</b>
CO <sub>2</sub>	1386.0	1107.6	1650.3	1537.6	1618.2	1932.5	2076.4	2188.1
CH <sub>4</sub>	3.2	2.6	3.8	3.5	3.7	4.4	4.8	5.0
N <sub>2</sub> O	10.9	8.7	13.0	12.1	12.7	15.1	16.2	17.1

\*Memo item. Emissions not included in national totals

#### 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:

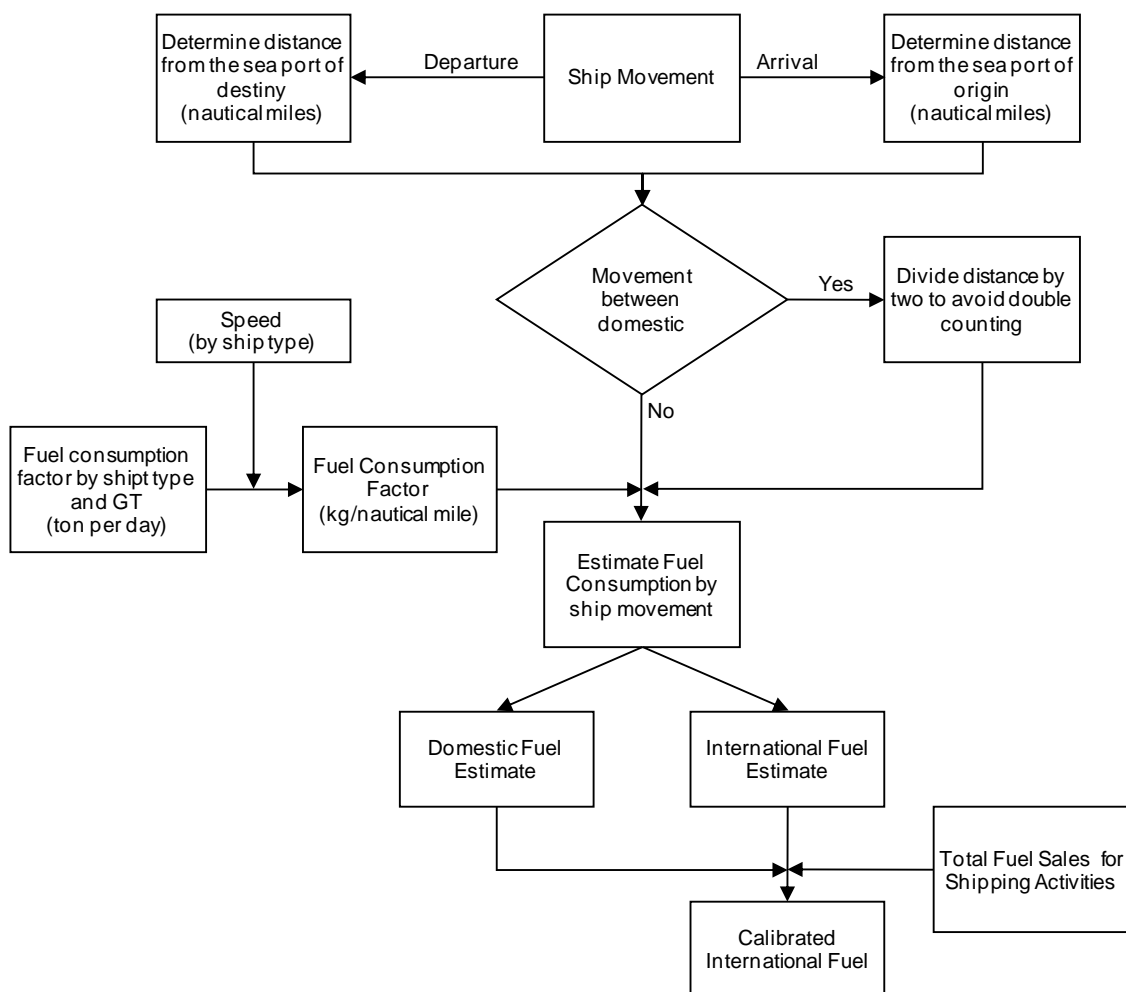
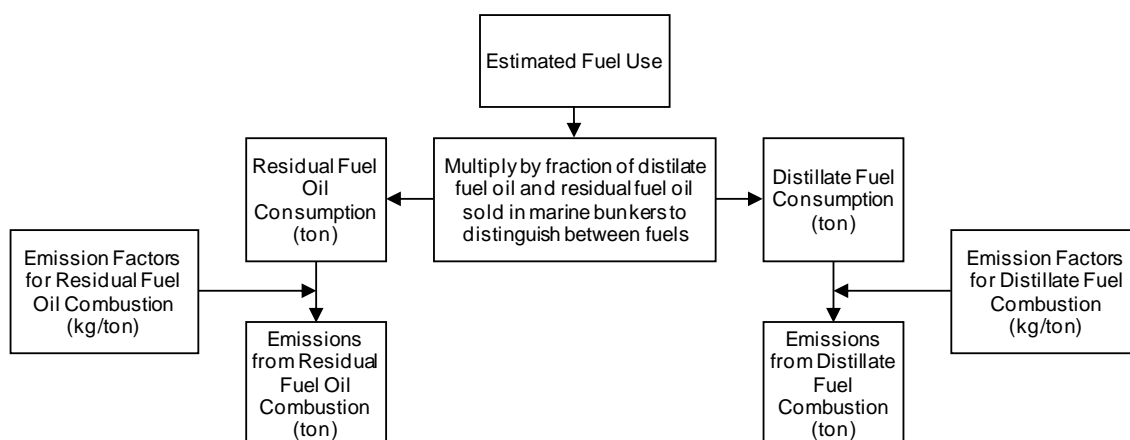


Figure 3.65 – Generic methodology flowchart.

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, and the CH<sub>4</sub> and N<sub>2</sub>O emission factors were obtained from IPCC 2006 Guidelines.

When estimating CO<sub>2</sub>, it was assumed that a fraction of carbon (0,01) remains unoxidized and stored indefinitely, as follows:

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

Table 3.106 - Low Heating Value (LHV) - Navigation

Fuel		NAPFUE	LHV
			MJ/kg
Gas-oil	L	204	42.60
Residual Fuel-oil	L	203	40.00

Source: DGEG

Table 3.107 – Carbon content - Navigation

Fuel	Default carbon content		
	Value	Unit	Reference
Gas-oil	20.20	t/TJ	IPCC 2006
Residual Fuel-oil	21.10	t/TJ	IPCC 2006

Table 3.108 - Emission factors for Greenhouse gases - Navigation

Fuel	CO <sub>2</sub> <sup>(a)</sup>			CH <sub>4</sub>			N <sub>2</sub> O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Gas-oil	73.3	t /TJ	IPCC 2006	7.0	kg/TJ	IPCC 2006	2.0	kg/TJ	IPCC 2006
Residual Fuel-oil	76.6	t /TJ	IPCC 2006	7.0	kg/TJ	IPCC 2006	2.0	kg/TJ	IPCC 2006

<sup>(a)</sup> The CO<sub>2</sub> emission factors takes into account an oxidation factor of 0.990

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 IPCC 2006.

Table 3.109 – Consumption factors

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

Legend:

gt – gross tonnage

<sup>(a)</sup> – a factor of 0.8 was applied to obtain consumption for cruise.

Source: (IPCC 2006)

#### 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 2013. 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 3.110 – Ship docks**

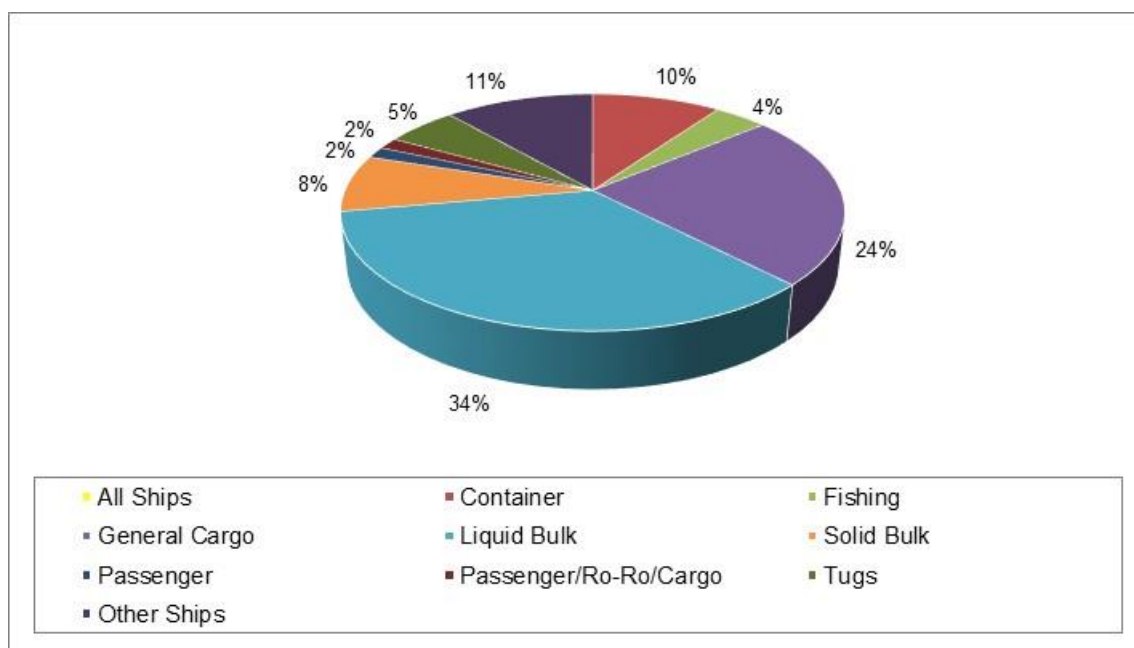
Sea Port	Location	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aveiro	Mainland	docks	876	920	965	1 009	1 054	1 098	1 080	1 062	1 045	1 027	1 009	1 042
Caniçal	Madeira	docks	76	76	76	76	76	76	76	76	76	76	76	76
Faro	Mainland	docks	163	163	163	163	163	163	163	163	163	163	163	89
Figueira 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	2013
Aveiro	Mainland	docks	1 021	1 013	1 053	1 028	1 002	977	1 010	848	961	874	837	922
Caniçal	Madeira	docks	57	76	94	178	263	347	431	347	390	345	276	283
Faro	Mainland	docks	69	51	36	32	27	23	17	15	12	24	70	35
Figueira da Foz	Mainland	docks	260	262	292	321	349	378	406	359	476	477	471	523
Funchal	Madeira	docks	1 076	1 090	1 022	948	874	800	726	800	758	902	771	719
Leixões	Mainland	docks	3 090	2 952	2 815	2 814	2 814	2 813	2 727	2 637	2 612	2 637	2 608	2 564
Lisboa	Mainland	docks	3 735	3 713	3 473	3 474	3 474	3 475	3 455	3 251	3 129	3 063	2 652	2 658
Ponta Delgada	Azores	docks	1 047	1 125	1 067	1 078	1 090	1 101	1 112	1 095	1 035	1 035	912	886
Portimão	Mainland	docks	28	33	56	42	29	15	42	97	136	122	56	105
Porto Santo	Madeira	docks	402	399	398	400	403	405	407	405	392	429	383	368
Setúbal	Mainland	docks	1 603	1 609	1 669	1 592	1 516	1 439	1 389	1 404	1 632	1 609	2 604	1 426
Sines	Mainland	docks	806	753	927	1 124	1 321	1 518	1 518	1 458	1 632	1 565	1 636	1 991
Viana do Castelo	Mainland	docks	315	262	208	214	220	226	246	179	179	218	248	214

#### 3.3.3.4.2 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 3.66 – Ship fleet.



#### 3.3.3.4.3 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 3.111 – Total fuel sales

Fuel Sales		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gas-oil	L	204	126 903	123 797	123 902	120 747	114 490	141 272	148 771	137 420	132 235	142 877	125 554	104 612
Residual Fuel-oil	L	203	407 823	406 206	403 591	334 853	305 775	290 920	306 451	311 196	320 960	416 843	475 743	331 358

Fuel Sales		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Gas-oil	L	204	94 901	110 683	108 590	110 197	97 014	88 729	114 495	105 133	94 064	96 886	84 929	95 729
Residual Fuel-oil	L	203	366 423	444 170	529 904	457 115	516 191	552 950	590 249	547 252	506 320	597 752	664 621	697 217

Source: DGEG

Table 3.112 – Estimated fuel consumption (t)

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Fuel-oil	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
Residual Fuel-oil	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>Residual Fuel-oil</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
Gas-oil	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
Gas-oil	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>Gas-oil</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	2013
Residual Fuel-oil	Domestic	47 600	47 939	48 931	48 804	48 828	48 852	49 836	52 816	53 458	47 488	53 052	58 204
Residual Fuel-oil	International	420 785	415 054	423 117	411 428	399 120	386 812	402 246	479 587	515 738	486 036	463 153	710 727
<b>Residual Fuel-oil</b>	<b>Total</b>	468 384	462 993	472 048	460 233	447 948	435 664	452 082	532 403	569 196	533 523	516 205	768 931
Gas-oil	Domestic	17 979	18 107	18 482	18 434	18 443	18 452	18 824	19 949	20 192	17 937	20 038	21 984
Gas-oil	International	158 935	156 770	159 816	155 401	150 752	146 103	151 932	181 145	194 799	183 581	174 938	268 449
<b>Gas-oil</b>	<b>Total</b>	176 914	174 877	178 297	173 835	169 195	164 555	170 756	201 094	214 991	201 517	194 976	290 433



Table 3.113 – Estimated fuel consumption after top-down calibration (t).

Fuel	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Residual Fuel-oil	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
Residual Fuel-oil	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>Residual Fuel-oil</b>	<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
Gas-oil	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
Gas-oil	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>Gas-oil</b>	<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	2013
Residual Fuel-oil	Domestic	47 600	47 939	48 931	48 804	48 828	48 852	49 836	52 816	53 458	47 488	53 052	58 204
Residual Fuel-oil	International	318 823	396 231	480 974	408 311	467 363	504 098	540 413	494 436	452 862	550 264	611 569	639 013
<b>Residual Fuel-oil</b>	<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	697 217
Gas-oil	Domestic	17 979	18 107	18 482	18 434	18 443	18 452	18 824	19 949	20 192	17 937	20 038	21 984
Gas-oil	International	76 922	92 576	90 109	91 763	78 571	70 277	95 672	85 184	73 872	78 949	64 890	73 745
<b>Gas-oil</b>	<b>Total</b>	94 901	110 683	108 590	110 197	97 014	88 729	114 495	105 133	94 064	96 886	84 929	95 729

### 3.3.3.4.3.1 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 3.114. Specific tug fuel consumption factors were supplied by IPTM.

Table 3.114 – 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 3.115 – Ship type classification for tugs fuel consumption estimation.

Ship Type	gt
Small Size	gt≤1000
Medium Size	10000≤gt<1000
Large Size	50000≤gt<10000
Super Large Size	gt>50000
gt: gross tonnage	

Finally the fuel consumption was added to the ship that needed the tugs service. The fuel tables presented above include fuel consumption in tugs operations.

### 3.3.3.4.5 Uncertainty Assessment

Activity level uncertainty refers to the fuel consumption uncertainty which depends on the number of movements, the distance travelled and fuel consumption factors. The global uncertainty is therefore obtained from:

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

Movement's uncertainty was assumed to be 5% as suggested in IPCC Good Practice Guidance and Uncertainty Management. The distance uncertainty was calculated assuming that ships speeds were constant between origin and destiny seaports. This allows the indirect assessment of the uncertainty through 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 3.116.

Table 3.116 – 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 0.4% in 2008 which could result from rounding values.

#### 3.3.3.4.7 Recalculations

Recalculations for this source category comprise:

- revision of 2012 energy balance data for Gas-oil;
- revision of CH<sub>4</sub> and N<sub>2</sub>O emission factors for all fuels based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### 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).

### 3.3.3.6 Other Sectors (CRF 1.A.4.)

#### 3.3.3.6.1 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.

Table 3.117 – Estimated emissions from Other Sectors (Gg CO<sub>2</sub> eq)

Source Category/Pollutant	1990	1995	2000	2005	2010	2011	2012	2013
<b>Commercial/Institutional</b>	<b>747.7</b>	<b>1112.7</b>	<b>2637.2</b>	<b>3137.3</b>	<b>1300.4</b>	<b>1101.8</b>	<b>1093.5</b>	<b>1069.6</b>
CO <sub>2</sub> Fossil	744.8	1109.0	2627.0	3124.4	1293.3	1089.3	1083.2	1059.4
CO <sub>2</sub> Biomass*	0.0	0.0	2.2	5.6	12.5	296.2	174.7	170.5
CH <sub>4</sub>	0.4	0.7	1.3	1.3	0.5	1.1	0.9	0.8
N <sub>2</sub> O	2.4	3.1	8.9	11.7	6.6	11.4	9.4	9.3
<b>Residential</b>	<b>2158.7</b>	<b>2414.4</b>	<b>2856.5</b>	<b>2712.2</b>	<b>2832.8</b>	<b>2492.0</b>	<b>2335.0</b>	<b>2258.1</b>
CO <sub>2</sub> Fossil	1655.7	1955.6	2435.8	2355.5	2541.0	2186.6	2031.3	1949.3
CO <sub>2</sub> Biomass*	6097.3	5449.4	4858.0	4094.2	3332.5	3551.2	3553.1	3630.2
CH <sub>4</sub>	409.9	366.4	326.9	275.5	224.3	239.0	239.0	244.2
N <sub>2</sub> O	93.2	92.4	93.8	81.2	67.5	66.4	64.7	64.6
<b>Agriculture /Forestry /Fishing</b>	<b>1812.3</b>	<b>1823.8</b>	<b>1375.2</b>	<b>1442.1</b>	<b>1171.0</b>	<b>1146.5</b>	<b>1131.2</b>	<b>1170.3</b>
CO <sub>2</sub> Fossil	1661.2	1661.4	1279.3	1321.7	1072.5	1049.6	1033.2	1069.2
CO <sub>2</sub> Biomass*	0.0	0.0	0.5	1.6	64.8	65.3	68.4	69.0
CH <sub>4</sub>	3.9	4.0	3.1	3.2	2.8	2.7	2.7	2.8
N <sub>2</sub> O	147.2	158.4	92.8	117.2	95.7	94.1	95.3	98.3

\*Information item. Emissions not included in national totals.

### 3.3.3.6.2 Commercial/Institutional (CRF 1.A.4.a)

#### 3.3.3.6.2.1 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.

#### 3.3.3.6.2.2 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 IPCC 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):

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

where:

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

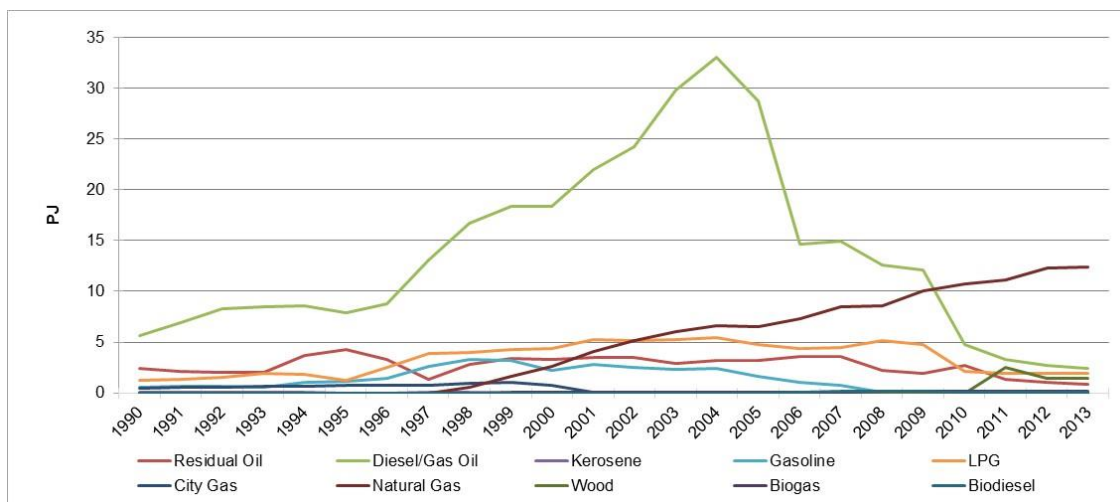
$EF_{(p,f,s,t)}$  - Emission Factor for pollutant p, specific of fuel type f, used in sub-sector s and equipment t (g/GJ except CO<sub>2</sub> in kg/GJ);

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

### 3.3.3.6.2.2.1 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following figures and Annex E.

Figure 3.67 – Fuels consumed in the commercial, services and institutional sector



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 3.68 – Total Energy Consumption in fuels in the commercial, services and institutional sector

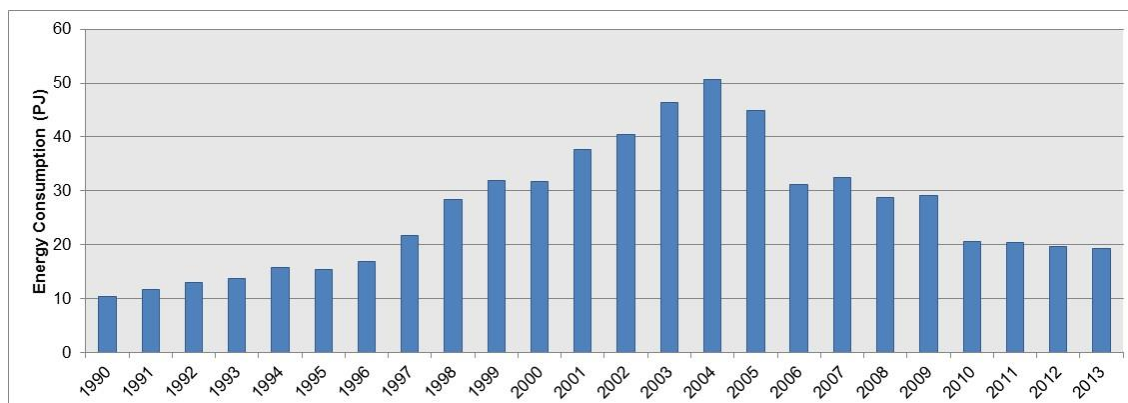
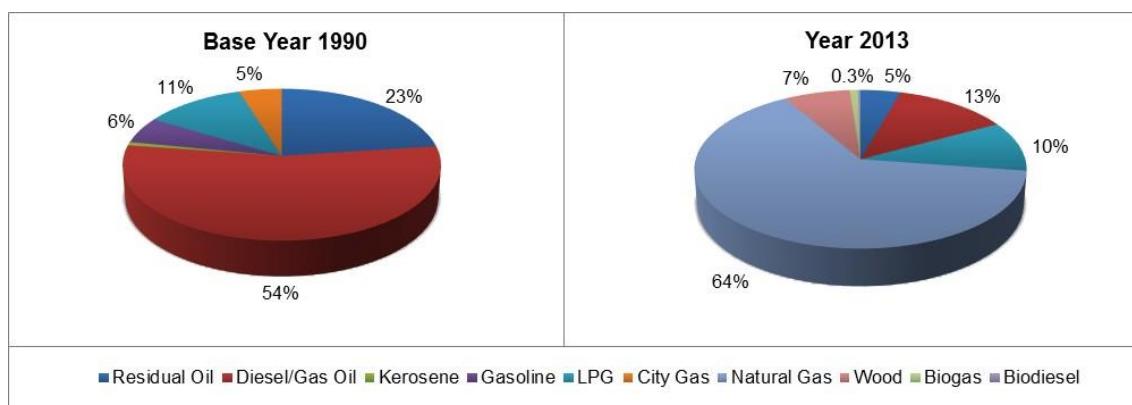


Figure 3.69 – Consumption of energy in fuels in the commercial, services and institutional sector in 1990 and 2013



### 3.3.3.6.2.2.2 Emission Factors

The emission factors that were used were collected from IPCC guidelines.

Table 3.118 – Low Heating Value (LHV) - Commercial, services and institutional sector

Fuel		NAPFUE	LHV
			MJ/kg
Residual Oil	L	203	40.0
Gas Oil / Diesel Oil	L	204	42.6
Kerosene	L	206	43.8
Motor Gasoline	L	208	44.0
LPG	L	303	46.0
City Gas	L	308	15.7
Natural Gas	G	301	46.1
Wood	B	111	12.6
Biogas	B	309	34.7
Biodiesel	B	223	37.0

Source: DGEG

Table 3.119 – Oxidation factor and Percentage of carbon from fossil origin in fuels - Commercial, services and institutional sector

Fuel	Oxidation factor		% C fossil	
	Value	Unit	Value	Unit
Residual Oil	0.990	Ratio	100	%
Gas Oil / Diesel Oil	0.990	Ratio	100	%
Kerosene	0.990	Ratio	100	%
Motor Gasoline	0.990	Ratio	100	%
LPG	0.995	Ratio	100	%
City Gas	0.995	Ratio	100	%
Natural Gas	0.995	Ratio	100	%
Wood	1.000	Ratio	0	%
Biogas	1.000	Ratio	0	%
Biodiesel	1.000	Ratio	0	%

Table 3.120 – Emissions factors for Greenhouse gases - Commercial, services and institutional sector

Fuel	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Residual Oil	77.4	kg/Gj	IPCC 2006	1.4	g/Gj	IPCC 2006	0.3	g/Gj	IPCC 2006
Gas Oil / Diesel Oil	74.1	kg/Gj	IPCC 2006	0.7	g/Gj	IPCC 2006	0.4	g/Gj	IPCC 2006
Kerosene	71.9	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
Motor Gasoline	69.3	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
LPG	63.1	kg/Gj	IPCC 2006	0.9	g/Gj	IPCC 2006	4.0	g/Gj	IPCC 2006
City Gas	57.6	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006
Natural Gas	56.1	kg/Gj	IPCC 2006	1.0	g/Gj	IPCC 2006	1.0	g/Gj	IPCC 2006
Wood	111.8	kg/Gj	IPCC 2006	11.0	g/Gj	IPCC 2006	7.0	g/Gj	IPCC 2006
Biogas	54.6	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006
Biodiesel	70.8	kg/Gj	IPCC 2006	0.7	g/Gj	IPCC 2006	0.4	g/Gj	IPCC 2006

### 3.3.3.6.2.3 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.

### 3.3.3.6.2.4 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). 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.



### 3.3.3.6.2.5 Recalculations

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline, Wood, City Gas, Biogas, and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Diesel oil, Wood, City Gas, Biogas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Diesel oil, Residual oil, Wood, City Gas, Biogas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

### 3.3.3.6.2.6 Further Improvements

No further improvements are planned for this sector.

## 3.3.3.7 Residential (CRF 1.A.4.b)

### 3.3.3.7.1 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.

### 3.3.3.7.2 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 IPCC methodology.

For Carbon Dioxide (CO<sub>2</sub>), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

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

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

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 (%);

$F_{acOX(f)}$  – 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):

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

where:

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

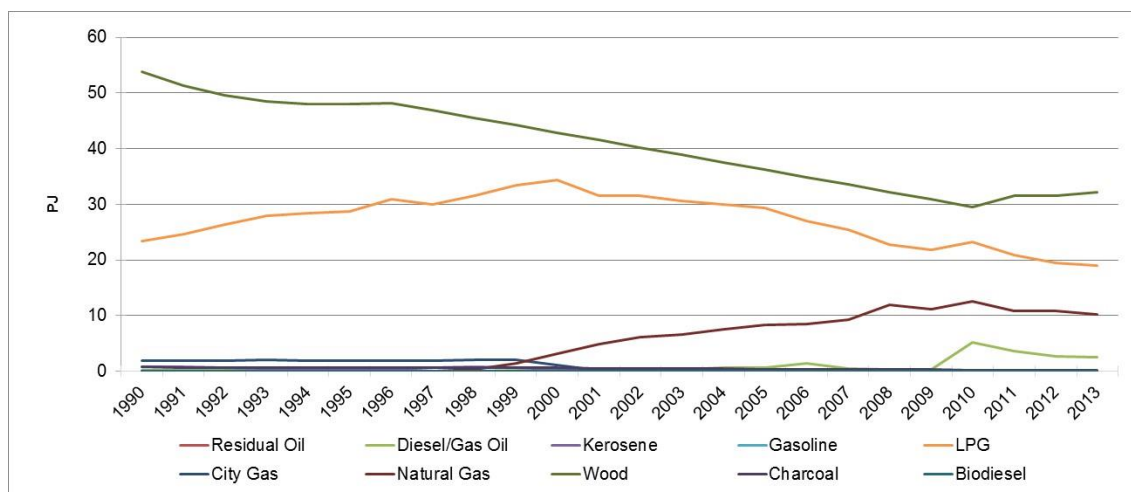
$EF_{(p,f,s,t)}$  - Emission Factor for pollutant  $p$ , specific of fuel type  $f$ , used in sub-sector  $s$  and equipment  $t$  (g/GJ except CO<sub>2</sub> in kg/GJ);

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

#### 3.3.3.7.2.1 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following figures and Annex E. Charcoal consumption was obtained from an inquiry made to the residential sector by DGEG.

Figure 3.70 – Fuels consumed in the residential sector



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 3.71 – Total Energy Consumption in fuels in the residential sector

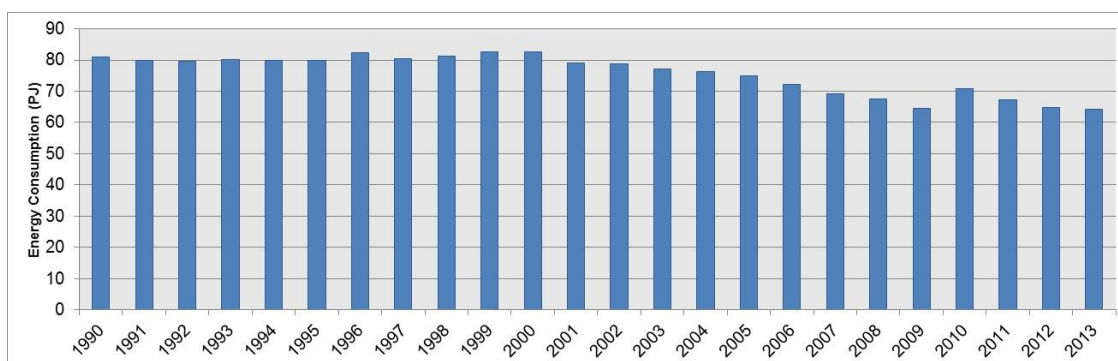
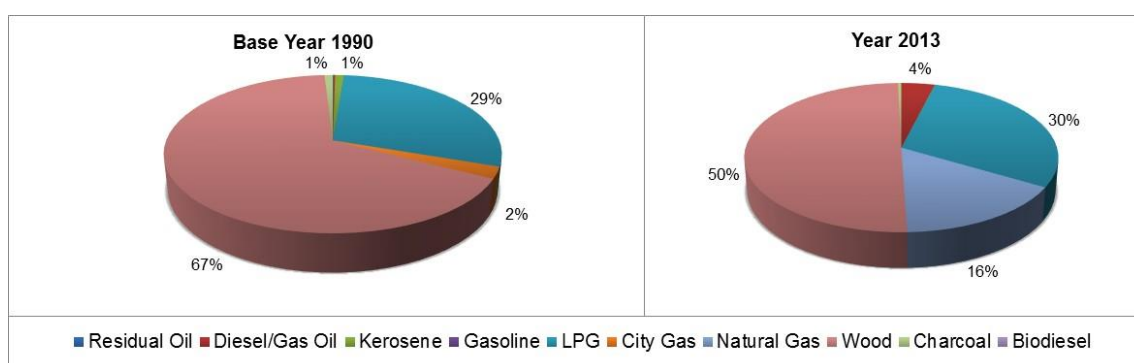


Figure 3.72 – Consumption of energy in fuels in the residential sector in 1990 and 2013



### 3.3.3.7.2.2 Emission Factors

The emission factors that were used were collected from IPCC guidelines.

Table 3.121 – Low Heating Value (LHV) - Residential sector

Fuel		NAPFUE	LHV
			MJ/kg
Residual Oil	L	203	40.00
Diesel/Gas Oil	L	204	42.60
Kerosene	L	206	43.75
Motor Gasoline	L	208	44.00
LPG	L	303	46.00
City Gas	L	308	15.69
Natural Gas	G	301	46.07
Wood	B	111	12.55
Charcoal	B	112	25.10
Biodiesel	B	223	37.00

Source: DGEG

Table 3.122 – Oxidation factor and Percentage of carbon from fossil origin in fuels – Residential sector

Fuel	Oxidation factor		% C fossil	
	Value	Unit	Value	Unit
Residual Oil	0.990	Ratio	100	%
Diesel/Gas Oil	0.990	Ratio	100	%
Kerosene	0.990	Ratio	100	%
Motor Gasoline	0.990	Ratio	100	%
LPG	0.995	Ratio	100	%
City Gas	0.995	Ratio	100	%
Natural Gas	0.995	Ratio	100	%
Wood	1.000	Ratio	0	%
Charcoal	1.000	Ratio	0	%
Biodiesel	1.000	Ratio	0	%

Table 3.123 – Emissions factors for Greenhouse gases - Residential sector

Fuel	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Residual Oil	77.4	kg/Gj	IPCC 2006	1.4	g/Gj	IPCC 2006	0.3	g/Gj	IPCC 2006
Diesel/Gas Oil	74.1	kg/Gj	IPCC 2006	0.7	g/Gj	IPCC 2006	0.4	g/Gj	IPCC 2006
Kerosene	71.9	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
Motor Gasoline	69.3	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
LPG	63.1	kg/Gj	IPCC 2006	0.9	g/Gj	IPCC 2006	4.0	g/Gj	IPCC 2006
City Gas	57.6	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006
Natural Gas	56.1	kg/Gj	IPCC 2006	1.0	g/Gj	IPCC 2006	1.0	g/Gj	IPCC 2006
Wood	111.8	kg/Gj	IPCC 2006	300.0	g/Gj	IPCC 2006	4.0	g/Gj	IPCC 2006
Charcoal	111.8	kg/Gj	IPCC 2006	300.0	g/Gj	IPCC 2006	4.0	g/Gj	IPCC 2006
Biodiesel	70.8	kg/Gj	IPCC 2006	0.7	g/Gj	IPCC 2006	0.4	g/Gj	IPCC 2006

### 3.3.3.7.3 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.

### 3.3.3.7.4 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.

### 3.3.3.7.5 Recalculations

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline, Wood, City Gas, Charcoal and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Diesel oil, City Gas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Motor Gasoline, Kerosene, Diesel oil, Residual oil, Wood, City Gas, Charcoal, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

### 3.3.3.7.6 Further Improvements

No further improvements are planned for this sector.

## 3.3.3.8 Agriculture / Forestry / Fishing – Stationary (CRF 1.A.4.c.i)

### 3.3.3.8.1 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.

### 3.3.3.8.2 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 IPCC 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):

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

where:

$Emi_{(p,s)}$  - Total emissions of pollutant p for sub-sector s (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, used in sub-sector s and equipment t (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).

### 3.3.3.8.2.1 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following figures and Annex E.

Figure 3.73 – Fuels consumed in the agriculture and forestry sector (excluding mobile sources)

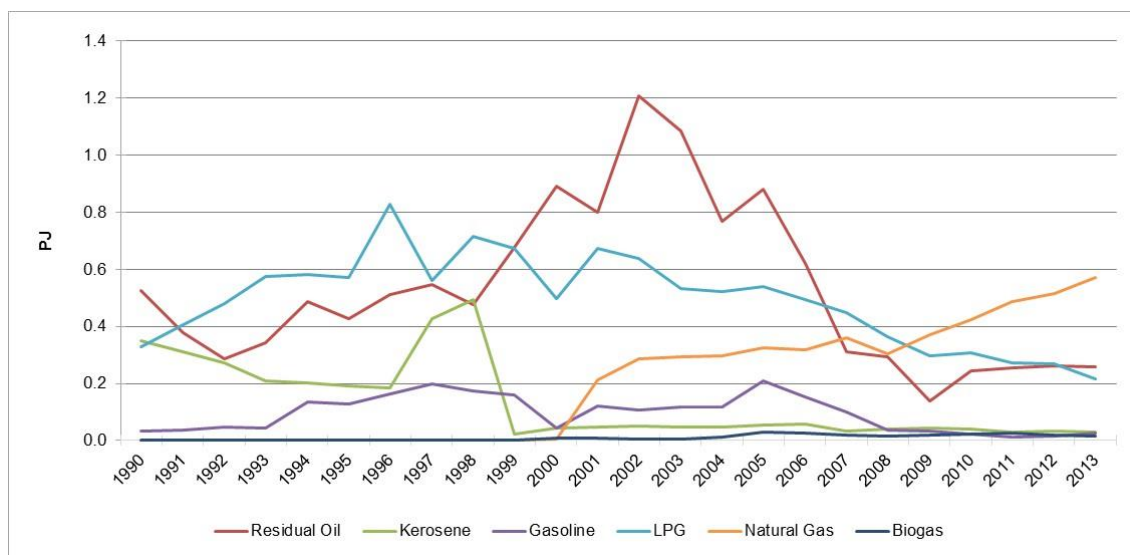


Figure 3.74 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources)

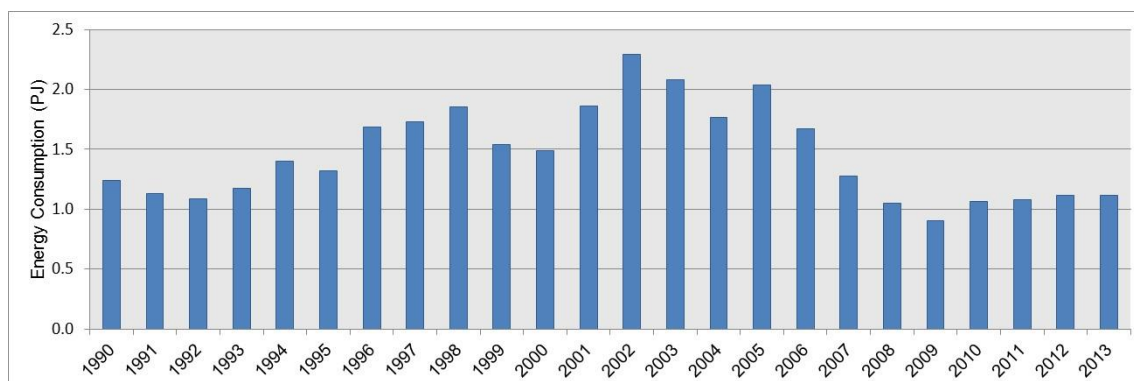
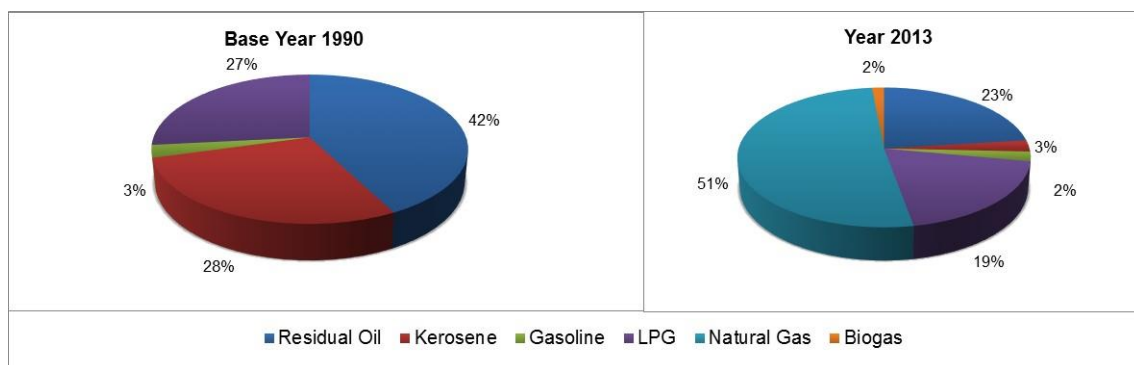


Figure 3.75 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2013



### 3.3.3.8.2.2 Emission Factors

The emission factors that were used were collected from IPCC guidelines.

Table 3.124 – Low Heating Value (LHV) - Agriculture / Forestry / Fishing – Stationary sector

Fuel		NAPFUE	LHV
			MJ/kg
Residual Oil	L	203	40.00
Kerosene	L	206	43.75
Motor Gasoline	L	208	44.00
LPG	L	303	46.00
Natural Gas	G	301	46.07
Biogas	B	309	34.70

Source: DGEG

Table 3.125 – Oxidation factor and Percentage of carbon from fossil origin in fuels - Agriculture / Forestry / Fishing – Stationary sector

Fuel	Oxidation factor		% C fossil	
	Value	Unit	Value	Unit
Residual Oil	0.990	Ratio	100	%
Kerosene	0.990	Ratio	100	%
Motor Gasoline	0.990	Ratio	100	%
LPG	0.995	Ratio	100	%
Natural Gas	0.995	Ratio	100	%
Biogas	1.000	Ratio	0	%

Table 3.126 – Emissions factors for Greenhouse gases - Agriculture / Forestry / Fishing – Stationary sector

Fuel	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Residual Oil	77.4	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
Kerosene	71.9	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
Motor Gasoline	69.3	kg/Gj	IPCC 2006	10.0	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
LPG	63.1	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006
Natural Gas	56.1	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006
Biogas	54.6	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006

#### 3.3.3.8.3 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.

#### 3.3.3.8.4 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.

#### 3.3.3.8.5 Recalculations

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline and Biogas based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;



- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Natural Gas and Biogas based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Natural Gas and Biogas based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### 3.3.3.8.6 Further Improvements

No further improvements are planned for this sector.

### 3.3.3.9 Agriculture / Forestry / Fishing – Off-road Vehicles and Other Machinery (CRF 1.A.4.c.ii)

#### 3.3.3.9.1 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.

#### 3.3.3.9.2 Methodology

Emissions to atmosphere of ultimate CO<sub>2</sub> from fossil origin were estimated from CO<sub>2</sub> total emissions by:

$$\text{FossilCO}_{2(y)} = \sum_f [\text{EF}_{\text{CO}_2} * \text{FaCO}_X * \text{Cons}_{\text{Fuel}(y)} * \text{LHV}] * 10^{-5}$$

where

FossilCO<sub>2(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);

FaCO<sub>X</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);

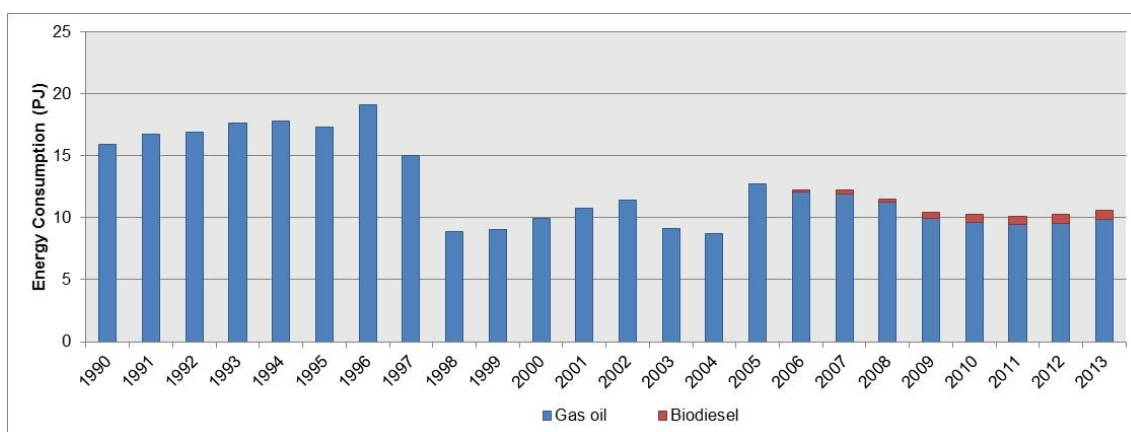
$EF_{(p)}$  - Emission factor for pollutant p (kg/ton);

$Cons_{Fuel(y)}$  - consumption of gas oil in agriculture machines and off-road vehicles during in year y (ton/yr).

### 3.3.3.9.2.1 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 and in Annex E.

Figure 3.76 - Consumption of gas-oil in machines and other off-road vehicles



### 3.3.3.9.2.2 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 3.127 – 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
NM VOC	8.4	8.4	
CH <sub>4</sub>	0.3	0.3	
CO	20.7	20.7	
CO <sub>2</sub>	73.3	74.1	kg/GJ
%CO <sub>2</sub> Fossil	100	0.0	%
Fac <sub>ox</sub>	0.990	1	0..1
N <sub>2</sub> O	1.3	1.3	g/kg

#### 3.3.3.9.3 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.

#### 3.3.3.9.4 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.

#### 3.3.3.9.5 Recalculations

Recalculations for this sector comprise the revision of 2011 and 2012 energy balance data.

#### 3.3.3.9.6 Further Improvements

No further improvements are planned for this sector.

### 3.3.3.10 Agriculture / Forestry / Fishing – Fishing (CRF 1.A.4.c.iii)

#### 3.3.3.10.1 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-sea fishing and cod-fish fishing vessels.

In the inventory process it was assumed that marine diesel engines are the main power source for ships either for transport or shipping activities. Small local fishing and sport ships do in fact use petrol-engines but they represent a small proportion of total consumption and for most situations their fuel consumption cannot be individualised from road traffic consumption. Again consumption of biodiesel was determined as a part of the gas oil since 2006.

### 3.3.3.10.2 Methodology

#### 3.3.3.10.2.1.1 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 IPCC 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):

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

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).

#### 3.3.3.10.2.1.2 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:

$$FossilCO_2(n,y) = \sum_f [EF_{CO_2(f)} * Fac_{OX(f)} * C_{Fossil(f)} * Cons_{Fuel(n,f,y)} * LHV_{(f)}] * 10^{-5}$$

Where,

$FossilCO_2(y)$  - Emissions of carbon dioxide to atmosphere from combustion of fossil origin from ships of class  $n$  (ton);

$EF_{CO_2(f)}$  - Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg  $CO_2$ /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).

### 3.3.3.10.2.1.3 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 figures and Annex E.

Figure 3.77 – Fuels consumed in fisheries (excluding consumption in fishing vessels)

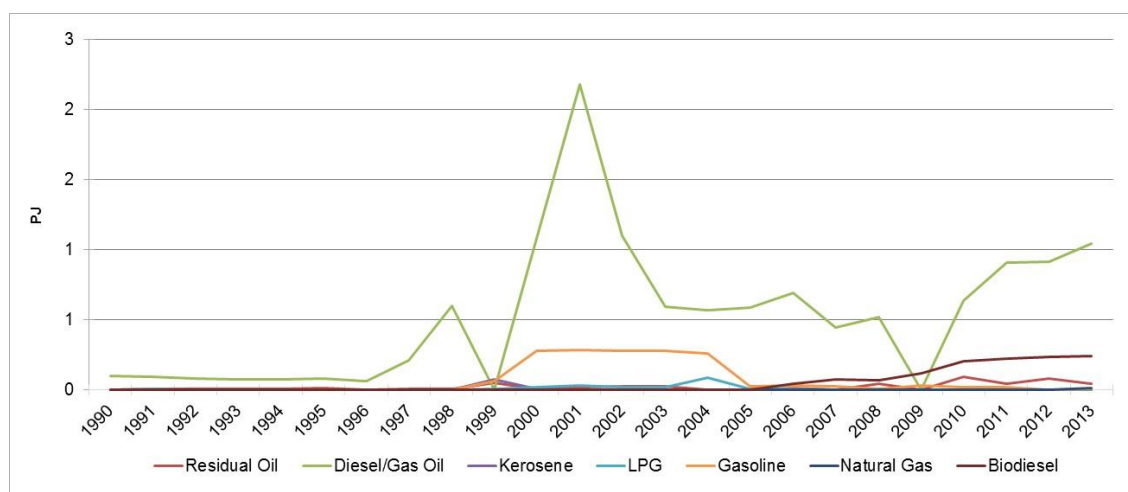


Figure 3.78 – Total Energy Consumption in fuels in fisheries (excluding consumption in fishing vessels)

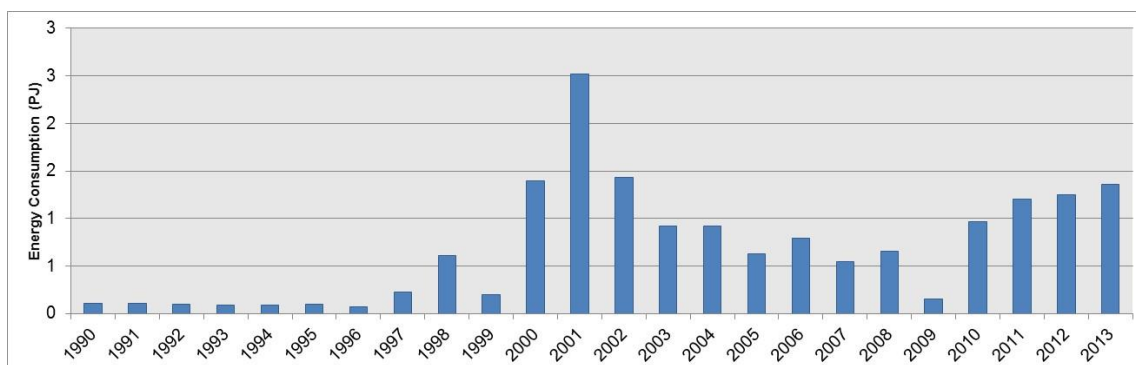
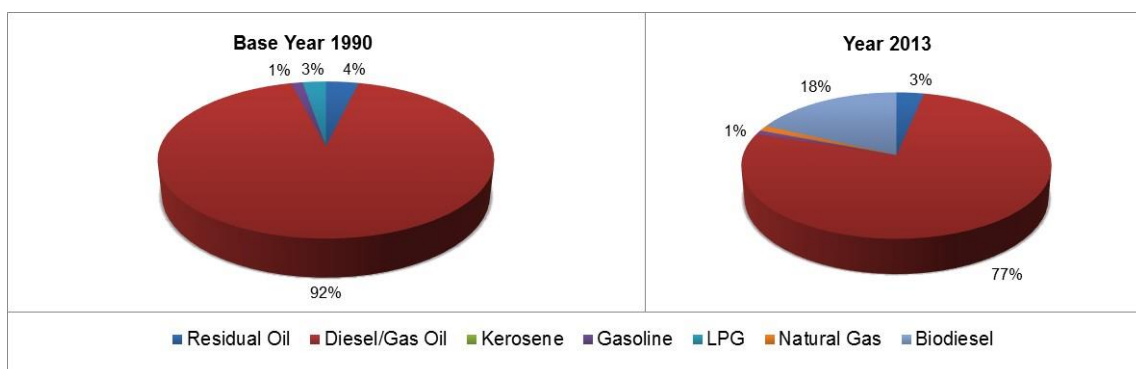


Figure 3.79 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2013



Total fuel consumption in fishing bunkers can be seen in the following figures and Annex E.

Table 3.128 - Fuels consumed in fishing bunkers <sup>26</sup>

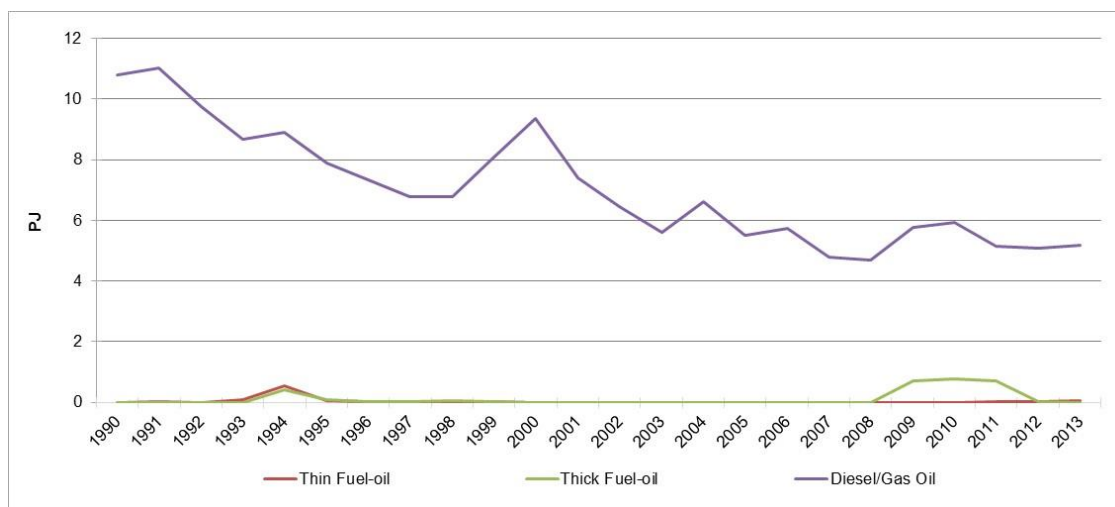
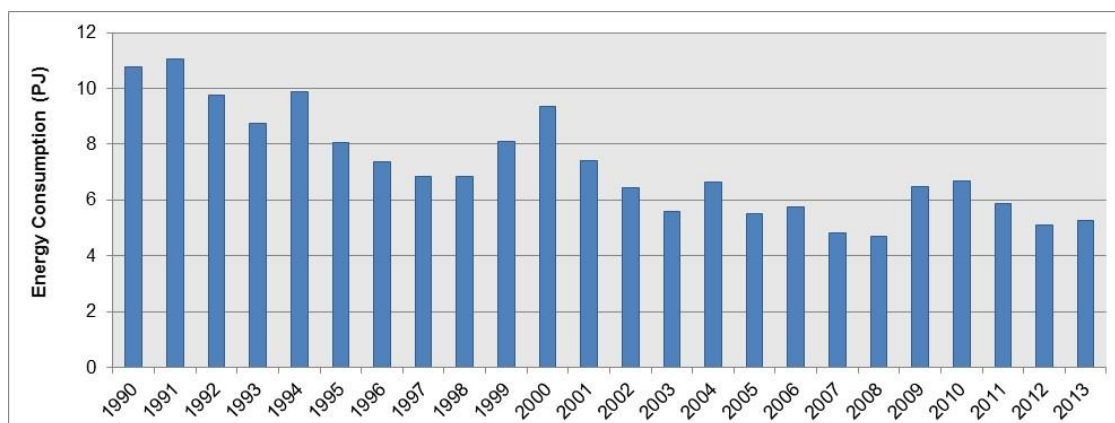


Figure 3.80 – Total Energy Consumption in fishing bunkers

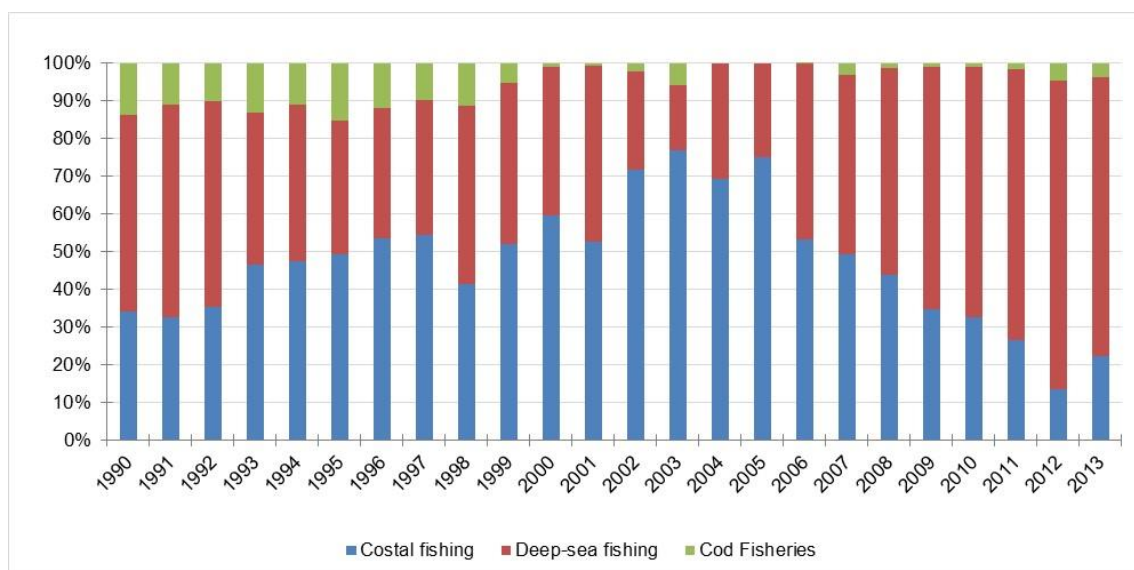


Additional information in DGEG annual reports, allows for the division of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels<sup>27</sup>. Percentage for each type of fisheries is presented in next figure.

<sup>26</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

<sup>27</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.

Figure 3.81 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries



#### 3.3.3.10.2.1.4 Emission Factors

### Stationary Equipment

The emission factors that were used were collected from 2006 IPCC guidelines.

Table 3.129 – 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	10.0	0.6
Gas Oil/Diesel oil	L	204	42.6	74.1	0.990	100	10.0	0.6
Kerosene	L	206	43.8	71.9	0.990	100	10.0	0.6
Motor Gasoline	L	208	44.0	69.3	0.990	100	10.0	0.6
LPG	L	303	46.0	63.1	0.995	100	5.0	0.1
Natural Gas	G	301	46.0	56.1	0.995	100	5.0	0.1
Biodiesel	B	223	37.0	70.8	1.000	0	10.0	0.6

### 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 3.130 – 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
NM VOC	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					

### 3.3.3.10.2.2 Uncertainty Assessment

## 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.

## 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.

### 3.3.3.10.2.3 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.

#### 3.3.3.10.2.4 Recalculations

Recalculations for Stationary Equipment comprise:

- revision of 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Diesel oil, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### 3.3.3.10.2.5 Further Improvements

No further improvements are planned for this sector.

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

#### 3.3.4.1 Mobile (CRF 1.A.5.b)

##### 3.3.4.1.1 Military Use

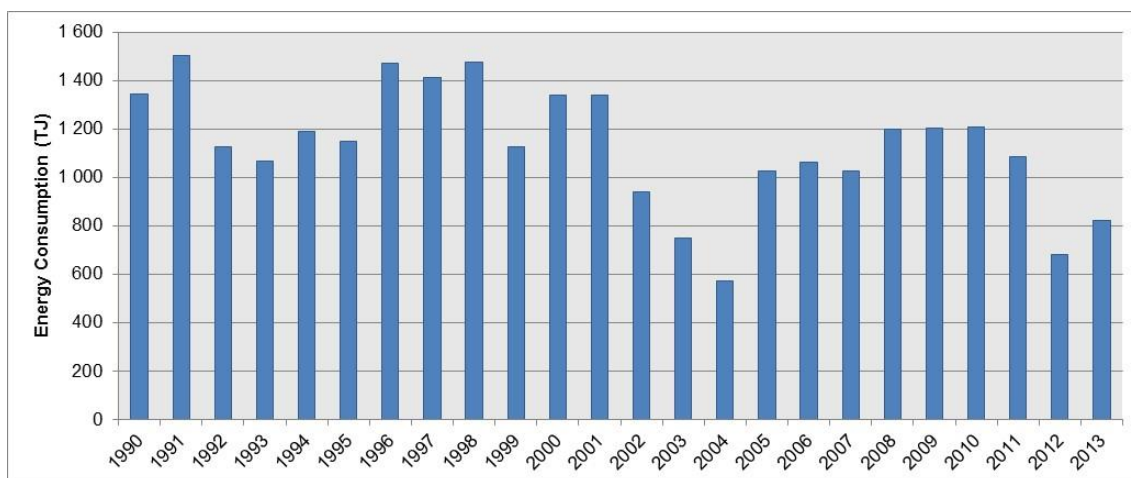
Emissions from military reported under category 1 A 5 b include only military aviation.

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 2006, 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.

Figure 3.82 – Energy Consumption in Military aviation



The emission factors used to estimate emissions are IPCC 2006 default emission factors.

Table 3.131 – Emission factors.

Fuel	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Jet Fuel	70.8	tCO <sub>2</sub> /TJ	IPCC 2006	0.5	kg/TJ	IPCC 2006	2.0	kg/TJ	IPCC 2006

Effective CO<sub>2</sub> emission factor was obtained from:

$$EF_{CO_2}[t/TJ] = \text{Default carbon content } [t/TJ] \times \text{Carbon Oxidized Fraction} \times 44/12$$

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

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

#### 3.3.4.1.1.1 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.

#### 3.3.4.1.1.2 Recalculations

No recalculations were made for this subsector.

#### 3.3.4.1.1.3 Further Improvements

No further improvements are planned for this sector.

### 3.3.5 Fugitive Emissions from Fossil Fuels (CRF 1.B.)

#### 3.3.5.1 Fugitive Emissions from Solid Fuels (CRF 1.B.1.)

##### 3.3.5.1.1 Coal Mining and Handling

###### 3.3.5.1.1.1 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 - *Pejão* and *S. Pedro da Cova* - are located in northern region of Portugal. Coal from these mines is classified as lignite, it has a low energy value and it was used mainly as fuel for one public power energy plant near Oporto (*Tapada do Outeiro* power plant). Moreover the coal production during the exploration period was of small importance (less than 300 kt in 1990, see figure below). Both mines (*Pejão* 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.

###### 3.3.5.1.1.2 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:

$$Em_{CH_4} = [(EF_{U}^{ex} + EF_{U}^{post}) * Coal_U] * 0.67 * 10^{-3}$$

where

$Em_{CH_4}$  - 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);

$EF_{NMVOV}$  - 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).

### 3.3.5.1.1.3 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 3-132– Emission Factors for coal extraction and processing

Parameter	Type of Emission	Emission Factor	Value (kg/ton)	Source
CH <sub>4</sub>	Extraction	EF <sub>U</sub> <sup>ex</sup>	11.73	Revised 1996 IPCC Guidelines
	Post-mining	EF <sub>U</sub> <sup>post</sup>	1.64	Revised 1996 IPCC Guidelines
NM VOC	-	-	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).

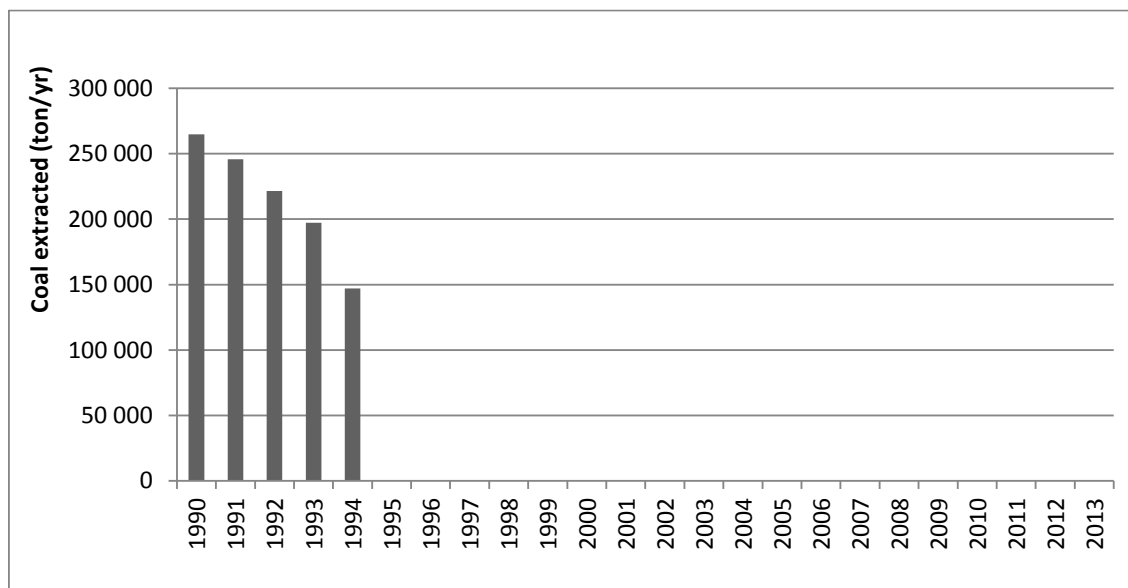
Table 3-133– Emission Factors for abandoned underground mines

Parameter	Unit	Value	Source
Fraction of gassy coal mines	%	54 (8-100)	2006 IPCC Guidelines
CH <sub>4</sub> Emission factor	10 <sup>6</sup> m <sup>3</sup> CH <sub>4</sub> /mine	0.507-1.561	2006 IPCC Guidelines

### 3.3.5.1.1.4 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 3-83 – 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.

#### *3.3.5.1.1.5 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.

#### *3.3.5.1.1.6 Recalculations*

No recalculations were made.

#### *3.3.5.1.1.7 Further Improvement*

No further improvements are planned for this sector.

### *3.3.5.2 Fugitive Emissions from Oil Production and Refining (CRF 1.B.2.a.)*

#### *3.3.5.2.1 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.

#### *3.3.5.2.2 Fugitive emissions from oil exploration (CRF 1.B.2.a.1)*

There is no oil exploration in Portugal.

#### *3.3.5.2.3 Fugitive emissions from the production of crude oil (CRF 1.B.2.a.2)*

There is no crude oil production in Portugal.

### 3.3.5.2.4 Transport of Crude/ Marine Terminals (CRF 1.B.2.a.3)

#### 3.3.5.2.4.1 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 were all located at a small distance from the sea coast. Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

#### 3.3.5.2.4.2 Methodology

Emissions of CH<sub>4</sub> and NMVOC were 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>:

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

#### 3.3.5.2.4.3 Emission Factors

Table 3-134– Total Organic Emission Factors for Marine Vessel Loading Operations

Loading Operations	Gasoline (mg/L)	Crude <sup>28</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:

<sup>28</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.



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

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”.

CH<sub>4</sub> emission factor (60 g/ton of Crude) is obtained from EMEP/Corinair.

#### 3.3.5.2.4.4 Activity data

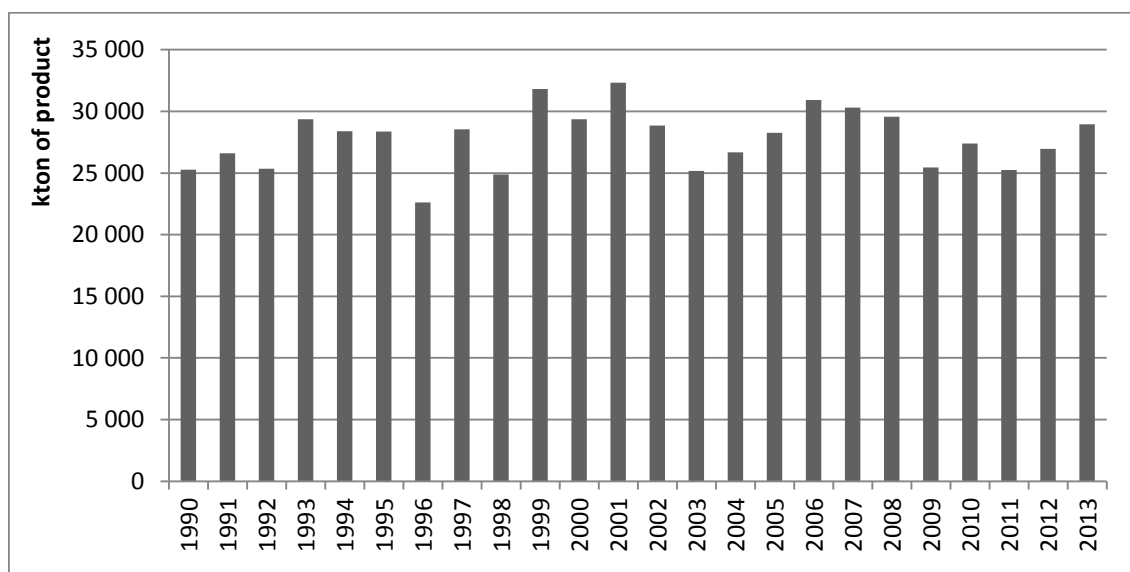
Data was obtained for year 2005, from:

- Ports Authorities (Port of Sines, Port of Lisbon, Port of Leixões, Port of Setúbal);
- Depots Companies (BP, Cepsa, CLCM, Esso, ETC, LBC Tanquapor, 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 3-84 – Total amounts of loaded and unloaded crude and fuels in Marine Terminals (kton)



#### 3.3.5.2.4.5 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.

#### 3.3.5.2.4.6 Recalculations

No recalculations were made.

#### 3.3.5.2.5 Refining and Storage (CRF 1.B.2.a.4)

##### 3.3.5.2.5.1 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>29</sup> scattered through the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NMVOC emissions resulting from non-condensable 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.

#### *3.3.5.2.5.2 Methodology*

##### *3.3.5.2.5.2.1 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

<sup>29</sup> Sometimes only these emissions are referred as fugitive emissions from refineries.

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>30</sup>.

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

#### 3.3.5.2.5.2.2 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.

#### 3.3.5.2.5.2.3 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:

$$U_{\text{CO}_2} = 44/12 * (0.60 * \text{NMVOC} + 12/16 * \text{CH}_4 + 12/28 * \text{CO}) * 10^{-3}$$

#### 3.3.5.2.5.3 Emission Factors

##### 3.3.5.2.5.3.1 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

<sup>30</sup> This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

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>31</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.

Table 3-135 – 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

<sup>31</sup> This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

TANKS4.0 methodology differentiates the following emissions, according to the cause of release:

Table 3-136 – 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>32</sup> in each refinery, are presented in next table. From 2006 onwards the emission factors were forecasted based on total throughput.

Table 3-137 – 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

<sup>32</sup> Crude oil input added to input of other materials.

#### 3.3.5.2.5.3.2 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 3-138 – 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

#### 3.3.5.2.5.3.3 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.

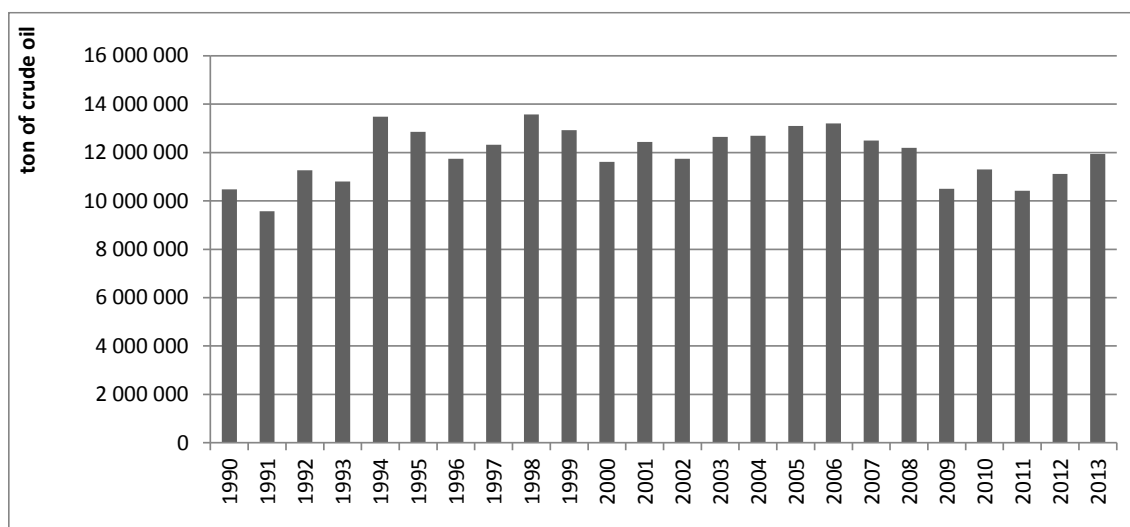
Table 3-139 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Parameter	Emission Factor kg/ton coke
UCO <sub>2</sub>	3 373

#### 3.3.5.2.5.4 Activity data

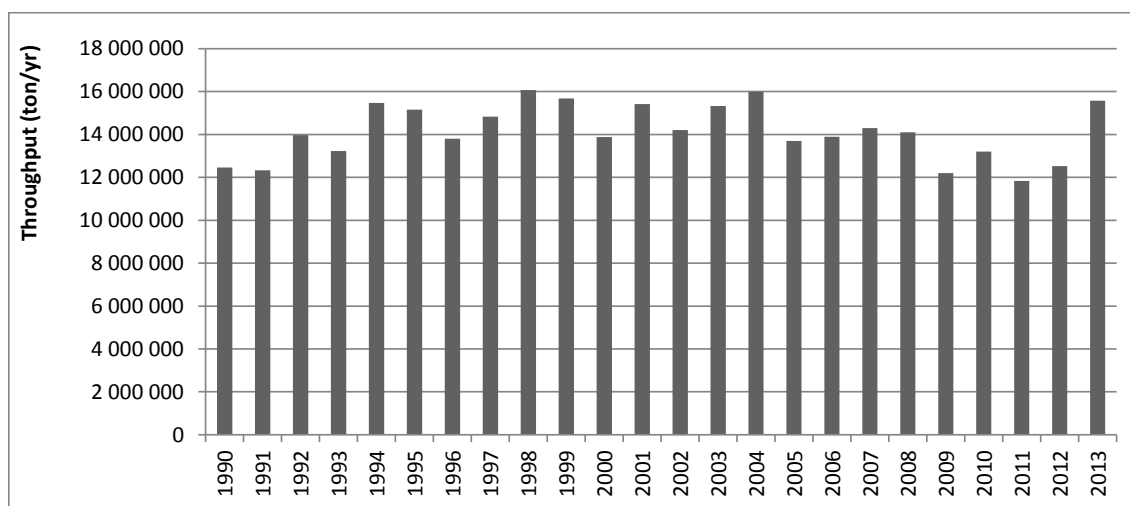
The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed (see next figure).

Figure 3-85 – 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 3-86 – 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.



#### 3.3.5.2.5.5 *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>33</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).

#### 3.3.5.2.5.6 *Recalculations*

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60 percent of carbon. Previously it was considered that emitted VOC have on average 85 percent of carbon.

#### 3.3.5.2.5.7 *Further Improvements*

No further improvements are planned for this sector.

### 3.3.5.2.6 *Distribution of Oil Products (CRF 1.B.2.a.5)*

#### 3.3.5.2.6.1 *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;

---

<sup>33</sup> The uncertainty of NMVOC was considered to be the uncertainty of CO<sub>2</sub> emission factor.

- Vapours emitted when filling vehicles in result of displacement of filling air and from splashing and turbulence during filling;
- Unwanted spillage.

#### 3.3.5.2.6.2 Methodology

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

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

##### 3.3.5.2.6.2.1 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)

$V_{\text{StageIB}}$  - Gasoline throughput at Service Stations with Stage IB ( $\text{m}^3$ )

EFStageIB – Emission Factor for Filling Underground Tanks at Service Stations with Stage IB ( $\text{kg}/\text{m}^3/\text{Kpa TVP}$ )

### 3.3.5.2.6.3 Emission Factors

#### 3.3.5.2.6.3.1 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 3-140 – Filling Underground Tanks NMVOC Emission Factors

Filling Underground Tank	Emission Factor ( $\text{kg}/\text{m}^3/\text{kPa TVP}$ )
Without Stage IB	$2.44\text{E}^{-02}$
With Stage IB	$1.1\text{E}^{-03}$

#### 3.3.5.2.6.3.2 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” ( $=3.30\text{E}^{-03} \text{ kg}/\text{m}^3/\text{kPa TVP}$ ).

#### 3.3.5.2.6.3.3 Vehicle Refueling Operations

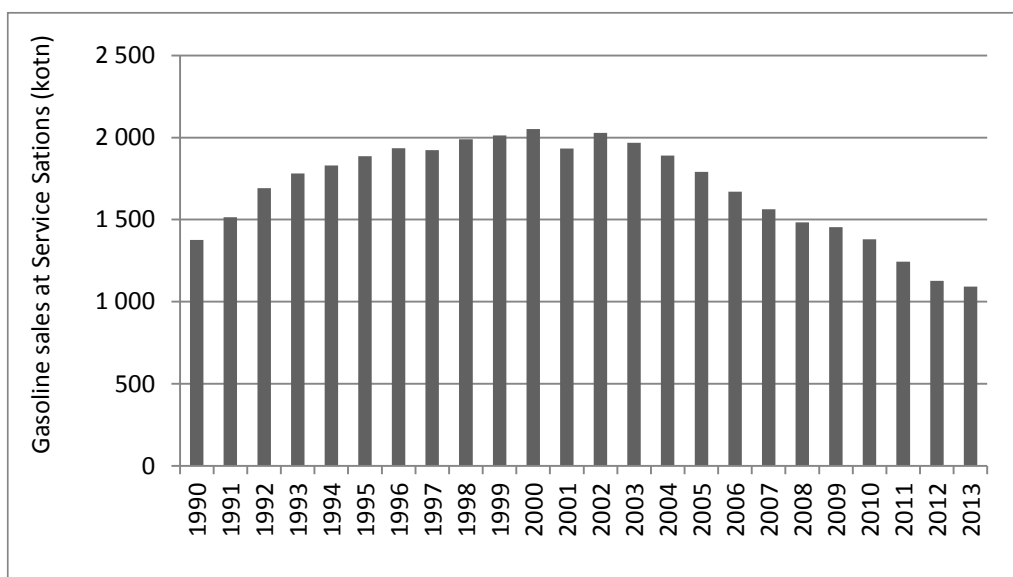
Table 3-141 – Vehicle Refueling Operations NMVOC Emission Factors

Vehicle Refuelling Operations	Emission Factor ( $\text{kg}/\text{m}^3/\text{kPa TVP}$ )
Drips and Minor Spillage	$2.20\text{E}^{-03}$
Refuelling with no emission controls in operations (without Stage II measures)	$3.67\text{E}^{-02}$

#### 3.3.5.2.6.4 Activity data

Data on gasoline sales was obtained from DGEG Energy Balance for the entire period.

Figure 3-87 – Fuel Sales at Service Stations



#### 3.3.5.2.6.5 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.

#### 3.3.5.2.6.6 Recalculations

No recalculations were made.

#### 3.3.5.2.6.7 Further Improvements

Efforts should be addressed in order to verify stage II implementation at service stations in Portugal.

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

#### 3.3.5.3.1 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.

### 3.3.5.3.2 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>34</sup> as activity data:

<sup>34</sup> Equals imports in Portugal

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

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 ( $\text{Emi}_{\text{GAS}}$ ):

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

### 3.3.5.3.3 Emission Factors

The emission factors are based on the IPCC Good Practice (IPCC, 2000), and are reported in Table 3-142.

Table 3-142 – 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.

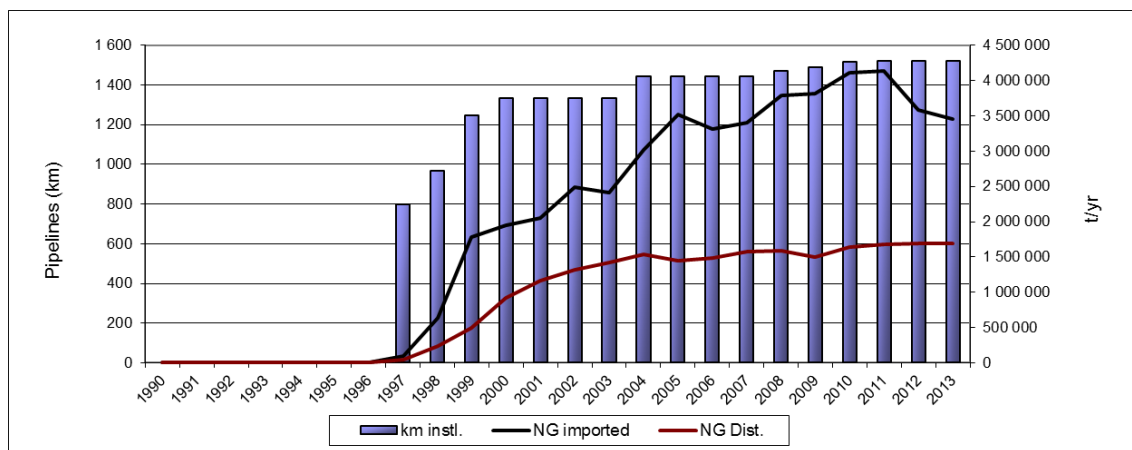
### 3.3.5.3.4 Activity data

According to the above explained methodology, activity data comprehends:

- extension of pipelines for transmission. Total extension of pipelines in kilometres was estimated from data concerning the operational launch of each pipeline. Because of this the activity data for transmission for each year since 1997 represents the new pipeline extension added to the total length from previous years. This pipeline data was received via DGEG from TRANSGAS;
- importation of natural gas, obtained from the DGEG's Energy Balances;
- consumption of Natural Gas. Distribution emissions were assumed to result only from small and medium size units. Therefore, total consumption was subtracted from consumption in sectors characterized for high consumptions per unit: Paper pulp; Chemical Industry; Ceramics; Cement; Glass and related products and Iron and Steel.

All tree variables used as activity data are represented in the next figure.

Figure 3-88 – Activity data used to estimate GHG emissions from Natural gas transmission, distribution and transformation

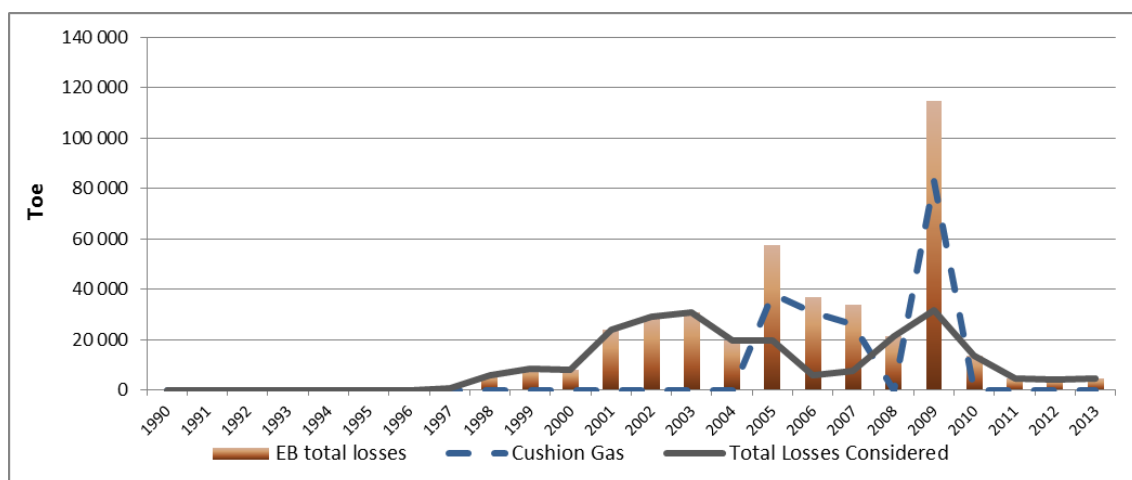


In 2009 new data was obtained from DGE concerning the consumption of cushion gas. This gas is used for maintaining constant pressure within underground storage tanks and it is considered to be confined within the tank only resulting in emissions when the tank is deactivated. Because there is no specific category in the energy balance for this type of consumption, DGE reports cushion gas together with natural gas Losses in Transmission and Distribution. This led to an overestimation of 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 begins its operation which results in a large inter-annual variation in the consumption of this gas.

Figure 3-89 – 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.

#### 3.3.5.3.5 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.

#### 3.3.5.3.6 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.

#### 3.3.5.3.7 Recalculations

Recalculations for this source category comprise only the revision of the 2003, 2008, 2009, 2010 and 2011 energy balance data (2003, 2008-2011);

#### 3.3.5.3.8 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>35</sup> and the major Portuguese company responsible for gross transport of natural gas<sup>36</sup>, in order to increase the tier level of the methodology. Results and changes in estimates are expected in the coming years.

### 3.3.5.4 Flaring in Oil Industry (CRF 1.B.2.c.2)

#### 3.3.5.4.1 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.

#### 3.3.5.4.2 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:

$$U_{CO_2} = EndofPipe_{CO_2} + 44/12 * (0.60 * NMVOC + 12/16 * CH_4 + 12/28 * CO) * 10^{-3}$$

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.

CO<sub>2</sub> emissions are estimated from:

$$Emis_{CO_2(y)} = Flare_{Gas(y)} * LHV_{Gas(y)} * EF_{CO_2} * OF_{Gas(y)} * 10^{-3}$$

Where,

$Emis_{CO_2(y)}$  – Emission of CO<sub>2</sub> in year y (ton/yr);

$Flare_{Gas(y)}$  – Quantity of gas flared in year y (ton/yr);

$LHV_{Gas(y)}$  – Low Heating Value of gas flared in year y (GJ/ton);

$EF_{CO_2}$  – Emission factor of CO<sub>2</sub> (kg/GJ);

$OF_{Gas(y)}$  – Oxidation factor of gas flared in year y (dimensionless).

CH<sub>4</sub> and NMVOC emissions are estimated from:

<sup>35</sup> Direcção Geral de Energia e Geologia/ General Directorate of Energy and Geology

<sup>36</sup> TRANSGAS

$$Emis_{(p,y)} = EF_{(p)} * Flare_{GAS(y)} * m_{(p,y)} / m_{(gas,y)} * 10^{-3}$$

Where,

$Emis_{(p,y)}$  – Emission of pollutant p in year y (ton/yr);

$EF_{(p)}$  – Emission factor (Kg/ton gas);

$Flare_{GAS(y)}$  – Quantity of gas flared in year y (ton/yr);

$m_{(p,y)} / m_{(gas,y)}$  – Mass fraction of pollutant p in year y.

N<sub>2</sub>O emissions are estimated from:

$$Emis_{(y)} = EF_{(p)} * Crude * Dens_{Crude}$$

Where,

$Emis_{(y)}$  – Emission of N<sub>2</sub>O in year y (ton/yr);

$EF_{(p)}$  – Emission factor (ton/m<sup>3</sup> crude);

Crude – Quantity of crude processed in the refinery in year y (ton/yr);

$Dens_{Crude}$  – Density of the crude oil processed in the refinery in year y (ton/m<sup>3</sup>).

#### 3.3.5.4.3 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>.

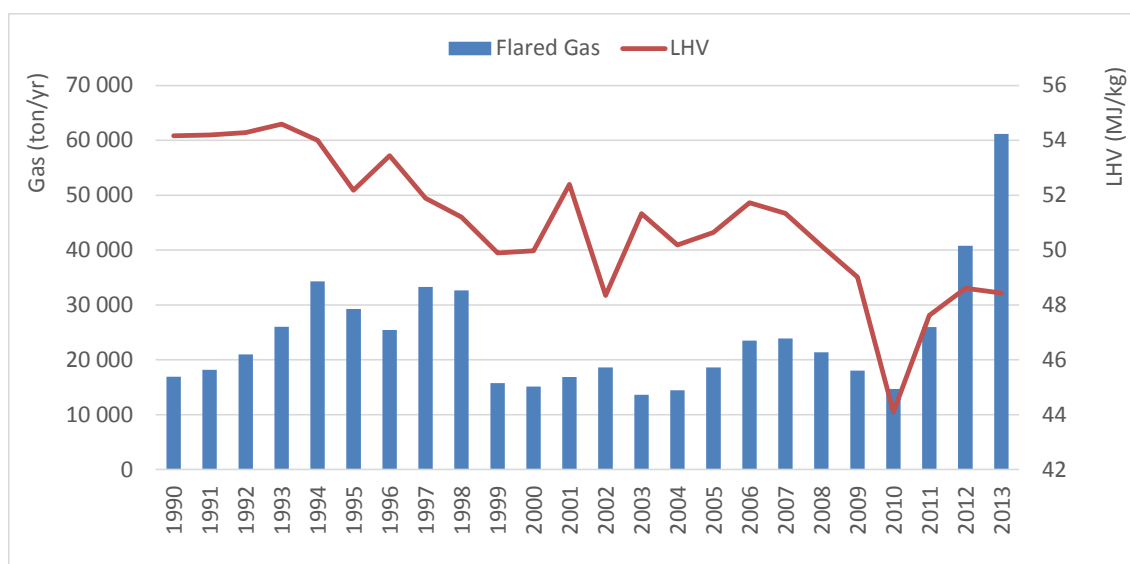
Table 3-143 – Emission Factors for flaring in refineries

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>37</sup>	ton/m <sup>3</sup> oil	6.4x10 <sup>-7</sup>

#### 3.3.5.4.4 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.

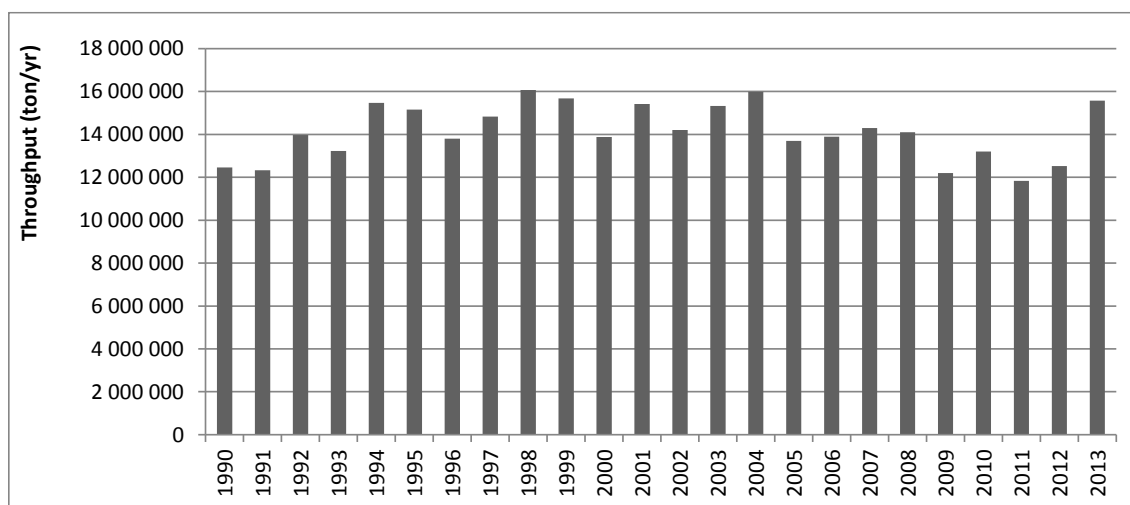
Figure 3-90 – Total consumption of flare gas in Portuguese refineries and Low Heating Value



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

<sup>37</sup> Table 2.16 of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Oil Production – Conventional Oil – Flaring)

Figure 3-91– Total throughput entered in Lisbon, Oporto and Sines refineries



#### 3.3.5.4.5 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.

#### 3.3.5.4.6 Recalculations

No recalculations were made.

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

#### 3.3.5.5.1 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.

#### 3.3.5.5.2 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

#### 3.3.5.5.3 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>38</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 3-144 – – Emission Factors for Gheothermal 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 factor adopted for geothermal power plants is the average of the last three years, 199 tCO<sub>2</sub>/GWh.

<sup>38</sup> Secretaria Regional dos Recursos Naturais – Direcção Regional do Ambiente.

#### 3.3.5.5.4 Activity Data

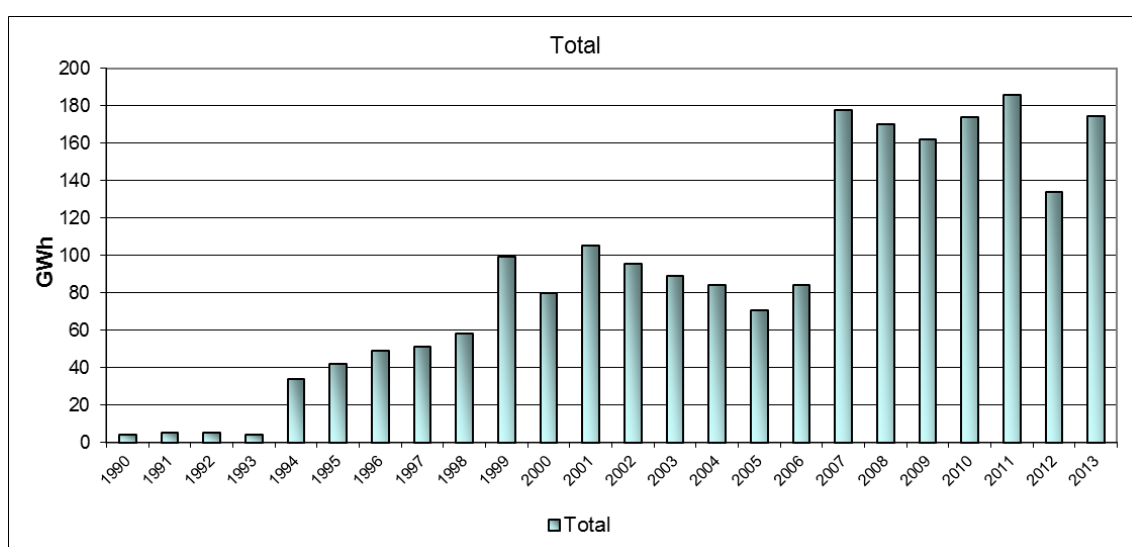
Activity data consists of geothermal production. The time series was constructed using data from the regional authority in Azores:

Pico Vermelho – from 2000 to 2013;

Ribeira Grande – from 1994 to 2013;

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 3-92 – 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).

#### 3.3.5.5.5 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)..

#### 3.3.5.5.6 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

#### 3.3.5.5.7 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

No recalculations were made.

#### 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. 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>39</sup> for estimation of CO<sub>2</sub> emissions from fossil fuel combustion, in addition to the bottom-up sectoral methodology.

The Reference Approach is a top-down approach, using a country’s energy supply data to calculate the emissions of CO<sub>2</sub> from combustion of mainly fossil fuels. The Reference Approach is a straightforward method that can be applied on the basis of relatively easily available energy supply statistics. Excluded carbon has increased the requirements for data to some extent. However, improved comparability between the sectoral and reference approaches continues to allow a country to produce a second independent estimate of CO<sub>2</sub> emissions from fuel combustion with limited additional effort and data requirements. It is good practice to apply both a sectoral approach and the reference approach to estimate a country’s CO<sub>2</sub> emissions from fuel combustion and to compare the results of these two independent estimates. (IPCC. 2006)

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.

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<sup>39</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 (2006):

- Step 1: Estimate Apparent Fuel Consumption in Original Units
- Step 2: Convert to a Common Energy Unit
- Step 3: Multiply by Carbon Content to Compute the Total Carbon
- Step 4: Compute the Excluded Carbon
- Step 5: Correct for Carbon Unoxidised and Convert to CO<sub>2</sub> Emissions ;

#### 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>40</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 3-145.

<sup>40</sup> Ton of oil equivalent

Table 3-145 – 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	21.0	0.99
		Natural Gas Liquids	-	-
	Secondary Fuels	Gasoline	18.9	0.99
		Jet Kerosene	19.5	0.99
		Other Kerosene	19.6	0.99
		Shale Oill	-	-
		Gas / Diesel Oil	20.2	0.99
		Residual Fuel Oil	21.1	0.99
		LPG	17.2	0.99
		Ethane	-	-
		Naphtha	20.0	0.99
		Bitumen	22.0	0.99
		Lubricants	20.0	0.99
		Petroleum Coke	26.6	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	25.8	0.98
		Sub-bit. Coal	26.2	0.98
		Lignite	27.6	0.98
		Oil Shale and tar sand	29.1	0.99
	Secondary Fuels	BKB & Patent Fuel	22.0	0.98
		Coke Oven/Gas Coke	29.2	0.98
		Coal tar	-	-
Gaseous Fossil		Natural Gas (Dry)	15.3	1.00
Waste (non-biomass fraction)			35.2	1.00
Peat			-	-
Biomass	Solid Biomass		29.9	1.00
	Liquid Biomass		20.0	1.00
	Gas Biomass		30.6	1.00

### 3.6.2.4 Carbon Excluded

The aim of the Reference Approach is to provide an estimate of fuel combustion emission, so the amount of carbon which does not lead to fuel combustion emissions is excluded. Carbon excluded from fuel combustion is either emitted in another sector of the inventory (industrial process emission) or is stored in a product manufactured from the fuel.

The main flows of carbon concerned in the calculation of excluded carbon are those used as feedstock, reductant or as non-energy products.

Feedstock - Carbon emissions from the use of fuels listed above as feedstock are reported within the source categories of the Industrial Processes and Product Use (IPPU) chapter.

Consequently, all carbon in fuel delivered as feedstock is excluded from the total carbon of apparent energy consumption.

Non-energy products use – The Inventory excludes consumptions of bitumen, lubricants, paraffin, solvents and propylene, these are classified as non-energy oil in the National Energy Balance.

The quantity of carbon to be excluded from the estimation of fuel combustion emissions is calculated according to following equation.

$$\text{Excluded Carbon}_{\text{fuel}} (\text{Gg C}) = \text{Activity Data}_{\text{fuel}} (\text{TJ}) \times \text{Carbon Content}_{\text{fuel}} (\text{C/TJ}) \times 10^{-3}$$

### 3.6.3 Actual Carbon Dioxide Emissions

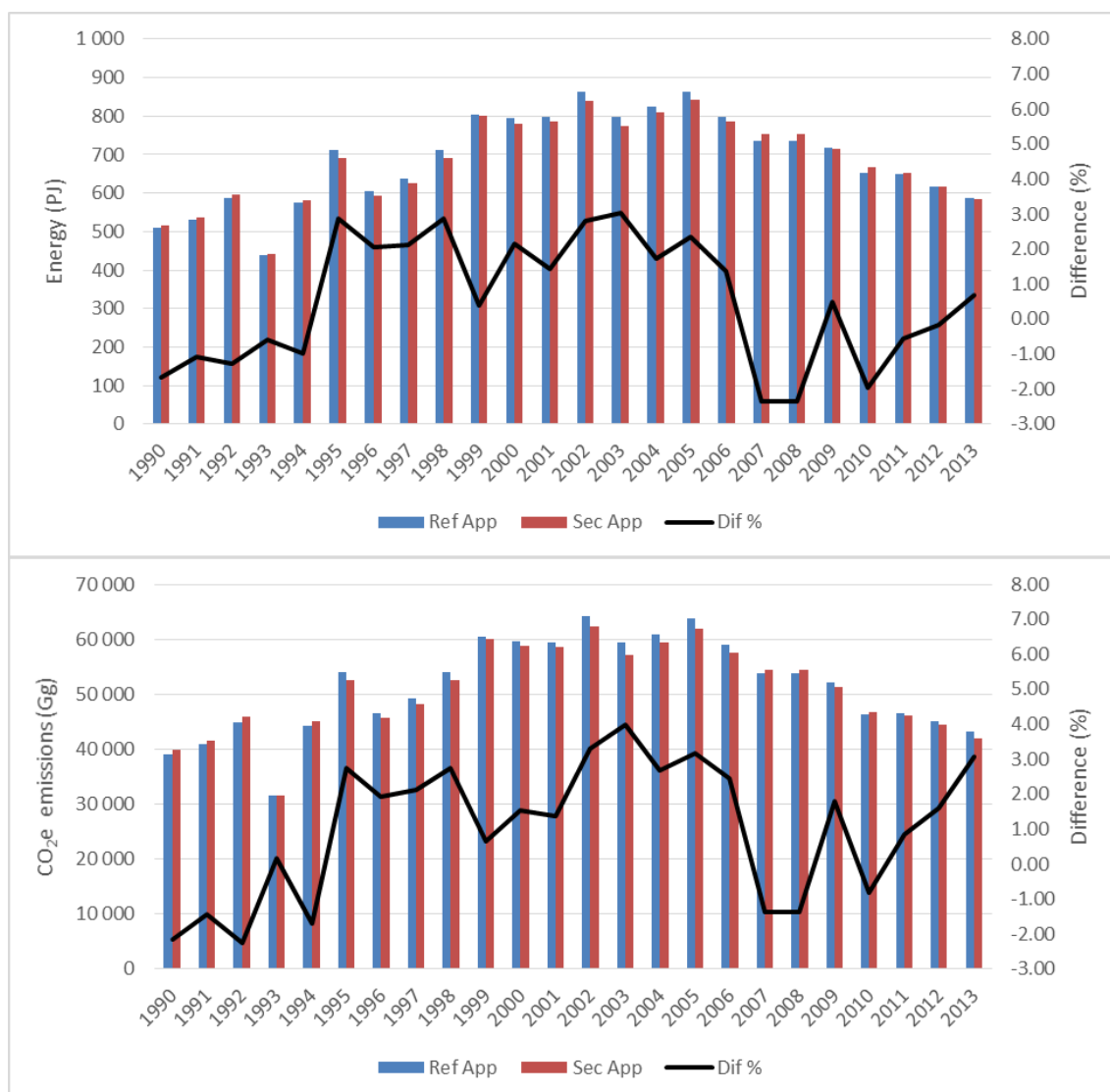
Estimated simply from:

$$\text{CO}_2 \text{ Emission} = 44/12 * (\text{Apparent Consumption} - \text{Excluded Carbon}) * \text{Oxidation Factor}$$

### 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 3-93.

Figure 3-93 – 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.

#### **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>41</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).

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>42</sup>.

In terms of total GHG, emissions from the industrial production sector have increased from about 5.2 Mton CO<sub>2</sub>e in 1990 to 5.8 Mton CO<sub>2</sub>e in 2013, as may be seen from the figure below, i.e. emissions estimated for 2013 changed 12.8 percent when compared to emissions estimated for 1990<sup>43</sup>. The majority of emissions, expressed in CO<sub>2</sub>e, are associated with mineral industry, responsible for 69.4 percent of total emissions from this sector in 1990, and 60.9 percent of total emissions from this sector in 2013, as may be seen in Figure 4.2. The remaining sub-source sectors (2B, 2C, 2D, 2E, 2F, 2G and 2H<sup>44</sup>) have a lower importance, contributing to 39.1 percent of total emissions in 2013. There is a relevant increase in sub-category 2F, consumption of Halocarbons and SF<sub>6</sub>, which represents in 2013 about 29.7 percent of total GHG emissions from this source sector, and shows a fast grow over years.

<sup>41</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>42</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>43</sup> Base year for F-gases is however 1995.

<sup>44</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

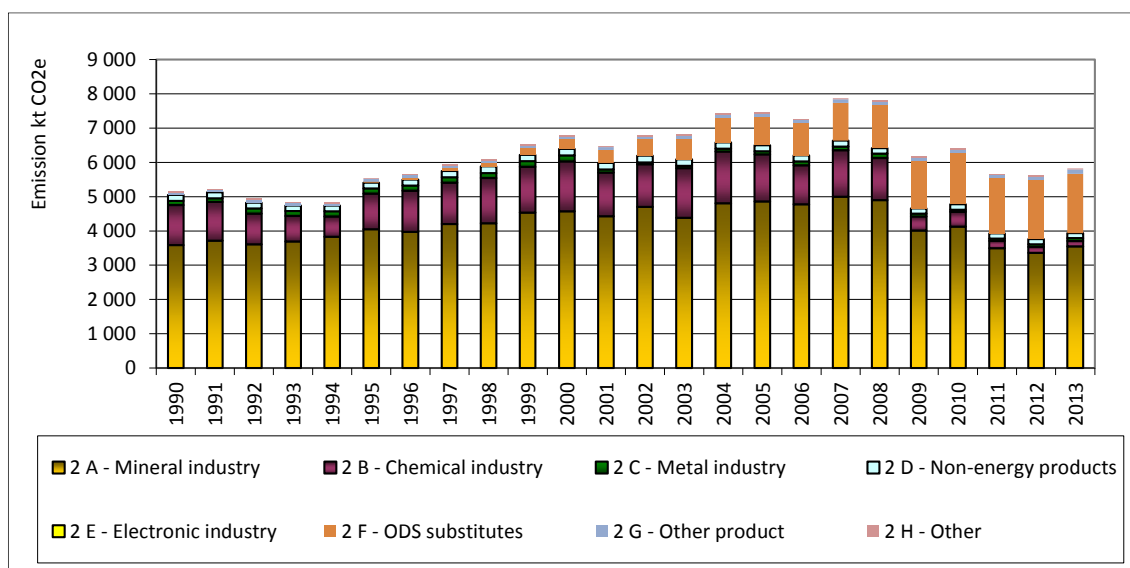
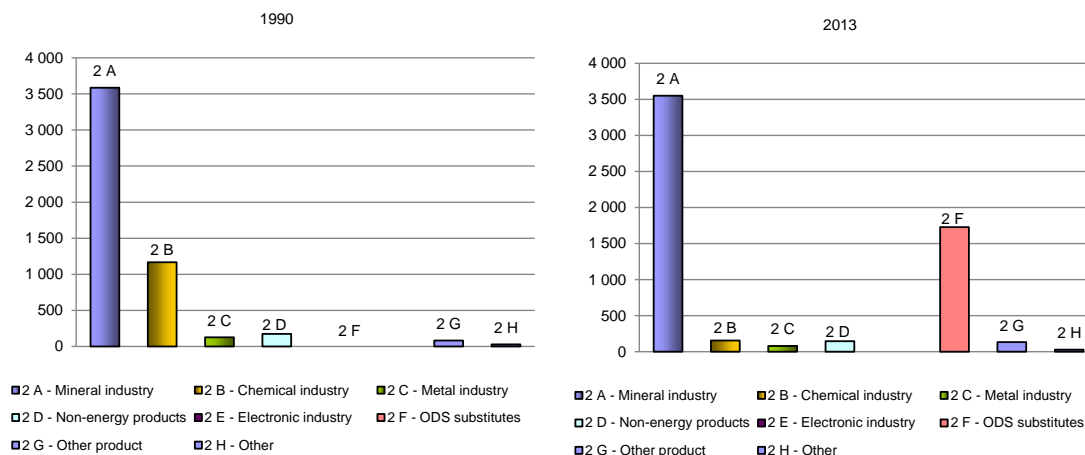
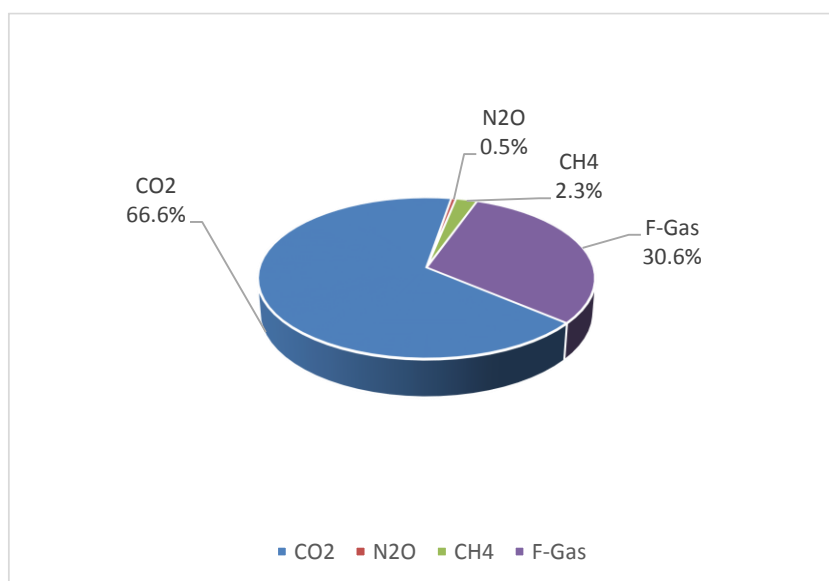


Figure 4.2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2013 (kton CO<sub>2</sub>e)



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 2013. 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 2013



## 4.2 Recalculations

To be provided later.

## 4.3 Mineral Industry (CRF 2.A.)

### 4.3.1 Cement Production (CRF 2.A.1.)

#### 4.3.1.1 Overview

There are six cement production plants operating in Portugal, mostly dedicated to Portland cement production<sup>45</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>46</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

<sup>45</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>46</sup> One calciner is a false pre-calciner.



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.

#### 4.3.1.2 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).

From 2005 onwards, emissions of carbon dioxide resulting from carbon in raw meal are determined according to the following equation:

$$Em_{CO_2} = \text{Raw meal} * EF * CF$$

Where

$Em_{CO_2}$  – emissions of CO<sub>2</sub> 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 CO<sub>2</sub>/ton of raw meal);

CF – Conversion factor (0 to 1).

We have estimated plant specific average ratio between CO<sub>2</sub> emissions and clinker production for each facility in the period 2005-2009 and used this average value to back cast CO<sub>2</sub> emissions in the period 1990-2004, taking also in consideration clinker production for each facility in the period 1990-2004. From 1990 to 2004, emissions of carbon dioxide are estimated according to the following equation:

$$Em_{CO_2, x} = \text{Clinker Production}_{, x} * EF_{(2005-2009)}$$

Where

$Em_{CO_2, x}$  – emissions of CO<sub>2</sub> from cement production in year “x” of the period 1990-2004 (kton CO<sub>2</sub>);

Clinker Production, x – Clinker production in year “x” of the period 1990-2004 (ton clinker/yr);

EF – average emission factor (kton CO<sub>2</sub>/ton clinker) in the period 2005-2009;

#### 4.3.1.3 Emission Factors

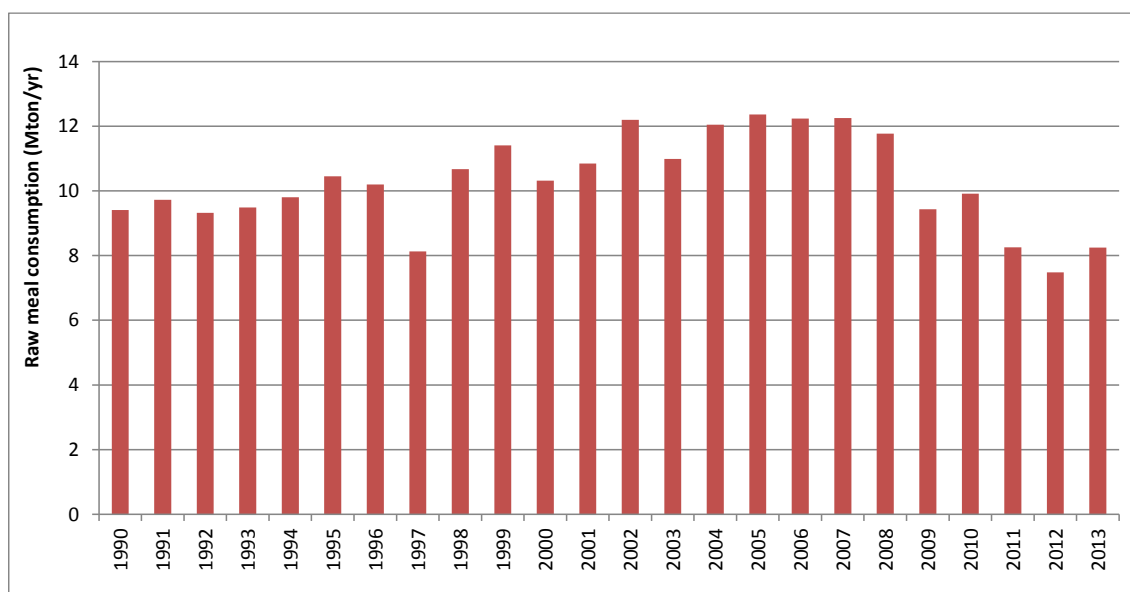
From 2005 onwards we have used raw meal carbon content characterization to estimate CO<sub>2</sub> emissions based on raw meal consumption in the kilns. We have estimated plant specific average ratio between CO<sub>2</sub> emissions and clinker production for each facility in the period 2005-2009 and used this average value to back cast CO<sub>2</sub> emissions in the period 1990-2004, taking also in consideration clinker production for each facility in the period 1990-2004.

The fluctuation in the implied emission factor (IEF) from 2005 onwards is due to changes in the recirculation rate, meaning changes in the amount of alternative fuels (partially composed of biomass).

#### 4.3.1.4 Activity Data

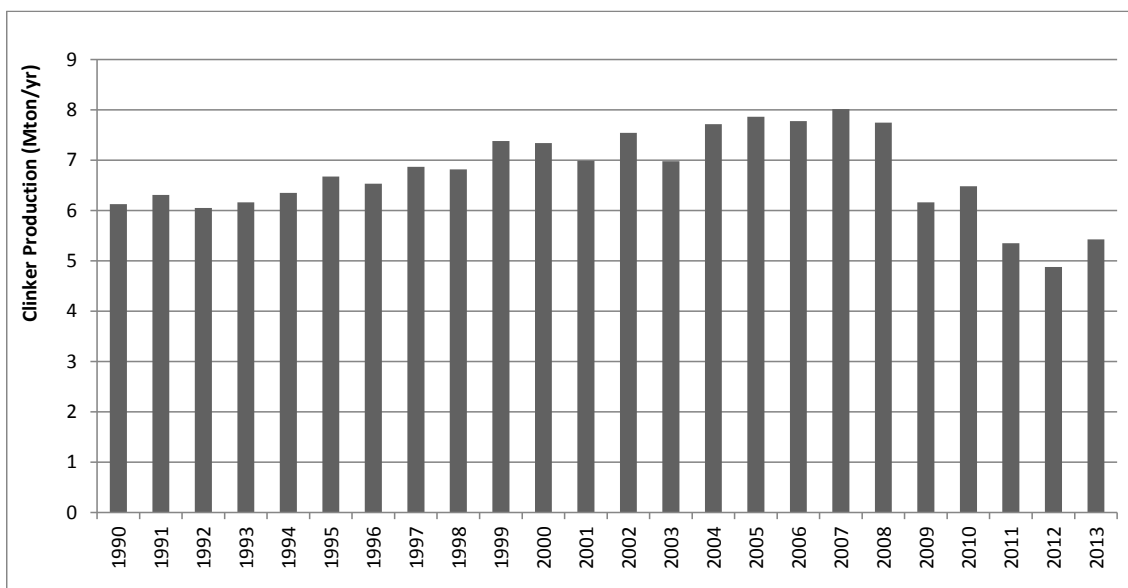
EU-ETS data on raw meal consumption is used from 2005 onwards. From 1990-2004, raw meal consumption was obtained directly from the plants.

Figure 4.4 – 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 4.5 – Total Production of cement clinker in Portugal



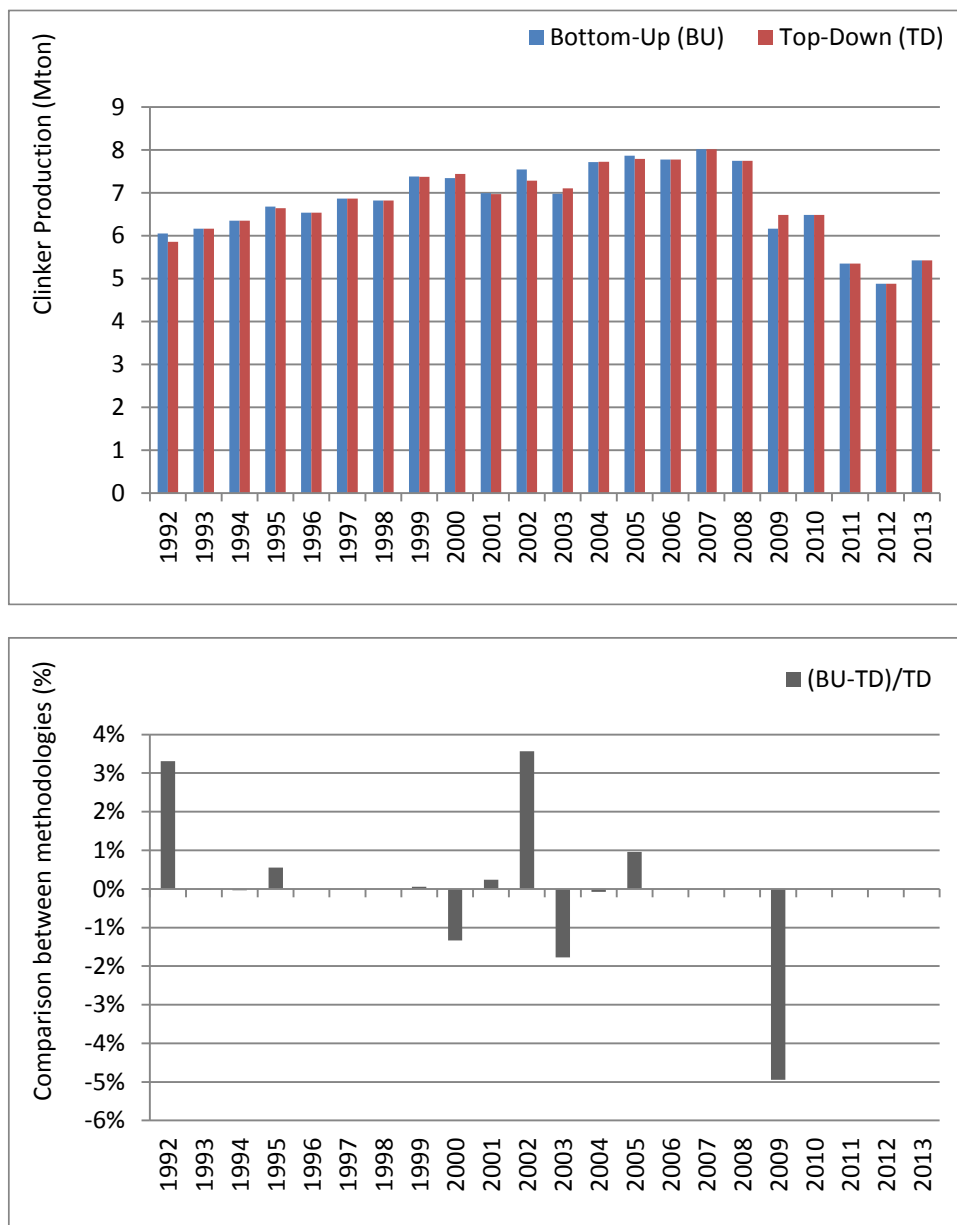
The decrease from 2011 to 2012 is 0.47 Mton and is due to a demand decrease in Portugal, Spain and North Africa market. From 2012 to 2013 there is an overall increase in clinker production of 0.55 Mton due to exports rise to Africa and South America. However in the last two years there is a decrease in clinker and cement internal market sales.

#### 4.3.1.5 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.

#### 4.3.1.6 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.



#### 4.3.1.7 Recalculations

No recalculations were made.

#### 4.3.1.8 Further Improvements

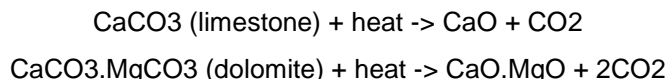
There are no further improvements planned for this sector.

### 4.3.2 Lime Production (CRF 2.A.2.)

#### 4.3.2.1 Overview

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200°C) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving

calcium oxide (CaO) or magnesium oxide (MgO) as valuable products. The following chemical conversion equation applies, where for each mol of oxide a mol of carbon dioxide is emitted.



Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy CaCO<sub>3</sub> content (at least 50 percent) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of Na<sub>2</sub>CO<sub>3</sub>, NaOH, steel, refractory material, SO<sub>2</sub> absorption, CaC<sub>2</sub>, glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;
- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45 percent in content). Dolomite quicklime is a mixture of CaO and MgO;
- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime: Ca(OH)<sub>2</sub>. It is produced from CaO and water. When an equivalent quantity of water is used is called slaked lime, when an excess water is used is milk of lime and a clear solution of Ca(OH)<sub>2</sub> in water is limewater. It is used as an industrial alkali and in the preparation of mortar (slaked lime plus sand) which sets to solid by reconversion of the hydroxide to CaCO<sub>3</sub> (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.

#### 4.3.2.2 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:

$$Emi_{CO_2} = \text{Kiln input} * EF * CF$$

Where

$Emi_{CO_2}$  – emissions of CO<sub>2</sub> 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 lime production data in the same year. For the period 1990-2004 we made a back cast based on lime production data and on the national IEF for the year 2005.

#### 4.3.2.3 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

#### 4.3.2.4 Activity Data

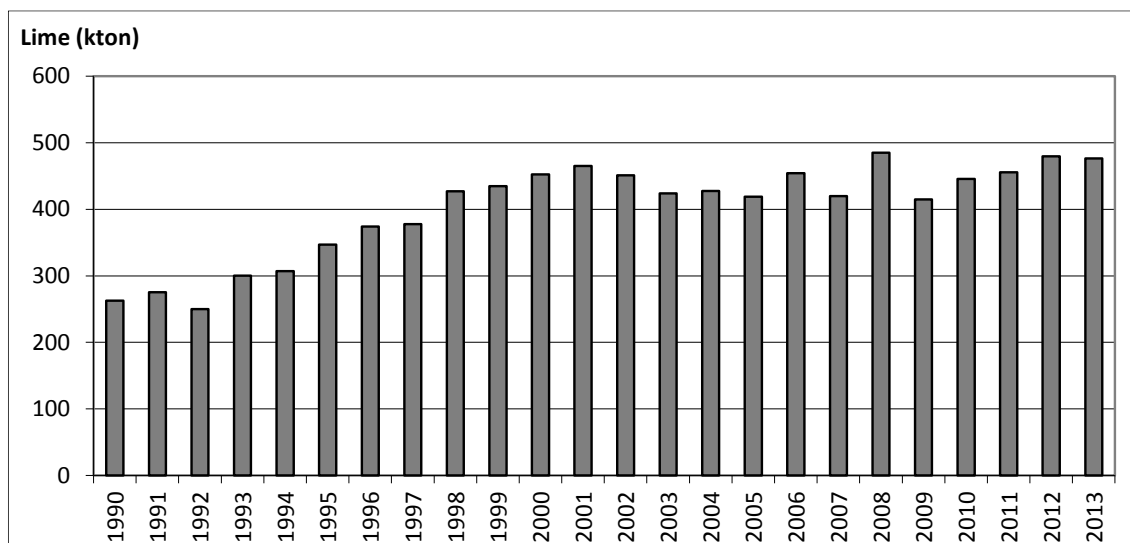
From 2005 onwards, data on consumption of raw materials was obtained from EU-ETS. Lime production was obtained from National Statistics (INE) IAPI industrial survey for the period 1990-2009 and corrected using production data from the facilities. From 2010 onwards, lime production data was obtained directly from the facilities.

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 2013 are 1.8 times larger than in 1990.

Figure 4.6 – Production of lime in Portugal



#### 4.3.2.5 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.

#### 4.3.2.6 Recalculations

Start using lime production data directly from the facilities.

#### 4.3.2.7 Further Improvements

No further improvements are expected.

### 4.3.3 Glass Production (CRF 2.A.3.)

#### 4.3.3.1 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>47</sup>.

#### 4.3.3.2 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.

#### 4.3.3.3 Emission Factors

The following emission factors from Annex IX of Directive 2003/87/EC were considered.

Table 4.1 – 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>v</sub> (CO <sub>3</sub> ) <sub>z</sub>	var	t CO <sub>2</sub> /t carbonate

#### 4.3.3.4 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<sup>2</sup>) or number of produced pieces.

Data on container glass production was obtained from AIVCERV/CTCV (Container Glass National Association).

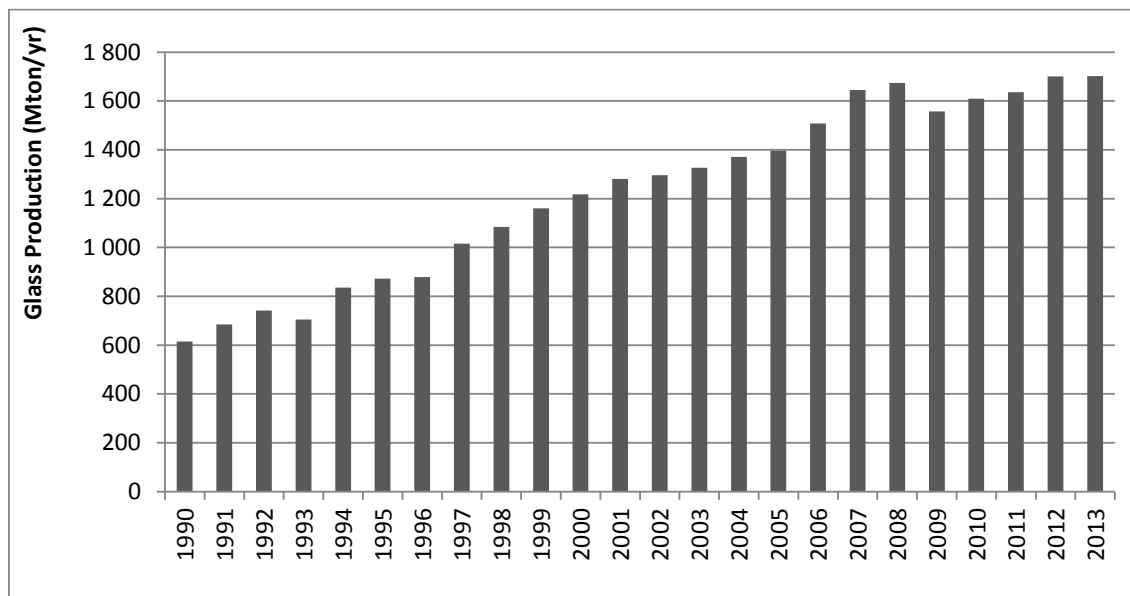
Flat Glass production data was obtained from the only industrial unit in Portugal. From 2009 onwards there is no Flat Glass production in Portugal.

Crystal Glass production data was obtained from AIC (Crystal Glass National Association).

<sup>47</sup> They were not used to derive the country specific emission factors for instance.



Figure 4.7 - Glass production

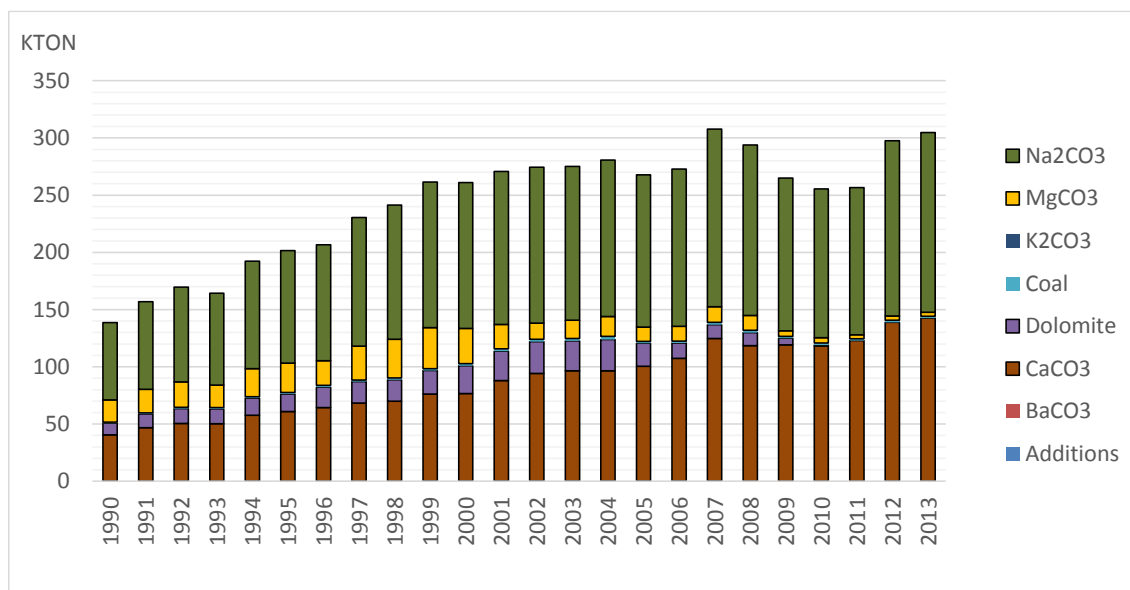


Due to confidentiality constraints concerning flat glass data (there was only one facility in Portugal until 2009), we don't present glass production data by glass type.

From 2005 onwards it is used ETS data on  $\text{Na}_2\text{CO}_3$ ,  $\text{MgCO}_3$ ,  $\text{CaCO}_3$ ,  $\text{BaCO}_3$ , 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  $\text{CO}_2$  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.

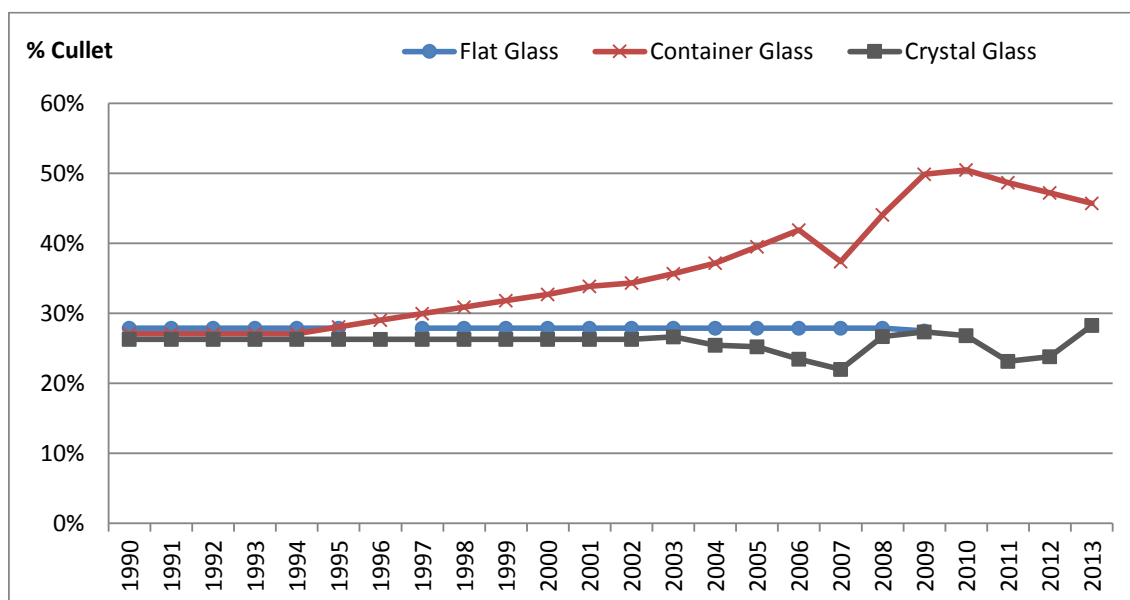
Raw materials consumption could be checked in the next figure.

Figure 4.8 – Raw materials consumption



Cullet incorporation ratio could be checked in the next figure.

Figure 4.9 - % of Cullet incorporation by type of glass



#### 4.3.3.5 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.

#### **4.3.3.6 Recalculations**

No recalculations were made.

#### **4.3.3.7 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.

#### **4.3.4 Uses of Carbonates in Ceramics (CRF 2.A.4.a)**

Estimates of emissions related to the uses of carbonates in ceramics are considered in CRF 2.A.4.d (Other uses of carbonates). In future submissions, these emissions should be addressed individually and relocated to CRF 2.A.4.a (Uses of Carbonates in Ceramics).

#### **4.3.5 Soda Ash Consumption (CRF 2.A.4.b)**

##### **4.3.5.1 Overview**

Soda Ash ( $\text{Na}_2\text{CO}_3$ ) is consumed as a raw material in the Glass Production (CRF 2.A.7), in paper pulp production (CRF 2.H.1), ceramics and other sectors with less consumption relevance.

##### **4.3.5.2 Methodology**

In a first step we estimate the soda ash apparent consumption, based on national production, imports and exports data:

$$\text{Apparent Consumption} = \text{National Production} + \text{Imports} - \text{Exports}$$

In a second step we estimate the soda ash apparent consumption in sectors for which the ETS data represents the national total (Paper, Pulp and Glass Production). We subtract these values to national total apparent consumption and the result is the apparent consumption for the remaining sectors (not fully addressed under ETS).

$$\text{Apparent Consumption (other sectors)} = \text{AC (total)} - \text{AC (Glass)} - \text{AC (Paper and Pulp)}$$

where

Apparent Consumption (other sectors) – soda ash apparent consumption in sectors other than Glass Production or Paper Pulp Production (ton  $\text{Na}_2\text{CO}_3$ );

AC (Total) – soda ash national total apparent consumption (ton  $\text{Na}_2\text{CO}_3$ );

AC (Glass) – soda ash consumption in Glass Production (ton  $\text{Na}_2\text{CO}_3$ );

AC (Paper and Pulp) – soda ash consumption in Paper and Pulp Production (ton  $\text{Na}_2\text{CO}_3$ ).

#### 4.3.5.3 Emission Factors

Carbon content of soda ash was set from molecular stoichiometry:

Table 4.2 - Carbon content of soda ash

Material	Ccontent
Sodium Carbonate (Soda Ash)	0.415

#### 4.3.5.4 Activity Data

Previously the estimates were based on carbonates national sales (National Statistics). Following the last National Inventory Review, it was implemented a new methodology based on soda ash apparent consumption (National Production + Imports – Exports). Soda Ash imports and exports data was obtained directly from Eurostat. Soda Ash national production was obtained from national statistics.

Figure 4.10 – Soda Ash apparent consumption

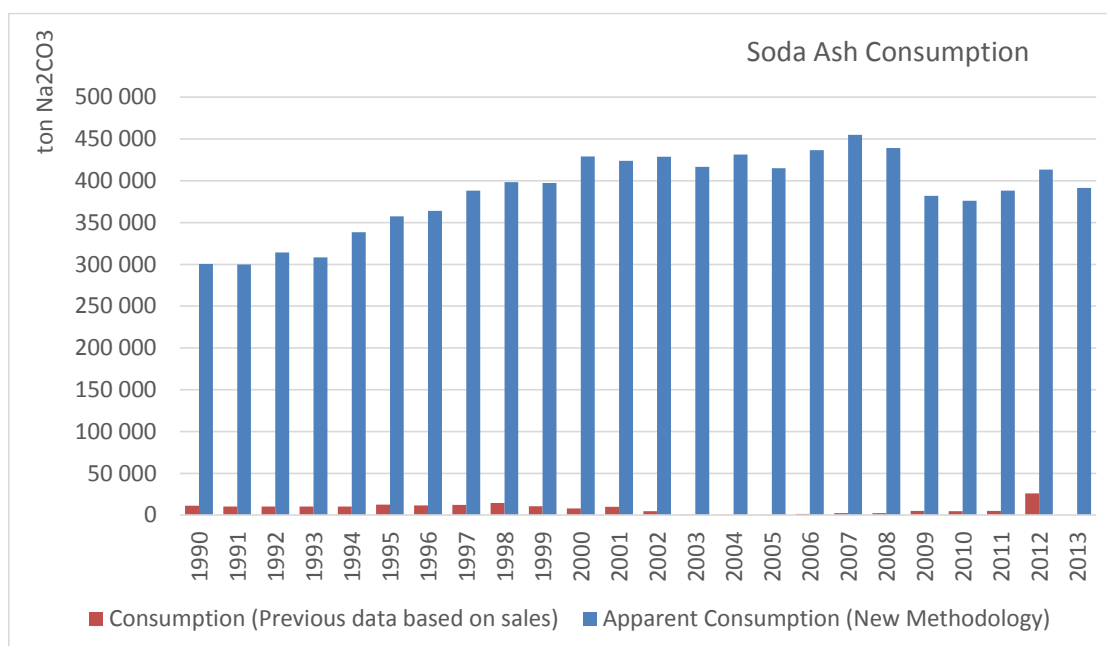
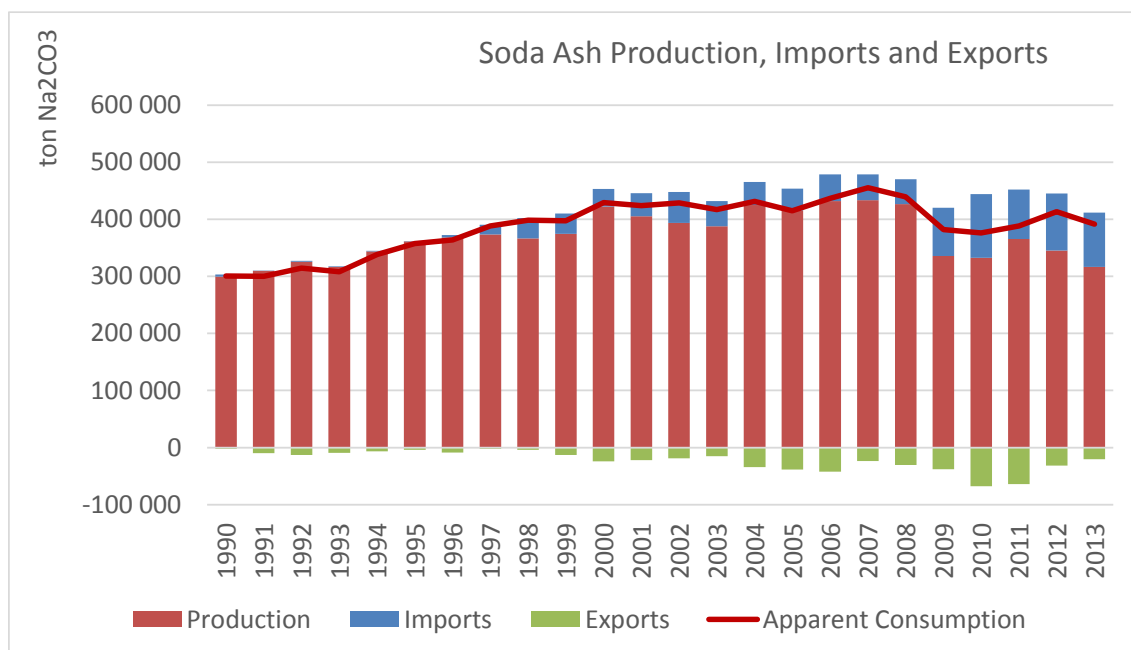
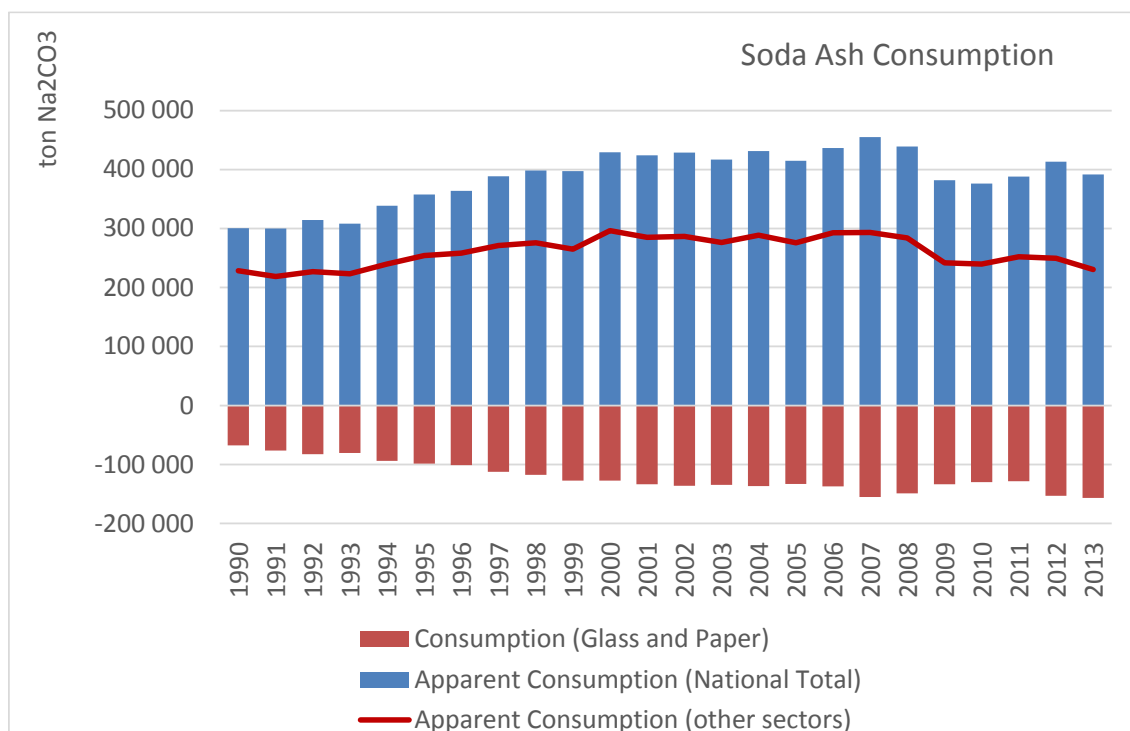


Figure 4.11 – Soda Ash national production, imports, exports and apparent consumption



Consumption of soda ash in paper, pulp and glass sectors was obtained directly from ETS data (see Figure 4.12).

Figure 4.12 – Soda ash apparent consumption for the remaining sectors (after subtraction of soda ash consumption from Glass, Pulp and Paper sectors)



#### 4.3.5.5 Recalculations

Previously the estimates were based on carbonates national sales (National Statistics). Following the last National Inventory Review, it was implemented a new methodology based on soda ash apparent consumption.

#### 4.3.5.6 Further Improvements

No further improvements are expected.

#### 4.3.6 Non-metallurgical Magnesium Production (CRF 2.A.4.c)

There is no non-metallurgical magnesium production in Portugal.

#### 4.3.7 Other Process Uses of Carbonates (CRF 2.A.4.d)

##### 4.3.7.1 Overview

Carbon dioxide liberation to atmosphere occurs from several industrial activities that use limestone (CaCO<sub>3</sub>), dolomite rock (CaCO<sub>3</sub>.MgCO<sub>3</sub>) 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, CO<sub>2</sub> emissions resulting from production of calcium and magnesium nitrates in paper pulp production are reported in source category 2A4d.

Use of carbonate materials in glass industry is covered in sector activity 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 2A4d but the methodology is described in source category 1A1a.

Non-CO<sub>2</sub> 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.

#### 4.3.7.2 Methodology

CO<sub>2</sub> emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of CO<sub>2</sub> that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

$$Emi_{CO_2 (y)} = 44/12 * Mat_{Carb (m,y)} * C_{content (m)} * 10^{-3}$$

where

$Emi_{CO_2 (y)}$  - emission of carbon dioxide in year y (kton/yr);

$Mat_{Carb (m,y)}$  - consumption of carbonate containing material m in year y (ton/yr);

$C_{content (m)}$  - carbon content of material m consumed in year y (ton C/ton).

#### 4.3.7.3 Emission Factors

Carbon content of materials consumed in Portugal was set from molecular stoichiometry<sup>48</sup>:

<sup>48</sup> It was assumed that limestone was totally pure, which causes over-estimated emissions.

Table 4.3 - Carbon content of carbonate materials

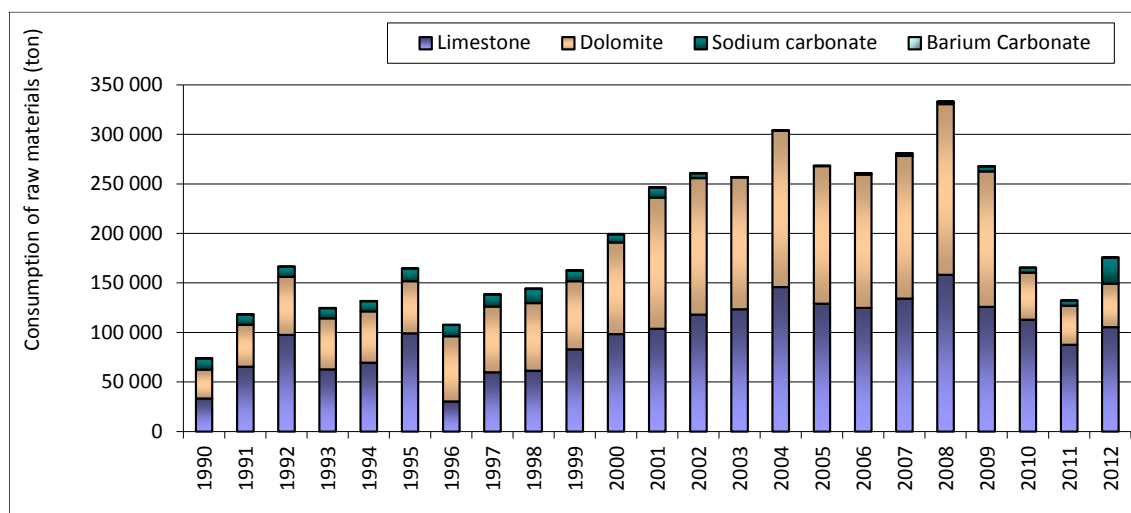
Material	Ccontent
Sodium Carbonate	0.42
Barium Carbonate	0.22
Limestone*	0.44
Dolomite #	0.48
Magnesium Carbonate	0.52
Coal (Electrodes) to be removed	3.67

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

#### 4.3.7.4 Activity Data

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 onwards. 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 Union Emissions Trading Scheme (EU-ETS), and production of construction ceramics and pavement ceramics, which is available from INE industry surveys IAIT and IAPI, was used to obtain the full time series. From 2010 onwards there is a strong decrease in limestone and dolomite consumption related to a decrease in calcium nitrate production.

Figure 4.13 - Consumption of carbonate materials in industry



#### 4.3.7.5 Uncertainty Assessment

There are no proposed values in GPG for the consideration of uncertainty values for  $\text{CO}_2$  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.

#### 4.3.7.6 Recalculations

Data on fertilizer production has been revised from 2010 onwards. This revision led to carbonate consumption values revision related to fertilizer production.

#### 4.3.7.7 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).

## 4.4 Chemical Industry (CRF 2.B.)

### 4.4.1 Ammonia Production (CRF 2.B.1.)

#### 4.4.1.1 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.

#### 4.4.1.2 Methodology

Carbon dioxide emissions were estimated from feedstock consumption using the following formulation:

$$EmicO_2(y) = 44/12 * Feedstock_{(y)} * C_{Feed(y)} * 10^{-5}$$

where

EmicO<sub>2(y)</sub> - Emission of carbon dioxide (kton/yr);

FeedStock<sub>(y)</sub> - Annual consumption of feedstock (ton/yr)

$C_{Feed(y)}$  - Carbon content of feedstock (%).

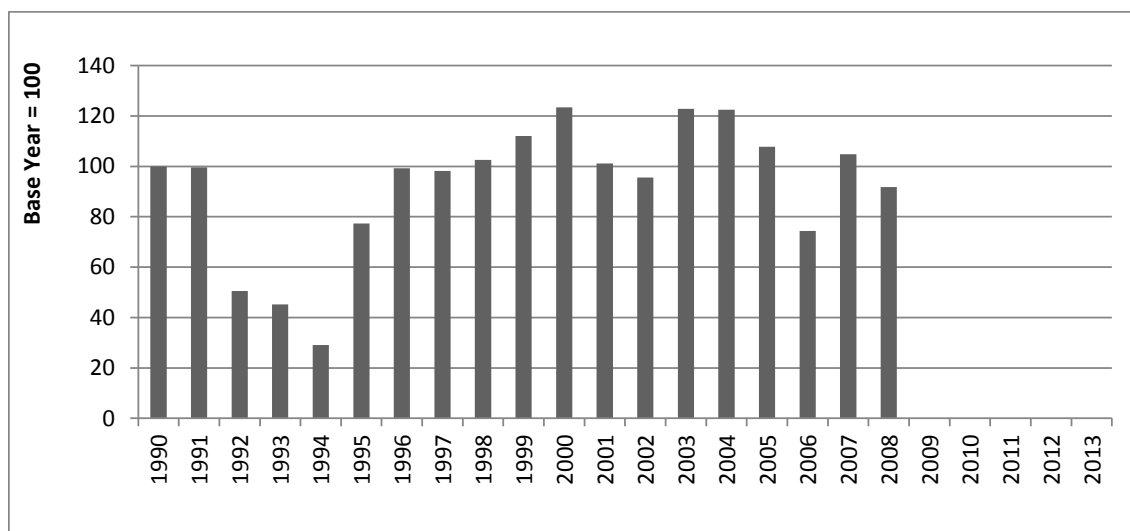
#### 4.4.1.3 Emission Factors

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

#### 4.4.1.4 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 4.14 - 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.

#### **4.4.1.5 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>49</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.

#### **4.4.1.6 Recalculations**

No recalculations were made.

#### **4.4.1.7 Further Improvements**

No further improvements are planned.

### **4.4.2 Nitric Acid (CRF 2.B.2.)**

#### **4.4.2.1 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.

Nitric Acid manufacture results in air emissions primarily of  $\text{NO}_x$  ( $\text{NO}$  and  $\text{NO}_2$ ), trace amounts of  $\text{HNO}_3$  acid mist, ammonia ( $\text{NH}_3$ ) and Nitrous Oxide ( $\text{N}_2\text{O}$ ). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of  $\text{NO}_x$  are controlled by catalytic reduction. Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

#### **4.4.2.2 Methodology**

For all pollutants emissions are estimated using the following equation:

---

<sup>49</sup> A further doubling was used to convert from standard deviation to 95% confidence interval.

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

where

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

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

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

#### 4.4.2.3 Emission Factors

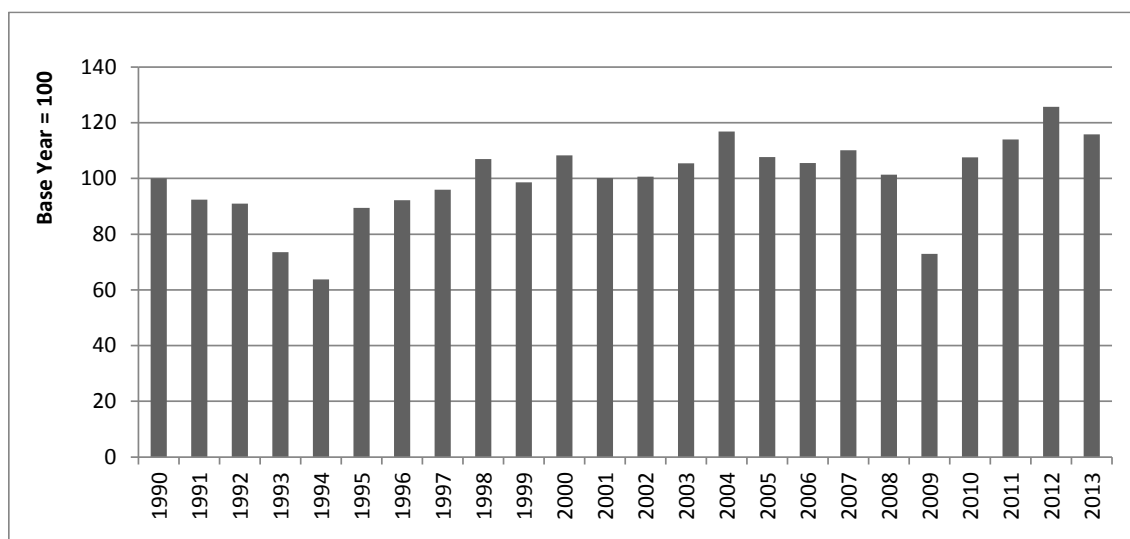
Due to confidentiality constraints it is not possible to publish the chosen emission factors. They were estimated based on monitoring data from the facilities.

#### 4.4.2.4 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 4.15 - Trend in Nitric Acid production



#### 4.4.2.5 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.

#### **4.4.2.6 Recalculations**

There were no recalculations.

#### **4.4.2.7 Future Improvements**

No further improvements are planned for this sector.

#### **4.4.3 Adipic Acid Production (CRF 2.B.3.)**

According to the information provided by the Portuguese Economy Ministry, there is no adipic acid production in Portugal.

#### **4.4.4 Caprolactam, Glyoxal and Glyoxylic Acid Production (CRF 2.B.4)**

According to the information provided by the Portuguese Economy Ministry, there is no caprolactam, glyoxal or glyoxylic acid production in Portugal.

#### **4.4.5 Silicon Carbide and Calcium Carbide Production (CRF 2.B.5)**

According to the information provided by the Portuguese Economy Ministry, there is no silicon carbide or calcium carbide production in Portugal.

#### **4.4.6 Titanium Dioxide Production (CRF 2.B.6)**

According to the information provided by the Portuguese Economy Ministry, there is no titanium dioxide production in Portugal.

#### **4.4.7 Soda Ash Production (CRF 2.B.7)**

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.

#### **4.4.8 Methanol Production (CRF 2.B.8.a)**

There is no methanol production in Portugal.

#### 4.4.9 Ethylene Production (CRF 2.B.8.b)

##### 4.4.9.1 Overview

There is only one ethylene plant in Portugal located in the southern part of the country, near Sines. The basic process in this unit is 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.

##### 4.4.9.2 Methodology

Emissions estimates are based on the use of emission factors multiplied by quantity of material produced:

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

where

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

$\text{ActivityRate}_{(y)}$  - Indicator of activity in the production process. Quantity of product produced per year is used as a general rule for this emission source sector (ton/yr);

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

##### 4.4.9.3 Emission Factors

A specific and detailed inventory survey was made for Repsol Polímeros unit in 1993-1994<sup>50</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 and using ethylene production as activity rate indicator<sup>51</sup>. Emissions from flares and flue gas combustor were included in the emission factors.

Table 4.4 – Emission Factors for determination of process emissions in Repsol Polímeros (kg/ton)

Description	NMVOC	CH4
Ethylene	0.8	1.2
Butadiene	1.2	-
HDPE	9.6	-
LDPE	4.8	-
PP	8.0	-

<sup>50</sup> Unpublished.

<sup>51</sup> This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

#### **4.4.9.4 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 “Repsol Polímeros” Petrochemical Plant in Sines - produced quantities were provided directly from the facility from 1990 onwards.

#### **4.4.9.5 Uncertainty Assessment**

The uncertainty of activity data received from Large Point Sources was set as 10 percent.

#### **4.4.9.6 Recalculations**

No recalculations were made.

#### **4.4.9.7 Further Improvements**

In future submissions it will be introduced emission factors updates based on monitoring data.

#### **4.4.10 Ethylene Dichloride and Vinyl Chloride Monomer Production (CRF 2.B.8.c)**

There is vinyl chloride monomer in Portugal and activity data is obtained from national statistics. This sector will be further developed in the next NIR submission.

#### **4.4.11 Ethylene Oxide Production (CRF 2.B.8.d)**

There is no ethylene oxide production in Portugal.

#### **4.4.12 Acrylonitrile Production (CRF 2.B.8.e)**

There is no acrylonitrile production in Portugal.

#### **4.4.13 Carbon Black Production (CRF 2.B.8.f)**

##### **4.4.13.1 Overview**

There is only one Carbon Black plant in Portugal, located in the southern part of the country, near Sines. Evonik 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.

##### **4.4.13.2 Methodology**

For this sub-sector emissions estimates are extensively based on the use of emission factors multiplied by quantity of material produced:

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

where

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

$\text{ActivityRate}_{(y)}$  - Indicator of activity in the production process. Quantity of product produced per year is used as a general rule for this emission source sector (ton/yr);

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

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,

$C_{\text{TailGas}}$  – carbon emitted in tail gas (ton C/yr);

$C_{\text{Feedstock}}$  – Carbon entered in feedstock (ton C/yr);

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

$C_{\text{CarbonBlack}}$  – carbon stored in carbon black and not emitted to atmosphere (ton C/yr).

#### 4.4.13.3 Emission Factors

The carbon black industrial unit was subjected, 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.

Table 4.5 – 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

#### 4.4.13.4 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.



Production of carbon black is available since 1990 from INE Statistical Database (IAIT and IAPI surveys).

#### **4.4.13.5 Uncertainty Assessment**

The uncertainty of activity data received from Large Point Sources was set as 10 percent.

#### **4.4.13.6 Recalculations**

No recalculations were made.

#### **4.4.13.7 Further Improvements**

In future submissions it will be introduced emission factors updates based on monitoring data.

### **4.4.14 Other Chemical Industry Products (CRF 2.B.8.g)**

#### **4.4.14.1 Overview**

Other chemical industrial activities were included as area sources in this sub-source sector<sup>52</sup>:

- Low Density Poly-ethylene (LDPE);
- Poly Vinyl Chloride (PVC);
- Poly propylene (PP);
- Poly styrene (PS);
- Formaldehyde.

#### **4.4.14.2 Methodology**

For this sub-sector emissions estimates are extensively based on the use of emission factors multiplied by quantity of material produced:

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

where

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

$\text{ActivityRate}_{(y)}$  - Indicator of activity in the production process. Quantity of product produced per year is used as a general rule for this emission source sector (ton/yr);

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

<sup>52</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

#### 4.4.14.3 Emission Factors

Table 4.6 – Emission Factors (kg/ton)

Description	NMVOC
HDPE	9.6
LDPE	4.8
PP	8.0

#### 4.4.14.4 Activity Data

Statistical information was obtained from the National Statistics.

#### 4.4.14.5 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>53</sup>.

#### 4.4.14.6 Recalculations

No recalculations were made.

#### 4.4.14.7 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 relies more and more in detailed plant information, i.e. increasing the number of Large Point Sources. Only deep knowledge of LPS units will allow quantification of air emission with reduced uncertainty, either using technology specific emission factors from literature or either using monitoring data. This improvement may imply coordination with 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:

<sup>53</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.

- 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.

#### **4.4.15 Fluorochemical Production (CRF 2.B.9)**

There is no fluorochemical production in Portugal.

#### **4.4.16 Ammonium Sulphate Production (CRF 2.B.10.b)**

To be provided in future NIR submissions.

#### **4.4.17 Explosives Production (CRF 2.B.10.c)**

To be provided in future NIR submissions.

#### **4.4.18 Solvent Use in Plastic Products Manufacturing (CRF 2.B.10.d)**

To be provided in future NIR submissions.

### **4.5 Metal Industry (CRF 2.C)**

#### **4.5.1 Iron and Steel Production (CRF 2.C.1)**

##### **4.5.1.1 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 coke plant 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 coke plant, 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.

#### 4.5.1.2 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 coke plant 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>, CO and NMVOC emissions are based on monitoring data and reported under source code “2.C.1.1”.

#### 4.5.1.3 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 4.7 - 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)	EHF (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>	-
NMVOC	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 4.8 – 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

From 2002 onwards, CH<sub>4</sub>, CO and NMVOC emissions are based on monitoring data. It is not possible to treat separately process and combustion related emissions, and so they are reported under CRF 2.C.1.1 (emission factors could be checked in the next table).

Table 4.9 – CH<sub>4</sub>, CO and NMVOC emission factors

Pollutant	EF	Unit EF
CH <sub>4</sub>	0.323	t CH <sub>4</sub> / t steel
CO	0.516 - 0.612	t CO / t steel
NMVOC	0.038 – 0.118	t NMVOC / t steel

#### 4.5.1.4 Activity Data

There are differences in the activity data used in estimates for the period 1990-2001 and from 2002 onwards.

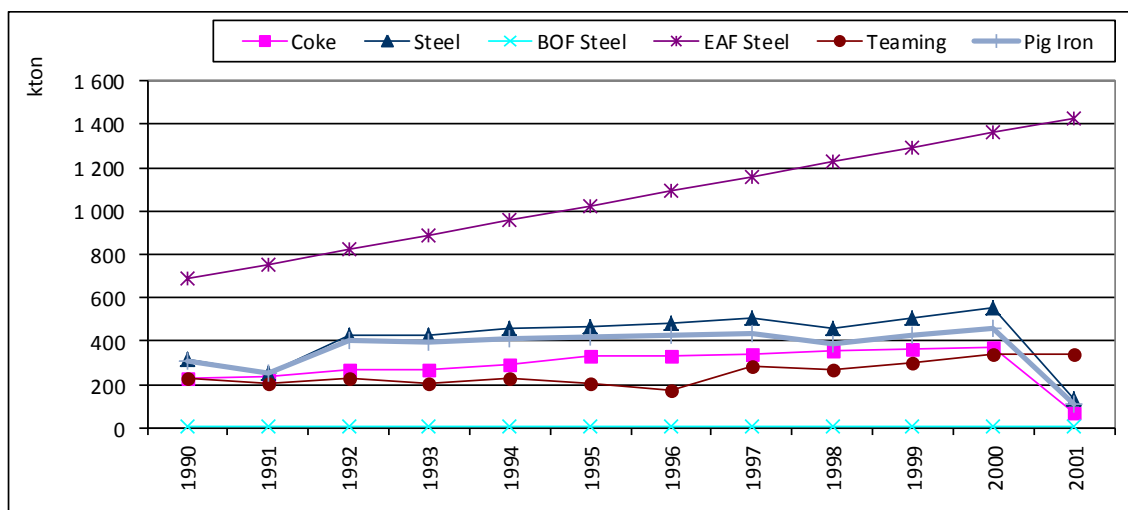
Activity data for emissions estimates from iron and steel production for the period 1990-2001 comprehend coke, sinter, pig iron and steel production and also scrap consumption, and time series for each product may be seen in the figure below. The following sources of information were used to establish activity data time series:

- Coke production is available from DGEG (Coke plant 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;

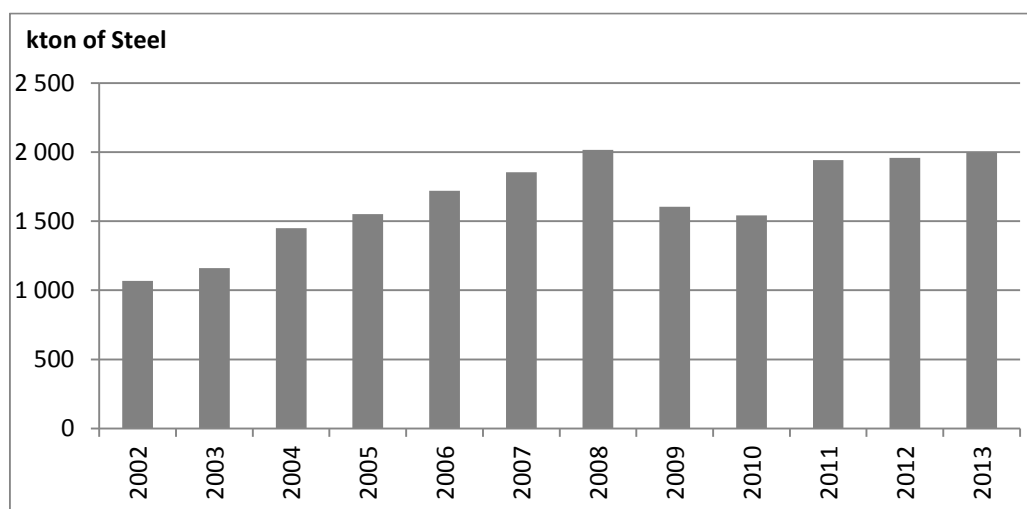
Production of total steel and intermediate products in the period 1990-2001 could be checked in the next figure.

Figure 4.16 - 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 4.17 - Production of secondary steel from 2002 onwards



#### 4.5.1.5 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.

#### 4.5.1.6 Recalculations

There are no recalculations.

#### 4.5.1.7 Further Improvements

No further improvements are expected.

### 4.5.2 Ferroalloys Production (CRF 2.C.2)

There is no ferroalloys production in Portugal in the period considered in this inventory.

### 4.5.3 Aluminium Production (CRF 2.C.3)

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.

#### 4.5.4 Magnesium Production (CRF 2.C.4)

There is no Magnesium Production in Portugal.

#### 4.5.5 Lead Production (CRF 2.C.5)

There is no Lead Production in Portugal.

#### 4.5.6 Zinc Production (CRF 2.C.6)

There is no Zinc Production in Portugal.

### 4.6 Non-energy Products from Fuels and Solvent Use (CRF 2.D)

#### 4.6.1 Lubricants Use (CRF 2.D.1)

##### 4.6.1.1 Overview

Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. In Portugal, they are used in several sectors, however the most relevant uses are road transportation, transforming industries, agriculture and services.

##### 4.6.1.2 Methodology

CO<sub>2</sub> emissions are estimated based on:

$$\text{CO}_2 \text{ Emissions} = \text{Lubricants}_{\text{Cons}} * (\text{DCC} * 44/12 * 10^{-3}) * \text{ODU}$$

Where

CO<sub>2</sub> Emissions – CO<sub>2</sub> emissions (ton);

Lubricants<sub>Cons</sub> – Consumption of Lubricants (GJ);

DCC – Default Carbon Content (= 20 kg C/GJ);

ODU – Oxidized During Use factor (=0.2).

#### 4.6.1.3 Emission Factors

Both default carbon content and oxidized during used factor were obtained from 2006 IPCC Guidelines (chapter 5.2.2.2.)

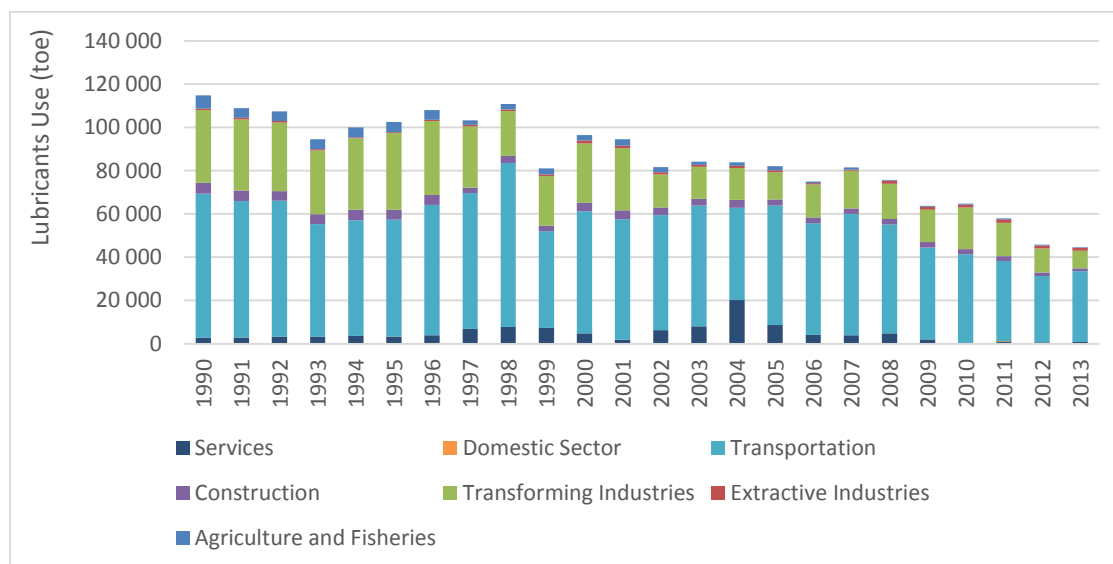
Table 4-10– Emission Factors for Lubricant Use

Parameter	Unit	Value	Source
Default Carbon Content	Kg C/GJ	20	2006 IPCC Guidelines
Oxidized During Use Factor	adimensional	0.2	2006 IPCC Guidelines

#### 4.6.1.4 Activity Data

The amounts of lubricants used in Portugal, were obtained from the national Energy Balance.

Figure 4-18 – Amounts of Lubricants used in Portugal



#### 4.6.1.5 Uncertainty Assessment

To be provided in the next submission.

#### 4.6.1.6 Recalculations

This sector was not previously considered.

#### 4.6.1.7 Further Improvements

No further improvements are expected.

### 4.6.2 Paraffin Wax Use (CRF 2.D.2)

#### 4.6.2.1 Overview

Paraffin waxes are separated from crude oil during the production of light lubricating oils and are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes and surfactants. In Portugal, the most relevant sectors were paraffin

waxes are used are chemical/plastics industry, wood products, rubber industry, metalworking industry and paper industry.

#### 4.6.2.2 Methodology

CO<sub>2</sub> emissions are estimated based on:

$$\text{CO}_2 \text{ Emissions} = \text{PW} * (\text{CC}_{\text{Wax}} * 44/12 * 10^{-3}) * \text{ODU}_{\text{Wax}}$$

Where

CO<sub>2</sub> Emissions – CO<sub>2</sub> emissions (ton);

PW – Consumption of Paraffin Waxes (GJ);

CC<sub>Wax</sub> – Paraffin Waxes Default Carbon Content (= 20 kg C/GJ);

ODU<sub>Wax</sub> – Paraffin Waxes Oxidized During Use factor (=0.2).

#### 4.6.2.3 Emission Factors

Both default carbon content and oxidized during used factor were obtained from 2006 IPCC Guidelines (chapter 5.3.2.2.)

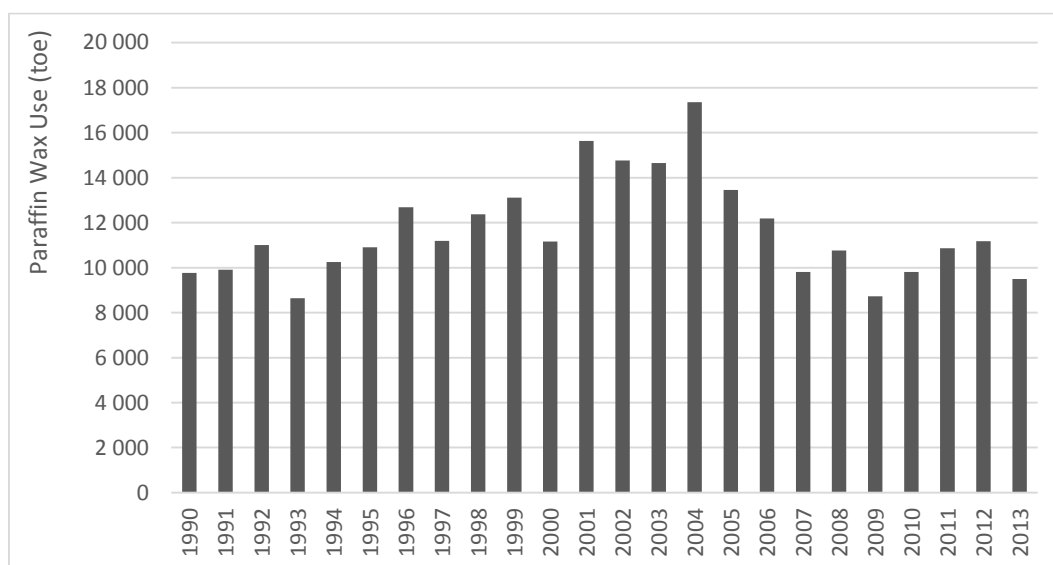
Table 4-11– Emission Factors for Paraffin Waxes Use

Parameter	Unit	Value	Source
Default Carbon Content	Kg C/GJ	20	2006 IPCC Guidelines
Oxidized During Use Factor	adimensional	0.2	2006 IPCC Guidelines

#### 4.6.2.4 Activity Data

The amounts of paraffin waxes used in Portugal, were obtained from the national Energy Balance.

Figure 4-19 – Amounts of Paraffin Waxes used in Portugal



#### 4.6.2.5 Uncertainty Assessment

To be provided in the next submission.

#### 4.6.2.6 Recalculations

This sector was not previously considered.

#### 4.6.2.7 Further Improvements

No further improvements are expected.

### 4.6.3 Solvent Use (CRF 2.D.3.a)

#### 4.6.3.1 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.

NM VOC 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 NM VOC compounds are fully oxidized in air to carbon dioxide contributing thence to the atmospheric pool.

#### 4.6.3.2 Paint Application

##### 4.6.3.2.1 Overview

This sub-source sector covers NM VOC 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>54</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 Chemical Products sub-sector.

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 NM VOC 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).

##### 4.6.3.2.2 Methodology

NM VOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$E_{miNMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$E_{miNMVOC(y)}$  – NM VOC 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);

<sup>54</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.

$EF_{(p)}$  – NMVOV emission factor (solvent content) resulting from application of substance p (kg/ton).

For specific sectors where more detailed activity data and emissions factors were available a product base methodology was used. This is the case for:

- Cars manufacturing;
- Truck cabin coating;
- Leather finishing.

The product based methodology can be described as following.

$$Emi_{NMVOC(p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(p,y)}$  – NMVOC emissions resulting the production of product p during year y (t/yr);

$Product_{(p,y)}$  – Production units of product p during year y (cars/yr, truck cabins/yr, kg leather/yr);

$EF_{(p)}$  – NMVOV emission factor for production of product p (kg/car, kg/truck cabin, kg/kg leather)

p – product (cars, truck cabin, leather).

Ultimate CO<sub>2</sub> emissions were calculated assuming that 60 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>2e</sub>.

$$U_{CO_2} = NMVOC * 0.60 * (44/12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

#### 4.6.3.2.3 Emission Factors

Emission factors were taken from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_t \left( \frac{CS_{(t,y)}}{100} \times \left( 1 - \frac{AT_{(t)}}{100} \right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$  – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$  – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$  – Efficiency of abatement technology t (%);

t – abatement technology;

$EF_{NMVOC(default)}$  – Default NMVOC emission factor.

In cases where industrial detailed information was not available, Tier 1 emission factors for industrial paint application were used. This emission factor is based on the quantity of coating applied.

Table 4.12 – NMVOC Tier 1 emission factor for industrial application

NFR	NFR Title	Tier 1 EF	EF Unit
2 D 3 d	Industrial coating application	400	g/kg paint

Source: (EEA/EMEP, 2013)

#### 4.6.3.2.3.1 Construction and buildings (SNAP 060103)

Table 4.13 – Default emission factor

SNAP	Unit	NMVOC
Construction and buildings	g/kg paint	230

Source: (EEA/EMEP, 2013)

Table 4.14 – 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, 2013)

Table 4.15 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2013
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 4.16 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF	g/kg paint applied	221	170	140	105	69	69

#### 4.6.3.2.3.2 Wood (SNAP 060107)

Table 4.17 – Default emission factor

SNAP	Unit	NMVOC
Wood	g/kg paint applied	800

Source: (EEA/EMEP, 2013)

Table 4.18 – 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, 2013)



**Table 4.19 – Control strategy**

Technology	Unit	1990	1995	2000	2005	2010	2013
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 4.20 – Final emission factor**

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF	g/kg paint applied	440	440	440	440	273	273
Final EF	t/t	0.4	0.4	0.4	0.4	0.3	0.3
Final EF	wt %	44.0	44.0	44.0	44.0	27.3	27.3

#### 4.6.3.2.3.3 Manufacture of automobiles (SNAP 060101)

**Table 4.21 – Default emission factor**

SNAP	Unit	NM VOC
Manufacture of automobiles: Car coating	kg/car	8

Source: (EEA/EMEP, 2013)

**Table 4.22 – 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, 2013)

Table 4.23 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2013
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 4.24 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF Car coating	kg/car	8.0	6.2	4.4	2.6	0.8	0.8

#### 4.6.3.2.3.4 Truck cabin coating (SNAP 060108)

Table 4.25 – Default emission factor

SNAP	Unit	NM VOC
Industrial coating application: Vehicle refinishing	kg/vehicle	8

Source: (EEA/EMEP, 2013)

Table 4.26 – 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, 2013)

Table 4.27 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2013
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 4.28 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0	8.0

#### 4.6.3.2.3.5 Leather finishing (SNAP 060108)

Table 4.29 – Default emission factor

SNAP	Unit	NMVOC
Industrial coating application: leather finishing	g/kg leather	200

Source: (EEA/EMEP, 2013)

Table 4.30 – 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, 2013)

Table 4.31 – Control strategy

Technology	Unit	1990	1995	2000	2005	2010	2013
Use of water based products (30 wt-% solvent content)	%	0	0	0	10	30	42
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	53

Source: (IIASA, 2009)

Table 4.32 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF leather finishing	g/kg leather	200.0	200.0	200.0	187.0	152.9	137.3

#### 4.6.3.2.4 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:

$$\text{TotalCons}_{(y)} = \text{Production}_{(y)} + \text{Imports}_{(y)} - \text{Exports}_{(y)}$$

where:

$Total_{Cons(y)}$  - Consumed paint and varnish in year  $y$  (t/yr);

$Production_{(y)}$  - National Produced paint and varnish in year  $y$  (t/yr);

$Imports_{(y)}$  - Imported paint and varnish in year  $y$  (t/yr);

$Exports_{(y)}$  - 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 4.33.

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 4.34.

Total consumption of paints was calculated and the resultant time series is presented in Table 4.35.

Table 4.33 – 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	2013
Produced paints	154 992	155 081	154 221	149 706	148 908	165 048	161 165	135 826	155 209	133 748	119 692	121 150

Table 4.34 – 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

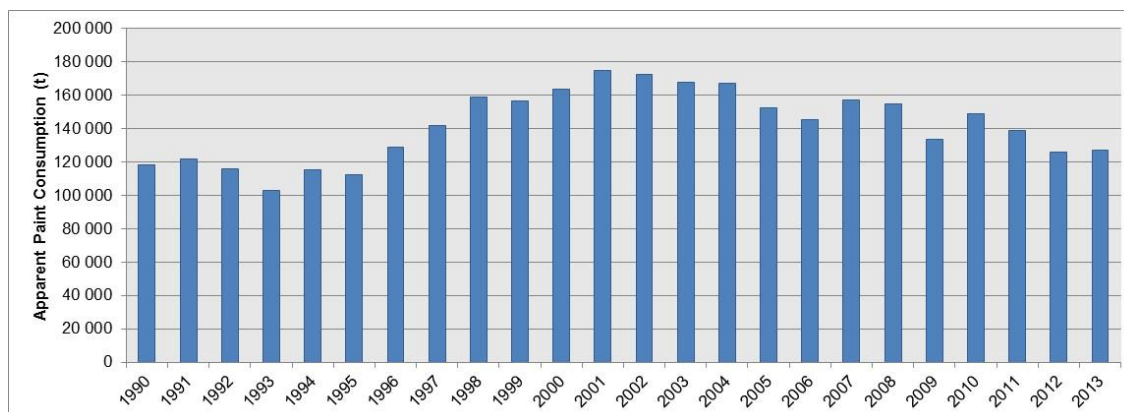
Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Imports	37 990	36 398	38 680	37 097	37 371	35 624	35 883	34 466	33 044	45 556	41 781	41 193
Exports	20 545	23 827	25 973	34 089	40 749	43 510	42 435	36 546	39 398	40 338	35 838	35 334

Table 4.35 – 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	2013
Apparent Consumption	172 437	167 651	166 928	152 714	145 530	157 162	154 612	133 746	148 855	138 965	125 635	127 010

Figure 4.20 - 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 4.36. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction<sup>55</sup>.

<sup>55</sup> No further disaggregation by this uses is possible from available statistical information

Table 4.36 - 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
60103	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
60104	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
60101	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
60107	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
60108	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
60108	Industrial coating application	Other industrial paint application: truck cabin	391	391	391	391	391	391	562	523	381	433	631	534
60108	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	2013
60103	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	8 117
60104	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	102 224
60101	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	1 142
60107	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	4 033
60108	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	11 438
60108	Industrial coating application	Other industrial paint application: truck cabin	534	534	320	363	489	242	158	99	113	111	108	106
60108	Industrial coating application	Other industrial paint application: leather finishing	152	102	52	130	137	621	923	973	1 159	1 144	1 107	1 092

Table 4.37 Final activity data used for paint application emission calculation

SNAP Title	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Paint application: construction and buildings	t paint	10 738	10 326	9 248	8 388	8 760	8 486	9 447	9 225	7 761	7 069	8 399	7 866
Paint application: domestic use (except 060107)	t paint	91 969	95 902	92 001	79 659	92 249	90 715	102 421	111 519	129 668	125 779	130 608	147 593
Paint application: manufacture of automobiles	n vehicles	134 109	139 145	156 142	90 462	76 324	100 170	177 518	210 174	208 458	199 250	195 309	200 089
Paint application: w ood	t paint	6 508	6 824	5 583	5 917	5 567	4 061	4 813	5 057	4 626	3 849	2 836	3 862
Other industrial paint application	t paint	8 475	8 475	8 475	8 475	8 475	8 475	11 609	15 400	16 351	19 319	20 891	14 867
Other industrial paint application: truck cabin coating	n vehicles	9 608	9 164	4 947	3 949	2 228	2 557	3 012	4 847	5 246	5 724	6 929	7 088
Other industrial paint application: leather finishing	t leather	834	834	834	733	651	534	603	806	1 480	2 098	2 386	7 399

SNAP Title	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Paint application: construction and buildings	t paint	7 524	7 328	8 613	9 242	10 373	10 374	11 120	8 385	9 846	7 390	6 658	8 117
Paint application: domestic use (except 060107)	t paint	147 528	145 161	144 863	129 412	115 964	130 607	123 686	108 092	119 610	114 261	102 550	102 224
Paint application: manufacture of automobiles	n vehicles	193 917	171 207	161 465	146 340	152 884	173 864	173 054	125 965	157 552	187 256	159 577	154 902
Paint application: w ood	t paint	3 872	3 740	4 333	4 493	5 078	5 257	5 402	4 244	5 018	3 918	3 464	4 033
Other industrial paint application	t paint	12 827	10 787	8 746	9 074	13 489	10 061	13 324	11 952	13 110	12 140	11 748	11 438
Other industrial paint application: truck cabin coating	n vehicles	6 378	5 576	6 687	6 203	6 101	5 935	5 789	4 202	4 396	3 788	3 657	3 951
Other industrial paint application: leather finishing	t leather	10 718	10 611	8 758	8 932	13 122	16 043	13 171	12 431	14 854	11 946	9 010	7 987



Table 4.38 Final NMVOC emission factors data used for paint application emission calculation

SNAP Title	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Paint application: construction and buildings	g/kg paint applied	220.8	210.7	200.6	190.4	180.3	170.2	164.2	158.2	152.3	146.3	140.3	133.2
Paint application: domestic use (except 060107)	g/kg paint applied	220.8	210.7	200.6	190.4	180.3	170.2	164.2	158.2	152.3	146.3	140.3	133.2
Paint application: manufacture of automobiles	kg/car	8.0	7.6	7.3	6.9	6.6	6.2	5.8	5.5	5.1	4.8	4.4	4.0
Paint application: wood	g/kg paint	439.9	439.9	439.9	439.9	439.9	439.9	439.9	439.9	439.9	439.9	439.9	439.9
Other industrial paint application	g/kg paint	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0
Other industrial paint application: truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Other industrial paint application: leather finishing	g/kg leather	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	197.4

SNAP Title	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Paint application: construction and buildings	g/kg paint applied	126.0	118.9	111.8	104.7	97.5	90.4	83.3	76.1	69.0	69.0	69.0	69.0
Paint application: domestic use (except 060107)	g/kg paint applied	126.0	118.9	111.8	104.7	97.5	90.4	83.3	76.1	69.0	69.0	69.0	69.0
Paint application: manufacture of automobiles	kg/car	3.7	3.3	3.0	2.6	2.2	1.9	1.5	1.2	0.8	0.8	0.8	0.8
Paint application: wood	g/kg paint	439.9	439.9	439.9	439.9	406.6	373.3	340.0	306.7	273.4	273.4	273.4	273.4
Other industrial paint application	g/kg paint	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0
Other industrial paint application: truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Other industrial paint application: leather finishing	g/kg leather	194.8	192.2	189.6	187.0	180.2	173.4	166.5	159.7	152.9	147.7	142.5	137.3

#### 4.6.3.2.5 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 35.4% for all uses of paint.

The uncertainty associated with the activity data from INE was assumed to be 10%.

An overall uncertainty of 36.8% was calculated for the paint application sector.

#### 4.6.3.2.6 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

Recalculations for this sub-source sector also comprise the revision of NMVOC emission factor for Paint application: wood based on EMEP 2013 guidelines. Emission factor changed from 960g/kg paint applied to 800g/kg paint applied.

#### 4.6.3.2.7 Further Improvements

No further improvements are planned for this sector.

### 4.6.3.3 *Degreasing and Dry Cleaning*

#### 4.6.3.3.1 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>56</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.

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<sup>56</sup> Emissions from degreasing in this industry are included under rubber processing

#### 4.6.3.3.2 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 60 percent of the mass emissions of NMVOC is carbon:

$$U_{CO_2} = NMVOC * 0.60 * (44/12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton);

NMVOC - Global emissions of NMVOC (ton).

#### 4.6.3.3.3 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 4.39, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

Table 4.39 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	2005	2013
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>57</sup> consumed in Portugal is used in dry-cleaning<sup>58</sup> activity and that all PER used is imported (no national

<sup>57</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>58</sup> There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

production). Annual apparent consumption was estimated from INE's statistical databases on external trade from 1990 to 2013 and assumed as equal to solvent use.

Table 4.40 - Annual consumption of PER (Tetra-chloro-ethylene) (t)

Parameter	1990	1995	2000	2005	2010	2011	2012	2013
Imports	2 172	1 155	1 649	0	1 108	948	874	862
Exports	0	0	0	0	49	55	12	12
Apparent Consumption	2 172	1 155	1 649	0	1 059	893	862	850

Source: INE.

#### 4.6.3.3.4 Uncertainty Assessment

The time trend of activity data for metal degreasing is very incomplete and an uncertainty of 100% was considered. Because emissions from PER use in dry cleaning were established from importation of this product the error is mostly due to incorrect allocation of emission, i.e. considering in dry cleaning a fraction of PER emissions that were realized in fact in other industrial activity. The final effect in inventory totals is therefore not significant and an error of 10% was used (USEPA). The uncertainty of emissions from both sectors are fully considered under activity data.

#### 4.6.3.3.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.3.6 Further Improvements

No further improvements are planned for this sector.

### 4.6.3.4 Chemical Products, Manufacture and Processing

#### 4.6.3.4.1 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.

#### 4.6.3.4.2 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 60% of carbon:

$$Emi_{CO2} = Emi_{NMVOC} * 0.60 * (44 / 12)$$

#### 4.6.3.4.2.1 Polyester processing

##### 4.6.3.4.2.1.1 Methodology

Emissions from polyester processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook. A tier 2 approach was used as activity data and emissions factors were stratified for polyester processing.

Emissions were estimated from the quantity of polyester processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} * Proc_{POYESTER(y)} * 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from polyester processing (t/yr);

$EF_{NMVOC}$  – NMVOC emission factor for polyester processing (g/kg monomer used);

$Prod_{FOAM(y)}$  – Quantity of monomer used y (t/yr).

##### 4.6.3.4.2.1.2 Emission Factors

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). The emissions factor was assumed constant for all covered period.

Table 4.41 – NMVOC foam processing emission factor

SNAP	Unit	NMVOC
Polyester processing	g/kg monomer used	50

Source: (EEA/EMEP, 2013)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60% of carbon:

$$Em_{CO_2} = Em_{NMVOC} * 0.60 * (44 / 12)$$

#### 4.6.3.4.2.1.3 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 4.42 –Polyester processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2013
Polyester processing	t monomer	5	57	870	405	1 061	1 734

Source: INE

#### 4.6.3.4.2.1.4 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%.

#### 4.6.3.4.2.1.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.4.2.1.6 Further Improvements

No further improvements are planned for this sector.

#### 4.6.3.4.2.2 Polyvinylchloride processing

##### 4.6.3.4.2.2.1 Methodology

Emissions from polyvinylchloride processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). 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:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Pro_{RESIN(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from polyvinylchloride processing (t/yr);

$EF_{NMVOC}$  – NMVOC emission factor for polyvinylchloride processing (g/kg resin);

$Pro_{RESIN(y)}$  – Quantity of polyvinylchloride resin (t/yr).

#### 4.6.3.4.2.2.2 Emission Factors

The default emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). The emissions factor was assumed constant for all covered period.

Table 4.43 – Tier 1 emission factor for chemical product use

Source category	Unit	NMVOC
Chemical products, manufacture and processing	g/kg product	10

Source: (EEA/EMEP, 2013)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60% of carbon:

$$Emi_{CO2} = Emi_{NMVOC} \times 0.60 \times (44 / 12)$$

#### 4.6.3.4.2.2.3 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 4.44 – Polyvinylchloride processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2013
Polyvinylchloride processing	t PVC	95 993	102 618	138 944	74 862	60 512	56 300

Source: INE

#### 4.6.3.4.2.2.4 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%.

#### 4.6.3.4.2.2.5 Recalculation

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.4.2.2.6 Further Improvements

No further improvements are planned for this sector.

#### 4.6.3.4.2.3 Polyurethane and polystyrene foam processing

##### 4.6.3.4.2.3.1 Methodology

Emissions from polyurethane and polystyrene foam processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). 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:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Prod_{FOAM(y)} \times 10^{-3}$$

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).

##### 4.6.3.4.2.3.2 Emission Factors

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). The emission factor was assumed constant for all covered period.

Table 4.45 – 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, 2013)



Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60% of carbon:

$$Emi_{CO_2} = Emi_{NMVOC} * 0.60 * (44 / 12)$$

#### 4.6.3.4.2.3.3 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 4.46 –Foam processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2013
Polyurethane processing	t foam	5 700	6 322	11 704	16 989	10 038	17 182
Polystyrene processing	t foam	11 222	14 454	22 212	16 561	16 995	19 909

Source: INE

#### 4.6.3.4.2.3.4 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%.

#### 4.6.3.4.2.3.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.4.2.3.6 Further Improvements

No further improvements are planned for this sector.

#### 4.6.3.4.2.4 Rubber processing

##### 4.6.3.4.2.4.1 Methodology

Emissions from rubber processing was estimated according with EMEP/CORINAIR Guidebook. Rubber processed for tyre production is not included in this sector.

Statistical information for year 2008 was not yet available, therefore emissions were estimated according with a forecast based on historical emissions from the last five year period.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$E_{\text{NMVOC}(y)} = EF_{\text{NMVOC}} \times \text{Prod}_{\text{RUBBER}(y)} \times 10^{-3}$$

Where:

$E_{\text{NMVOC}(y)}$  – NMVOC total emissions from rubber processing (t/yr);

$EF_{\text{NMVOC}}$  – NMVOC default emission factor for rubber processing (g/kg rubber produced);;

$\text{Prod}_{\text{RUBBER}(p,y)}$  – Production of rubber in year y (t/yr).

#### 4.6.3.4.2.4.2 Emission Factors

The emission factor used for rubber processing was obtained from EMEP/CORINAIR guidebook. The same emission factor was used for year 1990 to 2008.

Table 4.47 – NMVOC rubber processing emission factor

SNAP	Unit	NMVOC
Rubber processing	g/kg rubber produced	8

Source: EMEP/CORINAIR 2013, 2.D.3.g Chemical Products, table 3-5, pp18

#### 4.6.3.4.2.4.3 Activity Data

Production data of rubber artefacts was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 4.48 –Rubber processed

SNAP Title	Unit	1990	1995	2000	2005	2010	2013
Rubber processed	t rubber	26 871	24 484	29 915	32 818	68 442	70 088

Source: INE

#### 4.6.3.4.2.4.4 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%.

#### 4.6.3.4.2.4.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon

fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.4.2.4.6 Further Improvements

No further improvements are planned for this sector.

#### 4.6.3.4.2.5 Paints, Inks and Glues Manufacturing

##### 4.6.3.4.2.5.1 Methodology

Emissions from paints, inks and glue manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(p,y)} = EF_{NMVOC(y)} \times ProductManuf_{(p,y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(p,y)}$  – NMVOC emissions from manufacturing of product p in year y (t/yr);

$EF_{NMVOC(y)}$  – NMVOC emission factor for production of paints, inks and glue during year y (g/kg product);

$ProductManuf_{(p,y)}$  – Quantity of product p manufactured in year y (t/yr);

p – product (paint, ink, glue)

y – year

##### 4.6.3.4.2.5.2 Emission Factors

Emission factors were taken from EMEP/CORINAIR guidebook 2013. Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_t \left( \frac{CS_{(t,y)}}{100} \times \left( 1 - \frac{AT_{(t)}}{100} \right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$  – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$  – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$  – Efficiency of abatement technology  $t$  (%);

$t$  – abatement technology;

$EF_{NMVOC(\text{default})}$  – Default NMVOC emission factor.

Table 4.49 – Default emission factor (Source: EMEP/CORINAIR 2013)

SNAP	Unit	NMVOC
Paints, Inks and Glue Manufacturing	g/kg product	11

Table 4.50 – Abatement technology (Source: EMEP/CORINAIR 2013)

Abatement Technology	Unit	Efficiency
Use of good practices	%	27

Table 4.51 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2010	2013
Use of good practices	%	0	0	0	50	100	100
No control	%	100	100	100	50	0	0

Table 4.52 – Final emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF	g/kg product	11.0	11.0	11.0	9.5	8.0	8.0

#### 4.6.3.4.2.5.3 Activity Data

Production data of paints, inks and glue was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in the following table.

Table 4.53 – Production of paints, inks and glue

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2013
060307	Paints manufacturing	t paint	117 961	96 320	146 854	158 181	169 908	133 120
060308	Inks manufacturing	t ink	3 677	1 166	3 266	2 262	3 485	2 875
060309	Glues manufacturing	t glue	29 666	23 451	79 466	60 524	61 882	38 928

Source: INE

#### 4.6.3.4.2.5.4 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%.

#### 4.6.3.4.2.5.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.4.2.5.6 Further Improvements

No further improvements are planned for this sector.

#### 4.6.3.4.2.6 Manufacture of Tyres

##### 4.6.3.4.2.6.1 Methodology

Emissions from tyre manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the number of tyres produced according to:

$$Em_{NMVOC(y)} = EF_{NMVOC(y)} \times Tyres_{(y)} \times 10^{-6}$$

Where:

$Em_{NMVOC(y)}$  – 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

##### 4.6.3.4.2.6.2 Emission Factors

Emission factors were taken from EMEP/CORINAIR guidebook 2013. Control strategies were obtained from GAINS model developed by IIASA (<http://gains.iiasa.ac.at>).

Default emission factors and abatement technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_t \left( \frac{CS_{(t,y)}}{100} \times \left( 1 - \frac{AT_{(t)}}{100} \right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$  – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$  – Control strategy, share of abatement technology t during year y (%);

$AT_{(t)}$  – Efficiency of abatement technology t (%);

t – abatement technology;

$EF_{NMVOC(default)}$  – Default NMVOC emission factor.

Table 4.54 – Default emission factor (Source: EMEP/CORINAIR 2013)

SNAP	Unit	NMVOC
Tyre production	g/kg tyre	10

Table 4.55 – Abatement technology (Source: EMEP/CORINAIR 2013)

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 4.56 – Control strategy (Source: IIASA, 2009)

Technology	Unit	1990	1995	2000	2005	2010	2013
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 4.57 – Final NMVOC emission factor

Parameter	Unit	1990	1995	2000	2005	2010	2013
Final EF	g/kg tyre	10	7	4	4	4	4
Final EF	g/tyre	150	108	67	67	67	67

#### 4.6.3.4.2.6.3 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 4.58 – Production of tyres

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2013
060314	Manufacture of tyres	tyres	4 218 714	5 891 971	11 605 755	14 748 990	15 595 153	17 072 469

Source: INE

#### 4.6.3.4.2.6.4 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%.

#### 4.6.3.4.2.6.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.4.2.6.6 Further Improvements

No further improvements are planned for this sector.

### 4.6.3.5 Other use of solvents and related activities

#### 4.6.3.5.1 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.

#### 4.6.3.5.2 Printing

##### 4.6.3.5.2.1 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 repellant 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).



#### 4.6.3.5.2.2 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 60 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.

$$U_{CO_2} = NMVOC * 0.60 * (44 / 12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

#### 4.6.3.5.2.3 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 4.59 – NMVOC emission factor for printing activities

SNAP	Unit	NMVOC
Printing	g/kg ink	500

Source: EMEP/CORINAIR 2013

#### 4.6.3.5.2.4 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 2013 values were forecasted based on 1990-2010 values.

Table 4.60 – Consumption of inks in printing industry

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2013
060403	Printing Industry	t ink	5 372	5 372	9 290	8 722	9 336	8 796

Source: INE

#### 4.6.3.5.2.5 *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%.

#### 4.6.3.5.2.6 *Recalculations*

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.5.2.7 *Further Improvements*

No further improvements are planned for this sector.

#### 4.6.3.5.3 *Edible and non edible oil extraction*

##### 4.6.3.5.3.1 *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>59</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.

##### 4.6.3.5.3.2 *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:

$$E_{\text{minMVOC}}(y) = \text{MakeUp}_{\text{Solvents}}(y)$$

where:

<sup>59</sup> Classified as virgin olive oil

$E_{NMVOC}(y)$  - Emissions of NMVOC (ton/yr);

$MakeUp_{Solvents}(y)$  - annual consumption of solvent in edible and non-edible oil industry, to replenish losses (ton/yr).

Ultimate CO<sub>2</sub> emissions are calculated assuming that 60 percent of the mass emissions of NMVOC is carbon<sup>60</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.

$$U_{CO_2} = NMVOC * 0.60 * (44 / 12)$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

#### 4.6.3.5.3.3 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 4.61, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole covered period.

Table 4.61 – 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

#### 4.6.3.5.3.4 Activity Data

Oil refining data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2010. The 2013 values were forecasted based on 1990-2010 values. Annual

<sup>60</sup> From hexane chemical formula

values are reported in Table 4.62. Production of olive oil by mechanical pressure does not cause NMVOC emissions.

Table 4.62 - Refining of edible and non-edible oils in Portugal

Parameter	1990	1995	2000	2005	2010	2013
Oil refining	201 569	220 672	184 406	280 430	186 238	168 115

Source: National Statistics Institute (INE)

#### 4.6.3.5.3.5 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%.

#### 4.6.3.5.3.6 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.6.3.5.4 Industrial application of glues and adhesives

##### 4.6.3.5.4.1 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)

#### 4.6.3.5.4.2 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 4.63 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 4.64). 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 4.63 - 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 4.64 - 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.

#### 4.6.3.5.4.3 Activity Data

Table 4.65 - Activity Data for non-natural glues and adhesives (ton)

Year	1990	1991	2013
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)

#### 4.6.3.5.4.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

#### 4.6.3.5.4.5 Recalculations

No recalculations were made for this source sector.

#### 4.6.3.5.5 Wood Preservation

##### 4.6.3.5.5.1 Overview

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts and building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

##### 4.6.3.5.5.2 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.

##### 4.6.3.5.5.3 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.

#### 4.6.3.5.5.4 Activity Data

Table 4.66 - Wood preservation products consumption (ton)

Year	1990	1991	Average
Wood Preservation products Consumption (ton)	2083	2900	2491

Source: National Statistics Institute (INE)

#### 4.6.3.5.5.5 Uncertainty Assessment

The activity data and emission factors have a high level of uncertainty and errors therefore an uncertainty of 100% was assumed in both cases.

#### 4.6.3.5.5.6 Recalculations

No recalculations were made for this source sector.

#### 4.6.3.5.6 Domestic solvent use including fungicides (CRF 3.D.5)

##### 4.6.3.5.6.1 Methodology

This sector addresses emissions from the use of solvent containing products by the public in their homes. This sector does not include the use of decorative paints which is covered by source category 3.A. Paint Application.

NMVOC's are used in a large number of products sold for use by the public. These include:

- Cosmetics and toiletries; Products for the maintenance or improvement of personal appearance, health or hygiene.
- Household products; Products used to maintain or improve the appearance of household durables.
- Construction/Do-It-Yourself; Products used to improve the appearance or the structure of buildings such as adhesives and paint remover.
- Car care products; Products used for improving the appearance of vehicles to maintain vehicles or winter products such as antifreeze.

Pesticides such as garden herbicides and insecticides and household insecticide sprays may be considered as consumer products. Most agrochemicals, however, are produced for agricultural use and fall outside the scope of this section.

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:

NMVOCi - Emissions of NMVOC associated to the use of domestic products containing solvents [t]

Populationi – inhabitants in year i;

EF<sub>NMVOC</sub> - Emission factor associated with the use of domestic products containing solvents [kg/person/year]

#### 4.6.3.5.6.2 Emission Factors

Emission factor for NMVOC was obtained from EMEP/CORINAIR Guidebook, 2013. This default emission factor has been derived from an assessment of the emission factors presented in GAINS model developed by IIASA.

Table 4.67 – Default emission factor.

Description	Unit	Value
Emission factor for domestic solvent use including fungicides	kg/person/year	2.7

#### 4.6.3.5.7 Activity Data

Table 4.68 - Activity data (inhabitants)

Description	1990	1995	2000	2005	2010	2013
Inhabitants	9 970 441	10 043 180	10 256 658	10 569 592	10 636 979	10 427 301

Source: National Statistics Institute (INE)

#### 4.6.3.5.8 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%.

#### 4.6.3.5.9 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

Recalculations for this sub-source sector also comprise the revision of NMVOC emission factor based on EMEP 2013 guidelines. Emission factor changed from 1.0kg/person/year to 2.7 kg/person/year.



#### 4.6.4 Road Paving with Asphalt (CRF 2.D.3.b)

##### 4.6.4.1 Overview

Emission estimates reported in this source category include emissions occurring from paving road surfaces with asphalt materials as well as emissions occurring during operation of hot mix asphalt plants. Emissions from production of asphalt emulsions and cold asphalt mixtures are not included in the inventory estimates, being assumed that they are negligible.

Roads pavement with asphalt is done by the application of several layers over road bed. In volume, the majority of pavement is composed of layers of a compact aggregate and an asphalt binder (asphalt concrete). Asphalt concretes are classified either as hot mix or as cold mixes: cutback and emulsified asphalts. Liquefied asphalts – cutbacks and emulsions - are also used directly in seal and priming roadbed operations, sometimes in intermediate layers between applications of asphalt cement layers. Aggregate materials incorporated in asphalt concrete are usually composed of coarse unconsolidated rock fragments, either obtained from rock crushing, natural alluvial deposits or by products from metal ore refining.

Hot mix asphalts are made by mixing the aggregate material together with the asphalt cement using high temperatures (150°-160°)<sup>61</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 (40-60°).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers<sup>62</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 vapor pressure (USEPA, 2001 – EIIP Volume III Chapter 17).

Asphalt pavements dominate road paving activity in Portugal, whereas rigid cement pavements are only about 5 percent of total paved areas (APORBET).

Emissions during fabrication of asphalt concretes are estimated only for hot mix asphalt and comprehend NMVOC and Particulate Material that escape mostly from the drier. Other pollutants are also emitted but they result mostly from combustion of fuels and are considered in chapter Energy (1A2)<sup>63</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

<sup>61</sup> That are needed to fluidize the asphalt cement.

<sup>62</sup> And also a solvent in several emulsion types.

<sup>63</sup> To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity<sup>64</sup>.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible<sup>65</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.

#### 4.6.4.2 Methodology

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100 percent composed of VOC (USEPA, 2001) and that emitted VOC have on average 60 percent of carbon<sup>66</sup>:

$$Em_{CO_2} = 44 / 12 * 0.60 * Em_{NMVOC}$$

Different methodologies were used to estimate emissions of NMVOC during asphalt application or from asphalt production.

##### 4.6.4.2.1 Application of Asphalt Concretes and Liquefied Asphalts

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA, 1997; USEPA, 2001):

$$Em_{NMVOC(y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Em_{NMVOC(y)}$  - Emissions of NMVOC from asphalt application during year y (ton/yr);

$Binder_{(y)}$  – Total quantity of asphalt binder used in road paving during year y (ton/yr);

<sup>64</sup> It is not possible to distinguish fuel combustion in hot mix production activity.

<sup>65</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>66</sup> 2006 IPCC Guidelines.

$SLV_{Fac}$  - Fraction of distillate (solvent) in asphalt ( $m^3/m^3$ );

$d_{Siv}$  - density of solvent added to liquefied asphalt (kg/l);

$d_{BIN}$  - density of bitumen binder mixture (kg/l);

$Cure_{FC}$  - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

#### 4.6.4.2.2 Hot Mix Asphalt Production

For calculation of hot mix production emissions, emission calculation is based on total product:

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

Where,

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

$Hotmix_{Batch(y)}$  and  $Hotmix_{Drum(y)}$  – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

$EF_{(p)}$  and  $EF_{(p)}$  – Emission Factors for pollutant p used respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

Although available methodologies allow the calculation of emissions of several other pollutants from Hot mix asphalt production, in order to avoid double counting – and because fuel consumption in this activity could not be individualized from total fuel use in construction and building – only emissions of NMVOC and PM were estimated here. Although double counting could nevertheless be made for these pollutants, it was considered that the production process results in specific emissions of these two pollutants, 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.

#### 4.6.4.3 Emission Factors and Parameters

The following parameters were chosen to determine emission factors for application of emulsified and cutback asphalts. These values were chosen according to recommendations in AP-42, EMEP/CORINAIR or industrial expert guess.

Table 4.69 - 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 4.70 - Emission Parameters for Hot Mix asphalt production

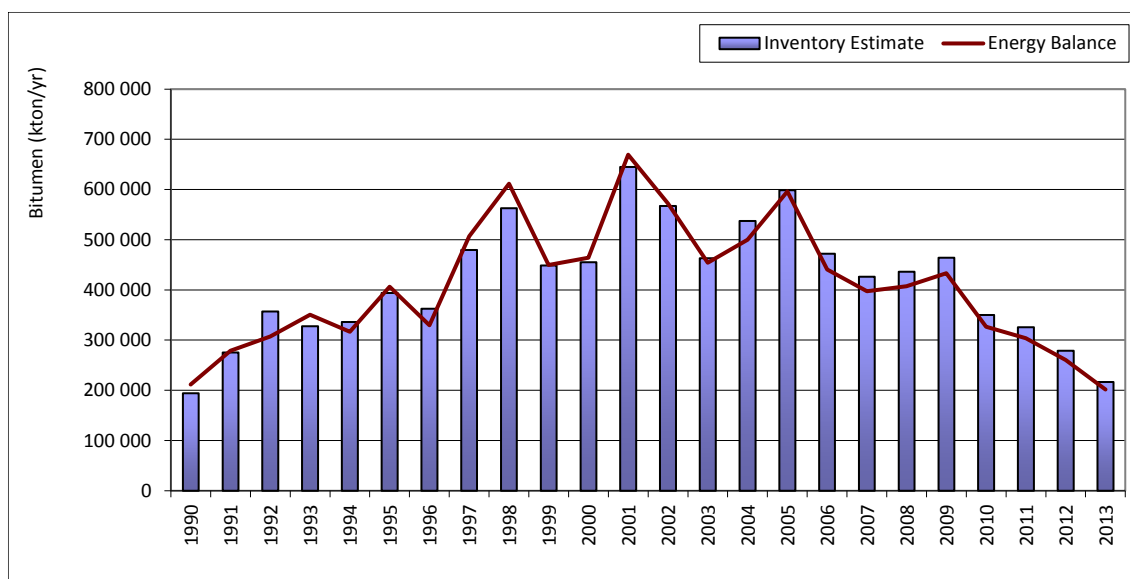
Pollutant	Continuous	Batch	Unit EF
NMVOC	32.0	22.1	g/ton
CH <sub>4</sub>	12.0	7.4	g/ton

Source: USEPA (2000)

#### 4.6.4.4 Activity Data

The total quantity of bitumen sold to construction and building economic sector is available from the Energy Balance and was collected by the General Directorate of Energy and Geology (DGEG) based on surveys<sup>67</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 4.21 - 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



<sup>67</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

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 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 4.71 – Amounts 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	2013
Cutback	ton	501	340	0	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	18 560

Figure 4.22 - Amounts of asphalt binders (cutback and emulsified asphalts) consumed in Portugal

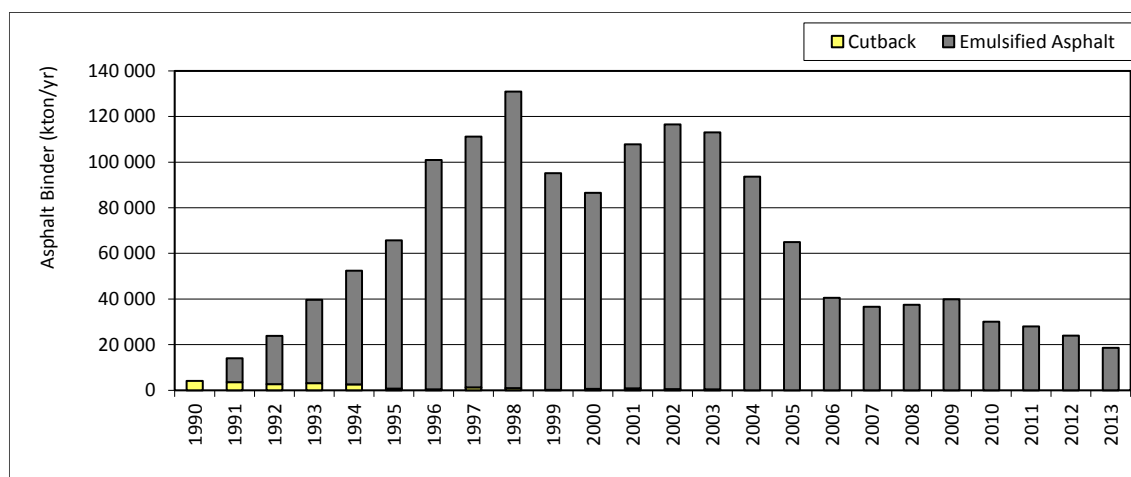
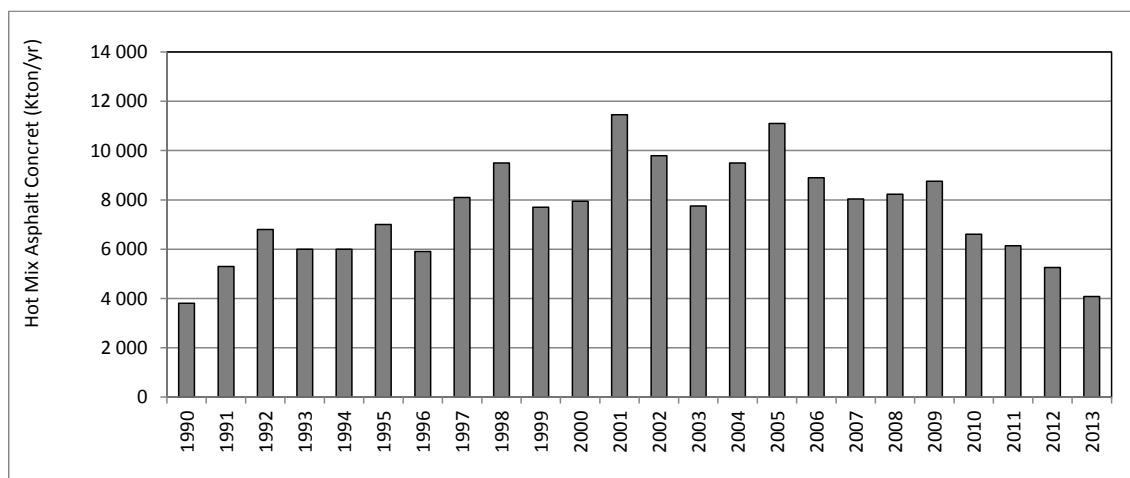


Figure 4.23 – Total Production of Hot Mix Asphalt



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).

#### 4.6.4.5 Uncertainty Assessment

There is no specific information in the GPG concerning uncertainty values for this source sector. Uncertainty in activity data was estimated as the maximum difference between the total bitumen quantities estimated by the inventory and reported in the DGGE energy balance: 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 or as hot mix. Because of the very variable emission factor according to which asphalt type is being considered two orders of magnitude was considered for the uncertainty value of the emission factors for NMVOC and CO<sub>2</sub>.

#### 4.6.4.6 Recalculations

It was made a recalculation due to a correction of the carbon fraction in NMVOC. Previously it was assumed 85% (m/m) value that was corrected to 60% (m/m), according to 2006 IPCC Guidelines.

#### 4.6.4.7 Further Improvements

It was still however not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation and asphalt roofing. Improvements in this separation are expected in following submissions.

## 4.7 Electronics Industry (CRF 2.E)

### 4.7.1 Integrated Circuit or Semiconductor (CRF 2.E.1)

This sector will be fully addressed in future NIR submissions.

### 4.7.2 TFT Flat Panel Display (CRF 2.E.2)

This sector will be fully addressed in future NIR submissions.

### 4.7.3 Photovoltaics (CRF 2.E.3)

According to the information provided by the Portuguese Economy Ministry, there is no production of Photovoltaics with fluorinated gases in Portugal.

### 4.7.4 Heat Transfer Fluid (CRF 2.E.4)

According to the information provided by the Portuguese Economy Ministry, there is no Heat Transfer Fluid production in Portugal.

## 4.8 Product Uses as Substitutes for ODS (CRF 2.F)

### 4.8.1 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>68</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:

<sup>68</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.

- 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).

#### **4.8.2 General Methodology**

For those sources with sufficient available data, actual emissions were estimated with a Tier 2 (advanced or actual method) approach which is considered Good Practice in accordance with GPG. This approach allows the quantification of emissions in the year in which they actually occurred accounting for the time lag between consumption and emissions. On the contrary, the Tier 1, or potential approach, allocates emissions in the year that the chemical is sold into a particular end-user.

As a general rule, bottom-up methodologies were used, and thus overall methodology should be classified as Tier 2a. This approach departs from the knowledge of the number of equipments using Fluorinated compounds and estimates emissions to atmosphere from charge (amount of chemical used in the equipment), service life, emission rate during the various periods of the equipment life and possible recovery of emissions.

Whenever possible emission estimates include:

- assembly emissions - when equipment is first filled<sup>69</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.

#### **4.8.3 Recalculations**

No recalculations were made.

#### **4.8.4 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.

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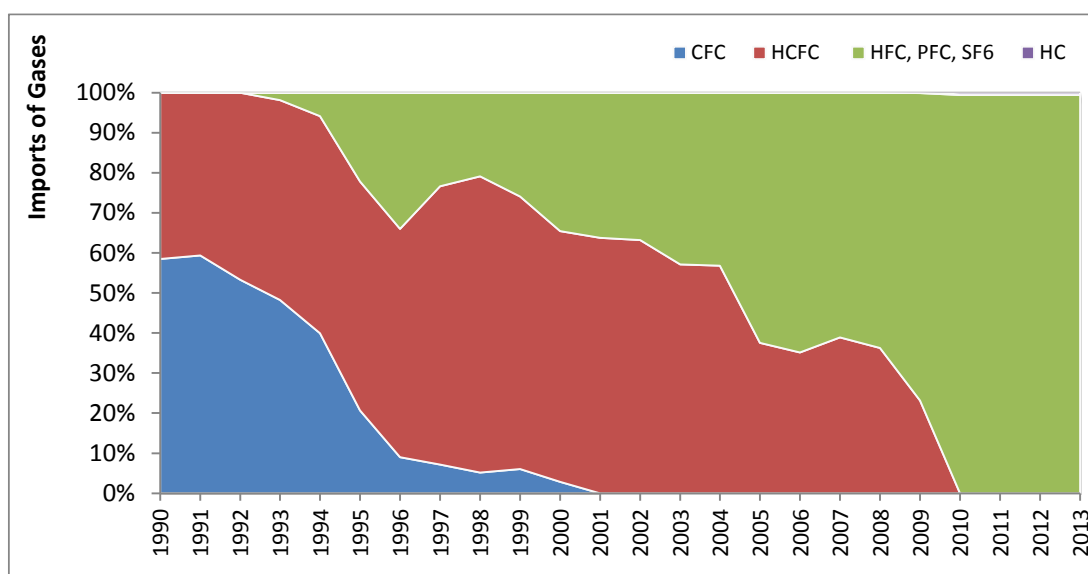
<sup>69</sup> Assembly emissions could include also emissions during refilling but no data was available to make this distinction



#### 4.8.5 Importers Data

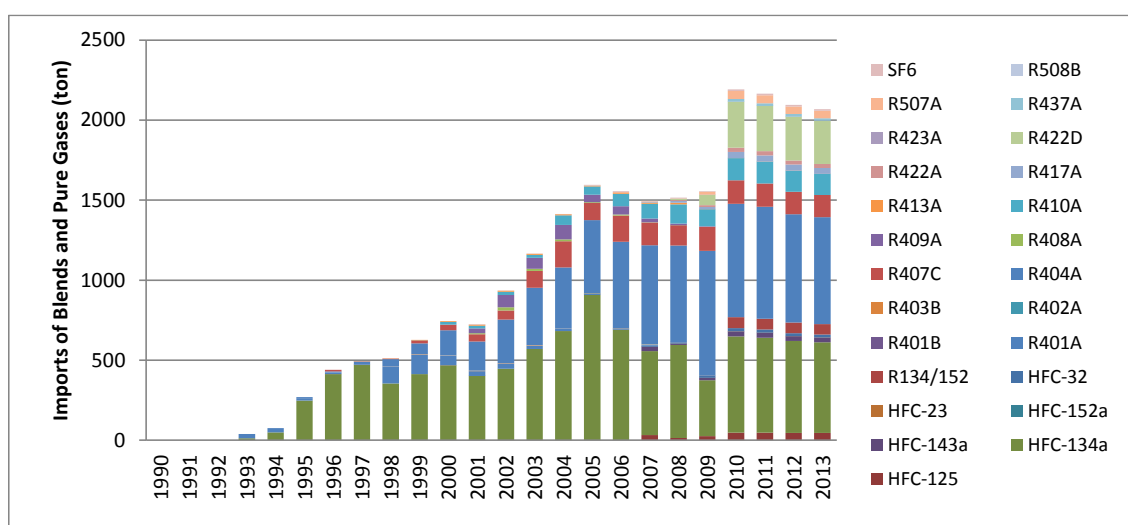
The share of each F-gas used in the assembling of refrigeration equipments was estimated for each year relying on imports data from the major national suppliers of assembled units. Although data from suppliers does not cover the total national market, it was assumed to represent 60 percent (value agreed upon with suppliers) and there were made corrections to the total value in order to obtain a well representative situation. Fluorinated Gases have been imported since 1993 and have been increasingly replacing HCFC imports. The share of imports of each gas can be checked in the following figure.

Figure 4.24 - Percentage of imported gases in Portugal by gas type



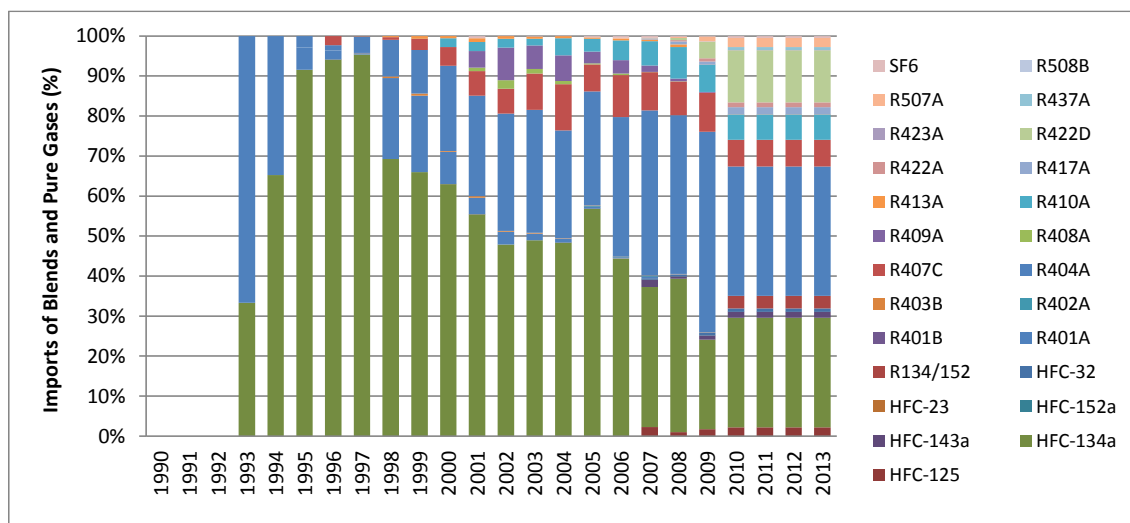
Source: Fluid Suppliers

Figure 4.25 – Imported amounts of pure HFC, PFC, SF<sub>6</sub> and Blends containing HFC and PFC



Source: Fluid Suppliers

Figure 4.26 – Percentual Distribution of pure HFC, PFC, SF<sub>6</sub> and Blends containing HFC and PFC



Source: Fluid Suppliers

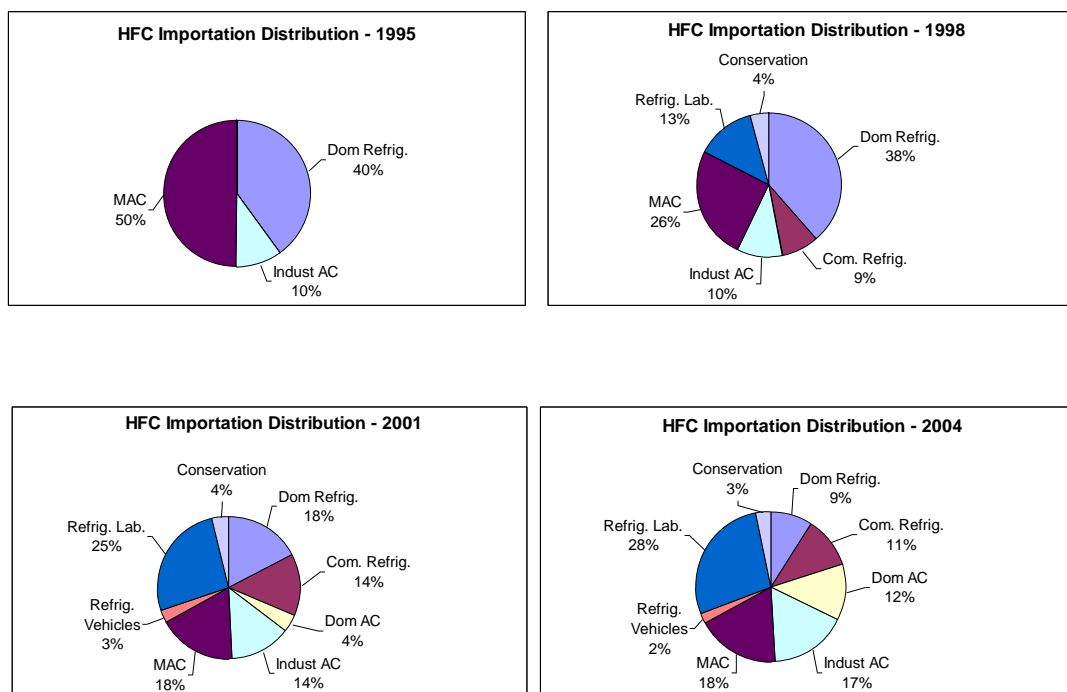
Table 4.72 – Constitution of each blend

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%
	HFC-134a	4%
	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-22	60%
R-410a	HCFC-124	25%
	HCFC-142b	15%
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%
	HFC-143a	50%
	HFC-23	46%
	PFC-116	54%

Source: HRP – Supplier to the Refrigeration and Air Conditioning Equipment

Figure 4.27 - Percentage of imported F-Gases in Portugal by sub sector



Source: Importers

#### 4.8.6 Commercial Refrigeration (CRF 2.F.1.a)

##### 4.8.6.1 Methodology

CFC, HCFC and F-Gases emissions from operation and disposal of Commercial 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

$$\text{AssEmi (t)} = \text{Equip}_{\text{Assembly (t)}} * \text{Initial}_{\text{Charge (t)}} * (k/100)$$

Operation/Lifetime

$$\text{Oper}_{\text{Emi (t)}} = \text{Equip}_{\text{Stock (t)}} * \text{Initial}_{\text{Charge (t)}} * (x/100)$$

Disposal

$$\text{DispEmi (t)} = \text{Equip}_{\text{Disposal (t)}} * \text{Initial}_{\text{Charge (t-lifetime)}} * (y/100) * (1-z/100)$$

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.

#### 4.8.6.2 Emission Factors

Emission factors were set as the average values from the proposed range in IPCC GPG table 3.22.

Table 4.73 – 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 4.74 – 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

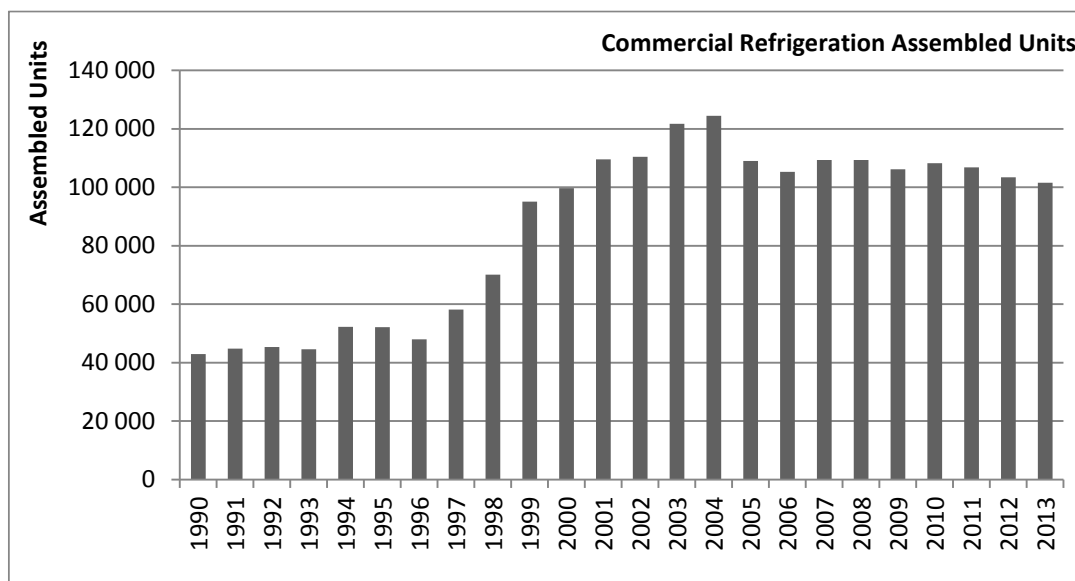
Equipments lifetime was set as 14 years.

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%.

#### 4.8.6.3 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 4.75 – 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 4.76 – 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 4.77 – 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 4.78 – 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

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.

#### 4.8.6.4 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%.

#### 4.8.6.5 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.

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.

<sup>70</sup> In consequence no emissions of HFC from disposal are estimated for the reported period.

<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 4.79 – 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

#### 4.8.7 Laboratory Refrigeration (CRF 2.F.1.a)

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 %).

#### 4.8.8 Domestic Refrigeration (CRF 2.F.1.b)

##### 4.8.8.1 Methodology

It was used the same methodology as for Commercial Refrigeration (CRF 2.F.1.a).

##### 4.8.8.2 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 4.80 - Emission Factors of F-gases from Domestic Refrigeration

k (%)	x (%)	y (%)	z (%)
0.6	0.2	90.0	70.0

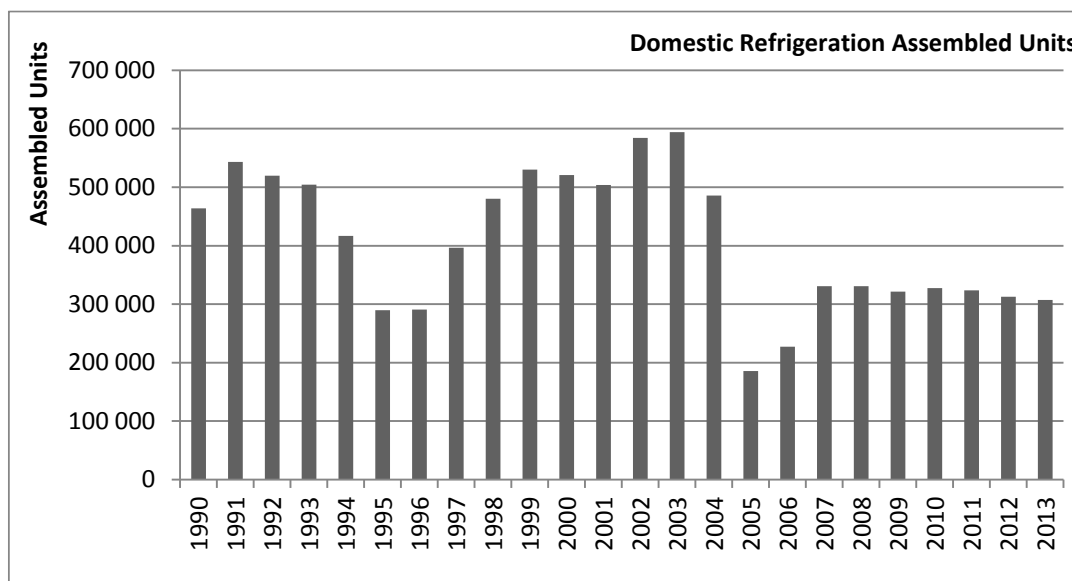
Source: IPCC GPG (table 3.22)

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%.

##### 4.8.8.3 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 from 2011 onwards were forecasted by APA based on gross domestic product.

Figure 4.29 – 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” until 2012 and forecasted based on gross domestic product in 2013.

Figure 4.30 – Number of Households

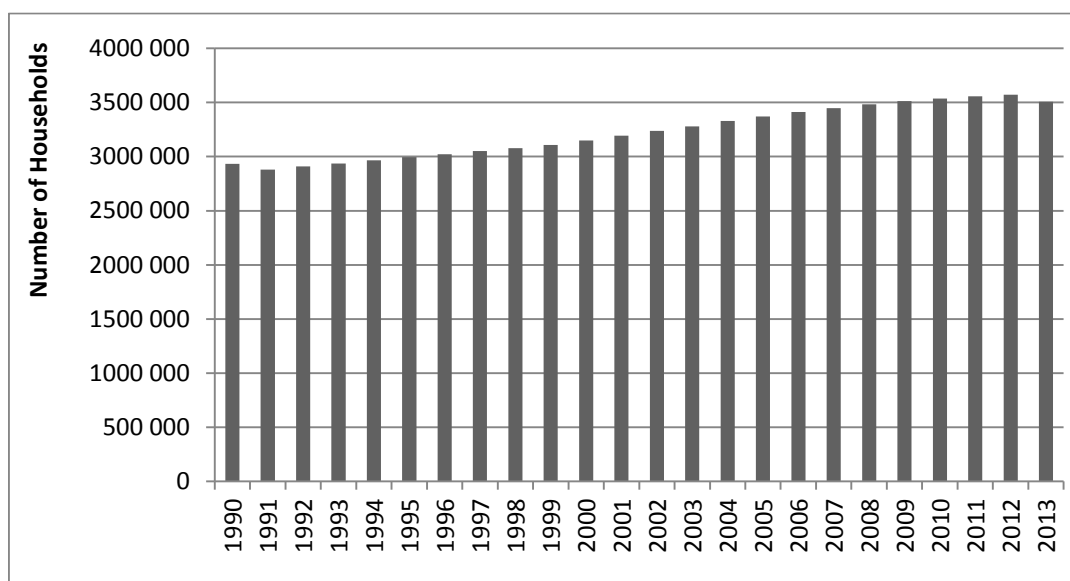


Table 4.81 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000	2013
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>72</sup>. It was assumed an average lifetime of 12 years to combined equipments (fridge+freezer) and 14 years to freezers.

#### 4.8.8.4 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%.

#### 4.8.8.5 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 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 4.82 – 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).

<sup>72</sup> In consequence no emissions of HFC from disposal are estimated for the reported period.

#### 4.8.9 Industrial Refrigeration (CRF 2.F.1.c)

Emissions from Industrial Refrigeration are included in Commercial Refrigeration (CRF 2.F.1.a). These emissions will be relocated to Industrial Refrigeration (CRF 2.F.1.c) in future submissions.

#### 4.8.10 Transport Refrigeration (CRF 2.F.1.d)

##### 4.8.10.1 Methodology

It was used the same methodology as for Commercial Refrigeration (CRF 2.F.1.a).

##### 4.8.10.2 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%.

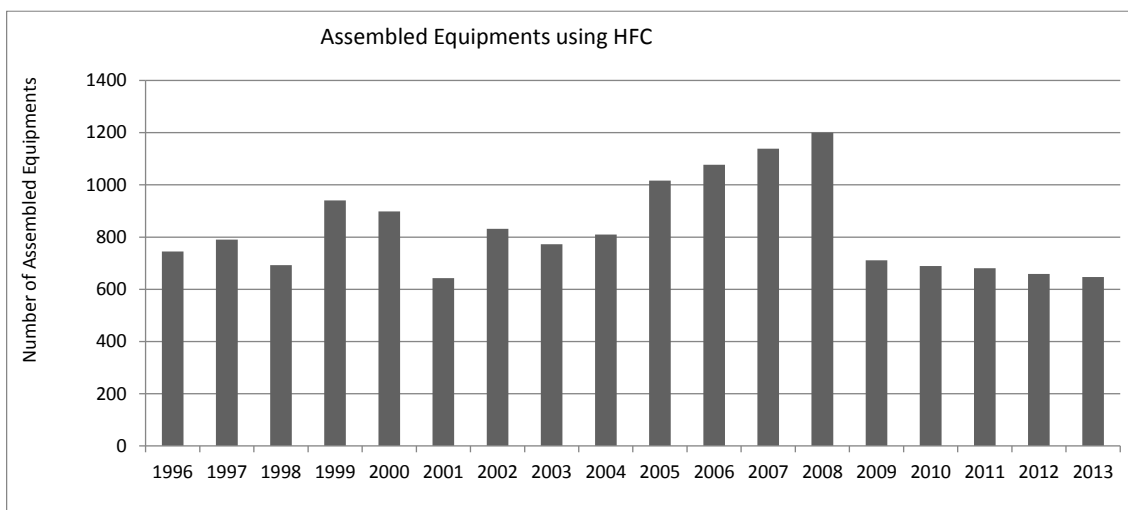
Table 4.83 – Transport Refrigeration emission factors

	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

##### 4.8.10.3 Activity Data

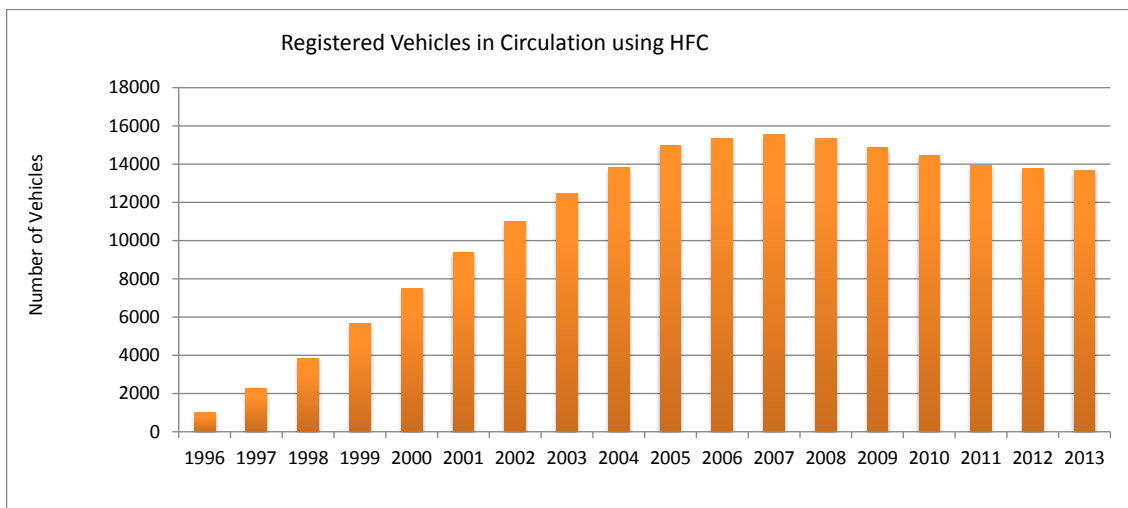
It was assumed that, before 1996, CFC-12 was used instead of HFC as Refrigeration Fluid in Portugal. Data on the number of equipments assembled in Portugal was collected from equipment manufacturers.

Figure 4.31 – 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 4.32 – Number of Registered Vehicles in circulation in Portugal using HFC



#### 4.8.10.4 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%.

#### 4.8.10.5 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 4.84 – 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

#### 4.8.11 Mobile Air Conditioning (CRF 2.F.1.e)

##### 4.8.11.1 Methodology

It was used the same methodology as for Commercial Refrigeration (CRF 2.F.1.a).

##### 4.8.11.2 Emission Factors

Operation emission factors were estimated at an annual rate of 15 percent, corresponding to the average of the updated default range (10-20 percent) in IPCC GPG (table 3.23). Lifetime was set to 12 years, also corresponding to the default value both in IPCC 96 and IPCC GPG.

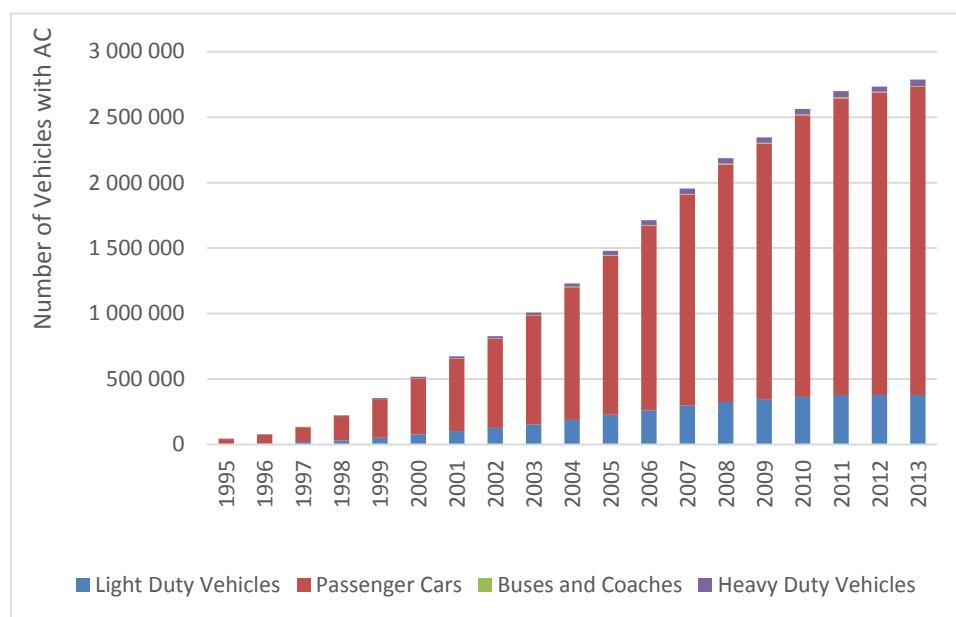
Variable y was set to 40 percent (default value in IPCC GPG). Variable z was set to 70 percent.

##### 4.8.11.3 Activity Data

Estimates for Road Transportation and Railways were made separately.

The number of light vehicles with MAC was estimated from the total number of light vehicles sold each year, using the same information used to establish the time series of car sales and fleet in chapter 1A3, and the percentage of new cars sold with MAC at each year was estimated according to data provided by manufacturers.

Figure 4.33 – Fleet of Vehicles equipped with AC systems



#### 4.8.11.4 Other Relevant Data and Parameters

The amount at initial charge of 0.77 kg/MAC unit for Passenger Cars and Light Duty Vehicles was considered. The initial charge values of 1.2 kg/MAC unit and 7.5 kg/MAC unit were considered for Heavy Duty Vehicles and for Buses and Coaches, respectively (these values were agreed upon with equipment manufacturers).

It was assumed that HFC-134a is the only HFC replacing CFC and HCFC in MAC associated to Road Transportation, which is in accordance with IPCC GPG. In Portugal the use of HFC-134a associated to MAC equipments reports to year 1993.

In MAC equipments associated to Trains and Subway, both HFC-134a and R-407C are used. For trains, the initial charge amount was considered 1.05-1.5 kg/MAC unit and 4-20 kg/MAC unit, on the crew room and on passenger rooms, respectively.

#### 4.8.11.5 Recalculations

The fleet data has been revised and streamlined with the fleet used for transport sector. The percentages of vehicles with mobile air conditioning equipment have been revised.

#### 4.8.11.6 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 4.85 – 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

#### 4.8.12 Domestic Stationary Air conditioning (CRF 2.F.1.f)

##### 4.8.12.1 Methodology

It was used the same methodology as for Commercial Refrigeration (CRF 2.F.1.a).

##### 4.8.12.2 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 4.86 – 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



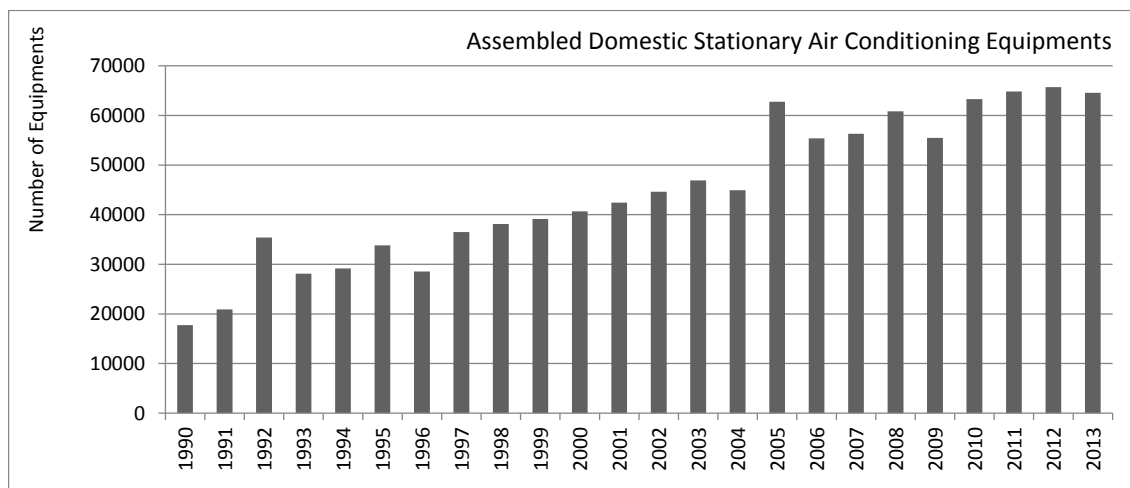
#### 4.8.12.3 Activity Data

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 later 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 90 percent of stocks and assembled air conditioning equipments are domestic equipments.

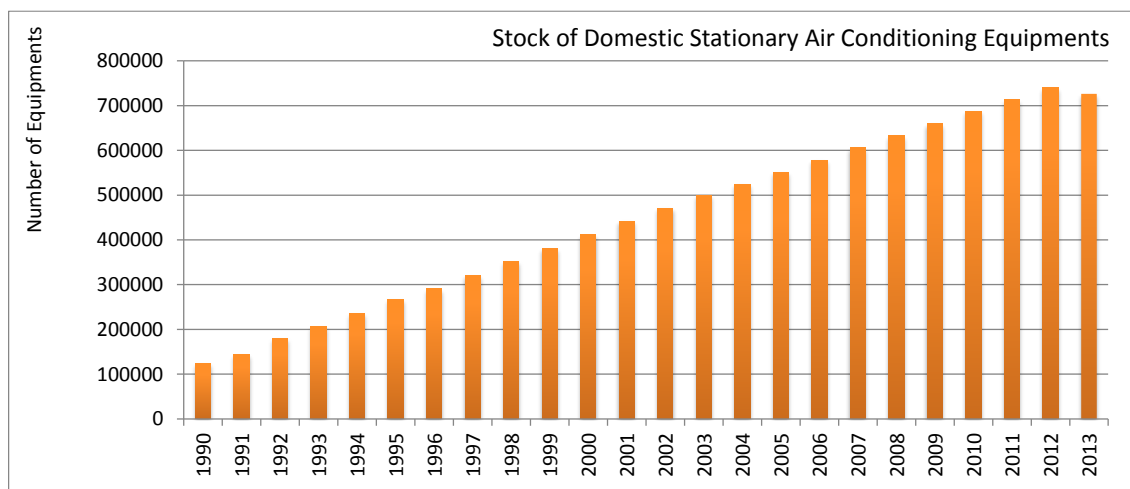
The number of assembled domestic stationary air conditioning equipments was available from unpublished information received from IST-UTL (see next figure) from 1990 onwards.

Figure 4.34 - Number of Domestic Stationary Air Conditioning Equipments assembled in Portugal



Annual stock of domestic stationary air conditioning equipments (see next figure) and yearly disposed units were also available from the same unpublished information received from IST-UTL from 1990 onwards.

Figure 4.35 - Annual Stock of Domestic Stationary Air Conditioning Equipments in Portugal



#### 4.8.12.4 Recalculations

No recalculations were made.

#### 4.8.12.5 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 4.87 – 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

### 4.8.13 Industrial Stationary Air Conditioning (CRF 2.F.1.f)

#### 4.8.13.1 Methodology

It was used the same methodology as for Commercial Refrigeration (CRF 2.F.1.a).

#### 4.8.13.2 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 4.88 – Industrial Stationary Air conditioning emission factors

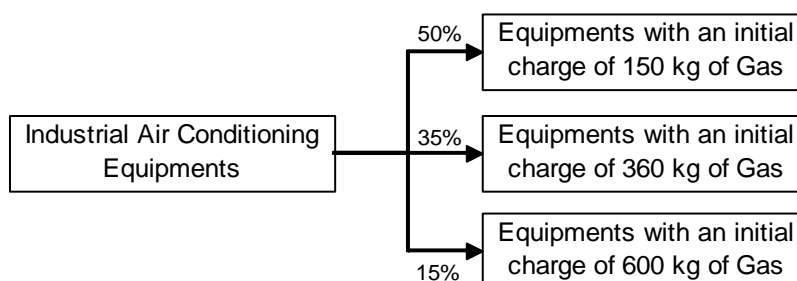
	Unit	Emission Factor
Initial Charge	Kg/equipment	291 <sup>73</sup>
Initial Emission (k)	%	0.6
Lifetime Emission (x)	%	3.0
Fluid remaining in the equipment at the end of lifetime (y)	%	90.0
Fluid recovered from the equipment at the end of lifetime (z)	%	50.0

#### 4.8.13.3 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 later uses different products categories. IAIT survey categories are not detailed enough to differentiate the production of refrigeration components – from which no emissions occur - from their final assembling. The closedown of an important factory in that period further complicates the determination of the time series. This situation is nonetheless irrelevant for the inventory because F-gases emissions in the assembling of AC equipments did not occur in that period.

It was assumed that 10 percent of stocks and assembled air conditioning equipments are included in the industrial category (see figure below).

Figure 4.36 – Subdivision of Industrial Air Conditioning Equipments by type



<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.

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.

Figure 4.37 – Number of Industrial Stationary Air Conditioning Equipments Assembled in Portugal

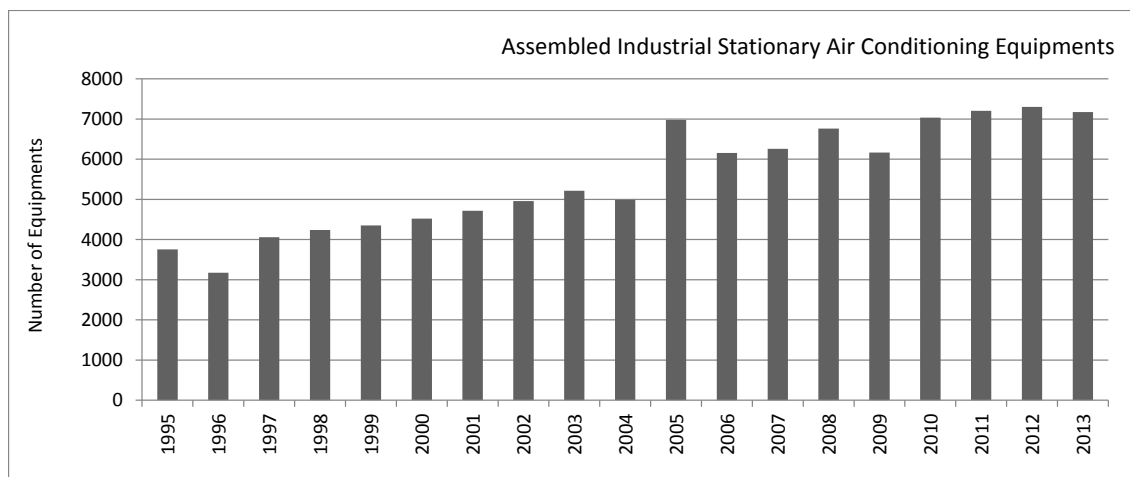
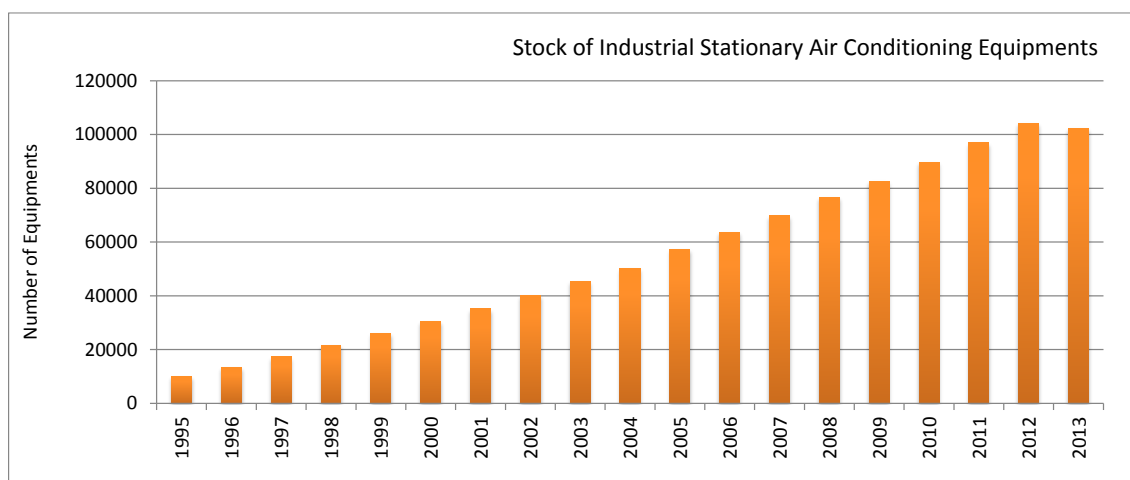


Figure 4.38 – Annual Stock of Industrial Stationary Air Conditioning Equipments in Portugal



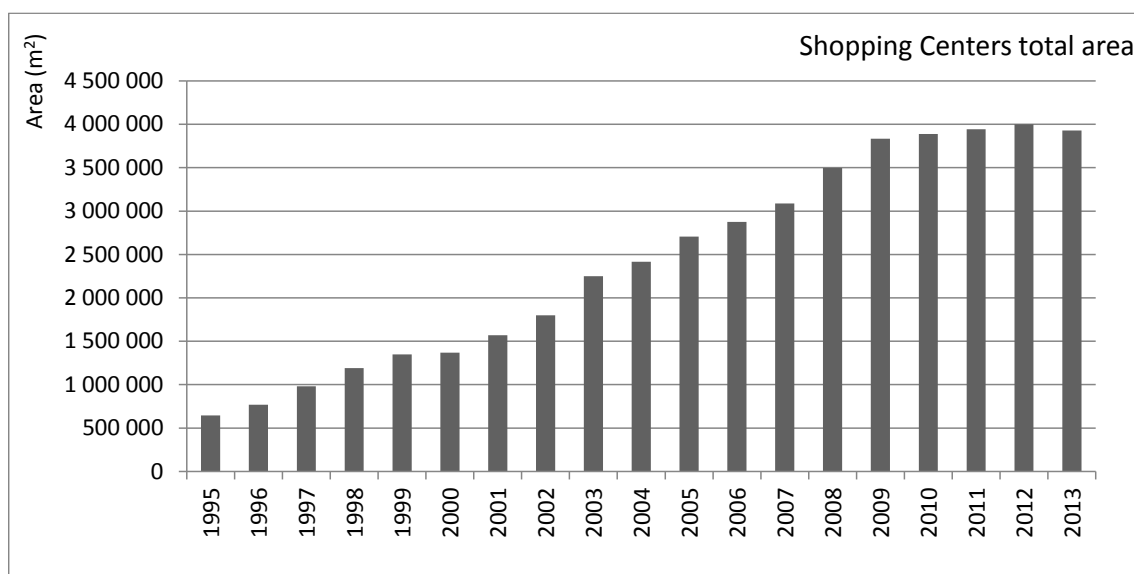
Data on the Temporal Distribution by type of gas was obtained from fluid suppliers.

#### 4.8.13.4 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, and the 2013 value was obtained using gross domestic value trend. The figure below shows shopping centers total area.

Figure 4.39 – 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.

#### 4.8.13.5 Recalculations

No recalculations were made.

#### 4.8.13.6 Uncertainty Assessment

The uncertainty assessment is explained in the chapter describing Domestic Stationary Air Conditioning.

### 4.8.14 Foam Blowing (CRF 2.F.2)

#### 4.8.14.1 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.

#### 4.8.14.2 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.

#### 4.8.14.3 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 4.89 - Emission Factors to estimate F gas emissions from foam losses

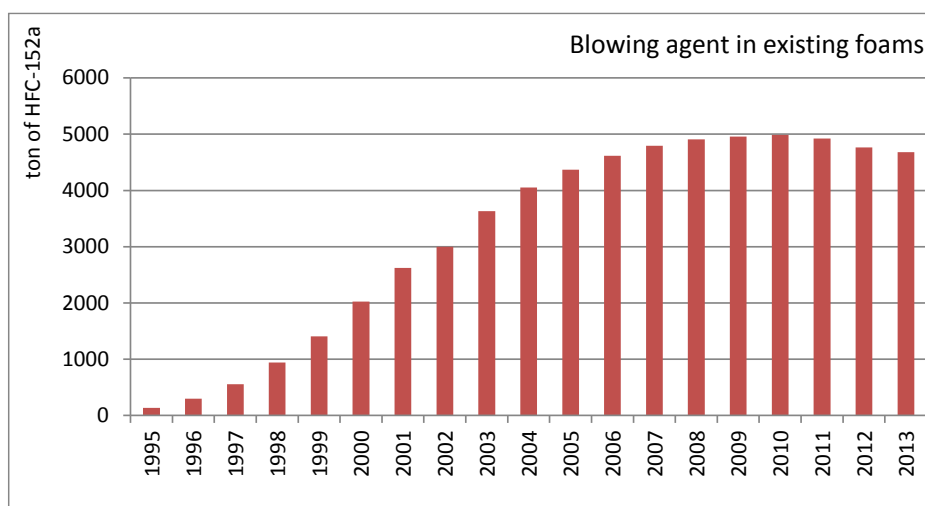
Type of Foam	Emission Factor		EF (% Original Charge)
Open Cell	K	First Year Losses	100
Closed Cell	K	First Year Losses	10
Closed Cell	x	Annual Losses	4.5

#### 4.8.14.4 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 4.40 – Amount of blowing agents used in Existing Foams in Portugal (ton/yr)



<sup>75</sup> Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

#### 4.8.14.5 Uncertainty Assessment

According to recommendations of GPG for country-specific top-down information, the uncertainty in fill gas consumption was maintained at 50 percent, but the establishment of a better foam stock time series allowed the reduction of uncertainty in operation from one order of magnitude to 100 percent.

The uncertainty in emission factors result from the uncertainty in the release rate (emission), the life time, and also gas composition. The values set from the range in GPG (IPCC, 2000) are shown in the next table.

Table 4.90 – 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

#### 4.8.15 Fire Protection (CRF 2.F.3)

##### 4.8.15.1 Overview

The fire protection equipments used in Portugal contain HFC-23 and HFC-227ea.

##### 4.8.15.2 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)

##### 4.8.15.3 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.

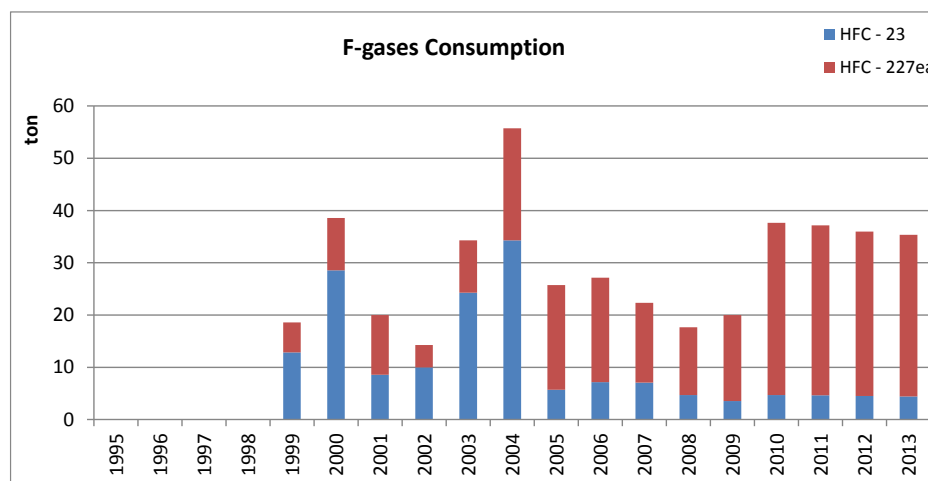
##### 4.8.15.4 Activity Data

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 from 2011 onwards 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 2000-2004 period 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)



#### 4.8.15.5 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.

#### 4.8.15.6 Further Improvements

Activity data will be updated in next submission based on information provided by sellers and responsible enterprises for equipments filling.

### 4.8.16 Aerosols - Metered Dose Inhalers (CRF 2.F.4.a)

#### 4.8.16.1 Overview

Fluorinated gases are used as propellants in pressurized solutions (metered dose inhalers) in the treatment of asthma.

#### 4.8.16.2 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.

$$Emi_{HFCt} = [\sum (Sold\ MDI_{t-1} * K_{t-1}) + \sum (Sold\ MDI_t * K_t)] / 2 * 10^{-6}$$

Where

$Emi_{HFCt}$  - Emission of F-gas in year t

$Sold\ MDI_{t-1}$  - Number of Sold units of each MDI in year t-1

$K_{t-1}$  - Charge of gas of each equipment sold in year t-1

$Sold\ MDI_t$  - Number of Sold units of each MDI in year t

$K_t$  - Charge of gas of each equipment sold in year t

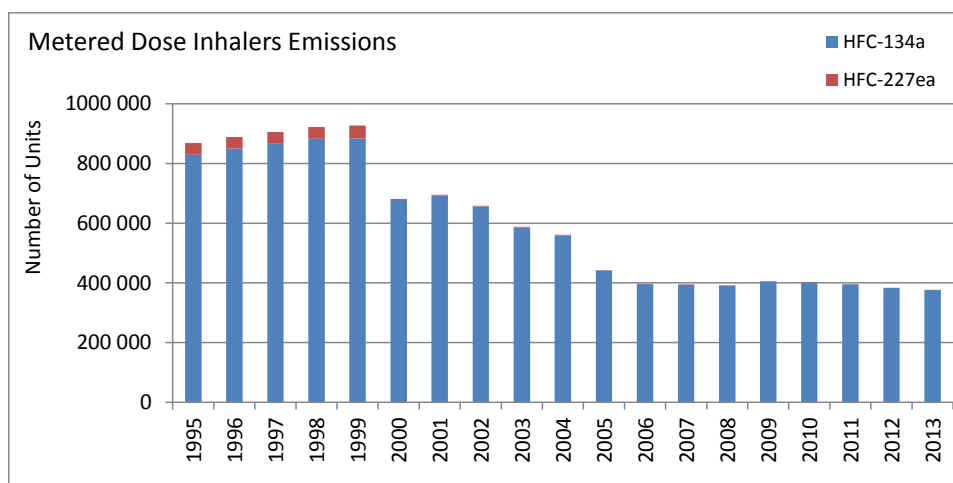
#### 4.8.16.3 Emission Factors

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.

#### 4.8.16.4 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 4.42 – Sold Metered Dose inhalers using F-gases as propellant



#### 4.8.16.5 Further Improvements

More detailed information should be provided by manufacturers in the future, in order to obtain a better characterization of the inhalers market.

#### 4.8.16.6 Uncertainty Analysis

The uncertainty in MDI was assumed as 63 percent, due to yearly changes.

## 4.9 Other Product Manufacture and Use (CRF 2.G)

### 4.9.1 Electrical Equipment Manufacturing (CRF 2.G.1)

#### 4.9.1.1 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.

#### 4.9.1.2 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.

#### 4.9.1.3 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.

#### 4.9.1.4 Activity Data

Activity data on SF<sub>6</sub> consumption in electric equipment manufacturing was obtained from national equipment producers from 1995 onwards, 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.

#### 4.9.1.5 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.

#### 4.9.1.6 Further Improvements

No further improvements are expected.

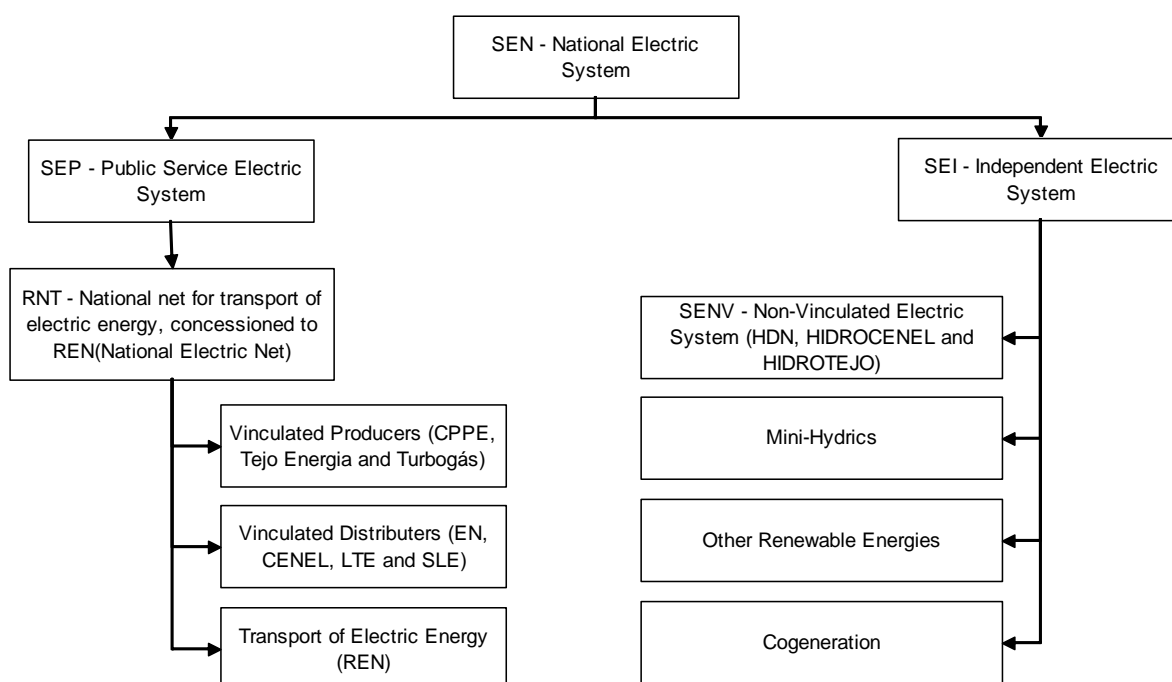
### 4.9.2 Electrical Equipment Use (CRF 2.G.1)

#### 4.9.2.1 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 4.43 - 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 4.44 – Map of National Network of Electric Energy Transport



#### 4.9.2.2 Methodology

There are different estimates methodologies for:

- REN;
- EDP Distribuição, EDP Produção, Tejoenergia and Turbogás;
- Other Companies.

##### 4.9.2.2.1 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:

T<sub>i</sub> and P<sub>i</sub> - Measured Temperature and Pressure at the beginning of reposition of lost SF<sub>6</sub>;

T<sub>f</sub> and P<sub>f</sub> - 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;

Z<sub>i</sub> - Compressibility Factor at Pressure P<sub>i</sub> and Temperature T<sub>i</sub>;

Z<sub>f</sub> - Compressibility Factor at Pressure P<sub>f</sub> and Temperature T<sub>f</sub>;

n<sub>i</sub> - Mole number of SF<sub>6</sub> at pressure P<sub>i</sub> and T<sub>f</sub> before the reposition of gas;

n<sub>f</sub> - Mole number of SF<sub>6</sub> at pressure P<sub>f</sub> and T<sub>f</sub> 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.

#### 4.9.2.2.2 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:

$$Em_{SF_6(t)} = Stock_{SF_6(t)} * (EF/100)$$

where:

$Em_{SF_6(t)}$  - Equipment use emissions, including leakage emissions, servicing and maintenance;

$Stock_{SF_6(t)}$  - total SF<sub>6</sub> gas in existence at year t in all electrical equipments;

EF – Emission Factor, corresponding to the percentage of SF<sub>6</sub> in stock at year t that is emitted to atmosphere.

#### 4.9.2.2.3 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.

#### 4.9.2.3 Emission Factors

There are different emission factors for:

- REN;
- EDP Distribuição;
- EDP Produção;
- Tejoenergia;
- Turbogás;
- Other Companies.

#### 4.9.2.3.1 REN

The database on SF<sub>6</sub> 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.

#### 4.9.2.3.2 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”;

#### 4.9.2.3.3 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.

#### 4.9.2.3.4 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”.

#### 4.9.2.3.5 Other Companies

It is assumed that 50% of the equipments are “Closed Pressure” and 50% are “Sealed Pressure. We use the emission factors proposed on table 8.3 of “2006 IPCC Guidelines for National Greenhouse Gas Inventories” for “Closed Pressure Electrical Equipment” and “Sealed Pressure Equipment”.

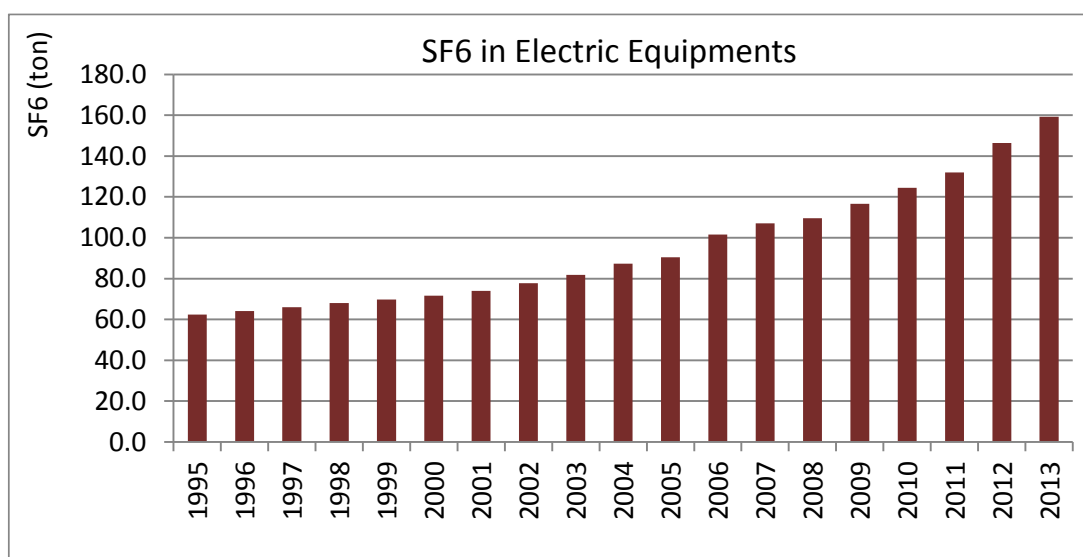
#### 4.9.2.4 Activity Data

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). From 2013 onwards we start using data reported by companies under F-Gas Legislation (<https://formularios.apambiente.pt/GasesF/>).

Table 4.91 – 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 4.45 - Total SF<sub>6</sub> in stock in electric equipments in Portugal



#### **4.9.2.5 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.

#### **4.9.2.6 Recalculations**

The amounts of SF<sub>6</sub> in the equipments have been revised based on data reported by companies under F-Gas Legislation (<https://formularios.apambiente.pt/GasesF/>).

#### **4.9.2.7 Further Improvements**

No further improvements are expected.

### **4.9.3 SF<sub>6</sub> and PFCs from Other Product Use (CRF 2.G.2)**

There are no other product uses of SF<sub>6</sub> and PFCs in Portugal.

### **4.9.4 N<sub>2</sub>O from Product Use – Medical Applications (CRF 2.G.3.a)**

#### **4.9.4.1 Overview**

Evaporative emissions of nitrous oxide (N<sub>2</sub>O) can arise from various types of product use. In general, medical applications (anaesthetic use, analgesic use and veterinary use) and use as a propellant in aerosol products are likely to be larger sources than others.

#### **4.9.4.2 Medical Applications (CRF 2.G.3.a)**

##### **4.9.4.2.1 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.

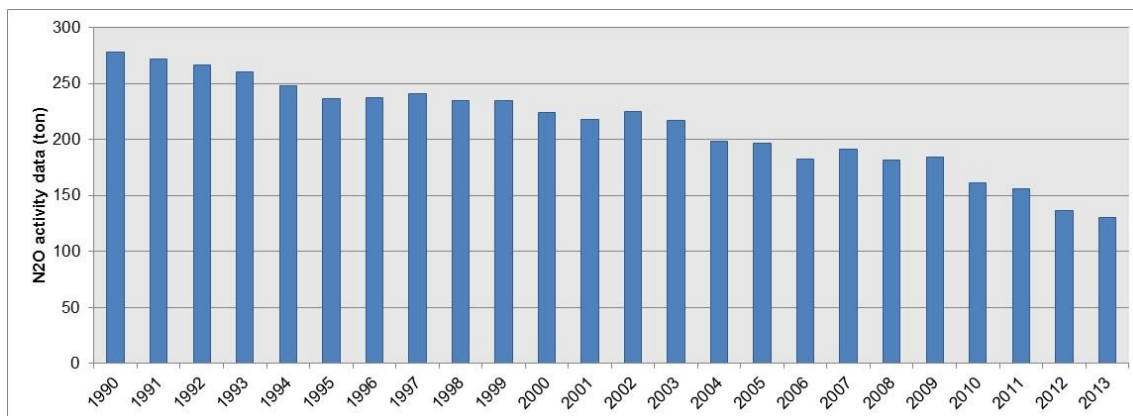
##### **4.9.4.2.2 Emission Factors**

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.

##### **4.9.4.2.3 Activity Data**

Consumption of N<sub>2</sub>O emissions are calculated from data collected from enterprises (1990 to 2013). This set of activity data includes estimatives due to lack of data.

Figure 4.4 – N<sub>2</sub>O activity data (ton)



#### 4.9.4.2.4 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; 2008-2013: 1 per cent.

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

No category-specific QA/QC has been made for this category.

#### 4.9.4.2.6 Recalculations

No recalculations were made for this category.

#### 4.9.4.2.7 Further Improvements

No further improvements are under consideration at this time.

### 4.9.4.3 Other (CRF 2.G.3.b)

#### 4.9.4.3.1 Propellant for pressure and aerosol products

Emissions from this category are not occurring.

## 4.10 Other (2.H)

### 4.10.1 Paper pulp production (CRF 2.H.1)

#### 4.10.1.1 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 ( $\text{Na}_2\text{S}$ ) and sodium hydroxide ( $\text{NaOH}$ ) (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).

#### 4.10.1.2 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:

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

#### 4.10.1.3 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 Calciner and Bleaching;
- Acid sulphide: Digester and Blow Pit.

Table 4.92 – 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

#### 4.10.1.4 Activity Data

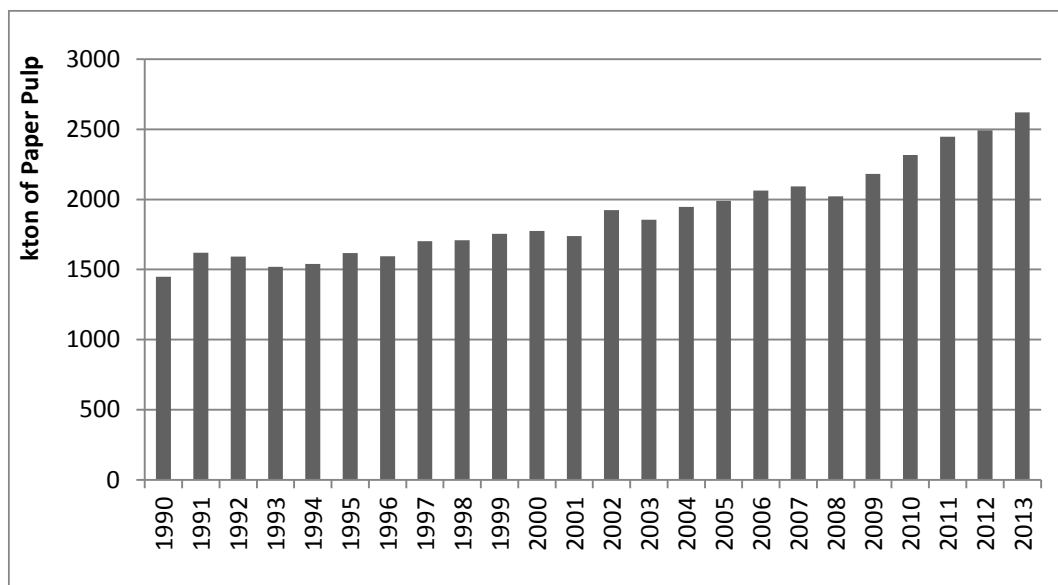
Production of paper pulp expressed in air dried weight during the period 1990-2009 was obtained directly from CELPA (the Portuguese Paper Industry Association). Since 2010, activity data is obtained from EU-ETS. Acid Sulphide production is only a minor component of total production<sup>76</sup> but may not be published individualised due to confidentiality constraints. However,

<sup>76</sup> Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

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 reporting period.

The following figure presents total production of paper pulp.

Figure 4.46 – Total production of paper pulp - Kraft and semi-sulphide



#### 4.10.1.5 Recalculations

No recalculations were made.

### 4.10.2 Food Manufacturing (CRF 2.H.2)

#### 4.10.2.1 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.

#### 4.10.2.2 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

Emission<sub>NM VOC</sub> - annual emission of NMVOC in year y (ton/yr);

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

EF<sub>NM VOC</sub> - emission factor (kg/ ton)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60 percent of carbon:

$$Em_{CO_2} = 44 / 12 * 0.60 * Em_{NM VOC} / 1000$$

where

Em<sub>CO<sub>2</sub></sub> – annual emission of CO<sub>2</sub> in year y (kton/yr);

Emission<sub>NM VOC</sub> - annual emission of NMVOC in year y (ton/yr).

#### 4.10.2.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (2.D.2. Food and Drink).

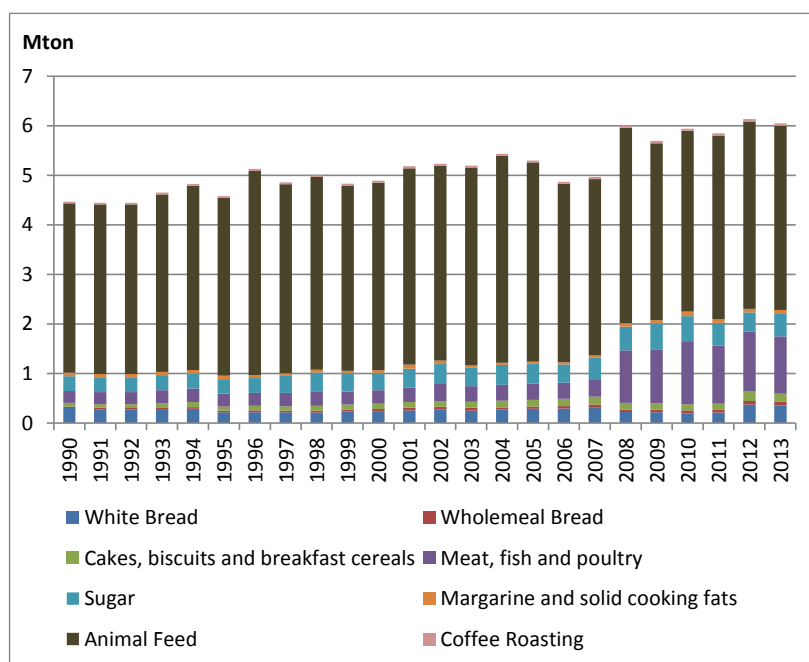
Table 4.93 – Emission Factor for each food product

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

#### 4.10.2.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4.47 – Food manufacturing by food product



#### 4.10.2.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.10.2.6 Further Improvements

No further improvements are planned.

### 4.10.3 Drink Manufacturing (CRF 2.H.2)

#### 4.10.3.1 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.

#### 4.10.3.2 Methodology

We used the same methodology described in Food Manufacturing sector.

#### 4.10.3.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (2.D.2. Food and Drink).

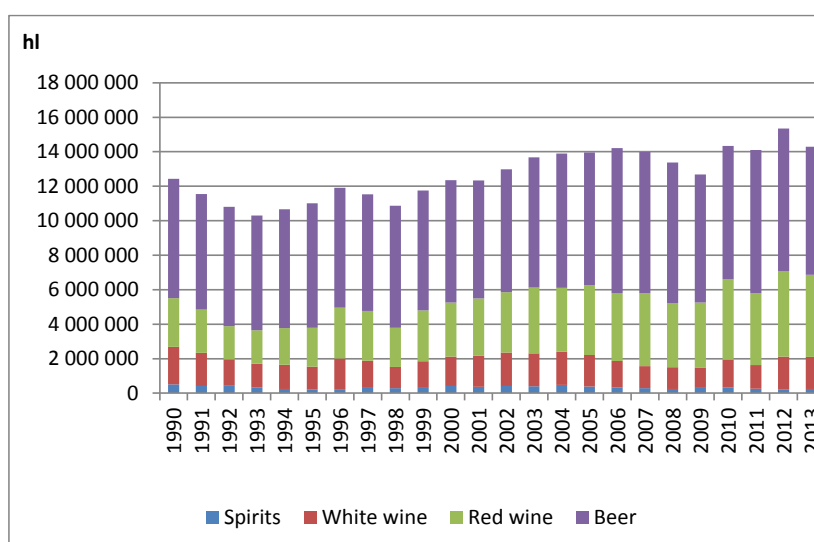
Table 4.94 – Emission Factor for each alcoholic beverage

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

#### 4.10.3.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4.48 – Drink manufacturing by alcoholic beverage



#### 4.10.3.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 4.10.3.6 Further Improvements

No further improvements are planned.



#### **4.10.4 Wood Chipboard Production (CRF 2.H.3.a)**

##### **4.10.4.1 Overview**

Chipboard manufacturing involves solvent emission but it is included in this source sector.

##### **4.10.4.2 Methodology**

We used the same methodology described in Food Manufacturing sector.

##### **4.10.4.3 Emission Factors**

NMVOC emission factor is 0.9 kg/ton, from Corinair90 Default Emission Factor Handbook.

##### **4.10.4.4 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.

##### **4.10.4.5 Recalculations**

No recalculations were made.

##### **4.10.4.6 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.

## 5 AGRICULTURE (CRF 3.)

### 5.1 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 (3.A); CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management (3.B); direct and indirect N<sub>2</sub>O emissions from agriculture soils (3.D); CH<sub>4</sub> from rice cultivation (3.C); CH<sub>4</sub> and N<sub>2</sub>O emissions from field burning of agriculture residues (3.F) and CO<sub>2</sub> from liming and urea application (3.G-H). There are no ecosystems in Portugal that could be considered natural savannahs and no greenhouse gas emissions exist therefore for this sub-category (3.E). GHG emissions from combustion processes in agriculture are discussed in sector Energy: Other sectors (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 12.47 per cent in 1990 to 10.92 per cent in 2013.

Total GHG emissions from agriculture sector decreased by 5.80 per cent from 1990 to 2013: 7.57 Mt of CO<sub>2</sub>eq in 1990 and 7.13 Mt CO<sub>2</sub>eq in 2013 (Table 5.1). Most significant reduction occurred with nitrous oxide emissions, minus 8.12 per cent, while methane emissions reduced minus 4.96 per cent.

Table 5.1 – Total Greenhouse Gas Emissions from Agriculture MtCO<sub>2</sub>eq

Gas/Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>CH<sub>4</sub></b>	<b>4.93</b>	<b>5.19</b>	<b>5.34</b>	<b>5.06</b>	<b>4.82</b>	<b>4.76</b>	<b>4.74</b>	<b>4.68</b>
Enteric Fermentation	3.34	3.61	3.82	3.71	3.48	3.42	3.40	3.34
Manure Management	1.41	1.45	1.37	1.17	1.17	1.17	1.17	1.17
Rice Cultivation	0.13	0.10	0.12	0.15	0.14	0.15	0.15	0.14
Field Burning of Agricultural Residues	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
<b>N<sub>2</sub>O</b>	<b>2.61</b>	<b>2.52</b>	<b>2.76</b>	<b>2.25</b>	<b>2.21</b>	<b>2.21</b>	<b>2.29</b>	<b>2.40</b>
Manure Management	0.25	0.24	0.26	0.22	0.21	0.21	0.21	0.21
Agricultural Soils Management	2.34	2.26	2.49	2.01	1.98	1.98	2.07	2.17
Field Burning of Agricultural Residues	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
<b>CO<sub>2</sub></b>	<b>0.03</b>	<b>0.02</b>	<b>0.05</b>	<b>0.03</b>	<b>0.03</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>
Liming and Urea application	0.03	0.02	0.05	0.03	0.03	0.05	0.05	0.05
<b>Total</b>	<b>7.57</b>	<b>7.73</b>	<b>8.14</b>	<b>7.44</b>	<b>7.06</b>	<b>7.02</b>	<b>7.08</b>	<b>7.13</b>

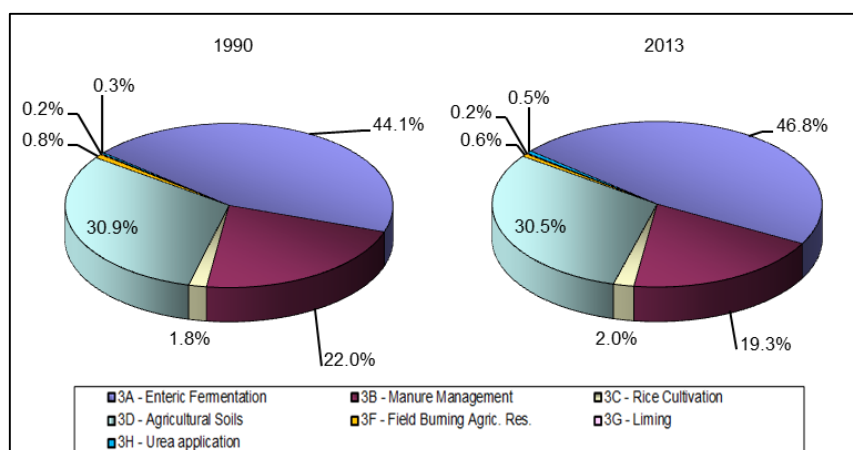
Note: Emissions values are presented in CO<sub>2</sub> equivalent mass units using IPCC AR4 GWP values (CH<sub>4</sub>-25;N<sub>2</sub>O- 298)

In 2013, the contribution of each GHG emissions in the total emissions from agriculture, expressed in CO<sub>2</sub>eq is: CH<sub>4</sub> emissions 65.7 per cent (65.1 in 1990); N<sub>2</sub>O emissions 33.6 per cent (34.5 in 1990) and CO<sub>2</sub> emissions 0.7 per cent (0.4 in 1990).

The majority of emissions from agriculture in 1990 and 2013 are the result of three main 3 sub-sources (figure below): Enteric Fermentation, Agriculture Soils and Manure Management (hierarchically listed in order of the most prevalent). Rice cultivation, Field burning and Liming

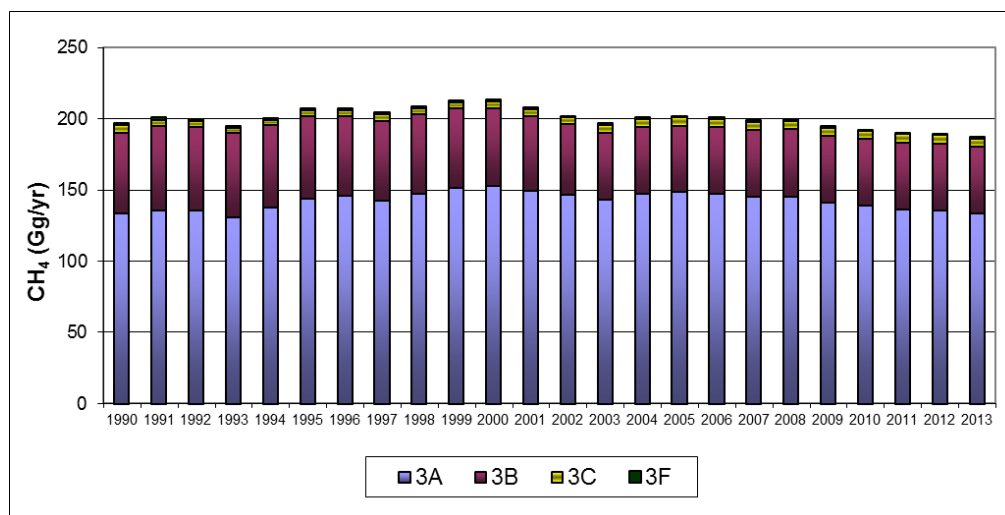
and Urea application are minor sub-sources representing all together no more than 3.5 per cent of the total emissions from agriculture.

Figure 5.1 - Importance of agriculture sub-sectors GHG emissions in 1990 and 2013



Annual emissions of CH<sub>4</sub> from agriculture have decreased (4.96 percent) from 1990 to 2013 (Figure 5.2). The Enteric Fermentation was responsible, in 2013, for 71.3 per cent of the sectorial methane emissions and Manure Management accounted for 25.0 per cent of the sectorial emissions in the same year. The remaining 3.7 per cent of emissions resulted mainly from Rice Cultivation, with only a very small contribution from Field Burning of Residues, 0.6 per cent, of total CH<sub>4</sub> emissions in the same year.

Figure 5.2 - Methane emissions from agriculture – trend by source

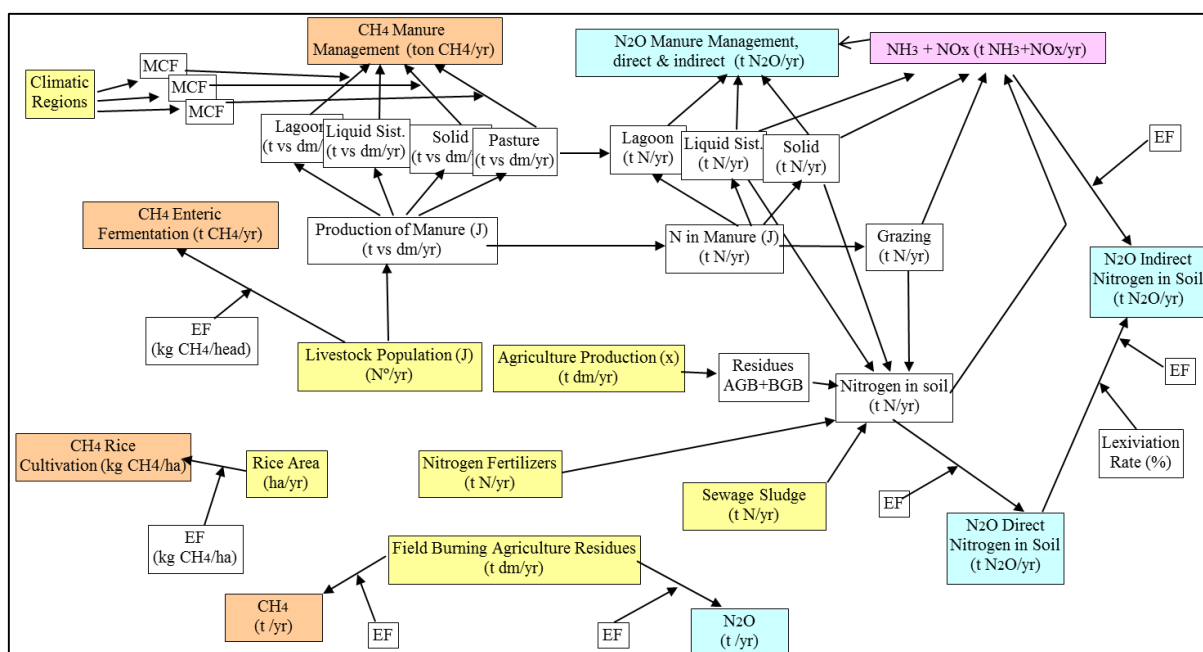


Following the same trend, N<sub>2</sub>O emissions have decreased by 8.12 per cent from 1990 to 2013 (Figure 5.3). The great majority of emissions in 2013 were associated with direct and indirect emissions from Agricultural Soils (90.7 percent), Manure Management is responsible for 8.6 per cent of emissions, while the small remaining fraction results from Field Burning of agricultural residues (0.7 per cent).

Bar chart showing annual  $N_2O$  emissions (Gg/yr) from 1990 to 2012. The y-axis ranges from 0 to 10 Gg/yr. The x-axis lists years from 1990 to 2012. The legend indicates three categories: 3B (dark purple), 3D (light blue), and 3F (dark green). Emissions are generally high, peaking around 9.2 Gg/yr in 2000, and show a slight downward trend after 2002.

Year	3B (Gg/yr)	3D (Gg/yr)	3F (Gg/yr)
1990	0.8	8.0	0.1
1991	0.8	8.0	0.1
1992	0.8	7.8	0.1
1993	0.8	7.8	0.1
1994	0.8	7.8	0.1
1995	0.8	7.6	0.1
1996	0.8	8.2	0.1
1997	0.8	8.2	0.1
1998	0.8	8.0	0.1
1999	0.8	8.0	0.1
2000	0.8	9.2	0.1
2001	0.8	8.2	0.1
2002	0.8	8.2	0.1
2003	0.8	7.0	0.1
2004	0.8	7.2	0.1
2005	0.8	6.8	0.1
2006	0.8	6.5	0.1
2007	0.8	7.0	0.1
2008	0.8	6.8	0.1
2009	0.8	6.5	0.1
2010	0.8	6.5	0.1
2011	0.8	6.5	0.1
2012	0.8	6.8	0.1

Figure 5.4 - Overview of Methodology



MAOTE

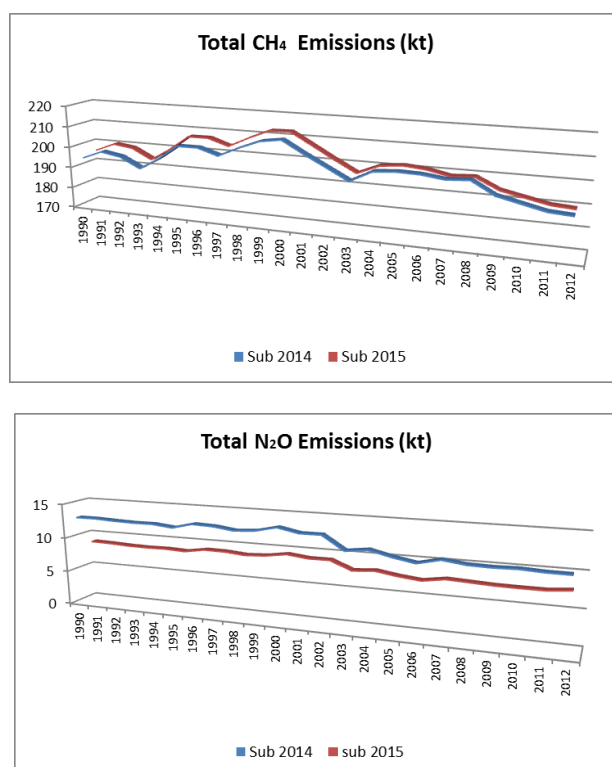
## 5.2 Recalculations

The major changes between submissions result from the implementation of the IPCC 2006 Guidelines and the application of the methodologies, parameters and emission factors defined therein for each source category.

Any other causes for recalculation, e.g. update of activity data, will be highlighted in chapter description of each emission source categories.

In general, the changes introduced led to differences between last year submission and this year submission that are presented in the figures below for the total methane emissions and for the total nitrous oxide emissions from agriculture sector. Considering the impact in the time series (1990-2012) the CH<sub>4</sub> emissions had an average increase of 1.00 per cent and N<sub>2</sub>O emissions had an average decrease of 31.34 per cent.

Figure 5.5 - Differences between submission 2014 and submission 2015 for CH<sub>4</sub> and N<sub>2</sub>O emissions from agriculture sector



## 5.3 CH<sub>4</sub> Emissions from Enteric Fermentation (CRF 3.A)

### 5.3.1 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, poultry 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.

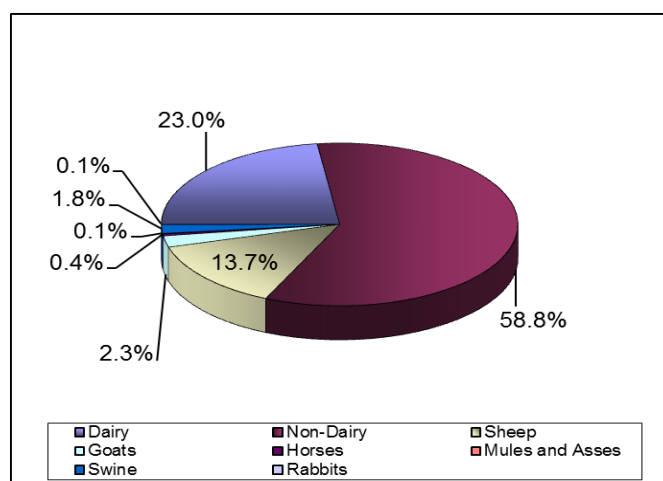
In Table below are present the estimates of CH<sub>4</sub> emission from enteric fermentation.

Table 5.2 – CH<sub>4</sub> emissions from enteric fermentation (kt)

Livestock type	1990	1995	2000	2005	2010	2011	2012	2013
Dairy cattle	38.19	37.34	39.95	35.57	32.71	31.77	31.56	30.68
Non- dairy cattle	55.20	63.24	68.93	77.70	77.13	78.05	78.24	78.52
Sheep	29.50	33.53	34.80	27.98	22.78	20.57	19.66	18.23
Swine	3.09	3.07	2.79	2.32	2.31	2.31	2.32	2.34
Goats	5.83	5.03	4.37	3.49	3.21	3.14	3.28	3.02
Horses	0.59	0.86	1.05	0.93	0.68	0.60	0.54	0.48
Mules and asses	1.18	1.03	0.69	0.40	0.22	0.20	0.18	0.15
Rabbits	0.13	0.11	0.09	0.08	0.07	0.07	0.07	0.07
<b>Total</b>	<b>133.71</b>	<b>144.21</b>	<b>152.67</b>	<b>148.48</b>	<b>139.12</b>	<b>136.71</b>	<b>135.84</b>	<b>133.50</b>

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 5.6. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents, according to different years, 23.0 per cent to 28.6 percent of total CH<sub>4</sub> emissions from Enteric Fermentation, while non-dairy cattle represents about 41.3 to 58.8 percent of total CH<sub>4</sub> from enteric fermentation. Together, in 2013, cattle were responsible for about 81.8 percent of total CH<sub>4</sub> emissions from enteric fermentation.

Figure 5.6 - Relative Importance of emissions of CH<sub>4</sub> from Enteric Fermentation per each animal species in 2013



Sheep is also an important source of methane, for which emissions have oscillated between 13.7 and 24.1 per cent of total CH<sub>4</sub> from Enteric Fermentation. Emissions from goats were 2.3 to 4.4 percent of total enteric fermentation and swine represented 1.6 to 2.4 percent of emissions. Total emissions of methane for all other species varied between 0.5 and 1.5 percent, for the same period and have less importance.

### 5.3.2 Methodology

Emissions were estimated for each animal type<sup>77</sup> by multiplication of the number of animals by the respective emission factor, in accordance to equation 10.19 of the IPCC 2006.

$$Em_{CH_4}(y) = \sum_t [EF_{(i,y)} * N_{(i,y)}]$$

where, for each specie:

$Em_{CH_4}$  - 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 - number of animals of type i in year y, head.

### 5.3.3 Emission Factors

Emission factors may be seen in Table 5.3, where is presented the range of values according to time variation, which will be further discussed ahead. There are no emissions factors in IPCC 2006 for broilers, laying hens, turkeys, ducks, geese, guinea fowl and other poultry, thus the emissions from these livestock categories 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 2006 (table 10.10) 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>77</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 5.3 - Emission Factors for Enteric Fermentation (kg CH<sub>4</sub>/head/year), time-series range

Animal type	sub-class	EF (kg CH <sub>4</sub> /hd/yr)	
Dairy-Cattle	Dairy Cows	93.5-131.1	T2
non-dairy cattle	Beef calves (<1 yr)	19.9-22.7	T2
	Calves, Males for Replacements (<1 yr)	43.3-49.5	T2
	Calves, Females for Replacements (<1 yr)	37.0-42.2	T2
	Males 1-2 yrs	61.7-70.4	T2
	Beef Females 1-2 yrs	42.1-48.1	T2
	Females for Replacemet 1-2 yrs	52.3-59.7	T2
	Steers (>2 yrs)	83.1-94.8	T2
	Heifers for Beef (>2 yrs)	56.0-64.0	T2
	Heifers for Replacements (>2 yrs)	56.0-64.0	T2
	non-dairy cows	84.2-96.1	T2
Swine	Piglets (<20 kg)	0.3	T2
	Fattening Pigs (20-50 kg)	1.1	T2
	Fattening Pigs (50-80 kg)	1.6	T2
	Fattening Pigs (80-110 kg)	2.0	T2
	Fattening Pigs (> 110 kg)	2.1	T2
	Boars (>50 kg)	1.6	T2
	Sows, pregnant	1.6	T2
	Sows, non-pregnant	3.3	T2
Sheep	Ewes	8.5-10.4	T2
	Other: rams and young males	11.1-13.7	T2
	Lambs	2.9-3.5	T2
Goats	Does	7.5-8.7	T2
	Other: bucks and young males	5.1-5.9	T2
	kids	2.9-3.4	T2
Equides	Horses	18.0	T1
	Asses, Mules and hynies	10.0	T1
Other	Rabbits	3.6	T2

#### 5.3.3.1 Determination of tier 2 emission factors

For the most significant animal types, a tier 2 analysis was implemented to establish the respective emission factors for the enteric fermentation.

According to the IPCC 2006, at Tier 2 level, the emission factors for enteric fermentation are developed following the equation 10.21, described below:

$$EF_{CH_4} = \{[GE * (Y_m/100) * 365 \text{ days}] / 55.65\}$$

where:

EF<sub>CH<sub>4</sub></sub> - emission factor, kg CH<sub>4</sub>/hd/yr

GE - gross energy intake, MJ/hd/day



$Y_m$  - methane conversion factor. Percent of gross energy in feed that is converted to methane.

The factor 55.65 (MJ/kg CH<sub>4</sub>) is the energy content of methane.

#### 5.3.3.1.1 Dairy Cattle

For dairy cattle and to the Gross Energy (GE) estimation, two country regions were considered separate, 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>78</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 (kg/hd/d) was estimated dividing the annual production over the number of cows in production<sup>79</sup> and 365 days. Therefore, lactating and non – lactating periods are included in the estimation of the CH<sub>4</sub> 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>80</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 from available data (1999-2013) of National Animal Registration (SNIRA)<sup>81</sup>. For the period 1990 – 1998 data were completed through a linear regression developed by the Statistics Unit (DSE) of GPP (MAM).

Table 5.4 presents the time series (1990 - 2013) for the relevant country<sup>82</sup> specific parameters used to estimated CH<sub>4</sub> dairy cow emissions from enteric fermentation.

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<sup>78</sup> Dra Olga Moreira e Eng<sup>a</sup> Teresa Dentinho - Unit of Animal Production and Health

<sup>79</sup> The same time series used in the inventory but not averaged over 3 years.

<sup>80</sup> Dr Vicente de Almeida - Animal Genetic Resources Department ; Dr José Neves – Unit of Animal Identification, Registration and Movement

<sup>81</sup> Provided by Funding Institute for Agriculture and Fisheries (IFAP),

<sup>82</sup> Weighted average

Table 5.4 – Time series of country parameters to estimate Methane Emission Factor from enteric fermentation - 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	21.32	73.36
1991	600	12.16	3.96	75.08	22.25	73.33
1992	600	12.09	3.95	74.88	21.26	73.35
1993	600	11.26	3.94	74.84	21.50	73.35
1994	600	11.84	3.93	74.81	21.90	73.35
1995	600	12.48	3.92	74.8	22.14	73.34
1996	600	13.00	3.91	74.78	22.61	73.33
1997	600	13.19	3.9	74.86	23.61	73.32
1998	600	13.63	3.88	74.98	25.27	73.29
1999	600	15.67	3.87	75.22	28.01	73.23
2000	600	17.16	3.86	75.16	28.22	73.19
2001	600	17.81	3.83	75.31	30.42	73.14
2002	600	19.27	3.83	76.93	32.29	73.09
2003	600	18.54	3.79	75.24	32.45	73.05
2004	600	18.56	3.84	75.02	32.49	73.03
2005	600	19.82	3.83	74.94	33.97	73.01
2006	600	20.10	3.79	75.34	34.80	72.99
2007	600	20.03	3.84	74.48	35.10	72.96
2008	600	20.92	3.83	74.09	34.98	72.95
2009	600	21.44	3.78	73.96	36.72	72.93
2010	600	21.61	3.78	74.16	37.61	72.91
2011	600	21.72	3.76	75.65	37.64	72.88
2012	600	22.40	3.77	76.54	38.95	72.86
2013	600	21.92	3.75	75.36	38.67	72.85

The improvement in breeding conditions and of the technological development of dairy farms led to a general increase in milk yield in the overall period. Annual variations show sometimes decreases that are related to unfavourable climacteric conditions such as droughts, as can be seen in the temporary decreases in 1993, 2003 and 2004, and recovery periods thereafter.

Table 5.5 shows the time series for the different Net Energies required for maintenance, animal activity, lactation, pregnancy, growth and work ( $NE_m$ ,  $NE_a$ ,  $NE_l$ ,  $NE_p$ ,  $NE_g$ ,  $NE_{work}$ ), the results for Gross Energy (Mj/d) and the estimated CH<sub>4</sub> Emission Factor (kg CH<sub>4</sub>/hd/yr) from dairy cows enteric fermentation, which were calculated based on the equations described in IPCC 2006<sup>83</sup> (Net energies equations 10.3, 10.4, 10.8, 10.13, 10.6, 10.11; Gross energy equation 10.16 which includes equation 10.14 for REM fraction calculation).

A constant methane conversion factor of 6.5% of gross energy intake was applied.

<sup>83</sup> Volume 4, Chapter 10

**Table 5.5 - 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	37.440	0.00	3.520	0.54	227.17	96.85
1991	46.80	1.77	0.00	37.220	0.00	3.520	0.54	226.75	96.71
1992	46.80	1.69	0.00	36.900	0.00	3.510	0.54	225.89	96.27
1993	46.80	1.71	0.00	34.330	0.00	3.510	0.54	219.43	93.53
1994	46.80	1.74	0.00	36.030	0.00	3.510	0.54	223.74	95.43
1995	46.80	1.76	0.00	37.940	0.00	3.500	0.54	228.67	97.52
1996	46.80	1.80	0.00	39.490	0.00	3.500	0.54	232.72	99.25
1997	46.80	1.88	0.00	39.970	0.00	3.500	0.54	234.17	99.92
1998	46.80	2.01	0.00	41.230	0.00	3.510	0.54	237.81	101.52
1999	46.80	2.23	0.00	47.350	0.00	3.520	0.54	254.32	108.50
2000	46.80	2.25	0.00	51.770	0.00	3.520	0.54	265.49	113.35
2001	46.80	2.42	0.00	53.560	0.00	3.530	0.54	270.83	115.57
2002	46.80	2.57	0.00	58.050	0.00	3.600	0.54	283.29	120.73
2003	46.80	2.58	0.00	55.580	0.00	3.520	0.54	277.36	118.01
2004	46.80	2.58	0.00	55.920	0.00	3.510	0.54	278.03	118.37
2005	46.80	2.70	0.00	59.610	0.00	3.510	0.54	288.06	122.54
2006	46.80	2.77	0.00	60.090	0.00	3.530	0.54	288.98	123.23
2007	46.80	2.79	0.00	60.330	0.00	3.490	0.54	289.61	123.48
2008	46.80	2.78	0.00	62.900	0.00	3.470	0.54	295.54	126.24
2009	46.80	2.92	0.00	64.080	0.00	3.460	0.54	299.83	127.78
2010	46.80	2.99	0.00	64.500	0.00	3.470	0.54	300.87	128.39
2011	46.80	2.99	0.00	64.650	0.00	3.540	0.54	302.13	128.67
2012	46.80	3.10	0.00	66.650	0.00	3.580	0.54	307.61	131.14
2013	46.80	3.08	0.00	65.200	0.00	3.530	0.53	300.42	129.33

(1) Assumed no gain weight as definition of dairy cows category are mature cows.

Country EF estimation are close to the default IPCC 2006 emission factor (table 10.11) for similar milk productions and parameters (table 10.A.1). For the year 2013 the estimated EF is 129.33 (kg CH<sub>4</sub> / hd / yr) for an average milk production of 8 000 (kg CH<sub>4</sub> / yr) and the default value for a milk production of 8 400 (kg CH<sub>4</sub> / yr) is 128 (kg CH<sub>4</sub> / hd / yr).

#### 5.3.3.1.2 Non-dairy Cattle

The Ministry of Agriculture (MAM/<sup>84</sup>) compiled in 1998, information from the seventeen breeders associations existing in Portugal, this database comprehending the number of registered producers, number of animals, the main productive function (milk, meat), weaning age, the age at slaughtering, 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 subcategory, determined from the available statistical information:

<sup>84</sup> Directorate for Veterinary, presently Directorate for Food and Veterinary.

Table 5.6.- Livestock population by age – Non dairy cattle.

<1 yr	Beef Calfs
	Calfs, Males for Replacements
	Calfs, Females for Replacements
1-2 yr	Males
	Beef Females
	Females for Replacement
>2 yr	Steers
	Heifers for Beef
	Heifers for Replacements
	Non-dairy cows

Feed intake estimates for each cattle subcategory was determined using the energy model of the IPCC 2006<sup>85</sup>. First, Net Energies required for maintenance, animal activity, lactation, pregnancy, growth and work ( $NE_m$ ,  $NE_a$ ,  $NE_l$ ,  $NE_p$ ,  $NE_g$ ,  $NE_{work}$ ) were calculated using equations 10.3, 10.4, 10.8, 10.13, 10.6 and 10.11.

The ratios of the net energy available for maintenance and for growth in a diet to digestible energy consumed, REM and REG, were calculated using equations 10.14 and 10.15 (IPCC 2006<sup>85</sup>).

Finally Gross Energy Intake (GE), expressed in energy, was calculated using equation 10.16 (IPCC 2006)<sup>85</sup>.

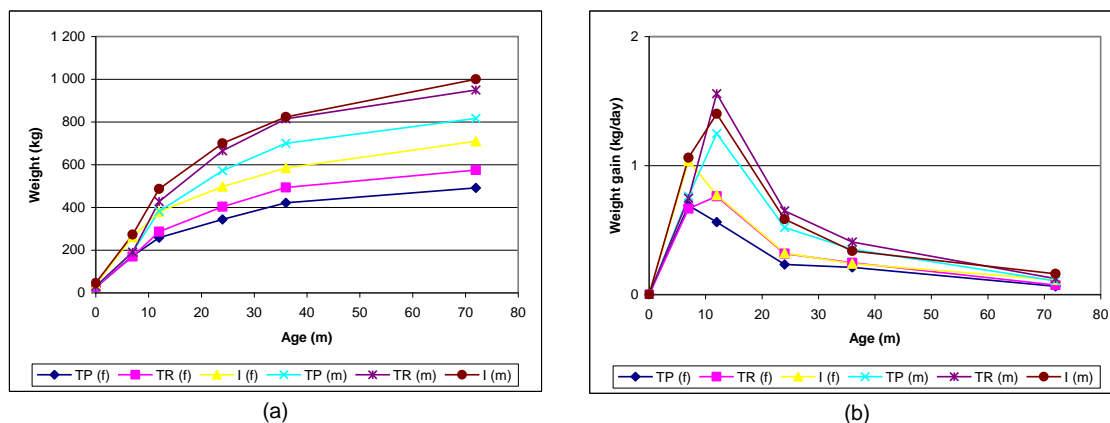
For each cattle breed the values chosen for parameters, such as weight, weight gain and feeding situation, were established from the available information. Three different cattle types were considered: (1) Imported breeds; (2) Traditional breeds on pasture; (3) Traditional breeds on range<sup>86</sup>. 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>85</sup> Volume 4, Chapter 10

<sup>86</sup> Imported breeds are Charolês; Limousine; Simmental Fleckvieh and Salers. Breeds in traditional pasture are: Arouquesa, Barrosã, Marinhosa, Maronesa, Minhota/ Galega, Cachena, Ramo Grande and Mirandesa. Traditional range breeds are: Alentejana, Garvonesa, Brava, Mertolenga and Preta.

Figure 5.7 – 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. The average values of the parameters and the average values of the values calculated are presented in Table 5.7 though Table 5.10.

Table 5.7 – Parameters used in determination of Net Energy for non-dairy cattle. Weighted averages of individual breed.

sub-class	W (kg)	WG (kg/ d)	Cfi	NEm (Mj/ d)	Ca <sup>i</sup>	NEa (Mj/ d)	Cg	NEg (Mj/ d)	Work (h/d)	NEw (kg/d)
Beef calves (<1 yr)	212	0.948	0.322	17.807	0.177	2.809	0.9	8.580	--	--
Calfs, Males Rep. (<1 yr)	230	1.139	0.322	18.997	0.177	3.165	1.0	8.913	--	--
Calfs, Fem. Rep. (<1 yr)	182	0.757	0.322	15.920	0.177	2.552	0.8	7.867	--	--
Males 1-2 yrs	543	0.589	0.322	36.199	0.177	6.273	1.0	8.228	--	--
Beef Fem. 1-2 yrs	366	0.295	0.322	26.862	0.177	4.441	0.8	4.711	--	--
Females for R. 1-2 yrs	366	0.295	0.322	26.862	0.177	4.441	0.8	4.711	--	--
Steers (>2 yrs)	789	0.249	0.322	47.889	0.177	8.404	1.2	3.697	0.04	0.178
Heifers for Beef (>2 yrs)	462	0.160	0.322	32.053	0.177	5.383	0.8	2.871	--	--
Heifers for Rep. (>2 yrs)	462	0.160	0.322	32.053	0.177	5.383	0.8	2.871	--	--
Non-dairy cows <sup>ii</sup>	599	0.000	0.344	41.592	0.177	6.939	0.8	0.000	--	--

i) Weighted average for different feeding situations: Stall, Pasture and Grazing large areas.

ii) Cfi value – weighted average of lactating and non - lactating cows

Table 5.8 – Parameters used in determination of Net Energy for non-dairy cattle (specific parameters for mother cows)

Parameter	Value
Percent Pregnant	0.670
Milking Period (days /yr)	188
Milk Yield during milking period (kg /d) <sup>i</sup>	8.000
F (Fat content of Milk) (%)	4.000
NE <sub>i</sub> (MJ/ day)	12.615
C <sub>pregnancy</sub>	0.100
NE <sub>p</sub> (MJ /d)	2.787

i) Value considered for non-dairy cows sub class. Milk yield for all other sub classes considered 0 kg/ d.

Table 5.9 – Parameters used in determination of Net Energy for non-dairy cattle (weighted averages of Mature Weight, MW).

MW	kg
Male	930
Female	600

Table 5.10 – Non dairy cattle estimated Gross Energy (GE) and CH<sub>4</sub> Emission Factor (EF) from enteric fermentation. Weighted averages from individual breeds.

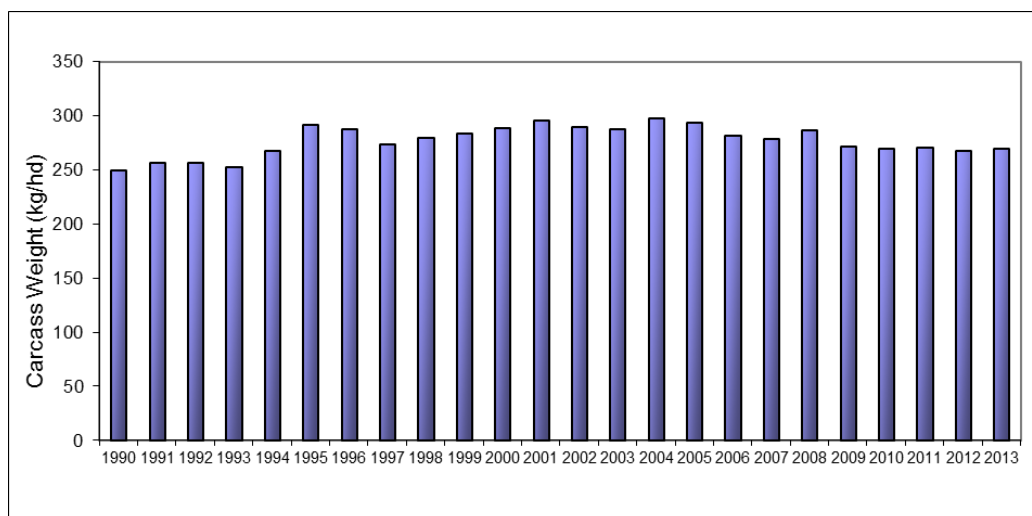
sub-class	Σ NE (MJ/d)	REM (ratio)	REG (ratio)	DE (%)	GE (MJ/d)	Ym (%)	EF CH <sub>4</sub> (kg/hd/yr)
Beef calves (<1 yr)	29.196	0.514	0.308	65.0	104.5	6.5	21.7
Calves, Males for Rep. (<1 yr)	31.075	0.514	0.308	65.0	110.8	6.5	47.2
Calves, Females for Rep. (<1 yr)	26.340	0.514	0.308	65.0	94.5	6.5	40.3
Males 1-2 yrs	50.701	0.495	0.278	60.0	192.4	5.2	67.3
Beef Fem. 1-2 yrs <sup>i</sup>	36.014	0.495	0.278	60.0	133.7	5.2	45.9
Females for R. 1-2 yrs <sup>i</sup>	36.014	0.495	0.278	60.0	133.7	6.5	57.0
Steers (>2 yrs)	60.168	0.495	0.278	60.0	212.4	6.5	90.6
Heifers for Beef (>2 yrs)	40.307	0.495	0.278	60.0	143.3	6.5	61.1
Heifers for Rep. (>2 yrs)	40.307	0.495	0.278	60.0	143.3	6.5	61.1
Non-dairy cows	63.934	0.495	0.278	60.0	215.4	6.5	91.8

i) -Ym – 35, 7% of population feedlot fed

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 5.8, was used 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>) by the power function used for NE<sub>m</sub>. This procedure resulted in an average CH<sub>4</sub> emission factor per animal in 2013, 6.1 per cent higher than the corresponding 1990 value.

$$Par_x = Par_{base} * (Cweight_x^{0.75} / Cweight_{base}^{0.75})$$

Figure 5.8 – Total Cattle: average carcass weight at slaughtering.



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 5.11 – Determination of  $C_{weight}$  values and correlation factor between 1998 (base) year and the other years of the time – series

Year	Carcass (number)	Carcass weight (t)	$C_{weight}$ (kg/hd)	Factor (%) <sup>1</sup>
1990	436 055	109 650	249	91.7
1991	463 070	118 676	256	93.7
1992	443 833	113 782	256	93.7
1993	422 377	106 710	253	92.7
1994	326 507	87 367	268	96.8
1995	325 093	94 568	291	103.0
1996	307 741	88 368	287	102.0
1997	348 550	95 210	273	98.3
1998	282 266	78 927	280	100.0
1999	275 244	77 948	283	101.0
2000	276 788	79 818	288	102.3
2001	248 162	73 138	295	104.2
2002	284 058	82 286	290	102.7
2003	283 612	81 594	288	102.2
2004	320 336	95 227	297	104.7
2005	314 255	92 185	293	103.7
2006	302 520	84 982	281	100.3
2007	283 281	78 745	278	99.6
2008	306 031	87 508	286	101.7
2009	294 226	79 843	271	97.8
2010	270 810	72 860	269	97.2
2011	270 124	73 047	270	97.5
2012	256 927	68 703	267	96.7
2013	231 649	62 479	270	97.3

1)  $C_{weight_x}^{0.75}/C_{weight_{base}}^{0.75}$

Table 5.12 – Methane emission factor values (kgCH<sub>4</sub>/hd/yr) per animal sub-class for the time series

Year	Beef calves (<1 yr)	Calfs, males for Rep (<1 yr)	Calfs, females for Rep (<1 yr)	Males (1-2 yrs)	Beef females. (1-2 yrs)	Females for Rep (1-2 yrs)	Steers (>2 yr)	Heifers for Beef (>2 yr)	Heifers for rep (>2 yr)	Non dairy cows
1990	19.9	43.3	37.0	61.7	42.1	52.3	83.1	56.0	56.0	84.2
1991	20.3	44.3	37.8	63.0	43.0	53.4	84.8	57.2	57.2	86.0
1992	20.3	44.3	37.8	63.0	43.0	53.4	84.8	57.3	57.3	86.0
1993	20.1	43.8	37.4	62.3	42.5	52.8	83.9	56.6	56.6	85.1
1994	21.0	45.7	39.0	65.1	44.4	55.1	87.6	59.1	59.1	88.9
1995	22.3	48.7	41.5	69.3	47.3	58.7	93.3	62.9	62.9	94.6
1996	22.1	48.2	41.1	68.6	46.8	58.1	92.4	62.3	62.3	93.7
1997	21.3	46.4	39.6	66.1	45.1	56.0	89.0	60.0	60.0	90.2
1998	21.7	47.2	40.3	67.3	45.9	57.0	90.6	61.1	61.1	91.8
1999	21.9	47.7	40.7	67.9	46.3	57.5	91.4	61.7	61.7	92.7
2000	22.2	48.3	41.2	68.9	47.0	58.3	92.7	62.5	62.5	94.0
2001	22.6	49.2	42.0	70.1	47.8	59.4	94.4	63.7	63.7	95.7
2002	22.3	48.5	41.4	69.1	47.1	58.5	93.0	62.7	62.7	94.3
2003	22.1	48.3	41.2	68.7	46.9	58.2	92.5	62.4	62.4	93.8
2004	22.1	49.5	42.2	70.4	48.1	59.7	94.8	64.0	64.0	96.1
2005	22.7	49.0	41.8	69.7	47.6	59.1	93.9	63.3	63.3	95.2
2006	22.5	47.4	40.4	67.5	46.1	57.2	90.9	61.3	61.3	92.2
2007	21.7	47.0	40.1	67.0	45.7	56.7	90.2	60.8	60.8	91.4
2008	21.6	48.0	41.0	68.4	46.7	58.0	92.1	62.1	62.1	93.4
2009	21.2	46.2	39.4	65.8	44.9	55.7	88.5	59.7	59.7	89.8
2010	21.1	45.9	39.2	65.4	44.6	55.4	88.0	59.4	59.4	89.2
2011	21.1	46.1	39.3	65.6	44.8	55.6	88.3	59.6	59.6	89.6
2012	21.0	45.7	39.0	65.1	44.4	55.1	87.6	59.1	59.1	88.8
2013	21.1	46.0	39.2	65.5	44.7	55.5	88.1	59.5	59.5	89.4

In 2013, the non-dairy cattle Implied Emission Factor (IEF) was 62.4 kg CH<sub>4</sub>/hd/yr, which is higher but not much different, than the default IPCC 2006 values of 57/58 kg CH<sub>4</sub>/hd/yr.

#### 5.3.3.1.3 Sheep and Goats

The same database from MAM that was referenced previously for non-dairy cattle includes also information for the twelve<sup>87</sup> native Portuguese breeds of sheep and the five native Portuguese breeds of goats<sup>88</sup>. Three imported breeds of sheep<sup>89</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.

In a similar mode to that used for cattle, the energy model proposed in the IPCC 2006<sup>90</sup> for sheep was used.

<sup>87</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>88</sup> Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

<sup>89</sup> Assaf, Ile de France and Merino Precoce.

<sup>90</sup> Volume 4, Chapter 10



First, Net Energies required for maintenance, animal activity, lactation, pregnancy and wool production ( $NE_m$ ,  $NE_a$ ,  $NE_l$ ,  $NE_p$ ,  $NE_g$ ,  $NE_{wool}$ ) were calculated using equations 10.3, 10.5, 10.9, 10.13, 10.7, and 10.12.

The ratios of the net energy available for maintenance and for growth in a diet to digestible energy consumed, REM and REG, were calculated using equations 10.14 and 10.15 (IPCC 2006).

Finally Gross Energy Intake (GE), expressed in energy, was calculated using equation 10.16 (IPCC 2006).

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 5.13 – Parameters used in determination of Net Energy 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	19.1	37.5	28.5	10.0
$C_{fi}^i$	0.250	0.217	0.254	0.250	0.217	0.254
$NE_m$ (MJ/day)	6.58	4.30	2.28	3.79	2.68	1.43
$C_a^{ii}$	0.017	0.017	0.017	0.024	0.024	0.024
$NE_a$ (MJ/day)	1.39	0.93	0.33	0.90	0.68	0.24
WG (kg/day)	-	-	0.064	-	-	0.160
$NE_g$ (MJ/day)	-	-	0.90	-	-	1.08
Wool (kg/yr)	6.5	3.6	-	-	-	-
$NE_{wool}$ (MJ/day)	0.43	0.23	-	-	-	-
Milk Production (kg/day)	-	0.184	-	-	1.238	-
Energy Value of Milk (Mj/kg) <sup>iii</sup>	-	4.60	-	-	2.80	-
$NE_l$ (Mj/day)	-	0.96	-	-	3.47	-
$C_{pregnancy}$	-	0.077	-	-	0.077	-
$NE_p$ (MJ/day)	-	0.33	-	-	0.20	-

i – For Ram and Bucks  $C_{fi}$  value was increased by 15% for intact males; for lambs and kids  $C_{fi}$  value was increased by 15% for intact males (half of the young population)

ii -Sheep - Average for different feeding situations: grazing flat and hilly pasture. Goats – Grazing hilly pasture.

iii-Jarrige (1988); McDonald (2002)

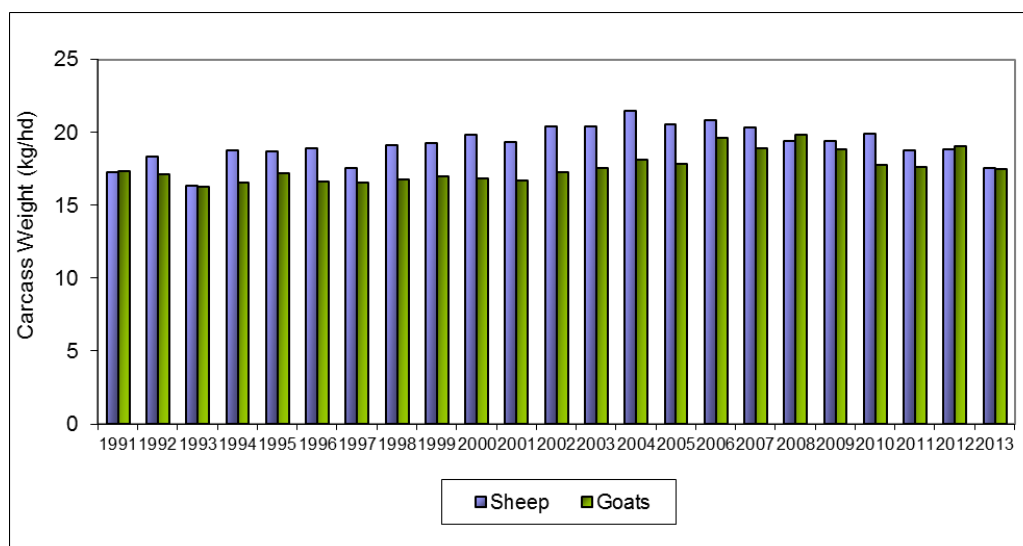
Table 5.14 – Sheep and goats estimated Gross Energy (GE) and CH<sub>4</sub> Emission Factor from Enteric Fermentation (weighted averages of individual breeds)

Sub-class	Sheep			Goats		
	Ram	Ewe	Lamb	Buck	Doe	Kid
REM	0.495	0.495	0.529	0.495	0.495	0.5
REG	0.278	0.278	0.333	0.278	0.278	0.333
DE (%)	60	60	70	60	60	70
GE (MJ/day)	29.38	23.00	10.94	15.80	23.71	9.14
Ym (%)	6.5	6.5	4.5	5.0	5.0	5.0
EF (kg CH <sub>4</sub> /hd/yr)	12.53	9.81	3.23	5.18	7.78	3.00

Data on the average carcass weight at slaughter in Figure 5.9 is also available for Sheep and Goats. The time series for sheep shows a trend in animal size that was used, in a similar mode that was already explained for non-dairy cattle, to add a time trend to the estimated quantities, assuming that overall parameters at a given year ( $Par_x$ ) could be approximately related to carcass weight in the same year ( $Cweight_x$ ), from the values of the parameters and weight at base year ( $Par_{base}$  and  $Cweight_{base}$ ). This procedure resulted in the CH<sub>4</sub> emission factors for sheep, per animal, being 1.0 per cent higher in 2013 than the corresponding values in 1990 and the same situation for goats, per animal.

$$Par_x = Par_{base} * (Cweight_x^{0.75} / Cweight_{base}^{0.75})$$

Figure 5.9 – Sheep and goats: average carcass weight at slaughtering.



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

The next table shows  $C_{weight}$  values used for estimating CH<sub>4</sub> EF from 1990 to the last inventory year.

Table 5.15 – Determination of  $C_{weight}$  values and correlation factor between 1998 (base) year and the other years of the time – series - Sheep

Year	Carcass (number)	Carcass weight (t)	$C_{weight}$ (kg/hd)	Factor (%) <sup>1</sup>
1990	183 478	3 213	17.5	91.6
1991	177 547	3 075	17.3	90.6
1992	141 768	2 602	18.4	96.0
1993	233 548	3 814	16.3	85.4
1994	153 228	2 875	18.8	98.1
1995	145 499	2 724	18.7	97.9
1996	129 211	2 446	18.9	99.0
1997	144 632	2 547	17.6	92.1
1998	100 041	1 913	19.1	100.0
1999	76 177	1 469	19.3	100.8
2000	68 700	1 363	19.8	103.8
2001	74 903	1 450	19.4	101.2
2002	65 518	1 337	20.4	106.7
2003	49 520	1 011	20.4	106.8
2004	39 963	860	21.5	112.5
2005	43 814	903	20.6	107.8
2006	46 188	965	20.9	109.3
2007	58 906	1 198	20.3	106.4
2008	72 642	1 410	19.4	101.5
2009	76 451	1 484	19.4	101.5
2010	75 807	1 512	19.9	104.3
2011	76 409	1 434	18.8	98.1
2012	80 889	1 523	18.8	98.5
2013	108 837	1 911	17.6	91.8

1)  $C_{weight_x}^{0.75}/C_{weight_{base}}^0$

Table 5.16 – Determination of  $C_{weight}$  values and correlation factor between 1998 (base) year and the other years of the time – series- Goats

Year	Carcass (number)	Carcass weight (t)	$C_{weight}$ (kg/hd)	Factor (%) <sup>1</sup>
1990	42 687	740	17.3	103.4
1991	42 687	740	17.3	103.4
1992	53 063	909	17.1	102.1
1993	38 729	632	16.3	97.3
1994	47 363	786	16.6	99.0
1995	45 980	793	17.2	102.8
1996	50 121	833	16.6	99.1
1997	45 604	755	16.6	98.7
1998	38 997	654	16.8	100.0
1999	28 457	483	17.0	101.2
2000	22 192	375	16.9	100.8
2001	16 348	273	16.7	99.6
2002	14 239	246	17.3	103.0
2003	12 102	213	17.6	104.9
2004	7 563	137	18.1	108.0
2005	3 809	68	17.9	106.5
2006	5 755	113	19.6	117.1
2007	6 804	129	19.0	113.1
2008	6 638	132	19.9	118.6
2009	6 789	128	18.9	112.4
2010	6 407	114	17.8	106.1
2011	10 808	191	17.7	105.4
2012	8 592	164	19.1	113.8
2013	7 889	138	17.5	104.3

1)  $C_{weight_x}^{0.75}/C_{weight_{base}}^0$

Table 5.17 – Methane emission factor values (kg CH<sub>4</sub>/hd/yr) per animal sub-class for the time series - Sheep

Year	Ewes	Rams and young males	Lambs
1990	9.1	11.6	3.0
1991	9.1	11.6	3.0
1992	9.5	12.1	3.1
1993	8.7	11.1	2.9
1994	9.7	12.3	3.2
1995	9.7	12.3	3.2
1996	9.7	12.4	3.2
1997	9.2	11.8	3.0
1998	9.8	12.5	3.2
1999	9.9	12.6	3.3
2000	10.1	12.9	3.3
2001	9.9	12.6	3.3
2002	10.3	13.2	3.4
2003	10.3	13.2	3.4
2004	10.7	13.7	3.5
2005	10.4	13.3	3.4
2006	10.5	13.4	3.5
2007	10.3	13.1	3.4
2008	9.9	12.7	3.3
2009	9.9	12.7	3.3
2010	10.1	12.9	3.3
2011	9.7	12.4	3.2
2012	9.7	12.4	3.2
2013	9.2	11.8	3.0

Table 5.18 – Methane emission factor values (kg CH<sub>4</sub>/hd/yr) per animal sub-class for the time series - Goats

Year	Does	Bucks and young males	Kids
1990	9.0	5.3	3.1
1991	9.1	5.3	3.1
1992	9.5	5.3	3.0
1993	8.8	5.1	2.9
1994	9.8	5.1	3.0
1995	9.8	5.3	3.1
1996	9.8	5.1	3.0
1997	9.3	5.1	3.0
1998	9.9	5.2	3.0
1999	9.9	5.2	3.0
2000	10.1	5.2	3.0
2001	9.7	5.2	3.0
2002	9.8	5.3	3.1
2003	9.7	5.4	3.1
2004	10.1	5.5	3.2
2005	9.8	5.4	3.1
2006	9.9	5.8	3.4
2007	9.7	5.7	3.3
2008	9.3	5.9	3.4
2009	9.3	5.7	3.3
2010	9.6	5.4	3.1
2011	9.1	5.4	3.1
2012	9.1	5.7	3.3
2013	8.6	5.3	3.1

In 2013, the Implied Emission Factor (IEF) from enteric fermentation by sheep was 8.63 (kg CH<sub>4</sub>/hd/yr) and the IEF for goats enteric fermentation was 7.46 (kg CH<sub>4</sub>/hd/yr). Both IEFs are higher than the default values IPCC 2006, but similar with the values of other countries that

used a Tier 2 approach to estimate emission factors from enteric fermentation of sheep and goats.

#### 5.3.3.1.4 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 5.19.

Table 5.19 – Parameters used in determination of Gross Energy (GE) and enteric fermentation methane emission factor by swine and rabbits (all values INRA (1984))

sub-class	Weight (kg)	ED (MJ/day)	DE (% GE)	EF (kg CH <sub>4</sub> /h/y)	Ym (%)	Notes
Swine						
Piglets (<20 kg)	10	6.2	88.2	0.31	6,0	Avg. 22 d. to 20 kg
Fattening Pigs (20-50 kg)	35	23.4	83.4	1.27		Regression DE = 17.93*Ln(W)-40.13 (r <sup>2</sup> - 0.998)
Fattening Pigs (50-80 kg)	65	34.5	83.4	1.87		
Fattening Pigs (80-110 kg)	95	41.3	83.4	2.24		
Fattening Pigs (> 110 kg)	120	45.5	83.4	2.47		
Boars (>50 kg)	250	32.4	78.2	1.88		
Sows, pregnant	170	31.4	78.2	1.82		Sow in gestation
Sows, non-pregnant	195	64.9	78.2	3.75		Sow in lactation
Rabbits						
Reproductive Female	-	4.0	59.0	0.27	0.6 <sup>1</sup>	per female cage.

(1)From Italian NIR

In 2013, the IEF from enteric fermentation by swine was 1.2 (kg CH<sub>4</sub>/hd/yr) which is lower than the default IPCC 2006 but not so different.

#### 5.3.3.1.5 Poultry<sup>91</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>91</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 5.20 – Parameters used in determination of Gross Energy - Poultry

Animal Type	Energy Intake (MJ EM/day)	Metabolizability (EM/GE)	GE (MJ/day)	Ym
Broiler	1.03	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 <sup>#</sup>	1.46	65.8	2.22	NA

<sup>#</sup> used as reference for other fowl

It is important 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 maintain coherency between animal types.

#### 5.3.4 Activity Data

General census to agriculture<sup>92</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 (RA, 2009), considered the survey of all national territory at the same time. Inquiries were done at each individual production unit by direct interview,

The general 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”.

Also, through Farm Structure Survey about 40 000 farms (production units) are surveyed, every two years.

Annually livestock numbers for cattle, swine, sheep and goats are estimated through the use of the National Animal Registration database (SNIRA). Using that data sources, INE built

<sup>92</sup> Referred in Portuguese as Recenseamento Agrícola (RA, 2009). Previous census were referred as Recenseamento Geral da Agricultura (RGA)

consistent time series of annual livestock numbers from 1987 to 2013 for cattle, swine, sheep, goats, horses, mules and donkeys, disaggregated per region<sup>93</sup>, age and sex.

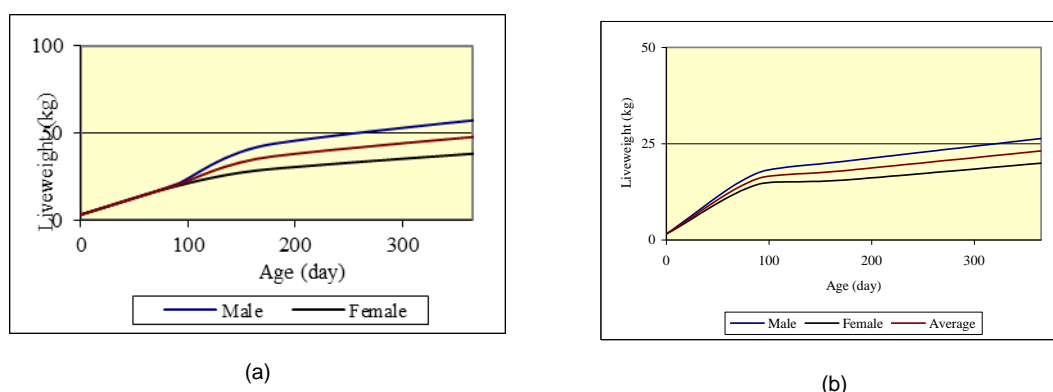
All original figures in statistical database represent the annual average population

Statistical data from the INE for the sheep and the goats does not distinguish the category "lambs" or "kids". The annual sheep and goat population is disaggregated between two broad categories: "ewes" and "other ovine", for sheep, and "does" and "other caprine", for goats. Thus, the annual number of lambs and kids was set from the number of registered slaughtered animals, as published by the National Statistics Institute (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>94</sup> for both species, Figure 5.10, using the weight at slaughter as published by INE, which values are presented in Figure 5.11. Resultant average ages are 114 days for lambs and 77 days for kids.

Figure 5.10 – Growth Model for Sheep (a) and Goats (b)

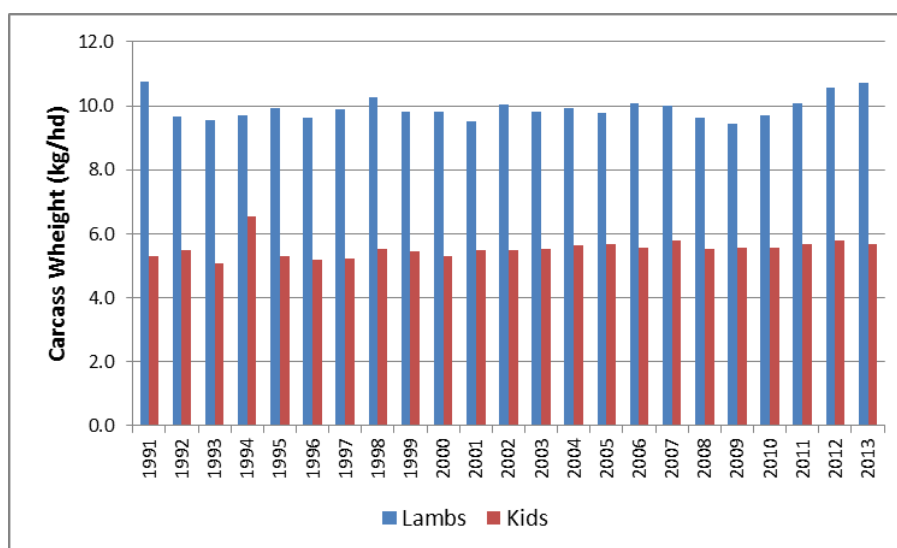


The number of animals remaining from the total Sheep and goats population after subtraction of number of females (ewes and does) and the number of youngsters (lambs and kids) is reported as "Other Ovine" and "Other Caprine". These animals are mostly adult males, but also young animals that are kept to reproductive functions and are not slaughtered.

<sup>93</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>94</sup> Model set from the information on the breeds existent in Portugal, complemented by information in Jarrige (1988) concerning growth pattern.

Figure 5.11 – Lambs and Kids: average carcass weight at slaughtering.



The population of poultry and rabbits is established from the results of the Agricultural Census, and the Farm Structure Survey. The disaggregation between hens for industrial egg production and hens for production of chicks was obtained from the results of the Annual Survey of Industrial Poultry and the Annual Survey of eggs production published by the INE.

Gaps in the livestock time series were corrected with linear interpolation.

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).

In Table 5.21 is presented the annual livestock numbers (1990, 1995, 2000, 2005 and 2010 to 2013) that are activity data for  $\text{CH}_4$  emission estimates from enteric fermentation (CRF 3A). In a consistent way same activity data are used to estimate  $\text{CH}_4$  emissions and  $\text{N}_2\text{O}$  emissions from manure management systems ((CRF 3B) and  $\text{N}_2\text{O}$  emissions from animal manure applied to soil and from urine and dung deposited by grazing animals (CRF 3D). The complete time series data can be seen in Annex G – Agriculture.



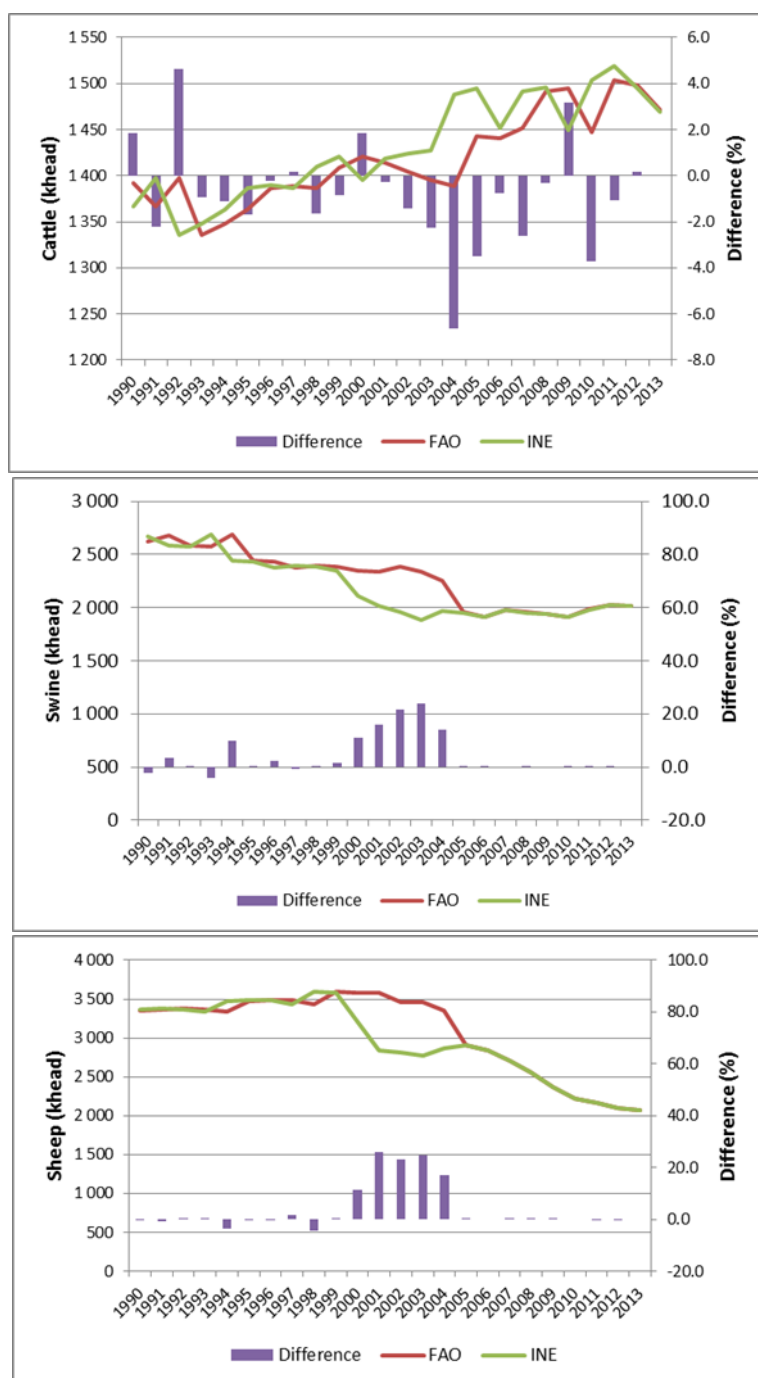
**Table 5.21 - Livestock Population (Thousands)**

Animal class	Sub-class	1990	1995	2000	2005	2010	2012	2013
Dairy-Cattle	Dairy cows	394	383	353	290	255	241	236
Non-dairy cattle	Beef calves (<1 yr)	46	60	67	104	114	125	119
	Calfs M.Rep. (<1 yr)	186	162	144	136	123	136	136
	Calfs F Rep. (<1 yr)	177	158	174	183	171	190	191
	Males 1-2 yrs	112	103	82	81	66	55	54
	Beef Fem. 1-2 yrs	18	22	17	17	20	20	19
	Females rep. 1-2 yrs	111	109	127	135	137	131	135
	Steers (>2 yrs)	38	33	26	25	38	44	42
	Heifers Beef (>2 yrs)	4	10	6	9	12	14	14
	Heifers rep. (>2 yrs)	45	52	67	94	110	110	105
	non-dairy cows	242	273	345	397	438	442	443
Swine	Piglets (<20 kg)	727	726	663	574	597	634	658
	Fatt. Pigs (20-50 kg)	662	660	585	467	448	455	464
	Fatt. Pigs (50-80 kg)	525	525	483	368	360	366	366
	Fatt. Pigs (80-110 kg)	218	198	174	214	244	255	263
	Fatt. Pigs (> 110 kg)	44	44	38	41	36	27	25
	Boars (>50 kg)	26	26	20	12	7	5	5
	Sows, pregnant	210	211	195	191	179	166	159
	Sows, non-pregnant	124	132	124	68	66	66	68
Sheep	Ewes	2 292	2 339	2 410	2 293	1 915	1 735	1 683
	Other Ovine	663	817	733	234	191	160	167
	Lambs	307	278	319	322	277	267	263
Goats	Does	614	517	460	380	356	349	342
	Other Caprine	149	151	129	57	40	35	36
	kids	47	41	33	26	29	28	27
Equide	Horses	33	48	58	52	38	30	27
	Asses & Mules	118	103	69	40	22	18	15
Poultry	Hens, reproductive	3 421	3 271	2 644	3 056	3 512	3 741	3 690
	Hens eggs	7 539	7 745	9 060	7 349	7993	8 237	8 289
	Broilers	18 524	18 813	24 374	18 686	19 474	20 254	20 254
	Turkeys	1 149	945	1 208	798	1 507	1 518	1 518
	Other poultry	1 667	1 648	1 707	1 353	1 568	1 601	1 601
Other	Rabbits	475	401	336	289	263	267	267

#### 5.3.4.1 Quality Assessment of Livestock Numbers

Livestock numbers<sup>95</sup> used in the inventory, as collected from National Statistics, were compared to FAO livestock numbers for years 1990-2013, and results are presented in the Figure 5.12 for cattle, swine and sheep.

Figure 5.12 – Livestock numbers: comparison between National Statistics and FAO database.



<sup>95</sup> Annual values, not 3 year averages.

FAO and INE livestock numbers have a good adhesion for all species. For swine and sheep they are even the same from 2005 onwards. For cattle the values in almost of time series are the same but one year delayed. FAO livestock number of year n is equal to INE livestock number for the year n-1. From 2012 onwards, values total agree in both dataset. For emission estimates we used in the inventory a three average number so this delay between series is diminished.

### 5.3.5 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 5.22.

Table 5.22 .– Livestock population uncertainty estimates.

Animal Type	U (%)
Dairy - Cattle	10
Non-dairy cattle	10
Sheep	10
Goats	10
Pigs	10
Horses	20
Mules& Asses	50
Hens	20
Broilers	20
Turkeys	30
Other	30

The uncertainty for digestibility estimates was assumed 20 percent where tier 2 was used, which is in line with the IPCC 2006.

The uncertainty of the emission factor was assumed to be 20 percent for all animals where tier 2 was used and 50 percent when tier 1 emission factors were used, in accordance with the IPCC 2006.-

### 5.3.6 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 Agricultural General Census (every 10 year) and data from Farm Structure Survey (every two year) concerning poultry and rabbits to check any outliers;
- Comparison between livestock data obtained from INE and FAO numbers for cattle, sheep, goats and swine population.

### 5.3.7 Recalculations

The major changes between submissions, last year and this year, result from the implementation of the IPCC 2006 Guidelines and the application the methodologies, parameters and emission factors defined therein for this source category (3A). Dairy cows had no change because the methodological revision made last year followed already the IPCC 2006 Guidelines.

Differences are shown in Figures below and are mostly due to the increase of Cfi value (from 0.0335 to 0.386) used on the calculation of Net Energy for maintenance, with special impact in non – dairy cows subclass, and the increase of Ym value from (6.0 % to 6.5 %) for most of the non- dairy cattle subclasses.

Figure 5.13– Total Enteric Fermentation Emissions (t CH<sub>4</sub>), differences between submissions (2014 and 2015)

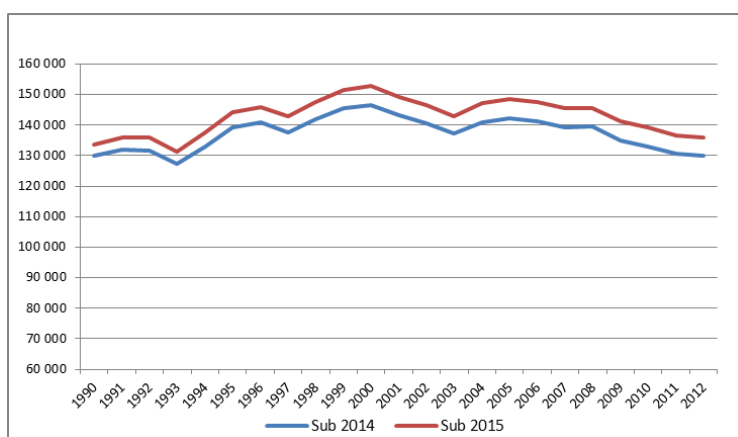
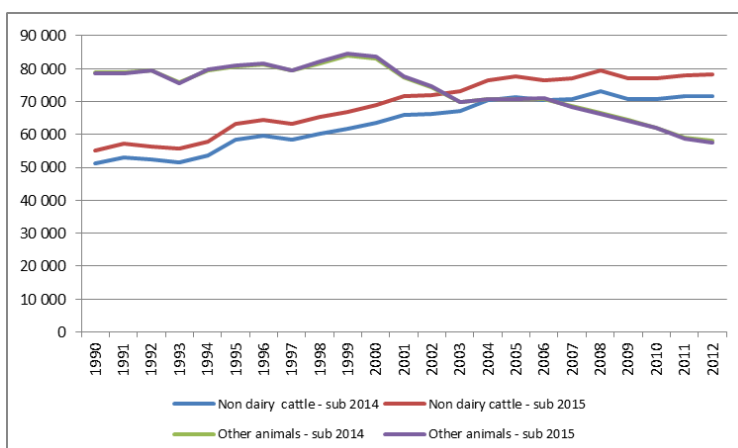


Figure 5.14 – Impact of Non- dairy cows enteric fermentation emissions (t CH<sub>4</sub>) in the differences between submissions (2014 and 2015)



### 5.3.8 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.

## 5.4 CH<sub>4</sub> Emissions from Manure Management (CRF 3.B.a)

### 5.4.1 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 are also included in this source category<sup>96</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.

In Table below are present the estimates of CH<sub>4</sub> emission from manure management.

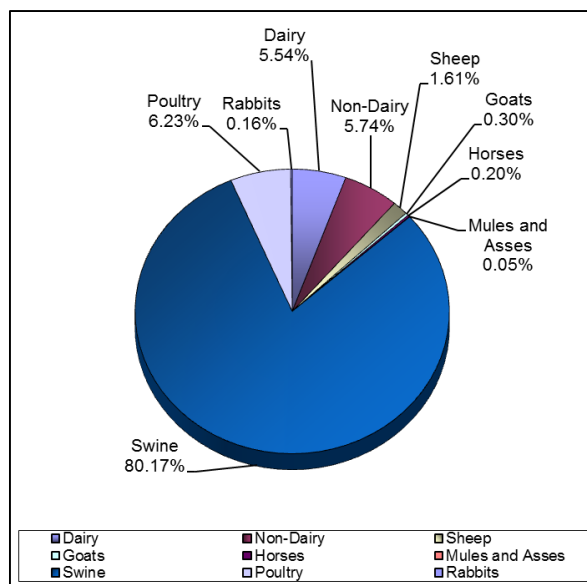
Table 5.23 – CH<sub>4</sub> emissions from manure management (kt)

Livestock type	1990	1995	2000	2005	2010	2011	2012	2013
Dairy cattle	2.00	2.24	2.74	2.74	2.81	2.74	2.73	2.61
Non- dairy cattle	2.10	2.39	2.50	2.79	2.69	2.71	2.70	2.71
Sheep	1.25	1.42	1.47	1.18	0.95	0.86	0.82	0.76
Swine	47.83	48.48	44.32	37.07	37.23	37.06	37.18	37.54
Goats	0.27	0.23	0.21	0.16	0.15	0.15	0.16	0.14
Horses	0.13	0.19	0.23	0.20	0.14	0.12	0.11	0.10
Mules and asses	0.20	0.17	0.11	0.06	0.03	0.03	0.03	0.02
Poultry	2.64	2.63	3.08	2.46	2.84	2.94	2.94	2.94
Rabbits	0.15	0.13	0.10	0.09	0.08	0.08	0.08	0.08
<b>Total</b>	<b>56.58</b>	<b>57.87</b>	<b>54.76</b>	<b>46.75</b>	<b>46.93</b>	<b>46.69</b>	<b>46.74</b>	<b>46.90</b>

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 80.24 per cent of emissions in 2013, as may be seen in Figure 5.15, and according to the good practice rule of thumb this specie is the only significant source.

<sup>96</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.

Figure 5.15 - Relative Importance of emissions of CH<sub>4</sub> from Manure Management per each animal species in 2013



#### 5.4.2 Methodology

Following the IPCC 2006, emission estimates are calculated based on the equation 10.22<sup>97</sup> 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.

#### 5.4.3 Emission Factors

Emissions Factors for each animal type were established according to the tier 2 methodology proposed in IPCC 2006 (equation 10.23<sup>97</sup>), 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:

$$EF_{(i)} = (VS_{(i)} * 365) * [Bo_{(i)} * 0.67 * \sum_{jk} MCF_{(jk)} / 100 * MMS_{(ijk)}]$$

<sup>97</sup> Volume 4, chapter 10

$EF_{(i)}$  - annual emission factor for a defined livestock animal species  $i$ , kg  $CH_4$ /hd/year;

$VS_{(i)}$  – volatile solids excreted for an average animal  $i$  in the livestock population, kg dm /day;

$Bo_{(i)}$  - maximum methane production capacity from manure ( $m^3$ /kg VS) for animal species  $i$ ,  $m^3$   $CH_4$ /kg VS excreted;

0.67 – conversion factor of  $m^3$   $CH_4$  to kg  $CH_4$ ;

$MCF_{(jk)}$  - methane conversion factor for each Manure Management System  $j$  and for each climate region , %;

$MMS_{(ijk)}$  - fraction of total manure from animal species  $i$  handled with Manure Management System  $j$  and for each climate region  $k$ .

$B_o$  values were set according to IPCC 2006. The amount of volatile solids (VS) excreted 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 10.24<sup>97</sup> of the IPCC 2006:

$$VS = \{GE * [1 - (DE/100)] + (UE * GE)\} * [(1 - ASH) / 18.45]$$

where

VS – volatile solid excreted on a dry matter basis, kg VS /day;

GE – daily average gross energy intake, MJ/day;

DE – digestibility of the feed in percent;

(UE\*GE) – urinary energy expressed as fraction of GE;

ASH – the ash content of manure calculated as a fraction of the dry matter feed intake;

18.45 – conversion factor for dietary GE per kg of dry matter, MJ/kg.

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. For cattle categories the urinary energy considered was 0.04.

Table 5.24 – Parameters used in the estimate of Volatile Solids and EF 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>	0.080	0.24
Non-dairy cattle	Calves (<1 yr)	65	0.080	0.17
	Other animals	60	0.080	0.17
Swine	Piglets (<20 kg)	88 <sup>#</sup>	0.045 <sup>*</sup>	0.45
	Fattening Pigs	83 <sup>#</sup>	0.045 <sup>*</sup>	0.45
	Sows and Boars	78 <sup>#</sup>	0.045 <sup>*</sup>	0.45
Sheep	Ewes & other ovine	60	0.080	0.19
Goats	Does & other caprine	60	0.080	0.18
Equides	Horses	70	0.040	0.30
	Asses & Mules	70	0.040	0.33
Poultry	Hens Reproductive	64 <sup>#</sup>	0.048 <sup>#</sup>	0.39
	Hens eggs	64 <sup>#</sup>	0.048 <sup>#</sup>	0.39
	Broilers	68 <sup>\$</sup>	0.020 <sup>#</sup>	0.36
	Turkeys	68 <sup>#</sup>	0.026 <sup>#</sup>	0.36
	Other poultry	66 <sup>#</sup>	0.020 <sup>#</sup>	0.36
Other	Rabbits	59 <sup>#</sup>	0.034 <sup>#</sup>	0.32

Note: all values IPCC default, except:

»-Country specific (Table 5.4); # - INRA (1984); \$- McDonald et al (2002); \* INIAV<sup>98</sup>

Expert guess<sup>99</sup>, based on survey data and field knowledge of technical personnel of the Ministry of Agriculture was used to establish the percent of each Manure Management System (MMS) 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 2013 we assume the 2010 distribution.

The values for the fraction of manure handled in each MMS in 1990 and in 2013 are presented in Table 5.25. The annual variation of the share of each MMS in the period 1990 – 2010 is shown in Table 5.26.

<sup>98</sup> Animal Nutrition expertise. Dr<sup>o</sup> Olga Moreira

<sup>99</sup> Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005, and in 7, October 2009, following update.



Table 5.25 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990 and 2013 (%).

Animal Type	1990					2013*				
	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

\*equal to 2010

Table 5.26 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type (1990 – 2010).

Animal Type	Lagoons	Tanks	Solid Storage	Pasture
Dairy Cows	0.100	-0.850	0.750	-
non-dairy cows	-	-	-	-
Other cattle	-	-	-1.500	1.500
Ewes	-	-	-	-
Other ovine	-	-	-	-
Does	-	-	-	-
Other caprine	-	-	-	-
Sows	0.250	-0.450	-0.100	0.300
Other Swine	0.250	-0.350	-0.050	0.150
Hens	-	-	-	-
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

Two climate regions occur in Portugal, in accordance with reporting table<sup>100</sup> classification: 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>101</sup> and for each animal sub-type. Within each *concelho* territorial area a homogenous distribution of animals was assumed;
- for each *concelho* territorial area in mainland Portugal and Madeira archipelago the percentage of land area above and below 15°C was determined using the annual average air temperature map, which is presented in Figure 5.16. All area in Azores islands were considered to be in temperate region;
- livestock numbers per animal type were available at *concelho* level from two Agriculture General Census (1989 and 1999)<sup>102</sup>. Data for 1999 was available for all

<sup>100</sup> CRF 3B classification of climate regions is different than IPCC 2006 Guidelines (page 3.39 of volume 4, chapter 3 and page G.11 of the Glossary).

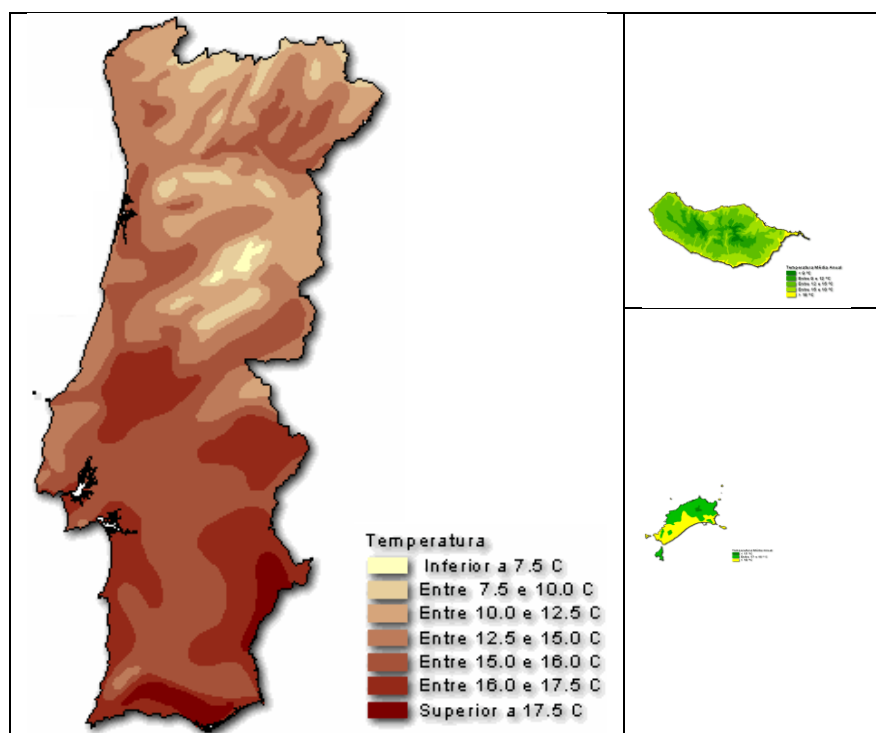
<sup>101</sup> Concelho territorial unit in Portugal is the designation to land areas associated with one municipal administrative authority. There are 306 concelhos in Portugal with an average area of 289 km<sup>2</sup>. A nut III level territorial unit is defined as a set of Concelhos.

<sup>102</sup> Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

animal types and for 1989 only for dairy cattle, other cattle, ewes, other sheep, female goats and other goats, sows and other swine;

- livestock numbers in each *concelho* area were allocated to each climate region, for year 1999, according to the land area percentage, and always assuming an homogeneous distribution of animals in the *concelho* territorial area. Animal numbers were summed at each Administrative Region (Região)<sup>103</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.

Figure 5.16 – 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 2013, obtained in accordance with the above explained procedure, is presented in Table 5.27.

<sup>103</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.

Table 5.27 – Share of livestock population in climate cool regions (%), 1990 and 2013.

Animal Type	1990	2013
Dairy Cows	48	39
Other Cattle	43	25
Sheep	29	34
Goats	51	47
Horses	34	50
Mules and Asses	58	67
Swine	22	15
Poultry	47	47
Other	60	73

Methane Conversion Factors (MCF) for each MMS are the default<sup>104</sup> ones from IPCC 2006, shown in Table 5.28, considering a mean annual temperature of 17° C for temperate climate region and a mean annual temperature of 14°C for the cool climate region:

Table 5.28 - Methane Conversion Factors (MCF), percent, for determination of CH<sub>4</sub> emissions from Manure Management

MMS	Temperate	Cool
Anaerobic Lagoons (uncovered)	76	73
Tanks <sup>1</sup>	3	3
Solid Storage	4	2
Pasture	1.5	1

(1) Combine with Short retention pits (<1 month)

Due to the length of the table is presented in Annex G – Agriculture the emission factors (EF) estimates for all livestock categories /sub classes for the full time series.

The final implied emission factors (IEF) of methane emissions from Manure Management, expressed in kg CH<sub>4</sub>/ hd / yr, that way derived for Portugal, is presented in table below. The comparison with the default emission factors was done considering the description of the manure management situations that better corresponded to our country's specific characteristics of manure management, with special focus on the following aspects:

- dairy cows in pasture has a significant expression in Portugal;
- the management of wastes from dairy cows kept in stall is split among solid storage and short retention time pits;
- non dairy cows with milking calves are usually kept on pasture, but fattening animals are usually grown in confined areas;
- 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;

<sup>104</sup> Table 10.17, Volume 4, chapter 10

- there is a small percentage of traditional swine kept outdoors and foraging in pasture range;
- daily spread and usage as fuel are practically unknown in Portugal;
- 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 5.29 – Manure management CH<sub>4</sub> Implied Emission Factors (IEF) and comparison with IPCC 2006 default emission factors (kg/hd/yr)

Livestock	1990	1995	2000	2005	2010	2011	2012	2013	Default * (cool – temperate)
Dairy cattle	5.08	5.85	7.76	9.48	11.02	11.11	11.33	11.07	<b>15-22</b> (Solid based systems are used for the majority of the manure (EE). Portugal also has a significant % of manure directly deposited on pasture, See table 5.25)
Non-dairy cattle	2.15	2.20	2.36	2.36	2.19	2.18	2.14	2.15	<b>1-2</b> (Non-dairy manure is usually managed as solid and deposited on pastures (NA <sup>m</sup> ). That is the situation in Portugal. See table 5.25))
Swine	18.87	19.23	19.56	19.33	19.38	19.20	19.00	18.84	<b>12-23</b> (About half of the swine manure is managed in anaerobic lagoons (Oc). Portugal has a greater % of swine manure managed in anaerobic lagoons. See table 5.25)
Sheep	0.38	0.38	0.43	0.41	0.40	0.38	0.38	0.36	0.19-0.28
Goats	0.34	0.33	0.33	0.35	0.35	0.36	0.38	0.35	0.13-0.20
Horses	3.95	3.95	3.92	3.80	3.77	3.75	3.70	3.60	1.56-2.34
Mules & Asses	1.66	1.66	1.62	1.57	1.53	1.52	1.53	1.56	0.76-1.10
Poultry	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.02-0.09
Rabbits	0.32	0.32	0.31	0.30	0.29	0.29	0.29	0.29	0.08

\*Table 10.14, page 10.38 (Cattle and swine), Table 10.15, page 10.40 (Other animal species) and Table 10.16, page 10.41. EE – Eastern Europe; NA<sup>m</sup> – North America; Oc – Oceania.

Reductions of CH<sub>4</sub> emissions related to biogas production only occur for swine livestock in a very small scale, corresponding to less than 1% of the CH<sub>4</sub> emissions from swine manure management and 0.3 % of the total CH<sub>4</sub> emissions from manure management of all livestock category, in average during the period 2000 to 2013. The 2000 year was the first year where production of biogas began in swine exploitations.

Biogas production data are collected every year by the Energy National Authority (DGEG)<sup>105</sup>.

Biogas recovery from pig manure occurs only in two farms through 3 anaerobic bio digesters that totalized a volume of 3 210 m<sup>3</sup>. The annual average swine population of the two farms is of 17 800 animals.

The MCF factor for the bio digesters was calculated with the formula 1 of table 10.17 of IPCC 2006 and the determined value was 20%.

Reductions of CH<sub>4</sub> emissions related to biogas recovery are reflected in the swine IEF reported in CRF which are slightly different of those presented in Table 5.29, as shown in the following box.

	2000	2005	2010	2011	2012	2013
IEF* Swine (kg CH <sub>4</sub> /hd/yr)	19.41	19.16	19.22	19.03	18.84	18.68

(\*) as reported in CRF tables

#### 5.4.4 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.

#### 5.4.5 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.

Concerning the uncertainty levels associated with emission factors 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>106</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

<sup>105</sup> Direcção Geral de Energia e Geologia

<sup>106</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.

stored; for solid storage and pasture, the uncertainty values of 50 per cent reflect the variation of this parameter;

- the error associated with the parameters  $B_0$  is specie dependent and was established from the range of possible values in the IPCC 2006, for developed and developing nations. Uncertainty values vary from 10 per cent for horses up to 22 per cent for dairy cows. The uncertainty of the biogas density was assumed not to be determinant of the overall uncertainty value;
- from observation of the climate maps it is evident that, from the particular conditions that affect Portuguese climate, small annual variations in average air temperatures and also mapping techniques could exert a profound modification in the percentage of livestock numbers that are classified as either cool or temperate. Territorial units under each climate class could easily change as much as 30 per cent in either direction, value that was assumed as representative of uncertainty for this factor.

The individual uncertainty values are presented in next table (using as base value 1990).

Table 5.30 – Uncertainty Values (in per cent) of the Emission Factors of CH<sub>4</sub> emissions from Manure Management

Specie	$\Sigma \text{MMS} \cdot \text{MCF}$	VS	$B_0$	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

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

QA/QC procedures included a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report.

#### 5.4.7 Recalculations

Differences between submissions, 2014 and 2015, are shown in the figures below. The main reason for these differences is related to the manure management system of sheep and goats. Previously there was an incorrect allocation of uncovered anaerobic lagoons that was corrected this year following an internal QA/QC. The characteristic manure management systems for sheep and goats are solid storage and pasture as presented in Table 5.25.

Figure 5.17 – Manure Management emissions (t CH<sub>4</sub>), differences between submissions (2014 and 2015)

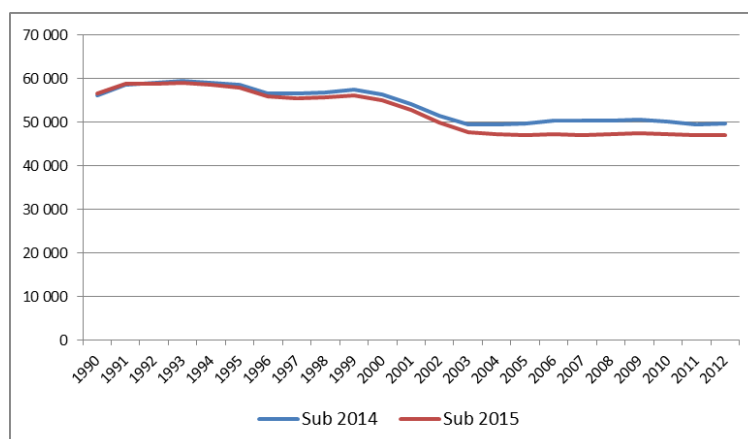
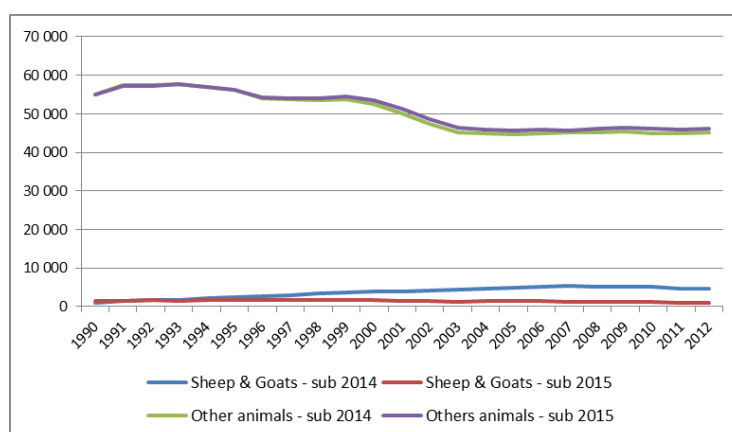


Figure 5.18 – Impact of sheep and goats manure management emissions (t CH<sub>4</sub>), in the differences between submissions (2014 and 2015)



#### 5.4.8 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.

## 5.5 CH<sub>4</sub> Emissions from Rice Cultivation (CRF 3.C)

### 5.5.1 Overview

Methane production is enhanced in rice cultivation areas (rice paddies) due to the prevalence of anaerobic conditions which result from flooding and high levels of organic material in soil surface. The methane that is formed in soil underwater escapes to atmosphere as greenhouse gas emission, as visible bobbles or trough transport inside plant stems.

In Table below are present the estimates of CH<sub>4</sub> emission from rice cultivation.



Table 5.31 – CH<sub>4</sub> emissions from Rice cultivation (kt)

	1990	1995	2000	2005	2010	2011	2012	2013
Rice cultivation	5.36	4.16	4.70	6.08	5.53	5.99	5.97	5.77

### 5.5.2 Methodology

Methane emissions from rice production were estimated following the equation 5.1 of IPCC 2006,<sup>107</sup> 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:

$$E_{\text{RiceCH}_4(y)} = EF * \text{RiceArea}_{(y)} * 10^{-3}$$

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 (kg/ha/yr);

$\text{RiceArea}_{(y)}$  - area under rice cultivation in year y (ha).

### 5.5.3 Emission Factors

According to equation 5.2 of IPCC 2006, the final value for the emission factor results from the multiplication of several scaling factors:

$$EF = EF_{\text{ct}} * SF_w * SF_p * SF_o * SF_s$$

where

EF - final emission factor seasonally integrated and adjusted for management practices (kg/ha/yr);

$EF_{\text{c}} (t)$  – baseline emission factor for continuously flooded fields without organic amendments, for the cultivation period of rice t (kg/ha/yr);

$SF_w$  - scaling factor for water management regime during the cultivation period of rice;

$SF_p$  – scaling factor to account for the differences in water regime in the pre – season before the cultivation period;

$SF_o$  - scaling factor for the type of organic amendment applied (rice straw, manure, compost, wastes), because easily decomposable carbon increase methane formation;

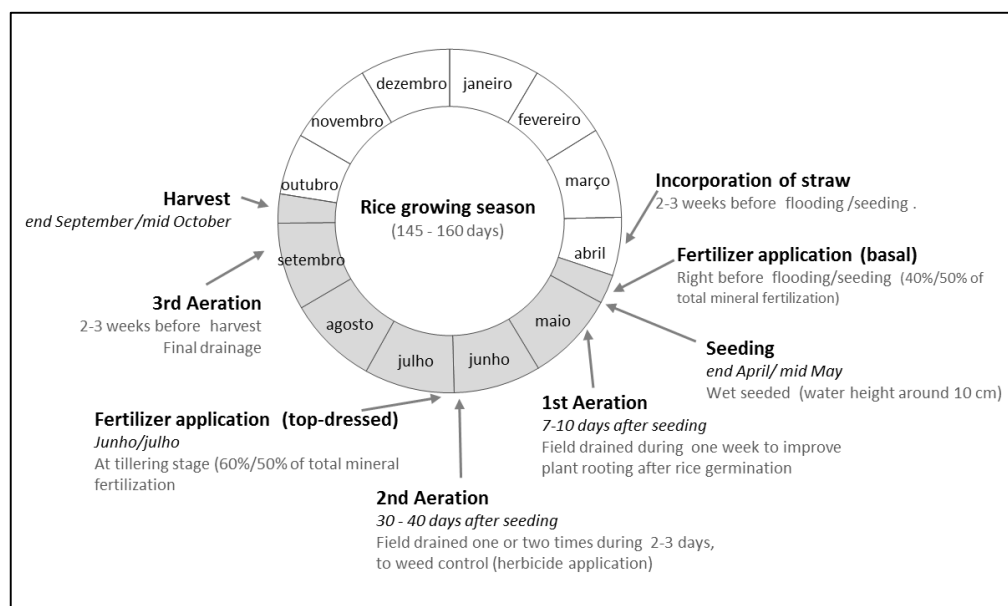
$SF_s$  - scaling factor for soil type.

<sup>107</sup> Volume 4, chapter 5

The default daily baseline emission factor, 1.30 kg/ha/day, proposed in Table 5-11 of IPCC 2006, is the most appropriate to use in Portugal <sup>108</sup> because a country specific EF<sub>c</sub> sufficiently robust was not yet determined. The cultivation period of rice in Portugal has, in average, duration of 153 days.

Rice cultivation has a long time tradition in Portugal with homogeneous practices in all national territory. In Figure 5.19 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 2006 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<sub>w</sub> was set as 0.60 based on Table 5.12 of IPCC 2006, and for parameter SF<sub>p</sub> the value considered was 0.68 (table 5.13, IPCC 2006).

Figure 5.19 – 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>109</sup> limits. In these situations the practice of burning crop

<sup>108</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

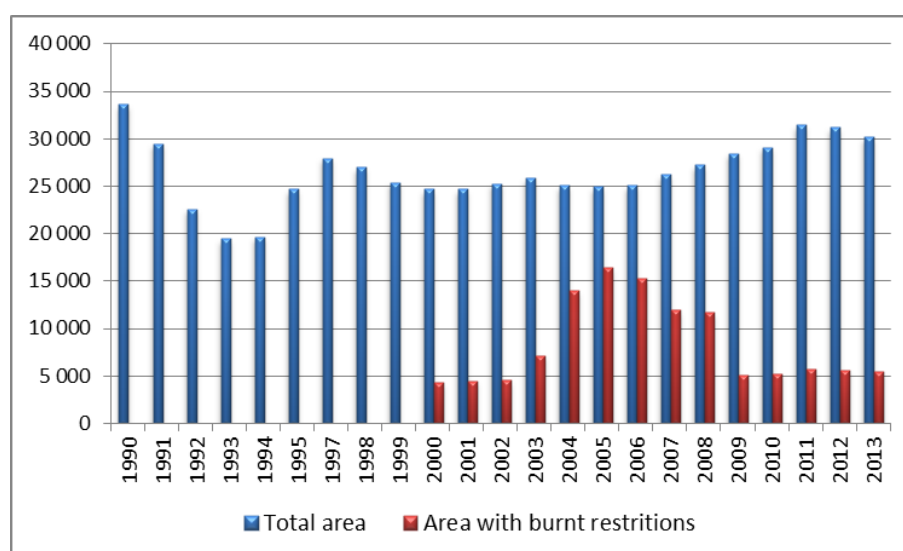
<sup>109</sup> Natura 2000 network includes Special Zones for Conservation (ZPC) established under Habitats Directive (92/43/CEE) and Special Protection Zones (ZPE) established under Birds Directive (last revision 2009/147/CE). <http://www.icnf.pt/portal/naturaclas/rn2000>

residues is forbidden<sup>110</sup>, for reasons of conservation of natural habitats and animal species, since 2000 until nowadays.

Outside the Natura 2000 network during the time period 2002-2008<sup>111</sup> all rice cultivation areas subjected to “Techniques of Integrated Production and Protection<sup>112</sup>” had the same burnt residues restrictions. Straw were left on ground and incorporated into soil by plowing before next crop season.

Figure below shows the evolution of rice cultivation areas where the practice of residues burnt is not allowed.

Figure 5.20 – Rice areas cultivated (ha) in Portugal



Source: Ministry of Agriculture, GPP 2014

Due to the above described, the amount of straw annually incorporated into the soil has variations along the time series, from a minimum of 2.13 t dm/ha to a maximum of 5.44 t dm/ha. The scaling factor Sfo, for organic amendment applied, was determined using the equation 5.3 of IPCC 2006, where the conversion factor (CFOA) took the value of one, corresponding to straw incorporated shortly before cultivation (<30 days), in accordance with default value of Table 5.14.

Finally, no information is available to establish the influence of soil type and SFs was set to one.

In Table 5.32 are summarized the parameters and emissions factors used to estimate methane emissions from rice cultivation in Portugal, for the full time series.

<sup>110</sup> National Laws: DL 140/99 artº 11º (revised by DL 49/2005); RCM 177/2008 artº 21º; RCM 182/2008 artº 8º.

<sup>111</sup> From 2009 onwards the limitation of residues burnt was removed (Circular / DSPFSV/ 08 from Directorate General of Agriculture and Rural Development -DGADR)

<sup>112</sup> “Modos de protecção e produção integrada” in the original in Portuguese.

Table 5.32 – Parameters and Emission Factor used to estimated CH<sub>4</sub> emissions from rice paddies in Portugal

Year	EF <sub>ct</sub> (kg CH <sub>4</sub> /ha/yr)	SF <sub>w</sub>	SF <sub>p</sub>	SF <sub>o</sub>	SF <sub>s</sub>	EF (kg CH <sub>4</sub> /ha/yr)
1990	198.90	0.60	0.68	1.96	1	159.24
1991	198.90	0.60	0.68	1.99	1	161.51
1992	198.90	0.60	0.68	2.01	1	163.31
1993	198.90	0.60	0.68	2.03	1	164.70
1994	198.90	0.60	0.68	2.05	1	166.32
1995	198.90	0.60	0.68	2.08	1	168.53
1996	198.90	0.60	0.68	2.08	1	169.20
1997	198.90	0.60	0.68	2.09	1	169.79
1998	198.90	0.60	0.68	2.09	1	169.50
1999	198.90	0.60	0.68	2.10	1	170.14
2000	198.90	0.60	0.68	2.34	1	190.26
2001	198.90	0.60	0.68	2.35	1	190.52
2002	198.90	0.60	0.68	2.34	1	189.56
2003	198.90	0.60	0.68	2.47	1	200.70
2004	198.90	0.60	0.68	2.86	1	231.70
2005	198.90	0.60	0.68	3.00	1	243.45
2006	198.90	0.60	0.68	2.93	1	238.17
2007	198.90	0.60	0.68	2.72	1	221.04
2008	198.90	0.60	0.68	2.68	1	217.23
2009	198.90	0.60	0.68	2.32	1	188.45
2010	198.90	0.60	0.68	2.34	1	190.05
2011	198.90	0.60	0.68	2.35	1	190.44
2012	198.90	0.60	0.68	2.36	1	191.55
2013	198.90	0.60	0.68	2.36	1	191.27

#### 5.5.4 Activity Data

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 5.20. 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.

#### 5.5.5 Uncertainty Assessment

The uncertainty in the adjusted seasonally integrated emission factor was considered to be 40 percent. For activity data, the standard deviation of inter-annual area under rice cultivation was considered: 34 per cent.

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

QA/QC procedures included a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report.

#### 5.5.7 Recalculations

The major changes between last year and this year submission, result from the application of the default parameters and emission factors defined in the IPCC 2006 Guidelines for this source category (3C), instead of the ones that were set in IPCC Good Practice Guidance.

The scaling factor related to water regime, SF<sub>w</sub>, has decreased (from 0.70 to 0.60) and a new scaling factor related to the pre- season water conditions, SF<sub>p</sub>; has been introduced (0.68) for the adjustment of the final emission factor, EF. Also important is the change in the calculation of the scaling factor related to organic amendments, SF<sub>o</sub>. The application of the new equation (5.3 of IPCC 2006) introduces an annual variation for SF<sub>o</sub> which did not happen when using the previous default values (table 4-2 of Good Practice Guidance).

Differences between submissions, 2014 and 2015, are shown on the figures below.

Figure 5.21 – Rice cultivation CH<sub>4</sub> emissions estimation (t CH<sub>4</sub>/yr), differences between submissions 2014 and 2015

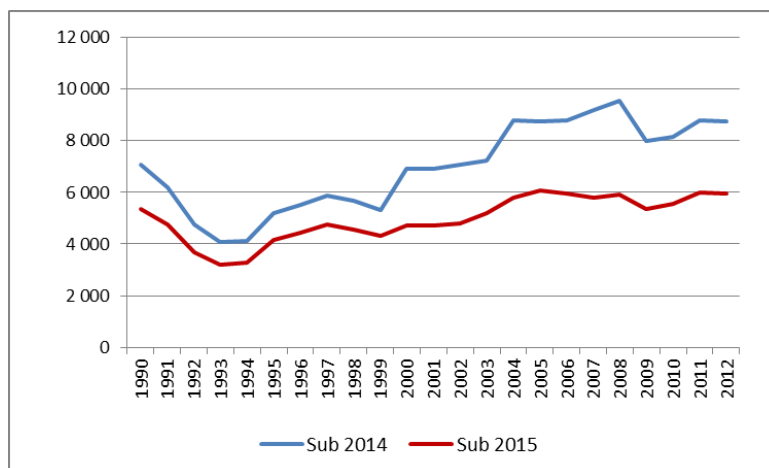
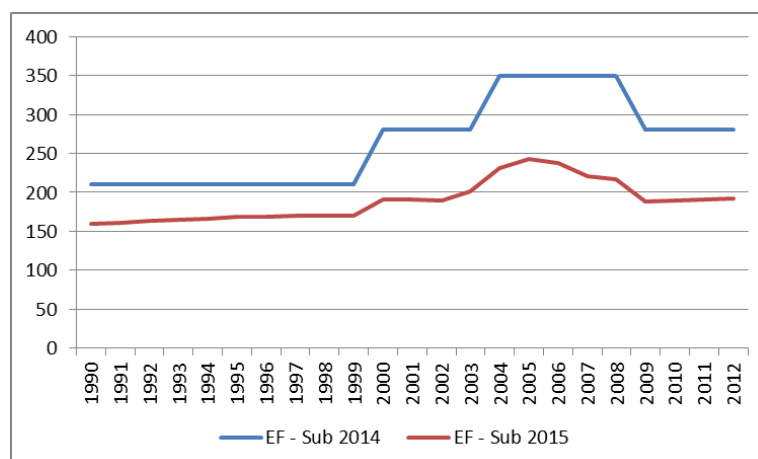


Figure 5.22 – Rice cultivation emission factors EF (kg CH<sub>4</sub>/ha/yr), differences between submissions, 2014 and 2015



#### 5.5.8 Further Improvements

No further improvements planned

### 5.6 N<sub>2</sub>O Emissions from Manure Management (CRF 3.Bb)

The estimates of total N<sub>2</sub>O emissions from manure management, direct and indirect emissions, are present in the table below. In the following chapters 5.6.1 – Direct N<sub>2</sub>O emissions from manure management and 5.6.2 – Indirect N<sub>2</sub>O emissions from manure management further details will be developed.

Table 5.33 – N<sub>2</sub>O emissions from manure management (kt)

Livestock type	1990	1995	2000	2005	2010	2011	2012	2013
<b>Direct emissions</b>	<b>0.47</b>	<b>0.46</b>	<b>0.49</b>	<b>0.42</b>	<b>0.41</b>	<b>0.40</b>	<b>0.40</b>	<b>0.39</b>
Dairy cattle	0.13	0.13	0.16	0.15	0.13	0.13	0.13	0.12
Non- dairy cattle	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.05
Sheep	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Swine	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Goats	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Horses	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mules and asses	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Poultry	0.14	0.14	0.17	0.13	0.15	0.15	0.15	0.15
Rabbits	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
<b>Indirect emissiona</b>	<b>0.37</b>	<b>0.36</b>	<b>0.38</b>	<b>0.32</b>	<b>0.31</b>	<b>0.31</b>	<b>0.31</b>	<b>0.30</b>
<b>Total</b>	<b>0.84</b>	<b>0.81</b>	<b>0.87</b>	<b>0.75</b>	<b>0.72</b>	<b>0.71</b>	<b>0.70</b>	<b>0.70</b>

### 5.6.1 Direct N<sub>2</sub>O emissions from manure management

#### 5.6.1.1 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 during manure application on soil and urine and dung deposited directly into soil by grazing are reported in the category N<sub>2</sub>O from managed soils (CRF 3D) following the UNFCCC reporting guidelines.

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).

In terms of the importance of each Manure Management System, observable in Figure 5.23, the great majority of emissions result from solid storage totalizing in 2013, 94.8 percent of direct N<sub>2</sub>O emissions from Manure Management. The remaining 5.2 percent N<sub>2</sub>O emissions are from liquid systems. There is no direct N<sub>2</sub>O emission estimates from manure managed in anaerobic lagoons because nitrification, which is a necessary prerequisite for the emission of N<sub>2</sub>O from stored animal manure, does not occur under anaerobic conditions. In terms of origin by animal type, emissions are dominated by poultry (38.9 percent) and dairy cattle (31.7 percent) which together comprehend about 70.6 percent of total emissions, as may be seen in Figure 5.24 for the year 2013.

Figure 5.23 – Distribution of direct N<sub>2</sub>O emissions from Manure Management per System in year 2013

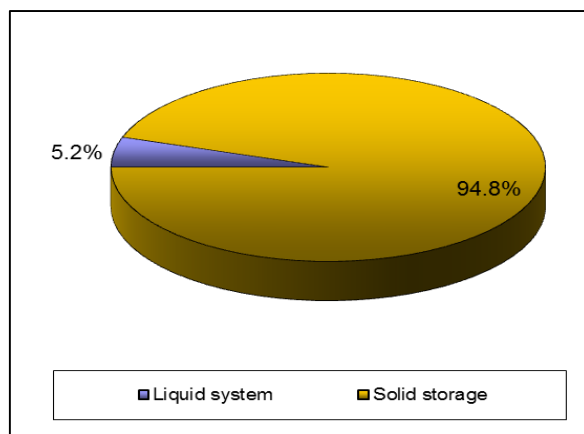
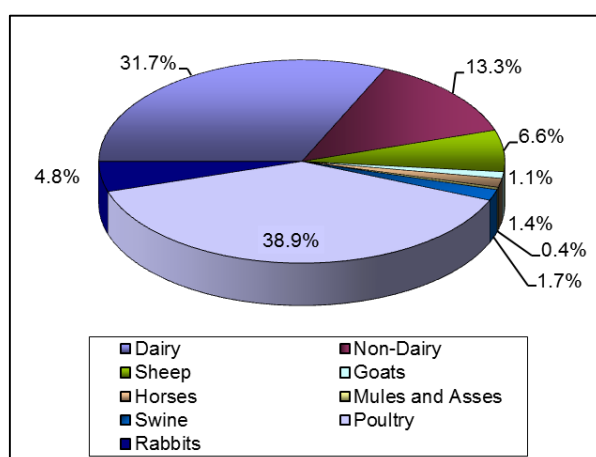


Figure 5.24 – Distribution of direct N<sub>2</sub>O emissions from manure managed per livestock category in year 2013



#### 5.6.1.2 Methodology

Direct N<sub>2</sub>O emissions from manure for each Manure Management System (MMS) were estimated from the following formula:

$$EN_{2O(s)} = \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)} * 44/28$$

where,

EN<sub>2O(s)</sub> - N<sub>2</sub>O emissions from manure in Manure Management System s;

s - Manure Management System;

i - Animal/species category of livestock;

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;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  that is managed in Manure Management System  $s$ ;

$EF3_{(s)}$  -  $N_2O$  emission factor for Manure Management System  $s$  (kg  $N_2O$ -N/kg N).

Total  $N_2O$  emissions result from the sum of the estimated emissions for each manure management system considered. This formulation follows the one proposed in IPCC 2006 (equation 10.25).

Manure Management Systems are the same that were used to estimate methane emissions from manure management Systems (Table 5.25 of chapter 5.4 of this report).

Table 5.34– Classification of Manure Management Systems in Portugal

MMS	CRF classification
Anaerobic Lagoon	Uncovered Anaerobic Lagoon
Tank, Pit storage (< 1 month)	Liquid System
Solid Storage	Solid Storage

$N_2O$  emissions from manure deposited in soil during grazing (Pasture Range and Paddock) are further discussed in 5.7- “Direct  $N_2O$  Emissions from agricultural soils”.

Parameters  $N_{(i)}$ ,  $Nex_{(i)}$  and  $MS_{(i,s)}$  will be discussed under “activity data” and  $EF3_{(s)}$  will be discussed as “emission factor”.

#### 5.6.1.3 Emission Factors

$N_2O$  emission factors are presented in next table for all MMS (although the uses of daily spread, use for fuel and other systems are not considered in the Portuguese inventory). These emission factors are the default IPCC 2006 emission factors (table 10.21) because there are no country-specific emission factors.

Table 5.35 –  $N_2O$  from Manure Management: Emission Factors per Manure Management System

MMS	$EF_3$ (kg $N_2O$ -N/kg N)
Uncovered Anaerobic Lagoon	0.000
Liquid Systems: Tank, Open Pit	0.002
Solid Storage	0.005

#### 5.6.1.4 Activity Data

Livestock population numbers used to estimate total nitrogen excretion are the same that were also used to estimate emissions of  $CH_4$  from Enteric Fermentation and  $CH_4$  from Manure Management, and which were already presented in the chapter concerning  $CH_4$  emissions from Enteric Fermentation.



The quantity of nitrogen excreted (Nex) per head results from expert information provided by the Ministry of Agriculture<sup>113</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 5.37) were established on the basis of the nitrogen excretion 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>114</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.

#### **a) Dairy Cattle Nex**

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 percent for every 1000 kg less of milk production;
- The Nex increases 2 percent for every 1000 kg extra of milk production.

Milk production and Nex are presented in Table 5.36.

<sup>113</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>114</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 5.36 – 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	117.7
2013	8000	117.3

#### *b) Final Nex for all livestock categories*

The following table presents the nitrogen excretion rates applied in the estimation of N<sub>2</sub>O from Manure Management and the defaults Nex, estimated with equation 10.30 as proposed in the IPCC 2006. There is an acceptable agreement between country-specific values and IPCC defaults for all species other than sheep and goats. 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 5.37 – N excretion rate per head and by animal species/category (Nex)**

		Nex			
Animal Class	Animal sub class	Country Specific (kg N/animal/yr)	IPCC Default		
			Typical animal mass (average) (Kg) *	kg N /1000 kg animal mass/day	Kg N/ animal/yr
Dairy-cattle	Dairy Cows	117.30**	600	0.48	105.12
Non-dairy cattle	Beef calves (<1 yr)	25.00	407	0.33	49.02
	Calfs, Males for Rep. (<1 yr)				
	Calfs, Females for Rep. (<1 yr)				
	Males 1-2 yrs	40.00			
	Beef Fem. 1-2 yrs				
	Females for R. 1-2 yrs				
	Steers (>2 yrs)	41.00			
	Heifers for Beef (>2 yrs)	55.00			
	Heifers for Rep. (>2 yrs)				
	non-dairy cows	80.0			
Swine	Piglets (<20 kg)	0.00	65	0.51	12.10
	Fat. Pigs (20-50 kg)	9.00			
	Fat Pigs (50-80 kg)	13.00			
	Fat Pigs (80-110 kg)				
	Fat Pigs (> 110 kg)				
	Boars (>50 kg)	18.0	205	0.42	31.43
	Sows, pregnant	20.0			
	Sows, non-pregnant	42.0			
Sheep	Ewes	9.17	54	0.85	16.75
	Other Ovines	6.60			
	Lambs	0.00			
Goats	Does	7.00	30	1.28	14.02
	Other Caprines	6.60			
	kids	0.00			
Equides	Horses	44.0	550	0.26	52.20
	Asses, Mules and hynies	22.0	245		23.25
Poultry	Hens Reproductive	0.34	1.8	0.96	0.63
	Hens eggs	0.80			
	Broilers	0.45	0.9	1.10	0.36
	Turkeys	1.40	6.8	0.74	1.84
	Other Poultry	0.45	2.7	0.83	0.82
Other	Rabbits	9.00	-	-	8.10

\*Average weight in the time series; \*\* The Nex value for dairy-cattle associated with Sub 2015 represents the value for latest year reported in that submission (2013).

Values for piglets (<20kg), lambs and caprine kids, are 0 kg N/hd/yr because the Nex is included with their respective mothers:

The total quantity of nitrogen in manure produced (including deposition on pasture) per animal type, and its annual variation in the period 1990 to 2013, is presented in the Annex G – Agriculture. For the year of 2013 the distribution of N manure by manure management system and deposition on pasture is shown in Figure 5.25. The major contributors to total nitrogen from livestock manure in Portugal in 2013 were non-dairy cattle and dairy cattle, as may be seen in Figure 5.26 .

Figure 5.25 – Distribution of total Nitrogen in manure produced in 2013 (%)

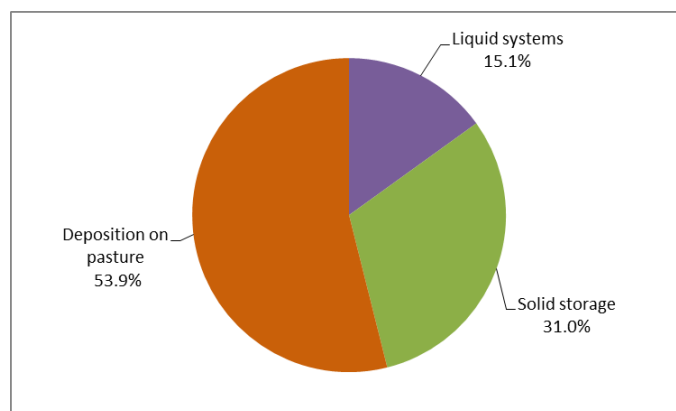
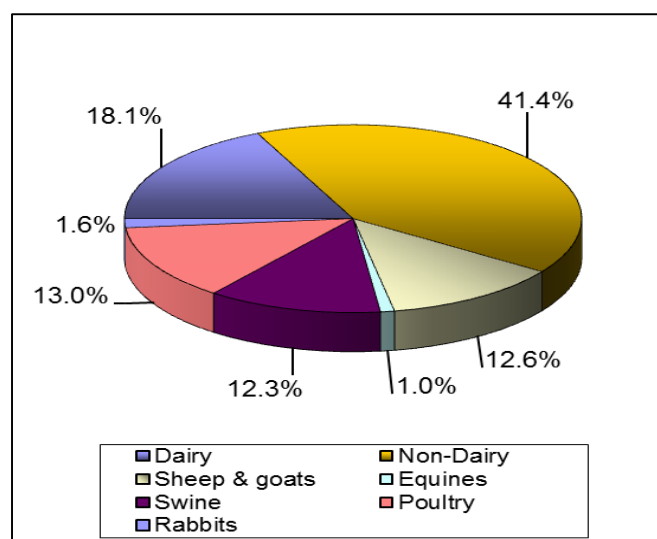


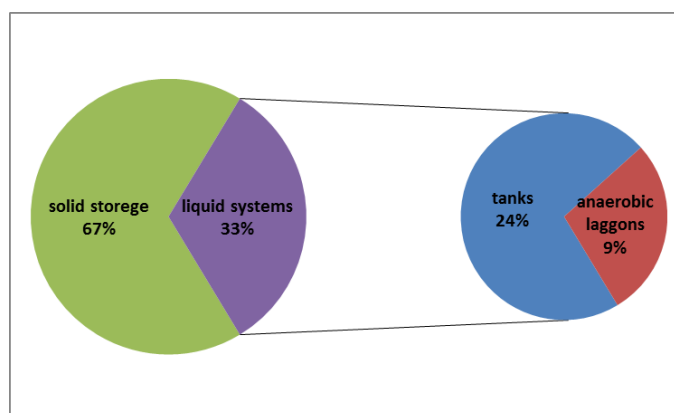
Figure 5.26 – Origin of total nitrogen in manure produced in 2013, per animal type



The N<sub>2</sub>O emissions estimates from urine and dung directly deposited on pasture are included in chapter 5.7 – “N<sub>2</sub>O Emissions from managed soils” and so the annual amount of nitrogen that constitutes activity data for estimation of those emissions will be further discussed there.

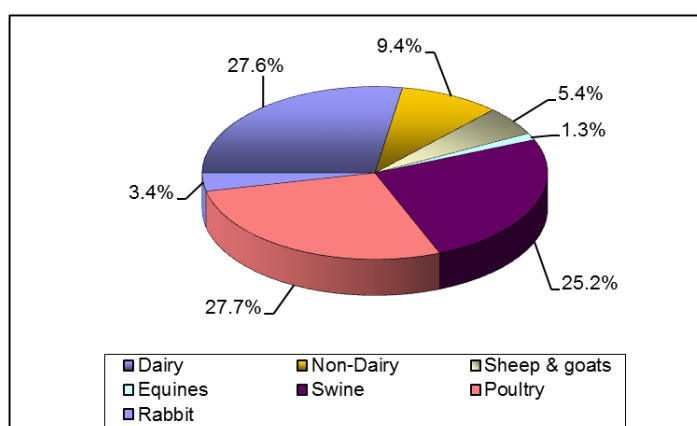
The percentage of nitrogen in manure stored and treated, per manure management system, is presented in the next figure for the year 2013.

Figure 5.27 – Share of nitrogen in manure per MMS, in 2013



The major contribution for stored and treated manure in 2013, were poultry, dairy cattle and swine as it is shown in figure below.

Figure 5.28 – Origin, by livestock class, of nitrogen in manure stored and treated in 2013



The percentage of manure that is attributed to each Manure Management System and to deposition on pasture was established in a coherent mode with the share considered for CH<sub>4</sub> emissions from Manure Management (Table 5.25 and Table 5.26 of this report).

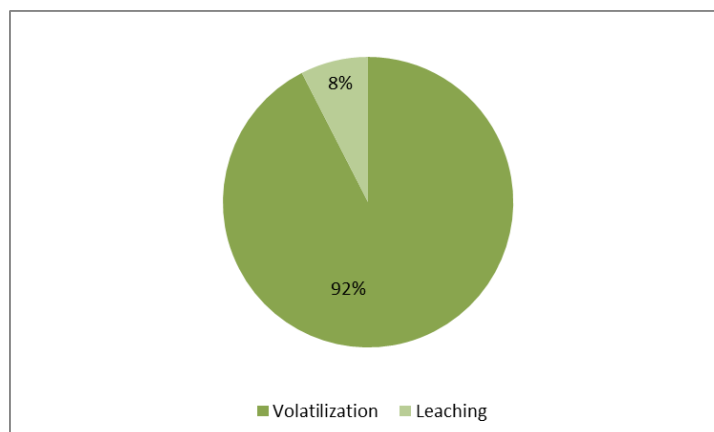
## 5.6.2 Indirect N<sub>2</sub>O emissions from manure management

### 5.6.2.1 Overview

Indirect N<sub>2</sub>O emissions result from volatile nitrogen losses, in forms of NH<sub>3</sub> and NO<sub>x</sub>, during manure collection and storage and from nitrogen lost through runoff and leaching into soil from solid storage of manure. Nitrogen losses begin at the point of excretion on houses and continue through on site management in storage systems.

The contribution of N losses from volatilization and from leaching and runoff to indirect N<sub>2</sub>O emissions from manure management is shown in figure below for the 2013 year

Figure 5.29 – Relative importance of the losses of volatile nitrogen and of nitrogen leached in total indirect  $N_2O$  emissions



#### 5.6.2.2 Methodology

Indirect  $N_2O$  emissions were estimated with equation 10.27 (IPCC 2006), in the case of the N lost due to volatilisation, and with equation 10.29 (IPCC 2006) for the indirect  $N_2O$  emissions due to N manure leached from manure management systems.

#### 5.6.2.3 Emission factors

Emission factors used were the default emission factors,  $EF_4$  (volatilisation) and  $EF_5$  (leaching), both from table 11.3 of IPCC 2006.

#### 5.6.2.4 Activity data

The amount of N that is lost due to volatilisation, in form of  $NH_3$  and  $NO_x$ , during animal housing and storage and treatment of the manure, was estimated using mass flow approach described in the EMEP/EEA Guidebook 2013, in coherence with UNECE/CLRTAP emission inventory.

Portugal has no country specific value for the N fraction leached into soil from solid storage manure, therefore, based on what is described in the note b) of table 10.23 (IPCC 2006), a leached fraction for solid storage systems was derived from the default values of tables 10.23 and 10.22 (IPCC 2006) in combination. Per animal category, the fraction leached was obtained subtracting to the total N losses fraction (losses N volatile + loss N from leaching and runoff) of table 10.23 the N loss fraction due to volatilisation from table 10.22 for the same animal category. The final leached fractions considered by animal category are presented in table below.

Table 5.38 – Estimates of the fraction leached from solid storage manure, by animal category

	Total N loss ( $Fra_{LossMS}$ , table 10.23)	N loss due to volatilization ( $Frac_{GasMS}$ , table 10.22)	N loss through leaching ( $N_{leaching}$ )
Dairy cattle	40%	30%	10%
Other cattle	50%	45%	5%
Swine	50%	45%	5%
Poultry	55%	55%	0%
Other*	15%	12%	3%

\*Other includes sheep, goats, horses, asses & mules and rabbits

The amount of N lost due to volatilisation and due to leaching and runoff for the time series is presented in the next table.

Table 5.39 – Amount of N lost due to volatilisation (NH<sub>3</sub>+NO<sub>x</sub>) and leaching during animal housing and manure storage (t N/yr)

Year	Volatilisation	Leaching
1990	21 965	2 095
1991	21 480	2 104
1992	21 391	2 083
1993	21 285	2 051
1994	21 222	2 083
1995	21 097	2 142
1996	20 765	2 176
1997	20 708	2 181
1998	21 048	2 198
1999	22 013	2 318
2000	22 281	2 364
2001	21 722	2 315
2002	20 919	2 305
2003	19 875	2 203
2004	19 354	2 202
2005	18 991	2 235
2006	18 597	2 218
2007	18 219	2 167
2008	18 338	2 146
2009	18 680	2 129
2010	18 232	2 090
2011	18 186	2 030
2012	18 033	1 989
2013	17 908	1 946

### 5.6.3 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 IPCC 2006 for default N-excretion rates (50 percent) 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 IPCC 2006, 100 per cent for all MMS.

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

For this source category QA/QC procedures consisted only on the comparison between inventory Nex values and the corresponding IPCC default (Table 5.37).

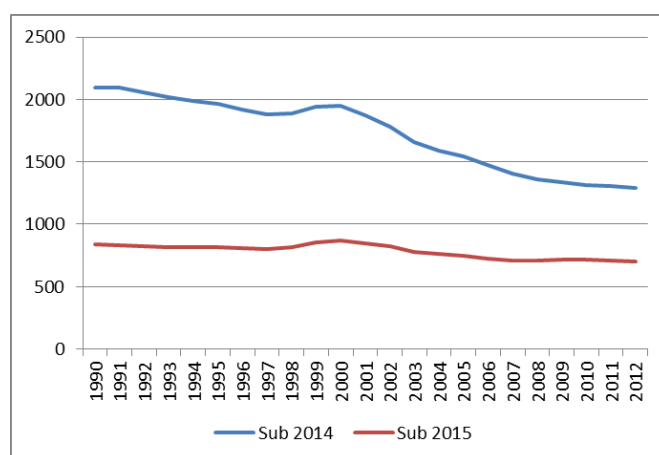
### 5.6.5 Recalculations

The major changes between last year and this year submission, result from the application of the methodologies and emission factors defined in the IPCC 2006 Guidelines to estimate direct and indirect N<sub>2</sub>O emissions from Manure Management Systems, instead of the ones that were set in previous IPCC Good Practice Guidance and Reference Manual.

Also, the implementation, for the first time, of the N-flow approach to estimate ammonia and nitrous oxide emissions from manure management, following the methodology of the EMEP/EEA Guidebook 2013, has influenced the estimates N<sub>2</sub>O indirect emissions from manure management.

Differences between submissions, last year and this year, are shown in the figure below

Figure 5.30 – Total N<sub>2</sub>O emissions from manure management systems, differences between 2014 and 2015 submission (t N<sub>2</sub>O)



The main drivers that contributed to the decrease of N<sub>2</sub>O emissions estimates were the changes of the following default emission factors

- Solid storage – previously (Revised IPCC 1996 & GPG) EF<sub>3</sub> was set 0.02 kg N<sub>2</sub>O-N/kg N excreted and now (IPCC 2006) default EF<sub>3</sub> equal to 0.005 kg N<sub>2</sub>O-N/kg N excreted. Portugal has a great percent of manure managed in this type of system and therefore the strong reduction (75%) on the EF<sub>3</sub> default value has an enormous impact in the N<sub>2</sub>O emissions estimates. The impact is bigger in the first decade of the time series because the percent of manure managed as solid storage was higher than in recent years (see Table 5.25 and Table 5.26);
- Anaerobic Lagoon - previously (Revised IPCC 1996 & GPG) EF<sub>3</sub> was set 0.001 kg N<sub>2</sub>O-N/kg N excreted and now (IPCC 2006) default EF<sub>3</sub> equal to 0 kg N<sub>2</sub>O-N/kg N excreted. Not so relevant but nevertheless with some impact in the N<sub>2</sub>O emissions of pig manure management;
- Leaching – EF<sub>5</sub> previous default value (Revised IPCC 1996 & GPG) was 0.025 kg N<sub>2</sub>O-N/kg N leached and the new default value (IPCC 2006) is 0.0075 kg N<sub>2</sub>O-N/kg N leached, which represents a significant reduction of the emission factor.



Not related with emission factors but also contributing to the differences between submissions, was the calculation revision of the fraction leached as described before (sub chapter 5.6.2.4 – Activity data of Indirect N<sub>2</sub>O emissions from manure management), in line with the IPCC revision of this issue, i.e., the N losses due to leaching from manure management systems.

### 5.6.6 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.

## 5.7 N<sub>2</sub>O Emissions from Managed Soils (CRF 3.D)

The estimates of total N<sub>2</sub>O emissions from managed soils, direct and indirect emissions, are present in the table below. In the following chapters 5.7.1 – Direct N<sub>2</sub>O emissions from managed soils and 5.7.2- Indirect N<sub>2</sub>O emissions from managed soils further details will be developed.

Table 5.40 – N<sub>2</sub>O emissions from managed soils (kt)

Gas/Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>Direct emissions</b>	<b>6.15</b>	<b>5.94</b>	<b>6.56</b>	<b>5.38</b>	<b>5.32</b>	<b>5.30</b>	<b>5.53</b>	<b>5.82</b>
Synthetic fertilizers	2.49	2.29	2.67	1.61	1.58	1.49	1.71	1.91
Organic Fertilizers	1.03	1.01	1.02	0.85	0.81	0.81	0.81	0.80
Urine and dung deposited by grazing animals	1.81	1.92	2.18	2.29	2.36	2.35	2.35	2.34
Crop residues	0.82	0.72	0.69	0.63	0.57	0.65	0.67	0.78
<b>Indirect emission</b>	<b>1.71</b>	<b>1.63</b>	<b>1.78</b>	<b>1.36</b>	<b>1.31</b>	<b>1.33</b>	<b>1.40</b>	<b>1.48</b>
<b>Total</b>	<b>7.85</b>	<b>7.58</b>	<b>8.34</b>	<b>6.74</b>	<b>6.63</b>	<b>6.63</b>	<b>6.93</b>	<b>7.30</b>

Note: Totals may not sum due to independent rounding

### 5.7.1 Direct N<sub>2</sub>O emissions from managed soils

#### 5.7.1.1 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. Nitrous oxide 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 N fertilizers;
- application of organic N as fertilizer (animal manure and sewage sludge);

- urine and dung deposited on pasture, range and paddock; by grazing animals;
- N input from incorporation of crop residues into soils;

Most effort was placed to make estimates of this source fully consistent in what concerns:

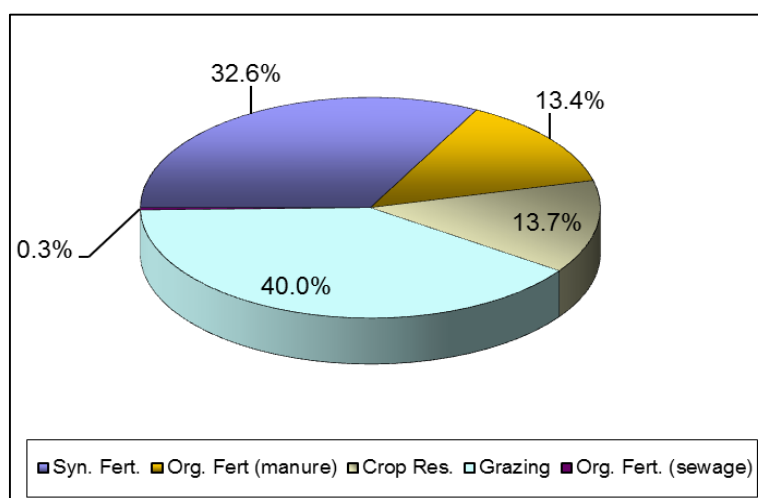
- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources:  $N_2O$ ,  $CH_4$  and  $NH_3$ .

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.

$N_2O$  emissions from N mineralisation associated with loss of soil organic matter resulting from change of land use are not estimated here but in LULUCF chapter.

The comparative importance of the several sub-source activities for 2013 to direct  $N_2O$  emissions from managed soils is shown in Figure 5.31, from where it is evident the major contribution from direct deposition of urine and dung on pasture (Grazing) 40.0 percent and synthetic fertilizers (Syn. Fert.) with 32.6 percent, which may be considered significant sources in accordance with the IPCC rule of thumb. Crop residues (Crop Res) source is responsible for 13.7 percent and organic fertilizers (Org. Fer. manure + sewage sludge) are also an important source, representing 14.0 percent of the direct  $N_2O$  emissions from managed soils.

Figure 5.31– Contribution of the various sub-sources to total  $N_2O$  emissions from direct managed soil emissions in 2013



### 5.7.1.2 Methodology

The approach used to estimate direct N<sub>2</sub>O emissions from managed soils follow the IPCC 2006 Tier 1 methodology with country specific activity data.

Final N<sub>2</sub>O emissions are estimated with a formulation derived from equation 11.1 of IPCC 2006:

$$\begin{aligned} \text{EN}_{2\text{O Direct}} &= (\text{N}_{2\text{O}} - \text{N}_{\text{N inputs}} + \text{N}_{2\text{O}} - \text{N}_{\text{N prp}}) * 44/28 \\ \text{N}_{2\text{O}} - \text{N}_{\text{N inputs}} &= (\text{F}_{\text{SN}} + \text{F}_{\text{AM}} + \text{F}_{\text{SEW}} + \text{F}_{\text{CR}}) * \text{EF}_1 \\ \text{N}_{2\text{O}} - \text{N}_{\text{N prp}} &= (\text{F}_{\text{prp, cpp}} * \text{EF}_{3 \text{ prp, cpp}}) + (\text{F}_{\text{prp, so}} * \text{EF}_{3 \text{ prp, so}}) \end{aligned}$$

where:

$\text{EN}_{2\text{O Direct}}$  – total direct emission of N<sub>2</sub>O from managed soils, kg N<sub>2</sub>O/yr

$\text{N}_{2\text{O}} - \text{N}_{\text{N inputs}}$  – annual direct N<sub>2</sub>O-N emissions from N inputs to managed soils, kg N<sub>2</sub>O-N/yr

$\text{N}_{2\text{O}} - \text{N}_{\text{N prp}}$  – annual direct N<sub>2</sub>O-N emissions from urine and dung directly deposited by grazing animals, kg N<sub>2</sub>O-N/yr

44/28 – conversion of N<sub>2</sub>O-N emissions to N<sub>2</sub>O emissions.

$\text{F}_{\text{SN}}$  - annual amount of synthetic fertilizer nitrogen applied to soils, kg N/yr

$\text{F}_{\text{AM}}$  - annual amount of animal manure nitrogen applied to soils, kg N/yr

$\text{F}_{\text{SEW}}$  – annual amount of nitrogen in sludge applied to agriculture soils, kg N/yr

$\text{F}_{\text{CR}}$  – annual amount of nitrogen in crop residues returned to soils, kg N/yr

$\text{EF}_1$  - emission factor for N<sub>2</sub>O emissions from N inputs to soil, kg N<sub>2</sub>O-N/kg N input

$\text{F}_{\text{prp, cpp}}$  – annual amount of urine and dung N deposited by grazing cattle, poultry and pigs (cpp) on pasture, kg N /yr

$\text{F}_{\text{prp, so}}$  - annual amount of urine and dung N deposited by grazing sheep and other animals (so) on pasture, kg N /yr

$\text{EF}_{3 \text{ prp, cpp}}$  - emission factor for N<sub>2</sub>O emissions from urine and dung N deposited by grazing animals (cpp) on pasture, kg N<sub>2</sub>O-N/kg N input

$\text{EF}_{3 \text{ prp, so}}$  - emission factor for N<sub>2</sub>O emissions from urine and dung N deposited by grazing animals (so) on pasture, kg N<sub>2</sub>O-N/kg N input.

### 5.7.1.3 Emissions factors

The emissions factors used for N<sub>2</sub>O emissions from N<sub>inputs</sub> to soil ( $\text{EF}_1$ ) and for N<sub>2</sub>O emissions from urine and dung N deposited by grazing animals on pasture ( $\text{EF}_{3 \text{ prp, cpp}}$  and  $\text{EF}_{3 \text{ prp, so}}$ ) were the default values of IPCC 2006, table 11.1.

In the next table are shown the values used for  $\text{EF}_1$ ,  $\text{EF}_{3 \text{ prp, cpp}}$  and  $\text{EF}_{3 \text{ prp, so}}$ .

Table 5.41 – Emission Factors used to estimate direct N<sub>2</sub>O emissions from managed soils

Emission Factor	Value (Kg N <sub>2</sub> O-N/kg N <sub>input</sub> )
EF <sub>1</sub>	0.01
EF <sub>3 prp, cpp</sub>	0.02
EF <sub>3 prp, so</sub>	0.01

#### 5.7.1.4 Activity data

The estimated quantities of nitrogen added to agricultural soils from each specific source, that are activity data for determining direct N<sub>2</sub>O emissions, are shown in Table 5.42 and in Annex G – Agriculture for the complete time series.

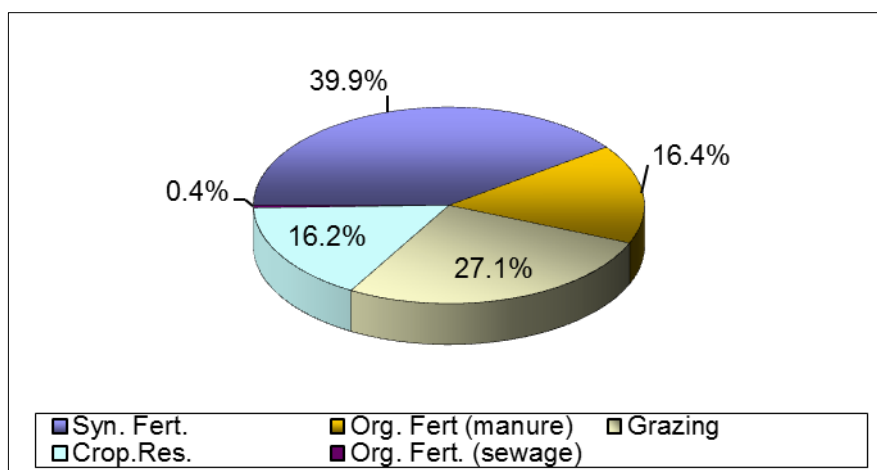
Total nitrogen added to soil was in 2013 about 12.3 per cent lower than what it was applied in 1990.

Table 5.42 - Total amounts of Nitrogen (t N/yr) added to managed soils: activity data for direct N<sub>2</sub>O emissions

Sources	1990	1995	2000	2005	2010	2011	2012	2013
Synthetic Fertilizer	158 500	145 815	170 009	102 663	100 249	95 088	108 526	121 413
Organic Fertilizer (manure)	65 327	64 153	64 930	53 591	51 227	50 806	50 243	49 791
Pasture	70 561	74 447	82 538	83 729	84 102	83 360	83 065	82 295
Crop Residues	52 258	45 925	43 685	40 017	36 214	41 392	42 558	49 404
Organic Fertilizer (sewage)	319	319	263	366	491	682	1 087	1 285
<b>Total</b>	<b>346 965</b>	<b>330 660</b>	<b>361 426</b>	<b>280 367</b>	<b>272 284</b>	<b>271 329</b>	<b>285 479</b>	<b>304 188</b>

For the last year in the inventory there are two categories that represent the majority of nitrogen added to soil: Synthetic Fertilizers (39.9 per cent) and direct droppings during grazing in Pasture (27.1 per cent) as shown in next figure.

Figure 5.32 – Sources of direct input of Nitrogen to agricultural soil in 2013



#### 5.7.1.4.1 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 communitarian 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>115</sup> and ADP<sup>116</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:

$$ACFA = \text{Prod} + \text{Imports} - \text{Exports}$$

Where Prod is the annual quantity of nitrogen fertilizers produced (excluding consumption in industry), and is based on the IAPI census<sup>117</sup>. Data of Imports and Exports are 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 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). 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, (158 500 t N/yr) was applied for all lacking years (1990-1994).

It is important to highlight the availability, for the first time, of the activity data for the inventory year 2013. This was an improvement that was been planned with INE, i.e, to have the fertilizer data for the year of the inventory which was not possible in previous submissions.

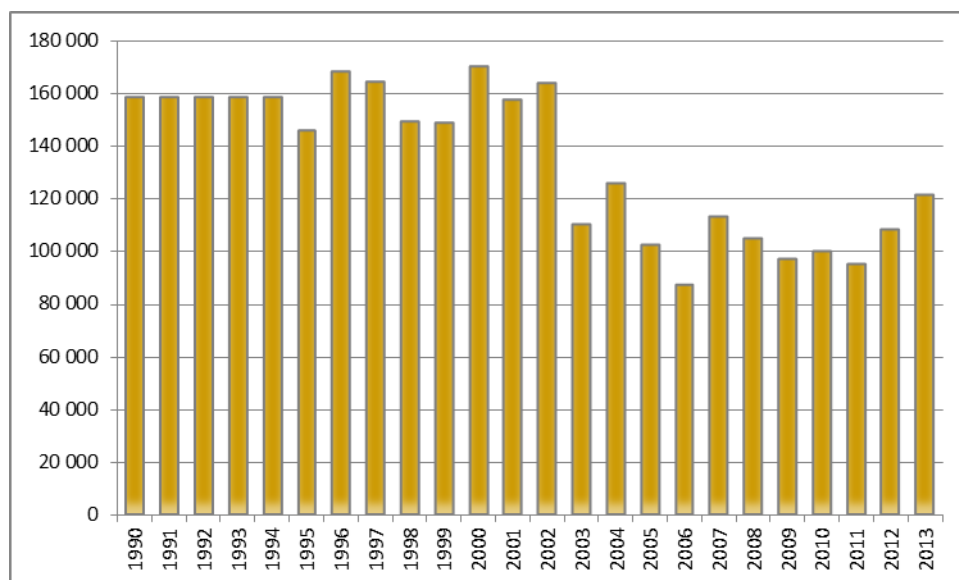
The available time series is presented in Figure 5.33. It shows a period until 2002 with a higher consumption of synthetic fertilizers and then a sharp decrease in 2003 closely linked with the significant change, at that time, of the direct support schemes under the common agricultural policy (Council Regulation (EC) No 1782/2003). The annual fluctuations are mainly connected with the different climatic conditions occurring each year, which may constrain production management decisions, for example carrying out the sowing of some crops.

<sup>115</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>116</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>117</sup> Annual census made to the Manufacturing Industry, by INE.

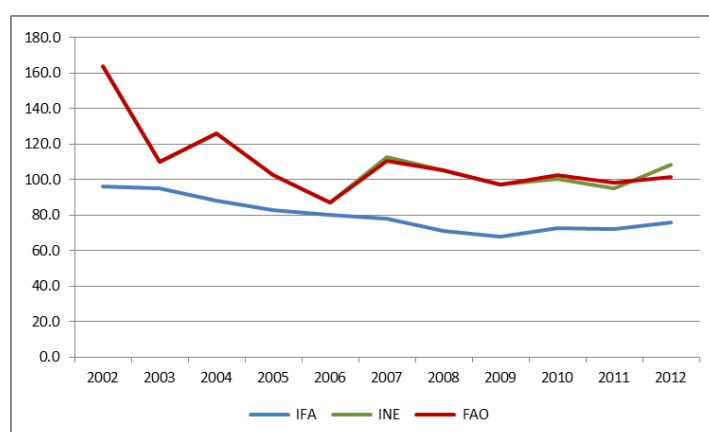
Figure 5.33- Use of Nitrogen Fertilizers (t N/yr) in Portugal, estimated from INE data (1995-2013) - Using a simple average value for 1990-1994.



In Annex G – Agriculture is also presented the annual amount of N synthetic fertilizer, disaggregated by type of N fertilizer, for the complete time series.

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<sup>118</sup> (<http://www.fertilizer.org/ifa/ifadata/search>) databases for the period 2002 – 2012. For previous years (1990-2001) FAO database archive has remarks in all figures highlighting that they are unofficial. In both database, FAO and IFA, 2012 is the last year available. Comparison results are shown in Figure 5.34.

Figure 5.34 – Data bases comparison of N inorganic fertilizers use



FAO and INE series agree quite well. The difference for 2012 is due to a recent INE update (December 2014) to the previous value that should then be transmitted by Eurostat to FAO, what apparently has not been done yet.

<sup>118</sup> International Fertilizers Association

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 when comparing with base year, 1990.

#### 5.7.1.4.2 Animal Manure applied to soil

The amount of managed manure nitrogen available for application to soil as fertilizer was estimated based on the equation 10.34 (IPCC 2006). In Table 5.44 are presented the final results of the estimates of the N manure from housing and storage systems available for application to managed soils. The use of manure for feed, fuel or construction purposes is not known in Portugal.

In the total N losses from manure management systems ( $Frac_{LossMS}$ ) are considered the losses of N in form of  $NH_3$ ,  $NO_x$ ,  $N_2O$  and  $N_2$  that occur at housing and storage systems and the N loss through leaching from solid storage. The N input from organic bedding material (straw) was also considered for solid storage systems, based on the default values of table 3-6 of EMEP/EEA Guidebook 2013, (page 21), and are shown in table below.

Table 5.43 – Average amount of straw use in animal bedding – solid manure management systems and N content of straw

Animal type	Straw (kg/hd/yr)	N added in straw (kg/hd/yr)
Dairy cattle	1596.9	6.4
Other cattle	486.0	1.9
Sheep & goats	47.7	0.2
Sows	567.8	2.3
Other swine	1902.6	0.8
Horses & asses	608.3	2.4

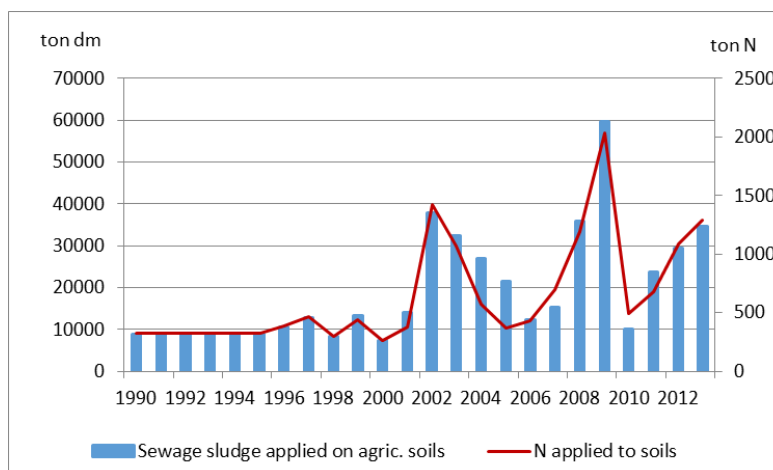
Table 5.44 – Estimates of the amount of manure managed nitrogen available for application to soils (t N/yr)

Year	N_ manure managed MS	N_ bedding MS	N_ total losses MS	Nms_ available for application to soils
1990	89 659	1 895	26 227	65 327
1991	90 473	1 784	25 722	66 535
1992	89 690	1 770	25 574	65 886
1993	88 917	1 783	25 372	65 328
1994	88 342	1 774	25 372	64 744
1995	87 742	1 785	25 373	64 153
1996	86 267	1 781	25 092	62 956
1997	85 647	1 769	24 971	62 445
1998	86 379	1 752	25 240	62 891
1999	89 507	1 732	26 356	64 883
2000	89 930	1 690	26 690	64 930
2001	87 139	1 623	26 091	62 671
2002	83 600	1 556	25 396	59 759
2003	79 144	1 505	24 260	56 389
2004	77 039	1 492	23 798	54 734
2005	75 658	1 478	23 545	53 591
2006	73 974	1 458	23 093	52 339
2007	72 066	1 422	22 561	50 927
2008	71 792	1 395	22 586	50 601
2009	72 277	1 368	22 873	50 772
2010	72 248	1 247	22 268	51 227
2011	71 713	1 202	22 109	50 806
2012	70 961	1 169	21 887	50 243
2013	70 333	1 141	21 683	49 791

#### 5.7.1.4.3 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 5.35 – Application of sewage sludge (ton dm/yr) and quantities of N (ton N) applied in agriculture soils





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.

Table 5.45 – Estimates of annual amounts of N sewage sludge applied in agriculture soils

	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
<b>Total N</b>	ton N	319	319	319	319	319	319	386	467	301	440	263	377

	Unit	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
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	34 651
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	0.0371
<b>Total N</b>	ton N	1 419	1 072	567	366	429	693	1 191	2 035	278	663	1 082	1 285

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.

#### 5.7.1.4.4 Urine and dung from grazing animals

Total amount of urine and dung N deposited on pasture by grazing animals was estimated with the same N excretion rates and disaggregated livestock population that were used to estimate N<sub>2</sub>O emissions from Manure Management (CRF 3Bb). The fraction of total annual N excretion deposited on pasture for each livestock species are presented in Table 5.25 and Table 5.26 of this report, along with the fraction of manure handled in other manure management systems considered in the Portuguese inventory.

The results of the calculation using equation 11.5 of IPCC 2006 are presented in Table 5.42 above and in the Annex G – Agriculture for the complete time series.

#### 5.7.1.4.5 Crop Residues returned to soil

The annual amount of N in crop residues (above and below ground) that returned to soils was estimated according to the equation 11.7A of IPCC 2006. The regression equations of table 11.2 of IPCC 2006 were used for the major crops.

Annual crop production (fresh) and area harvested, allowing the estimate of crop yield, was supplied by INE for the major crops.

Country specific data were used for the values of the fraction of crop that is harvested /removed from the fields (Frac<sub>remove</sub>) and for the percent of crop area with residues burnt *in situ* (Area<sub>burnt</sub>), according to the INE information, based on data from the last Agricultural General Census (RA09) which included a set of questions about some agricultural practices. On chapter 5.8 – Field burning of agricultural residues further details are given about crop residues burnt on field.

Whenever data for Frac<sub>remove</sub> are not available it was assumed no removal, according to IPCC 2006 recommendation.

Country specific data were also used for dry matter fraction (dmf) of harvested crop<sup>119</sup> for some legumes and N content of above ground residues (N<sub>AG</sub>) for cereals, potatoes and some legumes.<sup>120</sup> When national values are not available default values were used (table 11.2 IPCC 2006). In the same way, default values were used for the ratio of below – ground residues to above – ground biomass (R<sub>BG-BIO</sub>) and for N content of below-ground residues (N<sub>BG</sub>).

Table 5.46 – Parameters used to estimate nitrogen from crop residues returned to soil

Crop	dmf	FracRemoved	N <sub>AG</sub> (kg N/kg dm)	R <sub>BG-BIO</sub> (ratio)	N <sub>BG</sub> (kg N/kg dm)
Wheat	0.89	0.67#	0.0057#	0.24	0.009
Triticale	0.88	0.67#	0.0085#	0.22	0.009
Maize grain	0.87	0.65#	0.0095#	0.22	0.007
Barley	0.89	0.67#	0.0045#	0.22	0.014
Rye	0.88	0.67#	0.0085#	0.22	0.011
Oats	0.89	0.67#	0.0056#	0.25	0.008
Rice	0.89	year specific*	0.0088#	0.16	0.009
Other cereals	0.88		0.0060	0.22	0.009
Sunflower	0.87		0.0103#	0.22	0.009
Potatoes	0.19#		0.0142#	0.20	0.014
Other tubers	0.22		0.0190	0.20	0.014
Peas fresh	0.11#		0.1818#	0.19	0.008
Beans fresh	0.10#		0.0190	0.19	0.008
Dry beans	0.88		0.1000	0.19	0.008
Broad beans	0.89#		0.0337#	0.19	0.008
Peanuts	0.94		0.0160	0.19	0.008
Other legumes	0.91		0.0080	0.19	0.008
Tomatoes	0.06#		0.0190	0.20	0.009
Maize for forage	0.30#	0.91«	0.0060	0.22	0.012
Sorghum for forage	0.30#	0.91«	0.0070	0.22	0.012
Other forage	0.90	0.91«	0.0270	0.40	0.019

# Country specific; « Jarrige (1988); \* description at chapter 5.5 – rice cultivation

The annual crop yield (fresh) is presented in Table 5.47. The final amounts of Nitrogen added to soil from crop residues returned to soil are shown in Table 5.42 and in Annex G – Agriculture for the complete time series.

<sup>119</sup> In “Manual de Culturas Hortícolas”, Volume I e II de Domingos Almeida

<sup>120</sup> CBPA -Código das Boas Práticas Agrícolas. Agriculture Good Practice Code concerning the protection of waters against pollution caused by nitrates from agricultural sources, approved by the Ministry of Agriculture

**Table 5.47 – Crop Yield \_Fresh (kg/ha)**

<b>Crop</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
Wheat	1 858	1 679	1 366	1 504	1 430	1 200	1 077	1 753
Triticale	1 478	1 388	1 295	1 262	1 057	1 147	818	1 543
Maize grain	3 083	4 375	5 793	5 293	6 929	8 104	8 304	8 315
Barley	1 430	1 464	1 345	1 675	1 514	1 263	1 153	1 774
Rye	1 020	815	965	914	859	933	758	865
Oats	911	902	1 092	1 064	1 071	922	742	1 245
Rice	4 665	5 787	5 940	5 747	5 845	5 885	5 999	5 970
Other cereals	2 066	2 454	2 755	2 940	3 188	2 373	2 473	2 471
Sunflower	639	313	486	473	544	561	534	639
Potatoes	11 671	14 644	14 831	16 000	15 034	14 709	17 789	18 224
Other root crops	36 998	42 619	57 666	72 334	31 403	28 477	45 247	29 007
Peas fresh	7 781	9 472	10 013	12 741	15 344	16 298	19 710	15 400
Beans fresh	524	541	512	446	582	586	568	575
Dry beans	6 616	6 616	6 225	6 132	6 008	5 935	8 970	7 828
Broad beans	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
Peanuts	1 478	1 388	1 295	1 262	1 057	1 147	818	1 543
Other legumes	1 661	2 428	1 662	1 637	2 281	3 304	2 142	2 977
Tomatoes	46 169	56 378	69 746	78 137	83 096	74 368	90 482	75 914
Maize for forage	34 005	37 978	38 363	37 750	35 517	39 963	40 369	39 698
Sorghum for forage	24 568	21 224	21 818	21 942	22 162	18 801	11 964	17 860
Other forage	11 800	9 593	9 779	9 752	9 563	7 724	6 766	8 466

## 5.7.2 Indirect N<sub>2</sub>O emissions from managed soils

### 5.7.2.1 Overview

In addition to direct N<sub>2</sub>O emissions from managed soils, emissions of N<sub>2</sub>O also occur through two indirect pathways: via volatilisation NH<sub>3</sub> and N<sub>2</sub>O and via N lost from leaching and runoff.

Some of the N added to soils from synthetic and organic fertilizers and from urine and dung deposited by grazing animals is volatilised as NH<sub>3</sub> and NO<sub>x</sub>. A fraction of the N volatilised returns to the ground and is then re-emitted as N<sub>2</sub>O. In the same way, a fraction of the N added to soil, crop residues included, is lost through leaching and runoff and indirectly becomes N<sub>2</sub>O.

Share of indirect N<sub>2</sub>O emissions from managed soils, by pathway and by source, is shown in the next two figures for 2013.

Figure 5.36 – Share of indirect N<sub>2</sub>O emissions from managed soils by pathway: volatilisation and leaching and runoff, 2013.

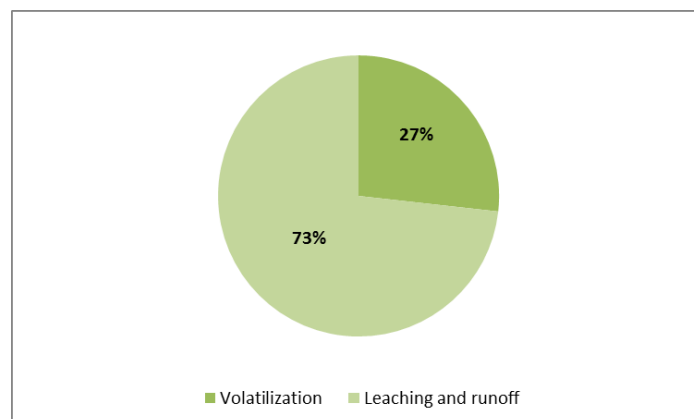
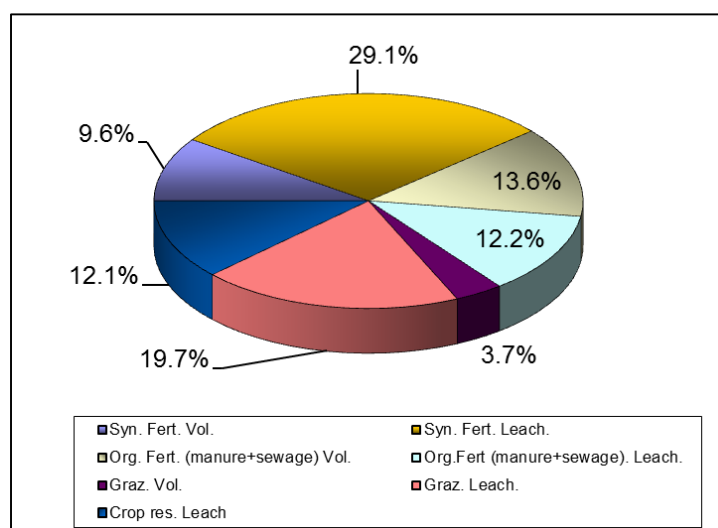


Figure 5.37 – Share of indirect N<sub>2</sub>O emissions from managed soils by source, 2013.



### 5.7.2.2 Methodology

#### Volatilisation/atmospheric deposition

Indirect N<sub>2</sub>O emissions due to volatilisation/atmospheric deposition of N added to soils were estimated based on equation 11.9 of IPCC 2006.

$$N_2O_{(ATD)} = [(F_{SN} * \text{Frac}_{GASF}) + (F_{ON} + F_{PRP}) * \text{Frac}_{GASM}] * EF_4 * 44/28$$

where:

N<sub>2</sub>O<sub>(ATD)</sub> – N<sub>2</sub>O emissions indirectly produced from atmospheric deposition of N volatilized from managed soils, kg N<sub>2</sub>O/yr;

$F_{SN}$  - annual amount of N synthetic fertilizers applied to soils, kg N/yr

$F_{ON}$  – annual amount of N organic fertilizers (manure+sewage sludge) applied to soils, kg N/yr

$F_{PRP}$  – annual amount of N from urine and dung deposited by grazing animals on pasture, kg N/yr;

$Frac_{GASF}$  – fraction of N from synthetic fertilizer N that volatilises as  $NH_3$  and  $NO_x$ , kg N volatilised/kg N applied,

$Frac_{GASM}$  – fraction of N from organic fertilizers (manure and sewage sludge) and from urine and dung deposited by grazing animals that volatilises as  $NH_3$  and  $NO_x$ , kg N volatilised/kg N applied and deposited.

$EF_4$  – emission factor for  $N_2O$  emissions from atmospheric deposition of N on soils, kg  $N_2O$ -N / kg  $NH_3$ -N+ $NO_x$ -N volatilised

44/28 - conversion of  $N_2O$ -N emissions to  $N_2O$  emissions

The collection of activity data for  $F_{SN}$ ,  $F_{ON}$  and  $F_{PRP}$  is described under chapter 5.7.1 - Direct  $N_2O$  emissions from managed soils.

The annual amount of N from synthetic fertilizers that volatilises as ammonia was estimated using the methodology of EMEP/EEA Guidebook 2013 keeping consistence with UNECE/CLRTAP inventory report. The country specific  $Frac_{GASF}$  determined varies between 0.057 and 0.080 (average 0.0705 for 1990-2013), which is related with the type of N fertilizer consumption in each year particularly the importance of urea use. In Annex G – Agriculture is presented the annual amount of N synthetic fertilizer used by type of fertilizer and the volatilization rates that were used for each type of fertilizer were obtained from the default Tier 2 EMEP/EEA Guidebook 2013, page 14 of chapter 3D – Agricultural soils.

In the same way, the annual amount of N from manure application and from urine and dung deposited by grazing animals on soil that volatilises as  $NH_3$  and  $NO_x$  was estimated using the  $N_{flow}$  methodology of EMEP/EEA Guidebook 2013. Country specific  $Frac_{GASM}$  are calculated separately for N manure applications and for excreta deposited on pasture. The  $Frac_{GASM}$  determined for manure applied to soil varies between 0.195 and 0.208 (average 0.201 for 1990-2013), which is in line with IPCC 2006 default value. The  $Frac_{GASM}$  obtained for urine and dung deposited by grazing animals varies between 0.04 and 0.05 (average 0.05 for 1990-2013) which is lower than the default IPCC 2006 value but nevertheless in the range of possible values.

For N sewage sludge additions on soils it was considered the default value of 0.20 (table 11.3, IPCC 2006) for the  $Frac_{GASM}$ .

In the table below are presented the annual values of  $Frac_{GASF}$  and  $Frac_{GASM}$  according to report requirements

Table 5.48 --  $Frac_{GASF}$  and  $Frac_{GASM}$  annual values

Year	$Frac_{GASF}$	$Frac_{GASM}^*$
1 990	0.071	0.146
1 991	0.071	0.141
1 992	0.071	0.141
1 993	0.071	0.141
1 994	0.071	0.141
1 995	0.075	0.139
1 996	0.075	0.137
1 997	0.071	0.137
1 998	0.066	0.137
1 999	0.074	0.139
2 000	0.072	0.139
2 001	0.070	0.139
2 002	0.062	0.138
2 003	0.069	0.136
2 004	0.062	0.134
2 005	0.057	0.132
2 006	0.075	0.131
2 007	0.066	0.129
2 008	0.077	0.129
2 009	0.080	0.131
2 010	0.059	0.126
2 011	0.075	0.127
2 012	0.079	0.126
2 013	0.075	0.127

\*  $Frac_{GASM}$ : (manure, applied, excreta deposited on pasture and sewage sludge applied)

### Leaching and runoff

Indirect  $N_2O$  emissions from leaching and runoff originate from applied N from synthetic fertilizer ( $F_{SN}$ ), organic N amendments ( $F_{ON}$ ), N excreta deposited by grazing animals ( $F_{PRP}$ ) and N from above and below ground crop residues ( $F_{CR}$ ) were estimated based on equation 11.10, IPCC 2006.

$$N_2O_{(L)} = (F_{SN} + F_{ON} + F_{PRP} + F_{CR}) * Frac_{LEACH}] * EF_5 * 44/28$$

Where:

$N_2O_{(L)}$  –  $N_2O$  emissions indirectly produced from leaching and runoff of N additions to managed soils, kg  $N_2O$ /yr;

$F_{SN} + F_{ON} + F_{PRP} + F_{CR}$  – defined above, kg N/yr

$Frac_{LEACH}$  – fraction of all N added to soils that is lost through leaching and runoff, kg N/kg N added

$EF_5$  – emission factor for  $N_2O$  emissions from N leaching and runoff, kg  $N_2O$ -N / kg N leached and runoff

The collection of activity data for  $F_{SN}$ ,  $F_{ON}$ ,  $F_{PRP}$  and  $F_{CR}$  is described under chapter 5.7.1 - Direct  $N_2O$  emissions from managed soils.

The value used for  $Frac_{LEACH}$  is the default one from table 11.3 of IPCC 2006, i. e., 0.30 kg N/kg N added.

### 5.7.2.3 Emission factors

The emission factors used are shown in the next table and correspond to the default values of table 11.3 of IPCC 2006.

Table 5.49 – Emission factors used for calculation of indirect N<sub>2</sub>O emissions from managed soils

Emission Factor	Value
EF <sub>4</sub>	0.01 Kg N <sub>2</sub> O-N/kg N <sub>volatilised</sub>
EF <sub>5</sub>	0.02 Kg N <sub>2</sub> O-N/kg N <sub>leaching</sub>

### 5.7.2.4 Activity data

As it was said above the collection of activity data for F<sub>SN</sub>, F<sub>ON</sub>, F<sub>PRP</sub> and F<sub>CR</sub> is described under chapter 5.7.1 - Direct N<sub>2</sub>O emissions from managed soils and the annual N amounts added to soil, by source, are summarized in Table 5.42 and in Annex G – Agriculture for the complete time series.

### 5.7.3 Uncertainty Assessment

The IPCC 2006 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<sub>2</sub>O 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<sub>2</sub>O 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 and crop residues. Considering that in the cases of nitrogen added to soil from 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.

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

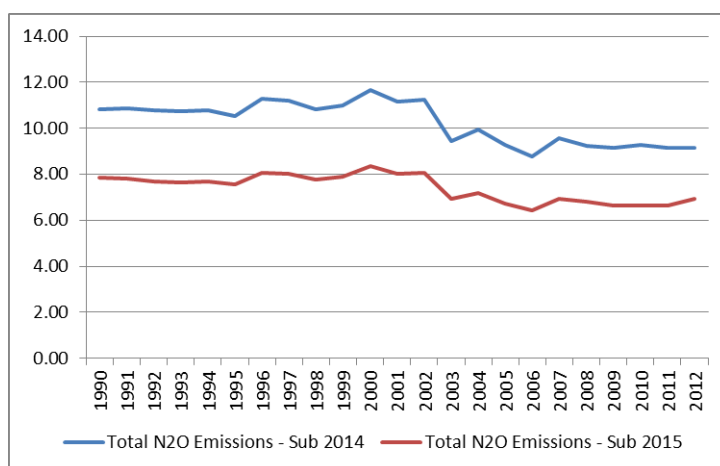
The QA/QC procedures applied in this source category comprehend a comparison between FAO and IFA data with INE values concerning the use of nitrogen fertilizers in Portugal. The results are presented in Figure 5.34 of this report.

#### 5.7.5 Recalculations

The major changes between last year and this year submission, result from the application of the methodologies and emission factors defined in the IPCC 2006 Guidelines to estimate direct and indirect N<sub>2</sub>O emissions from Managed Soils, instead of the ones that were set in previous IPCC Good Practice Guidance and Reference Manual.

Differences between submissions, last year and this year, are graphically represented in figure below

Figure 5.38 – Differences between submissions, 2014 and 2015 for N<sub>2</sub>O emissions from managed soils (kt N<sub>2</sub>O)



The decrease is mainly due to the indirect N<sub>2</sub>O emissions estimates, particularly those from leaching and runoff. Portugal has no country specific emission factor therefore used the EF<sub>5</sub> default value which was revised by IPCC 2006. Previously (Revised IPCC 1996 & GPG) EF<sub>5</sub> default value was set 0.025 kg N<sub>2</sub>O-N / kg N leaching and runoff and now (IPCC 2006) is 0.0075 kg N<sub>2</sub>O-N / kg N leaching and runoff. This represents a significant reduction on indirect N<sub>2</sub>O emissions

The estimates direct N<sub>2</sub>O emissions also observed a reduction due to the revision (IPCC 2006) to the default emission factors:

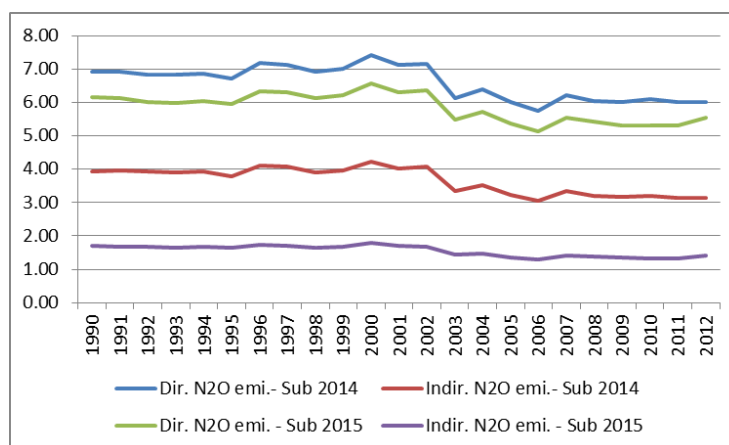
- EF<sub>1</sub> – the emission factor for N<sub>2</sub>O emissions from N additions to the soil (synthetic fertilizer, organic fertilizer and crop residues) was previously set at 0.0125 kg N<sub>2</sub>O-N / Kg N added and the new value is 0.010 kg N<sub>2</sub>O-N / Kg N added, although the amounts of N applied are no longer adjusted for volatilisation;
- EF<sub>3</sub> – the emission factor for N<sub>2</sub>O emissions from urine and dung deposited on pasture has been disaggregated for different animal types. There is a new default value for sheep, goats, horses, mules and asses that is half of the previously value. Before it was 0.02 kg N<sub>2</sub>O-N / Kg N deposited and now is 0.01 kg N<sub>2</sub>O-N / Kg N deposited. In the national conditions, particularly on sheep and goats, the majority of animal population



remain on pasture therefore the reduction of the emission factor has a significant impact in direct N<sub>2</sub>O emissions from excreta deposited by this type of animals.

In figure below are graphically represented the differences, between 2014 submission and 2015 submission, of N<sub>2</sub>O emissions from managed soils disaggregated by direct and indirect N<sub>2</sub>O emissions.

Figure 5.39 – Direct and Indirect N<sub>2</sub>O emissions from managed soils, differences between submission 2014 and submission 2015



#### 5.7.6 Further Improvements

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.

### 5.8 Field Burning of Agriculture Residues (CRF 3.F)

In table below are presented the estimates emissions from field burning of agriculture residues.

Table 5.50 – Methane and Nitrous Oxide estimates emissions from field burning of agriculture residues (kt)

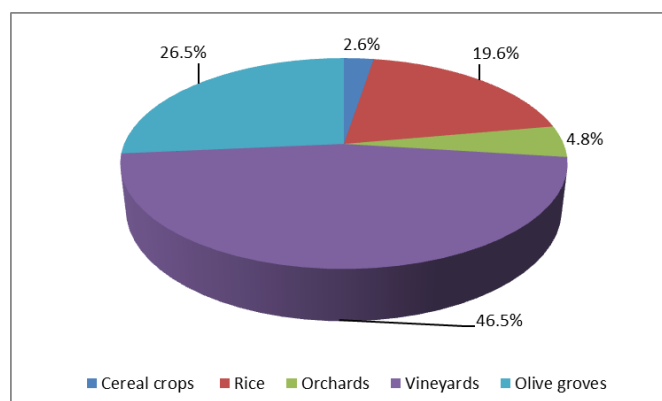
Gas/Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>CH<sub>4</sub></b>	<b>1.49</b>	<b>1.36</b>	<b>1.27</b>	<b>1.07</b>	<b>1.15</b>	<b>1.17</b>	<b>1.18</b>	<b>1.18</b>
Wheat	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Barley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
Rice	0.31	0.26	0.23	0.10	0.26	0.28	0.29	0.28
Other cereals	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Perennial woody crops	1.12	1.05	1.00	0.94	0.86	0.86	0.86	0.86
<b>N<sub>2</sub>O</b>	<b>0.07</b>	<b>0.07</b>	<b>0.06</b>	<b>0.06</b>	<b>0.05</b>	<b>0.06</b>	<b>0.06</b>	<b>0.06</b>
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rice	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Other cereals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perennial woody crops	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05

### 5.8.1 Overview

In-site burning of agricultural residues is still practiced nowadays in Portugal, being however forbidden by law-decree from May to September where the risk of forest fires is very high. 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.

The burning of agricultural residues occur with the straw of cereals and with the material of pruning permanent crops such as vineyards, olive groves and other orchards. Considering equivalent carbon dioxide emissions (Figure 5.40), burning of residues from vineyards is the most significant source of this non-key source.

Figure 5.40 – Importance of GHG emissions from field burning of agriculture residues by crop in 2013



### 5.8.2 Methodology

Emissions of in-site burning of agriculture residues were estimated based on equation 2.27<sup>121</sup> from the IPCC 2006 which is summarized in the following equation:

$$\text{Emission}_{(p,crop)} = A_{(crop)} * M_{B(crop)} * C_f * EF_{(p,crop)} * 10^{-3}$$

where

$\text{Emission}_{(p,crop,y)}$  - Emission estimate of pollutant p from field burning of residues from a specific crop, ton/year;

$A_{(crop)}$  – correspond to the crop area where the practice of field burning residues occurs, ha/yr ;

$M_{B(crop)}$  - Biomass of a specific crop that is available for combustion, t dm/ha/yr;

$C_f$  – combustion factor, dimensionless ;

$EF_{(p,crop)}$  - Emission factor from field burning of agriculture residues of a specific crop, g/kg dm burnt

### 5.8.3 Emission Factors

The emission factors used to estimate, CH<sub>4</sub>, N<sub>2</sub>O, CO, NMVOC and NO<sub>x</sub> emissions from field burning agricultural residues are the default values from IPCC 2006 (table 2.5<sup>122</sup>) and from EMEP/EEA Guidebook 2013 (chapter 3F). They are presented in the following table with source indication by crop and pollutant.

Table 5.51 – Emission factors for field burning of agricultural residues, g/kg dm burnt

Crop	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	CO
Wheat	2.7"	0.07"	2.3*	0.5*	66.7*
Barley	2.7"	0.07"	2.3*	11.7*	98.7*
Maize	2.7"	0.07"	1.8*	4.5*	38.8*
Rice	2.7"	0.07"	2.4*	6.3*	58.9*
Other cereals	2.7"	0.07"	2.3 <sup>#</sup>	0.5 <sup>#</sup>	66.7 <sup>#</sup>
Orchards	4.7"	0.26"	3.0"	0.5 <sup>#</sup>	107.0"
Vineyard	4.7"	0.26"	3.0"	0.5 <sup>#</sup>	107.0"
Olive grove	4.7"	0.26"	3.0"	0.5 <sup>#</sup>	107.0"

"Table 2.5 of IPCC guidelines 2006; #Table 3-1 of EMEP/EEA guidebook 2013; chapter 3F; \* Wheat, barley, maize and rice values from tables 3-3, 3-4, 3-5 and 3-6 of EMEP/EEA guidebook 2013; chapter 3F

### 5.8.4 Activity data

For cereals, other than rice, the practice of straw burning occurs in 1% of the cultivated area according to the INE information based on the last General Agricultural Census (RA09) which included a set of questions about some agricultural practice.

<sup>121</sup> Volume 4, chapter 2, pg 2.42

<sup>122</sup> Volume 4, chapter 2,pg.2.47

In chapter 5.5– CH<sub>4</sub> emissions from rice cultivation, has already been described the relevant rice cultivation practices in Portugal, including the burning of rice residues on field. The major fraction of rice stubbles and straw are burnt on fields except in the rice producing areas inside Natura 2000 where that practice is forbidden for reasons of conservation of natural habitats and animal species. Also in the period 2002-2008 all rice cultivation areas subjected to Techniques of Integrated Production and Protection” had the same burnt residues restrictions. The evolution of rice cultivation areas where the practice of residues burnt is not allowed is shown in Figure 5.20 in chapter 5.5 (CRF3C).

Each year the orchards, vineyards and olive groves are pruned and much of the resulting material of this action is burned in situ. This practice occurs in 22% of the orchards area, 52% of the vineyard areas and 65% of olive grove areas, according to the information collected in the General Agricultural Census (RA09).

The amount of biomass available for combustion for cereal crops (rice included) was estimated based on the same methodology used to estimate crop residues production, i.e., the regression equations in table 11.2 of IPCC 2006 volume 4, chapter 11, in consistence with calculations to estimate the amount of crop residues that returned to soil dealt on the chapter 5.7 (CRF 3D) of this report.

The amounts of pruning material produced for each of the permanent crops are country specific<sup>123</sup> values presented in Table 5.52.

Activity data and parameters used to estimate emissions from cereal and permanent crops residues burnt on field are summarized in table below for 2013. Combustion factors used for cereals are the default values from Table 2.6 of IPCC 2006<sup>124</sup>. For pruning material from permanent crops the combustion factor considered was made equal to 1, following the recommendation of the EMEP/EEA Guidebook 2013<sup>125</sup>

Table 5.52 – Activity data and parameters used to estimate emissions from field burning of agricultural residues, 2013

Crop	Area burnt* (kha)	Biomass available for combustion (t dm /ha)	Combustion factor
Wheat	0.46	2.88	0.9
Barley	0.17	2.14	0.9
Maize	1.57	8.06	0.8
Rice	17.01	7.51	0.8
Other cereals	1.17	2.00	0.9
Orchards	8.85	1.29	1.0
Vineyard	92.45	1.19	1.0
Olive grove	228.65	0.27	1.0

\*Area where the on field burning practice of crop residues occurs

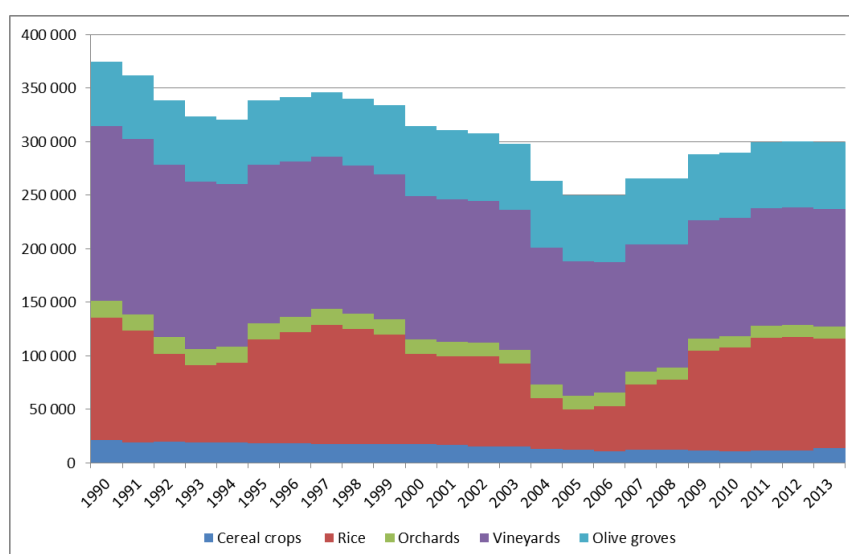
In next figure is shown the annual biomass burnt for the period 1990-2013

<sup>123</sup> Dias, J.J. Mestre (2002), “Utilização da biomassa: avaliação dos resíduos e utilização de pellets em caldeiras domésticas”.

<sup>124</sup> Volume 4, chapter 2, page 2.49

<sup>125</sup> Chapter 3F, page 6

Figure 5.41 – Annual biomass burnt (tdm/yr) for the time series



### 5.8.5 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).

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

QA/QC procedures included a series of checks: calculation formulas verification, data and parameters verification, and the information provided in this report.

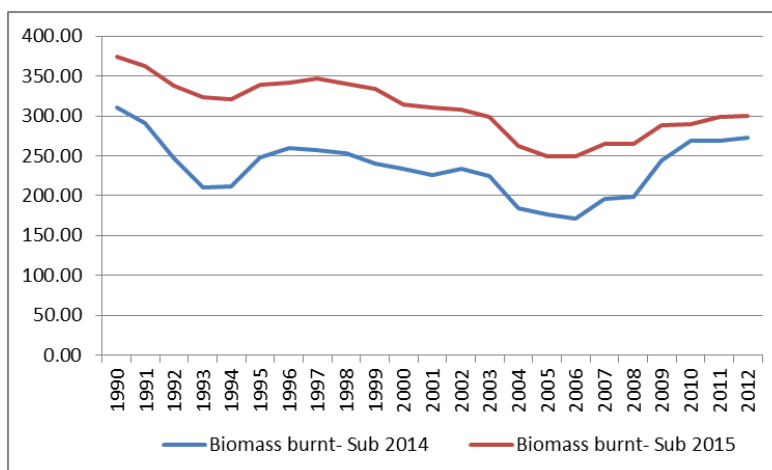
### 5.8.7 Recalculations

Recalculations to this source category (3.F) are related with:

- the implementation of IPCC 2006 methodology to estimate crop residues production, which for cereal crops (rice excluded) led to an increase on the amount of residues and consequently of the biomass available to combustion;
- revision of dry matter content of crop residues in line with the implementation of the above methodology;
- revision of the per cent of crop residues that are burnt on field according to the information of last General Agricultural Census (RA09). In the last year submission there were not considered for cereal crops, other than rice, the practice of burning residues on field. In this year submission cereal crops also contributes to GHG emissions from this source category;
- revision of the amount of pruning material produced from permanent crops management.

The differences between the amounts of total biomass burnt considered in the two submissions, 2014 and 2015, are shown in the next figure

Figure 5.42 - Amount of biomass burnt (kt dm) - differences between submission 2014 and submission 2015



### 5.8.8 Further improvements

No specific improvements are planned

## 5.9 CO<sub>2</sub> Emissions from liming application (CRF 3 G)

### 5.9.1 Overview

Liming of soils in agricultural and forest land is considered a minor practice in Portugal and information on the application of lime in soils is scarce. Prior to the 2015 submission, emissions from lime and dolomite were reported under LULUCF chapter.

In 2013 emissions from liming were estimated in 12,6 kt CO<sub>2</sub>, at the same level of the 1990 emissions.

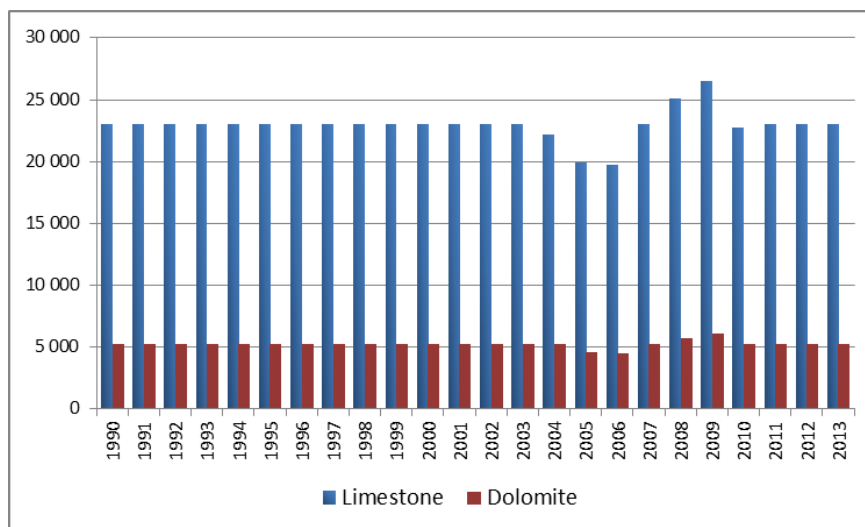
### 5.9.2 Methodological issues

Emissions associated with liming were estimated using a Tier 1 method (equation 11.12, IPCC 2006), using the default emission factors for carbon conversion of 0.12 for limestone and 0.13 for dolomite which are equivalent to carbonate carbon contents of the materials (12% for CaCO<sub>3</sub>, 13% for CaMg(CO<sub>3</sub>)<sub>2</sub>)

### 5.9.3 Activity data

The amount of carbonate containing lime applied annually to soils in the country was estimated on the basis of the information collected directly from the national producing limestone and dolomite for agricultural use. Due to the inherent characteristics of these products (low economic value and weight) it was assumed that no imports exist of these materials. The same was considered for exportation, information which was corroborated from the enquiries to the plants.

Figure 5.43 – Limestone and dolomite use on agricultural land (t/yr)



#### 5.9.4 Uncertainty Assessment

The uncertainty of CO<sub>2</sub> emissions from this category was assessed and estimated as 9%.

#### 5.9.5 Category specific QA/QC and verification

QA/QC procedures included the verification of calculation formulas and the consistency with previous submission estimates.

#### 5.9.6 Recalculations

No recalculations are observed.

#### 5.9.7 Further improvements

No specific improvements are planned.

### 5.10 CO<sub>2</sub> Emissions from urea application (CRF 3 H)

#### 5.10.1 Overview

Urea fertilizer is one of the N fertilizer type used in Portugal and in 2013 it accounts about 19.8% of the N synthetic fertilizers applications to the soil, more than double than 1990 (8,4%).

CO<sub>2</sub> emissions from urea application produced 38.2 kt CO<sub>2</sub> in 2013. This represents an increase of 79.8% compared to 1990 CO<sub>2</sub> emissions from urea applied to agricultural soils.

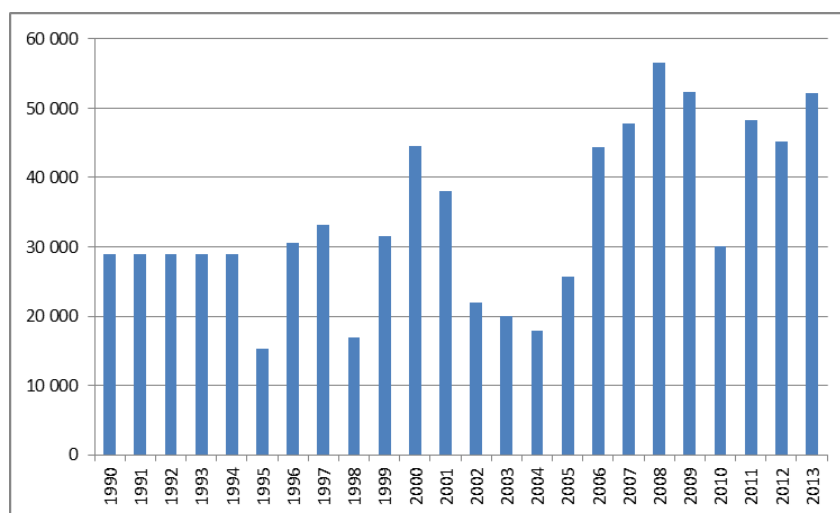
#### 5.10.2 Methodological issues

Emissions associated with the application of urea were estimated using a Tier 1 method (equation 11.13, IPCC 2006), using the default emission factors for carbon conversion of 0.20 which is equivalent to carbonate carbon contents of urea in an atomic weight basis.

#### 5.10.3 Activity data

Data on nitrogen fertilizers consumption, urea included, are provided by INE and are obtained as it was explained in chapter 5.7.1.4.1 - Synthetic Fertilizers (activity data). The total amount of urea fertilizer use is shown in the next figure.

Figure 5.44 – Urea fertilizer application on agricultural land (t/yr)



#### 5.10.4 Uncertainty assessment

Under the IPCC 2006 Tier 1 methodology, the default emission factor was used, which assume conservatively that all carbon in the urea is emitted as CO<sub>2</sub> into the atmosphere. The default emission factor represents the absolute maximum emissions associated with urea fertilization so is assumed certain.

#### 5.10.5 Category specific QA/QC and verification

QA/QC procedures included a series of checks: calculation formulas verification, data collection verification and the information provided in this report.

#### 5.10.6 Recalculations

The 2015 submission is the first year that CO<sub>2</sub> emissions from urea have been estimated and reported.

#### 5.10.7 Further improvements

No specific improvements planned



## 6 LAND USE, LAND USE CHANGE AND FORESTRY (CRF 5.)

### 6.1 Overview of LULUCF

#### 6.1.1 LULUCF Inventory Framework

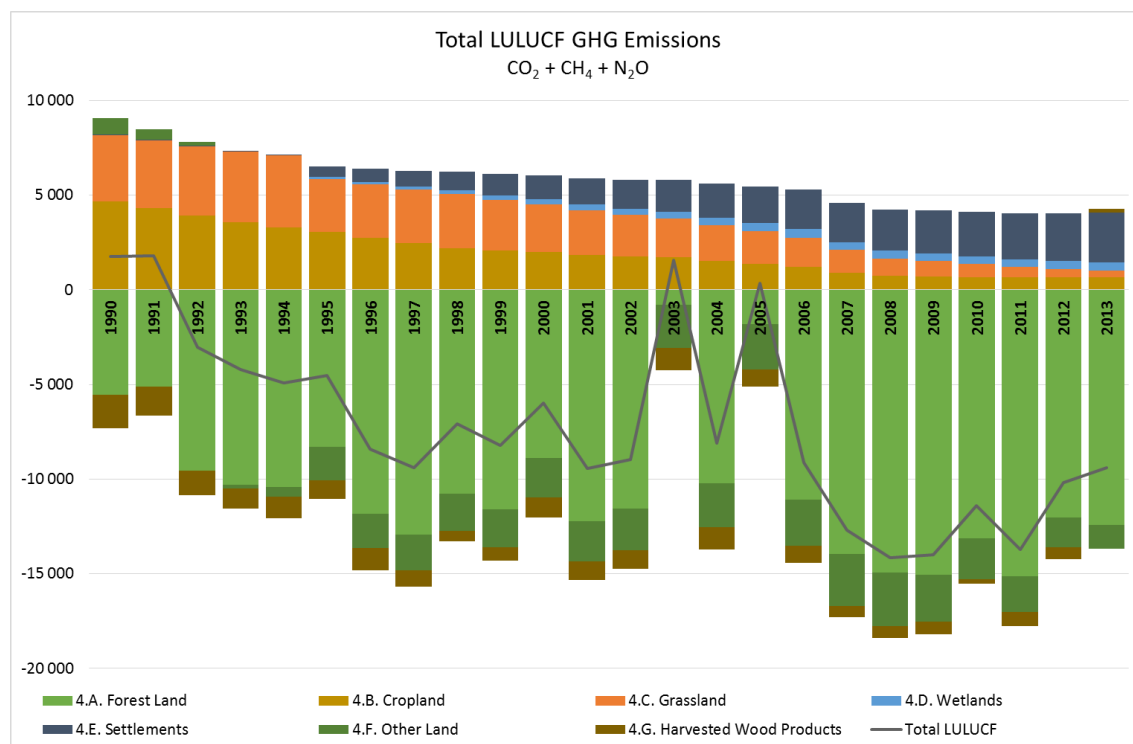
When considered in its entirety, the LULUCF sector is estimated as a net-sink for the whole time series period, except for the years 2003 and 2005, as represented in Figure 6-1.

In 2013 the carbon sink resulting from LULUCF is estimated at 9.4 Mt CO<sub>2</sub>eq. In the period 1990-2013 the average sink increase is 1.8Mt 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 6-1 – Overview of reported emissions and removals in the LULUCF Sector (kt CO<sub>2</sub>eq)

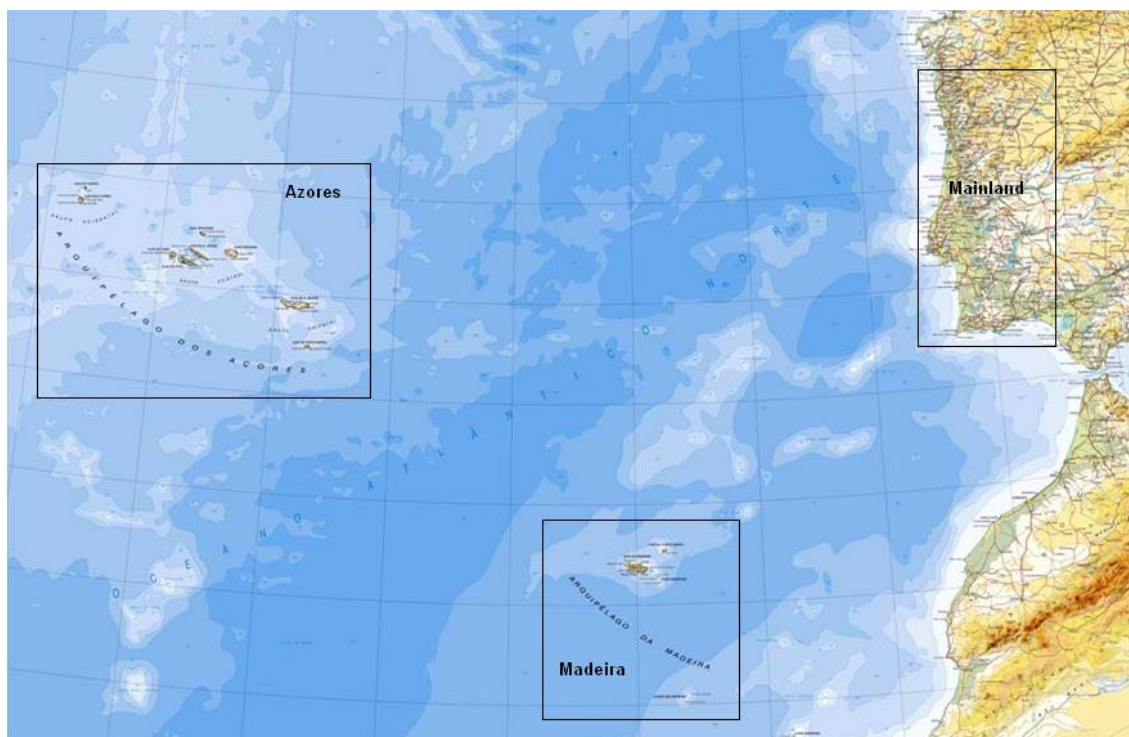


## 6.1.2 Representation of Land-Areas and Land-Use Changes

### 6.1.2.1 Approaches to Land Representation

The Portuguese territory is composed of three territorial units (see Figure 6-2): Mainland, the Archipelago of Azores (9 inhabited islands) and the Archipelago of Madeira (2 inhabited islands).

Figure 6-2 – 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.

### 6.1.2.2 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 6-1.

Table 6-1 – 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>126</sup>
	Other permanent crops	Includes all areas used for cultivation of all other species of woody crops, including fruit orchards <sup>127</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.

### 6.1.2.3 Mainland Portugal

The land-use and land-use change data for Mainland Portugal 1970-2013 was divided into two different time periods: 1970-1995 and 1995-2013.

<sup>126</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>127</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 1995-2013 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.

#### 6.1.2.3.1 Period 1995-2012

The main information source for this period is the Cartografia de Ocupação de Solo<sup>128</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.

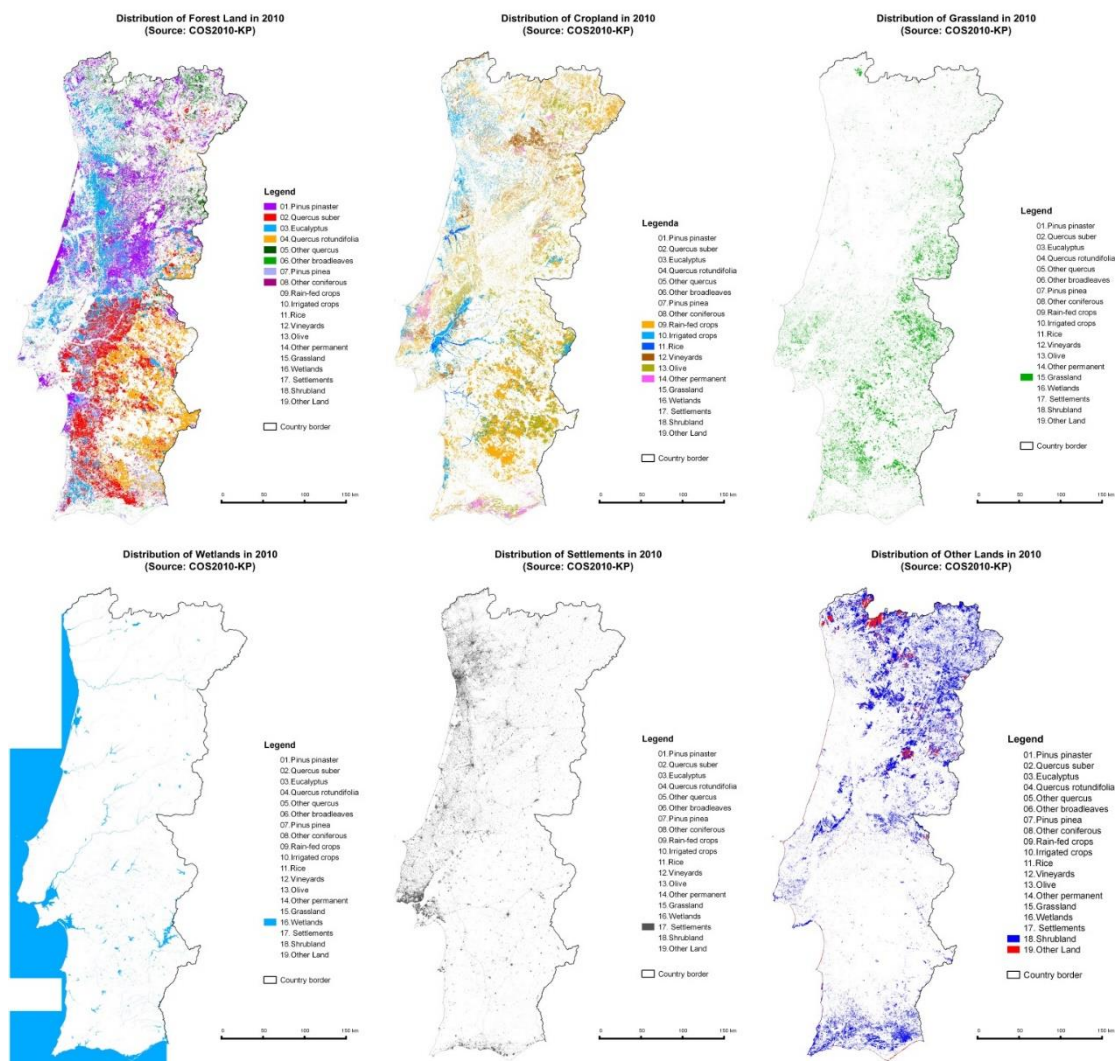
COS legend was consistent in all 3 maps and totalizes 225 classes. This extensive legend was after converted to the 19 strata described in section 6.1.2.2, which are used as a basis for both UNFCCC and KP reporting. The minimum area considered was 1ha and the minimum width for linear structures and other 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.

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<sup>128</sup> Land-Use Cartography. COS in the Portuguese acronym

Figure 6-3 – Map of the main land-uses in Mainland Portugal in 2010



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 2007-2013 and equal to the annual land-use changes derived in those periods.

Equation 6-1 - Estimation of annual land-use change 1995-2013

$$LUC_{x \rightarrow y[Y_i]} = \frac{LUC_{x \rightarrow y[1995-2007]}}{12}, Y_i = \text{any year in } [1995-2007]$$

$$LUC_{x \rightarrow y[Y_i]} = \frac{LUC_{x \rightarrow y[2007-2010]}}{3}, Y_i = \text{any year in } [2007-2013]$$

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. 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 6-7 and Table 6-8.

#### 6.1.2.3.2 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);

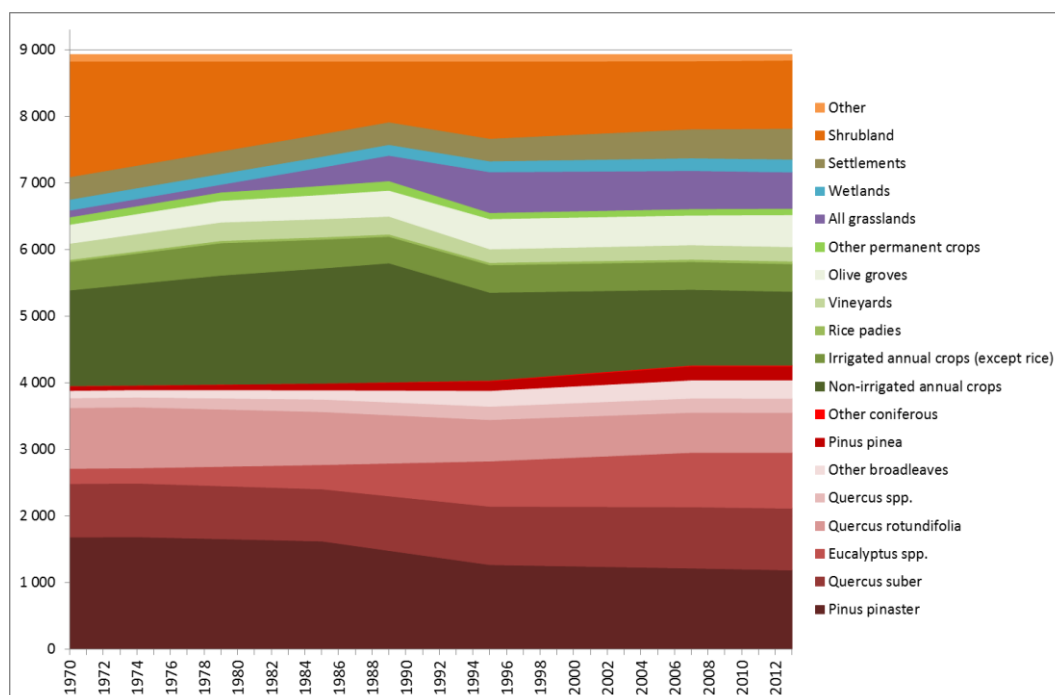
For “Cropland” and “Grasslands” the basis for information was the General Census of Agriculture from RGA (1979), RGA (1989) and RGA (1999). To maintain time series consistency, the following estimation methodology was used:

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 6-4.

Figure 6-4 – 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  $X \rightarrow Y$  (e.g. gross afforestation) and  $Y \rightarrow X$  (e.g. gross deforestation), as the only information available is the total of net-changes in area in each period, i.e.  $X \rightarrow Y$  plus  $Y \rightarrow X$  (e.g. net gains in forest area).

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 6-2.

Equation 6-2 - Estimation of Land-use Changes, when only net-changes in area are known

$$LUC_{x \rightarrow y, Y_i} = \sum LUC_{x \rightarrow all, Y_i} \times \frac{\sum LUC_{all \rightarrow y, Y_i}}{\sum LUC_{all, Y_i}}$$

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]

$\sum LUC_{x \rightarrow all, Y_i}$  = Net area loss of land-use type x in Year i (ha)

$\sum LUC_{all \rightarrow y, Y_i}$  = Net area gains of land-use type y in Year i (ha)

$\sum LUC_{all, Y_i}$  = Total land-use changes in Year i (ha)



The resulting annual land-use change matrices for this period are presented in Table 6-2 through to Table 6-6.

Table 6-2 – Annual land-use changes (ha) in the period [1970-1974]

1974	1970	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Con	Rf crps	Ir crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1970-1974
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 6-3 – 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	Ir 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	0	2,142	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
Annual Losses 1975-1979		5,742	2,115	0	10,815	0	0	0	486	0	0	0	0	0	0	0	0	0	43,002	0	62,160

Table 6-4 – 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	Ir 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	0	1,855	0	0	0	83	0	1,507	0	147	0	0	0	0	0	7,375	0	12,314	0
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	0	24	0	438	0	43	0	0	0	0	0	2,141	0	3,576	0
O. broadleaves		200	74	0	377	0	0	0	17	0	306	0	30	0	0	0	0	0	1,500	0	2,504	0
P. pinea		277	102	0	521	0	0	0	23	0	423	0	41	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	0	1,849	0	181	0	0	0	0	0	9,046	0	15,105	0
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	0
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
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	43,002	0	71,807	0

Table 6-5 – 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 crops	Ir crops	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	
Q. suber	3.100		0	1.520	0	0	0	0	0	0	769	0	75	0	0	0	0	0	0	3.903	9.367	
Eucalyptus	10.421	0		5.112	0	0	0	0	0	0	2.584	0	252	0	0	0	0	0	13.122	0	31.491	
Q. rotundifolia	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	0	103	0	10	0	0	0	0	0	524	0	1.257	57.154
O. broadleaves	3.268	0	0	1.603	0		0	0	0	0	810	0	79	0	0	0	0	0	4.114	0	9.874	4.323
P. pinea	1.390	0	0	682	0	0		0	0	0	345	0	34	0	0	0	0	0	1.751	0	4.201	
O. coniferous	319	0	0	156	0	0	0		0	0	79	0	8	0	0	0	0	0	402	0	964	
Rain-fed crops	4.999	0	0	2.452	0	0	0	0	0	0	1.239	0	121	0	0	0	0	0	6.294	0	15.105	
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	0	2		0	0	0	0	0	0	13	0	30	23.316
Vineyards	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.669
Olive	2.171	0	0	1.065	0	0	0	0	0	0	538	0	53		0	0	0	0	2.733	0	6.560	
O. permanent	536	0	0	263	0	0	0	0	0	0	133	0	13	0		0	0	0	675	0	1.620	
Grasslands	8.815	0	0	4.324	0	0	0	0	0	0	2.186	0	214	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	-44.629
Annual Losses 1985-1989	35.445	0	0	17.387	0	0	0	0	0	0	8.788	0	859	0	0	0	0	0	44.629	0	107.107	0
				52.831							9.647					0	0	0	44.629			

Table 6-6 – 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	Settl	Shrub	O. land	Annual Gains 1989-1995	Net Gains
P. pinaster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Q. suber	2.216		0	1.087	0	0	0	0	0	0	4.870	0	675	0	519	0	0	0	0	0	9.367	
Eucalyptus	7.449	0		3.654	0	0	0	0	0	0	16.374	0	2.269	0	1.746	0	0	0	0	0	31.491	
Q. rotundifolia	0	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	0	0	653	0	91	0	70	0	0	0	0	0	1.257	57.154
O. broadleaves	2.336	0	0	1.146	0		0	0	0	0	5.134	0	711	0	547	0	0	0	0	0	9.874	4.323
P. pinea	994	0	0	487	0	0		0	0	0	2.185	0	303	0	233	0	0	0	0	0	4.201	
O. coniferous	228	0	0	112	0	0	0		0	0	501	0	69	0	53	0	0	0	0	0	964	
Rain-fed crops	0	0	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	0	1.293	0	179	0	138	0	0	0	0	0	2.486	
Rice	16	0	0	8	0	0	0	0	0	0	35		5	0	4	0	0	0	0	0	67	13.020
Vineyards	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-83.998
Olive	2.476	0	0	1.214	0	0	0	0	0	0	5.442	0	754		580	0	0	0	0	0	10.467	
O. permanent	0	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	0	0	19.981	0	2.769	0	2.130		0	0	0	0	38.429	38.429
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	9.756	0	0	4.786	0	0	0	0	0	0	21.446	0	2.972	0	2.287	0	0	0	0	0	41.247	41.247
O. land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41.247
Annual Losses 1989-1995	35.445	0	0	17.387	0	0	0	0	0	0	77.914	0	10.797	0	8.307	0	0	0	0	0	149.850	0
				52.831							97.018				0	0	0	0	0			

Table 6-7 – 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			
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			
O. coniferous	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	1.093	526	5.481	3	20	1.164	5	12.490			
Irrigated crops	207	71	177	56	4	34	21	0	3.591		229	619	180	183	666	1	10	106	4	6.161			
Rice		0	0	0	0	1	0			8	368		1	0	2	10	1	1	0	0	392	30.044	-14.062
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	8.318	8.009	
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	11.668	-11.770
O. land	146	14	64	5	2	7	7	3	10	2		3	3	1	34	11	4	1.020		1.339			
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				

2010	2007	2007																	Annual Gains 2007-2010	Net Gains		
		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	Settll			Shrub	O. land
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. ratundifolia	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	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. confertus	49	2	11	2	7	48	5		15	3				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		
O. land	102	5	69	3	1	25	2	1	3	1		1	0		89		7	451		760		
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	1.010	11.694	19	490	7.241	2.831	61.866		

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 1970-2013 the following assumptions were made:
  - a. total forest area increased (in % annual change) from 1970 to 2013 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 2007-2013 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 1970-2013 the following assumptions were made:
  - a. total cropland + grassland area increased (in % annual change) from 1970 to 2013 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);

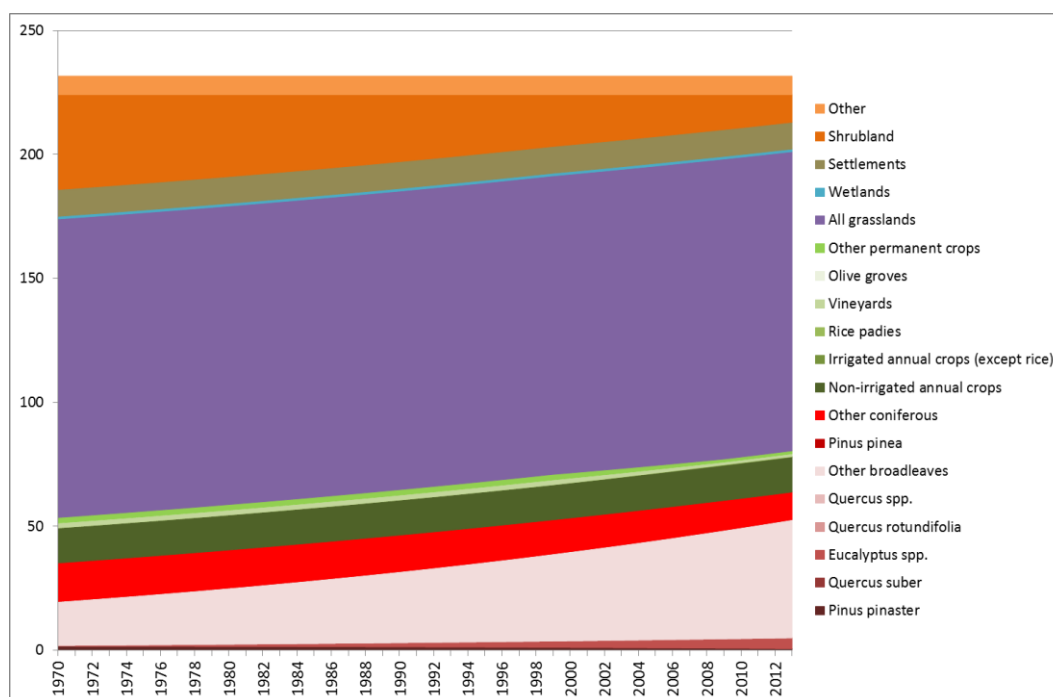
- c. the share of area per cropland or grassland type in the period 1999-2009 was interpolated considering the shares of each cropland or grassland types in RGA (1999) and RGA (2009);
- d. the share of area per cropland or grassland type in the period 2009-2013 was considered the same as RGA (2009).

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 1970-2013 the following assumptions were made:
  - a. The total area for the Autonomous Region of the Azores was maintained constant in the period 1970-2013 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 1970-2013 for the Azores are presented in Figure 6-5.

Figure 6-5 – Changes in Total Land-Use (1000 ha) in the Region of Azores



As mentioned above for the case of mainland Portugal, land use changes for the period 1970-2013 cannot be estimated separately for  $X \rightarrow Y$  (e.g. gross afforestation) and  $Y \rightarrow X$  (e.g. gross deforestation), as the only information available is the total of net-changes in area in each period, i.e.  $X \rightarrow Y$  plus  $Y \rightarrow X$  (e.g. net gains in forest area).

However, as Azores’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 6-2.

#### **6.1.2.5 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 2013 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 1970-2013 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 1970-2013 the following assumptions were made:
  - a. total cropland + grassland area increased (in annual change) from 1970 to 2013 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 2009-2013 was considered the same as RGA (2009).

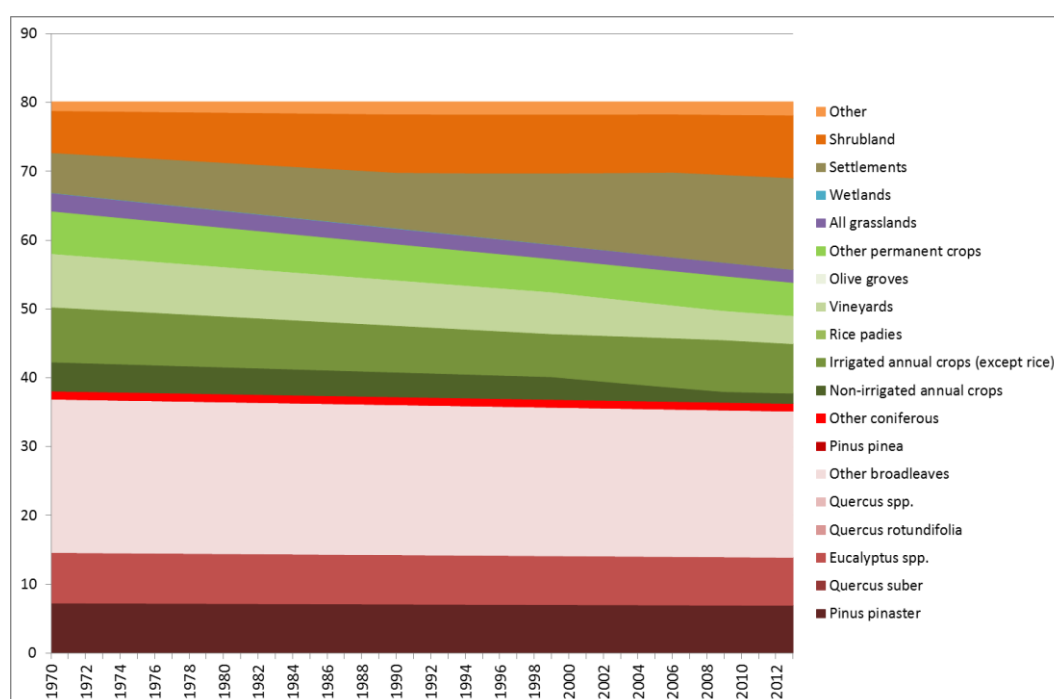
For “Wetlands”, “Settlements” and “Other Land” the following estimation methodology was used:

1. The total area of wetlands + settlements + other land (in hectares) of CLC (1990) and CLC (2006) was used directly;
2. For the period 1970-2013 the following assumptions were made:
  - a. total wetlands + settlements + other land area increased (in annual change) from 1970 to 2013 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 1970-2013 for Madeira are presented in Figure 6-6.

Figure 6-6 – Changes in Total Land-Use in the Region of Madeira (1000 ha)



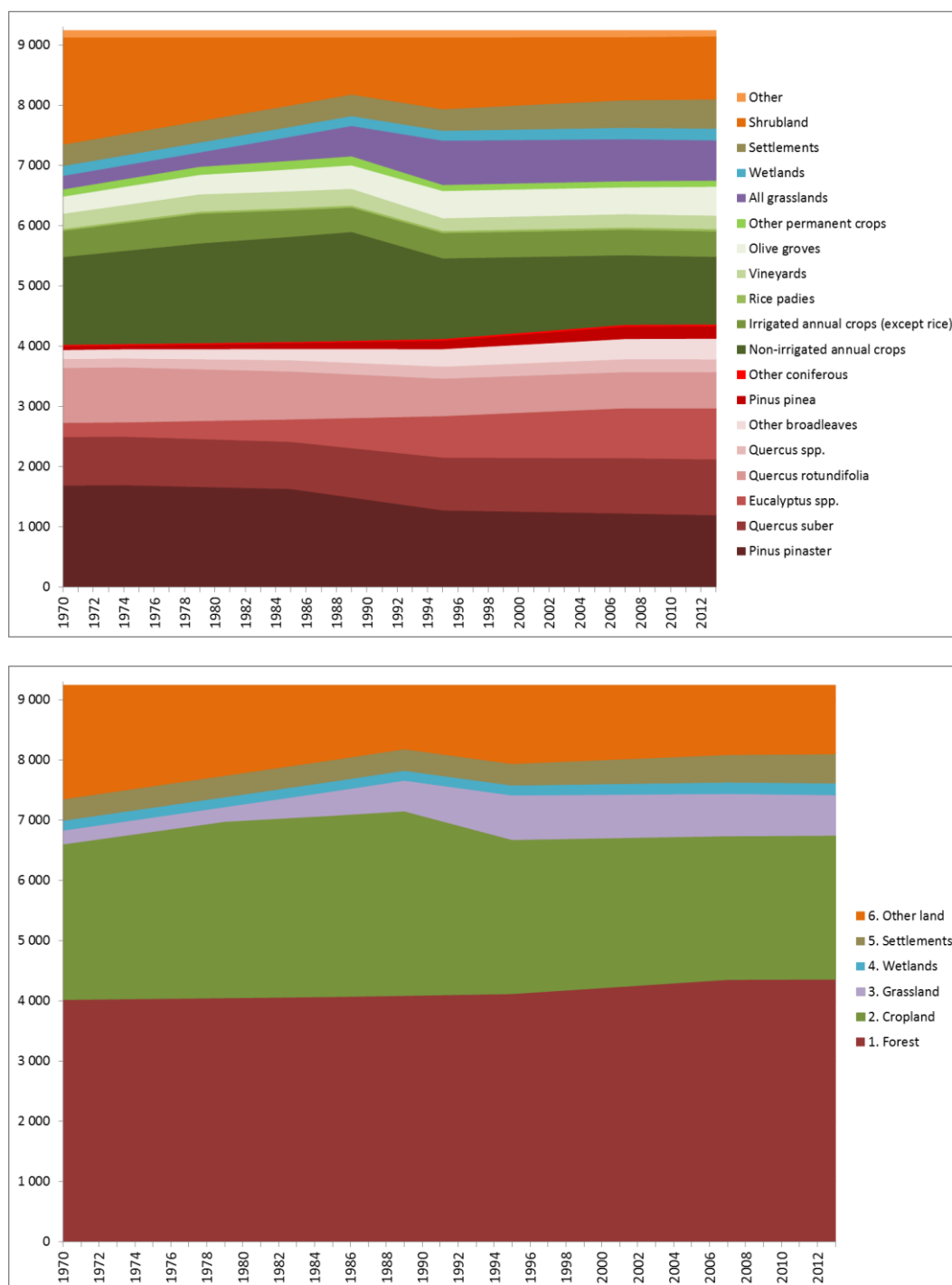
As mentioned above for the case of mainland Portugal, land use changes for the period 1970-2013 cannot be estimated separately for  $X \rightarrow Y$  (e.g. gross afforestation) and  $Y \rightarrow X$  (e.g. gross deforestation), as the only information available is the total of net-changes in area in each period, i.e.  $X \rightarrow Y$  plus  $Y \rightarrow X$  (e.g. net gains in forest area).

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 6-2.

#### 6.1.2.6 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 6-7.

Figure 6-7 – Changes in Total Land-Use (1000 ha) in Portugal



#### 6.1.2.7 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 6-1.

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 6-2 through Table 6-8, assuming a 20 year conversion period, as shown in Equation 6-3.

Equation 6-3 – 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 6-4.

Equation 6-4 – 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 6-7 (ha)

$LC_{y \rightarrow x, RY_i}$  = Land Y converted to Land X in reporting year i (ha)

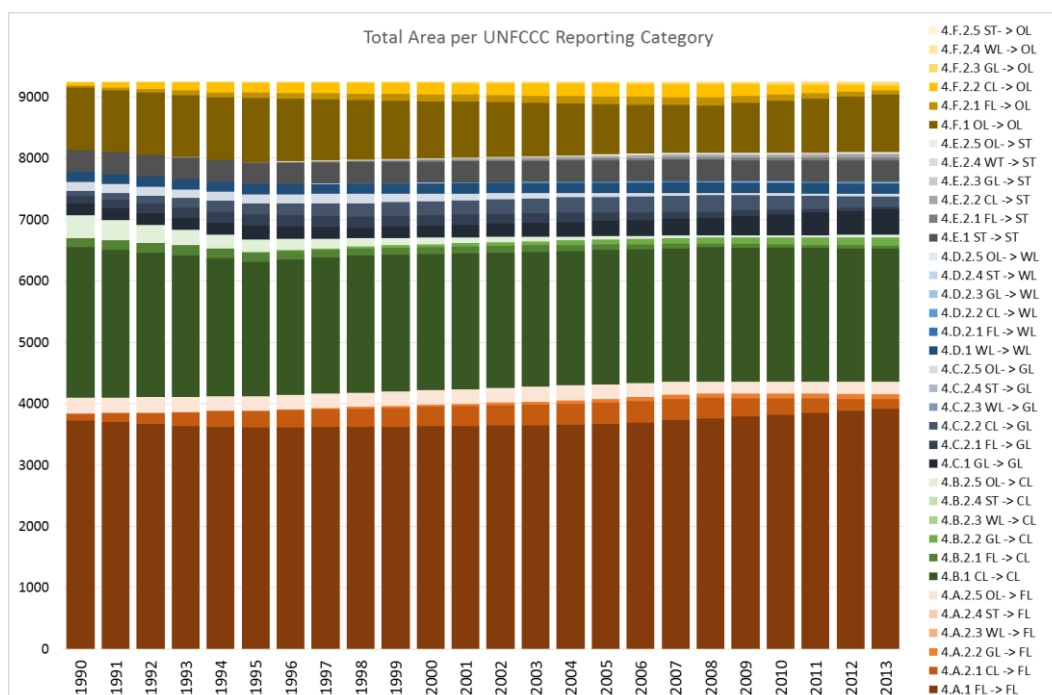
Land conversions within each broad UNFCCC reporting categories (e.g. changes from *Pinus pinaster* to *Eucalyptus sp*) were also estimated and used for estimating emissions and removals, but were reported as “Land remaining Land” (in the previous example, as “forest land remaining forest land”).

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 6-8.



Figure 6-8 – Total Areas (1000 ha) per UNFCCC Reporting Categories



#### 6.1.2.8 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 6-5.

Equation 6-5 – Estimation of KP Areas under Afforestation and Reforestation

$$AR_{RY_i} = \sum_{1990}^i \sum_{\substack{all\ y \\ all\ x}} ALC_{NFLU_y \rightarrow FLU_x, i}$$

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 6-6.

Equation 6-6 – 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 6-7.

Equation 6-7 – Estimation of KP Areas under Deforestation

$$D_{RY_i} = \sum_{1990}^i \sum_{\substack{all\ y \\ all\ x}} ALC_{FLU_y \rightarrow NFLU_x, i}$$

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 6-8.

Equation 6-8 – 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 6-7 (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 6-9.

Equation 6-9 Estimation of KP Areas under Cropland Management

$$CM_{RY_i} = TA_{CL,RY_i} - \sum_{1990}^i \sum_{\substack{\text{all } y \\ \text{all } x}} ALC_{FLU_y \rightarrow CL_x,i} + \sum_{2008}^i \sum_{\substack{\text{all } y \\ \text{all } x}} ALC_{CL_y \rightarrow NR_x,i}$$

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 6-7 (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)

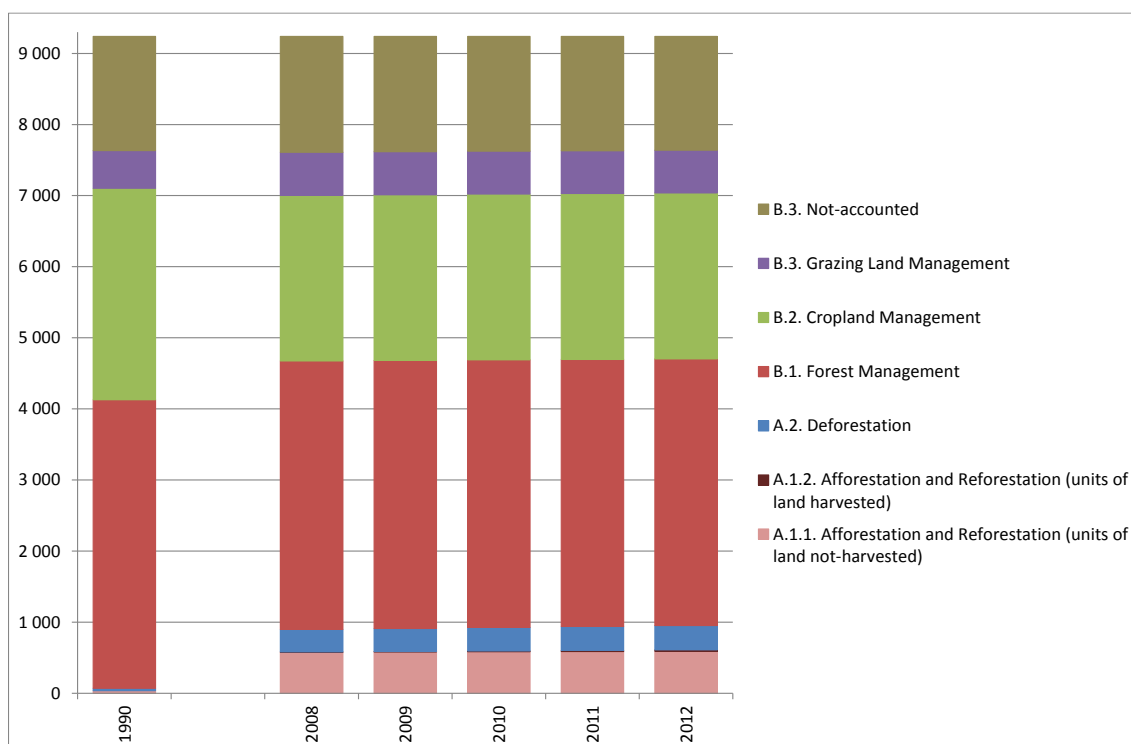
Conversions from cropland to grassland were reported as “Grazing land management”. Conversions between different cropland types were estimated and used in estimating emissions and removals, but the relevant conversion areas were included as “cropland management”.

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 6-9.

Figure 6-9 – Total Areas (1000 ha) per KP LULUCF Accounting Categories



### 6.1.3 Generic Methodologies Applicable to Multiple Land-Use Categories

#### 6.1.3.1 Biomass Expansion Factors, Root-To-Shoot factors and Carbon Fraction

##### 6.1.3.1.1 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.

#### 6.1.3.1.2 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.

#### 6.1.3.1.3 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 6-9 summarises the results obtained and the values used in the NIR.

Table 6-9 – 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 padies					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 "Shrubland", 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

#### 6.1.3.2 Mean Annual Increment / Growth Rates

##### 6.1.3.2.1 Forests

The values for Mean Annual Increments ( $MAI_{ff}$ ) used to estimate growth rates are intended to be representative of country wide averages for each type of forest considered and were obtained from expert judgement involving a consensus of a pool of forest experts with field

expertise in forest management, forest inventories and forest policy<sup>129</sup>. The values used in the NIR are presented in Table 6-10.

Table 6-10 – Mean Annual Increment per Forest Type (in pure and dominant stands)

Forest species	MAI <sub>ff</sub> m <sup>3</sup> /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

Both IFN (1995) and IFN (2005) 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:

$MAI_{yf}$  = Mean Annual Increment of dominated species y in Forest Type f

$MAI_{ff}$  = Mean Annual Increment of dominant species f in Forest Type f

$AVol_{yf}$  = 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 average volumes from IFN (1995) and IFN (2005) are presented, respectively, in Table 6-11 and Table 6-12.

<sup>129</sup> The pool of experts met on initiative of APA (Portuguese Environment Agency) and ICNF (Institute for Nature Conservation and Forests) and consisted of representatives of both institutions plus representatives of forest production and forest industries.

Table 6-11 – Average volume per hectare and per tree species by forest type, IFN (1995)

Mixed forests IFN (1995)		Forest Type							
average volume m <sup>3</sup> /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 6-12 – Average volume per hectare and per tree species by forest type (NFI5/2005)

Mixed forests IFN (2005)		Forest Type							
average volume m <sup>3</sup> /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 6-13 and Table 6-14, respectively for NFI4 and NFI5.

Table 6-13 – Mean Annual Increments per Forest Species and Forest Type IFN (1995)

Mixed forests IFN (1995)		Forest Type							
annual increment m <sup>3</sup> /ha.year		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	5,60	0,09	0,44	0,01	0,51	0,99	0,42	0,05
	Quercus suber	0,01	0,50	0,01	0,08	0,01	0,02	0,14	0,00
	Eucalyptus spp.	1,03	0,04	9,50	0,00	0,20	0,53	0,04	0,04
	Quercus rotundifolia	0,00	0,04	0,00	0,50	0,00	0,00	0,00	0,03
	Quercus spp.	0,14	0,02	0,03	0,01	2,90	0,32	0,04	0,10
	Other broadleaves	0,12	0,03	0,04	0,01	0,52	2,90	0,02	0,23
	Pinus pinea	0,18	0,39	0,01	0,02	0,04	0,07	5,60	0,00
	Other coniferous	0,04	0,07	0,01	0,24	0,03	0,20	0,03	5,00
Pure & dominant		5,60	0,50	9,50	0,50	2,90	2,90	5,60	5,00

Table 6-14 – Mean Annual Increments per Forest Species and Forest Type IFN (2005)

Mixed forests IFN (2005)		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	5,60	0,08	0,43	0,01	0,69	0,53	0,16	0,06
	Quercus suber	0,01	0,50	0,00	0,06	0,00	0,03	0,11	0,00
	Eucalyptus spp.	1,29	0,06	9,50	0,02	0,20	0,63	0,18	0,03
	Quercus rotundifolia	0,00	0,04	0,00	0,50	0,00	0,01	0,00	0,00
	Quercus spp.	0,12	0,01	0,02	0,03	2,90	0,46	0,00	0,09
	Other broadleaves	0,03	0,01	0,01	0,00	0,16	2,90	0,01	0,06
	Pinus pinea	0,05	0,34	0,02	0,01	0,00	0,05	5,60	0,02
	Other coniferous	0,01	0,00	0,00	0,00	0,06	0,20	0,01	5,00
Pure & dominant		5.60	0.50	9.50	0.50	2.90	2.90	5.60	5.00

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 6-15.

Table 6-15 – Mean Annual Increments (m<sup>3</sup>/ha.year) used for each Forest Type

annual increment m <sup>3</sup> /ha.year - Pinus pinaster		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

annual increment m <sup>3</sup> /ha.year - Quercus suber		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

annual increment m <sup>3</sup> /ha.year - Eucalyptus spp.		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

annual increment m <sup>3</sup> /ha.year - Quercus rotundifolia		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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



annual increment m <sup>3</sup> /ha.year - Quercus spp.		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

annual increment m <sup>3</sup> /ha.year - Other broadleaves		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

annual increment m <sup>3</sup> /ha.year - Pinus pinea		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

annual increment m <sup>3</sup> /ha.year - Other coniferous		1990- 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005- 2013
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

#### 6.1.3.2.2 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 6-10 - 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 6-16.

Table 6-16 – 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

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### 6.1.3.3 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.

#### 6.1.3.3.1 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 6-11 to Equation 6-13.

Equation 6-11 - Estimation of Total Average Living Biomass in Forests

$$LB_f = \sum_y AVol_{yf} \times BEF_y \times (1 + RTS_y) \times CF_y$$

Equation 6-12 - Estimation of Above Ground Living Biomass in Forests

$$AGB_f = \sum_y AVol_{yf} \times BEF_y \times CF_y$$

<sup>130</sup> For references of the sources of data for these values please check Table 6-17.

Equation 6-13 - Estimation of Below Ground Living Biomass in Forests

$$BGB_f = \sum_y AVol_{yf} \times BEF_y \times RTS_y \times CF_y$$

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

#### 6.1.3.3.2 Shrubland

For estimating above ground biomass the model proposed by Olson (1963) and adjusted for Portugal by Rosa (2009) was used.

Equation 6-14 - Estimation of Above Ground Living Biomass in Shrubland

$$AGB_s = 18.86 \times (1 - e^{-0.23t}) \times CF_s$$

Where:

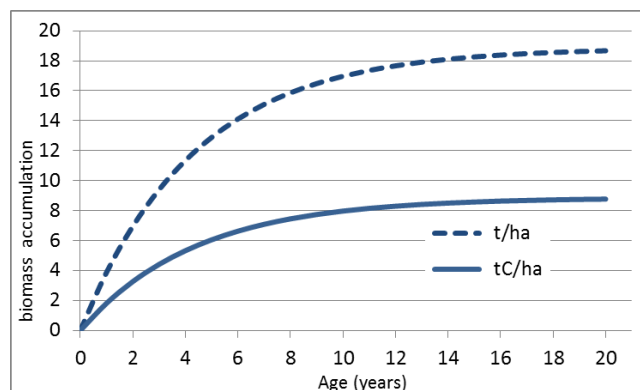
$AGB_s$  = Average Above Ground Biomass of shrubs (tC/ha)

$t$  = 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 6-10.

Figure 6-10 – Biomass accumulation in Shrubland in Portugal



Below ground and total living biomass were estimated using the root-to-shoot value presented in section 6.1.3.1.

#### 6.1.3.3.3 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 6-17: 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

#### 6.1.3.4 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 6-17 and a 20 year conversion period, as shown in Equation 6-15.

Equation 6-15 - 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 6-18 – Annual Emission/Sequestration Factors (GgC/1000 ha) for Litter

Changes		TO																		
		Forest land								Cropland						G	W	S	OL	
FROM		Pp	Qs	E spp	Qr	Q spp	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

#### 6.1.3.5 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 6-19.

Table 6-19 – Number of sample plots per land-use and soil depth

No. Plots C(0-20cm) (measured)	Source					Total		No. Plots C(20-40cm) (measured)	Source					Total
	LUCAS	ICP/Biosoil							LUCAS	ICP/Biosoil				
	2009	1995/99	2005	Total	2009				1995/99	2005	Total			
Legenda KP	2009	1995/99	2005	Total			Legenda KP	2009	1995/99	2005	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 6-20.

Table 6-20 – Average C Stock measured per land-use and soil depth

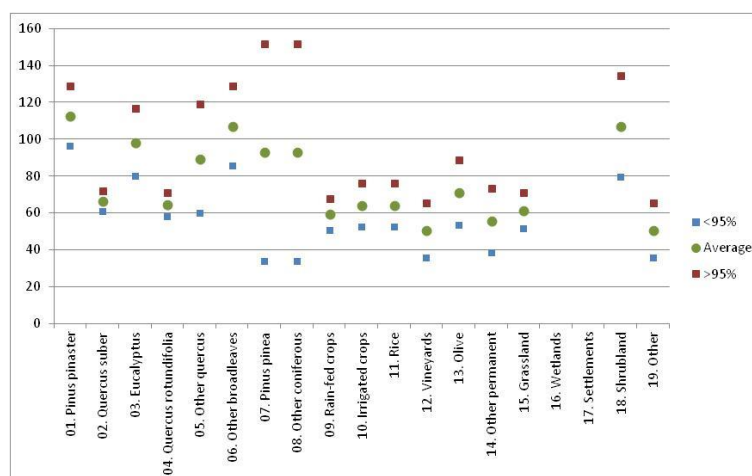
Average C (0-20cm) ton/ha (measured)	Source					Total		Average C (0-40cm) ton/ha (measured)	Source					Total
	LUCAS	ICP/Biosoil							LUCAS	ICP/Biosoil				
	2009	1995/99	2005	Average	20-40cm				0-20cm	20-40cm	0-40cm	40/20cm		
Legenda KP	2009	1995/99	2005	Average	2009	1995/99	2005	Average	20-40cm	0-20cm	20-40cm	0-40cm	40/20cm	
01. Pinus pinaster	70	73	72	72	71				01. Pinus pinaster	77	45	122	59%	
02. Quercus suber	46	43	40	41	43				02. Quercus suber	38	15	53	40%	
03. Eucalyptus	75	41	41	41	62				03. Eucalyptus	41	26	67	63%	
04. Quercus rotundifolia	41	43	45	44	43				04. Quercus rotundifolia	44	15	59	35%	
05. Other quercus	58	51	52	52	55				05. Other quercus	52	39	91	74%	
06. Other broadleaves	71	66	63	64	65				06. Other broadleaves	60	45	105	75%	
07. Pinus pinea + 08. Other coniferous	74	25	64	38	58				07. Pinus pinea + 08. Other coniferous	46	28	74	62%	
09. Rain-fed crops	40	27		27	37				09. Rain-fed crops	27	19	46	71%	
10. Irrigated crops + 11. Rice	39	39		39	39				10. Irrigated crops + 11. Rice	37	28	65	74%	
12. Vineyards	36	24		24	31				12. Vineyards	24	16	40	69%	
13. Olive	49	33		33	45				13. Olive	33	20	53	61%	
14. Other permanent	44	26		26	35				14. Other permanent	26	16	42	61%	
15. Grassland	43	30		30	39				15. Grassland	33	18	51	54%	
17. Settlements	55				55				17. Settlements					
18. Shrubland	70	52	88	58	68				18. Shrubland	58	33	91	58%	
Média global	52	44	50	46	49				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 6-21. Figure 6-11 shows graphically the averages per land-use type and the respective 95% confidence interval.

Table 6-21 – 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 6-11 – 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 6-16 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.

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 6-21 and a 20 year conversion period, as shown in Equation 6-16.

Equation 6-16 - 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)

Given the relatively low number of plots and relatively high variance of the results, the values obtained from Equation 6-16 were further modified in order to become more conservative by using the lower end of the 50% confidence intervals so that sequestration factors were decreased<sup>131</sup>.

<sup>131</sup> For example the sequestration factor for the conversion from 4. Quercus rotundifolia to 1. Pinus pinaster calculated by Equation 6-16 was 2.4 tC/year. The value used was 2.1, which corresponds to the lower end of the 50% confidence interval of the difference between the 2 mean C stocks. Conversely, for the reverse conversion (from 1. Pinus pinaster to 4. Quercus rotundifolia) the calculated emission factor of -2.4 tC/year was used.

Finally, and since there are no sample plots in settlements and wetlands, the soil C stock was considered zero in these land categories. Emissions resulting from conversions of other land uses to one of these two land-use categories considered the loss of all soil Carbon (a very conservative estimate), while the (symmetrical) sequestration in conversions from these categories to other land-uses was considered zero.

The resulting Soil Emission Factors in Table 6-22.

Table 6-22 – Estimated Annual Emission/Sequestration Factors (tC/ha) for Soil

Soil Emission Factors			TO																		
			Forest land								Cropland						Grassl	Wetl	Settm	Other Land	
FROM	Forest land	01. Pinus pinaster	0,0	-2,3	0,0	-2,4	0,0	0,0	0,0	0,0	-2,7	-2,4	-2,4	-3,1	-2,1	-2,8	-2,6	-5,6	-5,6	0,0	-3,1
		02. Quercus suber	2,0	0,0	1,3	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,3	-3,3	1,6	0,0
		03. Eucalyptus	0,0	-1,6	0,0	-1,7	0,0	0,0	0,0	0,0	-2,0	-1,7	-1,7	-2,4	-1,4	-2,1	-1,9	-4,9	-4,9	0,0	-2,4
		04. Quercus rotundifolia	2,1	0,0	1,4	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,2	-3,2	1,6	0,0
		05. Other quercus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-1,9	0,0	0,0	0,0	-4,5	-4,5	0,0	-1,9
		06. Other broadleaves	0,0	-2,0	0,0	-2,1	0,0	0,0	0,0	0,0	-2,4	-2,2	-2,2	-2,8	-1,8	-2,6	-2,3	-5,4	-5,4	0,0	-2,8
		07. Pinus pinea	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-4,7	-4,7	0,0	0,0
		08. Other coniferous	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-4,7	-4,7	0,0	0,0
	Cropland	09. Rain-fed crops	2,4	0,0	1,6	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,0	-3,0	1,9	0,0
		10. Irrigated crops	2,1	0,0	1,3	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,2	-3,2	1,6	0,0
		11. Rice	2,1	0,0	1,3	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,2	-3,2	1,6	0,0
		12. Vineyards	2,7	0,0	2,0	0,0	1,4	2,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-2,5	-2,5	2,3	0,0
		13. Olive	1,7	0,0	0,9	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,6	-3,6	1,2	0,0
		14. Other permanent	2,4	0,0	1,7	0,0	0,0	2,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-2,8	-2,8	2,0	0,0
	Grassland	15. Grassland	2,2	0,0	1,5	0,0	0,0	1,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-3,1	-3,1	1,8	0,0
	Wetlands	16. Wetlands	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Settlements	17. Settlements	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Other Land	18. Shrubland	0,0	-2,0	0,0	-2,1	0,0	0,0	0,0	0,0	-2,4	-2,2	-2,2	-2,8	-1,8	-2,6	-2,3	-5,4	-5,4	0,0	-2,8
		19. Other	2,7	0,0	2,0	0,0	1,4	2,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-2,5	-2,5	2,3	0,0

#### 6.1.3.6 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.

## 6.2 Forest Land (CFR 4.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 -7.8 Mt CO<sub>2</sub>eq and -15.7 MtCO<sub>2</sub>eq.



Figure 6-12 – Areas of Forest Land per UNFCCC Reporting Category (1000 ha)

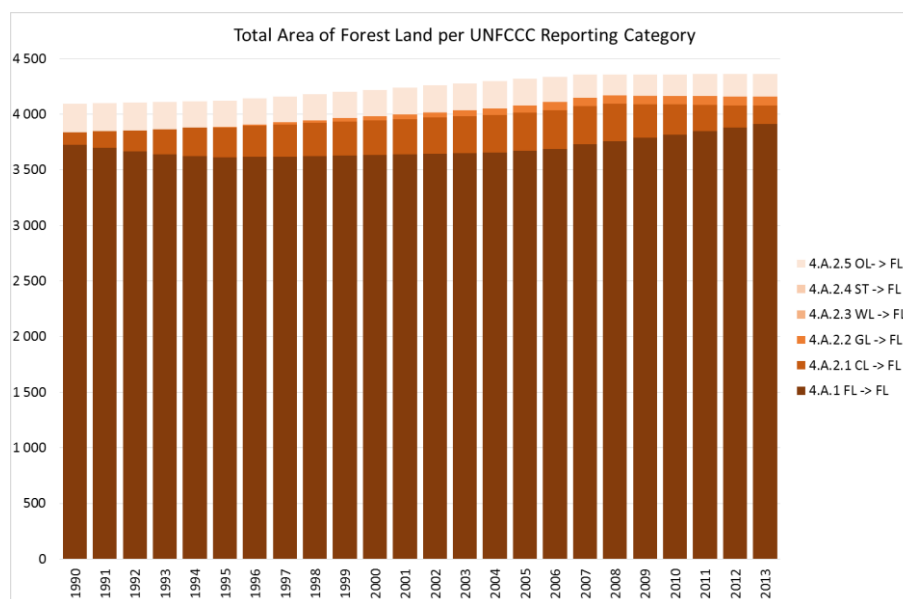
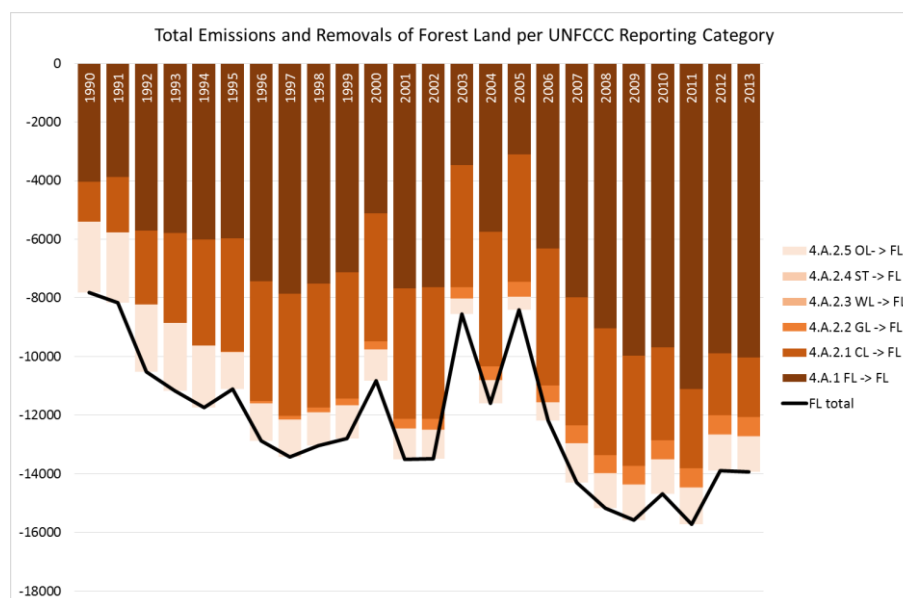


Figure 6-13: Total Emissions and Removals in Forest Land (kt CO2 eq.)



## 6.2.1 Forest Land Remaining Forest Land

### 6.2.1.1 Area

Area estimates for Forest Land Remaining Forest Land were made following the methodology outlined in section 6.1.2 - 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.

### 6.2.1.2 Living Biomass

#### 6.2.1.2.1 Gains in Living Biomass

Gains in living biomass refer to trees only and were estimated using Equation 6-17. Estimates were made for each forest type (8 forest types considered; see Table 6-1). Within each forest type the growth of different forest species was considered, reflecting the large share of mixed forests in Portugal (see Table 6-11 and Table 6-12).

Equation 6-17 – 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

$\sum_{FT_f}$  = Sum for all forest types

$\sum_{FS_y}$  = 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).

#### 6.2.1.2.2 Losses in Living Biomass

Losses of living biomass were categorised in different types / origins of loss and the corresponding emissions are estimated using different approaches according to loss type. Table 6-23 provides a summary of the types of losses considered in the reporting and how they were allocated to UNFCCC Categories “forest land remaining forest land” and “land converted to forest”.

Table 6-23: Summary of types of losses in living biomass considered in the estimations of emissions and removals in forest land

Type of C loss	Definition / data source	Allocation L->FL and FL->FL
Industrial harvest	Industry wood consumption. Hardwoods fully allocated to Eucalyptus spp. and softwoods fully allocated to Pinus pinaster as these are the main tree species used by industry; estimates include the loss of biomass from the entire tree (AG and BG biomass) at the year of harvest / INE	L->FL = only eucalyptus with 12 years in reporting year; other species assumed too young to be harvested FL->FL = total - L->FL
Other wood use	Wood uses for un-declared purposes (small industry or households), pruning and non-industrial thinning; estimated as 25% of mean annual increment / Expert judgment	L->FL = allocation based on area per forest type FL->FL = allocation based on area per forest type
Salvaged wood	Wood with industry or household use resulting from forest fires; estimates include the loss of biomass from the entire tree (AG and BG biomass) at the year of fire / Expert judgment	L->FL = allocation based on area per forest type FL->FL = allocation based on area per forest type
Forest conversion	Losses from converting one forest type into another forest type (change in dominant species); estimated based on loss of standing volume of previous forest type; estimates include the loss of biomass from the entire tree (AG and BG biomass) at the year of conversion / IFN (2005)	L->FL = not applicable FL->FL = based on land-use change areas in reporting year
Natural mortality (non-fire related)	Natural mortality and self-thinning of trees; estimated based on percentage of number of non-burnt dead trees and assuming all standing dead trees died over the past 3 years / IFN (2005)	L->FL = allocation based on area per forest type FL->FL = allocation based on area per forest type
Conversion to forest (afforestation)	Losses from converting a non-forest land-use type into a forest type; estimated based on loss of living biomass of previous land-use type / EEA and Spanish NIR	L->FL = allocation based on area per previous land-use x new forest type FL->FL = not applicable
Non-salvaged wood	Wood with industry or household use resulting from forest fires; estimates include the loss of biomass from the entire tree (AG and BG biomass) at the year of fire / Expert judgment	<u>Reported as “fire emissions” not as “losses”</u> L->FL = allocation based on area per forest type FL->FL = allocation based on area per forest type
Deforestation	Losses from converting one forest type into another land-use; estimated based on loss of standing volume of previous forest type; estimates include the loss of biomass from the entire tree (AG and BG biomass) at the year of deforestation / IFN (2005)	<u>Reported as “losses” from FL-&gt;L in the respective land-use and not as Forest land emissions</u>

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 4(V).

Emissions from industrial 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.”.

Eucalyptus plantations are harvested in a rotation period of 12 years, i.e., before the 20 years conversion period<sup>132</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

<sup>132</sup> Lands are moved from the category “Land converted to Forest” to “Forest Land Remaining Forest Land” 20 years after the afforestation took place.

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.

There are no statistics for harvesting from other wood use (domestic use of biomass for energy, thinning with no industrial use, and pruning). In those cases, it was assumed (expert judgement) 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.

Emissions from salvaged wood are considered in addition to emissions from industrial harvesting, which again is considered a conservative estimate, since salvaged wood has, by definition, industrial use.

Emissions from forest conversion are associated with changes in species, which may happen following final felling followed by a reforestation using a different species or by more subtle changes in dominant species (which lead to a change in forest type classification). Forest conversions are not deforestation (because a forest type is followed by another forest type), but the emissions from conversion are calculated in a similar manner as deforestation, i.e., it consists on the emission of all the living biomass carbon present in the previous forest type.

Emissions from conversions to forest (i.e. land converted to forest or afforestation) include the emissions related to the loss of carbon present in the previous land-use.

Finally emissions from natural mortality include emissions from trees that die from natural causes (self-thinning, pests and diseases) but excludes forest fires (since these emissions are reported in Table 4(V)). These are estimated from the number of dead trees from causes other than fire, assuming that all dead trees present at any point in time died in the past 3 years. This information is collected in the National Forest Inventory.

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 6-18: Estimation of losses in living biomass in Forest Land Remaining Forest Land

$$LBL_{RY_i} = LBLH_{RY_i} + LBLWU_{RY_i} + LBLSW_{RY_i} + LBLNM_{RY_i} + LBLFC_{RY_i}$$

$$LBLH_{RY_i} = \sum_{FS_y} (HARV_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y)$$

$$LBLWU_{RY_i} = \sum_{FS_y} (OWU_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y)$$

$$LBLSW_{RY_i} = \sum_{FS_y} (SW_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y)$$

$$LBLNM_{RY_i} = \sum_{FS_y} (NM_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y)$$

$$LBLFC_{RY_i} = \sum_{f \rightarrow x} AFC_{f \rightarrow x,RY_i} \times (AGB_f + BGB_f)$$

Where:

$LBL_{RY_i}$  = Living Biomass Losses in Reporting Year i (tC)

$LBLH_{RY_i}$  = Living Biomass Losses from Industrial Harvesting in Reporting Year i (tC)

$LBLOWU_{RY_i}$  = Living Biomass Losses from Other Wood Use in Reporting Year i (tC)

$LBLSW_{RY_i}$  = Living Biomass Losses from Salvaged Wood in Reporting Year i (tC)

$LBLNM_{RY_i}$  = Living Biomass Losses from Natural Mortality in Reporting Year i (tC)

$LBLFC_{RY_i}$  = Living Biomass Losses from Forest Conversion in Reporting Year i (tC)

$\sum_{FS_y}$  = Sum for all forest species

$\sum_{f \rightarrow x}$  = Sum for all conversions between forest types

$HARV_{y,RY_i}$  = Volume of industrial harvesting of forest species y in reporting year i (m<sup>3</sup>)

$OWU_{y,RY_i}$  = Volume of other wood use harvesting of forest species y in reporting year i (m<sup>3</sup>)

$SW_{y,RY_i}$  = Volume of salvaged wood harvesting of forest species y in reporting year i (m<sup>3</sup>)

$NM_{y,RY_i}$  = Volume of natural mortality volume 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 6-17)

$BGB_f$  = Average Below Ground Biomass of forest type f (tC/ha) (from Table 6-17)

$BEF_y$  = 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

#### 6.2.1.3 Dead Organic Matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 6.2.1.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 6.2.1.5 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).

### 6.2.2 Land Converted to Forest

#### 6.2.2.1 Area

Area estimates for Land Converted to Forest Land were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

#### 6.2.2.2 Living Biomass

##### 6.2.2.2.1 Gains in Living Biomass

Equation 6-17 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.

##### 6.2.2.2.2 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 6-17).

Eucalyptus plantations are harvested in a rotation period of 12 years, i.e., before the 20 years conversion period<sup>133</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.

<sup>133</sup> Lands are moved from the category “Land converted to Forest” to “Forest Land Remaining Forest Land” 20 years after the afforestation took place.

### 6.2.2.3 Dead Organic matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### 6.2.2.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## 6.3 Cropland (CRF 4.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 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. Emissions in the period have ranged between 0.6 and 4.3 Mt CO<sub>2</sub>/year and with clear trend for decreasing emissions.

Figure 6-14 – Areas of Cropland per UNFCCC Reporting Category (1000 ha)

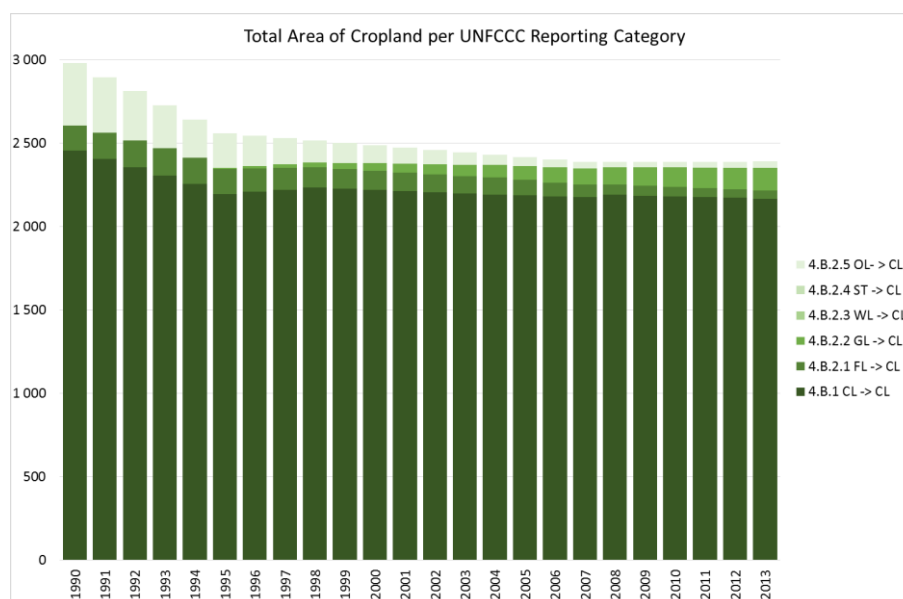
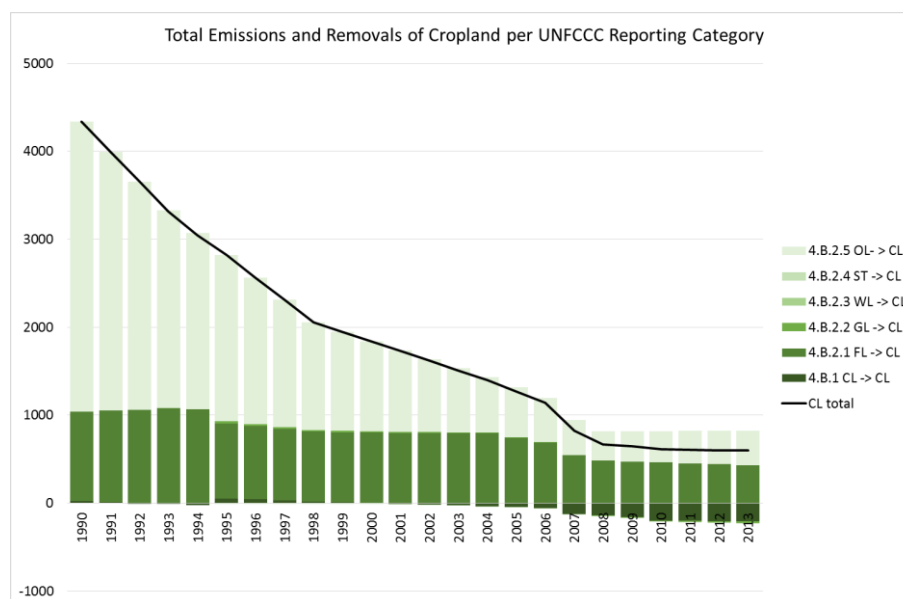


Figure 6-15 – Total Emissions and Removals in Cropland (kt CO<sub>2</sub> eq.)



### 6.3.1 Cropland Remaining Cropland

#### 6.3.1.1 Area

Area estimates for Cropland Remaining Cropland were made following the methodology outlined in section 6.1.2 - 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.

#### 6.3.1.2 Living Biomass

##### 6.3.1.2.1 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 6-16. 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).

##### 6.3.1.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

#### 6.3.1.3 Dead Organic Matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.



#### 6.3.1.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 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 6.3.1.5).

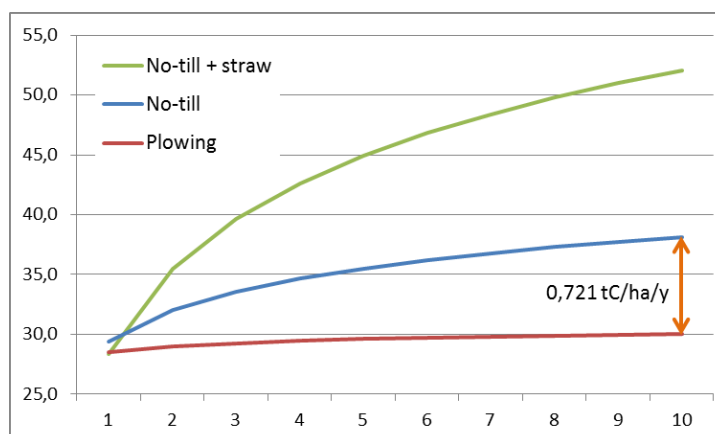
#### 6.3.1.5 Activity in Cropland: No tillage

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 6-16 – 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.

### 6.3.2 Land Converted to Cropland

#### 6.3.2.1 Area

Area estimates for Land Converted to Cropland were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

#### **6.3.2.2 *Living Biomass***

##### **6.3.2.2.1 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 6-16. 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).

##### **6.3.2.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

##### **6.3.2.3 *Dead Organic Matter***

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

##### **6.3.2.4 *Mineral Soils***

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### **6.4 Grassland (CRF 4.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.

Emissions in the period have ranged between 0.3 and 3.6 Mt CO<sub>2</sub>/year and with clear trend for decreasing emissions.

Figure 6-17 – Areas of Grassland per Reporting Category (1000 ha)

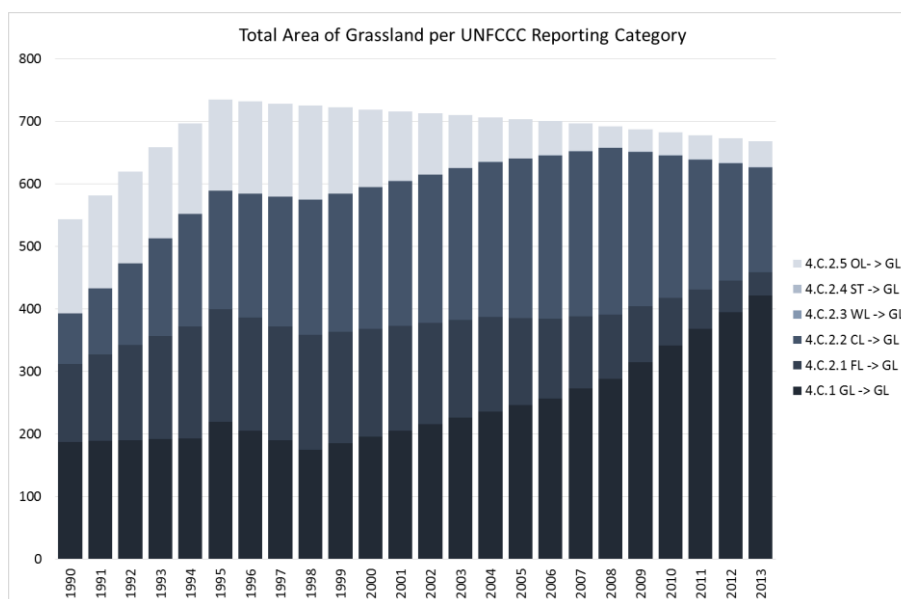
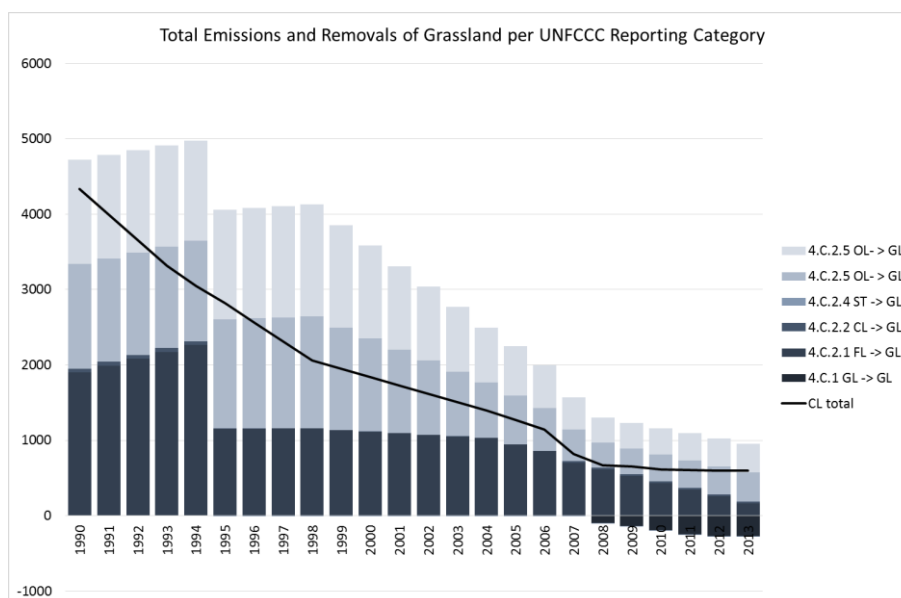


Figure 6-18 – Total Emissions and Removals in Grassland (kt CO<sub>2</sub> eq.)



## 6.4.1 Grassland Remaining Grassland

### 6.4.1.1 Area

Area estimates for Grassland Remaining Grassland were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

#### **6.4.1.2 Living Biomass**

##### **6.4.1.2.1 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.

##### **6.4.1.2.2 Losses in Living Biomass**

#### **6.4.1.3 The same assumption was used for losses in living biomass.**

##### **6.4.1.3.1 Dead Organic Matter**

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

##### **6.4.1.4 Mineral Soils**

The annual emission/sequestration factors of Table 6-22 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 6.4.1.4.1).

##### **6.4.1.4.1 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).

#### **6.4.2 Land Converted to Grassland**

##### **6.4.2.1 Area**

Area estimates for Land Converted to Grassland were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

### 6.4.2.2 Living Biomass

#### 6.4.2.2.1 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 6-16. All gains are assumed to occur in the year when the land-use change occurs.

#### 6.4.2.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

### 6.4.2.3 Dead Organic Matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### 6.4.2.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## 6.5 Wetlands (CRF 4.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.

Emissions in the period have ranged between 0 and 0.4 Mt CO<sub>2</sub>/year and with trend for increasing emissions.

Figure 6-19 – Areas of Wetlands per Reporting Category (1000 ha)

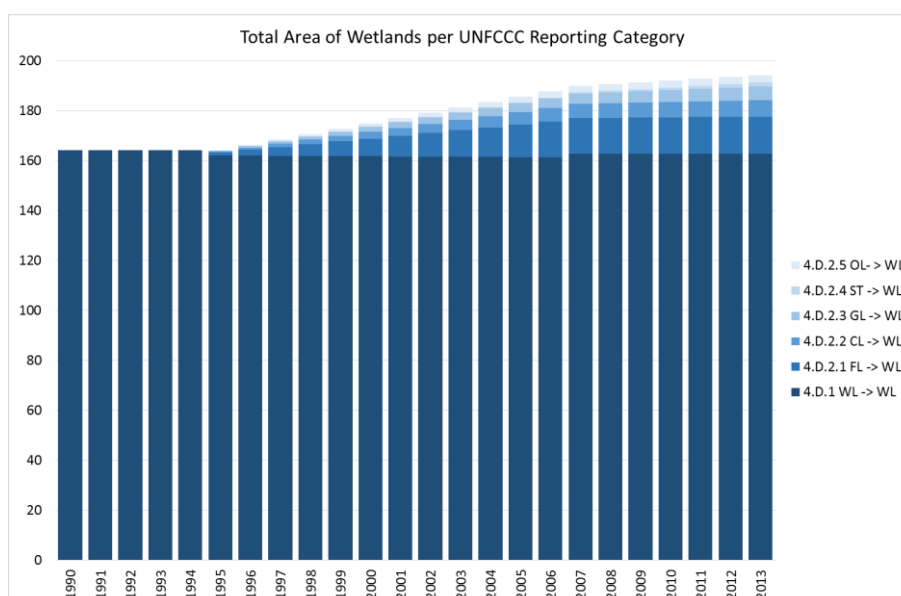
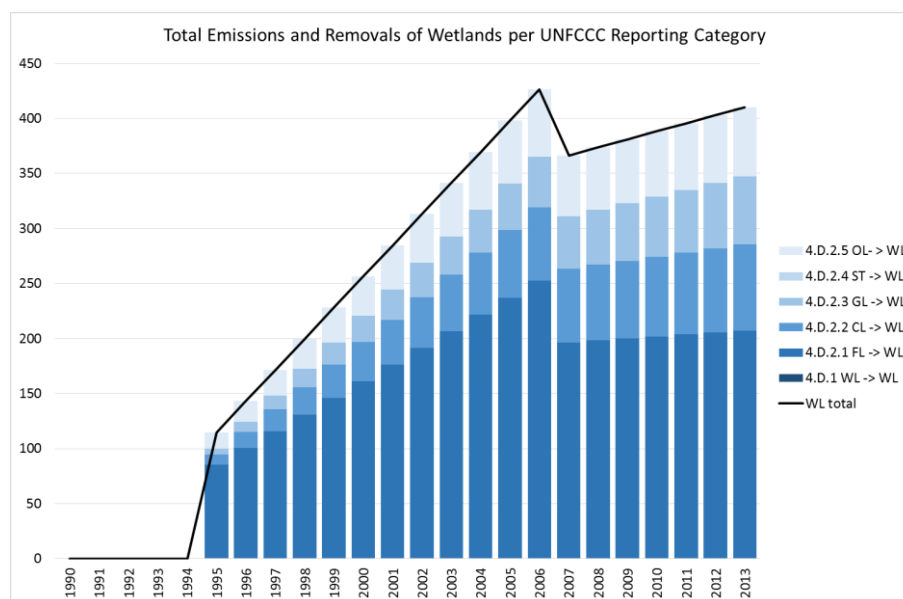


Figure 6-20 – Total Emissions and Removals in Wetlands (kt CO<sub>2</sub> eq.)



### 6.5.1 Wetlands remaining wetlands

Area estimates for Wetlands Remaining Wetlands were made following the methodology outlined in section 6.1.2 - 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.

### 6.5.2 Lands converted to wetlands

#### 6.5.2.1 Area

Area estimates for Land Converted to Wetlands were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

#### 6.5.2.2 Living Biomass

##### 6.5.2.2.1 Gains in Living Biomass

Gains in living biomass are estimated to be zero, according to the unit value presented in Table 6-16. All gains are assumed to occur in the year when the land-use change occurs.

##### 6.5.2.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

#### 6.5.2.3 Dead Organic Matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

#### 6.5.2.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## 6.6 Settlements (CFR 4.E)

Over the past 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.

Emissions in the period have ranged between 0 and 3.1 Mt CO<sub>2</sub>/year and with a trend for increasing emissions.

Figure 6-21 – Areas of Settlements per Reporting Category (1000 ha)

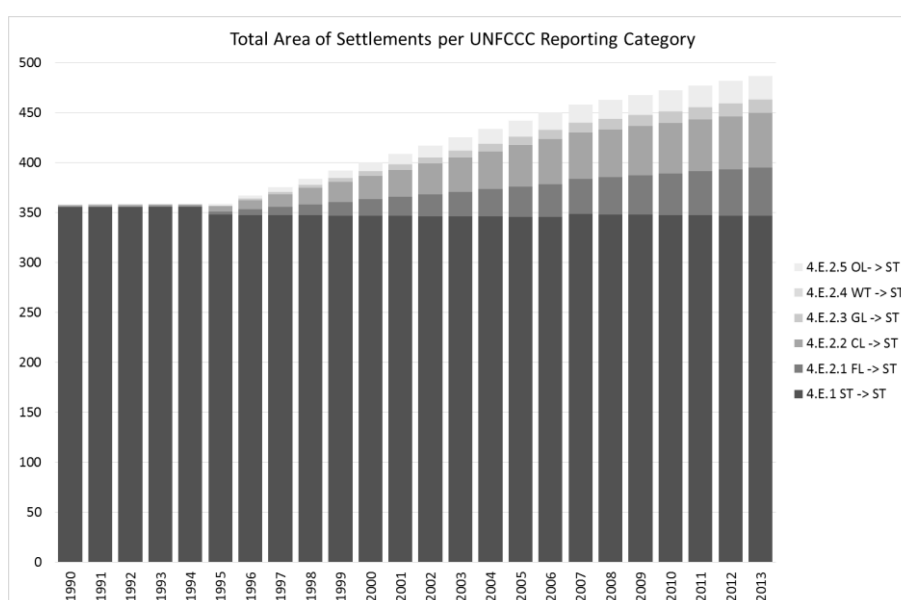
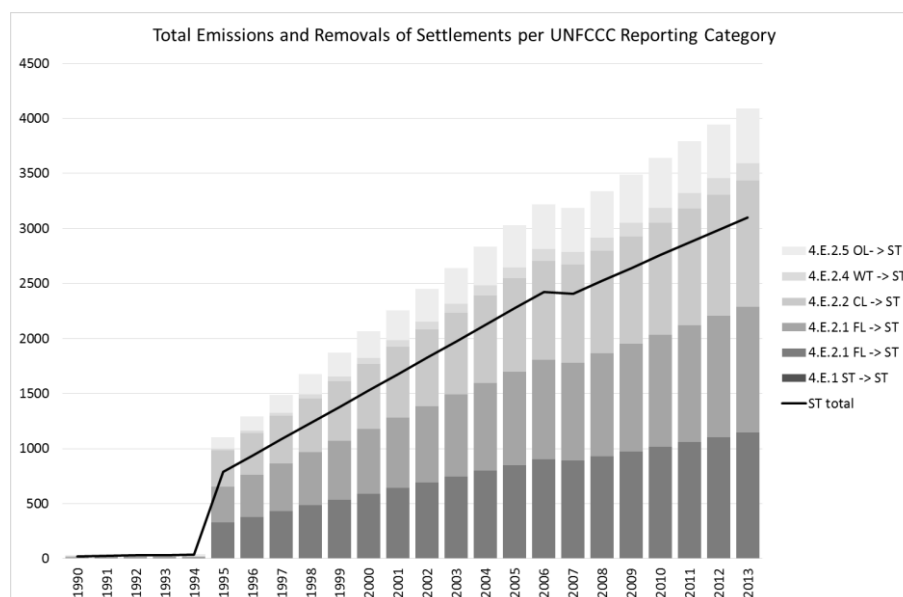


Figure 6-22 – Total Emissions and Removals in Settlements (kt CO<sub>2</sub> eq.)



### 6.6.1 Settlements remaining settlements

Area estimates for Settlements Remaining Settlements were made following the methodology outlined in section 6.1.2 - 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.

### 6.6.2 Lands converted to settlements

#### 6.6.2.1 Area

Area estimates for Land Converted to Settlements were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

#### 6.6.2.2 Living Biomass

##### 6.6.2.2.1 Gains in Living Biomass

Gains in living biomass are estimated to be zero, according to the unit value presented in Table 6-16. All gains are assumed to occur in the year when the land-use change occurs.

##### 6.6.2.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

#### 6.6.2.3 Dead Organic Matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.



#### 6.6.2.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### 6.7 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.

Emissions in the period have ranged between -2.8 and +0.9 Mt CO<sub>2</sub>/year and with a more recent trend for decreasing sequestration.

Figure 6-23 – Areas of Other Land per Reporting Category (1000 ha)

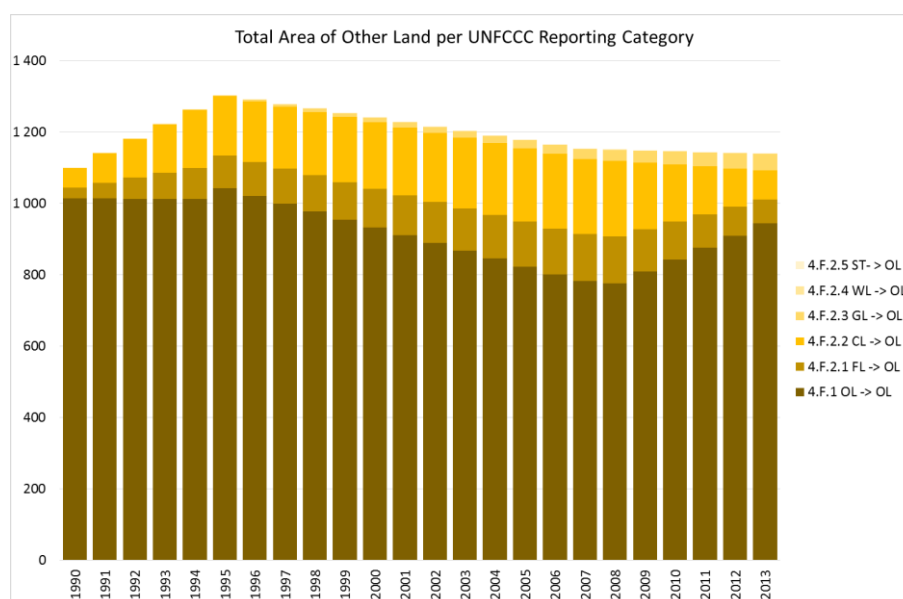
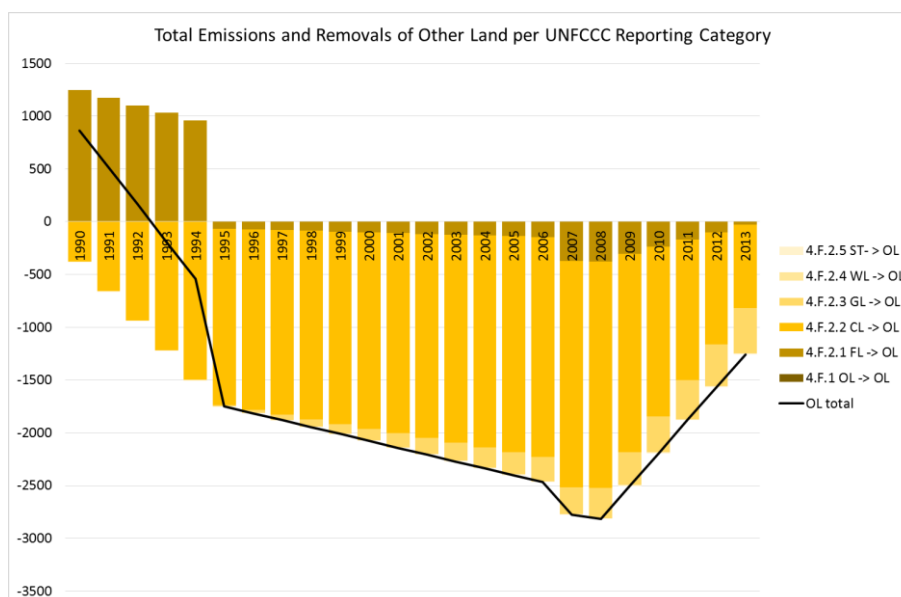


Figure 6-24 – Total Emissions and Removals in Other Land (kt CO<sub>2</sub> eq.)



## 6.7.1 Other land remaining other land

### 6.7.1.1 Area

Area estimates for Other land Remaining Other land were made following the methodology outlined in section 6.1.2 - 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.

### 6.7.1.2 Living Biomass

#### 6.7.1.2.1 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 6-16. All gains are assumed to occur over a 20 years period.

#### 6.7.1.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

### 6.7.1.3 Dead Organic Matter

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### 6.7.1.4 Mineral Soils

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## **6.7.2 Land converted to other land**

### **6.7.2.1 Area**

Area estimates for Land Converted to Other land were made following the methodology outlined in section 6.1.2 - Representation of Land-Areas and Land-Use Changes.

### **6.7.2.2 Living Biomass**

#### **6.7.2.2.1 Gains in Living Biomass**

Gains in living biomass were estimated using the unit values presented in Table 6-16. All gains are assumed to occur over a 20 years period.

#### **6.7.2.2.2 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 6-17. All losses are assumed to occur in the year when the land use change occurs.

### **6.7.2.3 Dead Organic Matter**

The annual emission/sequestration factors of Table 6-18 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

### **6.7.2.4 Mineral Soils**

The annual emission/sequestration factors of Table 6-22 combined with the relevant area estimates were used to estimate emissions and removals in this pool.

## **6.8 Harvested Wood Products (CRF 4.G)**

Data for production, imports and exports was derived from UNECE for the period 1964-2013. 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. The results are presented in Figure 6-25.

Product grades considered were wood pulp (UNECE product code 7, half-live of 2 years); wood panels (UNECE product code 6, half-live of 25 years) and sawn wood (UNECE product code 5, half-live 35 years). The results are presented in Figure 6-26.

Figure 6-25 – Reported Activity Data for Harvested Wood Products

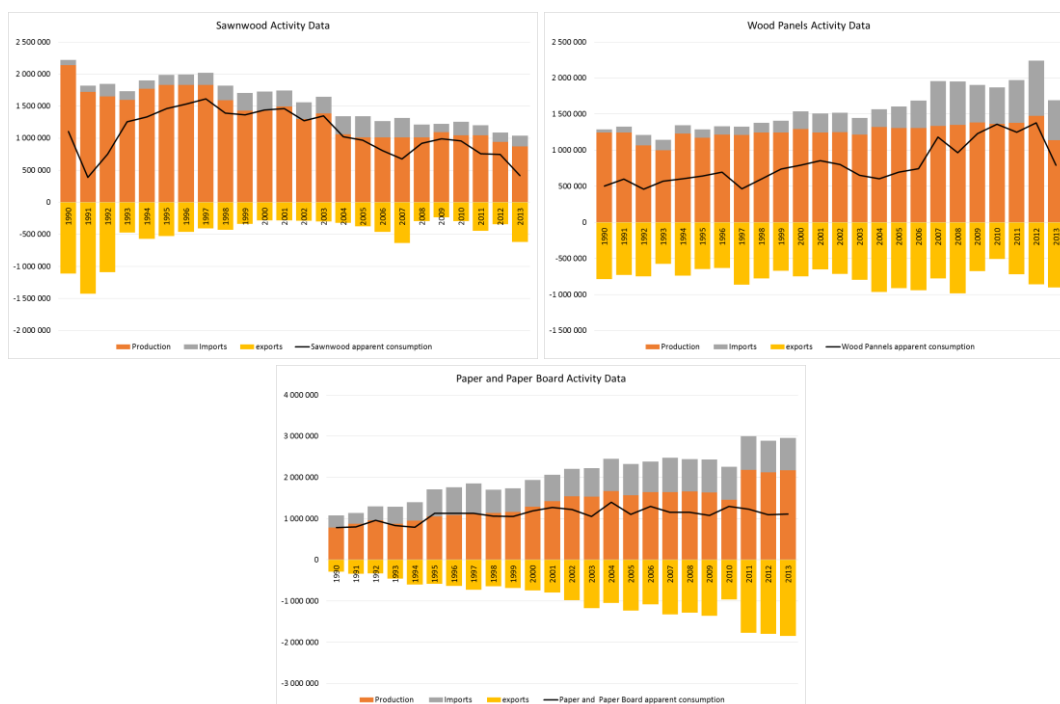
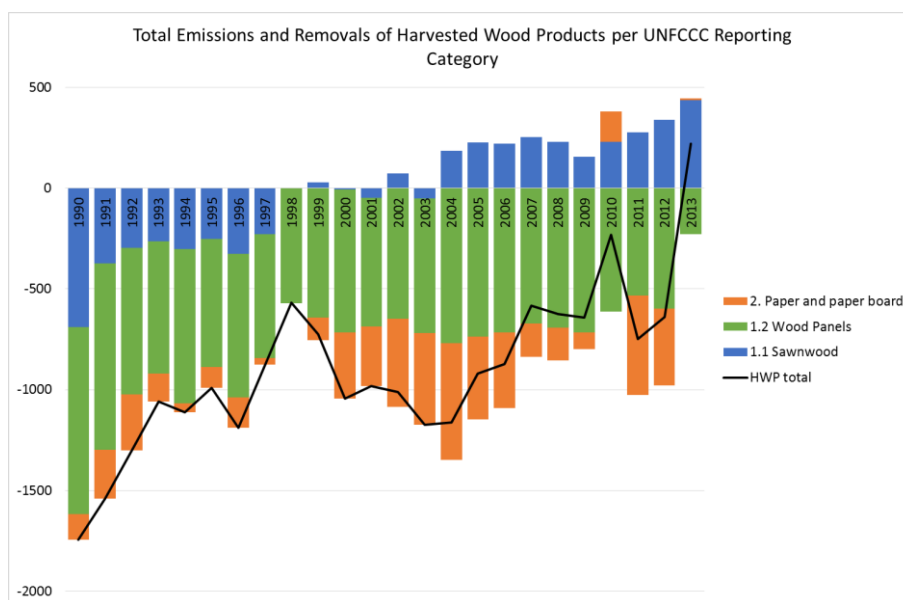


Figure 6-26 – Evolution of Carbon Stocks and Carbon Stock Changes in Harvested Wood Products



## 6.9 Direct N<sub>2</sub>O Emissions from N-Inputs to Managed Soils (CRF 4(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.

## 6.10 Emissions and Removals from Drainage and Rewetting and other Management of Organic and Mineral soils (CRF 4(II))

The source is considered negligible and is reported as "Not Occurring".

## 6.11 Direct N<sub>2</sub>O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter resulting from change of LU or management of Mineral Soils (CRF 4(III))

Emissions from N<sub>2</sub>O were estimated based on the areas where loss of soil carbon was taking place as a result of land-use change.

The equation used was

$$N_2O - N_{CLoss} = EF_1 \times \Delta C_{LCMineral} \times \frac{1}{C:N ratio} \times 10^{-6}$$

Where:

$N_2O - N_{CLoss}$  = N<sub>2</sub>O emissions associated with a Soil Carbon Loss, 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

## 6.12 Indirect N<sub>2</sub>O Emissions from managed soils (CRF 4(IV))

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.

## 6.13 Emissions from Biomass Burning (CRF 4(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 6-24.

Table 6-24 – Pools and Gases Included in Estimations of Fire Emissions

Land use	GHG → Pool ↓	Direct emissions CO <sub>2</sub>	Direct emissions N <sub>2</sub> O and CH <sub>4</sub>	Indirect emissions CO <sub>2</sub>
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 ⇒	Yes	Land-remaining-land No gains/losses are considered ⇒
Forest	Litter	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
Agriculture	Above ground biomass		Yes	
Grasslands	Above ground biomass		Yes	
Other land	Above ground biomass		Yes	
Other land	Litter		Yes	

### 6.13.1 Estimation of Burnt Areas

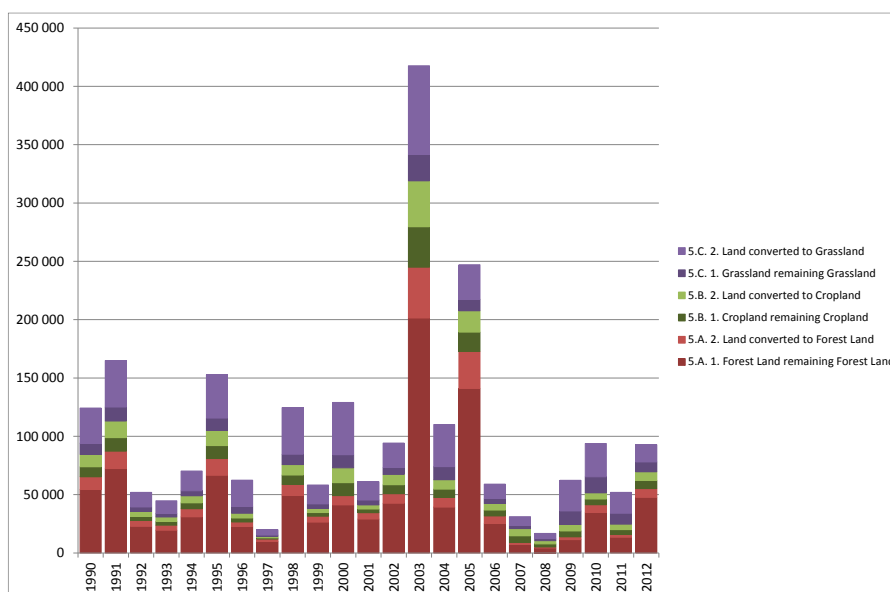
The main sources of burnt areas are the fire reports issued every year by the National Forest Authority, currently the Institute for Nature Conservation and Forestry (ICNF 1990-2012). The reports are derived from satellite imagery and the results cover all burnt areas.

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 6-27 – Burnt Areas per Reporting Category (ha)



### 6.13.2 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 6-17.

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 6-25.

Table 6-25 – 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%

### 6.13.3 Direct CO<sub>2</sub> Emissions from Fires

Direct CO<sub>2</sub> emissions from fires were estimated using Equation 6-19.

Equation 6-19 - Estimation of Direct CO<sub>2</sub> Emissions from Fires

$$E_{CO_2} = \sum_x BA_x \times BLF_x \times Cf \times CtoCO_2$$

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)

### 6.13.4 Direct CH<sub>4</sub> Emissions from Fires

Direct CH<sub>4</sub> emissions from fires were estimated using Equation 6-20.

Equation 6-20 - Estimation of Direct CH<sub>4</sub> Emissions from Fires

$$E_{CH_4} = \sum_x BA_x \times BLF_x \times Cf \times C/CH_4 \times CtoCH_4$$

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)

### 6.13.5 Direct $N_2O$ Emissions from Fires

Direct  $N_2O$  emissions from fires were estimated using Equation 6-21.

Equation 6-21 - Estimation of Direct  $N_2O$  Emissions from Fires

$$E_{N_2O} = \sum_x BA_x \times BLF_x \times Cf \times N/C \times N/N_2O \times NtoN_2O$$

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)

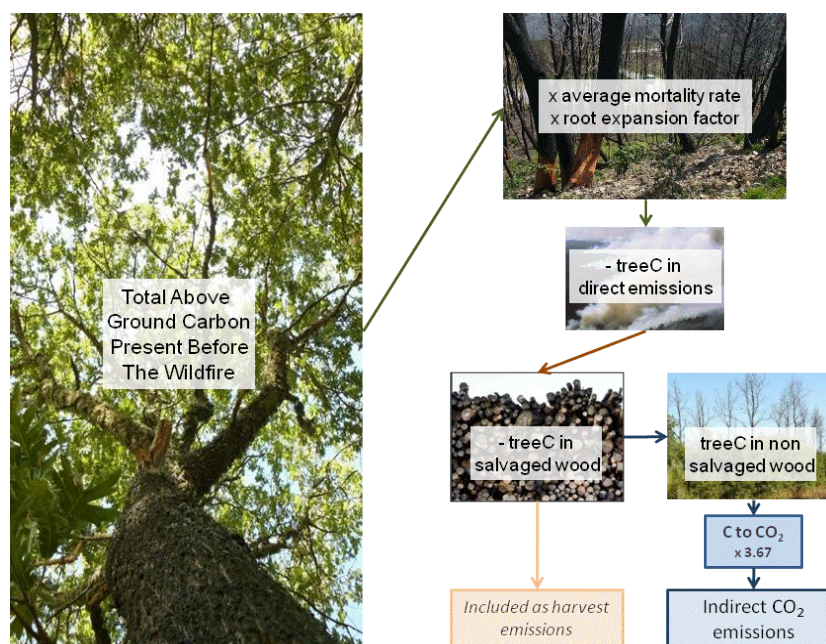
$N/N_2O$  = Nitrogen Lost as  $N_2O$  (IPCC Default = 0,007)

$NtoN_2O$  = Stoichiometric conversion from Nitrogen to  $N_2O$  (3,14)

### 6.13.6 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 6-28.

Figure 6-28 – Estimation of Indirect Fire Emissions



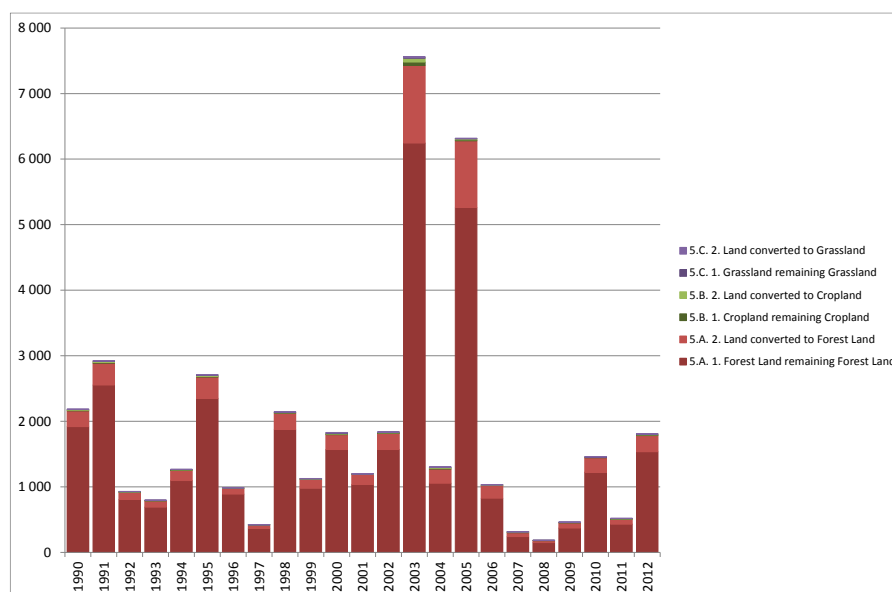
Average Mortality Rates and Salvage Wood were estimated by expert judgement, as presented in Table 6-26.

Table 6-26 – Mortality and Salvage Wood Rates

Land-use Type	Mortality %	Non-salvage %
<i>Pinus pinaster</i>	70%	60%
<i>Quercus suber</i>	30%	60%
<i>Eucalyptus</i> spp.	50%	50%
<i>Quercus rotundifolia</i>	10%	60%
<i>Quercus</i> spp.	30%	60%
Other broadleaves	30%	60%
<i>Pinus pinea</i>	30%	60%
Other coniferous	70%	60%

The results of the estimations are presented in the figure below.

Figure 6-29 – Total Emissions from Biomass Burning per Land-use Category (kt CO<sub>2</sub> eq.)



## 6.14 Uncertainty Assessment

### 6.14.1 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.

### 6.14.2 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.

### 6.14.3 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.

### 6.14.4 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.

### 6.14.5 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.

#### **6.14.6 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.

#### **6.14.7 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.

#### **6.14.8 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.

#### **6.14.9 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.

#### **6.14.10 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.

#### **6.14.11 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.

#### **6.14.12 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.

#### **6.14.13 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.

#### **6.14.14 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%.

#### **6.14.15 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%.

#### **6.14.16 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%.

### **6.15 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.

### **6.16 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 6.1.2.3.2). 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.

### **6.17 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.

## 7 WASTE (CRF 5.)

### 7.1 Overview

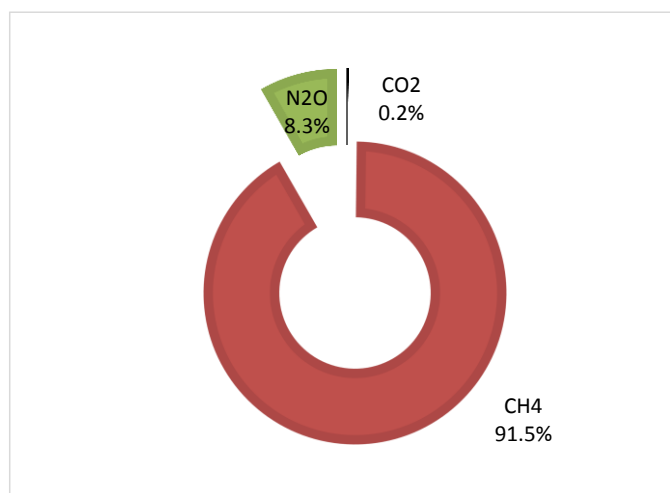
Waste management and treatment of industrial and municipal wastes are sources of GHG emissions. The inventory covers emissions resulting from landfilling, composting of organic waste, wastewater treatment, waste incineration and combustion of biogas.

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. N<sub>2</sub>O emissions are related with wastewater treatment and discharge of nitrogen into waterways.

CO<sub>2</sub> emissions in the waste sector are associated with incineration of waste containing fossil carbon, e.g. plastics. CO<sub>2</sub> emissions from biogenic origin are accounted as an information item.

Waste and wastewater treatment can also produce emissions of NMVOCs, NO<sub>x</sub>, CO as well as NH<sub>3</sub> which are also estimated.

Figure 7-1 – Emissions of direct GHG from waste by gas (2013)



Emissions generated from waste activities are estimated, in 2013, as 7.6 Mt CO<sub>2</sub>e., representing 11.6 per cent of total GHG emissions. The biggest sub-category within the sector refers to waste disposed on land (CRF 5A) – 4.0 Mt CO<sub>2</sub>e. - corresponding to approx. 52.7 per cent of the sector's emissions. Waste Water Handling (CRF 5D) contributes to the majority of the remaining emissions, with 46.6% of the sector emissions (Industrial WWH 29.7% and Urban WWH 16.9%). Additionally, biological treatment of solid waste and waste incineration without energy recovery (which occur in hospital and industrial units) represent minor shares of the sector emissions with 0.5% and 0.3 %, respectively.

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. Emissions from biogas combustion with energy recovery are also reported in CRF 1A1a.

Other waste treatment (CRF 5E) includes emissions from biogas burning without energy recovery.

Figure 7-2 – Sources of GHG in waste sector (2013)

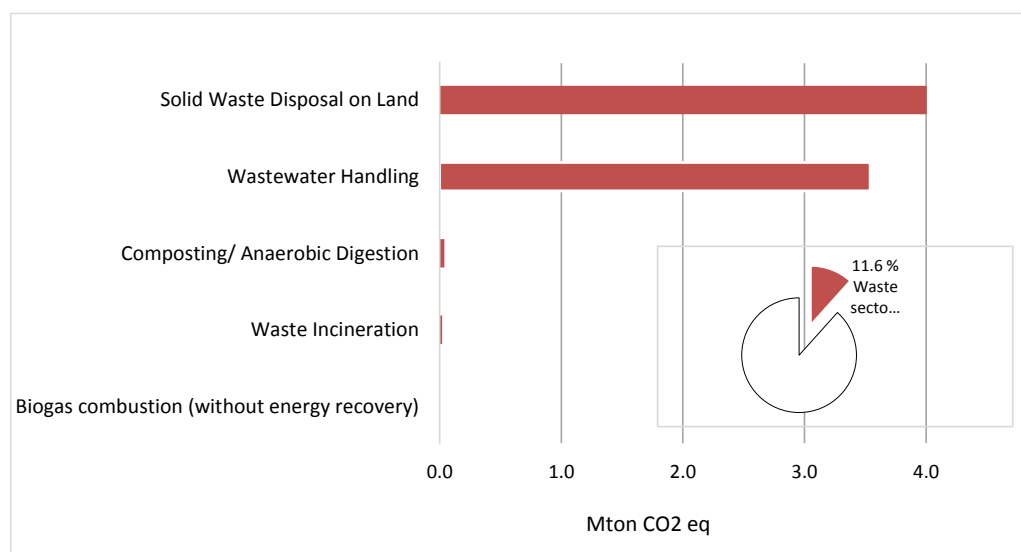


Table 7-1 – Total Greenhouse Emissions from Waste (ktCO<sub>2</sub>e.)

Gas/Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>CH<sub>4</sub></b>	<b>5,699.65</b>	<b>6,790.59</b>	<b>7,198.44</b>	<b>7,988.98</b>	<b>7,219.01</b>	<b>7,480.49</b>	<b>7,170.88</b>	<b>6,958.25</b>
Solid waste disposal	2,728.45	3,470.86	4,450.46	4,676.58	4,467.18	4,443.63	4,244.77	4,004.31
Biological treatment of solid waste	11.17	20.51	27.48	24.69	25.50	19.96	22.47	21.86
Incineration of waste (without energy recovery)	0.27	0.28	0.26	0.86	0.43	1.47	0.42	0.94
Waste water treatment	2,959.76	3,298.95	2,720.24	3,286.84	2,725.89	3,015.43	2,903.22	2,931.14
Other (biogas burning)	NO	NO	NO	0.01	0.01	0.00	NO	NO
<b>N<sub>2</sub>O</b>	<b>511.03</b>	<b>565.53</b>	<b>621.92</b>	<b>648.79</b>	<b>649.01</b>	<b>649.86</b>	<b>609.30</b>	<b>630.32</b>
Solid waste disposal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biological treatment of solid waste	9.98	18.33	24.57	22.07	22.31	16.09	14.18	15.81
Incineration of waste (without energy recovery)	0.90	0.97	1.05	4.31	2.03	7.42	2.07	4.74
Waste water treatment	500.15	546.23	596.30	622.30	624.55	626.33	593.06	609.78
Other (biogas burning)	NO	NO	NO	0.11	0.12	0.03	NO	NO
<b>CO<sub>2</sub></b>	<b>6.86</b>	<b>7.12</b>	<b>6.10</b>	<b>1.96</b>	<b>10.00</b>	<b>8.01</b>	<b>11.19</b>	<b>14.02</b>
Incineration of waste (without energy recovery)	6.86	7.12	6.10	1.96	10.00	8.01	11.19	14.02
<b>Total</b>	<b>6,217.55</b>	<b>7,363.24</b>	<b>7,826.46</b>	<b>8,639.73</b>	<b>7,878.01</b>	<b>8,138.36</b>	<b>7,791.37</b>	<b>7,602.59</b>

In the period 1990-2013 GHG emissions from waste activities have increased 22.3 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, 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 7-18).

The growth of the sector emissions is related in majority to the CH<sub>4</sub> emissions generated in Municipal Solid Waste landfilling, representing 31% of the sector emissions in 2013 and having registered a 87% increase since 1990.

The strongest increase of emissions occurred until 2004. In the mid of 2000, emissions have first stabilized and started after to decrease, due in particular to the increasing importance of biogas burning that can occur with and without energy recovery. Landfill gas with energy

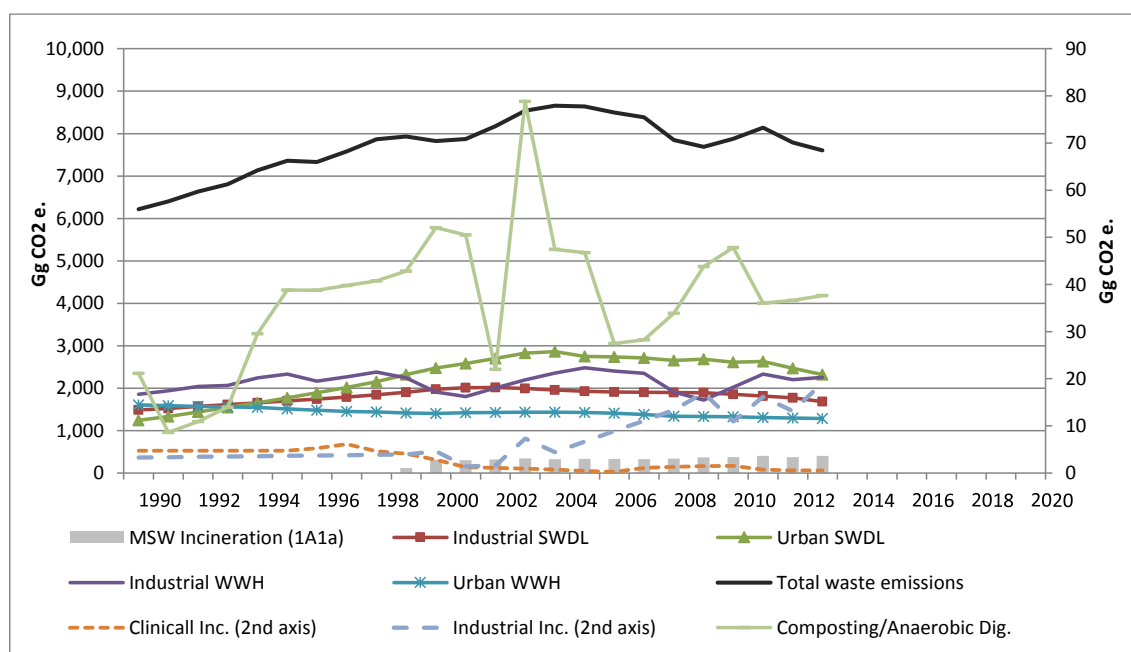


recovery is burned in several units which produce and sell electricity to the grid. Also, the quantities of selectively collected waste, which have more than doubled since 1999, have deviate waste flows from SWDS and incineration units, and contributed to this trend.

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 7-3 – Emission trends of GHG from waste by sub-category



In 2013, the management of municipal solid waste (MSW) in Portuguese mainland was under the responsibility of 23 entities, named 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.

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/anaerobic digestion, and material recycling. The inventory excludes the material recycling amounts.

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.

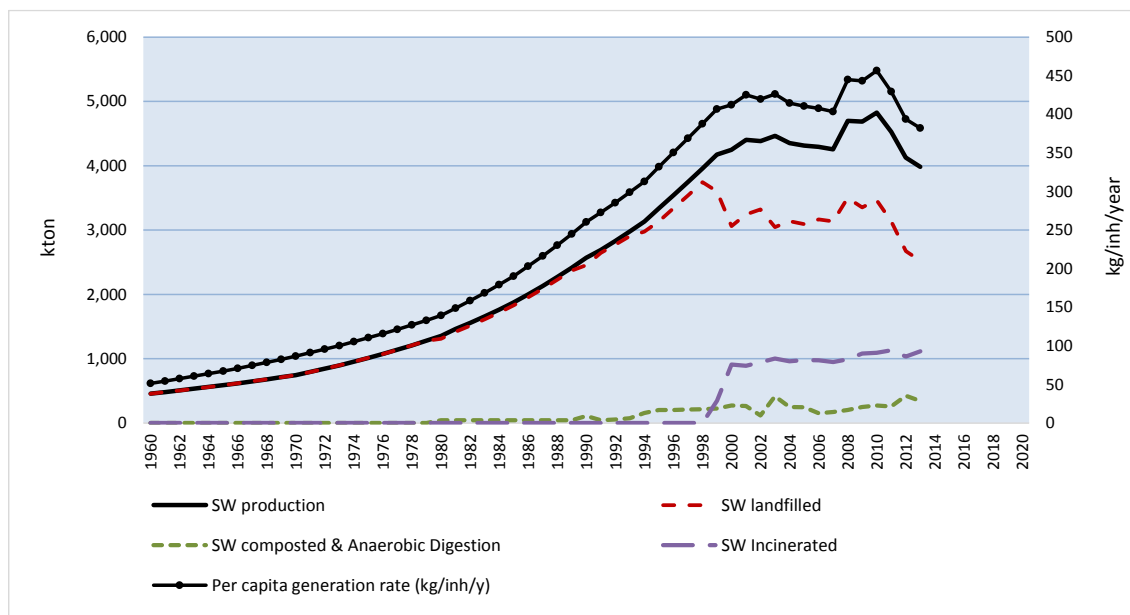
The National entity responsible for the definition, implementation and supervising the waste policies is the APA, I.P./ Waste Department, which is also responsible for the validation and treatment of the information collected via the electronic platform (SIRER/ Integrated System on Electronic Database 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 (Municipal Waste Registration Form), 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, recycling). Information on waste composition is also collected (the Ordinance 851/2009 defines the methodology for municipal waste characterization).

Next figure presents the trends of the waste generation per capita, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series. As presented in the graph, waste disposed to SWDS start reducing in 1999 which corresponds to the beginning of operation of two MSW incineration units. In the latest years, solid waste production presents a decreasing tendency, resulting from the policies on preventing, reducing and recycling of waste.

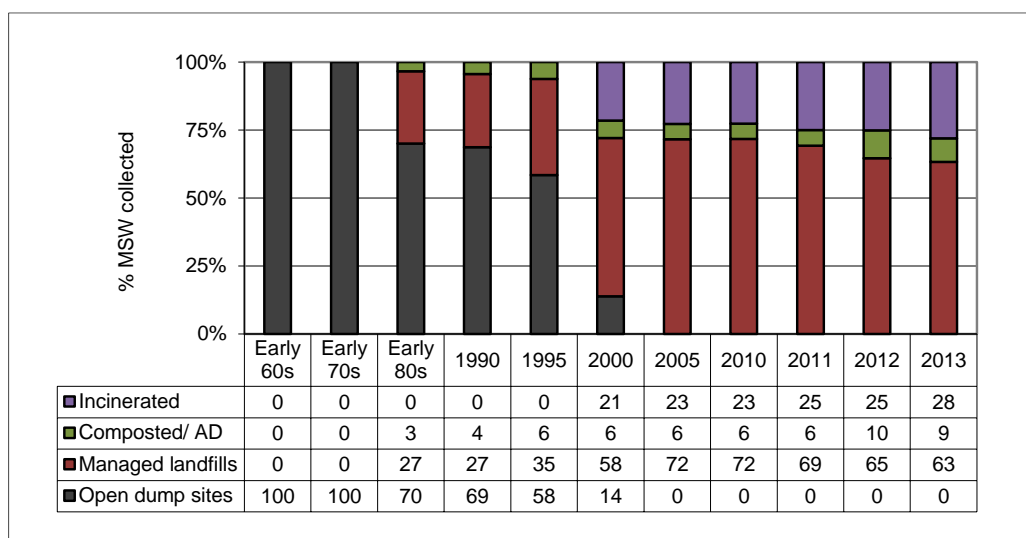
Figure 7-4 – Municipal waste (excluding material recycling)



Source: APA, include 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 of 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 2013 this figure fall to 63%, and the percentage of waste incinerated represents 28%). Composting has been progressively growing in importance and represents in 2013 approx. 9% of waste final disposal.

Figure 7-5 – Waste treatment (% of municipal solid waste without material recycling)



Source: APA estimates

## 7.2 Solid Waste Disposal on Land (CRF 5.A.)

### 7.2.1 Source category description

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>.

SWDS include solid municipal waste (household, garden, commercial-services wastes) and industrial wastes.

The source category solid waste disposal on land (SWDL) is a key category for CH<sub>4</sub>, both in terms of level and trend.

Table 7-2 – CH<sub>4</sub> (1) Emissions from Solid Waste Disposal (ktCO<sub>2</sub>e.)

Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>Municipal solid waste</b>	<b>1,243.2</b>	<b>1,771.3</b>	<b>2,476.4</b>	<b>2,749.0</b>	<b>2,610.6</b>	<b>2,630.4</b>	<b>2,469.6</b>	<b>2,320.2</b>
- managed disposal sites	359.7	647.0	1,221.7	1,808.8	1,948.0	2,012.7	1,893.6	1,783.1
- unmanaged disposal sites	883.6	1,124.3	1,254.7	940.2	662.6	617.8	576.0	537.1
<b>Industrial solid waste</b>	<b>1,485.2</b>	<b>1,699.5</b>	<b>1,974.1</b>	<b>1,927.6</b>	<b>1,856.6</b>	<b>1,813.2</b>	<b>1,775.1</b>	<b>1,684.1</b>
- managed disposal sites	361.9	541.1	863.8	1,114.4	1,283.6	1,278.9	1,277.0	1,219.6
- unmanaged disposal sites	1,123.3	1,158.4	1,110.3	813.2	573.0	534.3	498.2	464.5
<b>Recovered</b>								
- with energy recovery (2)				138.4	638.6	803.8	1,033.2	1,169.7
- flared				135.0	155.2	30.6	0.0	0.0
<b>Total</b>	<b>2,728.5</b>	<b>3,470.9</b>	<b>4,450.5</b>	<b>4,676.6</b>	<b>4,467.2</b>	<b>4,443.6</b>	<b>4,244.8</b>	<b>4,004.3</b>

Notes:

- 1) Emissions after flaring and recovery.
- 2) Emissions reported under category 1A1a and provided here for information only.

### 7.2.2 Methodological issues

Methane emissions are calculated on the basis of the First Order Decay Method (Tier 2), following the guidance from the 2006 IPCC Guidelines (Volume 5/ Chapter 3 on Solid Waste Disposal). The IPCC Waste Model was applied using Equations 3.2, 3.4, 3.5 and 3.6 and a single-phase approach based on bulk waste.

Parameter values used are:

- total amount of waste disposed;
- fraction of Degradable Organic Carbon (DOC);
- fraction of DOC dissimilated (DOCF);
- fraction of methane in landfill gas (F);
- methane correction factor (MCF);
- methane generation rate constant (k);
- landfill gas recovered (R).
- oxidation factor (OX);

#### 7.2.2.1 Quantities of waste landfilled

##### Municipal waste

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, 2006), it is good practice to estimate historical data if such data are not available, when this is a key source category (Annex A). The extent of the time series has been set to 30 years, in order to follow the guidance from IPCC (2000, 2006) which recommends to consider data on solid waste disposal (amount, composition) for 3 to 5 half-lives of the waste deposited at SWDS.

The first studies available with information on urban waste refer to PERSU (1997) and a study performed by Quercus (1995) with data from 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.

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:

$$[\text{Population (inhabitants)} * \text{Annual amount of municipal waste generated per capita (t/inhabitants/year)}]$$

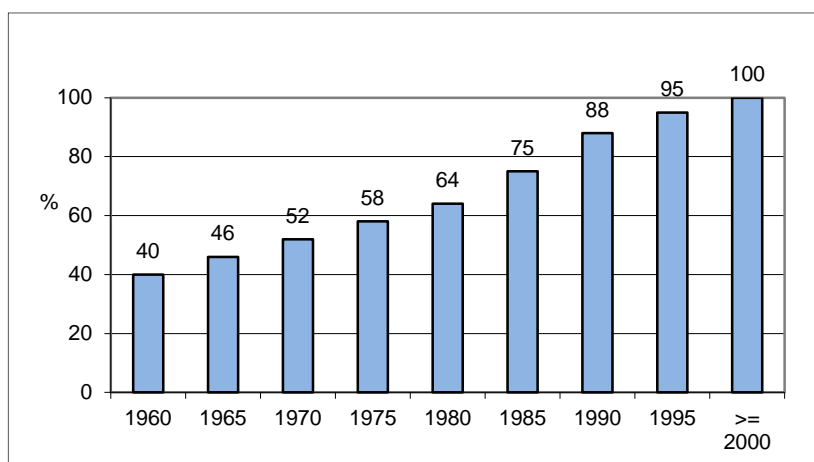
Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years for the years concerned are: 1960, 1970, 1981, 1991, and 2001. Population data for intermediate years were estimated, by interpolation, for each municipality.

Since 1999, data on MSW are collected from management systems operators. The quantities of MSW production between 1994 and 1999 were estimated by interpolation.

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:

$$\begin{aligned} \text{Waste disposed to SWDS} = & [\text{Population} * \text{Annual amount of municipal waste generated per capita} * \\ & \text{Percentage of Population served by waste collection}] \\ & - \text{Quantity of incinerated waste} - \text{Quantity of composted/digested waste} \end{aligned}$$

Figure 7-6 - Population served by waste collection systems



Source: APA

### Industrial waste

Industrial wastes considered refer only to the fermentable part of industrial waste.

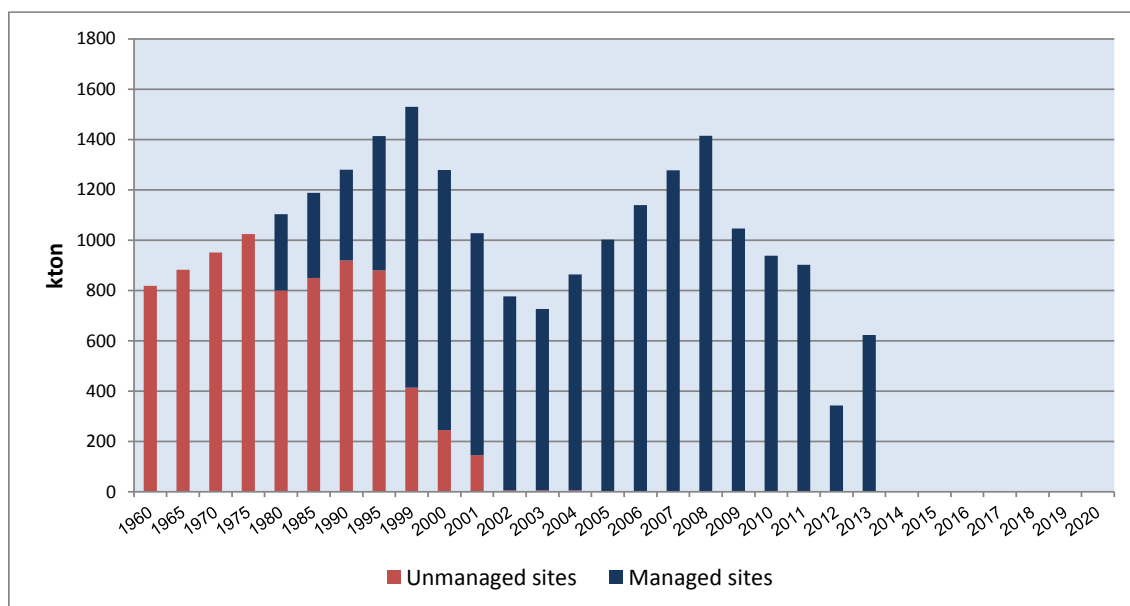
Historical time series are based on 1999 data, which refer to the first set of data available on industrial waste disposal that was collected via an annual registry of industrial declarations received from the regional environment directorates (CCDR).

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). In late 2014, the INE revised the time series (2008-2010) and provided data for the years 2011 and 2012. Data for 2013 are still under preparation by INE and the quantities of industrial waste landfilled have been estimated based on the average of the last available years (2011 and 2012).

All industrial waste generated was considered to be disposed in SWDS together with municipal waste. As there is no available information concerning industrial waste treatment for the earlier years, it was assumed that all estimated waste produced have followed the urban disposal pattern between uncontrolled and controlled SWDS.

Figure 7-7 – 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.

#### 7.2.2.2 Waste composition

Waste composition is one of the key parameters that influences the estimation of emissions from SWDS, which depend on the fraction of Degradable Organic Carbon (DOC) in the waste.

##### Municipal waste

Data on waste composition are scarce for the previous years of the time series. Nowadays, data refer to the information collected from all waste management systems, while for the first years data referred to studies which were based in more restricted information. Nevertheless, the first studies included all waste fractions.

The estimation of Degradable Organic Carbon (DOC), presented in the following table, was based on national information on the waste composition.



**Table 7-3 – Municipal waste composition disposed to SWDS and DOC**

Waste fractions	DOC content	Early 60s	Early 70s	Early 80s	Early 90s	Mid 90s	2000	2010	2011	2012	2013
Percentage of wet weight											
Paper/cardboard	40	17.0	17.0	17.0	21.1	22.7	26.4	13.7	12.9	12.3	13.6
Glass	-	2.5	2.5	2.5	4.4	5.1	7.4	3.7	3.6	4.0	4.5
Plastics	-	3.0	3.0	3.0	9.2	11.7	11.1	10.8	10.5	10.2	10.8
Metal	-	3.0	3.0	3.0	2.8	2.7	2.8	2.0	1.8	1.6	1.9
Food waste	15	59.9	59.9	59.9	42.0	34.8	26.5	42.8	43.0	40.9	36.6
Textiles	24	5.5	5.5	5.5	3.8	3.1	2.6	2.6	2.6	2.6	2.6
Non-food fermentable materials	20	0.0	0.0	0.0	13.4	18.7	17.4	14.3	14.3	14.3	14.3
Wood	43	0.0	0.0	0.0	0.2	0.3	0.5	1.5	1.0	1.1	1.1
Other	-	9.1	9.1	9.1	3.2	0.8	5.4	8.7	10.3	13.1	14.8
<b>DOC</b>	<b>-</b>	<b>17.1</b>	<b>17.1</b>	<b>17.1</b>	<b>18.4</b>	<b>18.9</b>	<b>18.9</b>	<b>16.0</b>	<b>15.5</b>	<b>15.0</b>	<b>14.9</b>

**Notes:**

Data on waste composition: 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 2010-13: APA

DOC content: 2006 IPCC defaults.

**Industrial waste**

Data on DOC 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.

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 (National Statistical Institute) 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 EWCSStat 4.0 categories that are considered as organic waste. These data are presented in the next table.

**Table 7.4 - Industrial organic waste composition and DOC**

waste groups	DOC (0..1)	1960-99	1999	2000	2001	2002	2003						
<b>ton</b>													
paper and textiles	0.40		841,899			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			0	0						
Plastic	-		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	-		83,191			0	31						
Synthetic fibres	-		2,073			0	0						
Non-natural organic substances	-		52			1410	2,643						
<b>TOTAL</b>	-	estimates	<b>1,530,654</b>	<b>1,279,615</b>	<b>1,028,576</b>	<b>777,537</b>	<b>726,946</b>						
<b>DOC (weighted average)</b>	-		<b>0.282</b>	<b>0.282</b>	<b>0.284</b>	<b>0.285</b>	<b>0.286</b>	<b>0.257</b>					

waste groups (EWC-Stat/Version 4)	DOC (0..1)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>ton</b>											
03.2 + 03.3 Sludge from industrial origin	0.14					20,104	35,918	27,236	32,028	23,219	27,623
05 Health care and biological wastes a)	0.15					9,803	9,790	9,759	10,698	9,916	10,307
07.2 Paper and cardboard wastes	0.40					3,921	4,263	1,573	54,590	535	27,562
07.5 Wood wastes	0.30					22,922	12,846	8,260	7,916	4,714	6,315
07.6 Textile wastes a)	0.24					29,563	25,602	36,111	24,200	14,936	19,568
09.1 Animal waste of food preparation and products	0.15					23,086	14,921	18,441	20,077	14,370	17,223
09.2 Vegetal waste	0.15					36,257	21,400	14,527	18,741	4,761	11,751
09.3 Slurry and manure	0.15					0	20	0	0	0	0
10.1 Household and similar wastes b)	0.17					116,1023	809,437	710,894	629,973	169,001	399,487
10.21 + 10.22 Mixed and undifferentiated materials	0.26					17,941	17,608	16,283	15,057	10,796	2,927
11 Common sludges	0.14					90,602	94,927	95,658	89,185	89,155	89,170
<b>TOTAL</b>	-	<b>864,603</b>	<b>1,002,259</b>	<b>1,139,915</b>	<b>1,277,572</b>	<b>1,415,228</b>	<b>1,046,747</b>	<b>938,743</b>	<b>902,465</b>	<b>343,800</b>	<b>623,133</b>
<b>DOC (weighted average)</b>	-	<b>0.241</b>	<b>0.224</b>	<b>0.207</b>	<b>0.190</b>	<b>0.174</b>	<b>0.173</b>	<b>0.172</b>	<b>0.188</b>	<b>0.188</b>	<b>0.188</b>

Notes:

a) IPCC 2006 table 2.6.

b) Regional default MSW composition data provided for Western Europe in table 2.3 of the 2006 IPCC Guidelines.

Data on italics: estimates.

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 2013 refer to the average of last available years (2011-2012). The amounts of waste 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.

### 7.2.2.3 Other parameters

Other parameters used in the calculation rely on some IPCC default values, and apply both to municipal and industrial waste.

**Table 7-5 – Parameters used in Lo calculation**

Parameter	Explanation	Value considered
MCF	IPCC defaults	Managed landfills = 1.0 Unmanaged/Uncategorised = 0.6
DOCF	2006 IPCC default (including lignin C)	0.5
F	2006 IPCC default	0.5

### Methane generation rate constant (k)

The value of landfill gas generation rate constant (k) depends on several factors as the composition of the waste and the conditions of the SWDS (e.g. climatic conditions).

This parameter is related to the time taken for the DOCm (Degradable Organic Matter) 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).

The  $k$  value used was estimated as a function of the national climatic conditions, using a Geographic Information System. A geographic database with the universe Landfill Sites (SWDS) licensed in Portugal was crossed with cartography on the following climatological variables: a) Annual Potential Evapotranspiration (PET); 2) Mean Annual Temperature (MAT); 3) Mean Annual Precipitation (MAP) (from IPMA). Each SWDS was classified according to the climatic conditions and a corresponding  $k$  value, based on the recommended default methane generation rate ( $k$ ) values from 2006 IPCC (Table 3.3, Chapter 3: SWD).

The 0.07 refer to the average conditions of the overall SWDS.

#### Landfill gas recovered (R)

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, 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.

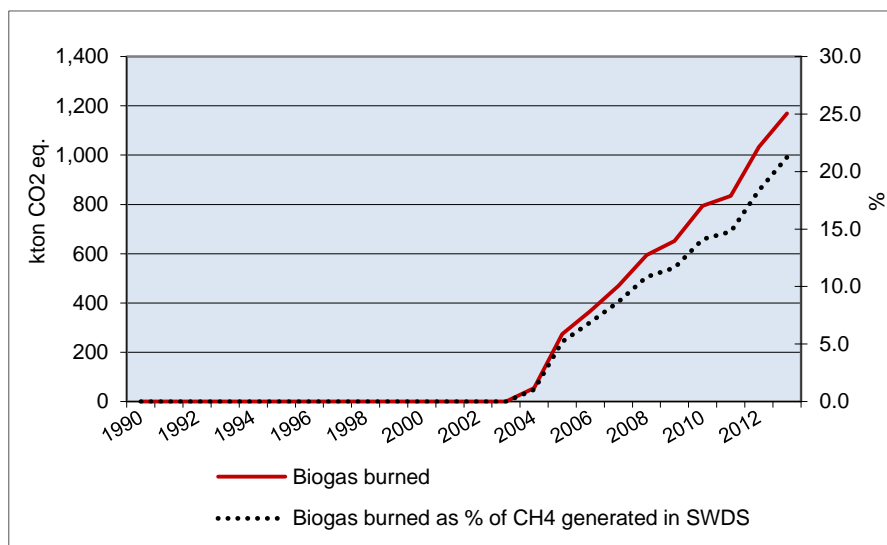
The annual quantities of biogas burnt (in flares and energy recovering units) reported by each landfill (in cubic meters) were converted into CH<sub>4</sub> amounts considering the CH<sub>4</sub> percentages in biogas (based on measurements) reported by management systems.

Table 7-6 –CH<sub>4</sub> in landfill gas

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Average share of CH <sub>4</sub>	%	54	51	53	52	52	52	54	51	52	52

Source: APA questionnaire.

Figure 7-8 – Quantities of CH<sub>4</sub> combusted (SWDS)



Source: APA questionnaire data (flared and energy recovered quantities); 2004: DGE data (energy recovery only).

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.

The fraction of methane in landfill gas (F) value used was based in the IPCC (0.5) default for the whole time series. Data presented in Table 7-6 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 7-6 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.

### 7.2.3 Uncertainty and time-series consistency

#### 7.2.3.1 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.

### 7.2.3.2 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>134</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.

## 7.2.4 Source-specific QA/QC and verification

### 7.2.4.1 Solid Waste Disposal on Land

#### 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.

#### QC2 procedures

Activity level parameters were compared with 2006 IPCC Guidelines default values.

National emission rates and implied emissions factors (IEF) were compared with other countries (UNFCCC Synthesis and Assessment Report on the GHG Inventories submitted in 2014/ FCCC/WEB/SAI/2014), in particular those with similar natural, demographic and economic conditions.

## 7.2.5 Source-specific recalculations

The recalculations made since last submission result mainly from:

- Solid Waste Disposed on Land
  - o revision of the FOD model approach according to the guidance from the 2006 IPCC Guidelines and revision of some parameters ( $DOC$  and  $DOC_f$ )

<sup>134</sup> The uncertainty for this variable affects nevertheless when emissions occur and not how much and affects emission estimates exponentially.

- Industrial Waste: data for 2008-2012 have revised according to the data revision made by INE (National Statistical Office);
- Industrial Waste: the separation between managed/unmanaged industrial waste disposal on land have been revised to follow more closely the split between managed/unmanaged waste disposed on land for municipal waste, assuming that, in the past, all industrial waste was considered to be disposed in SWDS together with municipal waste.

## 7.2.6 Source-specific planned improvements

To be developed in next year submission.

## 7.3 Biological treatment of solid waste (CRF 5.B.)

### 7.3.1 Source category description

This category refers to composting and anaerobic digestion of organic waste.

Table 7-7 – Emissions from Biological Treatment of Solid Waste (ktCO<sub>2</sub>e.)

Source	1990	1995	2000	2005	2010	2011	2012	2013
CH <sub>4</sub>	11.2	20.5	27.5	24.7	25.5	20.0	22.5	21.9
N <sub>2</sub> O	10.0	18.3	24.6	22.1	22.3	16.1	14.2	15.8
<b>Total</b>	<b>21.2</b>	<b>38.8</b>	<b>52.1</b>	<b>46.8</b>	<b>47.8</b>	<b>36.1</b>	<b>36.6</b>	<b>37.7</b>

### 7.3.2 Methodological issues

The emissions were estimated using the IPCC default (Tier 1) methodology (IPCC 2006), which is the product of the mass of organic waste treated by biological treatment and an emission factor. When CH<sub>4</sub> recovery occurs the amounts should be subtracted.

The activity level for past years is based on estimated data. Data for recent years refer to data collected from management systems. Anaerobic digestion started in 2006.

Figure 7.9 – Quantities of municipal waste composted/ Anaerobic Digestion and related emissions

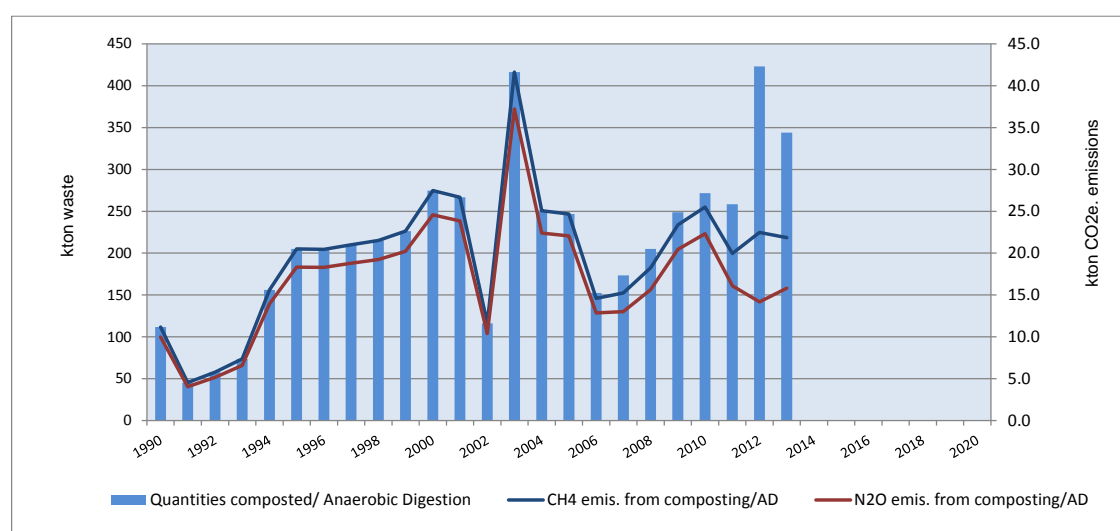


Table 7-8 – Default emission factors for CH<sub>4</sub> and N<sub>2</sub>O emissions from biological treatment (wet weight basis)

	CH <sub>4</sub> (g/kg waste treated)	N <sub>2</sub> O (g/kg waste treated)
Composting	4	0.3
Anaerobic digestion	1	Assumed negligible

Source: 2006 IPCC (table 4.1, Volume 5: Waste)

### 7.3.3 Uncertainty and time-series consistency

Under development.

### 7.3.4 Source-specific QA/QC and verification

To be developed in next year submission.

### 7.3.5 Source-specific recalculations

Category accounted for the first time in this submission.

### 7.3.6 Source-specific planned improvements

To be developed in next year submission.

## 7.4 Waste Incineration (CRF 5.C.)

### 7.4.1 Source category description

Waste incineration in Portugal includes combustion of municipal, clinical and industrial wastes.

Relevant gases emitted include CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. CO<sub>2</sub> emissions are dependent to a large extent on the amount of fossil carbon in the waste burned. The non-CO<sub>2</sub> emissions are more dependent on the technology and conditions during the incineration process.

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 recovery), 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.

Table 7-9 –Emissions from Waste Incineration (ktCO<sub>2</sub>e.)

Gas/Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>CO<sub>2</sub></b>								
<i>Non-biogenic</i>								
MSW incineration (CRF 1A1a)	0.0	0.0	293.1	314.7	351.3	383.3	350.4	381.6
Industrial solid wastes	2.4	2.7	3.5	1.5	8.6	7.3	10.7	13.5
Clinical waste	4.4	4.4	2.6	0.4	1.4	0.7	0.5	0.5
<i>Biogenic (memorandum item)</i>								
MSW incineration (CRF 1A1a)	0.0	0.0	436.3	468.5	523.0	555.4	507.6	530.0
Industrial solid wastes	9.5	10.5	13.6	86.0	44.3	147.5	46.4	101.7
Clinical waste	13.3	13.3	7.8	1.3	4.3	2.1	1.5	1.5
<b>CH<sub>4</sub></b>								
MSW incineration	0.0	0.0	5.3	5.7	6.4	6.6	6.1	6.6
Industrial solid wastes	0.1	0.2	0.2	0.8	0.4	1.5	0.4	0.9
Clinical waste	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
<b>N<sub>2</sub>O</b>								
MSW incineration	0.0	0.0	13.6	14.6	16.3	16.9	15.4	16.7
Industrial solid wastes	0.7	0.8	0.9	4.3	2.0	7.4	2.0	4.7
Clinical waste	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.0
<b>Total</b>	<b>30.8</b>	<b>32.1</b>	<b>777.1</b>	<b>898.0</b>	<b>958.0</b>	<b>1,128.7</b>	<b>941.0</b>	<b>1,057.7</b>

## 7.4.2 Methodological issues

### 7.4.2.1 CO<sub>2</sub> emissions

CO<sub>2</sub> emissions from waste incineration have been estimated using Tier 2a which requires the use of country-specific data on waste composition and default data on other parameters (equation 5.2 from 2006 IPCC).

For MSW and industrial waste incineration, CO<sub>2</sub> emissions were calculated on the basis of waste composition as following:

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \text{MSW} * \sum_j ( \text{WF}_j * \text{dm}_j * \text{CF}_j * \text{FCF}_j * \text{OF}_j ) * 44 / 12 )$$

where:

j - component of the MSW incinerated (such as paper, wood, plastics);

MSW - total amount of municipal solid waste as wet weight incinerated (Gg/yr);

WF<sub>j</sub> - fraction of waste type/material of component j in the MSW (as wet weight incinerated)

dm<sub>j</sub> - dry matter content in the component j of the MSW incinerated, (fraction);

CF<sub>j</sub> - Fraction of carbon in the dry matter (i.e., carbon content) of component j;

FCF<sub>j</sub> - Fraction of fossil carbon in the total carbon of component j;

OF<sub>j</sub> - oxidation factor, (fraction);

44/12 = conversion factor from C to CO<sub>2</sub>

For clinical wastes, the method applied is based on the total amount of waste combusted (based on equation 5.1 from 2006 IPCC), as follows:



$$\text{CO}_2 \text{ emissions (Gg/yr)} = ( \text{SW} * \text{CF} * \text{FCF} * \text{OF} * 44 / 12 )$$

where:

SW - amount of waste incinerated (Gg/yr);

CF - fraction of carbon content;

FCF - fraction of fossil carbon;

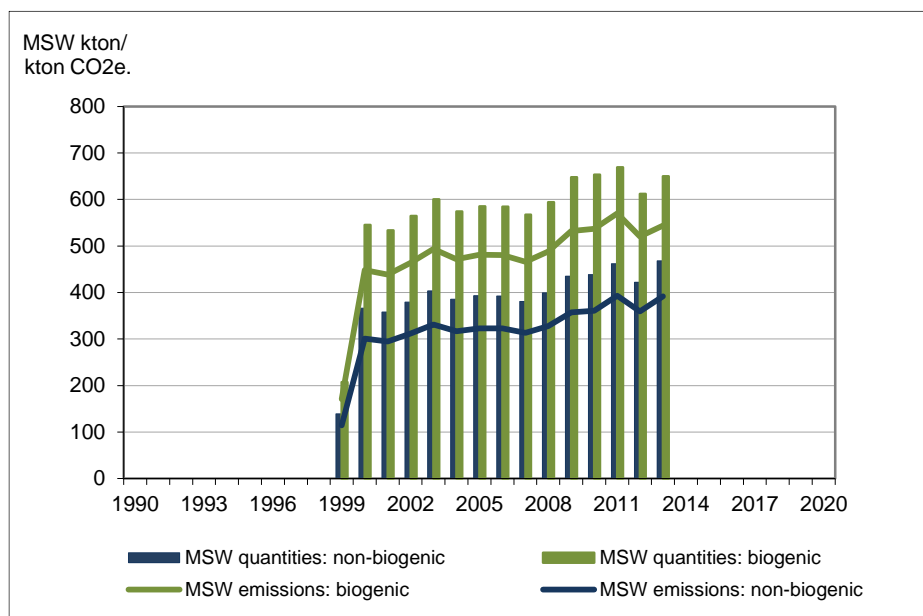
OF – oxidation factor (fraction).

### Municipal Solid Waste

In 1999, two 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. In 2003, 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.

The emissions from MSW incineration occur with energy recovery and are therefore accounted in the energy sector (category 1A1a).

Figure 7-10 – 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 continuous 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.

2006 IPCC considers good practice to make a distinction between composition of waste incinerated and the composition of waste delivered to other waste management systems. Accordingly, CO<sub>2</sub> emissions estimates consider the composition of waste incinerated.

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 incinerated waste weight. The total C content of MSW, which includes the biogenic and non-biogenic (fossil) components, results from the weighted average of the different waste fractions and the respective total C content. The % of fossil carbon in waste was then obtained dividing the fossil C component by the total C content in MSW.

Information used for the calculation is presented in the next table.

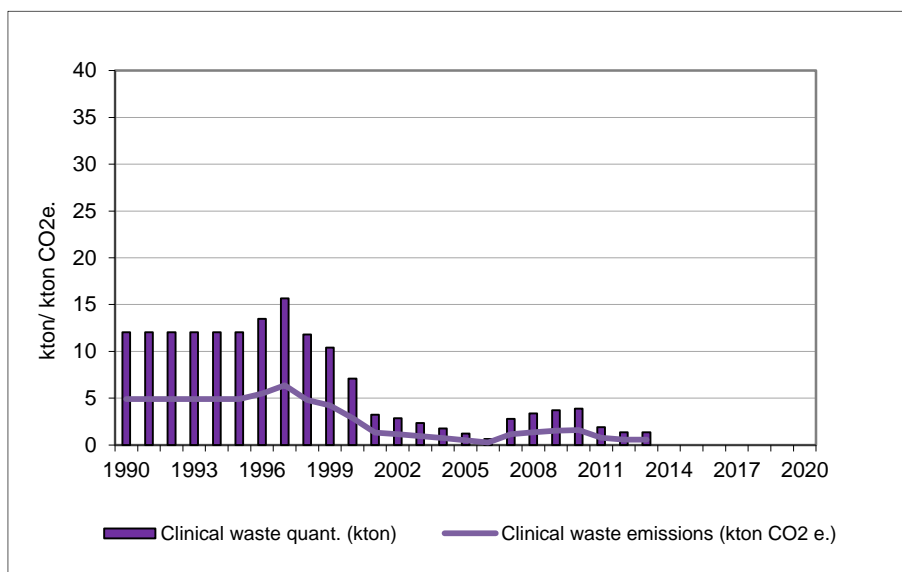
Table 7-10– Base table for MSW C content estimation

	C content		Waste composition (% of wet weight)							
	Non-biogenic	Total C	1990	1994	1999	2000	2010	2011	2012	2013
Paper/ Card	1	41	-	-	14.3	14.3	14.3	15.6	15.6	14.5
Glass	0	NA	-	-	4.7	4.7	4.7	5.7	5.7	5.1
Plastics	75	75	-	-	10.0	10.0	10.0	10.7	10.7	10.7
Metals	0	NA	-	-	2.0	2.0	2.0	1.9	1.9	1.8
Food waste	0	15	-	-	42.2	42.2	42.2	39.6	39.6	40.5
Textiles	16	40	-	-	2.7	2.6	2.6	2.6	2.6	2.6
Non-food fermentable materials	0	20	-	-	0.0	0.0	0.0	0.0	0.0	0.0
Wood	0	43	-	-	0.7	0.7	0.7	1.1	1.1	0.8
Other	3	3	-	-	23.4	23.4	23.4	22.8	22.8	24.0
C content in Plastics and Textiles (1)					8.8	8.8	8.8	9.2	9.2	9.3
<b>Total C of waste (2)</b>			-	-	<b>21.9</b>	<b>21.8</b>	<b>21.8</b>	<b>22.6</b>	<b>22.6</b>	<b>22.2</b>
<b>% non-biogenic C in waste (1)/(2) * 100</b>			-	-	<b>40.2</b>	<b>40.2</b>	<b>40.2</b>	<b>40.8</b>	<b>40.8</b>	<b>41.9</b>

### 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 7-11 – 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 parameters considered for clinical waste are presented in the the following table.

Table 7-11 - 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.

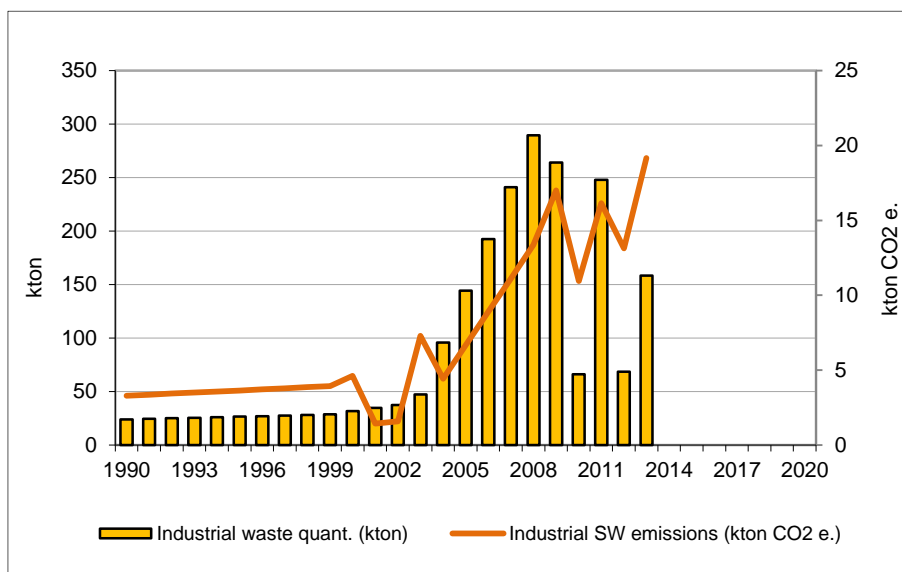
The oxidation factor in percentage of carbon input considered is 100% (IPCC default).

#### 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 (Statistical Institute) in order to extrapolate the information for the universe of each economic branch.

In late 2014, the INE revised the time series (2008-2010) and provided data for 2011 and 2012. Data for 2013 are still not available and the quantities of industrial waste incinerated have been estimated based on the average of the last available years (2011 and 2012).

Figure 7-12– Quantities of combusted industrial waste



Source: APA (include estimates).

The significant fluctuations on the amounts of industrial waste incineration, as shown in the previous figure, results, at least partially, from the variation of fluxes to other treatments (landfilling, export (e.g. dangerous waste) and recycling) as a consequence of the annual waste market demand.

Table 7-12- 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	%	100 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 **Erro! A origem da referência não foi encontrada.**). 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".

#### 7.4.2.2 Non-CO<sub>2</sub> emissions

Non-CO<sub>2</sub> emissions are dependent in particularly on the technology and conditions during the incineration process. The completeness of combustion (temperature, oxygen, residence time) is especially relevant for the CH<sub>4</sub> emissions. The N<sub>2</sub>O emissions are mainly determined by technology, combustion temperature and waste composition.

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)

$i$  – waste type (MSW, Industrial waste, clinical waste)

Emission factors applied are either country-specific (Tier 2), being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR (EEA,2002) (Tier 1).

The CH<sub>4</sub> emission factor considered follows the guidance from 2006 IPCC that says that for continuous incineration of MSW and industrial waste, it is good practice to apply the CH<sub>4</sub> emission factors for Stationary Combustion (Volume 2, Chapter 2).

For N<sub>2</sub>O emissions the default emission factor from table 5.6 of volume 5: waste of the 2006 IPCC was used.

Table 7-13 - 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	30.000	2006 IPCC
N <sub>2</sub> O	kg/ton MSW	0.0500	2006 IPCC
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 7-14 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: until 2004

Pollutants	Unit	EF	Source
LHV	MJ/kg W	13.82	Country Study (Environmental Impact Assessment)
CH <sub>4</sub>	g/GJ	30.00	2006 IPCC
N <sub>2</sub> O	kg/ton W	0.05	2006 IPCC
SO <sub>x</sub>	kg/ton W	1.09	2013 Guidebook (Tier 2, Uncontrolled)
NO <sub>x</sub>	kg/ton W	1.78	2013 Guidebook (Tier 2, Uncontrolled)
COVNM	kg/ton W	0.70	2013 Guidebook (Tier 2, Uncontrolled)
CO	kg/ton W	1.48	2013 Guidebook (Tier 2, Uncontrolled)

Table 7-15 - Emissions factors of GHG and precursors gases from incineration of clinical wastes: after 2005

Pollutants	Unit	EF	Source
LHV	MJ/kg W	13.82	Country Study (Environmental Impact Assessment)
CH <sub>4</sub>	g/GJ	30.00	2006 IPCC
N <sub>2</sub> O	kg/ton W	0.05	2006 IPCC
SO <sub>x</sub>	kg/ton W	0.09	2013 Guidebook (Tier 2, Controlled by various types of abatement)
NO <sub>x</sub>	kg/ton W	1.78	2013 Guidebook (Tier 2, Uncontrolled)
COVNM	kg/ton W	0.70	2013 Guidebook (Tier 2, Uncontrolled)
CO	kg/ton W	1.48	2013 Guidebook (Tier 2, Uncontrolled)

Table 7-16 - Emissions factors of GHG and precursors gases for Industrial solid waste incineration

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.82	PROET study
CH <sub>4</sub>	g/GJ	30.00	2006 IPCC
N <sub>2</sub> O	kg/ton MSW	0.10	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton MSW	0.05	2013 EEA Guidebook (Tier 1 default EF)
NO <sub>x</sub>	kg/ton MSW	0.87	2013 EEA Guidebook (Tier 1 default EF)
NM/OC	kg/ton MSW	7.40	2013 EEA Guidebook (Tier 1 default EF)
CO	kg/ton MSW	0.07	2013 EEA Guidebook (Tier 1 default EF)

### 7.4.3 Uncertainty and time-series consistency

#### 7.4.3.1 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.

#### **7.4.4 Source-specific QA/QC and verification**

##### **7.4.4.1 Waste Incineration**

###### *General QC 1*

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

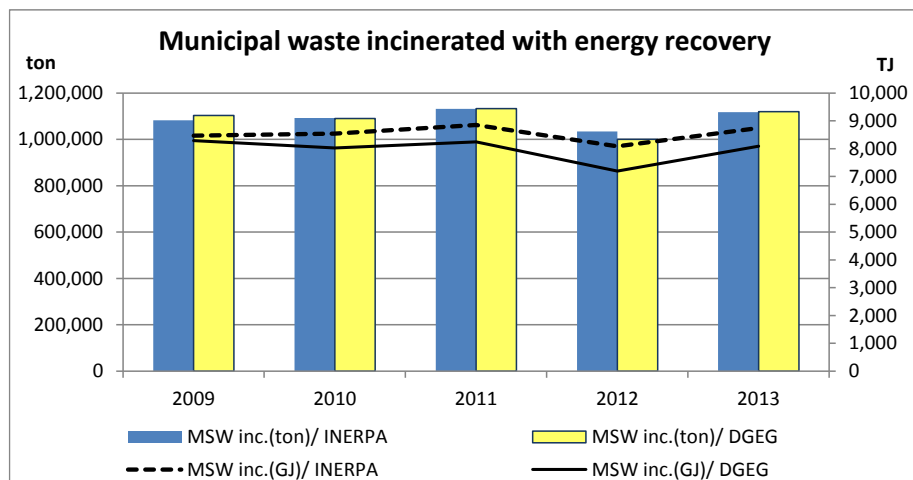
- Checks on data units, calculation procedures, and data field relationships
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

An analysis of emission trends and of IEF was performed to detect unusual trends in order to identify potential underlying problems.

###### *QC2 procedures*

National emission rates and implied emissions factors (IEF) were compared with other countries, in particular those with similar natural, demographic and economic conditions.

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 2012 (-3% in EB data)). As regards, the energy content (NCV), the values considered by the EB are lower than the value considered by the inventory. Data used in the inventory refer to a study done at past, whereas EB data are annual data from operators.



#### 7.4.5 Source-specific recalculations

The recalculations made since last submission result mainly from the:

- revision of activity data regarding the quantities industrial waste incinerated. Data for 2008-2012 have been revised according to data revision made by INE (National Statistical Office);
- revision of some parameters (DOC) based on 2006 IPCC default values;
- combustion efficiency changed from 95% to Oxidation Factor 100% (default 2006 IPCC);
- EF CH<sub>4</sub>: changed from 6.5 to 30 g/GJ;
- clinical incineration/ non-biogenic emissions: a correction of a compilation error was done, issued from QA/QC procedures.

#### 7.4.6 Source-specific planned improvements

To be developed in next year submission.

## 7.5 Wastewater Treatment and Discharge (CRF 5.D.)

### 7.5.1 Source category description

Wastewater treatment processes can produce CH<sub>4</sub> when treated or disposed anaerobically, and N<sub>2</sub>O. CO<sub>2</sub> emissions from wastewater are not considered as these are of biogenic origin and should not be included in the national total emissions.

Table 7-17 – Emissions from Wastewater Treatment and Discharge (ktCO<sub>2</sub>e.)

Gas/Source	1990	1995	2000	2005	2010	2011	2012	2013
<b>CH<sub>4</sub></b>	<b>2,959.8</b>	<b>3,299.0</b>	<b>2,720.2</b>	<b>3,286.8</b>	<b>2,725.9</b>	<b>3,015.4</b>	<b>2,903.2</b>	<b>2,931.1</b>
Domestic wastewater	1,257.6	1,142.8	1,002.9	1,020.8	894.7	888.2	884.7	879.5
Industrial wastewater	1,702.1	2,156.1	1,717.3	2,266.0	1,831.2	2,127.2	2,018.5	2,051.7
<b>N<sub>2</sub>O</b>	<b>500.2</b>	<b>546.2</b>	<b>596.3</b>	<b>622.3</b>	<b>624.5</b>	<b>626.3</b>	<b>593.1</b>	<b>609.8</b>
Domestic wastewater	345.8	368.1	401.4	406.0	432.2	421.6	409.1	405.2
Industrial wastewater	154.3	178.2	194.9	216.3	192.3	204.7	184.0	204.6
<b>Total</b>	<b>3,459.9</b>	<b>3,845.2</b>	<b>3,316.5</b>	<b>3,909.1</b>	<b>3,350.4</b>	<b>3,641.8</b>	<b>3,496.3</b>	<b>3,540.9</b>



## 7.5.2 Methodological issues

### 7.5.2.1 Domestic Wastewater CH<sub>4</sub> emissions

The accounting of this category is based on data trends for the public urban wastewater handling systems and types of treatment compiled by APA (previously INAG/National Institute for Water which was integrated in the APA).

CH<sub>4</sub> emissions from urban wastewater handling were estimated using a methodology adapted from 2006 IPCC, which follows three basic steps:

#### 1 – Determination of the total amount of organic material originated in each wastewater handling system

The main factor determining the 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.

The fraction of organic waste treated using wastewater handling system i (TOW<sub>i</sub>) is calculated as a percentage of population served by wastewater handling system.

$$TOW_i = (TOW_{dom} * U_i) - S_i$$

where:

U<sub>i</sub> – fraction of population served by each treatment/discharge pathway or system type i;

S<sub>i</sub> – organic component removed as sludge in each treatment system type i.

#### 2 – Estimation of emission factors

The emission factor for each wastewater depends on the maximum CH<sub>4</sub> producing potential of each waste type (B<sub>0</sub>) and a weighted average of CH<sub>4</sub> conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_0 * MCF_i$$

where:

EF<sub>i</sub> - emission factor (kg CH<sub>4</sub> /kg DC) for wastewater handling system type i;

B<sub>0</sub> - maximum methane producing capacity (kg CH<sub>4</sub>/kg BOD);

$MCF_i$  - methane correction factors of each wastewater system  $i$ .

Maximum CH<sub>4</sub> producing capacity ( $B_0$ ) is the maximum amount of CH<sub>4</sub> that can be generated from a given quantity of wastewater.

Methane Correction Factor (MCF) is an estimate of the fraction of DC that will ultimately degrade anaerobically. The MCF varies between 0 for a completely aerobic system to 1.0 for a completely anaerobic system.

### 3 – Calculation of emissions

Emissions are a function of total organic waste generated and an emission factor characterizing 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.

$$CH_4 \text{ emissions} = \sum_i (TOW_i * EF_i) - R$$

where:

CH<sub>4</sub> emissions - Total CH<sub>4</sub> emissions from wastewater handling in kg CH<sub>4</sub>/yr

$TOW_i$  - total organic waste in wastewater for type  $i$  in kg BOD/yr. (Step 1)

$EF_i$  - emission factor for waste type  $i$  in kg CH<sub>4</sub>/kg DC (Step 2)

$R$  - total amount of methane recovered or flared in kg CH<sub>4</sub>.

### Activity data and parameters

Total organic content of domestic sewage ( $TOW_{dom}$ ) was determined multiplying the total population for each year by a per capita wastewater BOD<sub>5</sub> production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991, 2001 and 2011, and 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.

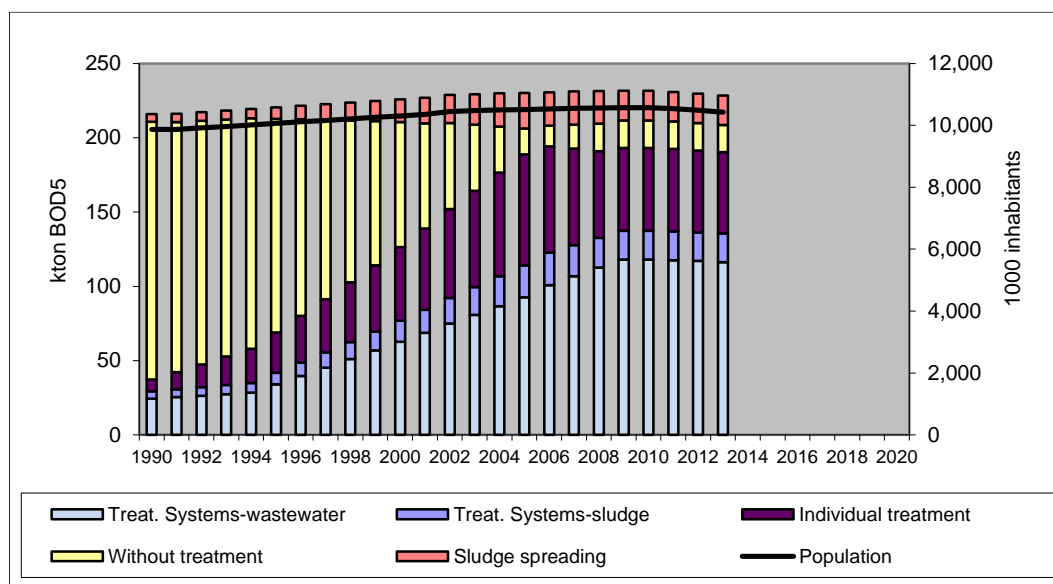
Until 1999, data for wastewater handling systems are based on a compilation study, performed by ex-INAG, of all surveys and inventories done in the past concerning sanitation and wastewater treatment infrastructures. Data from this study refer to 1990, 1994 and 1999. More recent data (from 2005 onwards) 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.

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 7-13 – 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 7-18 - 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	2013
		% population																
Population without sewerage																		
1.1-	% Pop: without sewerage (latrines)	37.0	23.4	6.4	5.3	4.3	3.2	2.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	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	21.0
Population with sewerage																		
2.1-	% de Pop: with discharge into the ocean, without treatment	6.5	6.5	6.5	5.6	4.7	3.8	2.8	1.9	1.0	1.0	1.3	1.5	1.2	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	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	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	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	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	3.0
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	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	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	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	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	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	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	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	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	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	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	1.8
3.4.9-	Inhoff 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	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	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	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	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	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	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 7-19 presents MCF factors used for each wastewater treatment system considered.

Table 7-19 - Wastewater handling systems and associated Methane Conversion Factors (MCF), and fraction of organic load treated as liquid and solid phase

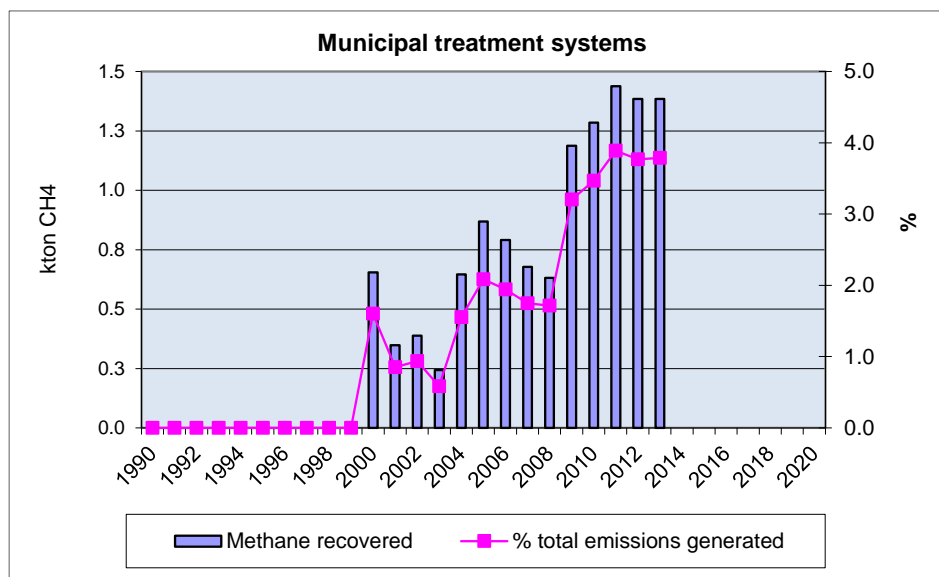
Wastewater handling systems			MCF		Share between liquid phase and solid treatment		Sludge spread in the environment e)
			Wastewater	Sludge	Wastewater	Sludge	
					(% of organic load)		
Population without sewerage							
1.1-	% Pop: without sewerage (latrines)	a)	0.61	-	-	-	
1.2-	% Pop: individual treatment (private septic tanks)		0.50	-	-	-	
Population with sewerage							
2.1-	% de Pop: with discharge into the ocean, without treatment		0.00	-	-	-	
2.2-	% de Pop: with discharge into inland waters, without treatment	b)	0.30	-	-	-	
2.3-	% de Pop: with discharge into soil, without treatment	b)	0.30	-	-	-	
2.4-	% de Pop: with unknown disposal		0.20	-	-	-	
3-	% Pop: with treatment						
3.1-	% Pop: colective septic tanks		0.50	-	-	-	
3.2-	% Pop: with preliminary treatment		0.00	0.00	-	-	
3.3-	% Pop: with primary treatment		0.00	0.00	70%		30%
3.4-	% Pop: with secondary and tertiary treatment		-	-	-	-	
3.4.1-	Biodisks w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.2-	Biodisks w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.3-	Activated sludge w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.4-	Activated sludge w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.5-	Laguning, w ith anaerobic pond	d)	0.20	0.00	100%	-	
3.4.6-	Laguning, w ithout anaerobic pond		0.00	0.00	63%	-	37%
3.4.7-	Percolation beds w ith anaerobic sludge digestion	c)	0.17	0.80	63%	37%	
3.4.8-	Percolation beds w ithout anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.9-	Imhoff Tank		0.80	0.00	100%	-	
3.4.10-	Oxidation ponds w ith anaerobic sludge digestion	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 biogas 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 7-14 - Methane recovery (Urban)



Source: Quantities based on data DGEG data.

### 7.5.2.2 Industrial Wastewater Handling CH<sub>4</sub> Emissions

#### Methodology

The method to estimate methane emissions from industrial wastewater handling is based on the methodology described in the IPCC (2006). The following formula is used:

$$Em_{CH_4} = \sum_i \{ (TOW_{(j)} - S_i) * \sum_h [WHS_{(j,h)} * MCF_{(h)}] - Rec_{CH_4(j,h)} \}$$

Where,

$Em_{CH_4}$  – 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;

$S_i$  – Organic component removed as sludge, expressed in COD/yr (value assumed as zero);

$WHS_{(j,h)}$  – Part of the total organic wastewater generated in industrial sector j that is handled by system h, fraction;

$MCF_{(h)}$  – Methane Correction Factor, fraction;

$Rec_{CH_4(j,h)}$  – Quantity of methane generated from Industrial Wastewater Handling system h and industrial sector j, that is recovered and not released directly or indirectly to atmosphere, t CH<sub>4</sub>/yr.

### Activity data

The organic wastewater load (TOW) was estimated using statistical data on industrial production (Ind<sub>PROD</sub>, ton product/yr) multiplied by pollution coefficients (Pol<sub>COEF</sub>, kg O<sub>2</sub>/ton product).

$$TOW = Ind_{PROD} * Pol_{COEF}$$

The pollution coefficients that were used 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>135</sup>. The main conclusions from the meeting were:

- The COD in the Cotton fibres processing industries is mainly generated in textile printing an ink application, and should not be applied twice to production of thread production and final textile production;
- Taking into account the scope of the COD coefficients it was necessary to revised some of the industrial activity data;
- It is important to find other data sources to validate/update some of the coefficients.

In 2007 and following the consultation with Leonor Cartaxo and after careful revision of the industrial initial data, some changes were made to the activity data of specific industrial sectors.

The following table shows the pollution coefficients that were used in organic load estimates, based on the coefficients available in Cartaxo et al (1985).The set of available coefficients determined the list of industrial sectors that were considered in the estimation of water pollution discharges. For the estimation of emissions of methane TOW equals COD load.

<sup>135</sup> -Cork Granulation; Aliphatic hydrocarbons; Cyclic hydrocarbons; Kraft pulping; Synthetic fertilizers; Acid sulphite pulping.

**Table 7-20 – Pollution Coefficients to estimate Industrial organic wastewater production**

Portuguese classification	IPCC industrial branches	Production Unit (PU)	Discharge (m <sup>3</sup> /PU)	BOD (kg/PU)	COD (kg/PU)	Inh.eq. (kg yr/PU)
Slaughter House	Meat & Poultry	ton	6	18	27	0.881
Slaughter House, swine	Meat & Poultry	ton	6	18	42	0.900
Slaughter House, Poultry	Meat & Poultry	ton	9	6	13	0.269
Meat Packing	Meat & Poultry	ton	10	20	30	0.978
Milk processing	Dairy Products	m <sup>3</sup>	1	1	2	0.044
Cheese	Dairy Products	m <sup>3</sup> milk	8	13	20	0.651
Other dairy products	Dairy Products	m <sup>3</sup> milk	5	7	10	0.347
Fruit and vegetables conservat	Vegetables, Fruits & Juices	ton	15	15	27	0.734
Tomato juice	Vegetables, Fruits & Juices	ton	100	19	32	0.930
Fruit Juices	Vegetables, Fruits & Juices	ton	9	45	77	2.216
Fish processing and canning	Fish Processing	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	Vegetable Oils	ton	3	13	19	0.612
Margarine	Dairy Products	ton	25	3	8	0.161
Grains milling and processing	Starch Production	ton	3	5	9	0.220
Sugar processing	Sugar Refining	ton	8	2	4	0.093
Yeast	-	ton	120	600	1,080	29.354
Ethanol	Alcohol Refining	m <sup>3</sup>	17	328	1,192	16.068
Spirits Distillation	Wine & Vinegar	m <sup>3</sup>	8	95	218	4.628
Wine Cellars	Wine & Vinegar	ton grapes	2	5	8	0.220
Beer	Beer & Malt	m <sup>3</sup>	5	4	9	0.215
Mineral water and similars	Vegetables, Fruits & Juices	ton	8	6	10	0.294
Wool production	Textiles (Natural)	ton	44	89	366	4.354
Wool processing	Textiles (Natural)	ton	537	87	347	4.256
Synthetic fibres processing	Textiles (Natural)	ton	155	155	268	7.583
Artificial fibres processing	Textiles (Natural)	ton	42	30	52	1.468
Cotton fibres processing	Textiles (Natural)	ton	317	155	268	7.583
Leather industry	-	ton	85	85	213	4.159
Cork processing	-	ton	1	2	8	0.073
Cork granulation	-	m <sup>3</sup>	1	83	1,104	4.061
Kraft pulping	Pulp & Paper (Combined)	ton	140	28	158	1.345
Acid sulphite pulping	Pulp & Paper (Combined)	ton	270	283	1,050	13.845
Kraft paper	Pulp & Paper (Combined)	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	Organic Chemicals	ton	190	285	570	13.943
Aliphatic Hydrocarbons	Organic Chemicals	ton	190	285	570	13.943
Synthetic fertilizers	-	ton	15	15	38	0.734
Pesticides	Drugs & Medicines	ton	4	23	30	1.111
Polymers	Plastics & Resins	ton	15	15	45	0.734
Synthetic rubber	Plastics & Resins	ton	15	15	45	0.734
Artificial fibres production	Plastics & Resins	ton	300	150	450	7.339
Polyester fibres production	Plastics & Resins	ton	348	6	16	0.313
Acrylic fibres production	Plastics & Resins	ton	65	50	121	2.422
Paints, varnishes and lacquers	Paints	ton	0	1	9	0.029
Pharmaceutical products	-	employe	0	0	14	0.462
Soaps	Soap & Detergents	ton	4	6	12	0.294
Detergents	Soap & Detergents	ton	3	1	2	0.029
Petroleum refining	Petroleum Refineries	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 2013. Nevertheless, efforts were made to guarantee that the consistency in time series was not impaired by the use of different origins of information, as will be later explained. Detailed



information on industrial production for each sector can not be delivered in this report, because of confidential restraints existing in certain sectors.

For the construction of the time series the following methodology was used:

- Identification of the industrial sectors which represented 95% of the total wastewater 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 2013;
- Production of paper pulp was available directly from the individual industrial plants, for the all period.

Table 7-21 and Table 7-22 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 2013, 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>136</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 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 7-21 - Sources of Information used to define the time-series of industrial production (1/2)

Industry	IAIT CAE rev1	IAPI PRODCOM	Infoline	Note
Slaughter House			1990-2013	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2013	
Slaughter House, Poultry			1990-2013	Broilers, Turkeys, ducks, quails, ostrich, guinea-fow I, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200	-	
Milk processing	3112		1994-2013	
Cheese	3112	15510	-	
Other dairy products	3112		1994-2013	Cream, yogurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2013	
Tomato juice			1994-2013	
Fruit Juices	3131+3132		1994-2013	
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			1993-2013	
Ethanol	313110	159101070; 1592011	-	
Spirits Distillation	3131+3132	1591010-159101070+1592012	-	
Wine Cellars	3131+3132	15930; 15950	2001-2013	
Beer	3133	1596010	-	
Mineral water and similars			1993-2013	

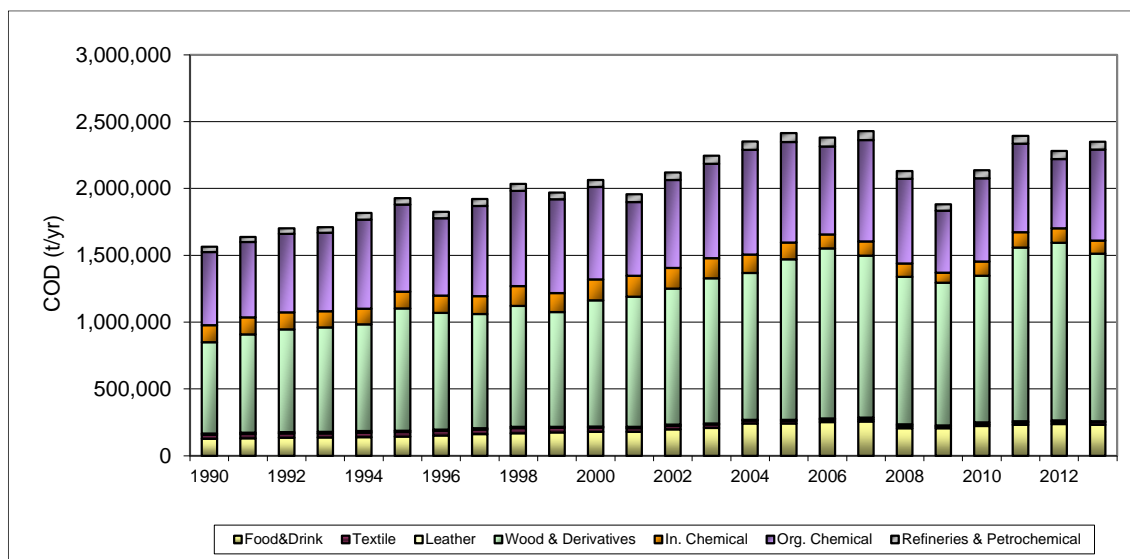
<sup>136</sup> It must be stressed though, that all information sources were produced by the National Statistical Institute (INE). Only methodological procedures for data collection change according to years.

**Table 7-22 - 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	-	
Chlorine and alkalis		241301111; 2413015; 2413022	-	
Inorganic acids		2413014-241301453- 241301475- 241301477	-	
Cyclic Hydrocarbons		2414312; 2414314	-	
Aliphatic Hydrocarbons		2414311	-	
Synthetic fertilizers		2415	-	Original units is kg N, kg P2O5 and K2O and were converted to ton of fertilizer
Pesticides	3512	242	-	
Polymers	351312	24160-2416058	-	
Synthetic rubber		2417	-	
Artificial fibres production		2470023; 247003070	-	
Polyester fibres production		247001130; 247001315; 247001350	-	
Acrylic fibres production		247001150	-	
Paints, varnishes and lacquers	3521	24301	-	
Pharmaceutical products			1998-2013	
Soaps		2451131	-	
detergents		2451120/32	-	
Petroleum refining			-	Energy Balance (DGGE): 1990-2013

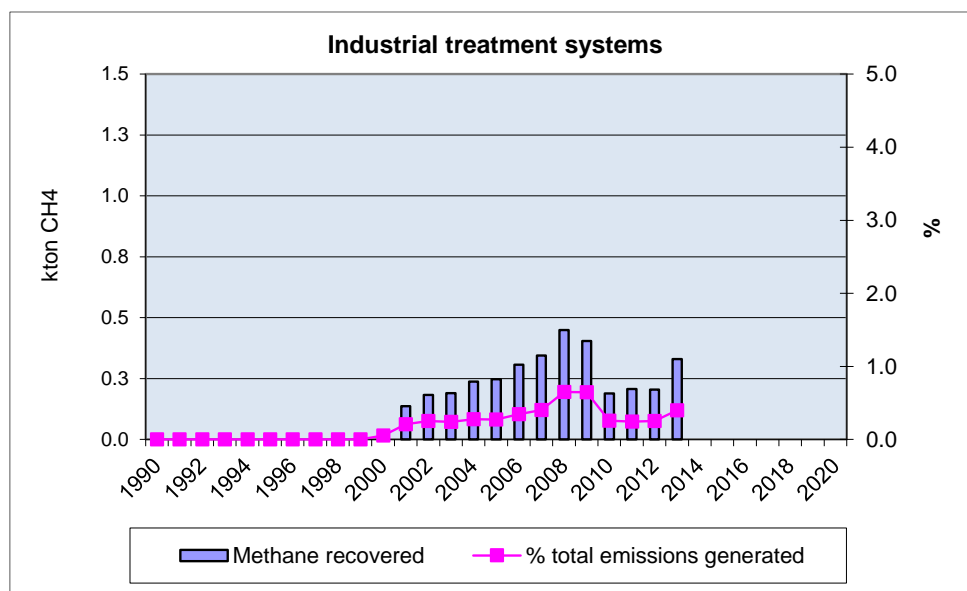
Total wastewater load aggregated per industrial group is presented in Figure 7-15 below, from where it is evident the continuous growth of discharge from 1990 to 2007, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry. In later years the situation stabilized or even decreased in some years.

Figure 7-15 - Industrial Wastewater load, expressed in COD, from major groups of industrial activity



Biogas generated in sludge treatment systems is flared for electrical production in cogeneration units. DGEG collects information on the amounts of biogas consumed in an annual inquiry. The quantities of biogas that are reported in Nm3 were converted into 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 7-16 – Methane recovery (Industry)



Source: Quantities based on DGEG data.

## Emission Factors

### *Wastewater handling systems*

As consequence of the fact that there was no available comprehensive information about the existence of each treatment system, the necessary information to determine the per cents for each sector had to be guessed specifically for the inventory using information collected from:

- EPER data. At the time that the inventory was compiled the EPER data was available for 2000 and partially for 2004. Information for the following sectors was available: paper pulp production; crude oil refining; slaughterhouses and meat processing; pig farms; olive oil extraction; fish canning and processing and chemical industry;
- Covenants of Environmental Adaptation. These were voluntary agreements between the Environmental Ministry, other ministries responsible for the permits of specific industrial sectors (Ministry of Economy or the Ministry of Agriculture, Rural Development and Fisheries) and several industrial associations in representation of the industrial units. The agreements were established between March 1997 and February 1998 with the objective to define a time schedule to reach the complete respect of legal constrains concerning the water, air, wastes and noise. The contract involved the elaboration of an *Assessment of the Environmental State*<sup>137</sup> and a *Specific Plan of Elaboration*<sup>138</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 instalations covered by the IPCC 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;

<sup>137</sup> Caracterização da Situação Ambiental, in the original Portuguese nomenclature.

<sup>138</sup> Plano Específico de Adaptação, in the original Portuguese nomenclature.

- 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.

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 2013.

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 2013 between 49% and 35% as presented in the next table.

Table 7-23 - 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	2013
No treatment, discharge in river or soil	%	11.6	14.3	10.0	11.7	10.5	11.7
Primary	%	5.9	5.2	5.3	6.5	1.0	0.8
Secondary treatment: Aerobic, well managed	%	17.5	14.4	15.0	14.5	25.0	23.9
Secondary treatment: Aerobic, not well managed	%	2.6	2.3	2.2	2.8	2.5	2.1
Secondary treatment: Anaerobic, no CH <sub>4</sub> recovery	%	0.0	0.0	0.1	1.1	1.4	1.3
Septic Tank	%	4.7	6.4	5.8	6.5	6.0	6.6
Municipal Sewer system, treatment with Municipal Waste Water	%	9.1	12.3	14.2	17.0	18.0	18.8
Unknown	%	48.6	45.2	47.4	39.9	35.5	34.8
<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>

#### *Methane Production Potential*

The parameter Bo, 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).

### *Methane Correction Factor*

MCF values used were established from the latest guidelines available (IPCC, 2006), and are presented in the next table.

Table 7-24 - 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 2013. 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 2013.

### *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>139</sup>, the comparison of the PC of Cartaxo et al (1985) (named CS) were compared with the equivalent IPCC in the next table<sup>140</sup>:

<sup>139</sup> The level of detail of the IPCC Pollutant Coefficients is not so detailed as the CS data set.

<sup>140</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 7-25 – 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 7-17 - Comparison between COD estimates using CS PC and IPCC defaults.

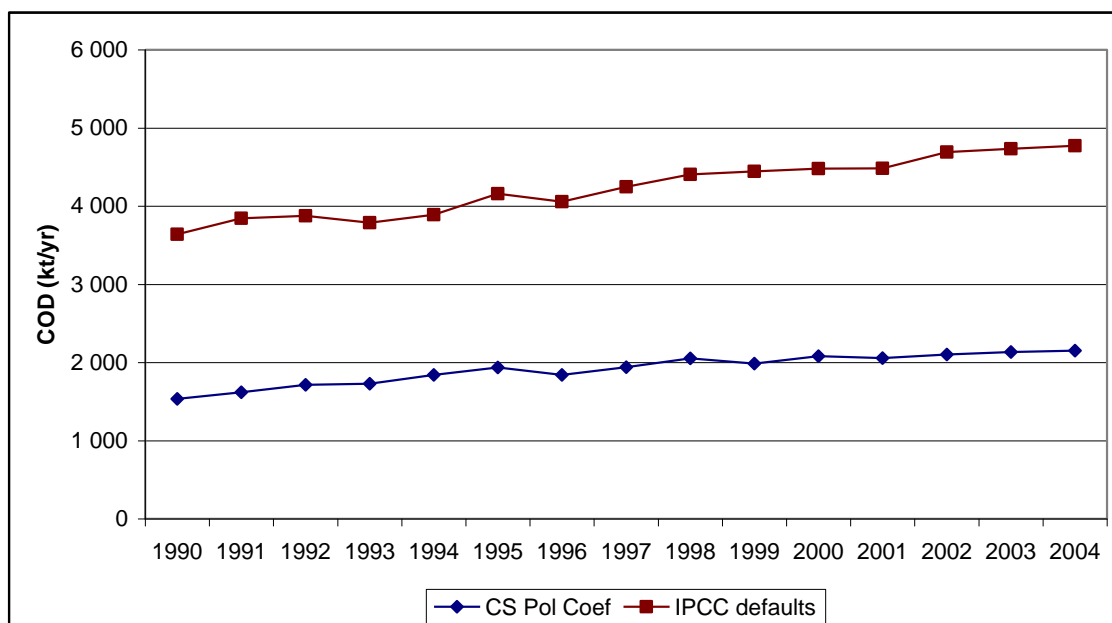
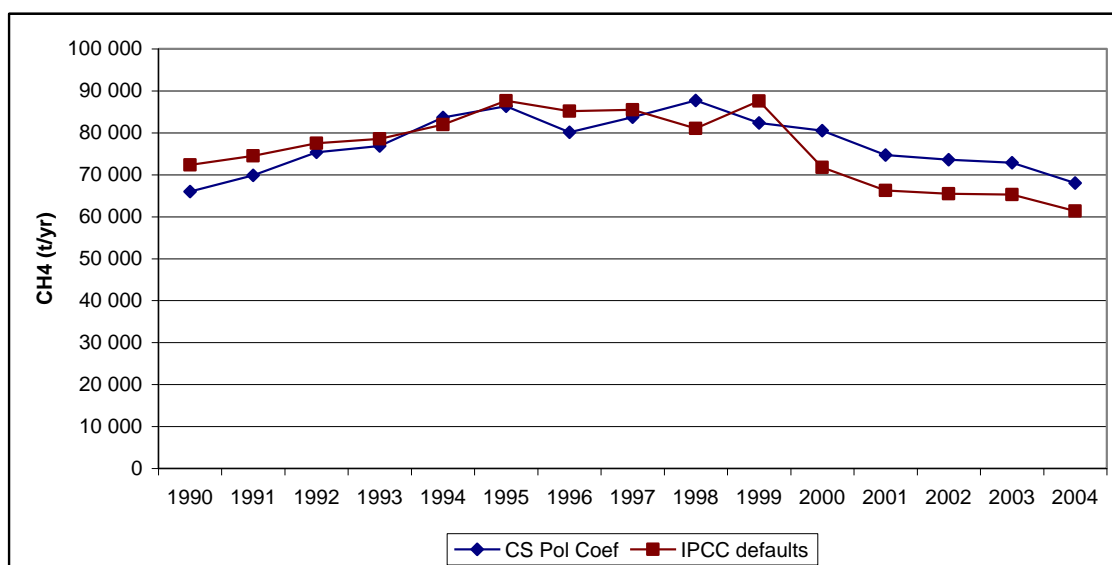


Figure 7-18 - Comparison between CH<sub>4</sub> emission estimates using CS PC and IPCC defaults.



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.

#### 7.5.2.3 N<sub>2</sub>O emissions from wastewater (Human Sewage)

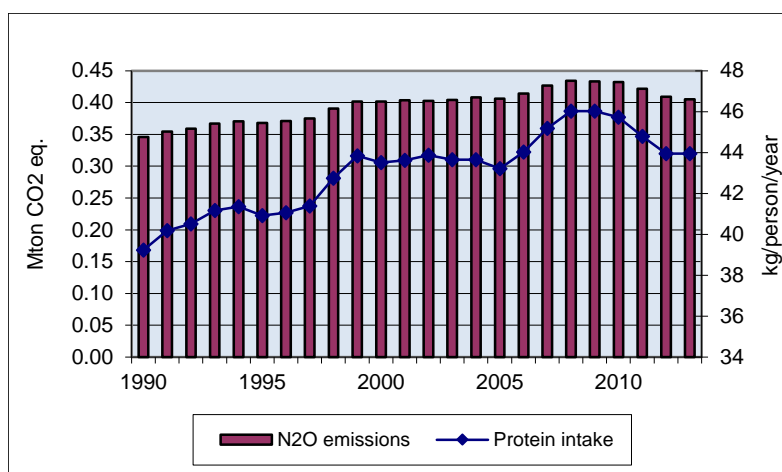
Human sewage can be disposed on land or discharged into aquatic environments (e.g. rivers and estuaries), either directly without treatment or after treatment in septic systems or wastewater treatment facilities. N<sub>2</sub>O can occur as direct emissions from treatment plants or

from indirect emissions from wastewater after disposal of effluent into aquatic environments. 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.

Direct emissions from wastewater treatment plants is considered a minor source and predominantly associated with advanced centralized wastewater treatment plants with nitrification/denitrification steps.

The inventory considers only indirect N<sub>2</sub>O emissions, Emissions from wastewater treatment that is discharged into aquatic environments are consider in this section, and those resulting from disposal of sludge in agriculture soils are included in the agriculture sector.

Figure 7-19 – N<sub>2</sub>O emissions from human sewage disposed into waterways and per capita protein intake



Source: Protein intake: INE data; 2009-2011 data refer estimates. .

### Methodology

Emissions of N<sub>2</sub>O from domestic wastewater were estimated following the IPCC (2006) methodology, considering that the amount of protein consumed by humans determines the quantity of nitrogen contained in sewage, and including calculations that take into account N removal with sewage sludge (applied in agriculture soils) and non-consumption of protein .

N<sub>2</sub>O emissions from domestic wastewater were estimated as follows:

$$N_2O_{(s)} = (P * Protein * Fra_{CNPR} * F_{NON-CON} * - F_{SEW}) * EF * 44/28$$

where:

N<sub>2</sub>O<sub>(s)</sub> - N<sub>2</sub>O emissions from human sewage (kg N<sub>2</sub>O-N/yr);

P - number of inhabitants in country;

Protein - annual per capita protein intake (kg/person/yr);

Fra<sub>CNPR</sub> - fraction of nitrogen in protein (kg N/kg protein);

Fra<sub>CNON-CON</sub> - factor for non-consumed protein added to the wastewater (0.2);

F<sub>SEW</sub> - nitrogen in sewage sludge applied to agriculture soils (please see CRF 4.D chapter)

EF - emission factor for N<sub>2</sub>O emissions from discharged wastewater (kg N<sub>2</sub>O-N/kg sewage-N produced);

44/28 is the molecular weight ratio of N<sub>2</sub>O to N<sub>2</sub>.

#### Activity data and parameters

Portuguese population refer to National Statistical Office (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. The latest data available refer to the 2013 enquiry that considers the 2008-2012 period. Data for 2013 refer to the latest available year (2012). Other parameters used in the estimations are based on the 2006 IPCC defaults. The value considered for non-consumed protein discharged to wastewater pathways is 1.2. This value refer to an expert guess that takes into consideration the fact that no garbage disposals are used in Portuguese homes.

Table 7-26 - 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	43.7
	2004	43.7
	2005	43.2
	2006	44.0
	2007	45.2
	2008	46.0
	2009	46.0
	2010	45.7
	2011	44.8
	2012	43.9
	2013	43.9
Fraction of nitrogen in protein	16%	IPCC default
Fraction of non-consumed	20%	Expert judgement
Emission factor	0.01 kg N <sub>2</sub> O-N/kg N	IPCC default

Note:  
2013: data refer to 2012.

#### 7.5.2.4 N<sub>2</sub>O Emissions from Industrial Wastewater Handling

##### Methodology

Despite the fact that 2006 IPCC includes guidance to estimate N<sub>2</sub>O emissions from industrial wastewater handling, the current inventory still uses the previous approach which is based on the CORINAIR/EMEP Handbook (EEA, 2000). This guidebook 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. This approach will be revised in the near future. At present, emissions are estimated from:

$$E_{\text{N}_2\text{O}} = \text{TLH}_j * \text{EF}_{\text{N}_2\text{O}}$$

Where,

$E_{\text{N}_2\text{O}}$  – Total nitrous oxide emissions from industrial wastewater handling, t N<sub>2</sub>O/yr;

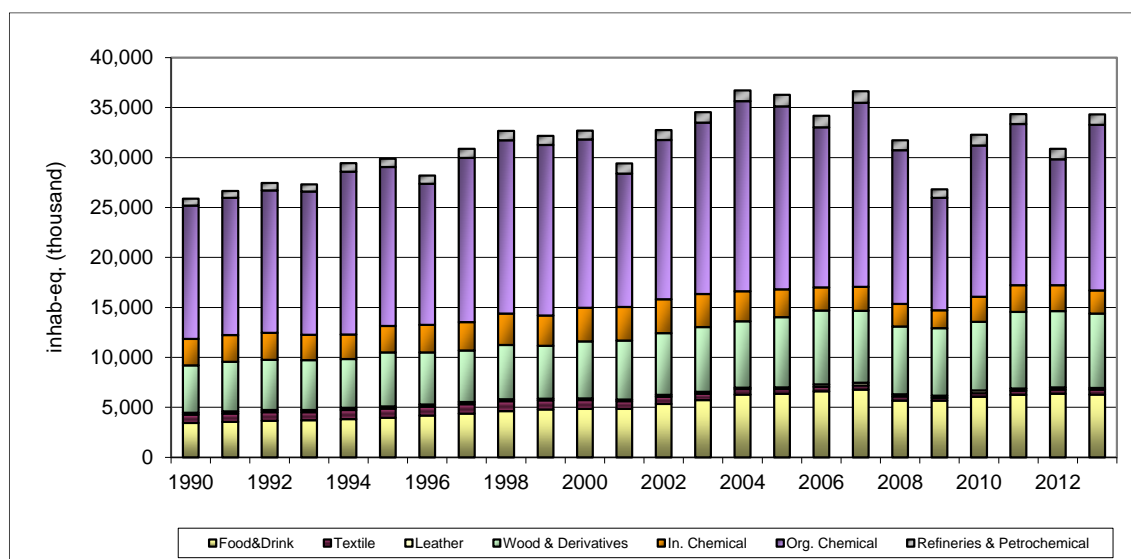
$\text{TLH}_j$  – Total Wastewater Load generated from industrial sector  $j$ , expressed in inhabitants-equivalent;

$\text{EF}_{\text{N}_2\text{O}}$  - Emission factor, kg N<sub>2</sub>O/inhab-eq/yr.

##### Activity Data

The total industrial load, in this case expressed in inhabitants-equivalent was also estimated from data on industrial production and multiplication by pollution coefficients. The methodology was already explained under CH<sub>4</sub> emissions from industrial wastewater management. The evolution of total load, and the contribution from major sectors, are presented in Figure 7-20.

Figure 7-20 - Industrial Wastewater load from major groups of industrial activity



##### 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.

### 7.5.3 Uncertainty and time-series consistency

#### 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.

Finally the error was determined for each industry and propagated accordingly. The final uncertainty varies in time from 29% to 35%.

## **7.5.4 Source-specific QA/QC and verification**

### **7.5.4.1 Wastewater Handling**

#### *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.

#### *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 data from other countries. Significant deviations were observed for domestic and industrial wastewater emissions. These differences are however difficult to explain as it implies a deep analysis of the methodologies used by other countries.

## **7.5.5 Source-specific recalculations**

Recalculations refer to Industrial wastewater treatment and refer to the revision of activity data for 2012 on industrial production.

## **7.5.6 Source-specific planned improvements**

Since the restructuration of the National Water Authority (ex-INAG), the referred “Inventário Nacional de Sistemas de Abastecimento de Água e Águas Residuais (INSAAR)”, the national data base for wastewater treatment systems, has been deactivated. Alternative data sources have to be developed or a new methodological approach should be followed in order to update or revise the time series for the whole period in a consistent way. This objective has been difficult to achieve as no alternative complete data sources exist. Efforts shall continue in order to update information on urban/domestic wastewater treatment systems.

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). Efforts will continue in order to update and improve the assessment of the situation concerning industrial wastewater handling systems, having as a basis the information collected from the Environmental Licensing (European Union’s IPPC directive).

Despite the fact that 2006 IPCC includes methodological guidance for N<sub>2</sub>O emission from industrial wastewater treatment, the current inventory uses the previous approach base in the EMEP/CORINAIR GUIDEBOOK 2002. The approach used should be revised on the basis of

the new guidelines and this task has been included in the Methodological Development Plan (PDM).

## **7.6 Biogas burning without energy recovery (CRF 5.E.)**

### **7.6.1 Source category description**

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 5E.

The inventory considers landfill gas recovery values since 2000. 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 2013, 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.

### **7.6.2 Methodological issues**

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).

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 7-27 – Activity data, emission factors and related emissions of biogas combusted**

<b>Quantities of landfill gas and biogas combusted</b>		<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
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	2,348,254
Flaring b)	GJ	-	-	-	-	-	266,085	440,544	420,404	416,178	356,085	287,131	60,069	not available	not available
<b>Emission factors</b>															
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 <sub>10C</sub>	g/GJ	2.5													
CO	g/GJ	17													
SO <sub>x</sub>	%	0.0016													
<b>Emissions with energy recovery (CRF 1A1a)</b>		<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
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	122.1
CH <sub>4</sub>	ton	0.1	0.0	0.0	0.0	0.2	0.5	0.4	0.8	1.2	1.2	1.6	2.4	3.1	3.6
N <sub>2</sub> O	ton	0.1	0.0	0.0	0.0	0.2	0.5	0.4	0.8	1.2	1.2	1.6	2.4	3.1	3.6
<b>Emissions without energy recovery (CRF 6D)</b>		<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
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	0.000
N <sub>2</sub> O	ton	-	-	-	-	-	0.373	0.617	0.589	0.583	0.499	0.402	0.084	0.000	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.

### 7.6.3 Uncertainty and time-series consistency

#### 7.6.3.1 Landfill gas and other biogas burning

CH<sub>4</sub> and N<sub>2</sub>O emissions from biogas flaring reported in category 5E 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.

#### 7.6.4 Source-specific QA/QC and verification

General CQ1 procedures were applied.

#### 7.6.5 Source-specific recalculations

Not occurred.

#### 7.6.6 Source-specific planned improvements

Not foreseen.



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## **8 RECALCULATIONS AND IMPROVEMENTS**

This section presents an overview of responses to the UNFCCC and information on recalculations made in the 2015 submission. The recalculations made result mostly from the implementation of the 2006 IPCC Guidelines and the recommendations issued from last UNFCCC reviews and updates of activity data.

### **8.1 Overview of the UNFCCC Review Process**

Regulation (EU) No 525/2013, requires Member States to report on the status of implementation of each adjustment and recommendation issued from the country UNFCCC review processes.

Table 8.1 – Reporting on implementation of UNFCCC recommendations and adjustments (Annex IV - Article 9(1) of the Commission Implementing Regulation (EU) No 749/2014)

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
General	QA/QC	Implement additional QC procedures to avoid mistakes or discrepancies in the CRF tables and the NIR	Table 3 /2014	Continuous improvement	Continuous improvement	
General	QA/QC	Provide information on the QC activities and their results	12/2014		Information to be provided in the final 2015 NIR	
General	Uncertainty analysis	Revise and update the uncertainty data for AD and EFs	Table 4 /2014	Uncertainty analysis to be revised in accordance with methodological changes and data revisions in 2015.	Under development	
General	Key categories	Identify key categories in accordance with the IPCC good practice guidance for LULUCF	16/2014	Key categories analysis to be revised in accordance with new categorisation of emission sources and revised uncertainty analysis.	Under development	
General	Uncertainty analysis	Improve the reporting of the uncertainty analysis by providing in the NIR the results of the level uncertainty for the last reported year and showing the results of the analysis in the table in the annex	17/2014		To be included in future NIR	
General	Inventory management	Improve the archiving system by providing further guidance on the record-keeping and archiving procedures	18/2014		To be further developed in the future	
General	Follow-up to previous reviews	Implement all recommendations made in previous review reports	19/2014	Continuous improvement	Continuous improvement	
Energy		The ERT encourages Portugal to continue its efforts to incorporate plant-specific data into its inventory	Previous 2012	Continuous improvement	Under Development	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy		Reiterating question from S&A report about CRF 1B2a: The inter-annual changes of CO <sub>2</sub> 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.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	Comparison of the reference approach with the sectoral approach and international statistics	Improve the consistency between the energy balance and the data available for LPS, and the split between domestic and international energy consumption for aviation and navigation	25/2014	Some improvements have been made in the consistency between energy balance and the slip between domestic and international energy consumption for aviation. Since 2007 the difference between the reference approach and the sectoral approach has decreased. Until 2006, data from the energy balance still differ because 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.	Under implementation	Section 3.2.1
Energy	Comparison of the reference approach with the sectoral approach and international statistics	Provide complete information related to the appropriate conversion factors for all fuels in the reference approach and the sectoral approach	26/2014	Under development	Information to be included in future NIR	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy	International bunker fuels	Improve the estimation of international aviation bunkers and resolve the discrepancy between the energy balance and IEA data	27/2014	Some improvements have been made and the discrepancy in the international aviation energy consumption data between energy balance and IEA data no longer exist from 2007 onwards. Until 2006 the discrepancy between the energy balance and IEA data results from a data treatment made by the IEA after receiving the information from the DGEG.	Implemented	Section 3.2.1
Energy	Feedstocks and non-energy use of fuels	Implement the planned revision and further development of the reporting of feedstocks and non-energy use of fuels and explain transparently the estimates and the notation keys reported in CRF table 1.A(d)	28/2014		Under Development	
Energy	Feedstocks and non-energy use of fuels	Correct the inconsistency of the reported data of LPG consumption in the CRF tables 1.A(b) and 1.A(d) and the NIR	29/2014		To be implemented in the Final 2015 NIR	
Energy	Feedstocks and non-energy use of fuels	Specify the fuel for "other non-specified" in non-energy use of fuels to improve transparency	30/2014			
Energy	Feedstocks and non-energy use of fuels	Explain the estimation of emissions for the CO <sub>2</sub> emissions resulting from the usage of the natural gas for hydrogen production in one refinery	31/2014			

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Analyse and consider in the emission estimates the humidity content of the incinerated wastes to ensure that the corresponding emissions are not overestimated	34/2014		To be implemented in the future.	
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Move the methodological description of the CO <sub>2</sub> emissions from limestone used for desulphurization in the NIR from the energy sector to the industrial processes sector	35/2014		To be implemented in the Final 2015 NIR	
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Include the information provided during the review on the estimations of plant-specific CO <sub>2</sub> EFs and AD for liquid and gaseous fuels combusted for energy purposes in the category petroleum refining in the NIR	36/2014		Under Implementation	
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Ensure consistency of the reported data for the consumption of oil waste and tar under iron and steel production in the CRF tables and the NIR	38/2014			
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Report consistent information on the CO <sub>2</sub> EF for gasoline in the NIR and the CRF tables; revise the QA/QC procedures	39/2014		To be implemented in the Final 2015 NIR	
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Improve the explanations on how the emissions of fuel gas, LPG, fuel oil, naphtha and natural gas in the production of city gas are estimated and allocated	41/2014		To be implemented in the Final 2015 NIR	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy	Stationary combustion: all fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Explain and justify in the NIR the circumstances which led to the inclusion of the emissions from fuel consumption in coal mining elsewhere, other than under the category manufacture of solid fuels and other energy industries	42/2014		To be implemented in the Final 2015 NIR	
Energy	Road transportation: liquid and gaseous fuels – CO <sub>2</sub>	Continue with the efforts to develop country-specific CO <sub>2</sub> EFs for gasoline and diesel oil.  The ERT recommends that Portugal investigate the possibility of obtaining a country-specific CO <sub>2</sub> EF from the gasoline and diesel oil reported under the EU ETS.	76/2012 and 44/2014	CO <sub>2</sub> emission factors from the gasoline and diesel oil reported under the EU ETS are based on inventory default EFs and do not refer to country-specific EFs.	No new developments	
Energy	Railways: liquid fuels – CO <sub>2</sub>	Provide an explanation of the recalculation CO <sub>2</sub> EF in the NIR	45/2014	CO <sub>2</sub> EF was revised according with the IPCC 2006 guidelines.	Implemented	Section 3.3.3
Energy	Railways: liquid fuels – CO <sub>2</sub>	Include in the NIR the information provided during the review to verify that the fuel reported under other fuels is biodiesel	46/2014	Biodiesel will be reported under Biomass in the new CRF table 1.A(a).	Implemented	
Energy	Fugitive emissions from oil refining: all fuels – CO <sub>2</sub>	Include in the NIR the information provided during the review on how Portugal ensures that some fugitive CO <sub>2</sub> emissions from oil refineries are not double counted or missed	47/2014		Under Implementation	
Energy	Fugitive emissions from oil refining: all fuels – CO <sub>2</sub>	Explain all recalculations in the NIR	48/2014		Under Implementation	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Energy	Other transportation: liquid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Explain in the NIR and in CRF table 1.A(a) what type of consumption is included in the item “Serviços” from the energy balance and consequently report the fuel consumption and the associated emission estimates under the appropriate category	49/2014		Under Development	
Energy	Other transportation: liquid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Report AD and emissions from ground activities in airports in the category other transportation	49/2014		Under Development	
Industrial processes and solvent and other product use	Time series consistency	Improve the transparency of the information on how the consistency of the time series is ensured for subcategories for which EU ETS data are used for only some years in the period 1990–2012	53/2014		Continuous Improvement	
Industrial processes and solvent and other product use	QA/QC	Include information in the NIR on specific QA/QC activities for industrial processes for which this information is not currently included	54/2014		Continuous Improvement	
Industrial processes and solvent and other product use	Cement production – CO <sub>2</sub>	Clarify the methodological description	55/2014		Under Implementation	



Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Industrial processes and solvent and other product use	Lime production – CO2	Ensure the consistency of the entire time series to estimate CO2 emissions from lime production	57/2014		Under Implementation	
Industrial processes and solvent and other product use	Limestone and dolomite use – CO2	Complete the AD on limestone and dolomite use to improve time-series consistency	58/2014		Under Implementation	
Industrial processes and solvent and other product use	Consumption of halocarbons and SF6 – HFCs and SF6	Provide in the NIR more detailed information on the methodology and other parameters used to estimate HFC emissions from fire extinguishers	60/2014		Under Implementation	
Industrial processes and solvent and other product use	Soda ash production and use – CO2	Correct figure 4-18 in the NIR to be consistent with the information provided during the review, report the AD for soda ash use in kt in CRF table 2(I).A-G and review the AD and emission estimates reported for soda ash to ensure that no double counting occurs	61/2014		Information to be provided in the final 2015 NIR	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Industrial processes and solvent and other product use	Other (chemical industry) – CO <sub>2</sub> and CH <sub>4</sub>	Explain the changes in the estimation methodology for the CO <sub>2</sub> and CH <sub>4</sub> emissions from ethylene production, including the data sources, and the changes in the emission estimates	62/2014		Information to be provided in the final 2015 NIR	
Agriculture	Transparency and consistency	Ensure consistency within the NIR and between the CRF tables and the NIR, and continue improving the transparency and the QC procedures	66/2014	Continuous improvement	Implemented	All agriculture chapters
Agriculture	Uncertainty analysis	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	67/2014	Some improvements have been made. The work on uncertainty analysis and development of country-specific values will continue.	To be further developed	
Agriculture	Manure management – CH <sub>4</sub>	Provide detailed information on the estimates for swine manure management Follow the methodological approach provided in the IPCC good practice guidance (table 4.10, footnote) to correctly reflect the practice of anaerobic digestion of swine manure, and document this approach in the NIR	68/2014	Continuous improvement	Implemented	Agriculture chapter CH <sub>4</sub> Emissions from manure management / section Emission Factors
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	69/2014	As a result of the meetings that were held with the National Statistics Institute (INE), the 2015 submission already includes the 2013 N fertilizer data	Implemented	Agriculture chapter N <sub>2</sub> O Emissions from agricultural soils / Section Synthetic fertilizers
Agriculture	Rice cultivation – CH <sub>4</sub>	Enhance the QC procedures to ensure the accuracy of the CRF tables and the NIR	70/2014	Continuous improvement	Implemented	All agriculture chapters

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
LULUCF	Transparency	Provide all methodological information in the NIR that is required by the IPCC good practice guidance for LULUCF	74/2014		Information to be provided in the final 2015 NIR	
LULUCF	Transparency	Continue to improve both the accuracy and the transparency of the AD in order to comply with the methodological requirements of the IPCC good practice guidance for LULUCF and continue to collect data on land-use change	75/2014		To be further developed.	
LULUCF	Transparency	Provide information on the applicability of each data set that is not country-specific, and document all information and considerations that lead to the application of these data	77/2014		To be included in the 2015 final NIR.	
LULUCF	Uncertainty analysis	Include in the NIR the information on the uncertainty analysis provided to the ERT during the review	78/2014		To be further developed.	
LULUCF	Forest land remaining forest land – CO <sub>2</sub>	Report the methodology on how the MAI is defined and estimated in detail	79/2014		To be included in the 2015 final NIR.	
LULUCF	Forest land remaining forest land – CO <sub>2</sub>	Complete the NFI6 to develop the average volume per hectare and average MAI data and use the results to report updated estimates based on the new inventory information	80/2014		Due to delays in the preparation of NFI6, to be considered in the 2016 submission	
LULUCF	Forest land remaining forest land – CO <sub>2</sub>	For “losses from living biomass” from forest land, explain the methodology used and the expert judgements and validate the expert judgements and/or replace them with specific measurements	87/2014		To be included in the 2015 final NIR.	

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
LULUCF	Forest land remaining forest land – CO <sub>2</sub>	For the loss type “other wood use”, include the explanation provided during the review and the respective expert judgements and validate the expert judgement and/or replace it with specific measurements	88/2014		To be included in the 2015 final NIR.	
LULUCF	Land converted to forest land – CO <sub>2</sub>	Address the inconsistency in the reporting of the value of harvesting under lands converted to forest in the calculations and in the NIR	90/2014		To be included in the 2015 final NIR.	
LULUCF	Land converted to forest land – CO <sub>2</sub>	Develop further the sampling and estimation system and the application of the sampling system in developing carbon stock change estimates	95/2014		Due to delays in the preparation of NFI6, to be considered in the 2016 submission	
LULUCF	Cropland remaining cropland – CO <sub>2</sub>	Include the information provided during the review on non-tillage of cropland occurred in the base year (1990) in the NIR	96/2014		To be included in the 2015 final NIR.	
LULUCF	Grassland remaining grassland – CO <sub>2</sub>	Include the information of the reporting on carbon stock gains in soils from areas under biodiverse pastures in the NIR to increase transparency	97/2014		To be included in the 2015 final NIR.	
Waste	Time series consistency	Address the time-series consistency issues separately for each category , explaining how it ensures time-series consistency when combining the data from different sources, and explain the reasoning for the choice of methods used to estimate missing data	102/2014		Under implementation.	

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>	Review the parameters used taking into account the national circumstances	104/2014		Under implementation/ to be further developed.	
Waste	Wastewater handling – CH <sub>4</sub> and N <sub>2</sub> O	Update the description of the estimation methodology, including any methodological changes	106/2014		To be included in the 2015 final NIR.	
Information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol	Land area identification	Continue to develop the land area identification system for Madeira to ensure that the land use and land-use change identification system meets the indicated area requirements	111/2014			
Information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol	Accuracy	Develop the estimation system for carbon stock changes in mineral soils	112/2014			

Sector	Category	Review recommendation	Review report paragraph / year	MS response	Status of Implementation	Chapter/section in the NIR
Information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol	Uncertainty analysis	Conduct an uncertainty analysis of the estimates for the activities of these activities.	113/2014	Uncertainty analysis to be further revised.	To be further revised.	
National registry	Publicly available information	Update the publicly available information on the national registry.s	121/2014		Implemented.	
Article 3, paragraph 14, of the Kyoto Protocol	Transparency	Report any change(s) in the information provided under Article 3, paragraph 14, of the Kyoto Protocol	134/2014		Information to be included in the 2015 final NIR.	

In order to comply with the UNFCCC decisions which adopted the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) as the standard methodological approach for Annex I countries inventories, this submission presents several changes in methodology, in emission sources categories and a new set of the global warming potentials (as per the IPCC 4th Assessment Report).

These changes resulted in a significant amount of recalculations in all inventory sectors.

In addition, several improvements have been implemented in order to respond to the latest UNFCCC inventory reviews.

A web-based version of the UNFCCC compilation software (CRF Reporter) has also been introduced.

## **8.2 Recalculations Energy sector (CRF 1)**

### **8.2.1 Overview**

The major changes between submissions (2014 and 2015) result from the revision of Emission factor according with the implementation of the IPCC 2006 Guidelines.

### **8.2.2 Energy industries (CRF 1.A.1)**

#### **8.2.2.1 Public electricity and heat production (CRF 1.A.1.a)**

Recalculations for this source category comprise:

- revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for stationary combustion based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

#### **8.2.2.2 Incineration of municipal waste (CRF 1A1a)**

Changes in the emission source refer to the revision of the composition of incinerated waste. Previously the composition of MSW landfilled was used. In this submission, composition of waste is specific to MSW incinerated with energy recovery.

The efficiency of combustion considered changed from 95% to the oxidation factor 100% (default 2006 IPCC).

The emission factors for CH<sub>4</sub> e N<sub>2</sub>O changed from 6.5 to 30 g/GJ for CH<sub>4</sub> and from 0.1 to 0.05 kg/ton MSW for N<sub>2</sub>O.

#### **8.2.2.3 Petroleum refining (CRF 1.A.1.b)**

- Revision of CH<sub>4</sub> emission factors based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- Revision of CO and NMVOC emission factors based on EMEP/EEA Emission Inventory Guidebook 2013.

#### **8.2.2.4 Manufacture of solid fuels and other energy industries (CRF 1.A.1.c)**

- Correction of an allocation error. Previously, some of the emissions related to coke production were reported under “2C1” and are now reported under “1A1c”.

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

#### 8.2.3.1 Iron and steel (CRF 1.A.2.a)

– Correction of the NMVOC to Indirect CO<sub>2</sub> conversion. Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

#### 8.2.3.2 Pulp, paper and print (CRF 1.A.2.d)

Recalculations for this source category comprise:

- revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for stationary combustion based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

#### 8.2.3.3 Food processing, beverages and tobacco (CRF 1.A.2.e)

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for stationary combustion based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

#### 8.2.3.4 Non-metallic minerals (CRF 1.A.2.f)

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for stationary combustion based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

#### 8.2.3.5 Other (CRF 1.A.2.g)

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for stationary combustion based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

### 8.2.4 Transport (CRF 1.A.3)

#### 8.2.4.1 Civil Aviation (CRF 1.A.3.a)

Recalculations for this source category comprise:

- revision of 2007 and 2009 energy balance data for Jet fuel;
- CO<sub>2</sub> fuel dependent emission factor revision for Jet fuel and Aviation gasoline based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### 8.2.4.2 Road Transportation (CRF 1.A.3.b)

Emissions were estimated using the new version of COPERT IV (version 11 - December 2014) and due to improved methodology and updated emission factors, results in the following changes:



- updated emission factors of regulated and non-regulated pollutants for Euro 5/V and Euro 6/VI vehicles, including N<sub>2</sub>O;
- revisions and updates, where necessary, of N<sub>2</sub>O emission factors for pre Euro 5/V technologies;
- a CO<sub>2</sub> correction methodology based on type-approval data for Euro 4-6 gasoline and diesel passenger cars has been introduced;
- CH<sub>4</sub> emission factors for gasoline passenger cars have been updated;
- emission factors for CNG vehicles of Euro 4-6 technologies have been introduced.

Recalculations for this source category also comprise:

- CO<sub>2</sub> fuel emission factor revision for Diesel, Gasoline and LPG based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### **8.2.4.3 Railways (CRF 1.A.3.c)**

Recalculations for this source category are mostly due to the revision of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for all fuels based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

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

Recalculations for this source category comprise the revision of CH<sub>4</sub> and N<sub>2</sub>O emission factors for all fuels based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

### **8.2.5 Other Sectors (CRF 1.A.4.)**

#### **8.2.5.1 Commercial/Institutional (CRF 1.A.4.a)**

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline, Wood, City Gas, Biogas, and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Diesel oil, Wood, City Gas, Biogas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Diesel oil, Residual oil, Wood, City Gas, Biogas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### **8.2.5.2 Residential (CRF 1.A.4.b)**

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline, Wood, City Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Diesel oil, City Gas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Diesel oil, Residual oil, Wood, City Gas, Natural Gas and Biodiesel based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

#### **8.2.5.3 Agriculture / Forestry / Fishing (CRF1.A.4.c)**

Recalculations for this source category comprise:

- revision of 2011 and 2012 energy balance data;
- revision of CO<sub>2</sub> emission factors for Motor Gasoline and Biogas based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of CH<sub>4</sub> emission factors for LPG, Motor Gasoline, Kerosene, Residual oil, Natural Gas and Biogas based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories;
- revision of N<sub>2</sub>O emission factors for LPG, Natural Gas and Biogas based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

### **8.3 Recalculations: Industrial Processes sector (CRF 2)**

#### **8.3.1 Overview**

The major changes between submissions (2014 and 2015) result from the revision of Emission factor according with the implementation of the IPCC 2006 Guidelines. Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines. Lime Production (CRF 2.A.2).

#### **8.3.2 Lime Production (CRF 2.A.2)**

Correction on the Activity Data.

#### **8.3.3 Nitric Acid Production (CRF 2.B.2)**

Correction on the N<sub>2</sub>O emissions from 2010 onwards based on revised emission factors derived from monitoring data.

#### **8.3.4 Iron and Steel Production (CRF 2.C.1)**

Correction of an allocation error. Previously, some of the emissions related to coke production were reported under “2C1” and are now reported under “1A1c”.

#### **8.3.5 Non-energy products from fuels and solvent use (CRF 2.D)**

##### **8.3.5.1 Solvent use (CRF 2.D.3.a)**

Differences in estimated emissions, from carbon emitted in the form of non-CO<sub>2</sub> species that oxidizes to CO<sub>2</sub> in the atmosphere, are mostly due to the consideration of a lower carbon fraction value in NMVOC by mass (from 0.85 to 0.6) in order to follow the 2006 IPCC Guidelines.

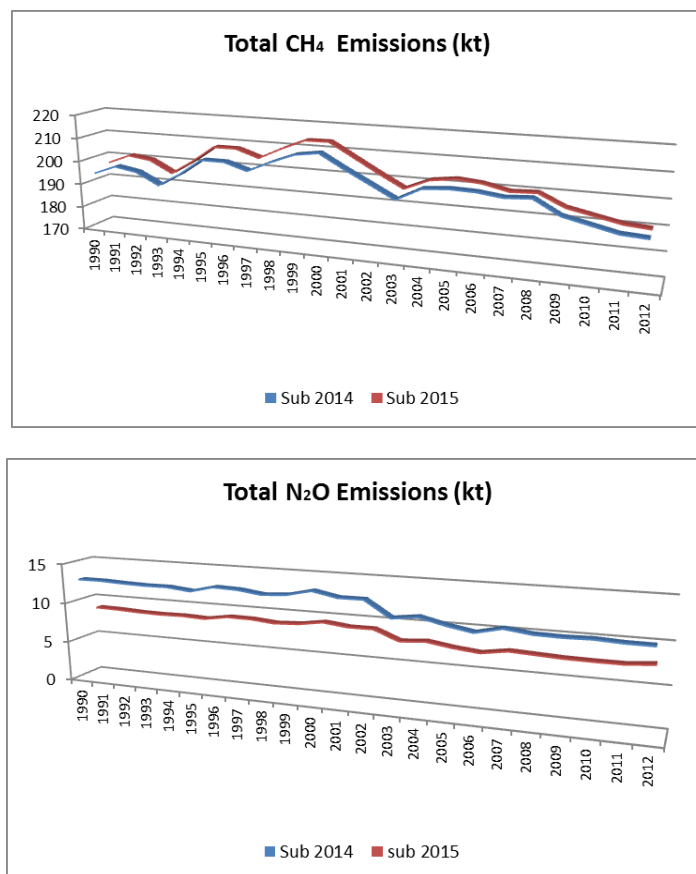
## 8.4 Recalculations: Agriculture sector (CRF 3)

### 8.4.1 Overview

The major changes between submissions (2014 and 2015) result from the implementation of the IPCC 2006 Guidelines and the application of the methodologies, parameters and emission factors defined therein for each source category.

Any other causes for recalculation, e.g. update of activity data, will be highlighted in chapter description of each emission source categories.

Considering the impact in the time series (1990-2012) the CH<sub>4</sub> emissions estimates had an average increase of 1.00 per cent and N<sub>2</sub>O emissions estimates had an average decrease of 31.34 per cent.



### 8.4.2 Enteric Fermentation (CRF 3A) - CH<sub>4</sub> emissions

Differences are mostly due to the increase of C<sub>fi</sub> value (from 0.0335 to 0.386) used on the calculation of Net Energy for maintenance, with special impact in non – dairy cows subclass, and the increase of Y<sub>m</sub> value from (6.0 % to 6.5 %) for most of the non- dairy cattle subclasses.

Dairy cows had no change because the methodological revision made last year followed already the IPCC 2006 Guidelines.

#### 8.4.3 Manure Management (CRF 3Ba) - CH<sub>4</sub> emissions

The main reason for differences is related to the manure management system of sheep and goats. In previous submissions there was an incorrect allocation of uncovered anaerobic lagoons that was corrected this year following an internal QA/QC.

#### 8.4.4 Manure Management (CRF 3Bb) – N<sub>2</sub>O emissions (direct and indirect)

The main drivers that contributed to the decrease of N<sub>2</sub>O emissions estimates were the changes of the following default emission factors

- d) Solid storage – previously (Revised IPCC 1996 & GPG) EF<sub>3</sub> was set 0.02 kg N<sub>2</sub>O-N/kg N excreted and now (IPCC 2006) default EF<sub>3</sub> equal to 0.005 kg N<sub>2</sub>O-N/kg N excreted. Portugal has a great percent of manure managed in this type of system and therefore the strong reduction (75%) on the EF<sub>3</sub> default value had an enormous impact in the N<sub>2</sub>O emissions estimates. The impact is bigger in the first decade of the time series because the percent of manure managed as solid storage was higher than in recent years;
- e) Anaerobic Lagoon - previously (Revised IPCC 1996 & GPG) EF<sub>3</sub> was set 0.001 kg N<sub>2</sub>O-N/kg N excreted and now (IPCC 2006) default EF<sub>3</sub> equal to 0 kg N<sub>2</sub>O-N/kg N excreted. Not so relevant but nevertheless with some impact in the N<sub>2</sub>O emissions of pig manure management;
- f) Leaching – EF<sub>5</sub> previous default value (Revised IPCC 1996 & GPG) was 0.025 kg N<sub>2</sub>O-N/kg N leached and the new default value (IPCC 2006) is 0.0075 kg N<sub>2</sub>O-N/kg N leached, which represents a significant reduction of the emission factor.

Not related with emission factors but also contributing to the differences between submissions, was the calculation revision of the fraction leached), in line with the IPCC revision of this issue, i.e., the N losses due to leaching from manure management systems.

Also, the implementation, for the first time, of the N-flow approach to estimate ammonia and nitrous oxide emissions from manure management, following the methodology of the EMEP/EEA Guidebook 2013, had influenced the estimates N<sub>2</sub>O indirect emissions from manure management.

#### 8.4.5 Rice cultivation (CRF 3C) – CH<sub>4</sub> emissions

The scaling factor related to water regime, SF<sub>w</sub>, has decreased (from 0.70 to 0.60) and a new scaling factor related to the pre- season water conditions, SF<sub>p</sub>; has been introduced (0.68) for the adjustment of the final emission factor, EF. Also important is the change in the calculation of the scaling factor related to organic amendments, SF<sub>o</sub>. The application of the new equation (5.3 of IPCC 2006) introduces an annual variation for SF<sub>o</sub> which did not happen when using the previous default values (table 4-2 of Good Practice Guidance).

#### 8.4.6 Agricultural soils (CRF 3D) – N<sub>2</sub>O emissions (direct and indirect)

The decrease is mainly due to the indirect N<sub>2</sub>O emissions estimates, particularly those from leaching and runoff. Portugal has no country specific emission factor therefore used the EF<sub>5</sub> default value which was revised by IPCC 2006. Previously (Revised IPCC 1996 & GPG) EF<sub>5</sub> default value was set 0.025 kg N<sub>2</sub>O-N / kg N leaching and runoff and now (IPCC 2006) is 0.0075 kg N<sub>2</sub>O-N / kg N leaching and runoff. This represents a significant reduction on indirect N<sub>2</sub>O emissions

The estimates direct N<sub>2</sub>O emissions also observed a reduction due to the revision (IPCC 2006) to the default emission factors:

- c) EF<sub>1</sub> – the emission factor for N<sub>2</sub>O emissions from N additions to the soil (synthetic fertilizer, organic fertilizer and crop residues) was previously set at 0.0125 kg N<sub>2</sub>O-N / Kg N added and the new value is 0.010 kg N<sub>2</sub>O-N / Kg N added, although the amounts of N applied are no longer adjusted for volatilisation;
- d) EF<sub>3</sub> – the emission factor for N<sub>2</sub>O emissions from urine and dung deposited on pasture has been disaggregated for different animal types. There is a new default value for sheep, goats, horses, mules and asses that is half of the previously value. Before it was 0.02 kg N<sub>2</sub>O-N / Kg N deposited and now is 0.01 kg N<sub>2</sub>O-N / Kg N deposited. In the national conditions, particularly on sheep and goats, the majority of animal population remain on pasture therefore the reduction of the emission factor has a significant impact in direct N<sub>2</sub>O emissions from excreta deposited by this type of animals.

#### 8.4.7 Field burning of agricultural residues (CRF 3F) – CH<sub>4</sub> and N<sub>2</sub>O emissions

Recalculations are related with:

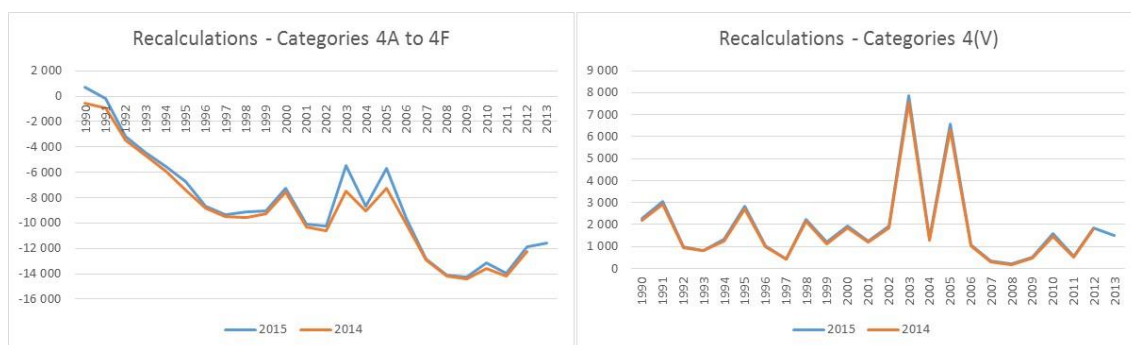
- the implementation of IPCC 2006 methodology to estimate crop residues production, which for cereal crops (rice excluded) led to an increase on the amount of residues and consequently of the biomass available to combustion;
- revision of dry matter content of crop residues in line with the implementation of the above methodology;
- revision of the per cent of crop residues that are burnt on field according to the information of last General Agricultural Census (RA09). In the last year submission there were not considered for cereal crops, other than rice, the practice of burning residues on field. In this year submission cereal crops also contributes to GHG emissions from this source category;
- revision of the amount of pruning material produced from permanent crops management.

### 8.5 Recalculations: LULUCF (CRF 4)

#### 8.5.1 Overview

The major changes between the 2014 and 2015 submissions result from the implementation of the IPCC 2006 Guidelines and the application of the methodologies, parameters and emission factors defined therein for each source category and the application of the new GWP from AR4.

Any other causes for recalculation, e.g. update of activity data, will be highlighted in chapter description of each emission source categories.



## 8.6 Recalculations: Waste sector (CRF 5)

### 8.6.1 Overview

The recalculations for the waste sector refer in majority to the application of the IPCC 2006 Guidelines.

### 8.6.2 Solid waste disposal (CRF 5A)

The recalculations for this category refer mostly to the application of the new formula for the calculation of CH<sub>4</sub> emissions from solid waste disposal on land, and the use of new parameters.

The AD for industrial solid waste disposed on land has been revised by the Statistical Office (INE) for the years 2008-2010 and new data for 2011-2012 were provided. The separation between managed/unmanaged industrial waste disposal on land have been revised to follow more closely the split between managed/unmanaged waste disposed on land for municipal waste, assuming that, in the past, all industrial waste was considered to be disposed in SWDS together with municipal waste.

Values for Degradable Organic Carbon (DOC) have been revised in accordance with data proposed in IPCC, 2006/ Chapter 2 waste, page 2.14/ Table 2.4. The fraction of DOC that can decompose (DOC<sub>f</sub>) has been changed from 0.6 to the proposed IPCC default value: 0.5.

### 8.6.3 Biological treatment of solid waste (CRF 5B)

The emissions from composting and anaerobic digestion of organic waste have been estimated for the first time in this submission, in accordance with the new guidance from IPCC 2006.

### 8.6.4 Incineration and open burning of waste (CRF 5C)

Recalculations for incineration of waste without energy recovery, include revisions of AD. Quantities of waste incinerated for the years 2008-2010 have been revised by the Statistical Office (INE) and new data for 2011-2012 were provided.

A correction of a compilation error was done for the non-biogenic emissions clinical incineration, issued from QA/QC procedures.

Other changes refer to the revision of the value used for the efficiency of combustion, which was changed from 95% to 100% (default 2006 IPCC for the oxidation factor).

The emission factor for CH<sub>4</sub> was also revised (from 6.5 to 30 g/GJ).

### 8.6.5 Wastewater treatment and discharge (CRF 5D)

The main change related to domestic wastewater treatment and discharge category refer to the introduction of a new factor not considered before concerning the Fraction of non-consumed protein added to the wastewater (FNON-CON), and resulted in an increase of N<sub>2</sub>O emissions.

### 8.6.6 Other/ Biogas burning without energy recovery (CRF 5E)

No changes occurred for this category.

## **PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1**

## **9 KP-LULUCF**

Given the problems observed with the CRF Reporter Software, which does not yet enable the reporting of KP LULUCF data in accordance with the reporting guidelines adopted for the 2<sup>nd</sup> Commitment Period, Portugal decided not to submit KP LULUCF information on this submission.

Portugal further informs that normal annual submission of this information will be resumed as soon as the relevant technical conditions are re-established.



## 10 INFORMATION ON ACCOUNTING KYOTO UNITS

This section includes supplementary information required under Article 7, paragraph 1, following the reporting requirements of the Annex of Decision 15/CMP.1.

### 10.1 Information Reported in the SEF Tables

The standard electronic format (SEF) tables have been attached (Annex A).

### 10.2 Discrepancies and notifications

No discrepancies or notifications registered.

The RREG2\_PT\_2014.xls, RREG3\_PT\_2014.xls, RREG4\_PT\_2014.xls and RREG5\_PT\_2014.xls were already provided to the UNFCCC.

### 10.3 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.

### 10.4 Calculation of the Commitment Period Reserve (CPR)

For the first commitment period, the 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. The CPR has not been changed since the previous submission.

As no assigned amount has been established for the second commitment period, no CPR can be calculated.

### 10.5 KP-LULUCF accounting

Portugal selected accounting of the KP-LULUCF activities at the end of the commitment period.

Information to be provided as soon as the relevant technical conditions related with the CRF Reporter Software are re-established.

## **11 CHANGES IN NATIONAL SYSTEM**

A new legal national arrangement has been adopted (Resolução do Conselho de Ministros n.º 20/2015) in order to take into account the recent developments at international level relating to the UNFCCC and the Kyoto Protocol, and the new monitoring and reporting requirements provided at the EU level by Regulation (EU) 525/2013 of the European Parliament and of the Council of 21 May 2013, on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC, and the Commission Implementing Regulation (EU) 749/2014 of 30 June 2014 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) No 525/2013 of the European Parliament and of the Council, and the requirements under the CLRTAP and the NECD.

Changes to the institutional arrangements since the 2014 submission refer to an update and enlargement of the number of institutions that make part of the National system and the reassignment of experts acting as Focal Points.

## 12 INFORMATION ON CHANGES IN NATIONAL REGISTRY

The following changes to the national registry of Portugal have therefore occurred in 2014.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a)  Change of name or contact	There has been no change in the name or contact of the National Registry.
15/CMP.1 annex II.E paragraph 32.(b)  Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.

Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(c)</p> <p>Change to database structure or the capacity of national registry</p>	<p>There have been changes in the database structure due to changes in the version of the CSEUR software. These changes were limited and only affected EU ETS functionality.</p> <p>An updated diagram of the database structure is attached as Annex A.</p> <p>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>
<p>15/CMP.1 annex II.E paragraph 32.(d)</p> <p>Change regarding conformance to technical standards</p>	<p>Although changes of the National Registry were limited and only affected EU ETS functionality, each release is always subject to both regression tests and tests related to new functionality.</p> <p>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 (see Annex B). Annex H testing will be carried out in February 2015 and the test report will be submitted thereafter.</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(e)</p> <p>Change to discrepancies procedures</p>	<p>No change of discrepancies procedures occurred during the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(f)</p> <p>Change regarding security</p>	<p>No change of security measures occurred during the reporting period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(g)</p> <p>Change to list of publicly available information</p>	<p>There have been changes to the list of publicly available information to reflect previous Annual Review recommendations.</p> <p>The url with the list of publicly available information changed and it is now available at <a href="https://ets-registry.webgate.ec.europa.eu/euregistry/PT/public/reports/publicReports.xhtml">https://ets-registry.webgate.ec.europa.eu/euregistry/PT/public/reports/publicReports.xhtml</a></p> <p>The update date is stated on the footer of the page. Publicly available information is updated on a monthly basis.</p>

Reporting Item	Description
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 since version 6.1.7.1 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 will be carried out in February 2015 and the test report will be submitted thereafter.</p>
The previous Annual Review recommendations	<p>In response to the previous Annual Review recommendations, the Party submitted R2-R5 reports and updated the list of public information with the SEF report. The Public Information is now available at</p> <p><a href="https://ets-registry.webgate.ec.europa.eu/euregistry/PT/public/reports/publicReports.xhtml">https://ets-registry.webgate.ec.europa.eu/euregistry/PT/public/reports/publicReports.xhtml</a></p> <p>This information is updated on a monthly basis.</p>

## **13 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14**

This chapter provides information on how Portugal is implementing its commitment under Article 3, paragraph 14 of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing countries.

Portugal's contribution to the minimization of the adverse effects of climate change in other Parties, particularly developing countries, is carried out first of all through a strong commitment to implementing the Convention and the Kyoto Protocol.

By working on the implementation of the Protocol, Portugal is struggling to minimize not only the adverse effects of climate change in specific sectors, industries or other Parties, but also any adverse effects due to the reduction of greenhouse gases. This is due to the development of different actions and implementation of different instruments conceived to promote sustainable development and the commitment to support developing countries.

The policies and measures implemented, adopted or foreseen in the National Plan for Climate Change (PNAC), targeting the six GHG of the Kyoto Protocol through its broad portfolio of instruments and wide-ranging coverage of all sectors of the economy, make up a significant effort by the Portuguese Government to address climate change, including the minimization of adverse effects of such policies.

The transition to a lower carbon Portuguese economy relies on the contribution of all sectors. Particularly, the Portuguese Energy Strategy relies to a great extent in the diversification of energy sources (including those referring to fossil fuels) and to the increase of endogenous resources (renewable). In some cases, the measures pertaining to the diversification of primary energy sources (namely shifting to natural gas), can simultaneously have positive effects on Portugal's emissions reduction and in the economy of some fossil fuel exporting countries.

As a member of the EU, Portugal also pursues the minimization of adverse effects of the policies and measures in this context through the implementation of activities such as the:

- EU Emissions Trading System (EU ETS): the EU's main policy mechanism for reducing CO<sub>2</sub> emissions from energy intensive sectors;
- Inclusion of aviation in the EU emission trading scheme which addresses the challenge of reducing emissions from this sector, and enables the creation of additional financial resources for climate change mitigation and adaptation in developing countries through the auction of emission allowances by member states;
- EU Renewables Directive (Directive 2009/28/EC): sets ambitious targets for each member state for the share of renewable energy generation by 2020 and the proportion of renewable energy in the transport sector (includes biofuels, biogas, hydrogen and electricity from renewables);
- Greenhouse Gas Effort Sharing Decision which sets targets for emissions reductions or growth limits in those sectors of Member States' economies not covered by the EU ETS (excluding Land Use, Land Use Change and Forestry);

- Roadmap for moving to a competitive low carbon economy in 2050, which outlines a strategy to meet the long-term target of reducing domestic emissions by 80 to 95% by 2050. Portugal is developing a national strategy to define the guidelines for the various sectors of activity and to serve as a supporting element for the preparation of future national plans for reducing emissions.
- (<http://www.apambiente.pt/index.php?ref=16&subref=81&sub2ref=117&sub3ref=303>)

Furthermore, the cooperation of Portugal with third countries looks to the integration of the adaptation dimension of climatic change in the several sectoral policies and instruments of planning, vulnerabilities and risks associates to climate change. The action of the Portuguese cooperation is developed on the basis of geographical priorities which are centered in the countries of Portuguese official language, in particular the Portuguese-speaking African countries/ Países Africanos de Língua Oficial Portuguesa (PALOP) and East Timor. All these countries are within the group of more vulnerable countries to the variations caused by climate changed either, because they are situated in its majority in Africa, or belong to the set of least developed countries and/or are small insular States.

At a multilateral level, Portugal supports the implementation of adaptation measures in the most vulnerable countries, in particular within the Community of Portuguese Speaking Countries/ Comunidade dos Países de Língua Portuguesa (CPLP), and contributes to the adaptation fund, in the framework of the EU responsibilities. It also supports institutional capacity building within the Portuguese Speaking Countries Network for Climate Change / Rede Lusófona para as Alterações Climáticas (RELAC).

At a bilateral level, assists ONGD (non-governmental organizations for development) projects in Angola, Cabo Verde, Guiné-Bissau, Moçambique e São Tomé e Príncipe; and promotes the sectoral integration the adaptation component in the Cooperation Programs, in particular in the scope of Superior education and of Research in the field of Environmental Engineering, Agriculture and Rural Development, and Health.

## 14 List of Acronyms

ABS	Acrylonitrile Butadiene Styrene	Acrilo Nitrilo Butadieno Estireno
AC	Air Conditioning	Ar condicionado
ACAP	Portuguese Association of Automobile Business	Associação do Comércio Automóvel de Portugal
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	Comissão de Coordenação e Desenvolvimento Regional de Lisboa



	Development Commission	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	General Directorate for Economic	Direcção Geral das Actividades

DGE)	Activities	Económicas
DGAV	General Directorate for Food and Veterinary	Direção 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	Hydrochlorofluorcarbons	-
HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias

HFC	Hydrofluorcarbons	-
APA	Portuguese Environmental Agency	Agência Portuguesa do Ambiente
IAIT	Annual Survey to Manufacturing Industry	Inquérito Anual à Indústria Transformadora
IAPI	Annual Survey to Industrial Production	Inquérito Anual à Produção Industrial
ICAO	International Civil Aviation Organization	
IEF	Implied Emission Factors	Factores de Emissão Implícitos
IEP	Portuguese Road Institute	Instituto de Estradas de Portugal
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
NM VOC	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



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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: SEF Tables**

Tables attached (SEF\_PT\_2014\_1\_12-9-47 9-1-2014.xls).

## **ANNEX B: Database Structure of the Consolidated European Registries (CSEUR)**

File attached.

## ANNEX C: Changes Regarding Test Results (CSEUR)

File attached.

## ANNEX D: ENERGY (CRF 1.A.3, 1.A.4 and 1.A.5)

## Transport (CRF 1.A.3)

Annex D Table 1– Activity data for CRF 1.A.3.a: Fuel consumption from Aviation sector (t)

Fuel Sales		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aviation Gasoline	L	209	1 893	1 751	1 560	1 212	1 435	1 914	1 540	1 876	1 925	1 964	2 353	2 304
Jet Fuel	L	207	554 471	564 264	596 977	565 406	572 457	599 465	595 172	613 723	654 021	720 960	752 932	741 541

Fuel Sales		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Aviation Gasoline	L	209	2 334	1 985	1 847	2 192	2 179	2 086	2 280	2 280	2 869	2 258	1 268	1 168
Jet Fuel	L	207	715 095	770 040	835 208	865 857	907 189	949 650	969 349	907 530	985 343	1 006 836	1 015 897	1 027 228

Annex D Table 2 – Activity data for CRF 1.A.3.b: Fuel consumption from Road Transport sector (t)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline	L	208	1376217	1513827	1690627	1781289	1828767	1885861	1935188	1923621	1990008	2013486	2052007	1932893
Diesel	L	205	1603658	1665579	1769092	1822672	1965847	2110210	2269116	2513347	2998556	3240566	3759009	3976418
LPG	L	303	21	56	98	109	117	289	1799	17321	19794	23862	22329	21653
CNG	G	302	0	0	0	0	0	0	0	0	0	0	648	4287
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	2013
Gasoline	L	208	2029090	1967402	1889720	1791425	1669150	1562258	1483025	1454631	1379897	1240759	1126235	1091788
Diesel	L	205	4029320	4065129	4121935	4147187	4290080	4272991	4270963	4273000	4280447	4014824	3644891	3604703
LPG	L	303	21213	20484	18869	20935	22356	23218	25865	30309	28944	28616	31229	33421
CNG	G	302	6616	9560	8517	9572	9508	10527	6065	10934	11459	11493	10946	11315
Biodiesel	B	223	0	0	0	0	66652	128777	127562	227495	342604	321520	304266	292430

Annex D Table 3 – Activity data for CRF 1.A.3.c: Fuel consumption from Railways sector (Gj)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Coal	S	102	845	456	583	482	502	185	255	0	0	0	0	0
Coke	S	108	252	168	168	84	84	28	56	0	0	0	0	0
Diesel-oil	L	204	2 389 791	2 501 912	2 507 433	2 292 868	2 275 613	2 326 174	2 119 240	2 035 611	1 889 302	1 858 765	1 828 984	1 630 079
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	2013
Coal	S	102	77	0	0	0	0	0	0	0	0	0	0	0
Coke	S	108	0	0	0	0	0	0	0	0	0	0	0	0
Diesel-oil	L	204	1 522 420	1 316 850	1 192 991	1 110 181	1 020 768	1 029 963	961 515	745 269	632 299	552 565	449 322	406 030
Biodiesel	B	223	0	0	0	0	13 775	26 434	23 959	33 799	43 399	37 892	32 070	28 177



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

Annex D Table 4 – Activity data for CRF 1.A.4.a: Fuel consumption 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
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
Wood	B	111	0	0	0	0	0	0	0	0	0	0	0	0
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	2013
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	1 385 221	1 031 064	850 701
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	3 311 336	2 678 119	2 450 992
Kerosene	L	206	9 494	7 344	7 216	6 334	8 228	4 563	1 298	5 191	879	2 219	2 177	4 103
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	0	0
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	1 927 378	1 919 549	1 958 527
City Gas	L	308	0	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	11 091 210	12 311 704	12 385 141
Wood	B	111	0	0	0	0	0	0	0	0	0	2 532 762	1 463 891	1 407 029
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	170 539
Biodiesel	B	223	0	0	0	0	98 637	176 804	128 939	199 180	54 483	54 422	42 171	54 560

Annex D Table 5 – Activity data for CRF 1.A.4.b: Fuel 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
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	2013
Residual Oil	L	203	0	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	2 516 857
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	19 803
Gasoline	L	208	24 864	36 183	37 371	57	79	0	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	18 948 048
City Gas	L	308	0	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	10 851 181	10 839 207	10 288 307
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	31 507 615	31 522 887	32 215 063
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	246 130
Biodiesel	B	223	0	0	0	0	1 566	2 794	1	42	28 620	729	3 128	80

Annex D Table 6 – Activity data for CRF 1.A.4.c.i: Fuel consumption in the agriculture and forestry sector (excluding mobile sources) (GJ)

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
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	2013
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	256 991
Kerosene	L	206	50 284	47 237	48 915	54 581	56 434	32 446	38 935	45 173	39 019	30 395	33 493	29 516
Gasoline	L	208	106 820	116 977	117 435	208 555	153 501	100 611	36 091	32 407	24 033	13 147	16 203	24 619
LPG	L	303	639 651	532 506	523 451	541 228	493 957	449 407	362 700	296 549	308 858	271 637	267 660	214 446
Natural Gas	G	301	284 851	292 066	295 599	325 872	319 153	360 944	305 260	370 699	423 872	486 213	516 693	572 671
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	16 527

Annex D Table 7 – Activity data for CRF 1.A.4.c.ii: Fuels consumption in machines and other off-road vehicles (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Diesel/Gas Oil	L	204	15 954 739	16 738 690	16 949 965	17 675 330	17 825 456	17 289 762	19 142 892	15 029 333	8 912 769	9 042 482	9 950 538	10 757 924
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	2013
Diesel/Gas Oil	L	204	11 433 231	9 133 707	8 703 013	12 775 956	12 051 305	11 905 291	11 241 254	9 986 593	9 609 238	9 470 309	9 579 273	9 903 883
Biodiesel	B	223	0	0	0	0	162 107	307 380	280 522	451 832	659 342	649 097	682 861	686 700

Annex D Table 8 – Activity data for CRF 1.A.4.c.iii: Fuels consumption 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
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	2013
Residual Oil	L	203	28 129	25 341	0	0	13 012	0	48 147	0	91 830	47 735	84 842	44 785
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	917 178	1 044 976
Kerosene	L	206	47	47	320	15	0	0	0	0	0	0	0	0
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	11 305
LPG	L	303	21 140	20 708	91 294	5 903	5 967	2 303	5 778	3 014	1 675	461	209	0
Natural Gas	G	301	0	0	0	0	1 363	2 261	2 010	3 098	4 396	4 145	2 219	16 789
Biodiesel	B	223	0	0	0	0	48 124	73 390	70 525	117 356	208 389	224 117	237 519	243 666

Annex D Table 9 – Activity data for CRF 1.A.4.c.iii: Fuels consumption in fishing bunkers (GJ)

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	204	0	0	0	0	413 200	96 000	24 000	22 400	42 240	21 120	0	0
Diesel/Gas Oil	L	206	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

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Thin Fuel-oil	L	203	0	0	0	0	0	0	0	0	0	22 014	18 018	52 026
Thick Fuel-oil	L	204	0	0	0	0	0	0	0	714 669	765 555	717 098	9 158	0
Diesel/Gas Oil	L	206	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	5 192 645
NATO's Nafta	L	208	0	0	0	0	0	0	0	0	0	0	0	0

## Other (Not Elsewhere specified) (CRF 1.A.5)

Annex D Table 10 – Activity data for CRF 1.A.5.b: Energy Consumption in Military aviation (TJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jet Fuel	L	207	1 344	1 504	1 127	1 065	1 188	1 149	1 471	1 413	1 474	1 127	1 338	1 338

Fuel		NAPFUE	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Jet Fuel	L	207	939	749	570	1 025	1 064	1 026	1 200	1 205	1 208	1 086	683	822

## ANNEX E: Energy Balance Sheet for 2013

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	Nafte	Coque de Petróleo	Total de Petróleo Energético	Lubrificantes	Asfaltos	Parafinas	Solventes	Propileno	Total de Petróleo Não Energético	Total de Petróleo	Gas Natural
2013 (provisório)		1	2	3	4 = 1+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
IMPORTAÇÕES	1.	2 620 306		67	2 620 373	12 550 412	1 490 030	663 615	107 486	1 025	15 279	587 826	358 521	214 839	311 758	16 300 791	39 262	151 615	4 312	996		196 185	16 496 976	3 830 773
PRODUÇÃO DOMÉSTICA	2.																							
VARIAÇÃO DE "STOCKS"	3.	- 122 665		- 715	- 123 380	305 687	- 479 361	- 18 190	70 762	- 13	50 836	- 482	- 237 547	23 160	- 25 343	- 310 491	- 885	3 233	- 2 693	- 761	- 641	- 1 747	- 312 238	61 802
SÁIDAS	4.	90 860			90 860		105 654	74 712	1 358 561		977 429	1 782 503	2 105 004	396 113		6 799 976	95 233	62 479	5 519	10 961	187 470	361 722	7 161 698	
Exportações	4.1	90 860			90 860		105 654	74 712	1 358 561		43 998	1 722 325	1 523 239	396 113		5 224 602	94 561	62 479	5 519	10 961	187 470	360 990	5 585 592	
Transportes Marítimos Internacionais	4.2											60 178	581 765			641 943	732					732	642 675	
Aviação Internacional	4.3										933 431					933 431						933 431		
CONSUMO DE ENERGIA PRIMÁRIA	5.	2 652 111		782	2 652 893	12 244 725	1 863 737	607 093	-1 321 837	1 038	-1 012 986	-1 194 195	-1 508 936	-204 434	337 101	9 811 306	-55 146	85 903	1 486	-9 204	-186 829	-163 790	9 647 516	3 768 971
PARA NOVAS FORMAS DE ENERGIA	6.	2 634 322			2 634 322	12 244 480	986 537	-286 761	-2 457 523	- 631	-1 162 154	-5 778 551	-1 848 177	-964 760		732 460	-102 599	-107 330	-7 941	-13 021	-186 829	-417 720	314 740	1 758 584
Briqueles	6.1																							
Coque	6.2																							
Produtos de Petróleo	6.3					12 244 480	932 269	-286 761	-2 457 523	- 631	-1 162 154	-5 799 094	-2 162 880	-1 009 119		298 587	-102 599	-107 330	-7 941	-13 021	-186 829	-417 720	-119 133	
Gas de Cidade	6.4																							
Petroquímica	6.5													44 359		44 359							44 359	
Electricidade	6.6	2 634 322			2 634 322							20 406	192 030			212 436							212 436	278 912
Cogeração	6.7						54 268					137	122 673			177 078							177 078	1 479 672
Produção de Electricidade	6.7.1												47	40 442		40 459							40 459	
Refinação de Petróleo	6.7.2						54 268						24 468			78 736							78 736	409 570
Gas de Cidade	6.7.3																							
Agricultura	6.7.4																							7 070
Alimentação, bebidas e tabaco	6.7.5											9	2 543			2 552							2 552	95 754
Têxteis	6.7.6											28	3 589			3 617							3 617	19 521
Papel e Artigos de Papel	6.7.7											2	21021			21023							21023	407 960
Químicas e Plásticos	6.7.8												8 063			8 063							8 063	220 579
Cerâmicas	6.7.9												1031			1031							1031	37 356
Vidro e Artigos de Vidro	6.7.10																							
Cimento e Cal	6.7.11																							2 778
Metalúrgicas	6.7.12																							
Siderurgia	6.7.13																							
Vestuário, Calçado e Curtumes	6.7.14																							8 244
Madeira e Artigos de Madeira	6.7.15											51	9 730			9 781							9 781	
Borracha	6.7.16																							15 484
Metal-eleto-mecânicas	6.7.17																							2 933
Outras Indústrias Transformadoras	6.7.18																							2 345
Indústrias Extractivas	6.7.19																							71 393
Serviços	6.7.20												18 16			18 16							18 16	78 685

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	Nafte	Coque de Petróleo	Total de Petróleo Energético	Lubrificantes	Asfaltos	Parafinas	Solventes	Propileno	Total de Petróleo Não Energético	Total de Petróleo	Gás Natural
2013 (provisório)	1	2	3	4 = 1+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.				245	877 628	1 367	- 244	- 2	950	6 375	168 237	2 406		1 056 962	2 427	- 301	101	- 39		2 188	1 059 150	426 813
Consumo Próprio da Refinação	7.1					873 004					2 418	165 587			1 041 009	15					15	1 041 024	421 803
Perdas da Refinação	7.2				245	4 624	1 367	- 244	- 2	950	3 950	2 650	2 406		15 946	704	- 301	101	- 39		465	16 411	
Coquerie e outras não especificadas	7.3																						
Centrais Eléctricas	7.4															1 704					1 704	1 704	
Bombagem Hidroeléctrica	7.5																						
Gás de Cidade	7.6																						
Extracção de Carvão, Petróleo e GN	7.7															2					2	2	239
Perdas de Transporte e Distribuição	7.8										7				7	2					2	9	4 771
<b>CONSUMO COMO MATÉRIA PRIMA</b>							291 479						752 549		1 044 028							1 044 028	
<b>DISPONÍVEL PARA CONSUMO FINAL</b>	8.	17 789		782	18 571	- 428	601 008	1 135 930	1 671	148 218	4 577 981	171 004	5 371	337 101	6 977 856	45 026	193 534	9 326	3 856		251 742	7 229 598	1 583 574
ACERTOS	9.	- 56		7	- 49	- 428	- 9 390	- 13 664	374	7 062	- 30 927	- 16 633	5 371	2 146	- 56 089	306	- 252	- 163	- 235		- 344	- 56 433	59 808
<b>CONSUMO FINAL</b>	10.	17 845		775	18 620		610 398	1 149 594	1 297	141 156	4 608 908	187 637		334 955	7 033 945	44 720	193 786	9 489	4 091		252 086	7 286 031	1 523 766
<b>AGRICULTURA E PISCAS</b>	10.1						5 122	858	705		345 737	2 496			354 918	300					300	355 218	7 009
Agricultura	10.1.1						5 122	588	705		252 948	805			260 168	75					75	260 243	6 608
Pescas	10.1.2							270			92 789	1 691			94 750	225					225	94 975	401
<b>INDÚSTRIAS EXTRATIVAS</b>	10.2						1 285				27 817	898			30 000	1 380					1 380	31 380	4 400
<b>INDÚSTRIAS TRANSFORMADORAS</b>	10.3	17 845		775	18 620		59 913	31	20		76 048	68 484		334 955	539 451	8 094		9 489	3 746		21 329	560 780	1 019 258
Alimentação, bebidas e tabaco	10.3.1						23 659		2		22 808	43 262			89 731	235					235	89 966	123 578
Têxteis	10.3.2						2 766				309	4 641			7 716	668					668	8 384	116 173
Papel e Artigos de Papel	10.3.3						1 619		9		3 429	8 604			13 661	281					281	13 942	80 205
Químicas e Plásticos	10.3.4	11 859		775	12 634		2 201		2		2 380	8 109			12 692	1 501		4 274	3 708		9 483	22 175	134 724
Cerâmicas	10.3.5						3 298		5		1 797	12		8 760	13 872	98					98	13 970	183 582
Vidro e Artigos de Vidro	10.3.6						135				1 028				1 163	158					158	1 321	201 189
Cimento e Cal	10.3.7						924				13 335	1 342		326 195	341 796	134					134	341 930	28 059
Metalúrgicas	10.3.8						2 533				580				3 113	143					143	3 256	16 890
Siderurgia	10.3.9	5 986			5 986		86				1 482				1 568	456					456	2 024	49 207
Vestuário, Calçado e Curtumes	10.3.10						2 778				1 812	1 087			5 677	18					18	5 695	11 777
Madeira e Artigos de Madeira	10.3.11						1 407				4 649	141			6 197	259		1 961			2 220	8 417	10 993
Borracha	10.3.12						118					35			153	1 811		497			2 308	2 461	5 018
Metalo-eleto-mecânicas	10.3.13						16 539	31	2		5 047	115			21 734	1 822		123			1 945	23 679	51 050
Outras Indústrias Transformadoras	10.3.14						1 850				17 392	1 136			20 378	510		2 634	38		3 182	23 560	6 813
<b>CONSTRUÇÃO E OBRAS PÚBLICAS</b>	10.4						8 009		1		69 444	12 900			90 354	1 377	193 760		63		195 200	285 554	17 815
<b>TRANSPORTES</b>	10.5						36 720	1 148 705		121 532	3 969 900	84 356			5 361 213	32 755					32 755	5 393 968	12 423
Aviação Nacionais	10.5.1							1 227		121 532					122 759	10					10	122 769	
Transportes Marítimos Nacionais	10.5.2							118			37 226	84 356			121 700	111					111	121 811	
Caminho de Ferro	10.5.3										10 371				10 371	2					2	10 373	
Rodoviários	10.5.5						36 720	1 147 360			3 922 303				5 106 383	32 632					32 632	5 139 015	12 423
<b>SETOR DOMÉSTICO</b>	10.6						452 570		473		60 117				513 160							513 160	245 732
<b>SERVIÇOS</b>	10.7						46 779		98	19 624	59 845	18 503			144 849	814	26		282		1 122	145 971	217 129

BALANÇO ENERGÉTICO tep		Gás de Cidade	Gás de Coque	Gás de Alto Forno	Alcatrão	Gases Incond. de Petroquímica	Hidrogénio	Gases e 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	Biocombus- tíveis	Renováveis Sem Eletricidade	TOTAL GERAL
2013 (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+46
IMPORTAÇÕES	1.													696 600		25 960		37 388			19 035		7 882	64 305	23 734 987
PRODUÇÃO DOMÉSTICA	2.								1 278 683	1 032 816	41 090	16 906		2 369 495		54 154	72 763	1 631 217	193 368	985 631	34 681	65 346	274 405	3 257 411	5 681 060
VARIAÇÃO DE "STOCKS"	3.																						- 13 838	- 13 838	- 387 654
SAÍDAS	4.													457 864				371 108					17 723	388 831	8 099 253
Exportações	4.1													457 864				371 108					17 723	388 831	6 523 147
Transportes Marítimos Internacionais	4.2																								642 675
Aviação Internacional	4.3																								933 431
CONSUMO DE ENERGIA PRIMÁRIA	5.								1 278 683	1 032 816	41 090	16 906		2 608 231		80 114	72 763	1 297 497	193 368	985 631	53 716	65 346	278 402	2 946 723	21 704 448
PARA NOVAS FORMAS DE ENERGIA	6.												-2 075 166	-2 075 166	-1 634 002	10 158		418 428	193 368	985 631		65 346	274 291	1 937 064	2 945 700
Briquetes	6.1																								
Coque	6.2																								
Produtos de Petróleo	6.3															- 6							274 291	274 291	155 152
Gás de Cidade	6.4																								
Petroquímica	6.5					- 44 359		- 44 359																	
Electricidade	6.6												-1 380 090	-1 380 090		6		266 856	193 368			61 745		521 969	2 267 555
Cogeração	6.7					44 359		44 359					- 695 076	- 695 076	-1 634 002	10 158		151 572		985 631		3 601		1 140 804	522 993
Produção de Electricidade	6.7.1												- 16 523	- 16 523	- 1 005										22 831
Refinação de Petróleo	6.7.2												- 137 350	- 137 350	-263 692										87 264
Gás de Cidade	6.7.3																								
Agricultura	6.7.4												- 2 898	- 2 898	- 1947							395		395	2 620
Alimentação, bebidas e tabaco	6.7.5												-25 823	-25 823	-57 421										25 062
Têxteis	6.7.6												-49 802	-49 802	-41743										31593
Papel e Artigos de Papel	6.7.7												-312 955	-312 955	-1031529			133 326		985 631			1 118 957	203 456	
Químicas e Plásticos	6.7.8					44 359		44 359					-64 815	-64 815	-27 046	6 708									87 848
Cerâmicas	6.7.9												-13 219	-13 219	-16 084										7 084
Vidro e Artigos de Vidro	6.7.10																								
Cimento e Cal	6.7.11												-1 168	-1 168	- 869										741
Metalúrgicas	6.7.12																								
Siderurgia	6.7.13																								
Vestuário, Calçado e Curtumes	6.7.14												-2 866	-2 866	-2 606										2 772
Madeira e Artigos de Madeira	6.7.15												-5 785	-5 785	-11033			18 246					18 246	11209	
Borracha	6.7.16												-3 899	-3 899	-10 600	3 450									4 435
Metálo-eleto-mecânicas	6.7.17												-1221	-1221	- 798										914
Outras Indústrias Transformadoras	6.7.18												-1201	-1201	-1112							1363		1 363	1395
Indústrias Extractivas	6.7.19												-24 889	-24 889	-34 060										2 444
Serviços	6.7.20												-30 662	-30 662	-30 357							1843		1 843	21325



BALANÇO ENERGÉTICO tep		Gás de Cidade	Gás de Coque	Gás de Alto Forno	Alcatrão	Gases Incond. 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 Sulfitivos	Outros Renováveis	Biogás	Biocombus- tíveis	Renováveis Sem Eletricidade	TOTAL GERAL
2013 (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 + 46
<b>CONSUMO DO SECTOR ENERGÉTICO</b>	7.													794 795	263 692										2 544 450
Consumo Próprio da Refinação	7.1													71 756	263 692										1 798 275
Perdas da Refinação	7.2																								16 411
Coquerie e outras não especificadas	7.3													8											8
Centrais Eléctricas	7.4													123 671											125 375
Bombagem Hidroeléctrica	7.5													125 431											125 431
Gás de Cidade	7.6																								
Extracção de Carvão, Petróleo e GN	7.7													359											600
Perdas de Transporte e Distribuição	7.8													473 570											478 350
<b>CONSUMO COMO MATÉRIA PRIMA</b>																									1 044 028
<b>DISPONÍVEL PARA CONSUMO FINAL</b>	8.													3 888 602	1 370 310	69 956	72 763	879 069			53 716		4 111	1 009 659	15 170 270
ACERTOS	9.													48									- 133	- 133	3 241
<b>CONSUMO FINAL</b>	10.													3 888 554	1 370 310	69 956	72 763	879 069			53 716		4 244	1 009 792	15 167 029
<b>AGRICULTURA E PESCAS</b>	10.1													81 060	1 947			3 093					10	3 103	448 337
Agricultura	10.1.1													76 120	1 947			3 093					7	3 100	348 018
Pescas	10.1.2													4 940									3	3	100 319
<b>INDÚSTRIAS EXTRATIVAS</b>	10.2													50 806	34 060										120 646
<b>INDÚSTRIAS TRANSFORMADORAS</b>	10.3													1 222 492	1 303 946	69 956		72 408			52 161		273	124 842	4 319 894
Alimentação, bebidas e tabaco	10.3.1													151 865	57 421	555		10 411						10 411	433 796
Têxteis	10.3.2													81 998	41 743			422						422	248 720
Papel e Artigos de Papel	10.3.3													263 260	1 031 529	206		12 890			910			13 800	1 402 942
Químicas e Plásticos	10.3.4													179 687	127 046	662		105					273	378	477 306
Cerâmicas	10.3.5													30 516	18 084	1 597		16 216			1 200			17 416	265 165
Vidro e Artigos de Vidro	10.3.6													35 499											238 009
Cimento e Cal	10.3.7													69 894	869	66 936		5 649			49 957			55 606	563 294
Metalúrgicas	10.3.8													19 746											39 892
Siderurgia	10.3.9													107 532											164 749
Vestuário, Calçado e Curtumes	10.3.10													23 888	2 606			869						869	44 835
Madeira e Artigos de Madeira	10.3.11													44 663	11 033			24 803			94			24 897	100 003
Borracha	10.3.12													17 475	10 600			625						625	36 179
Metalo-eleto-mecânicas	10.3.13													139 310	798			41						41	214 878
Outras Indústrias Transformadoras	10.3.14													57 159	2 217			377						377	90 126
<b>CONSTRUÇÃO E OBRAS PÚBLICAS</b>	10.4													30 954									50	50	334 373
<b>TRANSPORTES</b>	10.5													32 781									3 911	3 911	5 443 083
Aviação Nacionais	10.5.1																								122 769
Transportes Marítimos Nacionais	10.5.2																								121 811
Caminho de Ferro	10.5.3													32 781											43 154
Rodoviários	10.5.5																						3 911	3 911	5 155 349
<b>SETOR DOMÉSTICO</b>	10.6													1 059 014			31 737	769 940						801 677	2 619 583
<b>SERVIÇOS</b>	10.7													1 411 447	30 357		41 026	33 628			1 555			76 209	1 881 113

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## ANNEX F: Agriculture

Annex F Table 1 – Livestock numbers (thousands) – time series

Animal	Sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Dairy-Cattle	Dairy cows	394	388	381	383	382	383	380	379	375	369	353	331
Non-dairy cattle	Beef calves (<1 yr)	46	52	53	53	58	60	64	64	65	66	67	72
	Calves M.Rep. (<1 yr)	186	185	182	176	167	162	155	151	149	149	144	140
	Calves F Rep. (<1 yr)	177	178	178	174	164	158	152	152	155	165	174	180
	Males 1-2 yrs	112	114	114	108	103	103	105	101	95	86	82	81
	Beef Fem. 1-2 yrs	18	19	20	22	22	22	24	24	24	20	17	14
	Females rep. 1-2 yrs	111	115	112	109	106	109	112	109	108	116	127	135
	Steers (>2 yrs)	38	38	36	37	35	33	33	31	31	29	26	24
	Heifers Beef (>2 yrs)	4	5	7	9	10	10	9	9	9	7	6	6
	Heifers rep. (>2 yrs)	45	46	45	48	50	52	51	50	52	60	67	77
	non-dairy cows	242	245	238	241	252	273	296	316	332	338	345	352
Swine	Piglets (<20 kg)	727	756	756	750	735	726	703	701	695	691	663	626
	Fatt. Pigs (20-50 kg)	662	675	660	671	668	660	633	631	633	623	585	535
	Fatt. Pigs (50-80 kg)	525	545	544	539	532	525	505	496	492	498	483	446
	Fatt. Pigs (80-110 kg)	218	227	226	225	210	198	179	177	174	176	174	184
	Fatt. Pigs (> 110 kg)	44	46	46	47	45	44	40	39	38	38	38	43
	Boars (>50 kg)	26	28	27	28	28	26	24	23	23	22	20	19
	Sows, pregnant	210	219	218	220	216	211	204	204	202	201	195	197
	Sows, non-pregnant	124	131	135	136	134	132	127	128	127	127	124	111
Sheep	Ewes	2 292	2 293	2 257	2 268	2 303	2 339	2 376	2 368	2 367	2 388	2 410	2 388
	Other Ovines	663	725	789	794	811	817	813	802	834	840	733	506
	Lambs	307	326	320	300	279	278	292	297	301	307	319	320
Goats	Does	614	588	556	538	528	517	509	498	485	472	460	440
	Other Caprines	149	156	166	160	153	151	147	151	154	151	129	91
	kids	47	49	47	44	45	41	41	36	37	36	33	30
Equides	Horses	33	38	40	42	44	48	52	54	56	57	58	59
	Asses and Mules.	118	116	114	114	109	103	96	90	82	75	69	63
Poultry	Hens, reproductive	3 421	3 300	3 116	2 941	2 947	3 271	3 477	3 390	2 982	2 636	2 644	2 780
	Hens eggs	7 539	7 695	7 932	8 159	8 143	7 745	7 392	7 322	7 859	8 627	9 060	9 089
	Broilers	18 524	18 812	19 243	19 674	19 530	18 813	18 355	18 733	20 538	22 936	24 374	24 259
	Turkeys	1 149	1 122	1 082	1 041	996	945	936	972	1 061	1 158	1 208	1 201
	Other poultry	1 667	1 656	1 639	1 622	1 625	1 648	1 648	1 606	1 591	1 648	1 707	1 695
Other	Rabbits	475	464	447	430	415	401	384	363	346	338	336	332

Annex F Table 1 - continuation

Animal	Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Dairy-Cattle	Dairy cows	311	297	294	290	284	275	269	263	255	247	241	236
Non-dairy cattle	Beef calves (<1 yr)	75	82	91	104	108	108	108	109	114	120	125	119
	Calves M.Rep. (<1 yr)	137	141	140	136	131	129	127	123	123	128	136	136
	Calves F Rep. (<1 yr)	186	186	187	183	180	178	174	169	171	179	190	191
	Males 1-2 yrs	80	80	79	81	77	75	73	72	66	60	55	54
	Beef Fem. 1-2 yrs	14	15	16	17	17	16	17	18	20	19	20	19
	Females rep. 1-2 yrs	136	133	135	135	139	139	141	142	137	132	131	135
	Steers (>2 yrs)	23	23	23	25	28	31	33	34	38	41	44	42
	Heifers Beef (>2 yrs)	8	8	8	9	9	9	9	10	12	13	14	14
	Heifers rep. (>2 yrs)	80	86	90	94	96	96	97	102	110	111	110	105
	non-dairy cows	362	371	382	397	411	425	432	436	438	440	442	443
Swine	Piglets (<20 kg)	591	571	570	574	583	590	592	602	597	614	634	658
	Fatt. Pigs (20-50 kg)	493	471	467	467	466	468	464	460	448	446	455	464
	Fatt. Pigs (50-80 kg)	402	374	373	368	362	356	357	362	360	362	366	366
	Fatt. Pigs (80-110 kg)	197	208	213	214	221	222	227	237	244	251	255	263
	Fatt. Pigs (> 110 kg)	42	43	40	41	43	44	44	40	36	30	27	25
	Boars (>50 kg)	17	16	14	12	12	11	10	8	7	6	5	5
	Sows, pregnant	196	198	194	191	189	185	183	181	179	172	166	159
	Sows, non-pregnant	91	73	67	68	70	71	70	69	66	66	66	68
Sheep	Ewes	2 328	2 282	2 273	2 293	2 275	2 225	2 137	2 030	1 915	1 811	1 735	1 683
	Other Ovines	299	204	216	234	267	250	225	206	191	179	160	167
	Lambs	330	324	329	322	328	340	337	307	277	264	267	263
Goats	Does	417	392	382	380	380	373	365	358	356	353	349	342
	Other Caprines	62	48	52	57	65	59	52	44	40	38	35	36
	kids	29	28	28	26	25	28	30	31	29	29	28	27
Equides	Horses	59	58	56	52	49	47	46	42	38	33	30	27
	Asses and Mules.	57	51	45	40	36	33	29	26	22	20	18	15
Poultry	Hens, reproductive	3 019	3 206	3 253	3 056	2 800	2 717	2 877	3 218	3 512	3 715	3 741	3 690
	Hens eggs	8 739	8 440	7 942	7 349	6 830	6 490	6 758	7 341	7 993	8 264	8 237	8 289
	Broilers	22 590	20 921	19 620	18 686	17 885	16 848	16 780	17 915	19 474	20 254	20 254	20 254
	Turkeys	1 139	1 077	963	798	799	1 017	1 318	1 485	1 507	1 518	1 518	1 518
	Other poultry	1 613	1 531	1 445	1 353	1 314	1 332	1 414	1 504	1 568	1 601	1 601	1 601
Other	Rabbits	325	318	306	289	270	254	251	255	263	267	267	267

Annex F Table 2 – Methane Emission Factors from Manure Management (kg /hd/year), by livestock category – complete time series

Animal	Sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Dairy-Cattle	Dairy cows	5.08	5.23	5.36	5.35	5.59	5.85	6.10	6.30	6.58	7.23	7.76	8.13
Non-dairy cattle	Beef calves (<1 yr)	0.43	0.45	0.46	0.48	0.51	0.54	0.52	0.50	0.50	0.51	0.51	0.51
	Calves M.Rep. (<1 yr)	1.06	1.10	1.09	1.08	1.13	1.21	1.20	1.16	1.18	1.20	1.23	1.27
	Calves F Rep. (<1 yr)	0.91	0.93	0.93	0.92	0.96	1.03	1.02	0.99	1.01	1.03	1.05	1.07
	Males 1-2 yrs	4.14	4.22	4.21	4.14	4.22	4.43	4.33	4.13	4.16	4.18	4.22	4.33
	Beef Fem. 1-2 yrs	3.06	3.17	3.07	3.01	3.05	3.28	3.23	3.08	3.10	3.11	3.17	3.26
	Females rep. 1-2 yrs	2.91	3.02	3.01	2.97	3.02	3.20	3.14	3.00	3.03	3.05	3.06	3.08
	Steers (>2 yrs)	4.16	4.27	4.33	4.40	4.68	4.97	4.87	4.68	4.75	4.87	4.97	5.13
	Heifers Beef (>2 yrs)	3.25	3.22	3.13	3.06	3.09	3.26	3.10	3.00	3.05	3.10	3.18	3.34
	Heifers rep. (>2 yrs)	3.22	3.24	3.16	3.07	3.19	3.40	3.32	3.17	3.21	3.22	3.22	3.21
	non-dairy cows	2.34	2.41	2.42	2.42	2.55	2.72	2.70	2.60	2.66	2.70	2.74	2.81
Swine	Piglets (<20 kg)	2.89	2.90	2.91	2.92	2.93	2.94	2.94	2.95	2.96	2.97	2.98	2.99
	Fatt. Pigs (20-50 kg)	16.17	16.22	16.27	16.31	16.35	16.41	16.45	16.50	16.55	16.60	16.65	16.70
	Fatt. Pigs (50-80 kg)	23.79	23.87	23.94	24.02	24.10	24.17	24.24	24.31	24.38	24.44	24.52	24.59
	Fatt. Pigs (80-110 kg)	28.47	28.57	28.65	28.75	28.84	28.93	29.02	29.10	29.17	29.25	29.34	29.45
	Fatt. Pigs (> 110 kg)	31.32	31.45	31.53	31.65	31.76	31.86	31.96	32.05	32.14	32.23	32.33	32.44
	Boars (>50 kg)	31.33	31.42	31.52	31.59	31.68	31.79	31.88	31.99	32.10	32.18	32.24	32.30
	Sows, pregnant	30.37	30.45	30.53	30.61	30.69	30.78	30.87	30.96	31.05	31.14	31.23	31.34
	Sows, non-pregnant	62.69	62.83	63.02	63.21	63.42	63.62	63.79	63.98	64.16	64.34	64.54	64.74
Sheep	Sheep	0.38	0.38	0.40	0.37	0.41	0.41	0.41	0.39	0.42	0.42	0.43	0.41
Goats	Goats	0.34	0.33	0.33	0.32	0.32	0.33	0.32	0.32	0.32	0.33	0.33	0.33
Equides	Horses	3.95	3.95	3.95	3.95	3.95	3.95	3.94	3.92	3.90	3.90	3.92	3.93
	Asses and Mules.	1.66	1.66	1.66	1.66	1.66	1.66	1.65	1.64	1.63	1.62	1.62	1.61
Poultry	Hens, reproductive	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Hens eggs	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Broilers	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Turkeys	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Other poultry	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Other	Rabbits	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31

Annex F Table 2 - Continuation

Animal	Sub-class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Dairy-Cattle	Dairy cows	8.70	8.72	8.93	9.48	9.73	9.98	10.38	10.75	11.02	11.11	11.33	11.07
Non-dairy cattle	Beef calves (<1 yr)	0.51	0.52	0.54	0.55	0.53	0.52	0.54	0.52	0.52	0.52	0.52	0.52
	Calves M.Rep. (<1 yr)	1.26	1.26	1.29	1.28	1.25	1.25	1.28	1.23	1.22	1.23	1.22	1.23
	Calves F Rep. (<1 yr)	1.05	1.05	1.08	1.08	1.05	1.05	1.07	1.03	1.02	1.02	1.01	1.02
	Males 1-2 yrs	4.29	4.24	4.30	4.20	4.02	3.94	3.95	3.73	3.63	3.63	3.59	3.60
	Beef Fem. 1-2 yrs	3.18	3.15	3.20	3.07	2.88	2.76	2.76	2.59	2.55	2.59	2.60	2.64
	Females rep. 1-2 yrs	3.00	2.94	2.98	2.94	2.83	2.78	2.80	2.64	2.57	2.56	2.53	2.55
	Steers (>2 yrs)	5.03	4.97	5.00	4.89	4.67	4.58	4.59	4.33	4.24	4.25	4.22	4.26
	Heifers Beef (>2 yrs)	3.18	3.10	3.06	2.92	2.69	2.60	2.66	2.58	2.62	2.69	2.72	2.75
	Heifers rep. (>2 yrs)	3.15	3.11	3.19	3.12	2.98	2.91	2.95	2.82	2.77	2.77	2.73	2.75
	non-dairy cows	2.77	2.77	2.86	2.84	2.76	2.75	2.81	2.70	2.68	2.69	2.67	2.69
Swine	Piglets (<20 kg)	3.00	3.01	3.01	3.02	3.03	3.04	3.05	3.06	3.06	3.07	3.07	3.07
	Fatt. Pigs (20-50 kg)	16.74	16.79	16.84	16.89	16.94	16.99	17.04	17.09	17.14	17.15	17.15	17.16
	Fatt. Pigs (50-80 kg)	24.68	24.76	24.83	24.90	24.97	25.04	25.12	25.19	25.26	25.26	25.27	25.28
	Fatt. Pigs (80-110 kg)	29.55	29.64	29.72	29.80	29.88	29.97	30.06	30.15	30.24	30.25	30.26	30.27
	Fatt. Pigs (> 110 kg)	32.53	32.62	32.69	32.77	32.85	32.95	33.06	33.18	33.27	33.29	33.32	33.34
	Boars (>50 kg)	32.38	32.46	32.54	32.63	32.73	32.85	32.93	33.04	33.16	33.22	33.25	33.18
	Sows, pregnant	31.44	31.54	31.63	31.71	31.79	31.88	31.96	32.05	32.14	32.15	32.15	32.15
	Sows, non-pregnant	64.92	65.07	65.22	65.41	65.59	65.78	65.96	66.15	66.34	66.38	66.41	66.43
Sheep	Ewes	0.41	0.41	0.43	0.41	0.42	0.41	0.39	0.39	0.40	0.38	0.38	0.36
Goats	Does	0.35	0.35	0.36	0.35	0.38	0.37	0.38	0.37	0.35	0.36	0.38	0.35
Equides	Horses	3.92	3.89	3.83	3.80	3.77	3.77	3.76	3.76	3.77	3.75	3.70	3.60
	Asses and Mules.	1.60	1.59	1.58	1.57	1.56	1.56	1.55	1.54	1.53	1.52	1.53	1.56
Poultry	Hens, reproductive	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Hens eggs	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Broilers	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Turkeys	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Other poultry	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other	Rabbits	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.29	0.29	0.29	0.29

Annex F Table 3 – 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	2002
Dairy	33 850	33 196	32 476	31 322	32 165	33 282	33 824	34 052	34 384	36 952	37 590	36 125	35 826
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	53 869
Sheep	25 391	25 809	25 910	26 037	26 474	26 837	27 154	27 006	27 213	27 444	26 943	25 237	23 319
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	3 327
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	2 596
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	1 247
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	20 858
Poultry	17 889	18 060	18 316	18 568	18 430	17 839	17 407	17 523	18 745	20 483	21 574	21 577	20 503
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	2 923
Total	160 219	162 013	160 634	159 783	160 441	162 188	162 942	163 899	166 291	171 340	172 468	168 744	164 467

Animal Type	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Dairy	33 363	33 086	33 467	32 919	31 822	31 289	30 783	29 845	28 894	28 329	27 683
Non-Dairy	55 201	56 592	58 318	59 523	60 536	61 211	61 741	62 388	62 835	63 410	63 203
Sheep	22 270	22 274	22 565	22 621	22 054	21 087	19 975	18 824	17 793	16 970	16 529
Goats	3 060	3 016	3 041	3 094	3 004	2 898	2 793	2 758	2 717	2 670	2 631
Horses	2 567	2 449	2 273	2 141	2 083	2 009	1 833	1 672	1 467	1 320	1 173
Mules and Asses	1 115	983	880	785	726	645	565	491	433	396	337
Swine	19 650	19 285	19 190	19 248	19 183	19 131	19 114	18 836	18 696	18 703	18 820
Poultry	19 454	18 288	17 053	16 174	15 721	16 417	17 785	19 168	19 834	19 822	19 846
Other	2 862	2 754	2 599	2 429	2 290	2 256	2 294	2 369	2 406	2 406	2 406
Total	159 541	158 726	159 387	158 934	157 419	156 944	156 882	156 350	155 074	154 026	152 628

Annex F Table 4 – Total amounts of Nitrogen (t N/yr) added to managed soils: activity data for direct N<sub>2</sub>O emissions

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Synthetic Fertilizer	158 500	158 500	158 500	158 500	158 500	145 815	168 229	164 288	149 303	148 944	170 009	157 511	163 902
Organic Fertilizer (manure)	65 327	66 535	65 886	65 328	64 744	64 153	62 956	62 445	62 891	64 883	64 930	62 671	59 759
Pasture	70 561	71 541	70 944	70 865	72 099	74 447	76 675	78 252	79 912	81 833	82 538	81 605	80 868
Crop Residues	52 258	47 186	42 292	41 104	42 600	45 925	44 580	45 312	44 639	44 264	43 685	43 101	41 868
Organic Fertilizer (sewage)	319	319	319	319	319	319	386	467	301	440	263	377	1 419
Total	346 965	344 081	337 941	336 117	338 262	330 660	352 826	350 763	337 045	340 364	361 426	345 264	347 817

Sources	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Synthetic Fertilizer	110 132	125 844	102 663	87 391	113 005	105 131	97 293	100 249	95 088	108 526	121 413
Organic Fertilizer (manure)	56 389	54 734	53 591	52 339	50 927	50 601	50 772	51 227	50 806	50 243	49 791
Pasture e	80 397	81 686	83 729	84 961	85 352	85 152	84 605	84 102	83 360	83 065	82 295
Crop Residues	42 233	40 595	40 017	38 503	38 692	38 168	37 259	36 214	41 392	42 558	49 404
Organic Fertilizer (sewage)	1 072	567	366	429	693	1 191	2 035	491	682	1 087	1 285
Total	290 223	303 425	280 367	263 622	288 670	280 243	271 965	272 284	271 329	285 479	304 188



Annex F Table 5 – Nitrogen amount consumption (kt N/yr) by type of N-fertilizer - time series activity data

Type of fertilizers	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Ammonium nitrate (AN)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonium phosphate (MAP&DAP)	13.28	13.28	13.28	13.28	13.28	16.75	15.74	12.40	12.60	14.34	11.83	10.52	12.04	9.10	8.55	-
Ammonium sulphate (AS)	17.72	17.72	17.72	17.72	17.72	25.40	26.70	20.43	19.84	12.45	14.47	10.92	11.58	10.31	10.27	10.30
Calcium ammonia nitrate (CAN)	46.13	46.13	46.13	46.13	46.13	40.67	52.91	52.45	53.21	42.77	45.72	38.78	42.50	35.89	43.31	29.68
Urea	13.35	13.35	13.35	13.35	13.35	7.06	14.07	15.26	7.75	14.51	20.52	17.53	10.07	9.23	8.20	11.85
Other NK & NPK	49.54	49.54	49.54	49.54	49.54	40.76	42.54	43.45	36.29	46.45	57.74	59.10	69.99	30.64	37.00	39.94
Other N	18.49	18.49	18.49	18.49	18.49	15.18	16.26	20.30	19.60	18.43	19.72	20.67	17.73	14.96	18.51	10.90
<b>TOTAL</b>	<b>158.50</b>	<b>158.50</b>	<b>158.50</b>	<b>158.50</b>	<b>158.50</b>	<b>145.82</b>	<b>168.23</b>	<b>164.29</b>	<b>149.30</b>	<b>148.94</b>	<b>170.01</b>	<b>157.51</b>	<b>163.90</b>	<b>110.13</b>	<b>125.84</b>	<b>102.66</b>

Type of fertilizers	2006	2007	2008	2009	2010	2011	2012	2013
Ammonium nitrate (AN)	-	-	-	-	4.01	4.18	3.75	7.89
Ammonium phosphate (MAP&DAP)	-	-	-	1.01	0.54	0.21	1.92	2.08
Ammonium sulphate (AS)	4.22	5.86	2.54	1.95	3.06	0.00	0.95	0.00
Calcium ammonia nitrate (CAN)	19.21	34.63	26.75	27.18	34.99	23.49	17.83	25.81
Urea	20.45	21.98	26.01	24.06	13.85	22.19	20.78	23.99
Other NK & NPK	33.76	41.10	28.97	16.09	24.90	23.13	16.12	25.97
Other N	9.76	9.43	20.86	22.71	18.90	21.89	47.17	35.67
<b>TOTAL</b>	<b>87.39</b>	<b>113.01</b>	<b>105.13</b>	<b>97.29</b>	<b>100.25</b>	<b>95.09</b>	<b>108.53</b>	<b>121.41</b>

Annex F Table 6 - Volatilization rates from synthetic fertilizers applied to soil (kg NH<sub>3</sub> /kg N applied)

Type of fertilizers	EF
Ammonium nitrate (AN)	0.037
Ammonium phosphate (MAP&DAP)	0.293
Ammonium sulphate (AS)	0.221
Calcium ammonia nitrate (CAN)	0.022
Urea	0.243
Other NK & NPK	0.037
Other N*	0.077

\*EFs average

## ANNEX G: Methodological Note concerning the calculation of carbon sequestration in areas with sown biodiverse pastures

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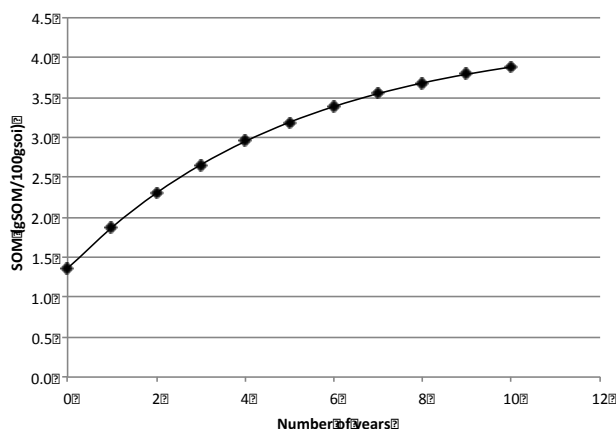
### Summary

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

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## References

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## **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**

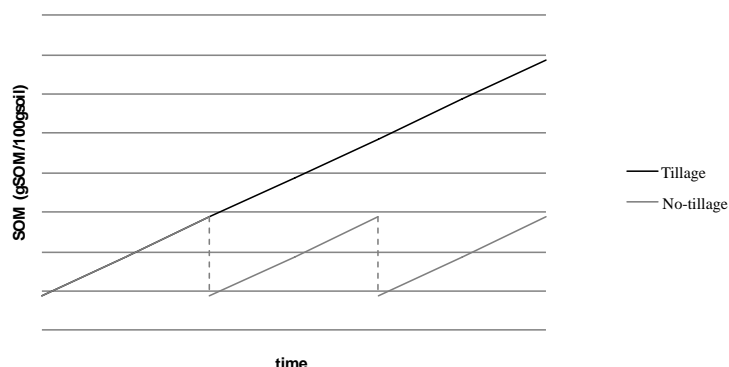
Harrowing is a common practice for shrub encroachment control in natural grasslands under canopy in Portugal. However, such operation is disruptive for the soil and leads to soil organic matter (SOM) loss and, consequently, carbon emissions. Less disruptive methods (eg. forestry mowers) lead to an increase 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 (gSOM/100gsoil).yr<sup>-1</sup> 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 gsoilcm<sup>-3</sup> (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 tCO<sub>2</sub>.ha<sup>-1</sup>.yr<sup>-1</sup>** for a period of 10 years.

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## Acknowledgments

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## ANNEX I: Waste Background Data Tables

Annex I Table 1 – 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/ Anaerobic digestion	Incinerated
	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	10,444,592	419.6	100	4,382.7	27.8	3,294.7	116.2	943.9
2003	10,473,050	426.3	100	4,464.6	25.9	3,019.2	416.1	1,003.4
2004	10,494,672	414.6	100	4,351.6	22.3	3,118.9	250.6	959.7
2005	10,511,988	410.6	100	4,316.2	0.0	3,091.0	246.9	978.4
2006	10,532,588	407.9	100	4,296.2	0.0	3,166.4	152.4	977.5
2007	10,553,339	403.4	100	4,257.2	0.0	3,136.0	173.4	947.9
2008	10,563,014	444.9	100	4,699.7	0.0	3,501.8	205.0	993.0
2009	10,573,479	443.2	100	4,686.4	0.0	3,354.8	249.0	1,082.6
2010	10,572,721	456.6	100	4,827.9	0.0	3,464.2	271.5	1,092.2
2011	10,542,398	429.5	100	4,528.0	0.0	3,138.0	258.5	1,131.5
2012	10,487,289	393.8	100	4,129.7	0.0	2,672.4	423.1	1,034.3
2013	10,427,301	382.2	100	3,985.3	0.0	2,523.6	343.9	1,117.8

Sources:INE; APA; Quercus Study



Annex I Table 2 – 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	876	566
1961	832	0	1979	1,087	0	1997	834	637
1962	844	0	1980	800	304	1998	604	896
1963	857	0	1981	807	313	1999	414	1,117
1964	870	0	1982	817	320	2000	246	1,034
1965	883	0	1983	828	326	2001	146	883
1966	896	0	1984	839	332	2002	6	771
1967	909	0	1985	850	339	2003	6	721
1968	923	0	1986	861	345	2004	6	858
1969	937	0	1987	873	352	2005	0	1002
1970	951	0	1988	885	359	2006	0	1140
1971	965	0	1989	897	365	2007	0	1278
1972	980	0	1990	920	361	2008	0	1415
1973	994	0	1991	855	451	2009	0	1047
1974	1,009	0	1992	875	457	2010	0	939
1975	1,024	0	1993	896	463	2011	0	902
1976	1,040	0	1994	857	530	2012	0	344
1977	1,055	0	1995	880	534	2013	0	623

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)

Annex I Table 3 – 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	54	1.0
2005	11	273	5.2
2006	15	368	6.9
2007	19	470	8.7
2008	24	595	10.8
2009	26	651	11.7
2010	32	794	14.1
2011	33	834	14.8
2012	41	1,033	18.4
2013	47	1,170	21.2

Source: APA's questionnaires ; 2013 : DGEG data.

Annex I Table 4 – 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	10,445	229	75	17	60	58	19
2003	10,473	229	81	19	65	44	21
2004	10,495	230	87	20	70	31	22
2005	10,512	230	93	22	75	17	24
2006	10,533	231	101	22	72	14	23
2007	10,553	231	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	117	19	55	18	20
2013	10,427	228	116	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.

Annex I Table 5 – 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	2.08	0.2	0.27
2006	0.8	1.94	0.3	0.35
2007	0.7	1.75	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	0.25
2013	1.4	3.79	0.3	0.40

Source: DGEG data

Annex I Table 6 – Quantities of waste incinerated (accounted CRF 5C)

Year	Clinical waste quantities incinerated		Industrial solid waste incinerated	
	Quantities	Emissions	Quantities	Emissions
	kton	kton CO2 e.	kton	kton CO2 e.
1990	12	5	24	3
1991	12	5	24	3
1992	12	5	25	3
1993	12	5	25	4
1994	12	5	26	4
1995	12	5	27	4
1996	13	5	27	4
1997	16	6	28	4
1998	12	5	28	4
1999	10	4	29	4
2000	7	3	32	5
2001	3	1	35	1
2002	3	1	38	2
2003	2	1	47	7
2004	2	1	96	4
2005	1	0	144	7
2006	1	0	193	9
2007	3	1	241	11
2008	3	1	289	13
2009	4	1	264	17
2010	4	2	66	11
2011	2	1	248	16
2012	1	1	69	13
2013	1	1	158	19

Note: Estimates in italics

Sources: APA (include estimates); DGS

Annex I Table 7 – 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	207	139	171	115
2000	545	366	448	301
2001	533	358	438	294
2002	565	379	464	312
2003	600	403	493	331
2004	574	386	472	317
2005	585	393	481	323
2006	585	393	481	323
2007	567	381	466	313
2008	594	399	488	328
2009	648	435	532	358
2010	653	439	537	361
2011	669	462	570	393
2012	612	422	521	359
2013	650	468	544	392