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PORTUGUESE NATIONAL INVENTORY REPORT

ON GREENHOUSE GASES, 1990 - 2015

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

Amadora

April, 15th 2017

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DGEG – Direção Geral de Energia e Geologia

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EDP – Energias de Portugal

Gabinete de Estratégia e Estudos/ Ministério da Economia

GPP - Gabinete de Planeamento, Políticas e Administração Geral/ Ministério da Agricultura, Florestas e Desenvolvimento Rural

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, APA, I.P.*), under the dependency of the Ministry for the Environment (*Ministério do Ambiente*), 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 Union.

This report aims to comply with the above-mentioned international commitments under the UNFCCC and the European Union (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 [1], 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.

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 1990-2015, which were compiled with the new CRF Reporter software (version 6.0.1.1);

3 – SEF (Standard Electronic Tables) for the CP2 reporting of Kyoto units in the national registry in 31.12.2016 and transfers of units during 2016; a resubmission of SEF for CP1 is also provided;

[1] [1] http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2

Table of Contents

EXECUTIVE SUMMARY

- Portuguese greenhouse gas emissions totals 68.9 Mt CO2 equivalent (CO_2-e) in 2015, representing an increase of 15.7 % since 1990 and 7.1 % compared to 2014.
- The largest contributor to the Portuguese emissions is the Energy sector (70 % of total emissions in 2015), with the energy industries and the transport activities amounting, respectively, to 27 and 24 % of total emissions.
- With the exception of Other sectors in Energy, all sub-sectors register a growth of emissions in 2015; the electro producer sector was one of the sub-sectors increasing the most (+29%).
- 2015 was an unfavorable year in terms of water availability (HPI = 0.67), resulting in a decrease of the hydropower production (order of -24%), and contributing to a greater use of coal and NG in the electro producer.
- The LULUCF sector is estimated as a sink in 2015 with - 8.8 Mt CO2-e, and a net emitter in 1990 with 1.3 Mt CO2-e.
- In 2015, GDP registered a positive variation of 1.6%, accelerating the tendency already verified in year before (0.9% in 2014).

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 (GHG) 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 2017 national inventory submission of GHG. The period covered is 1990-2015.

The 2006 IPCC Guidelines (2006, IPCC) have been applied in a large extent.

The GHG covered refer to emissions and removals of the carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).The indirect GHG, carbon monoxide (CO), sulphur dioxide

(SO_2), oxides of nitrogen (NO_X) 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 2015, 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 national registry, information related to Article 3, paragraphs 3 and 4, and Article 3, paragraph 14. It also presents information on the accounting of Kyoto units, including the Standard Electronic Tables (SEF).

The Portuguese Environmental Agency (APA) under the dependency of the Ministry for the Environment (*Ministério do Ambiente*), 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 (SNIERPA) that was first established through Council of Ministers Resolution 68/2005, of 17 March.

A new legal national arrangement has been adopted in 2015 (Council of Ministers Resolution 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, as well as complementary internal adjustments.

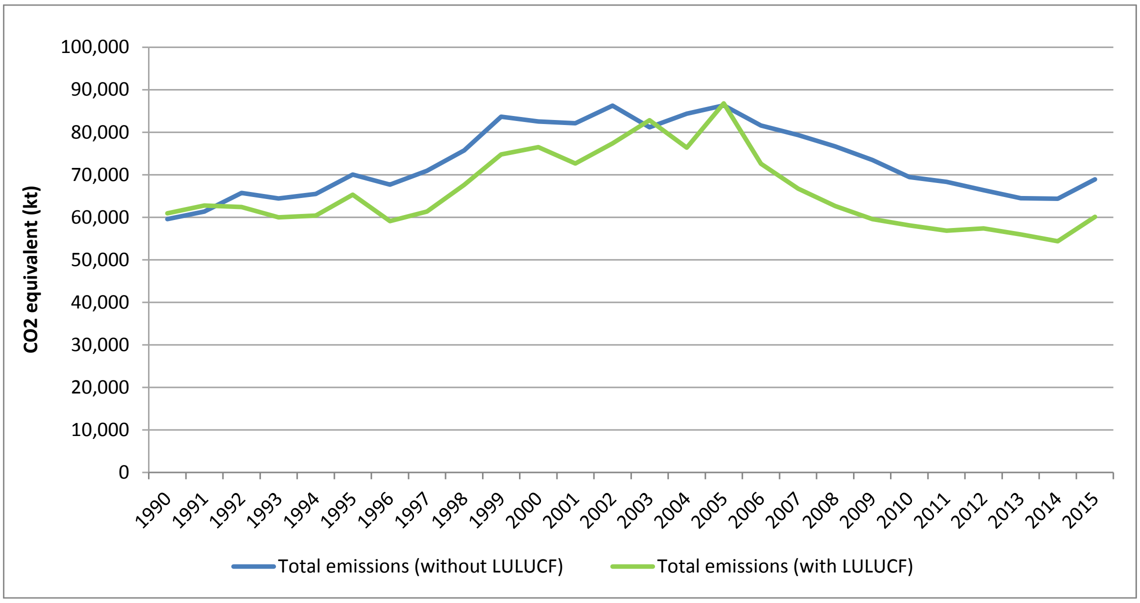
ES.2 Summary of national emissions and removal related trends

ES.2.1 Greenhouse Gas Inventory – UNFCCC

In 2015, total Portuguese GHG emissions, including indirect CO2, without land-use, land-use change and forestry (LULUCF) were estimated at about 68.9 Mt CO_2e, representing an increase of 15.7 % compared to 1990 levels and a decrease of 7.1% compared to the previous year (2014).

Throughout this report, emissions values are presented in CO_2 equivalent using IPCC AR4 GWP values. The reference to “total emissions” along the report is meant to refer to “total emissions without LULUCF, including CO2 indirect emissions”.

Figure 1.1 - 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, increased efficiency in energy use and to the more recent situation of stagnation or later recession of the Portuguese economy, which has begun recovering afterwards.

The trends registered in the most recent years reflect, to a certain extent, the decoupling of emissions growth from the economic activity.

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.

After the continuous decline in energy consumption (both primary and final) verified in the country since 2005, with a bigger expression after 2010, fact that may be explained by internal economic recession, along with the European economic and financial crisis, in 2015 there was an inversion of this pattern with a growth of 5.4% and 1.2% in 2015, respectively in primary energy consumption and final energy consumption.

The increase of primary energy consumption in 2015 was due to the greater use of coal and natural gas in comparison with 2014, and the final energy consumption was related to the rise of consumption in road transport, NG and electricity.

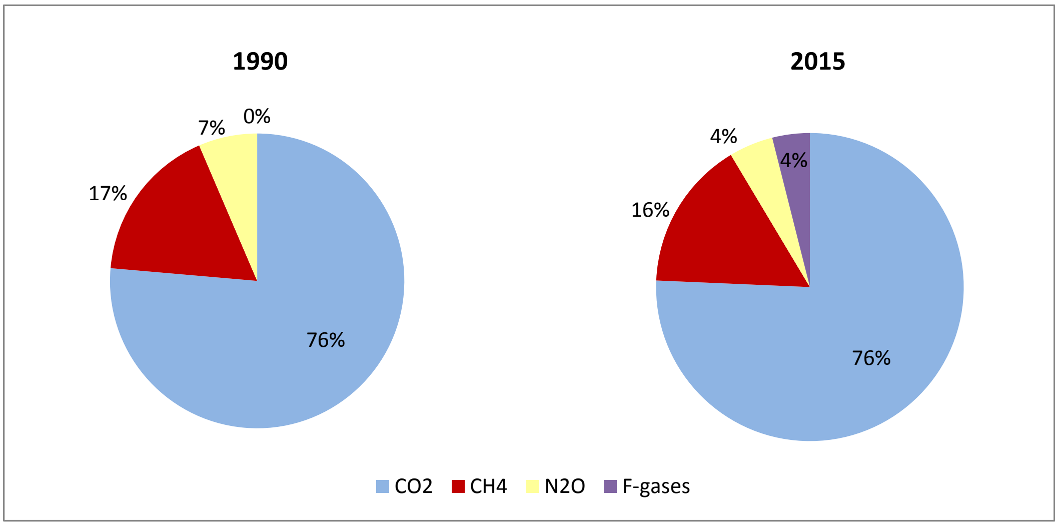
In 2015, GDP registered a positive variation of 1.6%, accelerating the tendency already verified in year before (0.9% in 2014).

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.

After the continuous decrease of national emissions verified since 2005, the emissions registered a significant growth in 2015, with an increase of 7.0% compared to the 2014. This growth is in majority related to the energy sector, and particularly to the “energy industries”, which is partly explained by the decrease of the hydropower production in 2015 (order of -24%) due to an unfavorable year in terms of water availability (HPI = 0.67), contributing to a greater use of coal and NG in the electro producer sector and consequently to a significant increase in emissions.

The figure below illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2015, being evident CO_2 as the primary GHG, accounting for about 76% of Portuguese emissions on a carbon equivalent basis in 2015 (LULUCF excluded). The second most important gas is CH_4, followed by N_2O, representing, respectively, 16% and 4% of total emissions in 2015. Portugal has chosen 1995 as the base year for fluorinated gases. In 2015 these gases represented about 4% of total GHG emissions. NF3 emissions are non-occurring in Portugal.

Figure 1.2 – GHG emissions by gas.



Over the 1990-2015 period, CO2 is the gas having registered the biggest increase (15%) and N_2O decreased by about 17%.

Table 1.1 – GHG emissions and removals in Portugal by gas.

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO_2 equivalent (Gg)												
CO2 emissions without net CO2 from LULUCF	45,371	46,992	51,226	49,829	50,570	54,533	51,827	54,824	59,297	66,911	65,683	65,362	69,199
CO2 emissions with net CO2 from LULUCF	45,947	47,593	47,313	44,819	44,852	49,052	42,687	44,783	50,526	57,502	58,997	55,371	59,662
CH4 emissions without CH4 from LULUCF	10,201	10,399	10,558	10,685	10,953	11,288	11,359	11,587	11,899	12,042	12,105	12,109	12,297
CH4 emissions with CH4 from LULUCF	10,406	10,675	10,646	10,760	11,072	11,543	11,456	11,626	12,104	12,149	12,290	12,220	12,468
N2O emissions without N2O from LULUCF	3,831	3,799	3,768	3,749	3,781	3,966	4,200	4,188	4,149	4,234	4,204	4,068	4,112
N2O emissions with N2O from LULUCF	4,394	4,358	4,266	4,226	4,256	4,467	4,665	4,636	4,633	4,690	4,675	4,518	4,569
HFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	35	59	101	146	212	281	365	481
PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO	NO	0	0	1	1	2	2
Unspecified mix of HFCs and PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO	NO	NO	NO	NO	NO	NO	NO
SF6	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	14	14	15	16	17	17	18	18
NF3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	**59,403**	**61,190**	**65,552**	**64,263**	**65,304**	**69,836**	**67,459**	**70,715**	**75,508**	**83,416**	**82,291**	**81,924**	**86,109**
Total (with LULUCF)	**60,747**	**62,626**	**62,225**	**59,804**	**60,180**	**65,111**	**58,881**	**61,162**	**67,426**	**74,570**	**76,260**	**72,493**	**77,200**
Total (without LULUCF, with indirect)	**59,584**	**61,365**	**65,747**	**64,454**	**65,509**	**70,035**	**67,656**	**70,920**	**75,714**	**83,627**	**82,502**	**82,101**	**86,278**
Total (with LULUCF, with indirect)	**60,928**	**62,801**	**62,420**	**59,995**	**60,385**	**65,310**	**59,078**	**61,367**	**67,632**	**74,780**	**76,472**	**72,671**	**77,369**

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	% change
	CO_2 equivalent (Gg)													1990-2015
CO2 emissions without net CO2 from LULUCF	64,076	66,860	69,142	64,429	61,937	59,634	56,801	52,616	51,471	49,658	47,866	47,741	52,017	**14.6**
CO2 emissions with net CO2 from LULUCF	64,468	58,294	68,565	54,929	48,960	45,259	42,450	40,707	39,588	40,108	38,807	37,400	42,810	**-6.8**
CH4 emissions without CH4 from LULUCF	12,525	12,680	12,293	12,215	12,032	11,555	11,340	11,346	11,457	11,209	10,925	10,703	10,812	**6.0**
CH4 emissions with CH4 from LULUCF	13,242	12,819	12,851	12,318	12,074	11,576	11,397	11,498	11,517	11,381	11,079	10,719	10,887	**4.6**
N2O emissions without N2O from LULUCF	3,745	3,900	3,762	3,638	3,807	3,710	3,403	3,377	3,101	3,113	3,109	3,179	3,192	**-16.7**
N2O emissions with N2O from LULUCF	4,307	4,343	4,280	4,048	4,182	4,058	3,762	3,757	3,462	3,498	3,493	3,531	3,548	**-19.2**
HFCs	617	731	907	1,088	1,321	1,569	1,764	1,910	2,078	2,216	2,383	2,535	2,679	**100.0**
PFCs	2	3	3.30	3.99	4.74	5.58	6.61	7.93	9.05	10.18	11.36	12.59	13.89	**100.0**
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	**0.0**
SF6	22	27	27	28	31	30	33	35	29	30	31	26	26	**100.0**
NF3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	**0.0**
Total (without LULUCF)	**80,986**	**84,200**	**86,134**	**81,403**	**79,133**	**76,503**	**73,347**	**69,292**	**68,145**	**66,238**	**64,325**	**64,196**	**68,740.8**	**15.7**
Total (with LULUCF)	**82,658**	**76,216**	**86,632**	**72,415**	**66,573**	**62,499**	**59,413**	**57,915**	**56,683**	**57,244**	**55,804**	**54,224**	**59,964.5**	**-1.3**
Total (without LULUCF, with indirect)	**81,157**	**84,377**	**86,308**	**81,575**	**79,309**	**76,675**	**73,507**	**69,459**	**68,304**	**66,399**	**64,494**	**64,360**	**68,915.7**	**15.7**
Total (with LULUCF, with indirect)	**82,829**	**76,393**	**86,806**	**72,587**	**66,748**	**62,671**	**59,573**	**58,083**	**56,843**	**57,404**	**55,973**	**54,389**	**60,139.4**	**-1.3**

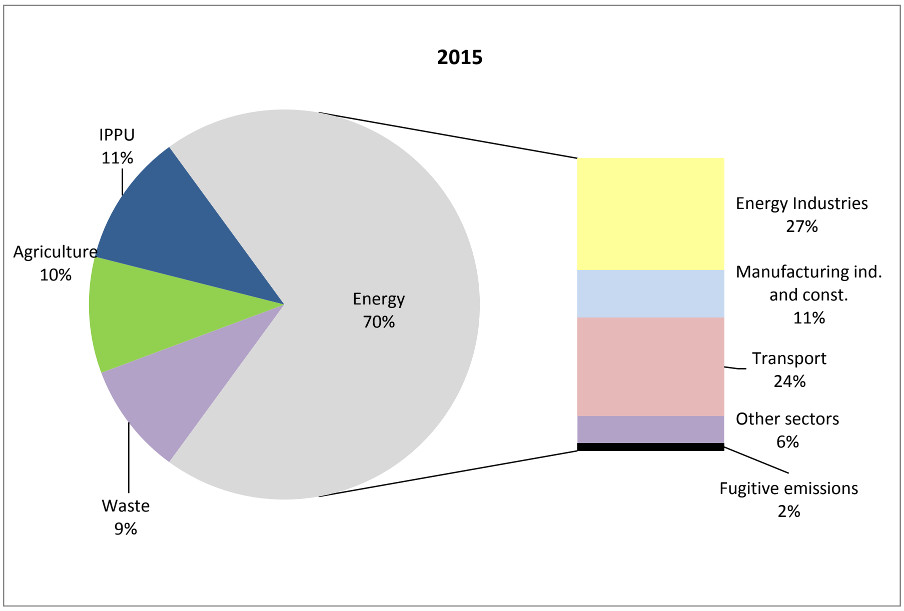
NA- Not applicable; NE - Not estimated; NO - Not occurring

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

ES.3.1 Greenhouse Gas Inventory – UNFCCC

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

Figure 1.3 - GHG emissions in Portugal by sector: 2015.



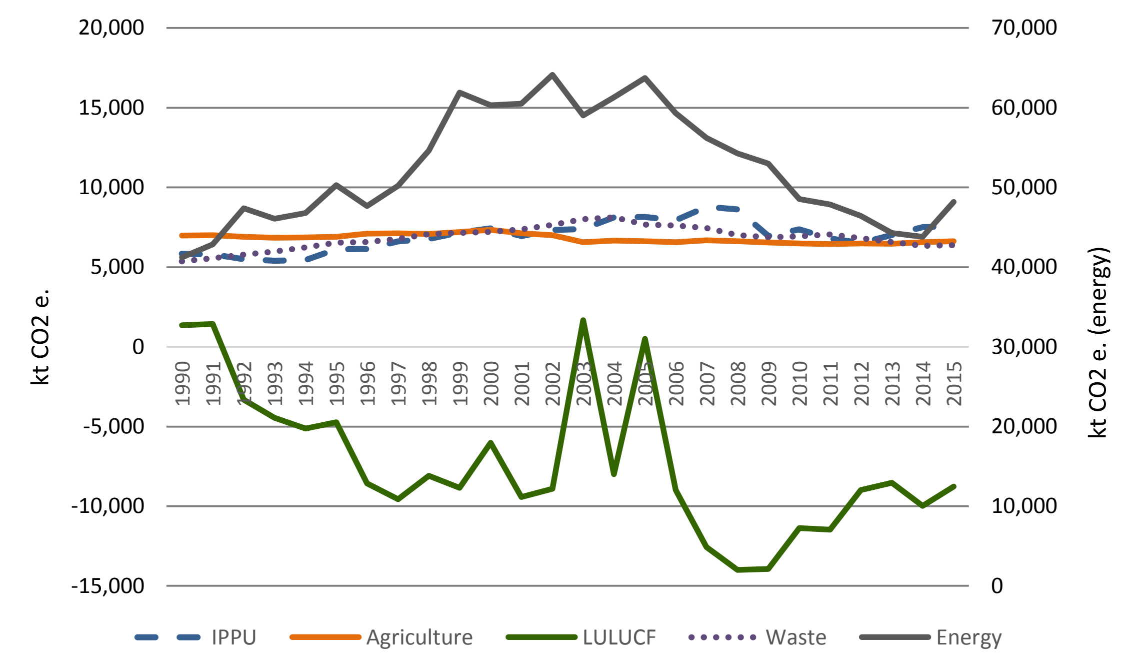
Energy is by far the most important sector, accounting for 70 % of total emissions in 2015, and presenting an increase of 17 % over the 1990-2015 period. Energy industries and transport are the two most important sources representing, respectively, approximately 27% and 24% of total emissions. Within the energy industries, public electricity and heat production represents alone 23% 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 more recent years, were we can observe a stagnation or decrease of these trends. In 2015, this pattern was, however, interrupted due to particularly unfavourable hydrologic conditions which contributed to a greater use of coal and NG in the electro producer sector and consequently to a significant increase in emissions.

Mobile sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2015 the emissions of transportation sources increased 61 %, 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 in 2005.

An inversion of this tendency is registered the most recent years, with an increase in transport emissions of 3.3% from 2013 to 2015.

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 % rise), but this tendency has decelerated (7 % decrease in the 1990-2015 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 1.4 – GHG emissions and removals by sector.



Agriculture was, in the period analysed, a significant source of GHG emissions, responsible for 10 % of the Portuguese emissions in 2015, corresponding to a decrease of 5 % since 1990. This fact is related to the relatively decrease of importance of the sector in terms of the national economy, and also 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 related to the conversion of arable crops to pastures.

Waste represented approximately 9 % of Portuguese emissions in 2015, recording an increase of approximately 19 % 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 1990 decade) and the deposition of waste in landfills.

Industrial processes and product use represented 11 % of the Portuguese emissions in 2015, and have grown 30 % 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 and glass , are mostly related to the increase of cement production, road paving, limestone and dolomite use, lime production, and glass..

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 (1.3 Mt CO2e) 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 2015 this sector represents a sequester of -8.8 Mt CO2e.

Figure 1.5 – GHGs emissions percentage change (1990-2015) by IPCC category (LULUCF excluded).

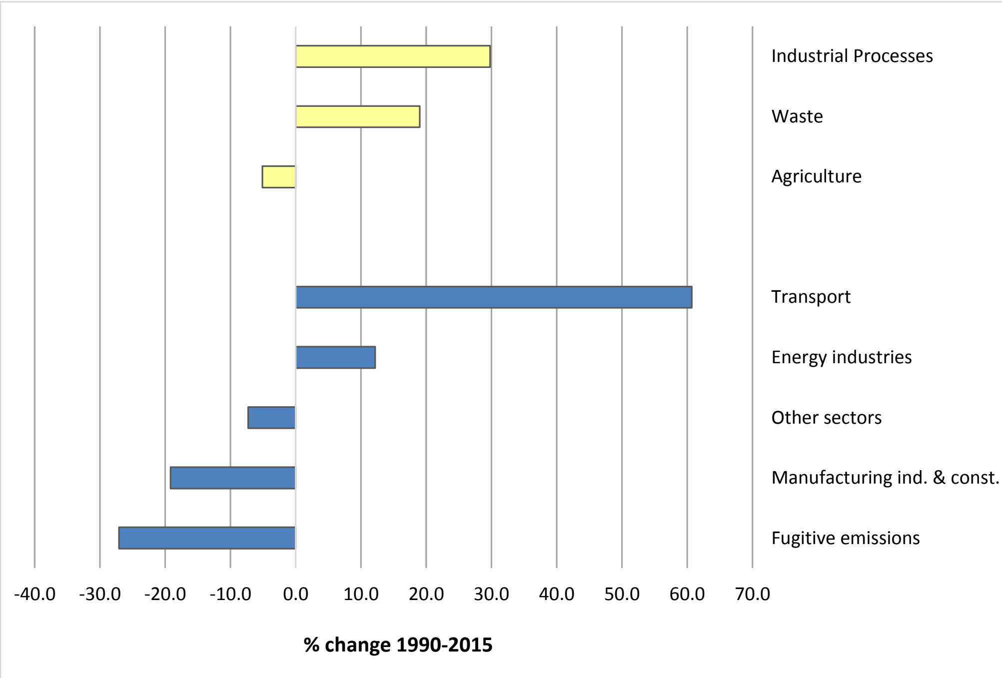


Table 1.2 – GHG emissions and removals by sector.

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO_2 equivalent (Gg)												
1. Energy	41,222	42837.714	47,376	46,063	46,768	50,291	47,655	50,209	54,603	61,907	60,311	60,493	64,129
2. Industrial processes and product use	5,839	5800.7327	5,504	5,398	5,429	6,107	6,131	6,608	6,772	7,168	7,421	6,956	7,319
3. Agriculture	6,981	7001.1512	6,891	6,838	6,864	6,903	7,100	7,124	7,071	7,203	7,344	7,113	7,007
4. Land use, land-use change and forestry(5)	1,344	1436.1064	-3,327	-4,459	-5,123	-4,724	-8,578	-9,553	-8,082	-8,847	-6,031	-9,431	-8,908
5. Waste	5,361	5550.3718	5,782	5,965	6,243	6,535	6,573	6,775	7,063	7,139	7,215	7,361	7,654
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

GHGs SOURCE AND SINK	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	% change
	CO_2 equivalent (Gg)													1990-2015
1. Energy	59,038.61	61,303.39	63,708.45	59,317.52	56,210.27	54,241.84	52,998.33	48,530.40	47,870.85	46,422.83	44,280.28	43,786.66	48,157.50	**16.8**
2. Industrial processes and product use	7,390.74	8,112.36	8,138.95	7,934.81	8,788.26	8,623.19	6,943.93	7,367.93	6,788.13	6,514.21	7,002.50	7,503.08	7,578.89	**29.8**
3. Agriculture	6,552.93	6,663.75	6,613.00	6,551.88	6,681.10	6,630.12	6,541.58	6,472.12	6,436.58	6,481.31	6,468.34	6,566.04	6,623.53	**-5.1**
4. Land use, land-use change and forestry(5)	1,671.89	-7,984.21	497.83	-8,987.83	-12,560.38	-14,004.39	-13,933.93	-11,376.84	-11,461.53	-8,994.41	-8,521.52	-9,971.68	-8,776.33	**-753.2**
5. Waste	8,004.04	8,120.72	7,674.08	7,599.01	7,453.69	7,008.20	6,862.70	6,921.27	7,049.17	6,819.89	6,574.23	6,339.83	6,380.89	**19.0**
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	**NO**

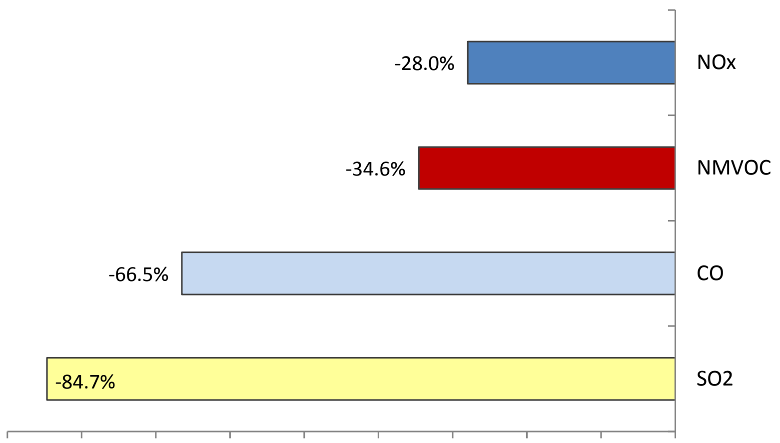
NA- Not applicable; NE - Not estimated; NO - Not occurring

ES.4 Other information

ES.4.1 Information on indirect GHG and SOx emissions

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

Figure 1.6 – Indirect GHG and SO_x emissions: 1990-2015 variation.



In 2015, all these gases emissions have decreased from 1990 levels: SO_x -85 %, CO -67 %, NMVOC -35 % and NOx -28 %.

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

Within energy, transportation is responsible for the major share of NO_x, emissions, approx. 46 % of 2015 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 since 2005. In the most recent years the situation has been inversed with an increase of emissions after 2013. In the period analysed, 1990-2015, NO_x emissions from transport decreased -10 per cent; and CO and NMVOC emissions registered reductions of more than -85 per cent.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 51 % of the 2015 totals.

SO_x emissions are mainly generated in the energy industry sector (approximately 30 % of total emissions in 2015) and combustion in manufacturing industries (approximately 35 % of total emissions in 2015), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. The situation is however improving with a significant development of renewable sources (mainly wind) and energy efficiency measures, among other factors as reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 from November 10th). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO_x emissions. The emissions variation in the period 1990-2015 shows a substantial decrease in SO_x emissions in both sub-categories: energy industries and manufacturing industries -93 % and -79 %. Since 2007, SO_x emissions from the energy industries registered a significant reduction (approximately -87 %) which is explained by the implementation of two new abatement systems (desulfurization in two Large Point Source Energy Plants in Mainland Portugal).

Table 1.3 – Indirect GHG and SOx emissions: 1990-2015.

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	(Gg)												
CO	801	815	853	832	812	800	787	752	728	702	651	570	552
NOx	245	256	275	266	266	276	264	262	269	277	274	273	280
NMVOC	275	281	287	277	279	274	276	275	276	270	259	249	248
SO2	324	315	376	320	296	332	273	288	336	303	264	250	250

Gas emissions	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	% change
	(Gg)													1990-2015
CO	512	480	440	409	385	360	340	323	303	288	281	274	268	**-66.5**
NOx	256	262	267	245	240	214	203	189	180	173	171	170	176	**-28.0**
NMVOC	234	227	215	209	204	195	185	186	178	174	175	174	180	**-34.6**
SO2	191	193	195	170	163	114	79	70	65	60	54	48	50	**-84.7**

PART I: ANNUAL INVENTORY SUBMISSION

1 INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 Global warming and climate change

Although key greenhouse gases - CO_2, CH_4, N_2O, 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 (SF6), and nitrogen trifluoride (NF3) - 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_x, and NMVOCs are precursor substances for ozone which is a GHG. SO_x produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Land-Use and Land-Use Change (LULUCF), particularly deforestation, is another factor that contributes to the phenomenon of global warming and climate change as it changes carbon stocks and carbon sequestration and consequently the CO_2 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.

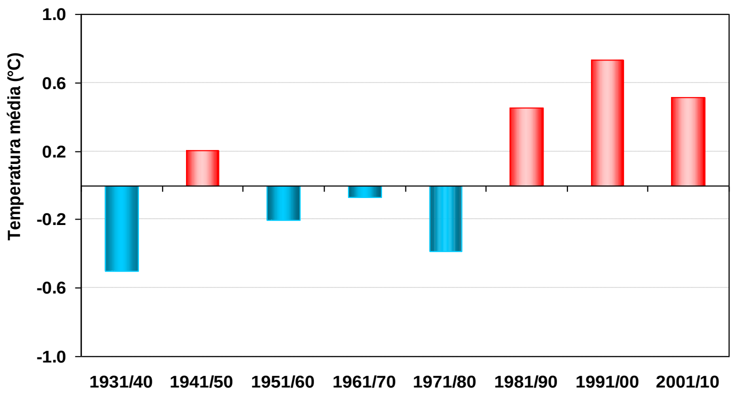
An increase in global temperatures can result in a cascade of environmental effects, including the rise of sea level and changes in the amount and pattern of precipitation. These changes may increase the frequency and intensity of extreme weather events, such as floods, droughts, heat waves, hurricanes,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



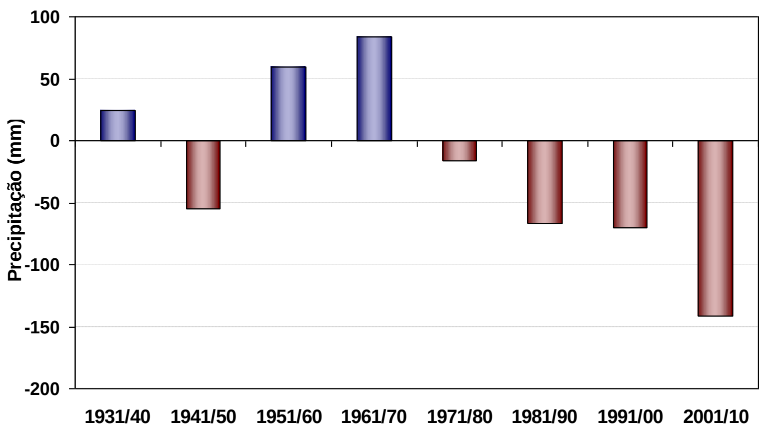
Source: IPMA, 2013

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 ºC higher than the daily mean value of the reference period (1961-1990). Although they can occur at any time of the year, heat waves have a more significant impact in the summer months. Heat waves were more frequent in the 1990s. The heat waves of 1981, 1991, 2003 and 2006 were of particular significance due to their duration and spatial extension.

The last 2 decades of the 20th century were particularly dry in mainland Portugal as opposed to the average values registered between 1961 and 1990. In fact, only in 6 of the last 20 years of the past century the annual precipitation was higher than the average. In 2001 and 2002, however, the annual precipitation values were higher than the average observed in the reference period. The driest of the past 75 years was 2005, and 2004 was the second driest on record. The first decade of the 21st 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 ºC and 7 ºC 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.

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.” Portugal has ratified the UNFCCC on May 31st, 1994.

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

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

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

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

In Doha, Qatar, on 8 December 2012, the Doha Amendment to the Kyoto Protocol was adopted. This launched a second commitment period, starting on 1 January 2013 until 2020, with a revised list of GHG to be reported and necessary updates for several articles of the Kyoto Protocol.

For the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020. The EU and its Member States have committed to this second phase of the Kyoto Protocol and established to reduce their collective emissions to 20% below their levels in 1990 or other chosen base years. The target will be fulfilled jointly with Iceland.

The 2015 Paris Agreement, adopted in Paris on 12 December 2015, marks the latest step in the evolution of the UN climate change regime and builds on the work undertaken under the Convention. The Paris Agreement charts a new course in the global effort to combat climate change for the period after 2020.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change.

The Paris Agreement entered into force on 4 November 2016, thirty days after the date on which at least 55 Parties to the Convention accounting in total for at least an estimated 55 % of the total global greenhouse gas emissions have deposited their instruments of ratification.

1.1.4 History of national inventories

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

The fulfilment of international commitments under conventions UNFCCC and CLRTAP, together with the publication of the IPCC Draft Guidelines for National Greenhouse Gas Inventories (IPPC, 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 fist 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 Plan (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;
- 2016 EU comprehensive review of national greenhouse gas inventory data pursuant to Article 19(1) of Regulation (EU) No 525/2013;
- UNFCCC centralised review of the 2015 and 2016 greenhouse gas emission inventory in September 2016.

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_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF3), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x). Emissions are estimated for each civil year since 1990.

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_2. The mass emission of each gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide equivalents (CO_2 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
CO2	1	1
CH4	21	25
N2O	310	298
HFC-23	11 700	14800
HFC-32	650	675
HFC-43-10mee	1 300	1640
HFC-125	2 800	3500
HFC-134[a]	1 300	1430
HFC-152[a]	140	124
HFC-143[a]	3 800	4470
HFC-227ea	2 900	3220
HFC-236fa	6 300	9810
CF4	6 500	7390
C2F6	9 200	12200
C4F10	7000	8860
C6F14	7400	9300
SF6	23 900	22800
NF3	NA	17200

1.2 Institutional arrangements for inventory preparation

1.2.1 National Inventory System

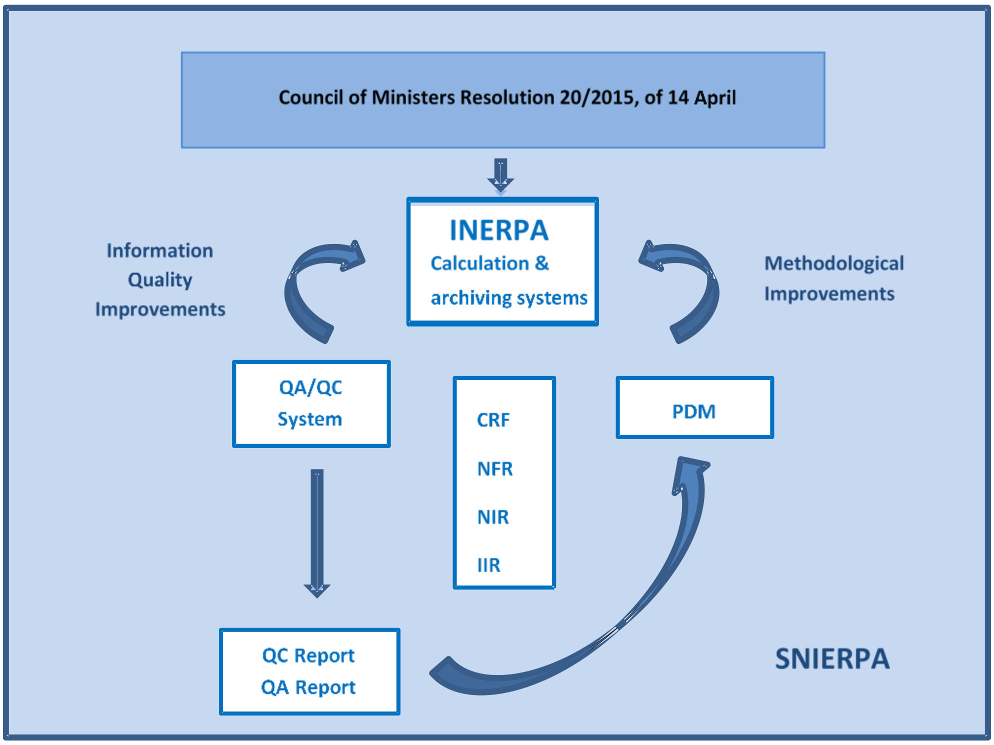
No major changes occurred in the national inventory system and the institutional arrangements since the 2016 submission.

The new legal national arrangement adopted in 2015 (Council of Ministers Resolution no. 20/2015) has been reorganized to take into account the developments at international level relating to the UNFCCC and the Kyoto Protocol, and the 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.

The new Council of Ministers Resolution, restructures and elaborates the previous legal framework on the National System (SNIERPA), specifying its 4 different components:

i) a calculation and archiving system of the national inventory;
ii) the QA\QC System;
iii) the Methodological Development Plan (PDM);
iv) the Archiving System.

Figure 1.1 – SNIERPA's main elements relations



Furthermore, it identifies the several outputs and formats of reporting to the international bodies, and specifies the functions of the entities making part of SNIERPA:

i) the coordinating entity;
ii) the sectorial Focal Points;
iii) the Involved Entities.

APA, is the Responsible Body for: the overall coordination and updating of the National Emissions Inventory (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 Climate Change Department (DCLIMA) is the unit responsible for the general administration of the inventory and for all aspects related to its compilation, reporting and quality management. Data from different sources is collected and processed by the inventory team, who is also responsible for the application of QA/QC procedures, the assessment of uncertainty and key category analysis, the compilation of the CRF tables and the preparation of the NIR, the response to the review processes and data archiving and documentation.

The sectorial Focal Points work with APA/DCLIMA 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. They are also responsible for the production of statistical information and data publication that are used in the inventory estimates.

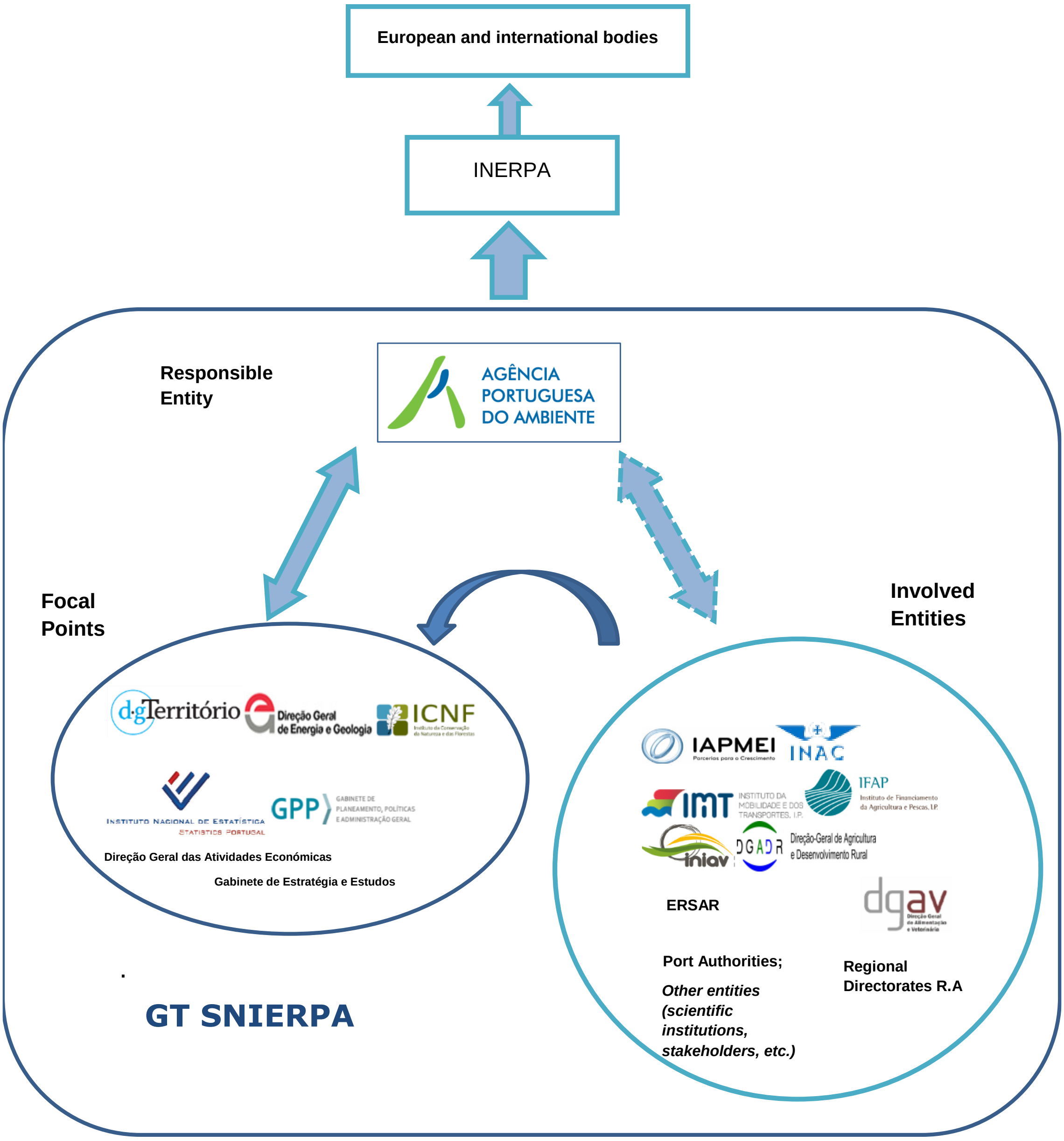
The involved entities are public or private bodies which generate or hold information which is relevant to the INERPA, and which actions are subordinate to the Focal Points or directly to the Responsible Body.

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.

Following the publication of the new Council of Ministers Resolution No. 20/2015 of 14 April, which restructured the SNIERPA, a set of implementing procedures were agreed within SNIERPA to facilitate the good functioning of the national system, defining in more detail some competences, such as the regularity of the meetings and the deadlines for the information´ transmission, among other issues.

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

Figure 1.2 – Main bodies of national system (SNIERPA)



1.2.2 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 panel was created in the scope of the 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 this inter-institutional panel aims at gathering the necessary competences, data and knowledge required to comply with the reporting and accounting requirements of these activities.

1.2.3 Overview of inventory planning

All the participating organizations represented in SNIERPA support the annual production of the national inventories and the fulfilment 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. To each issue identified is attributed a priority, considering their importance in terms of the contribution to total CO2 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, APA, as coordinator of SNIERPA, organizes a kick-off meeting to plan and launch, in coordination with the sectoral focal points and the involved entities, the work for the following inventory submission(s). Bilateral meetings occur as necessary as consequence of this meeting aiming at discussing the specific issues related to each sector and to agree on the actions to be implemented in the framework of SNIERPA during this inventory compilation regarding the next submission.

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

Table 1.2 - 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 of the QA/QC plan - discussion and of the inventory development priorities (PDM)
June - December	- end September: deadline for rotine 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	- approval of the QA/QC plan and of the PDM - collection of activity data and EFs update - implementation of methodological improvements - estimation of emissions/ removals - aplication of QA/QC checks - uncertainty and KC assessment - archiving of information - preparation of submissions by the inventory team
15 January	*Preliminary CRF and Short NIR submission to EC (DG CLIMA) [Monitoring Mech. of GHG under EU]*	*Reporting*	-
	Preparation of NFR submission	Inventory Verification/ Improvement	- aplication of QA/QC checks - implementation of corrections and late data updates
14 February	*Official consideration/approval of the NFR submission to UNECE [CLRTAP]*	*Approval*	*Approval by President of APA*
15 February	*Official NFR submission to NECD [EU] and UNECE [CLRTAP]*	*Reporting*	-
	- Revision of CRF submission - Preparation of NIR and IIR - Circulation of NIR and IIR comments among FP and/or IE	Inventory Verification/ Improvement	- aplication of QA/QC checks - implementation of corrections and late data updates
9 March	- Deadline for NIR and IIR comments from FP and/or IE	Inventory Verification	-
14 March	*Official consideration/approaval of the CRF and NIR submission to EC (DG CLIMA) [Monitoring Mech. of GHG under EU]*	*Approval*	*Approval by President of APA*
15 March	*Submission of CRF and NIR (final versions) to the EC (DG CLIMA) [Monitoring Mech. of GHG under EU]*	*Reporting*	-
15 March	*Submission of IIR to NECD [EU] and UNECE [CLRTAP]*	*Reporting*	-
	- Implementation of QA/QC checks	Inventory Verification	- aplication of QA/QC checks including the NIR
15 April	*Submission of CRF and NIR (final version) to the UNFCCC [UNFCCC and Kyoto Protocol]*	*Reporting*	-
8/27 May	*Resubmission (if needed) of CRF and NIR (final version) to the EC and UNFCCC [UNFCCC and Kyoto Protocol]*	*Reporting*	-

1.3 Inventory Preparation Process

1.3.1 Responsibility

As referred in section 1.2.1 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 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 82 93

Fax: + 351 21 471 90 74

Contact: Eduardo Santos – eduardo.santos@apambiente.pt (Head Department)

1.3.2 Calculation, data archiving and documentation system

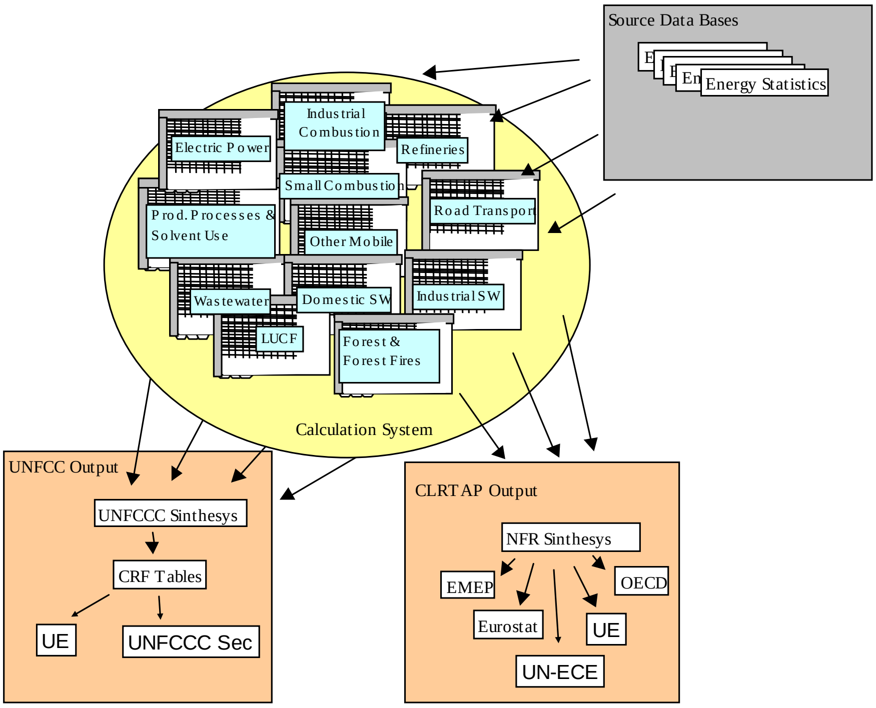
The emissions calculations have been performed by APA/DCLIMA. However many other institutions and agencies contributed to the inventory process, providing activity data, sectorial expert judgment, technical support and comments. All calculation and reporting rely in a set of different Excel spreadsheet 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 IT 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, and particularly after a reporting cycle, the older spreadsheets are frozen and work restarts with copies of those spreadsheets, making a clear reference to the period when they were used. Minor corrections, which do not affect the estimations, are not stored due to storage area limitations.

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



All the inventory material, calculation files and reported tables, as well as the underlying data, the scientif documentation and studies used are stored and archived electronically.

Furthermore, the present system existing in APA is considered to ensure the basic requirements/functions of an IT system: centralized data processing and storage.

In the latest years an effort has been made by the inventory team in order to better document and explain the calculation process and data sources used and procedures applied during an annual cycle for each sector. The several documents produced are stored in the inventory IT area, enabling a smoother transmission of knowledge and facilitation the continuity of the inventory compilation process in case of changes within the inventory team.

1.4 General overview of methodologies and data sources used

Methodologies are consistent with the IPCC Guidelines ((IPCC, 1997; IPCC, 2006; IPCC, 2000; IPCC, 2003) and EMEP/EEA Guidebooks (EMEP/CORINAIR, 2007; EMEP/EEA, 2009; EMEP/EEA, 2013; EMEP/EEA, 2016).

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

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

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		Unspecified mix of HFCs and PFCs		NF_3	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1. Energy	D,NO,T1,T2,T3	,D,NO,OTH,PS	,OTH,T1,T2,T3	R,D,NO,OTH,PS	D,NO,T1,T2,T3	,D,NO,OTH,PS										
A. Fuel combustion	T1,T2,T3	CR,D,OTH,PS	T1,T2,T3	CR,D,OTH,PS	T1,T2,T3	CR,D,OTH,PS										
1. Energy industries	T2	CR,D,PS	T2	CR,D	T2	CR,D										
2. Manufacturing industries and construction	T2,T3	CR,D,OTH,PS	T2,T3	CR,D,OTH,PS	T2,T3	CR,D,OTH,PS										
3. Transport	T1,T2,T3	D	T1,T2,T3	CR,D,OTH	T1,T2,T3	CR,D										
4. Other sectors	T1,T2	CR,D	T1,T2	CR,D	T1,T2	CR,D										
5. Other																
B. Fugitive emissions from fuels	D,NO	D,NO	CR,NO,OTH	CR,NO,OTH	D,NO	D,NO										
1. Solid fuels			NO	NO												
2. Oil and natural gas	D,NO	D,NO	CR,NO,OTH	CR,NO,OTH	D,NO	D,NO										
C. CO_2 transport and storage																
2. Industrial processes	CR,NO,T1,T2,T3	CS,NO,OTH,PS	D,NO,T3	CR,NO,OTH,PS	D	D,PS	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
A. Mineral industry	T1,T3	OTH														
B. Chemical industry	NO	NO	D,NO	CR,NO,OTH	D	PS										
C. Metal industry	T2	PS	T3	PS												
D. Non-energy products from fuels and solvent use	CR,NO	CR,CS,NO,OTH	NO	NO												
E. Electronic industry																
F. Product uses as ODS substitutes							IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
G. Other product manufacture and use					D	D	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
H. Other							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3. Agriculture	T1	D	T1,T2	CS,D	T1,T2	CS,D										
A. Enteric fermentation			T1,T2	CS,D												
B. Manure management			T1,T2	CS,D	T2	CS,D										
C. Rice cultivation			T1	CS,D												
D. Agricultural soils(3)					T1,T2	CS,D										
E. Prescribed burning of savannas																
F. Field burning of agricultural residues			T1,T2	D	T1,T2	D										
G. Liming	T1	D														
H. Urea application	T1	D														
I. Other carbon-containing fertilizers																
J. Other																
4. Land use, land-use change and forestry	CS,D,T2	CS,D	D	D	D	D										
A. Forest land	CS,T2	CS,D	D	D	D	D										
B. Cropland			D	D	D	D										
C. Grassland			D	D	D	D										
D. Wetlands																
E. Settlements																
F. Other land																
G. Harvested wood products	D	D														
H. Other																
5. Waste	T1,T2	CS,D	T1,T2	CS,D	T1,T2	CS,D										
A. Solid waste disposal			T2	CS,D												
B. Biological treatment of solid waste			T1	D	T1	D										
C. Incineration and open burning of waste	T1,T2	CS,D	T1	D	T1	D										
D. Waste water treatment and discharge			T2	CS,D	T2	CS,D										
E. Other			T1	D	T1	D										
6. Other *(as specified in summary 1.A)*																

Notation keys to specify the method applied:

D (IPCC default)
RA (Reference Approach)
T1 (IPCC Tier 1)
T1a, T1b, T1c (IPCC Tier 1a, Tier 1b and Tier 1c, respectively)
T2 (IPCC Tier 2)
T3 (IPCC Tier 3)
CR (CORINAIR) **M** (model)
CS (Country Specific)
OTH (Other)

Notation keys to specify the emission factor used:

D (IPCC default)
CR (CORINAIR)
CS (Country Specific)
PS (Plant Specific)
OTH (Other)
M (model)

The following table presents a summary of the activity data and sources used.

Table 1.3 – Main data sources used in the Portuguese inventory

IPCC Sector	Activity Data	Data Sources
1. ENERGY		
1 A – Energy. Fuel Combustion		
1A1 – Energy Industry		- Large Point Source Surveys (LPS)
		- Large Combustion Plants (LCP)
		- EDP Sustainability Annual Reports
	Fuel sales	- Energy Balance - General Directorate for Geology and Energy (DGEG)
		- Autonomous Gov. of Azores
		- National Statistical Institute (INE)
		- European Emissions Trading Scheme - APA
1A2 - Manufacturing Industries and Construction		- LPS, LCP, EPER/PCIP
		- Energy Balance (DGEG)
		- European Emissions Trading Scheme - APA
1A3 – Transport	Fuel sales	- Energy Balance - General Directorate for Geology and Energy (DGEG)
	Vehicle sales	- ACAP
		- ANECRA
		- Road Institute (IEP)
		- INE
		- General Directorate of Terrestrial Transportation (DGTT)
		- INAC
1A4 – Other Sectors	Fuel sales	- Energy Balance (DGEG)
	Equipments and fuel used	- Survey on Energy Consumption in the Residential Sector (DGEG)
1A5 – Other	Fuel sales	- Energy Balance (DGEG)
1 B – Fugitive Emissions from Fuels		- Energy Balance and statistical yearbooks (DGEG)
		- GALP
2 - IPPU		
2A - Mineral industry		- LPS, LCP
		- CIMPOR, SECIL
		- Energy Balance (DGEG)
		- Portuguese Association of Producers of Bitumen Materials (APORBET)
		- European Asphalt Pavement Association (EAPA)
		- Technology Centre for Ceramics and Glass (CTCV)
		- European Emissions Trading Scheme - APA
2B - Chemical industry		- Energy Balance (DGEG)
		- LCP
		- INE
2C - Metal industry		- Energy Balance (DGEG)
		- LCP
		- INE
		- SN
2D - Non-energy products from fuels and solvent use		- Energy Balance (DGEG)
		- Gen-Dir for Economic Activities Enterprise (DGAE)
		- INE
2F - Product uses as ODS substitutes		- INE
		- APIRAC
		- Data from Industry Importers
		- EDP, REN
		- Fluorinated Gas Inquiry (APA)
2G - Other product manufacture and use		- LCP
		- Energy Balance (DGEG)
3 – Agriculture		- GPP
		- ICNF
		- INE: agriculture survey
5 – Land Use, Land Use Change and Forestry	Biomass increment, Burnt area, Harvest	- ICNF
	Land use area, LUC	- COS cartography (DGT)
	Biomass increment	- ISA
5 – Waste		
5A – Solid Waste Disposal on Land	Amount of Waste (Municipal)	APA
	Amount of Waste (Industrial)	APA-INE
5B – Biological Treatment	Amount of Waste	APA
5C – Waste Incineration	Amount of Waste	APA
5D – Wastewater Handling		APA
	Industrial Production, Protein consumption	INE

1.5 Brief description of key source categories

Key category analysis to the 2017 Portuguese inventory estimates (1990-2015) was conducted using Approach 1 and Approach 2 with and without the LULUCF sector.

In accordance with the recommendations from the last UNFCCC review, the disaggregation level of the key category analysis has been revised in order to follow the guidance from 2006 IPCC.

Level assessment was undertaken for the base year and the latest reported inventory year; the trend assessment was performed for the 1990-2015 period. The analysis performed without LULUCF resulted in the identification of 33 key categories, listed in the following table.

Table 1.4 – Overview of key categories (without LULUCF) using Approach 1 and 2 for the base and latest inventory year.

IPCC CATEGORIES	GHG	Key source Category Flag	Criteria for Identification	Current year emissions (kton CO2 eq.)
1.A.3.b Road Transportation	CO2	√	Level 1 and 2, Trend 1 and 2	15358.3
1.A.1 Energy industries - Solid fuels	CO2	√	Level 1, Trend 1	12228.8
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	√	Level 1, Trend 1 and 2	3931.6
5.A Solid waste disposal	CH4	√	Level 1 and 2, Trend 1 and 2	3709.0
1.A.1 Energy industries - Gaseous fuels	CO2	√	Level 1, Trend 1 and 2	3568.5
3.A Enteric fermentation	CH4	√	Level 1, Trend 1	3479.4
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	3441.0
2.A.1 Mineral Industry - Cement production	CO2	√	Level 1 and 2, Trend 1 and 2	2921.2
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	2636.1
2.F.1 Refrigeration and Air Conditioning	Fgases	√	Level 1 and 2	2613.0
5.D Wastewater treatment and discharge	CH4	√	Level 1 and 2, Trend 1 and 2	2357.7
1.A.1 Energy industries - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	2024.5
3.D.1 Direct N2O Emissions From Managed Soils	N2O	√	Level 1 and 2, Trend 1 and 2	1690.2
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	√	Level 1, Trend 1 and 2	1336.5
1.B.2.a Fugitive emissions - Oil	CO2	√	Level 1 and 2, Trend 1 and 2	1001.2
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	√	Level 1	650.2
3.B Manure Management	CH4	√	Level 1, Trend 1	591.2
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	√	Level 1	423.5
1.A.1 Energy industries - Other fossil fuels	CO2	√	Level 1 and 2, Trend 1 and 2	411.8
1.A.3.a Civil (domestic) aviation	CO2	√	Level 1 and 2, Trend 2	366.0
2.A.4 Mineral Industry - Other Process Uses of Carbonates	CO2	√	Level 1	354.9
2.A.2 Mineral Industry - Lime production	CO2	√	Level 2, Trend 2	351.3
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	√	Trend 1 and 2	300.2
1.A.3.d Domestic navigation - Residual fuel oil	CO2	√	Level 1 and 2	266.4
5.D Wastewater treatment and discharge	N2O	√	Level 2	254.2
1.A.4 Combustion Other Sectors - Biomass	CH4	√	Level 1 and 2, Trend 1 and 2	241.2
2.D Non-energy products from fuels and solvent use	CO2	√	Level 2, Trend 2	191.7
3.C Rice cultivation	CH4	√	Level 2	142.0
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	√	Level 2, Trend 2	88.4
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	56.2
1.A.2 Manufacturing industries and construction - Biomass	N2O	√	Trend 2	46.1
2.B.2 Chemical Industry - Nitric acid production	N2O	√	Level 1, Trend 1 and 2	38.0
1.B.1.Fugitive emissions – Solid Fuels (Mining activities)	CH4	√	Trend 2	8.6

Including the LULUCF sector in the analysis, 42 categories were identified, as shown in the next table.

Table 1.5 – Overview of key categories (with LULUCF) using Approach 1 and 2 for the base and latest inventory year.

IPCC CATEGORIES	GHG	Key source Category Flag	Criteria for Identification	Current year emissions (kton CO2 eq.)
1.A.3.b Road Transportation	CO2	√	Level 1 and 2, Trend 1 and 2	15358.3
1.A.1 Energy industries - Solid fuels	CO2	√	Level 1, Trend 1	12228.8
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	√	Level 1, Trend 1	3931.6
5.A Solid waste disposal	CH4	√	Level 1 and 2, Trend 1 and 2	3709.0
1.A.1 Energy industries - Gaseous fuels	CO2	√	Level 1, Trend 1	3568.5
3.A Enteric fermentation	CH4	√	Level 1	3479.4
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	3441.0
2.A.1 Mineral Industry - Cement production	CO2	√	Level 1 and 2	2921.2
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	√	Level 1, Trend 1	2636.1
2.F.1 Refrigeration and Air Conditioning	Fgases	√	Level 1 and 2	2613.0
4.E.2 Land converted to Settlements	CO2	√	Level 1 and 2, Trend 1 and 2	2445.9
5.D Wastewater treatment and discharge	CH4	√	Level 1 and 2	2357.7
1.A.1 Energy industries - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	2024.5
3.D.1 Direct N2O Emissions From Managed Soils	N2O	√	Level 1 and 2, Trend 2	1690.2
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	√	Level 1, Trend 1	1336.5
1.B.2.a Fugitive emissions - Oil	CO2	√	Level 1 and 2, Trend 1 and 2	1001.2
4.B.2 Land converted to Cropland	CO2	√	Level 1 and 2, Trend 1 and 2	759.2
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	√	Level 1	650.2
3.B Manure Management	CH4	√	Level 1	591.2
4.C.2 Land converted to Grassland	CO2	√	Level 1 and 2, Trend 1 and 2	456.3
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	√	Level 1	423.5
1.A.1 Energy industries - Other fossil fuels	CO2	√	Level 2, Trend 1 and 2	411.8
4.D.2 Land converted to Wetlands	CO2	√	Level 2, Trend 1 and 2	394.4
1.A.3.a Civil (domestic) aviation	CO2	√	Level 2	366.0
2.A.2 Mineral Industry - Lime production	CO2	√	Level 2	351.3
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	√	Trend 1	300.2
1.A.3.d Domestic navigation - Residual fuel oil	CO2	√	Level 2	266.4
5.D Wastewater treatment and discharge	N2O	√	Level 2, Trend 2	254.2
1.A.4 Combustion Other Sectors - Biomass	CH4	√	Level 2, Trend 2	241.2
2.D Non-energy products from fuels and solvent use	CO2	√	Level 2, Trend 2	191.7
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	√	Level 2, Trend 2	88.4
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	√	Level 1, Trend 1 and 2	56.2
4.B.2 Land converted to Cropland	N2O	√	Level 2, Trend 1 and 2	49.8
2.B.2 Chemical Industry - Nitric acid production	N2O	√	Level 1, Trend 1	38.0
4.C.2 Land converted to Grassland	N2O	√	Trend 2	28.9
1.B.1.Fugitive emissions – Solid Fuels (Mining activities)	CH4	√	Trend 2	8.6
4.B.1. Cropland remaining Cropland	CO2	√	Trend 1	-204.4
4.C.1. Grassland remaining Grassland	CO2	√	Trend 1	-369.0
4.G. Other (Harvested Wood Products)	CO2	√	Level 1, Trend 1	-424.2
4.F.2 Land converted to Other Land	CO2	√	Level 1 and 2, Trend 1 and 2	-813.0
4.A.2 Land converted to Forest land	CO2	√	Level 1 and 2, Trend 1 and 2	-3043.5
4.A.1. Forest land remaining Forest land	CO2	√	Level 1 and 2, Trend 1 and 2	-8409.3

1.6 Information on QA/QC

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

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

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

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

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

- QA/QC Plan;
- Procedures Manual.

The first schedules the application of the general (QC1) and specific (QC2) as well as QA procedures, described in detail in a Manual (in Portuguese language), to be applied to defined source/sink categories. The procedures were defined according to Good Practice and Uncertainty Management Guide (IPCC, 2000 and 2006) and adapted to the specific National Inventory (INERPA) characteristics.

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

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

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

The sectorial Focal Points within SNIERPA have also an important role in the implementation of QA\QC activities. As foreseen in the implementing procedures document agreed under SNIERPA, APA transmits the reports to the focal points on each official submission for validation purposes of each sectoral component and proposed amendments and perform QA\QC validation procedures.

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

1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

The Portuguese uncertainty analysis follow Approach 1, based on the error propagation equations, proposed by the 2006 IPCC Guidelines.

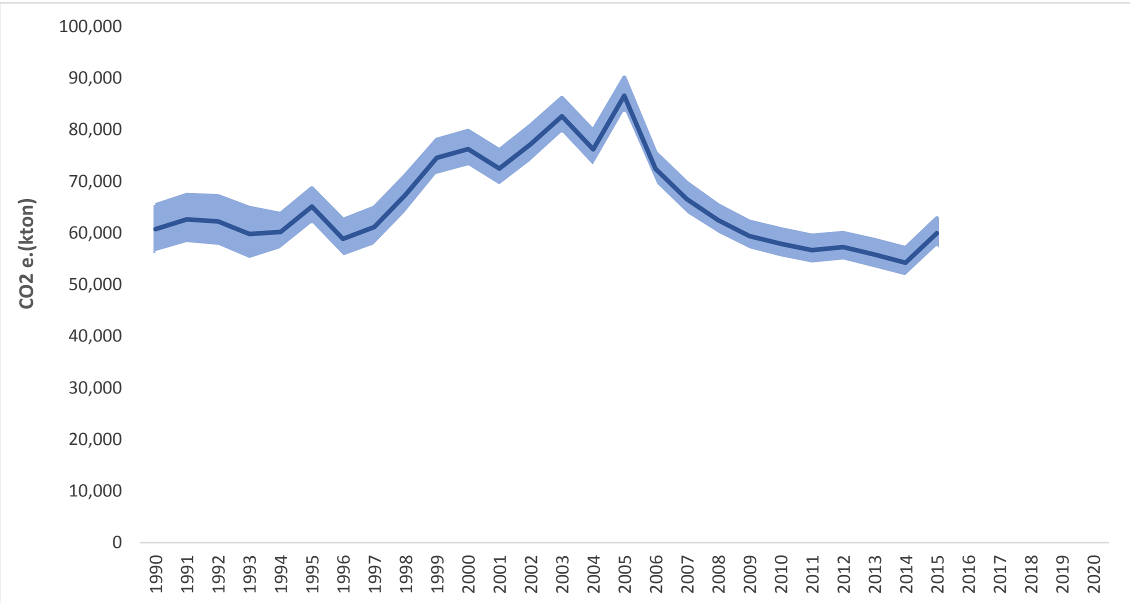
Despite the efforts done in order to cover all the categories considered in the inventory, it was not yet possible to include HWP and indirect CO2 in the uncertainty analysis.

The uncertainty values, both for activity data and emission factors, are discussed in the detailed analysis of emission estimates for each individual source sector.

For the 2015 total emission estimates without indirect CO2, an uncertainty of 5.7 % is estimated. The uncertainty in trend from 1990 to 2015 is 3.5 %.

Total uncertainty varies along the years from a maximum value of 8.5% to lower values in more recent years. Uncertainty values are defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000, IPCC 2006), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

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



1.8 Overview of the completeness

The inventory covers the gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x). NF_3 emissions do not to 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 Reporting on consistency of the reported data on air pollutants (CO, SO2, NOx and NMVOC)

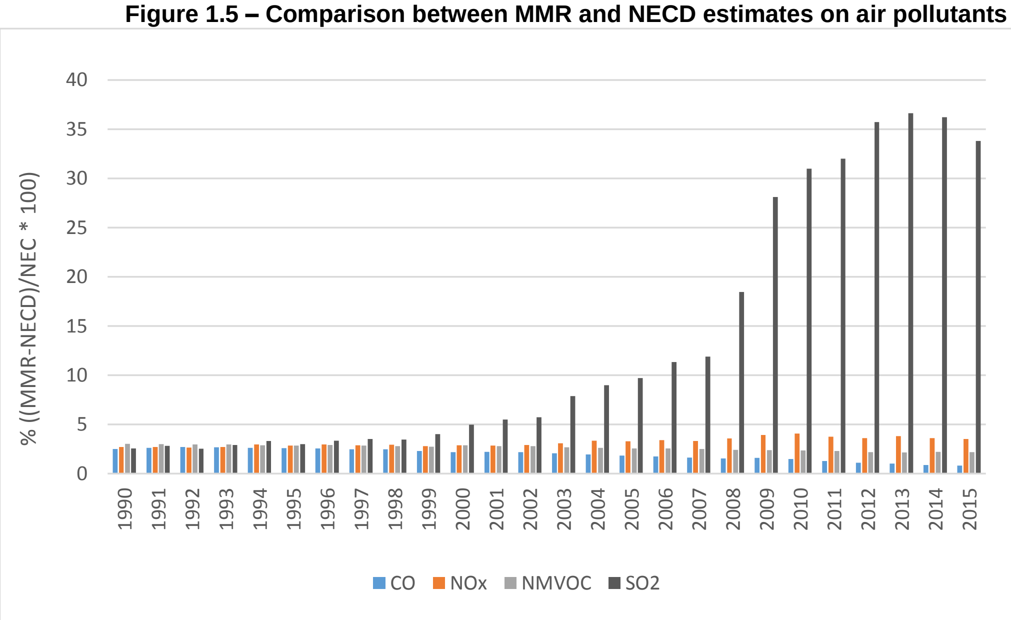
Article 7(1) of the Regulation (EU) No 525/2013 requires Member States to report on the results of the checks between emissions estimates of carbon monoxide (CO), sulphur dioxide (SO2), nitrogen oxides (NOx) and volatile organic compounds, in inventories submitted by the Member State under Directive 2001/81/EC of the European Parliament and of the Council, repealed by Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016, and under the UNECE Convention on Long-range Transboundary Air Pollution and the corresponding emission estimates in greenhouse gas inventories under Regulation (EU) No 525/2013.

The next figure presents the results of the assessment made using the lastest submission (15th March 2017) under Directive (EU) 2016/2284 of the European Parliament and of the Council (http://cdr.eionet.europa.eu/pt/eu/nec/envvoqlvw/) and data provided in this submission.

The differences for CO, NOx and NMVOC emissions are for most of the years in the range below 5 %. For SO2, the disparities are more significant in particular after 2007. The differences are the result in geographical coverage between submissions. The NECD (Directive 2001/81/EC) refers to Portugal Mainland and the MMR/UNFCCC submissions refer to the national total which includes the two Autonomous Regions of Açores and Madeira.

The difference in SO2 after 2007 is the result of the implementation of the abatement systems (desulfurization in two Large Point Source Energy Plants) in Mainland Portugal.

Figure 1.5 – Comparison between MMR and NECD estimates on air pollutants



1.10 Comparison of the sectoral approach with the reference approach

Article 7(1)(m)(iii) of Regulation (EU) No 525/2013, defines that Member States shall report information on the comparison between the sectoral approach used in the greenhouse gas inventory and the reference approach calculated on the basis of the data reported pursuant to Article 4 of, and Annex B to, Regulation (EC) No 1099/2008.

In the assessment made for this provisional submission, it was found significant differences (of more than +/– 2 % in the total national apparent fossil fuel consumption) for some of the years 1995, 1996, 1997, 1998 and 2000, that result from some missing information and other possible factors which require further development.

It is identified the improvement of the comparison exercise between the reference approach and the sectoral approach, namely in terms of the PDM, working together with the national energy authority (DGEG) in order to clarify the origin of these differences.

Differences between RA and SA have been reduced along the time due to the streamlining efforts between the energy balance team (DGEG) and inventory team (APA), which include the share of ETS data, and the use of the same criteria (IPCC) to distinguish between domestic and international fuel use in aviation.

The differences that remains can be partially explained by the use of some monitoring data in the sectoral approach, whereas the reference approach relies on IPCC default emission factors.

1.11 Future developments

Future improvements are defined under the PDM 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 PDM pretends to reflect the results of the various review processes, in particular the UNFCCC reviews, the annual inventory compilation process (all experts and entities involved can make proposals for methodological development), and generally the results of the application procedures of Quality Control and Quality Assurance which have been defined under the Control and Quality Assurance System.

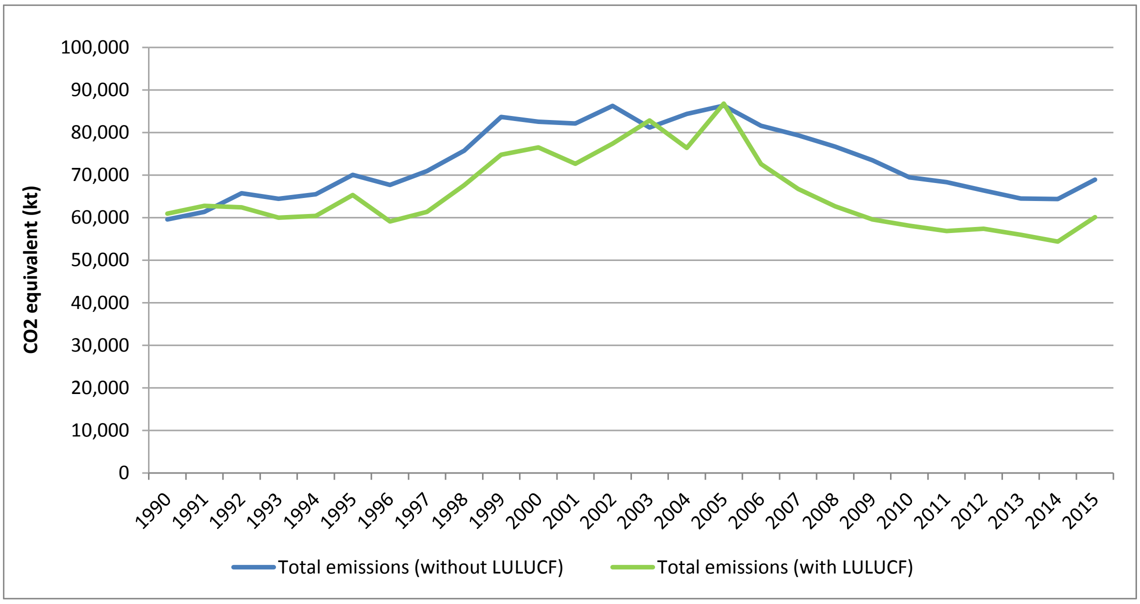
2 TRENDS IN PORTUGUESE GHG EMISSIONS

2.1 Trends of Total Emissions

In 2015, total Portuguese GHG emissions, including indirect CO2, without land-use, land-use change and forestry (LULUCF) were estimated at about 68.9 Mt CO_2e, representing an increase of 15.7 % compared to 1990 levels and an increase of 7.1 % compared to the previous year (2014).

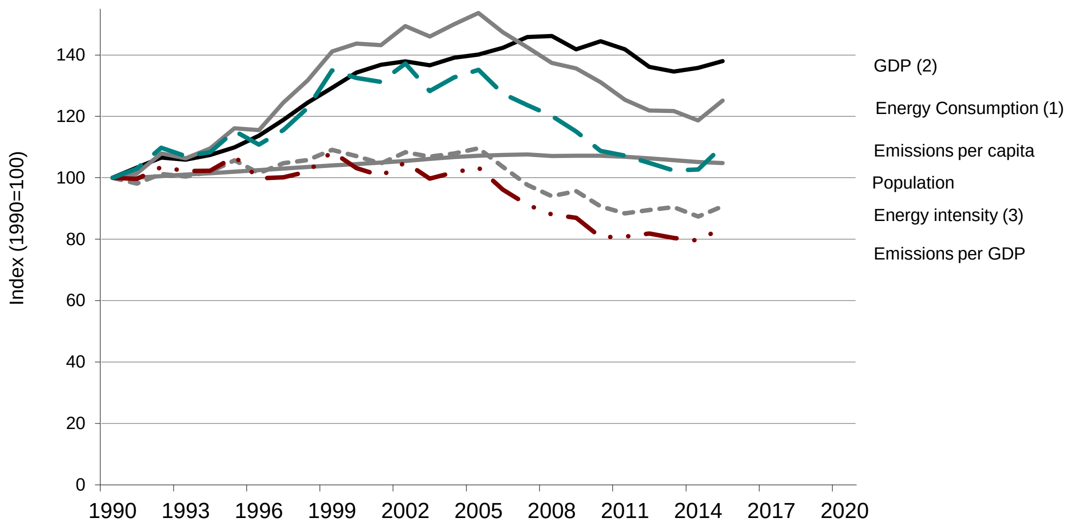
Throughout this report, emissions values are presented in CO_2e using IPCC AR4 GWP values. The reference to "total emissions" along the report is meant to refer to "total emissions without LULUCF, including CO2 indirect emissions".

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, increased efficiency in energy use and to the more recent situation of stagnation or later recession of the Portuguese economy, which has begun recovering afterwards.

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.

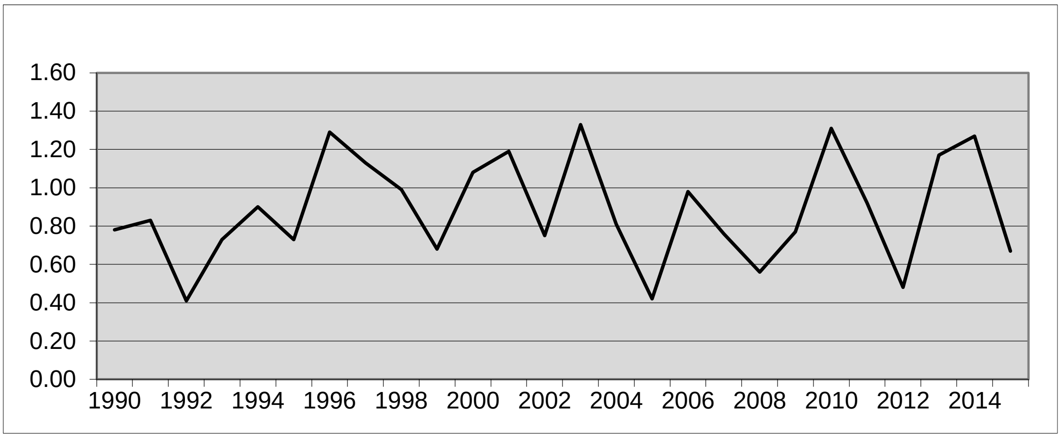
The tendencies of the latest years reflect also the recession effect of the Portuguese economy, which has been accompanied by the slowdown of industrial activity and consequent reduction in fuel consumption, and the cessation of some activities in the country such as the production of ammonia in 2009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

After the continuous decline in energy consumption (both primary and final) verified in the country since 2005, with a bigger expression after 2010, fact that may be explained by internal economic recession, along with the European economic and financial crisis, in 2015 there was an inversion of this pattern with a growth of 5.4% and 1.2% in 2015, respectively in primary energy consumption and final energy consumption.

The increase of primary energy consumption in 2015 was due to the greater use of coal and natural gas in comparison with 2014, and the final energy consumption was related to the rise of consumption in road transport, NG and electricity.

In 2015, GDP registered a positive variation of 1.6%, accelerating the tendency already verified in year before (0.9% in 2014). 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.

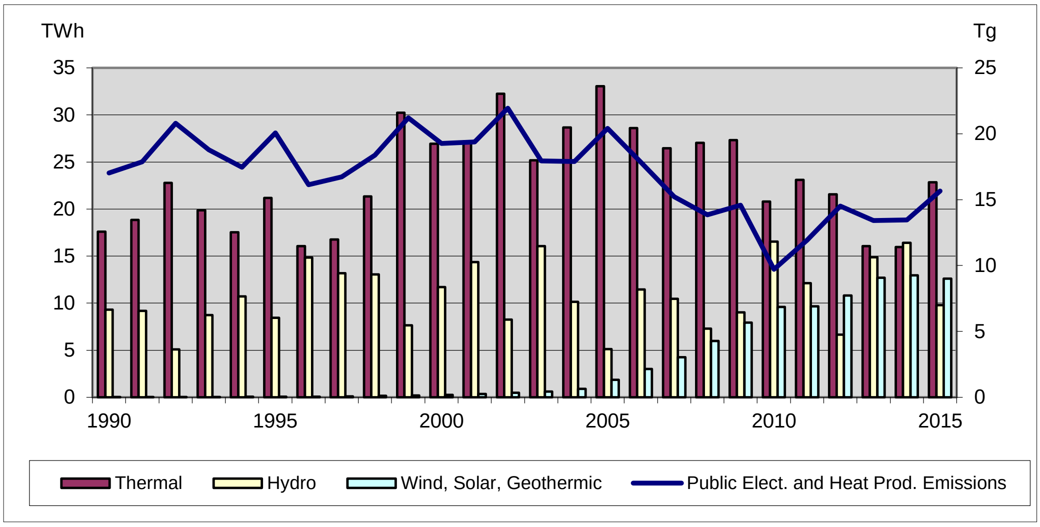


Note: HI = 1 corresponds to the average hydrologic availability.

Source: EDP, REN

After the continuous decrease of national emissions verified since 2005, the emissions registered a significant growth in 2015, with an increase of 7.1% compared to the 2014. This growth is in majority related to the energy sector, and particularly to the “energy industries”, which is partly explained by the decrease of the hydropower production in 2015 (order of -24%) due to an unfavorable year in terms of water availability (HPI = 0.67), contributing to a greater use of coal and NG in the electro producer sector and consequently to a significant increase in emissions.

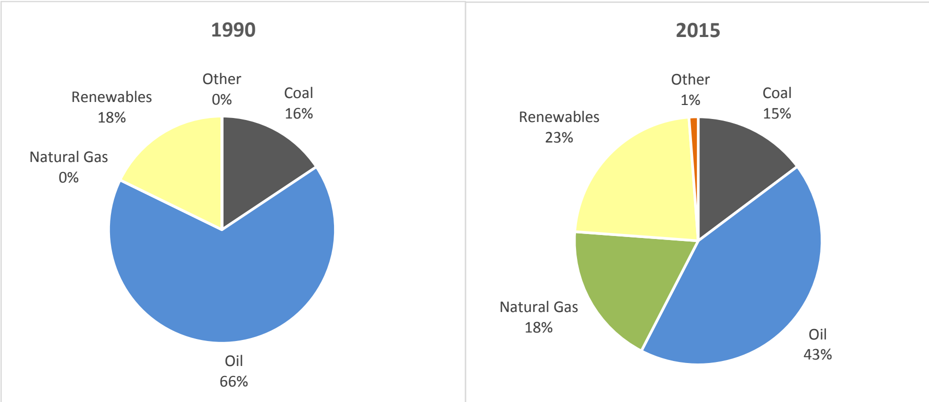
Figure 2.4 – Gross electric power production and emissions from electricity and heat generation.



Source: DGEG.

The analysis of the consumption of different energy sources in 2015, shows that Oil remains the main primary energy supply, followed by Renewables and Natural Gas. Nevertheless the weight of Oil has declined in recent years (66% in 1990 vs. 43% in 2015), whereas the importance of Renewables (18% in 1990 vs. 23% in 2015) and natural gas (non-existing in 1990) increased considerably.

Figure 2.5 – Primary energy consumption by energy source.

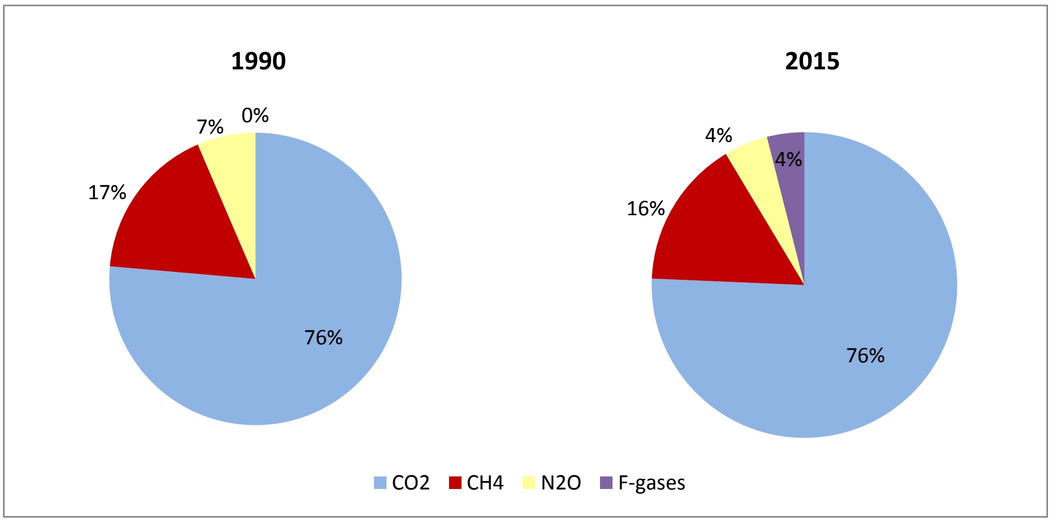


Source: DGEG.

2.2 Emissions by Gas

The figure below illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2015, being evident CO_2 as the primary GHG, accounting for about 76% of Portuguese emissions on a carbon equivalent basis in 2015 (LULUCF excluded). The second most important gas is CH_4, followed by N_2O, representing, respectively, 16% and 4% of total emissions in 2015. Portugal has chosen 1995 as the base year for fluorinated gases. In 2015 these gases represented about 4% of total GHG emissions. NF3 emissions are non-occurring in Portugal.

Figure 2.6 – GHG emissions by gas.



Over the 1990-2015 period, CO2 is the gas having registered the biggest increase (15%) and N_2O decreased by about 17%. F-gases are excluded from the figure as they are accounted since

1995, but they have been increasing importance particularly in latest years, representing in 2015 4% of the total emissions.

Figure 2.7 – Change of GHG emissions by gas over the period 1990-2015.

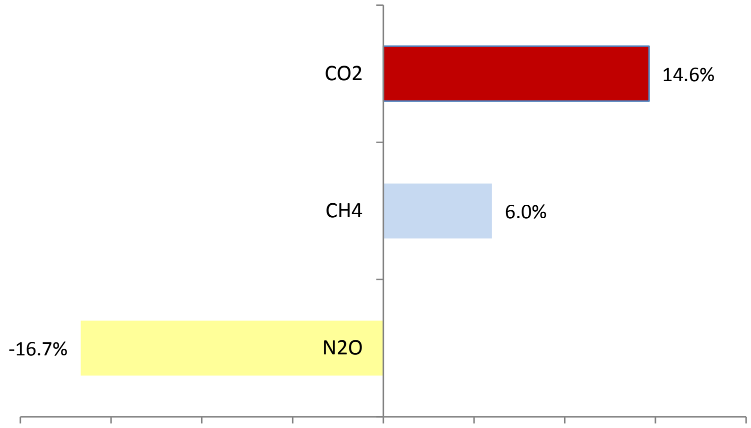


Table 2.1 – GHG emissions and removals in Portugal by gas.

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO_2 equivalent (Gg)												
CO2 emissions without net CO2 from LULUCF	45,371	46,992	51,226	49,829	50,570	54,533	51,827	54,824	59,297	66,911	65,683	65,362	69,199
CO2 emissions with net CO2 from LULUCF	45,947	47,593	47,313	44,819	44,852	49,052	42,687	44,783	50,526	57,502	58,997	55,371	59,662
CH4 emissions without CH4 from LULUCF	10,201	10,399	10,558	10,685	10,953	11,288	11,359	11,587	11,899	12,042	12,105	12,109	12,297
CH4 emissions with CH4 from LULUCF	10,406	10,675	10,646	10,760	11,072	11,543	11,456	11,626	12,104	12,149	12,290	12,220	12,468
N2O emissions without N2O from LULUCF	3,831	3,799	3,768	3,749	3,781	3,966	4,200	4,188	4,149	4,234	4,204	4,068	4,112
N2O emissions with N2O from LULUCF	4,394	4,358	4,266	4,226	4,256	4,467	4,665	4,636	4,633	4,690	4,675	4,518	4,569
HFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	35	59	101	146	212	281	365	481
PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO	NO	0	0	1	1	2	2
Unspecified mix of HFCs and PFCs	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO	NO	NO	NO	NO	NO	NO	NO
SF6	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	14	14	15	16	17	17	18	18
NF3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	**59,403**	**61,190**	**65,552**	**64,263**	**65,304**	**69,836**	**67,459**	**70,715**	**75,508**	**83,416**	**82,291**	**81,924**	**86,109**
Total (with LULUCF)	**60,747**	**62,626**	**62,225**	**59,804**	**60,180**	**65,111**	**58,881**	**61,162**	**67,426**	**74,570**	**76,260**	**72,493**	**77,200**
Total (without LULUCF, with indirect)	**59,584**	**61,365**	**65,747**	**64,454**	**65,509**	**70,035**	**67,656**	**70,920**	**75,714**	**83,627**	**82,502**	**82,101**	**86,278**
Total (with LULUCF, with indirect)	**60,928**	**62,801**	**62,420**	**59,995**	**60,385**	**65,310**	**59,078**	**61,367**	**67,632**	**74,780**	**76,472**	**72,671**	**77,369**

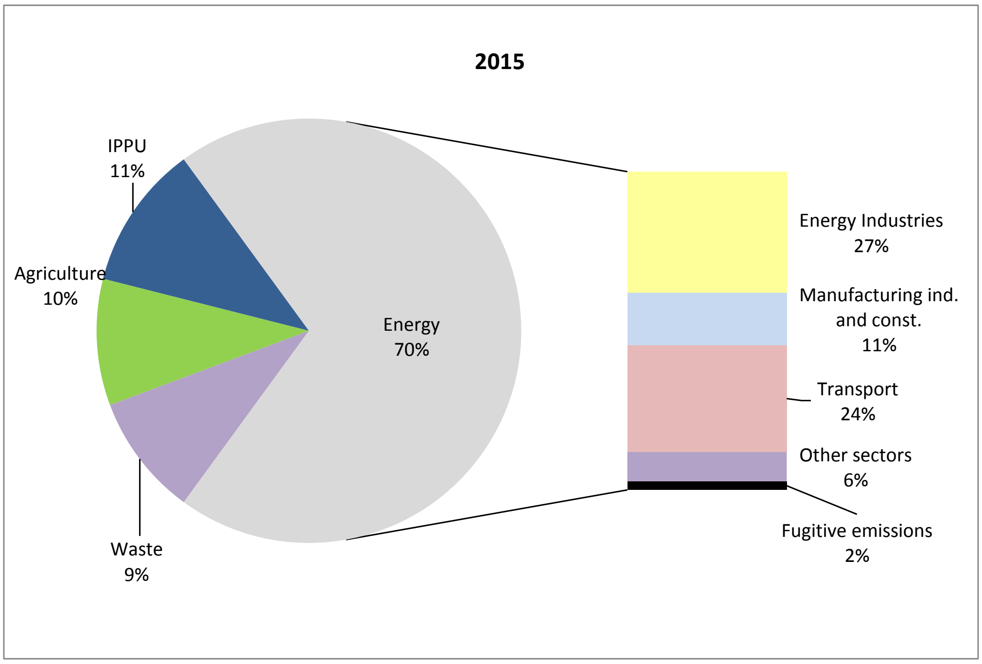
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	% change
	CO_2 equivalent (Gg)													1990-2015
CO2 emissions without net CO2 from LULUCF	64,076	66,860	69,142	64,429	61,937	59,634	56,801	52,616	51,471	49,658	47,866	47,741	52,017	**14.6**
CO2 emissions with net CO2 from LULUCF	64,468	58,294	68,565	54,929	48,960	45,259	42,450	40,707	39,588	40,108	38,807	37,400	42,810	**-6.8**
CH4 emissions without CH4 from LULUCF	12,525	12,680	12,293	12,215	12,032	11,555	11,340	11,346	11,457	11,209	10,925	10,703	10,812	**6.0**
CH4 emissions with CH4 from LULUCF	13,242	12,819	12,851	12,318	12,074	11,576	11,397	11,498	11,517	11,381	11,079	10,719	10,887	**4.6**
N2O emissions without N2O from LULUCF	3,745	3,900	3,762	3,638	3,807	3,710	3,403	3,377	3,101	3,113	3,109	3,179	3,192	**-16.7**
N2O emissions with N2O from LULUCF	4,307	4,343	4,280	4,048	4,182	4,058	3,762	3,757	3,462	3,498	3,493	3,531	3,548	**-19.2**
HFCs	617	731	907	1,088	1,321	1,569	1,764	1,910	2,078	2,216	2,383	2,535	2,679	**100.0**
PFCs	2	3	3.30	3.99	4.74	5.58	6.61	7.93	9.05	10.18	11.36	12.59	13.89	**100.0**
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	**0.0**
SF6	22	27	27	28	31	30	33	35	29	30	31	26	26	**100.0**
NF3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	**0.0**
Total (without LULUCF)	**80,986**	**84,200**	**86,134**	**81,403**	**79,133**	**76,503**	**73,347**	**69,292**	**68,145**	**66,238**	**64,325**	**64,196**	**68,740.8**	**15.7**
Total (with LULUCF)	**82,658**	**76,216**	**86,632**	**72,415**	**66,573**	**62,499**	**59,413**	**57,915**	**56,683**	**57,244**	**55,804**	**54,224**	**59,964.5**	**-1.3**
Total (without LULUCF, with indirect)	**81,157**	**84,377**	**86,308**	**81,575**	**79,309**	**76,675**	**73,507**	**69,459**	**68,304**	**66,399**	**64,494**	**64,360**	**68,915.7**	**15.7**
Total (with LULUCF, with indirect)	**82,829**	**76,393**	**86,806**	**72,587**	**66,748**	**62,671**	**59,573**	**58,083**	**56,843**	**57,404**	**55,973**	**54,389**	**60,139.4**	**-1.3**

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: 2015.

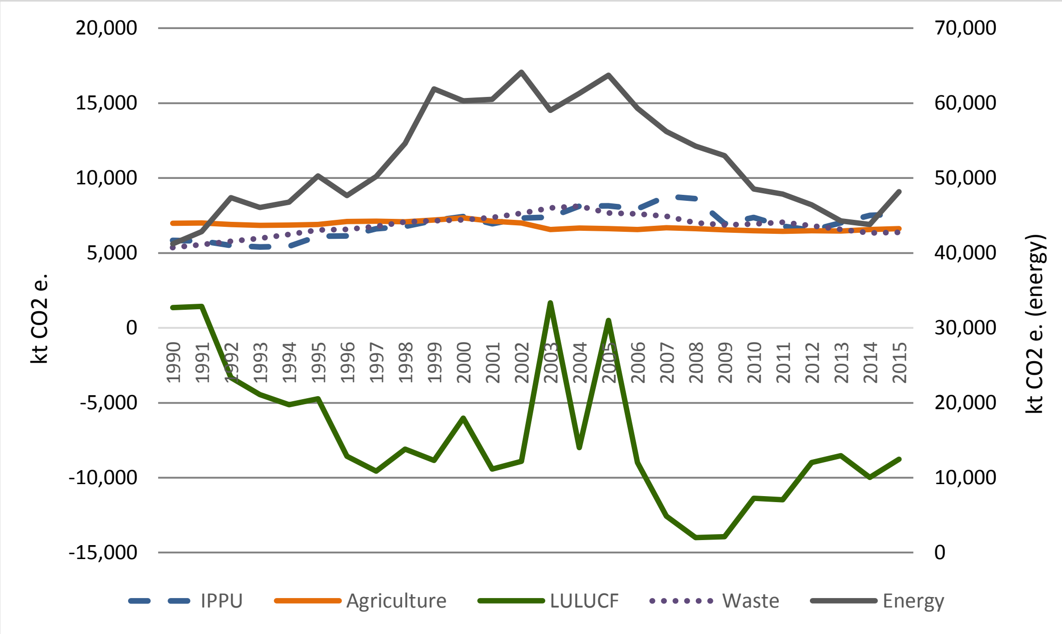


Energy is by far the most important sector, accounting for 70 % of total emissions in 2015, and presenting an increase of 17 % over the 1990-2015 period. Energy industries and transport are the two most important sources representing, respectively, approximately 27% and 24% of total emissions. Within the energy industries, public electricity and heat production represents alone 23 % 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 more recent years, were we can observe a stagnation or decrease of these trends. In 2015, this pattern was, however, interrupted due to particularly unfavourable hydrologic conditions which contributed to a greater use of coal and NG in the electro producer sector and consequently to a significant increase in emissions.

Mobile sources, which are largely dominated by road traffic, are one of the sectors that have risen faster. In the period 1990-2015 the emissions of transportation sources increased 61 %, 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. An inversion of this tendency is registered the most recent years, with an increase in transport emissions of 3.4 % from 2013 to 2015.

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 % rise), but this tendency has decelerated (7 % decrease in the 1990-2015 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 analysed, a significant source of GHG emissions, responsible for 10 % of the Portuguese emissions in 2015, corresponding to a decrease of 5 % since 1990. This fact is related to the relatively decrease of importance of the sector in terms of the national economy, and also 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 related to the conversion of arable crops to pastures.

Waste represented approximately 9 % of Portuguese emissions in 2015, recording an increase of approximately 19 % 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 11 % of the Portuguese emissions in 2015, and have grown 30 % 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 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 (1.3 Mt CO2e) 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 2015 this sector represents a sequester of -8.8 Mt CO2e.

Figure 2.10 – GHGs emissions percentage change (1990-2015) by IPCC category (LULUCF excluded).

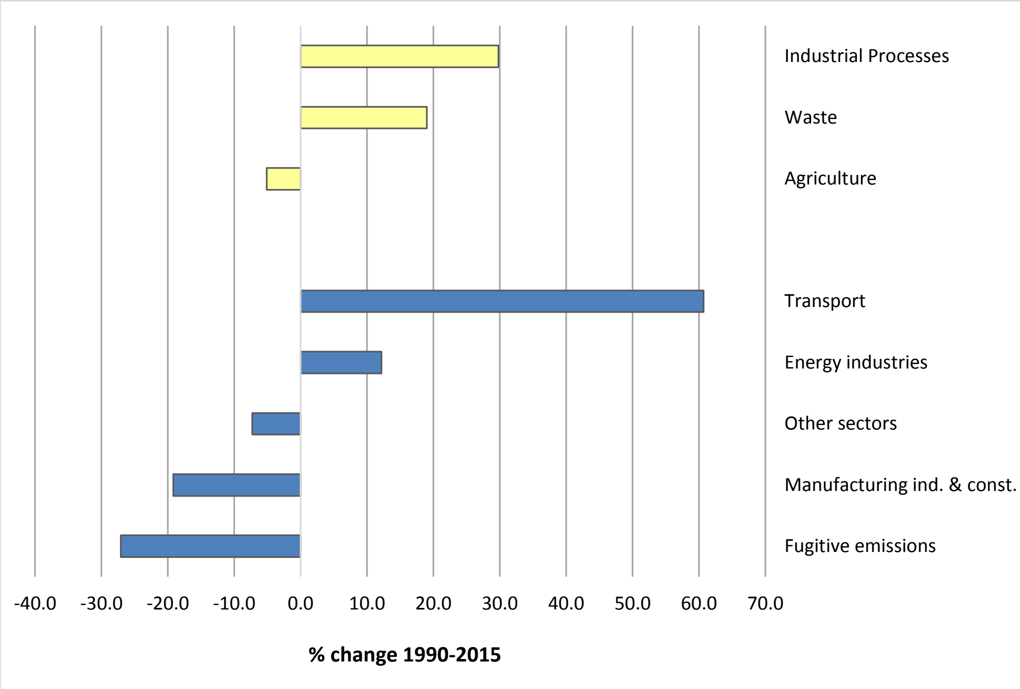


Table 2.2 – GHG emissions and removals by sector.

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO_2 equivalent (Gg)												
1. Energy	41,222	42837.714	47,376	46,063	46,768	50,291	47,655	50,209	54,603	61,907	60,311	60,493	64,129
2. Industrial processes and product use	5,839	5800.7327	5,504	5,398	5,429	6,107	6,131	6,608	6,772	7,168	7,421	6,956	7,319
3. Agriculture	6,981	7001.1512	6,891	6,838	6,864	6,903	7,100	7,124	7,071	7,203	7,344	7,113	7,007
4. Land use, land-use change and forestry(5)	1,344	1436.1064	-3,327	-4,459	-5,123	-4,724	-8,578	-9,553	-8,082	-8,847	-6,031	-9,431	-8,908
5. Waste	5,361	5550.3718	5,782	5,965	6,243	6,535	6,573	6,775	7,063	7,139	7,215	7,361	7,654
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

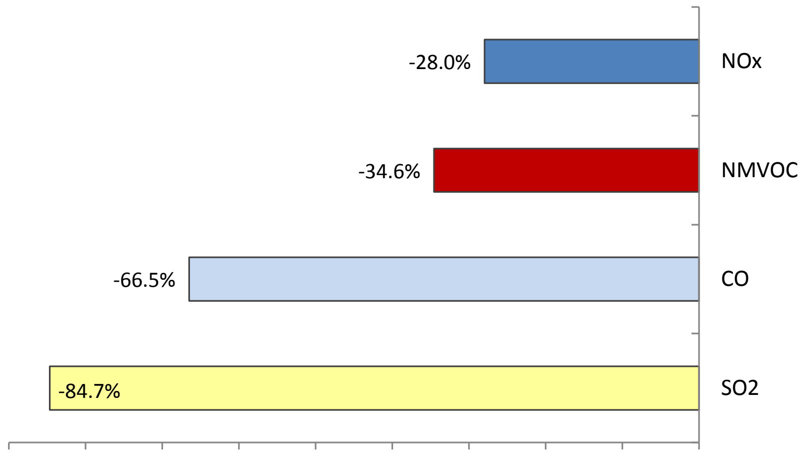
GHGs SOURCE AND SINK	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	% change
	CO_2 equivalent (Gg)													1990-2015
1. Energy	59,038.61	61,303.39	63,708.45	59,317.52	56,210.27	54,241.84	52,998.33	48,530.40	47,870.85	46,422.83	44,280.28	43,786.66	48,157.50	**16.8**
2. Industrial processes and product use	7,390.74	8,112.36	8,138.95	7,934.81	8,788.26	8,623.19	6,943.93	7,367.93	6,788.13	6,514.21	7,002.50	7,503.08	7,578.89	**29.8**
3. Agriculture	6,552.93	6,663.75	6,613.00	6,551.88	6,681.10	6,630.12	6,541.58	6,472.12	6,436.58	6,481.31	6,468.34	6,566.04	6,623.53	**-5.1**
4. Land use, land-use change and forestry(5)	1,671.89	-7,984.21	497.83	-8,987.83	-12,560.38	-14,004.39	-13,933.93	-11,376.84	-11,461.53	-8,994.41	-8,521.52	-9,971.68	-8,776.33	**-753.2**
5. Waste	8,004.04	8,120.72	7,674.08	7,599.01	7,453.69	7,008.20	6,862.70	6,921.27	7,049.17	6,819.89	6,574.23	6,339.83	6,380.89	**19.0**
6. Other	NO	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 SOx emissions

Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NOx, and NMVOC are precursor substances for ozone which is a GHG. SOx 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_x emissions: 1990-2015 variation.



In 2015, all these gases emissions have decreased from 1990 levels: SO_x -85 %, CO -67 %, NMVOC -35 % and NOx -28 %.

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

Within energy, transportation is responsible for the major share of NO_x, emissions, approx. 46 % of 2015 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 since 2005. In the most recent years the situation has been inversed with an increase of emissions after 2013. In the period analysed, 1990-2015, NO_x emissions from transport decreased -10 per cent; and CO and NMVOC emissions registered reductions of more than -85 per cent.

Other sectors (commercial/institutional, residential and agriculture/forestry) is a primary source of CO emissions representing 51 % of the 2015 totals.

SO_x emissions are mainly generated in the energy industry sector (approximately 30 % of total emissions in 2015) and combustion in manufacturing industries (approximately 35 % of total emissions in 2015), 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^{th}). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO_x emissions. The emissions variation in the period 1990-2015 shows a substantial decrease in SO_x emissions in both sub-categories: energy industries and manufacturing industries -93 % and -79 %. Since 2007, SO_x emissions from the energy industries registered a significant reduction (approximately -87 %) 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: 1990-2015.

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							(Gg)						
CO	801	815	853	832	812	800	787	752	728	702	651	570	552
NOx	245	256	275	266	266	276	264	262	269	277	274	273	280
NMVOC	275	281	287	277	279	274	276	275	276	270	259	249	248
SO2	324	315	376	320	296	332	273	288	336	303	264	250	250

Gas emissions	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	% change 1990-2015
					(Gg)									
CO	512	480	440	409	385	360	340	323	303	288	281	274	268	**-66.5**
NOx	256	262	267	245	240	214	203	189	180	173	171	170	176	**-28.0**
NMVOC	234	227	215	209	204	195	185	186	178	174	175	174	180	**-34.6**
SO2	191	193	195	170	163	114	79	70	65	60	54	48	50	**-84.7**

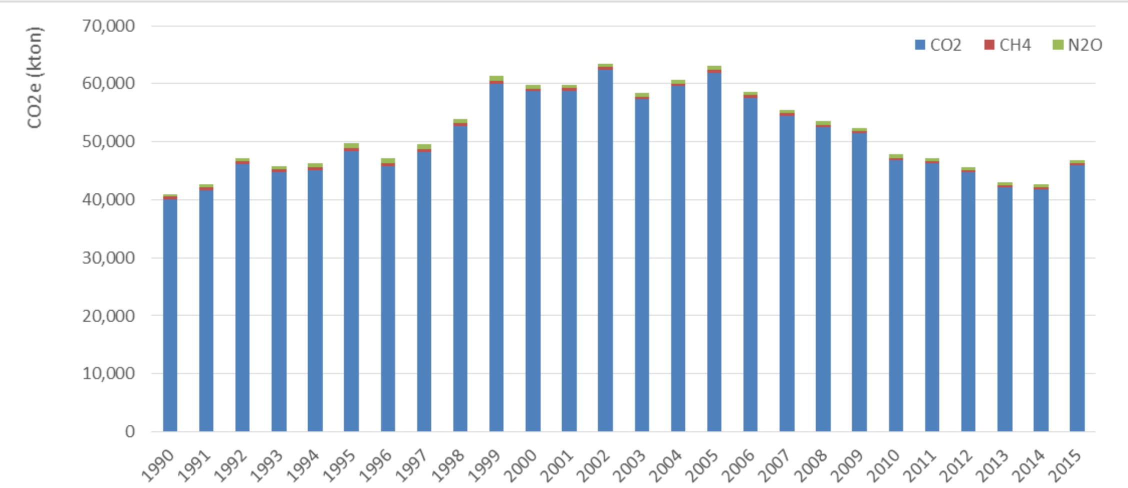
3 ENERGY (CRF 1.)

3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting in 2015 for 70.1 % of total emissions of CO_2e excluding LULUCF and including indirect CO2. Total emissions from this sector have increased 16.8 % 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_2e 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.

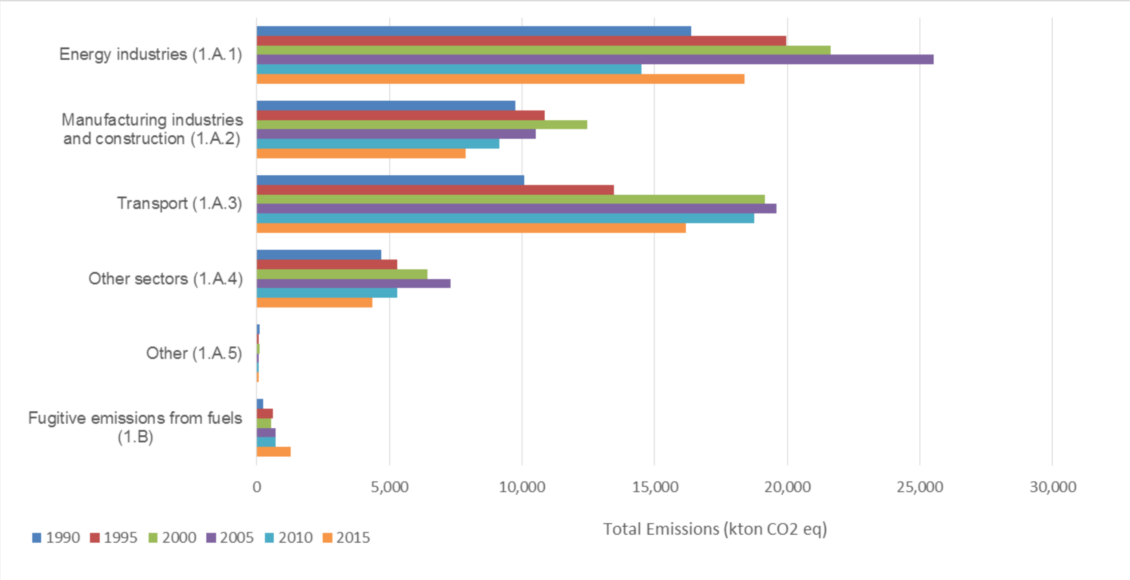
The relative importance of total CO_2e emissions from the Energy sector has incresed, from 69.4 % in 1990 to 70.1 % in 2015. By far the most important gas emitted by this sector in 2015 is CO_2, with 98.2 % of sector emissions expressed in CO_2e.

Figure 3.1 – Total CO_2e 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 2015 (except for 1A1 and 1B).

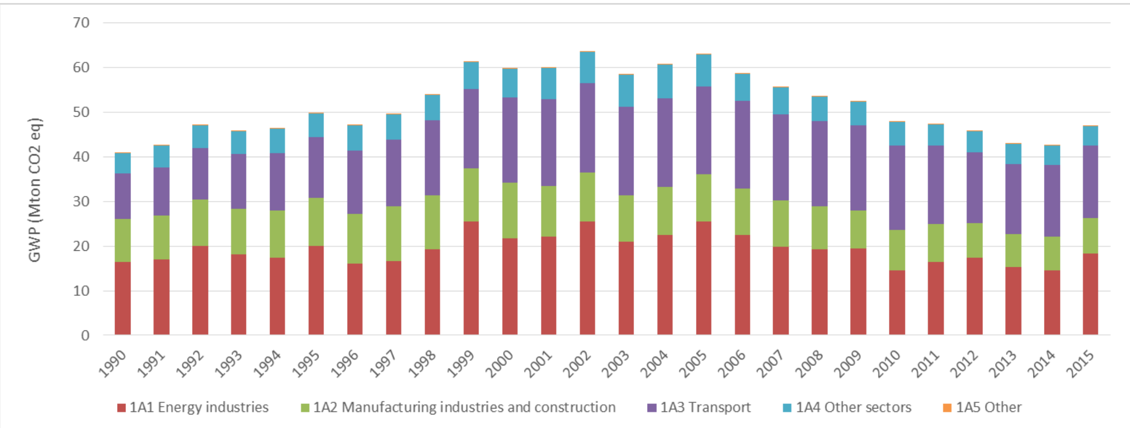
Figure 3.2 – Importance of CO_2e emissions from sub-sectors in Energy sector in selected years – 1990, 1995, 2000, 2005, 2010 and 2015.



3.1.1 Fuel Combustion Activities (CRF 1.A.)

Energy emissions are primarily related to fossil fuel combustion. In Portugal energy industries and transports were the primary sources of Portuguese GHG emissions, representing, respectively, 26.7 % and 23.6 % of total GHG emissions excluding LULUCF in year 2015. 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 % of total emissions in 2015. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 6.3 % 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_2e, by sub-sector.



GHG emissions from this activity sector are almost fully dominated by direct CO_2 emissions, which represent about 98.2 % of GHG emissions in 2015. CH_4 and N_2O are minor sources, respectively 0.7 % and 1.1 % of total GHG emissions from the 1 A sector in 2012.

CO_2 emissions are dependent on the carbon content of the fuel used and, for this reason, estimates of CO_2 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_4, CO, NMVOC and airborne particulate matter. It is presumed that all these other carbon containing non-CO_2 gases oxidise to CO_2 in the atmosphere and are include in carbon dioxide estimates (ultimate CO_2)[2].

Emissions from fossil fuel combustion include also other atmospheric contaminants such as N_2O, NO_x, SO_x; NH_3, particulate matter, heavy metals and toxic organic compounds. Unlike CO_2, 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_2, 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_2 pool. This activity is reported separately for information purposes only. Nevertheless non-CO_2 emissions from combustion of biofuels and other biomass fuels are however considered in inventory totals.

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

Apart from fuel combustion emissions, the Energy sector includes also other from production, transmission, storage and distribution of fossil fuels. Generated gases from these sources are CO_2, NMVOC, SO_x, CH_4, NO_x 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_2 are responsible for 92.0 % of 1B total emissions in 2015, emissions occurring as CH_4 represent 7.8 % of 1B total emissions and N_2O represent only 0.2 %. Emissions by gas are represented in Figure 3.5..

[2] Three CO_2 quantities may be referred in the inventory with different definitions: (1) End of pipe CO_2 - Carbon dioxide effectively emitted from the source: exhaust, chimney, etc; (2) Ultimate CO_2 - carbon dioxide increase contribution to atmosphere. Includes end of pipe CO_2 but also the conversion of other gases and particles that are emitted to atmosphere containing carbon and that are supposedly latter converted in CO_2; (3) Fossil ultimate CO_2 - CO_2 emissions resulting from carbon with fossil origin: fossil fuels, mineral rocks and all other non biomass carbon.

Figure 3.4 – Trend of total GHG emissions in source 1B, expressed as CO_2e, by sub-sector.

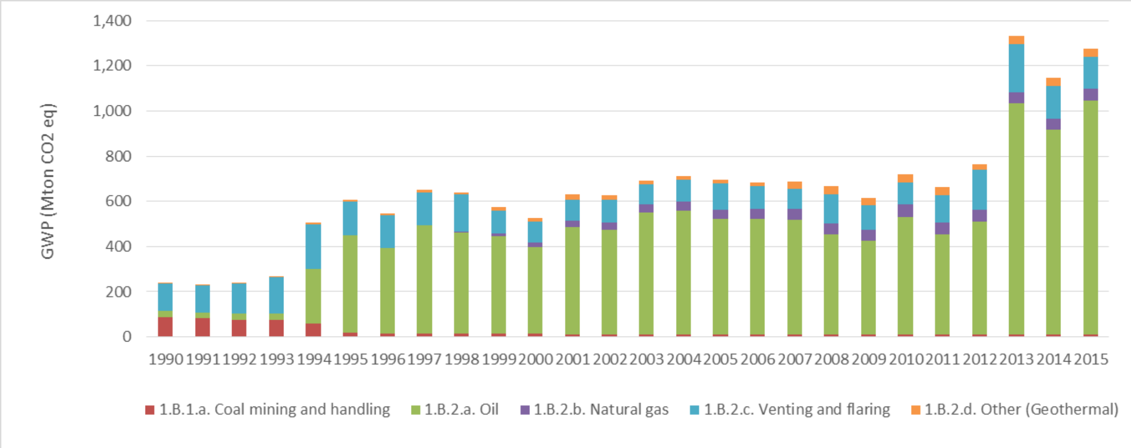
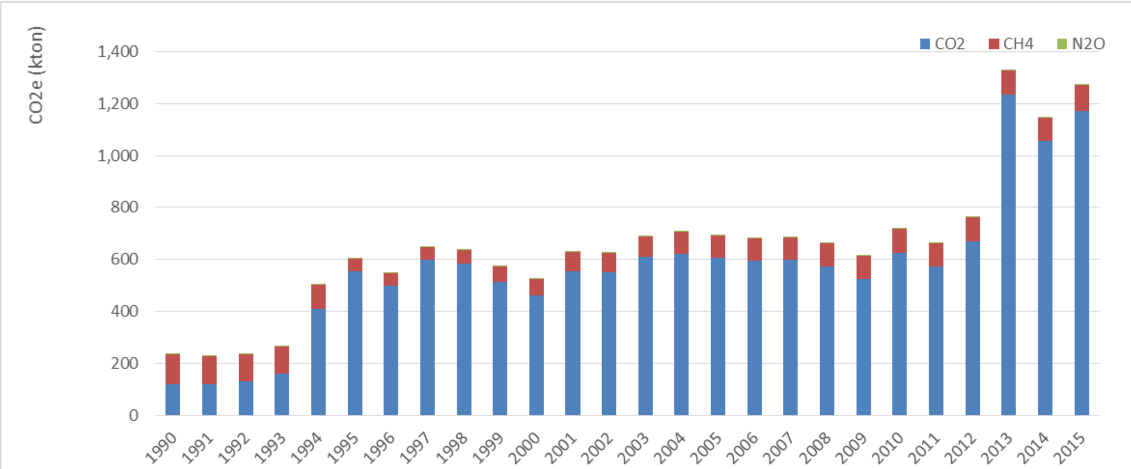


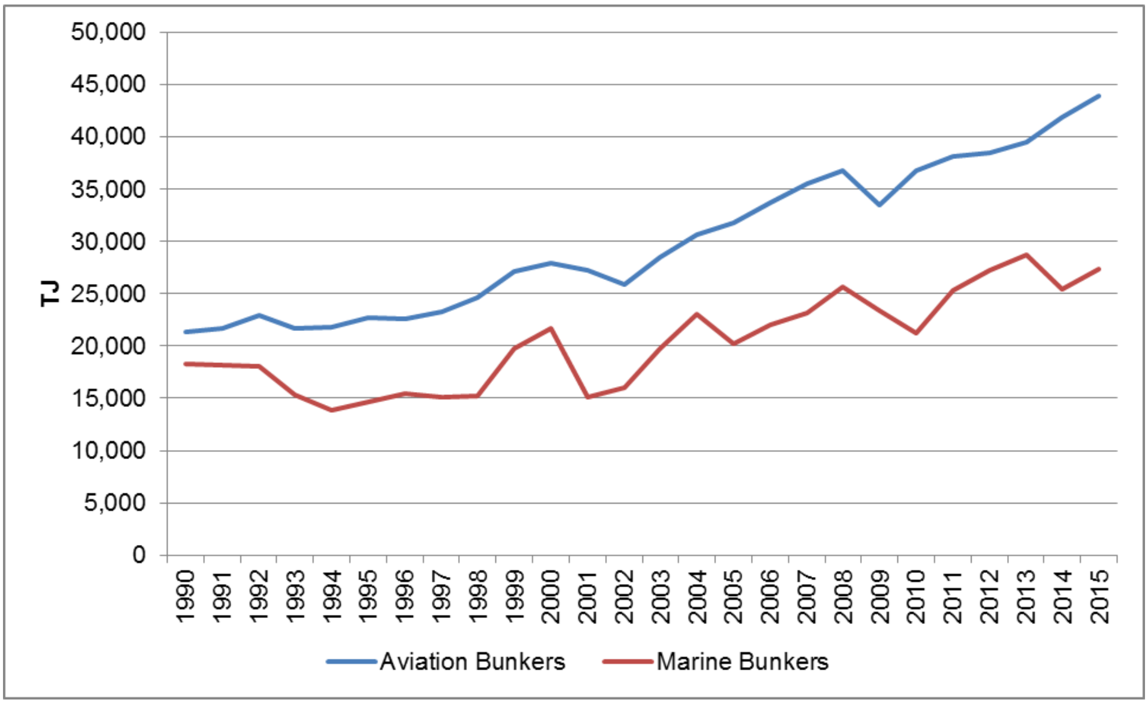
Figure 3.5 – Trend of total GHG emissions in source 1B, expressed as CO_2e, by GHG.



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.



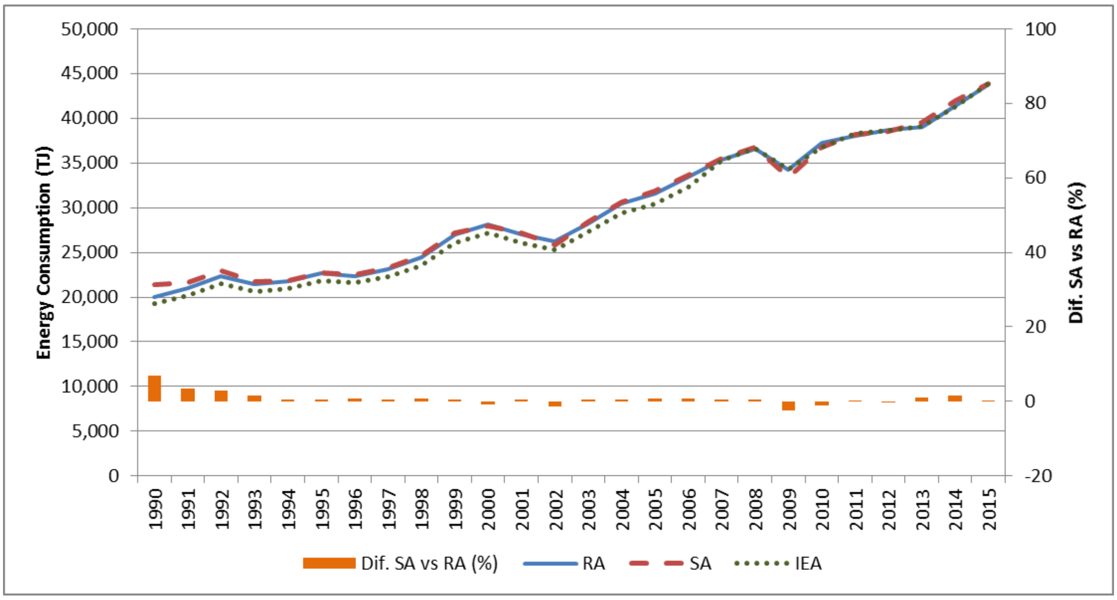
3.2.1 International aviation bunkers

The majority of jet fuel is used for international aviation. In 2015 the quantity of jet fuel for international aviation was about 90% 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. For the period between 1990 and 2006, the reference approach uses the energy consumption data from EUROSTAT.

The 1990 peak in the diference between sectoral approach and reference approach is due to a question raised during the 2016 UNFCC centralized review related with a higher consumption of jet kerosene in civil aviation. This question lead to the indentification of an error in the cruise cunsumption compilation and the correction of the jet kerosene consumption in that year.

Figure 3.7 – International aviation bunkers.



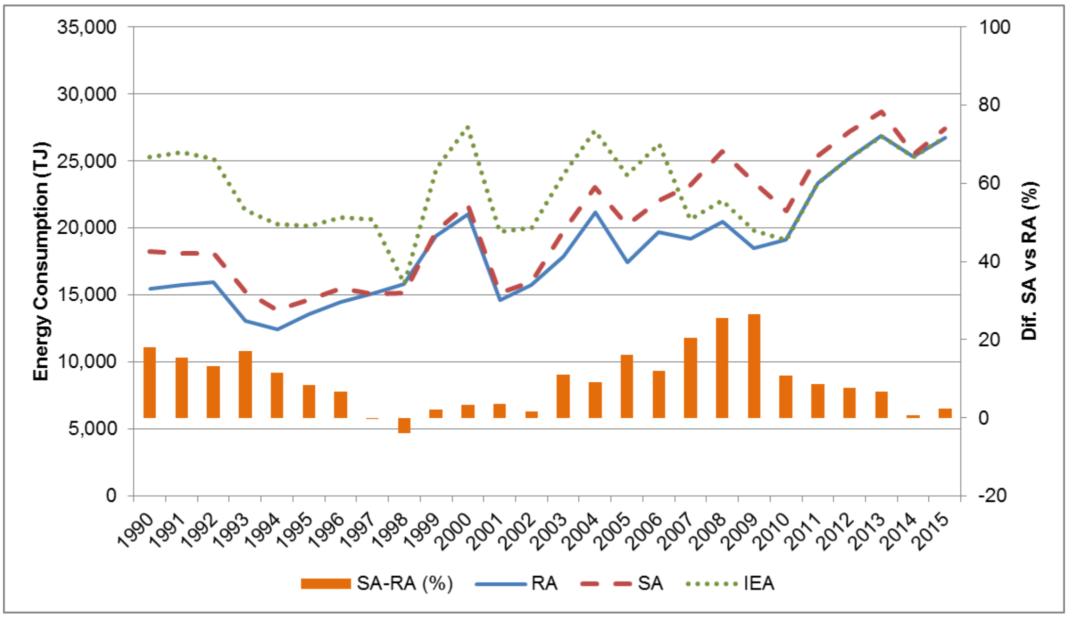
3.2.2 International marine bunkers

In 2015 the energy consumption for international navigation was about 89% of the total energy used in marine navigation. This percentage was estimated according with the origin and destiny of the flight as recommended by 2006 IPCC guidelines.

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

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

Figure 3.8 – 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[3] 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

[3] TER – Termoeléctrica do Carregado

economic activity occurs. The present source sector includes only emissions resulting from main power producers[4].

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

[4] 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)	-
Energin	Alhandra	2002	Deactivated (2014)	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	Deactivated (2013)	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	Deactivated (2013)	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 Orimolsion, 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_2 emissions are absorbed by lime, forming CO_2 and plaster (gypsum + H_2O) as by-products:

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$CaCO_3 + H_2SO_3 \rightarrow CaSO_3 + CO_2 + H_2O$$
$$CaSO_3 + 1/2O_2 + 2H_2O \rightarrow CaSO_4.2H_2O$$

These equations show that the wet flue gas desulfurization reduces the SO_2 emissions but increment de CO_2 emissions.

Since there is no CRF category specific for desulfurization, total CO_2 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
Vitória	Funchal	FO + GO + NG	326.4 MWt
Caniçal	Caniçal	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_2 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_2 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_2 and ultimate CO_2 emissions from fossil origin were estimated from:

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

$$Fossil_{CO2(y)} = \Sigma_u \Sigma_f \left[U_{CO2(u,f,y)} * C_{Fossil(f)} * 10^{-2}\right]$$

$U_{CO2(y)}$ – Total carbon released to atmosphere from consumption of fuel f in unit plant u, expressed in total carbon dioxide emissions (t);

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

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

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

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

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

This formula reflects the fact that some carbon in fuel is not oxidized and not emitted to atmosphere. Although, some carbon in the fuel is not released directly as carbon dioxide but instead in the form of carbon monoxide, methane, volatile organic compounds and even in soot, ash and particulate matter as consequence of the incomplete combustion of fuel. Emissions of these compounds in airborne fraction are transformed sooner or later into CO_2 in the atmosphere or after deposition on soil. Emissions of CO_2 at stack exhaust (End-of-pipe emissions) may be estimated from final CO_2 emissions from:

$$Stack_{CO2} = U_{CO2} - 44/12*(NMVOC * C_{NMVOC} + CO * 12/28 + CH_4 * 12/16 + TPM * C_{TPM}) * 10^{-3}$$

where:

$Stack_{CO2}$ - end of pipe emissions of carbon dioxide (kt);

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

CO - carbon monoxide emissions (t);

CH_4 - Methane emissions (t);

TPM - Total Particulate Matter emissions (t);

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

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

Since EU-ETS data is available for inventory use 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:

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

where:

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

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

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

3.3.1.1.2.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

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

$$CO_2\ Emission_{(u,y)} = CaCO_{3Cons(u,\ y)} * CO_2Ratio * 10^{-3}$$

$$SO_2\ Removal_{(u,y)} = CaCO_{3Cons(u,\ y)} * SO_2Ratio * 10^{-3}$$

CO_2 $Emission_{(u,y)}$ – Emission of CO_2 estimated from $CaCO_3$ consumption in power plant u in year y(t);

SO_2 $Removal_{(u,y)}$ – Quantity of SO_2 not emitted estimated from $CaCO_3$ consumption in power plant u in year y(t);

$CaCO_{3Cons(u,\ y)}$ – Consumption of $CaCO_3$ in power plant u in year y(t);

CO_2Ratio – Ratio between CO_2 emitted and $CaCO_3$ consumption;

SO_2Ratio – Ratio between the SO_2 removed and $CaCO_3$ consumption;

Since both energy plants are included in the EU-ETS the CO_2 ratio reported under this scheme was used in the inventory – 0.44 t CO_2/t Ca. Monitoring data from the two plant was used for determining the SO_2 ratio: estimation based in $CaCO_3$ consumption and the difference between the expected SO_2 emissions without abatement system (based in the fuel sulphur content) and what was actually emitted. Because of this the SO_2 ration is plant specific and varies over time.

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

3.3.1.1.3 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 2006 Revised Guidelines (IPCC,2006);
- 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	UCO2 (i) kg/GJ	Fac_{OX} (i) 0..1	FossilC %	CH4 (i) g/GJ	N2O (i) g/GJ
Lignite	101.0	1.00	100	1.0	1.5
Hard Coal	96.1	1.00	100	1.0	1.5
Fuel-oil	77.4	1.00	100	0.8	0.3
Orimulsion	77.0	1.00	100	3.0	0.6
Natural Gas	56.1	1.00	100	1.0	1.0 – 3.0
LPG	63.1	1.00	100	1.0	0.1
Biomass	112.0	1.00	0	11.0	7.0
Diesel	74.1	1.00	100	3.0	0.6

(i) IPCC (2006);

The following table shows the plant specific CO_2 emission factors obtained in the EU-ETS.

Table 3.4 – CO_2 Emission Factors for energy production sector – Plant specific.

Fuel	UCO2 (i) kg/GJ	Fac_{OX} (i) 0..1
Hard Coal	92.4 - 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 2006 Revised Guidelines (IPCC,2006);
- 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[5].

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

Region	Fuel	U_{CO2} (i) kg/GJ	Fac_{OX} (i) 0..1	$Fossil_C$ %	CH_4 g/GJ	N_2O (i) g/GJ
Azores	Fuel-oil	77.4	1.00	100	3.0	0.6
Azores	Diesel oil	74.1	1.00	100	3.0	0.6
Madeira	Fuel-oil	77.4	1.00	100	3.0	0.6
Madeira	Diesel oil	74.1	1.00	100	3.0	0.6
Madeira	LPG	63.1	1.00	100	1.0	0.1
Madeira	Natural Gas	56.1	1.00	100	1.0	3.0

(i) IPCC (2006);

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

Fuel	U_{CO2} (i) kg/GJ	Fac_{OX} (i) 0..1	$Fossil_C$ %	CH_4 g/GJ	N_2O (i) g/GJ
LPG	63.1	1.00	100	1.0	0.1
Fuel –oil	77.4	1.00	100	3.0	0.6
Diesel oil	74.1	1.00	100	3.0	0.6
Natural Gas	56.1	1.00	100	1.0	1.0

(i) IPCC (2006);

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:

[5] Power producers as main activity only.

- 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*)[6];
- 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 t or cubic meters of gas together with the Low Heating Value [7] for that specific year from where consumption of fuels in energy units are calculated from:

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

or:

$$\text{Energy (GJ)} = \text{Consumption (Nm}^3\text{/year)} * \text{LHV (MJ/Nm3)}$$

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

Table 3.7 – Low Heating Value per fuel type.

Fuel	LHV/NCV	
Lignite	16.42 (15.57 - 17.02)	MJ/kg
Hard Coal	25.62 (24.45 - 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	38.16 (36.02 - 39.16)	MJ/Nm^3
GPL	47.44 (47.28-48.55)	MJ/kg
Biomass	7.8	MJ/kg

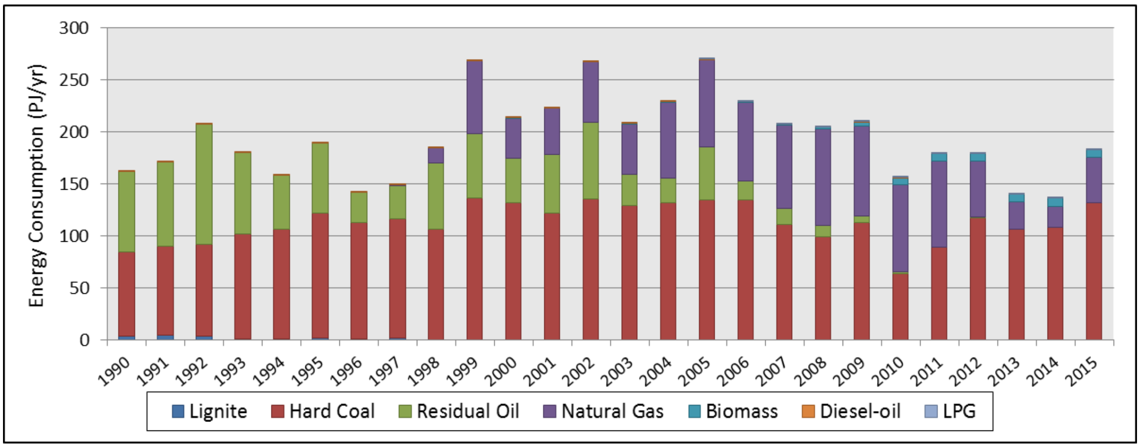
Source: The same as for the fuel consumption (including in some cases plants specific information)

[6] The *Auto-controlo* program is a legal obligation for major emitters.

[7] 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.

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 2015 (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 franction of total fuel consumption in this sector (less than 0.001 %). 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. In 2015 there is an increase in the consumption of Coal and Natural Gas, largely due to a dry year, reducing in this way the potential producer of hydro power plants

3.3.1.1.4.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

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

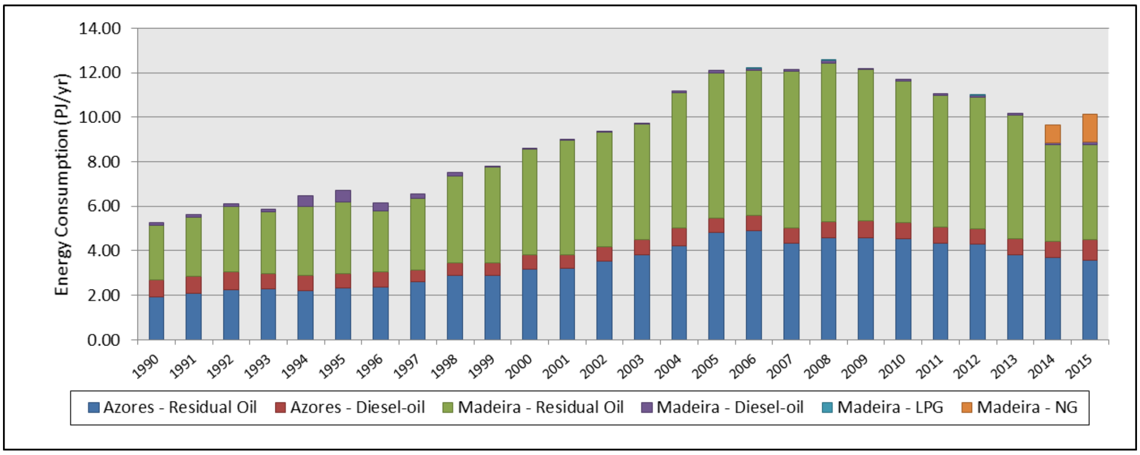
3.3.1.1.4.3 Energy Plants in Azores and Madeira Autonomous Regions

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.

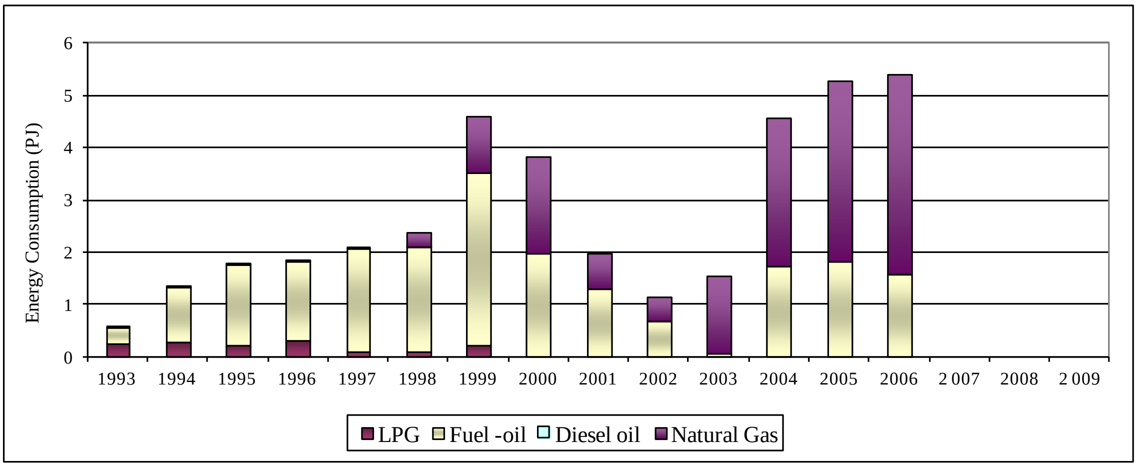
Region	Fuel type	LHV/NCV (MJ/kg)
Azores	Residual fuel oil	40.17
	Diesel oil	43.30
Madeira	Residual fuel oil	40.17
	Diesel oil	43.30
	LPG	47.28
	Natural Gas	37.9 – 38.0

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^3)

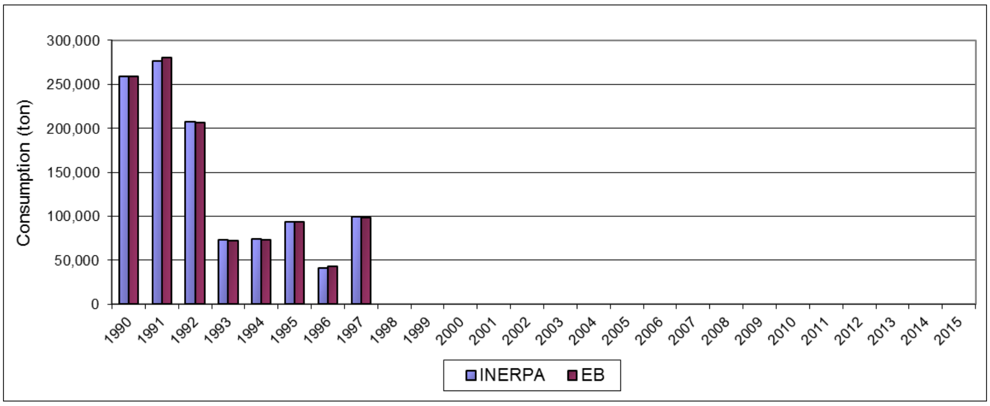
Source: The same as for the fuel consumption

3.3.1.1.4.5 Comparison of LPS data vs. National Statistics

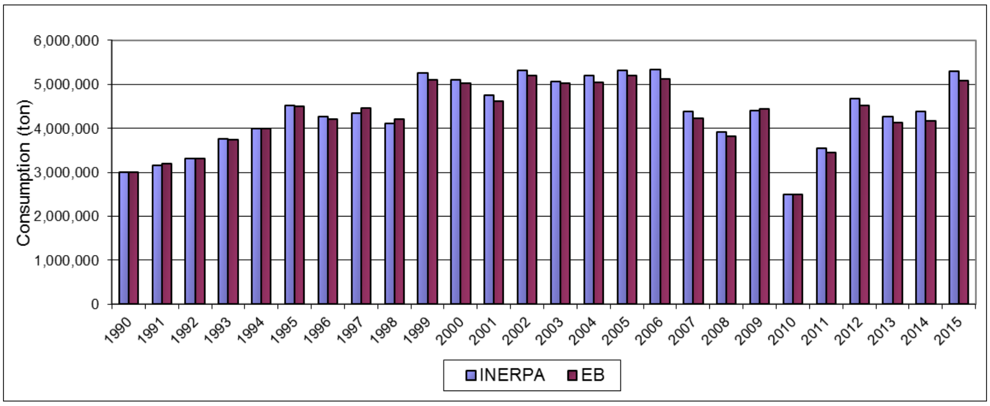
Consumption of fuel for electricity production in large units is also published in the Energy Balance of DGEG. Total consumption in all units was compared between the data in the inventory (INERPA) and the Energy Balance (EB) and graphs for the most important energy sources are presented in the figures below. For this analyses contacts were made with DGEG to obtain 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.

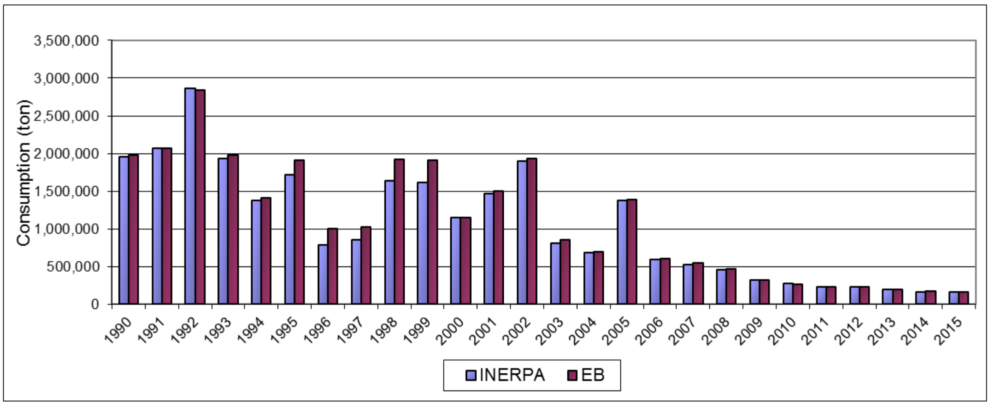
Lignite



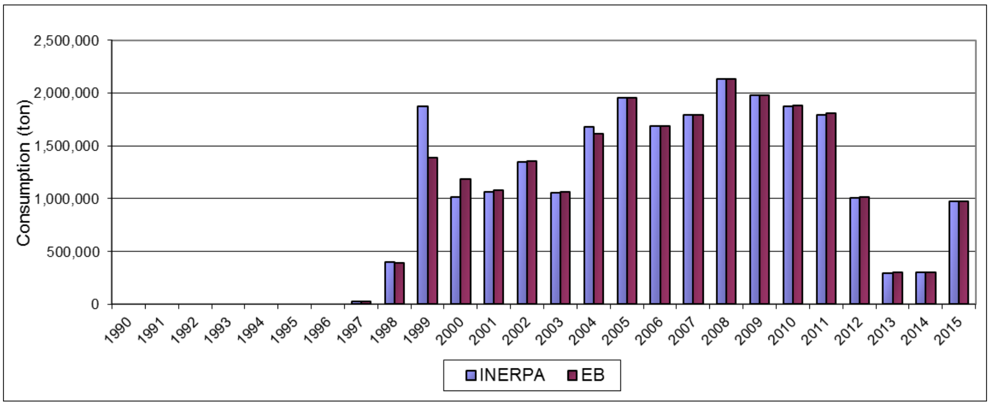
Hard Coal



Residual Fuel Oil



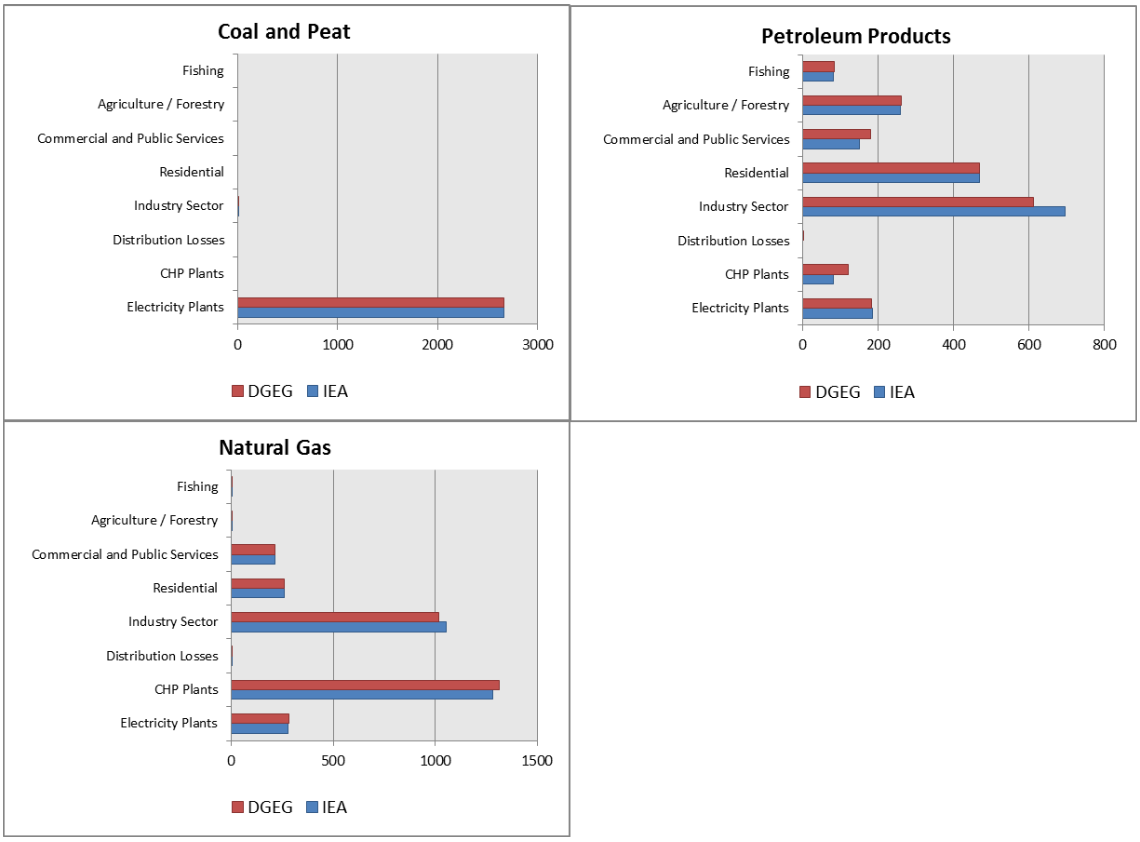
Natural Gas



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 collect 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 fuels 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 2014, 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 explained that the differences are due to the criteria used by the IEA when counting fuel consumption for production of heat in cogeneration: IEA only counts the sold consumption, while the Energy Balance considers all the heat.

3.3.1.1.5 Uncertainty Assessment

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

- for LPS the uncertainty value was set at 1 %, which is in the higher range of the uncertainty considered in GPG when good quality surveys are considered, which is the case; For some older information was employed the value of 2 % uncertainty;

- for area sources an uncertainty of 5 % 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 CO2 varies between 2 and 17 %, lower values are associated with monitoring facilities and the highest values correspond to default emission factors for fuels such as biomass. The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 % for CH_4 and 150 % for N_2O.

The EU-ETS defines a maximum uncertainty value of 7.5 % for the $CaCO_3$ consumption data reported by each plant.

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

3.3.1.1.6 Category-specific QA/QC and verification

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

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

3.3.1.1.7 Recalculations

Update of gas and biomass fuel consumption activity data for 2012, 2013 and 2014.

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[8] has set to streamline data collection for the inventories and for the EU-ETS[9]. 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.

[8] European Commission.

[9] European CO2 trading scheme.

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, xilene, 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_x 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_2 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_2 and of ultimate CO_2 from fossil origin were estimated using the following equation set:

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

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

where:

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

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

EF_C – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO_2/GJ);

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

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

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

For 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 (t);

$Energy_{Cons(e,f,y)}$ - 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_2 emission factors were obtained directly from EU-ETS data. For Lisbon refinery, CO_2 emission factors were derived from the 2006 IPCC Guidelines.

The same set of CH_4 and N_2O emission factors were used for all three refineries and were obtained in the 2006 IPCC Guidelines. 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	U_{CO2} kg/GJ(i)	Fac_{OX} (i) 0..1	$Fossil_C$ %	CH_4 (ii) g/GJ	N_2O (ii) g/GJ
Fuel-oil	var	0.995-1.000	100	3.0	0.6
Fuel gas	var	0.995-1.000	100	1.0	0.1
LPG	var	0.995	100	1.0	0.1
Diesel oil	var	0.990-1.000	100	3.0	0.6
Natural Gas	var	0.995-1.000	100	1.0	0.1
Acid Soluble Oil (ASO)	var	0.990-1.000	100	3.0	0.6
Off Gas	var	0.995-1.000	100	3.0	0.6
Tail Gas	var	0.995-1.000	100	3.0	0.6

(i) EU-ETS; (ii) 2006 IPCC Guidelines

3.3.1.2.4 Activity Data

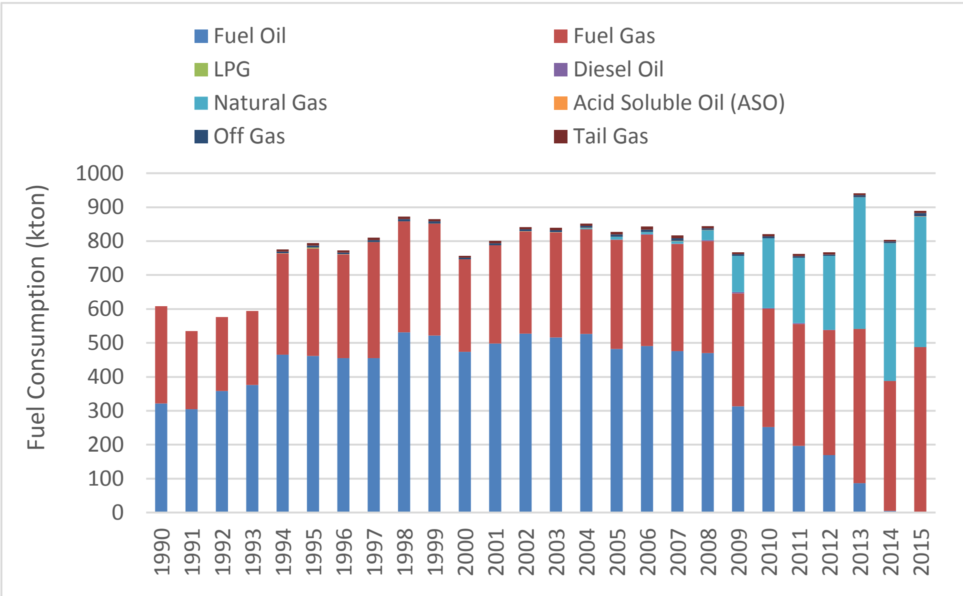
In 1990 there were three oil refining plants in Portugal: Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed and only two units remain now in operation.

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 and the use of fuel oil (RPC) less relevant. In one of the refineries there is also consumption of Acid Soluble Oil (ASO), Off Gas and Tail Gas.

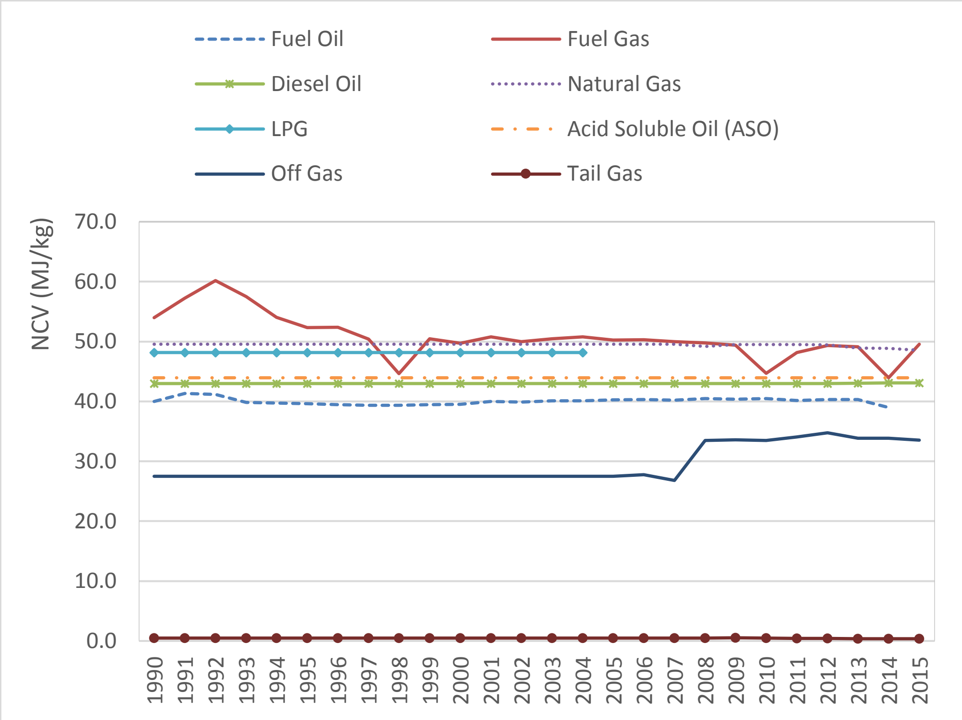
Figure 3.14 – Fuel consumption in Refineries.



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.

In 2015 there is no fuel oil consumption and there is an increase in fuel gas consumption. Fuel Oil CO2 emission factor lies between 3.15-3.17 t CO2/t fuel oil and fuel gas CO2 emission factor lies between 2.55-2.74 t CO2/t fuel gas. The decrease in the implied emission factor for liguid fuels is due to the increase of the contribution of a fuel with a lower emission factor (fuel gas).

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 %, in accordance with the fact that all data was obtained from direct inquiry to refinery units.

The uncertainty associated with the CO_2 emission factor is 5 %, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 % for CH_4 and 1000 % for N_2O.

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_2 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[10].

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_2), total emissions and ultimate fossil emissions are estimated using:

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

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

where:

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

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

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

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

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

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

For CH_4, N_2O and other GHG when the energy consumption approach is used the equation simplifies to:

$$Emi_{(p)} = \Sigma_f \Sigma_s \Sigma_t [EF_{(p,f,s,t)} * Energy_{(f,s,t)}] * 10^{-6}$$

where:

$Emi_{(p)}$ - Total emissions of pollutant p (t/yr except CO_2 in kt/yr);

$EF_{(p,f,s,t)}$ - Emission Factor for pollutant p, specific of fuel type f, sector activity s and technology/ combustion equipment t (g/GJ except CO_2 in kg/GJ);

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

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

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

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

where:

$Emi_{(p)}$ - Total emissions of pollutant p (t/yr except CO_2 in kt);

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

Production – Production activity rate (t/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[11]:

- 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 2006-2015

[11] 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.

Table 3.11 – Incorporation rate of biodiesel (% toe/toe).

	1990-2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Incorporation rate	0	1.31	2.50	2.43	4.16	6.03	6.25	6.22	6.09	5.94	6.80

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

3.3.2.1.2 Clinker Production

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

3.3.2.1.3 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_x, NO_x, NMVOC, CH_4 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_x, NO_x, CH_4 and CO are estimated using production information as activity data (production approach). Emissions for the remaining pollutants, CO_2 and N_2O 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_x, NO_x, NMVOC and CO) and production of lime (SO_x, NO_x, CO and CO_2) 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.

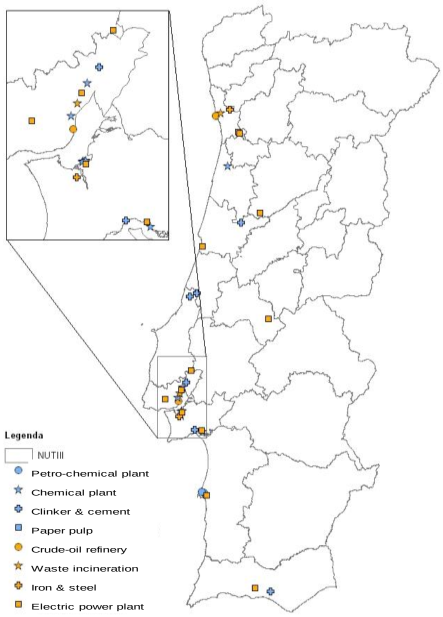
3.3.2.2.1 Combustion Data

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 Portugal mainland[12].



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:

$$Cons_{EB\ (f,s)} = \Sigma_c \{Energy_{EB\ (f,s,c)} / LHV_{EB\ (f,s)}\}$$

$$Energy_{AREA\ (f,s,e)} = \{Frac_{Equi\ (s,f)} * [Cons_{EB\ (f,s)} - \Sigma_u\ Cons_{LPS(u,f,e)}\ ]\ \} * LHV_{AREA(f,s,e)}$$

$$Energy_{LPS(u,f,e)} = Cons_{LPS(u,f,e)} * LHV_{LPS(u,f,e)}$$

where:

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

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

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

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

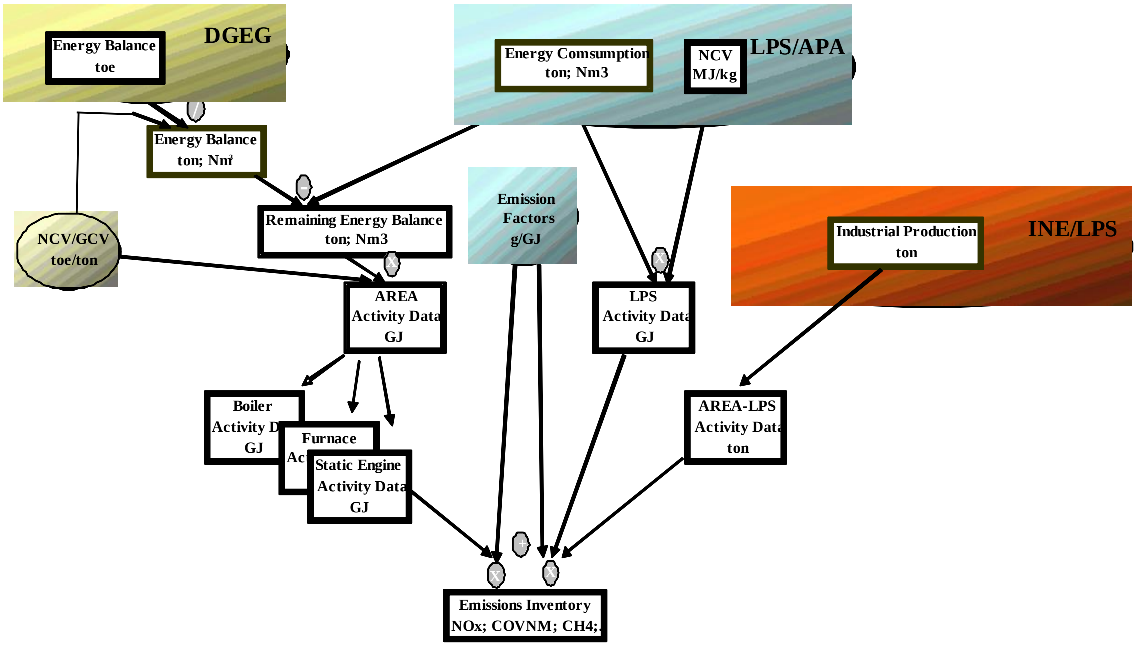
$Frac_{Equi\ (s,f)}$ – Fraction of consumption of fuel f in sector s that is used in equipment e (0..1);

$LHV_{LPS(u,f,e)}$ – 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/t 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)[13].

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 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 2015 is presented in ANNEX E: Energy Balance Sheet for 2015.

[13] In most cases similar values to Energy Balance are used

Table 3.12 – Structure of the Portuguese Energy Balance. Sectoral categories.

Primary		Imports
		Indigenous Production
		Stock variations
		Exports
		Foreign ships
		Foreign aircraft
		Primary Energy Consumption
For production of secondary energy sources		Briqettes
		Coke
		Crude oil products
		City gas
		Petro-chemical
		Electricity
Consumption in the Energy sector		Refineries (own consumption)
		Refineries (losses)
		Coquerie
		Electric Power Plants
		Hidropower pumping
		City gas
		Mining Industry
		Transport and distribution (losses)
Feedstocks		
Corrections		

Co-generation	Electric producers
	Barreiro power plant
	Crude oil refineries
	City gas
	Agriculture
	Food and Beverages
	Textile
	Paper pulp and paper
	Chemical and Plastics
	Ceramic
	Glass
	Cement
	Metalurgy
	Iron and steel
	Cloth, shoes, leather
	Wood
	Rubber
	Equipment
	Other Manufacturing Industries
	Extractive
	Services

Final Consumption	**Agriculture**	
	Fisheries	
	Mining Industry	
	Manufacturing Industry	Food and Beverages
		Textile
		Paper pulp and paper
		Chemical and Plastics
		Ceramic
		Glass
		Cement
		Metalurgy
		Iron and steel
		Cloth, shoes, leather
		Wood
		Rubber
		Equipment
		Other Manufacturing Industries
	Construction and Publick Works	
	Transport	National airplanes
		National ships
		Railways
		road
	Domestic	
	Services	

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

Coal	Imported coal
	National coal
	coal coke
Oil	Intermediate refinery products
	LPG
	Gasoline
	Kerosene
	Jets
	Diesel oil
	Residual fuel oil
	Naphta
	Petro coke
Gases	Natural gas
	City Gas
	Coke oven gas
	Blast Furnace gas
	Petrochemical gas
	Hydrogen
Other	Tar
	Wood and vegetable wastes
	Solid Urban Waste
	Industrial Waste
	Biogas
	Biodiesel
	Liquors
	Other

Non Energ Products	Lubricants
	Asphalts
	Parafin
	Solvents
	Propylene
Electr city	Hydro-electricity
	Wind and Geothermal
	Thermo-electricity

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/Nm3
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/Nm3	MJ/Nm3	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	Residual Oil	Natural Gas
1990	0	5,924,464	257,384	0	0	3,890	1,556,327	0
1995	0	7,015,624	239,855	0	0	4,663	1,328,397	0
2000	0	6,898,592	289,016	0	0	8,290	1,426,004	0
2005	0	0	40	0	0	0	716,823	179,427
2010	165,085	0	9	0	0	586	0	624,383
2013	253,553	43,418	0	0	0	3,987	0	673,236
2014	234,042	54,722	0	0	0	603	0	652,823
2015	310,870	57,402	0	0	0	303	0	705,162

Table 3.17 – Fuel consumption in the Iron and Steel Industry (GJ) (2/2)

Year	Coke oven gas	Blast furnace gas	Tar	Waste oil
1990	1,556,327	418,816	1,460,387	341,000
1995	1,328,397	654,721	1,343,038	272,878
2000	1,426,004	1,447,382	1,746,675	333,420
2005	716,823	0	0	0
2010	0	0	0	0
2013	0	0	0	0
2014	0	0	0	0
2015	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.

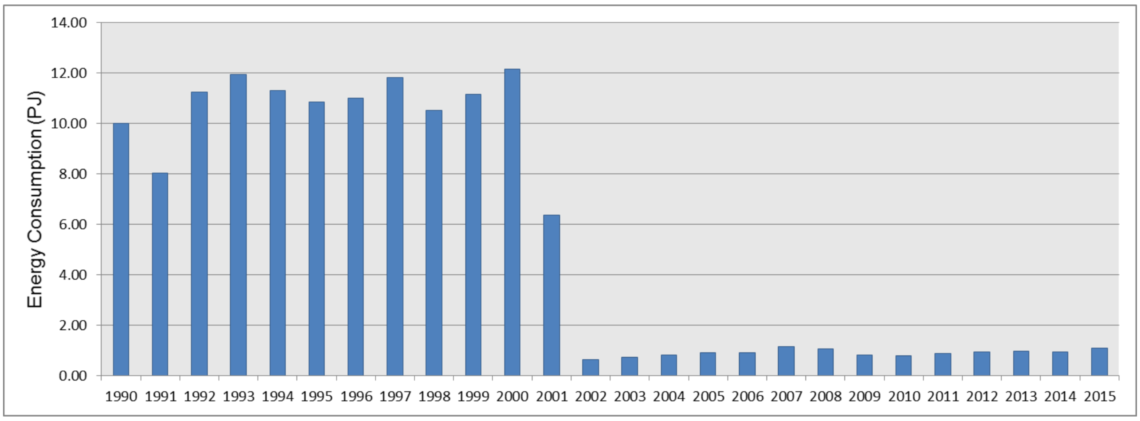
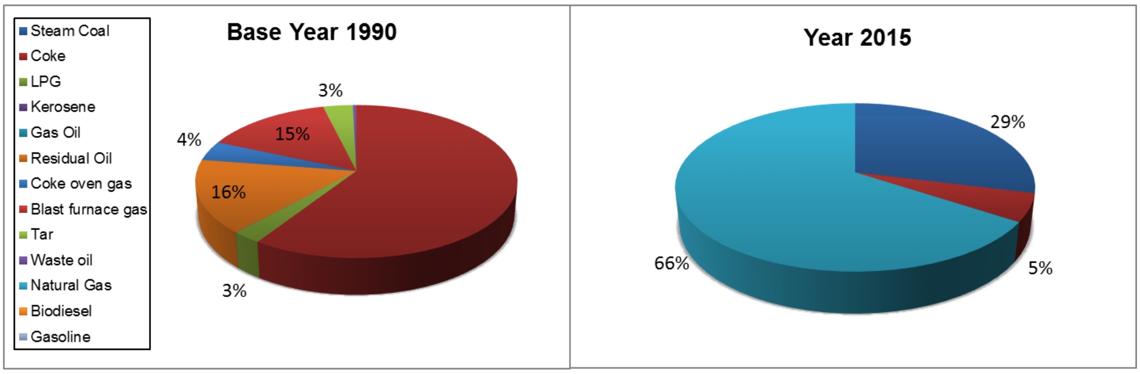


Figure 3.19 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2015.



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).

Year	Steam Coal	Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	132,971	381,617	535,849	1,715	35,795	1,163,364	0	142,678	0
1995	0	0	797,476	2,916	31,846	387,450	0	135,314	0
2000	0	0	241,885	593	47,627	81,208	1,334,087	143,515	0
2005	0	0	302,818	16	99,637	64,698	880,881	232,894	0
2010	0	0	157,373	126	31,761	31,233	661,870	239,874	1,950
2013	9,546	194,311	109,843	0	38,732	0	1,117,856	167	2,264
2014	7,243	196,614	105,272	0	42,313	0	1,013,529	167	844
2015	0	184,807	104,378	0	52,699	0	1,258,286	84	1,482

Table 3.20 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Biodiesel
1990	1,674	35,795	0
1995	8,587	31,846	0
2000	462	47,627	0
2005	350	99,637	0
2010	0	31,761	1,950
2013	0	38,732	2,264
2014	0	42,313	844
2015	0	52,699	1,482

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, since the late nineties (natural gas was introduced in Portugal in 1997).

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 2015 responsible for 72% of the consumption.

Figure 3.20 – Total Energy Consumption in the Metallurgy Industry.

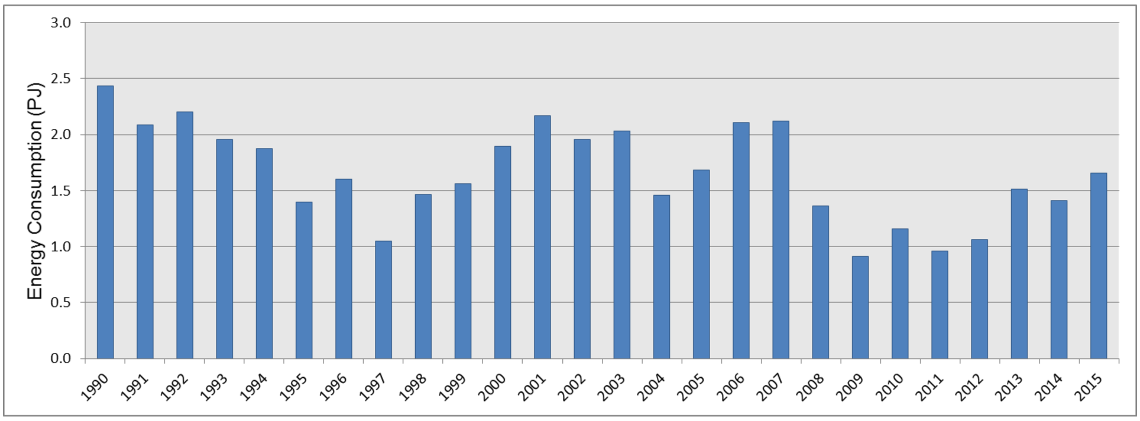
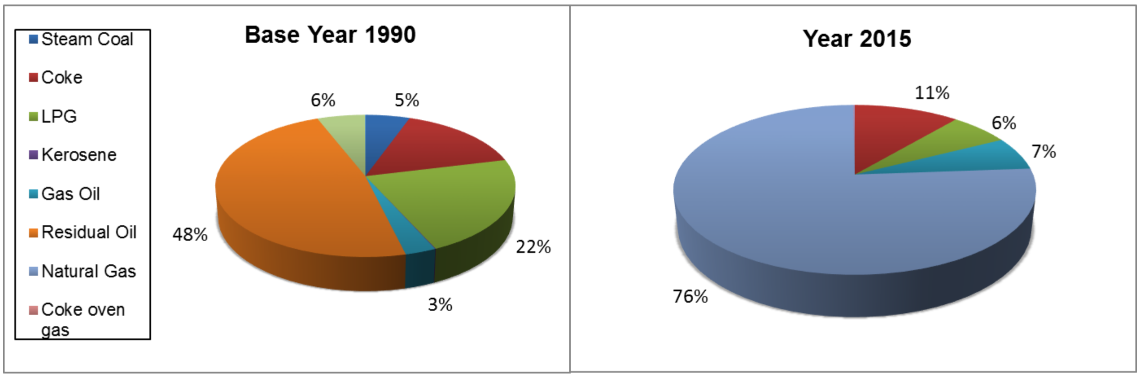


Figure 3.21 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2015.



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	43.8	42.6	39.61 – 40.0

Natural Gas	Wood	Fuel Gas[14]	Gasoline	Flare Gas[15]	Biodiesel
MJ/Nm3	MJ/kg	MJ/kg	MJ/kg	MJ/kg	MJ/kg
38.4 – 37.9	12.6	46.8 – 53.7	44.0	46.8 – 53.7	37.0

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

[14] Several streams of intermediate gaseous products and tail gases that are used as energy source

[15] 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	Coke	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Residual Gas	Biodiesel
1990	216,237	196,840	283,414	1,180	78,977	7,065,040	0	1,051,213	10,648,080	0
1995	0	492,226	1,603,061	54	170,090	6,942,874	0	996,904	9,552,594	0
2000	0	2,141,169	333,022	12,395	119,791	6,643,160	2,306,626	1,360,854	11,432,539	0
2005	482,572	135,743	1,173,641	2,360	100,475	3,883,228	3,904,192	1,471,332	11,183,390	0
2010	423,327	91,315	346,468	377	36,910	1,417,707	7,557,173	1,536,318	10,407,661	1,991
2013	496,512	32,448	88,793	84	46,694	347,704	9,045,541	17,113	8,898,555	8,583
2014	25,916	0	91,104	167	41,368	210,718	6,134,750	17,113	10,990,438	6,393
2015	0	0	101,487	84	45,814	159,179	6,197,329	44,979	11,733,143	8,806

Table 3.23 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Residual Oil	Biodiesel
1990	7,803	78,712	2,814,826	0
1995	166,006	169,825	3,710,999	0
2000	48,157	119,525	4,181,690	0
2005	12,349	102,028	3,960,893	0
2010	0	38,066	1,629,457	1,991
2013	0	47,100	335,567	8,583
2014	0	41,346	935,933	6,393
2015	0	46,100	961,141	8,806

Table 3.24 - Fuel consumption in Chemical and Plastics Industry – Flares (GJ).

Year	Residual Gas
1990	2,020,225
1995	2,027,080
2000	1,992,060
2005	2,052,772
2010	2,299,712
2013	1,560,830
2014	559,438
2015	462,716

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[16] 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 3.20. 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.

[16] 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.

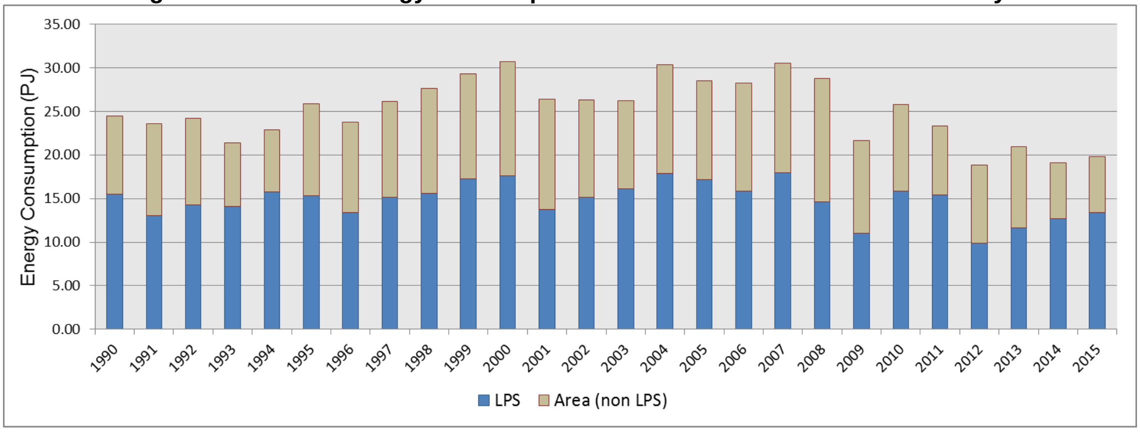
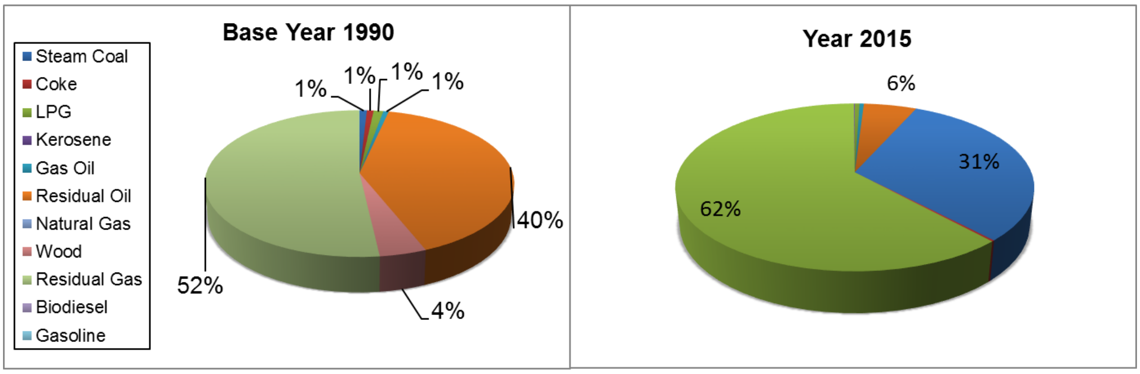


Figure 3.23 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2015.



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	Liquors	Biodiesel
1990	103,423	7	90,172	9,478,929	0	5,148,908	25,397,844	0
1995	283,226	23	72,544	11,038,222	0	7,360,136	27,222,347	0
2000	249,182	26	54,762	11,559,810	2,375,616	6,489,241	33,489,524	0
2005	92,399	55	81,294	4,988,837	3,578,750	7,431,556	31,534,746	0
2010	93,532	126	75,718	3,759,716	13,141,915	6,265,175	36,429,196	4,783
2013	67,784	377	67,430	1,437,235	14,960,569	6,672,518	39,127,798	4,375
2014	74,818	419	77,177	2,113,837	14,749,521	6,752,119	38,901,047	4,782
2015	84,070	293	93,623	2,561,616	15,888,423	6,257,489	39,102,146	6,697

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal from 1990 to 2015 (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 %). The lower temporary value in 2003 reflects a re-qualification period for one unit. Considering the share of energy sources, there is a dominance of liquor, followed by residual fuel oil, wood waste and natural gas - this last only recently - as auxiliary primary energy sources.

Table 3.27 - Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Biogas	Biodiesel
1990	2,678	90,172	0	0
1995	6,137	72,544	0	0
2000	796	54,762	9,705	0
2005	911	81,294	28,895	0
2010	335	73,596	34,055	4,783
2013	0	67,385	0	4,375
2014	0	74,287	225,243	4,782
2015	0	93,530	207,770	6,697

Figure 3.24 – Total Energy Consumption in the Paper and Paper Pulp Industry.

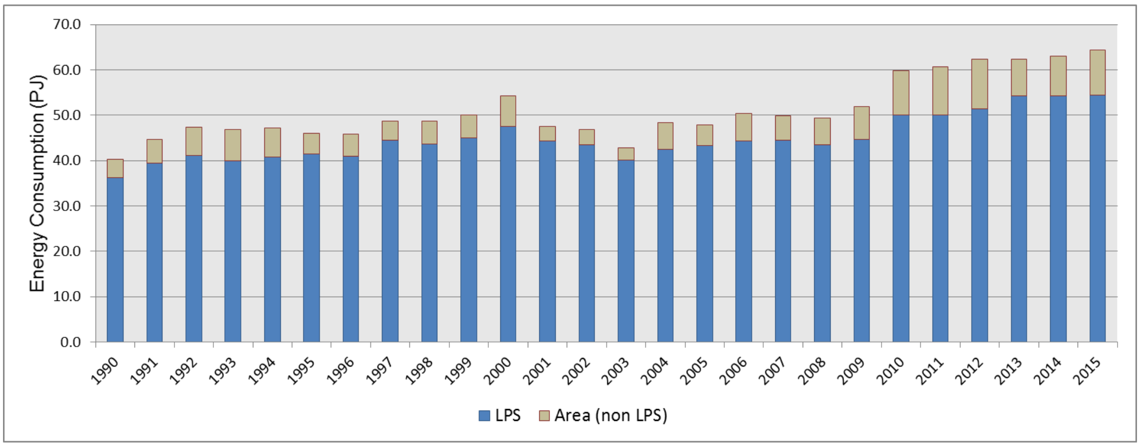
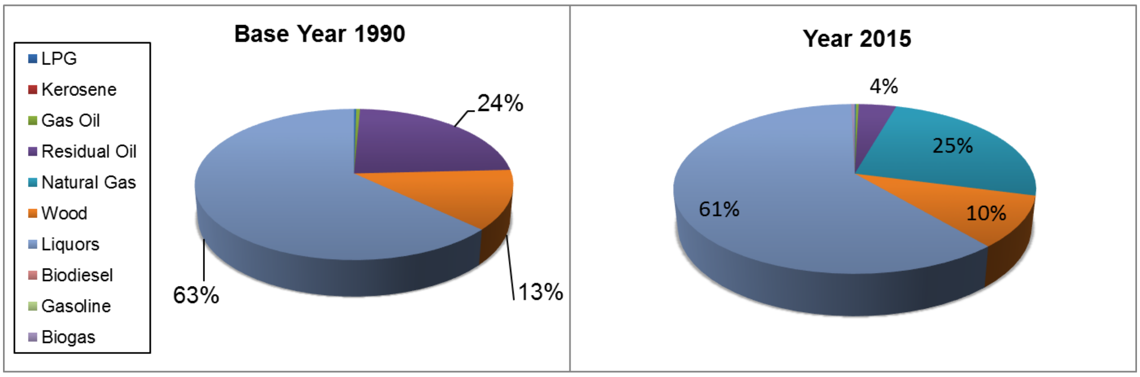


Figure 3.25 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2015.



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 Oil	Natural Gas	Wood	Biodiesel
1990	12,416	906,272	13,318	545,639	8,902,333	0	3,981,464	0
1995	0	1,462,813	5,078	735,940	9,399,512	0	3,775,858	0
2000	0	1,699,805	1,729	669,262	9,384,736	1,800,027	3,435,549	0
2005	0	1,231,248	5	753,087	5,798,837	4,518,346	3,714,314	0
2010	0	927,704	209	487,347	5,782,876	6,842,069	3,883,222	29,569
2013	0	990,547	84	449,216	2,336,404	9,194,548	978,787	28,429
2014	0	849,788	42	514,388	1,754,574	9,284,773	978,787	31,731
2015	0	743,025	251	619,924	1,573,037	9,623,025	1,153,640	44,848

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
1995	109,277	735,940	0	0
2000	117,945	669,262	0	0
2005	68,883	753,087	0	0
2010	22,023	487,347	61	29,569
2013	0	449,216	19,929	28,429
2014	0	514,388	34,301	31,731
2015	0	619,924	38,631	44,848

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.

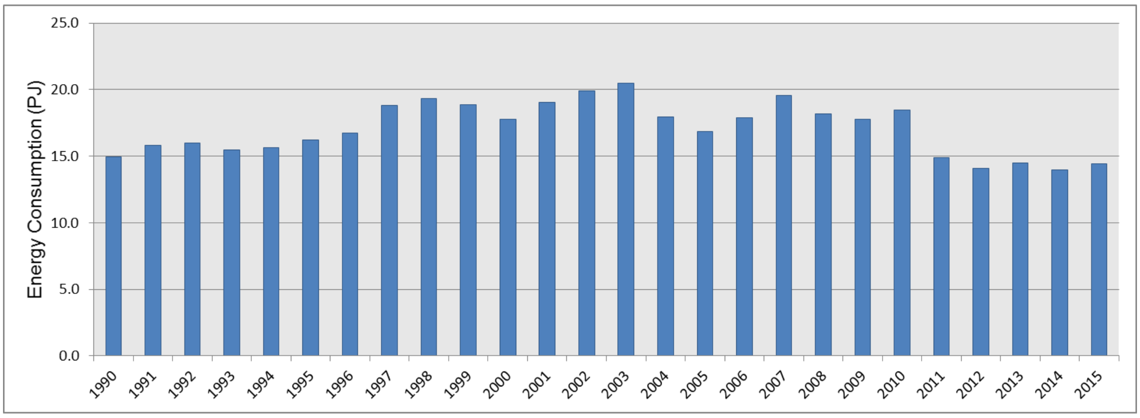
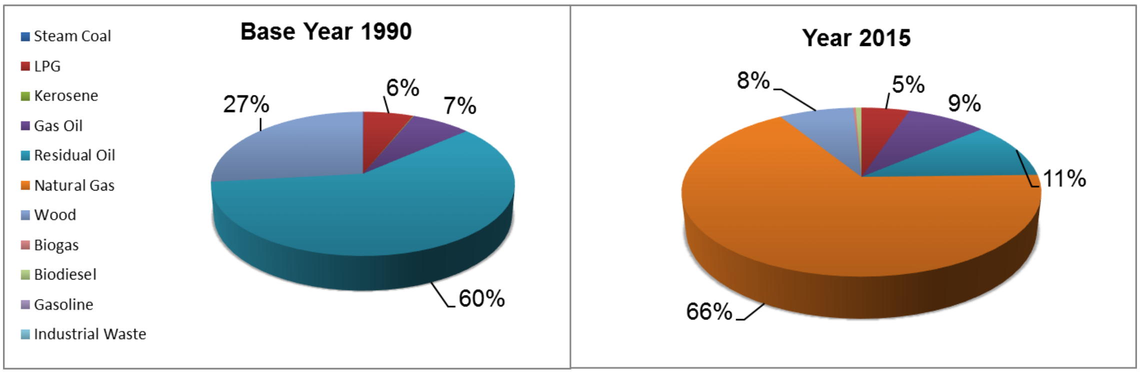


Figure 3.27 - Fuel consumption per fuel type in the Food Processing, Beverages and Tobacco Industries in 1990 and 2015.



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
1995	375,912	4	37,333	8,878,803	0	1,077,866	0
2000	508,000	0	75,347	11,337,089	4,196,215	2,059,507	0
2005	362,613	4	108,672	7,295,236	7,979,600	2,225,989	0
2010	134,730	42	19,604	3,921,248	7,845,017	2,328,954	597
2013	115,806	0	6,721	344,568	9,892,655	72,845	334
2014	104,878	0	7,968	174,293	9,570,522	72,845	405
2015	115,178	0	34,512	88,926	9,786,478	87,824	2,457

Table 3.33 – Fuel consumption in Textile Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Biodiesel
1990	4,315	27,579	0
1995	18,913	37,333	0
2000	66,391	75,347	0
2005	43,123	108,672	0
2010	0	19,604	597
2013	0	6,721	334
2014	0	7,968	405
2015	0	34,512	2,457

Figure 3.28 – Total Energy Consumption in the Textile Industry.

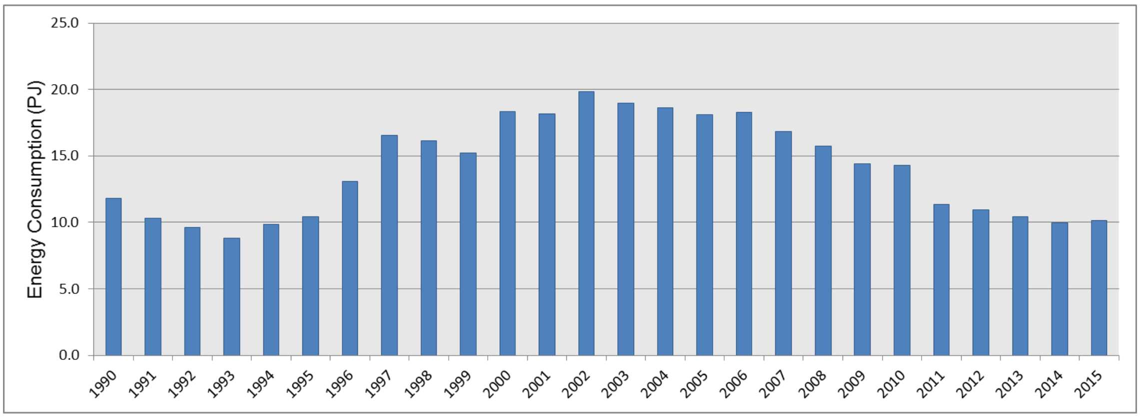
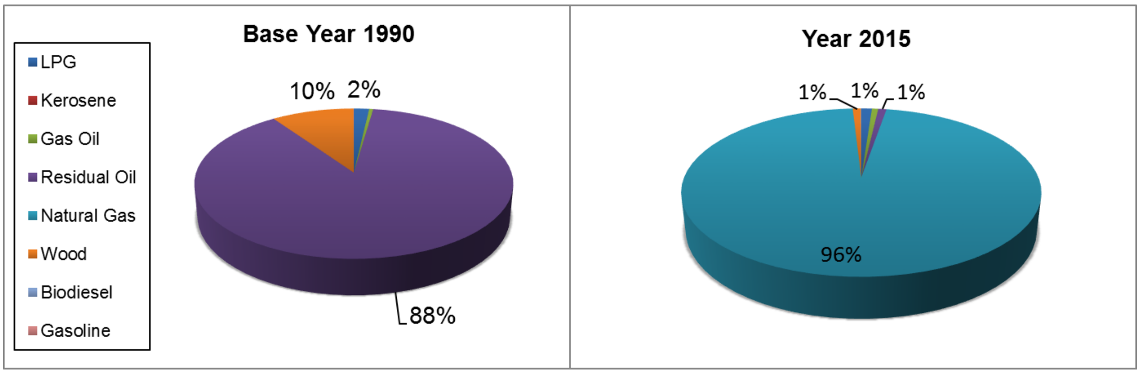


Figure 3.29 – Fuel consumption per fuel type in Textile Industry in 1990 and 2015.



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	Coal	Pet Coke	LPG	Kerosene	Gas oil	Residual Oil	Natural Gas	Wood	Industrial Waste	Biodiesel
1990	6,556	0	6,150,865	28	128,086	3,301,796	0	12,476,234	0	0
1995	0	0	8,792,146	0	130,307	3,727,408	0	11,831,883	0	0
2000	0	0	1,410,200	347	181,234	3,754,710	13,870,518	13,510,325	0	0
2005	0	539,058	540,176	166	126,016	810,594	14,790,173	14,022,734	480,348	0
2010	0	462,743	244,800	251	57,487	375,633	11,517,845	13,913,347	0	3,640
2013	0	366,911	138,080	209	35,325	43,668	9,260,657	678,494	66,863	2,293
2014	0	437,361	126,147	167	42,097	0	9,225,991	688,326	0	2,659
2015	0	447,330	149,174	84	75,153	0	9,458,232	748,410	0	5,484

Table 3.36 – Fuel consumption in the Ceramic Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Biodiesel
1990	38,533	128,086	0
1995	48,847	130,307	0
2000	17,199	181,234	0
2005	435	126,016	0
2010	377	57,487	3,640
2013	0	35,325	2,293
2014	0	42,097	2,659
2015	0	75,153	5,484

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 %, 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.

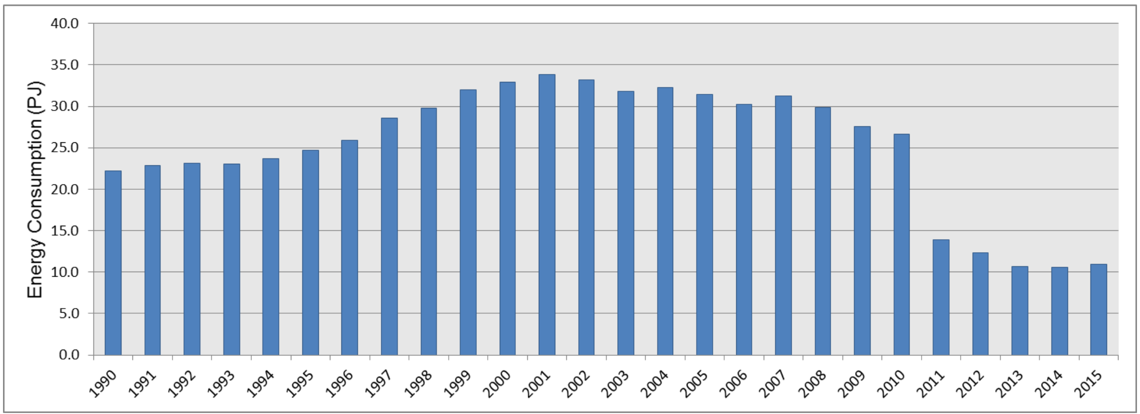
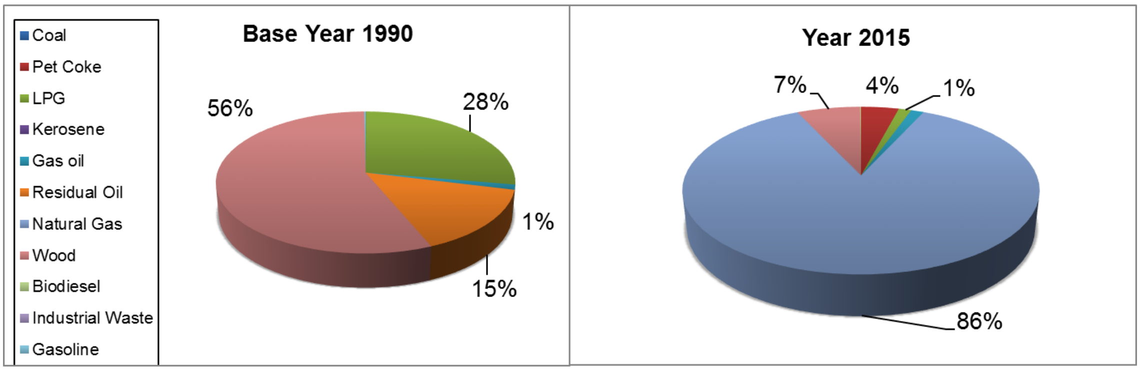


Figure 3.31 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2015.



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	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	324	1,162,470	0	25,226	4,460,995	0	1,381	0
1995	272	1,383,684	0	21,384	6,578,946	0	1,297	0
2000	356	346,329	7	23,699	3,739,016	5,243,975	1,381	0
2005	0	20,930	0	19,841	1,998,340	6,675,198	0	0
2010	5,766	13,287	0	27,212	146,454	7,702,477	0	1,723
2013	8,871	6,574	0	20,564	0	8,365,822	0	1,312
2014	7,501	5,671	0	24,178	0	8,126,059	0	1,507
2015	5,775	5,905	0	21,790	1,968	8,610,343	0	1,579

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

Year	Gasoline	Gas Oil	Biodiesel
1990	4,001	25,143	0
1995	3,648	21,274	0
2000	1,030	23,474	0
2005	174	18,734	0
2010	0	26,587	1,723
2013	0	19,861	1,312
2014	0	23,558	1,507
2015	0	21,487	1,579

In this sector 9 plants are treated as LPS, convering 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 % 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 decrese in residual oil consumption since 2011 results from fact that the only cogeneration plant from this sector ended its activity.

Figure 3.32 – Total Energy Consumption in the Glass Industry.

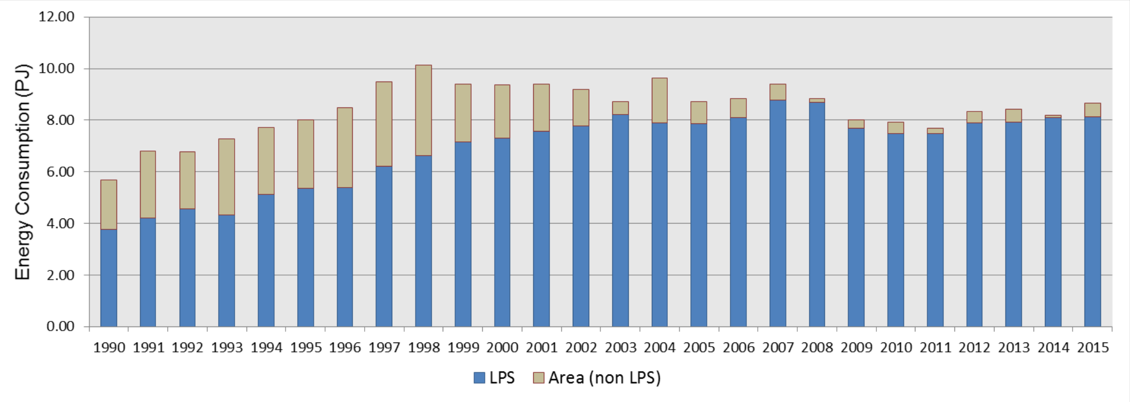
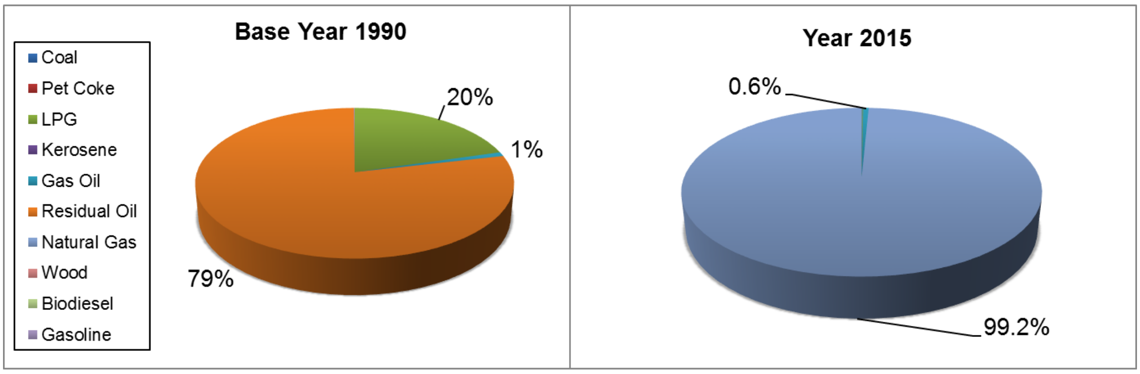


Figure 3.33 – Fuel consumption per fuel type in Glass Industry in 1990 and 2015.



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 % 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.

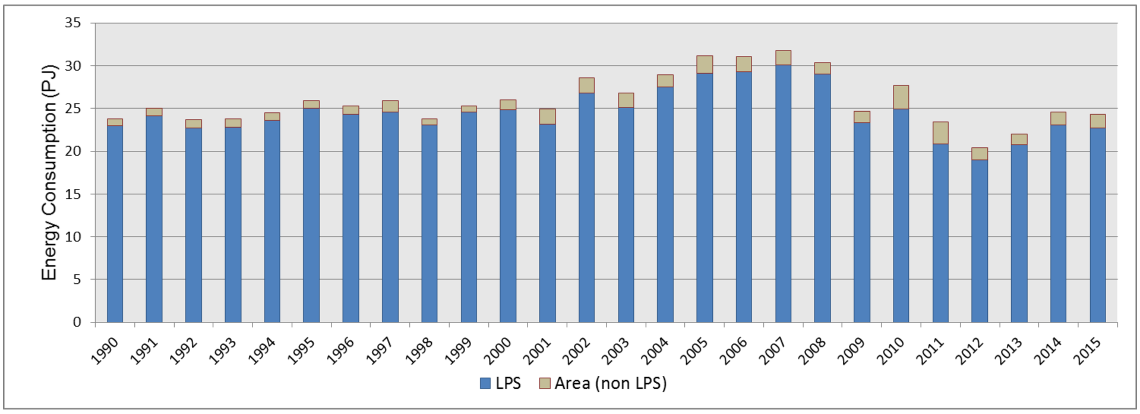
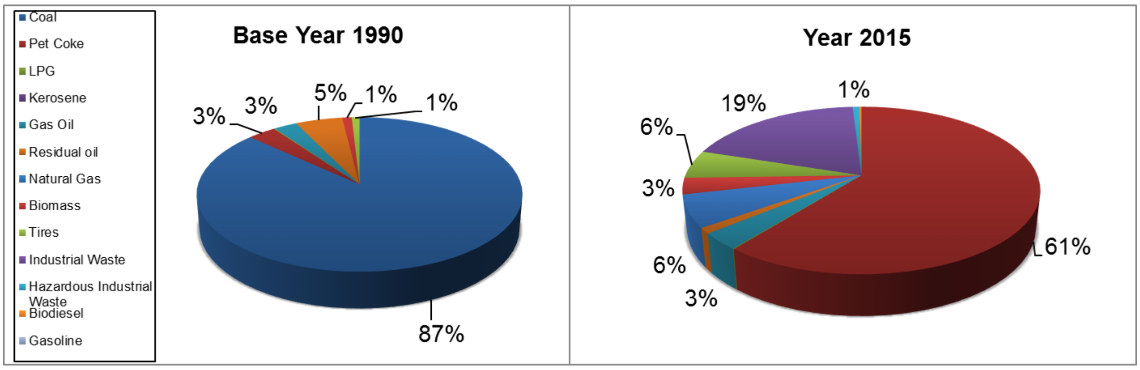


Figure 3.35 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2015.



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
1995	239,172	0	22,330	704,818	0	265,481	0
2000	226,044	0	15,078	350,076	148,572	282,636	0
2005	231,177	8	11,608	241,561	471,671	0	0
2010	155,078	0	7,382	373,331	767,189	0	384
2013	116,308	0	35,644	45,510	842,635	41,297	2,288
2014	115,345	0	39,739	47,352	843,682	41,297	2,484
2015	125,519	42	66,899	85,828	885,006	78,243	4,841

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
1995	8,668	22,330	0
2000	3,836	15,078	0
2005	465	11,608	0
2010	0	7,382	384
2013	0	35,644	2,288
2014	0	39,739	2,484
2015	0	66,899	4,841

Figure 3.36 – Total Energy Consumption in the Clothing, Shoes and Leather Industries.

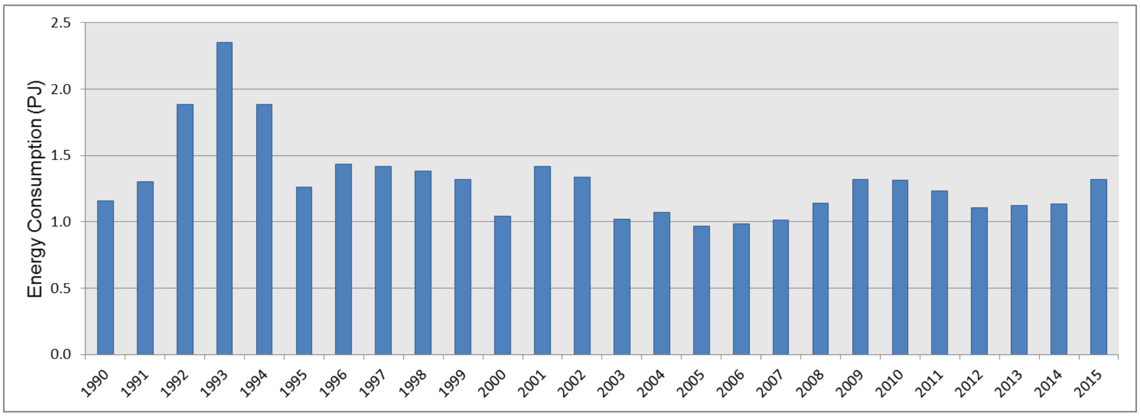
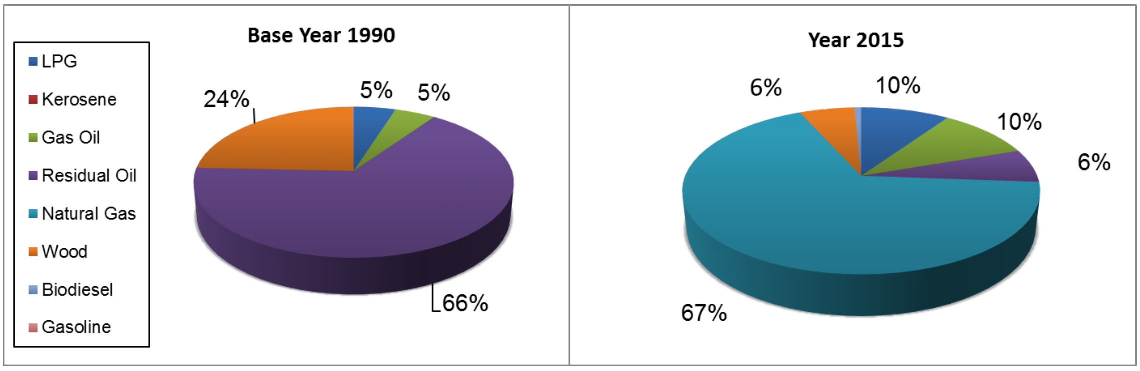


Figure 3.37 - Fuel consumption per fuel type in the Clothing, Shoes and Leather Industries in 1990 and 2015.



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
1995	115,297	0	192,250	3,036,372	0	1,241,590	0
2000	467,887	85	206,253	2,939,646	237,201	907,236	0
2005	260,611	1,127	215,627	1,998,707	524,175	1,632,259	0
2010	59,326	0	122,508	1,667,574	335,823	1,706,234	7,553
2013	58,908	0	92,777	413,272	460,255	1,801,213	5,612
2014	50,241	0	117,162	430,772	379,240	1,908,954	7,101
2015	70,212	0	138,456	551,350	327,994	2,022,887	10,048

Table 3.46 – Fuel consumption in the Wood Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Biodiesel
1990	793	250,404	0
1995	11,017	192,250	0
2000	4,050	206,253	0
2005	1,373	215,627	0
2010	0	122,508	7,553
2013	0	92,777	5,612
2014	0	117,162	7,101
2015	0	138,456	10,048

Although total consumption of energy from combustion has not changed much from 1990 to 2015, 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.

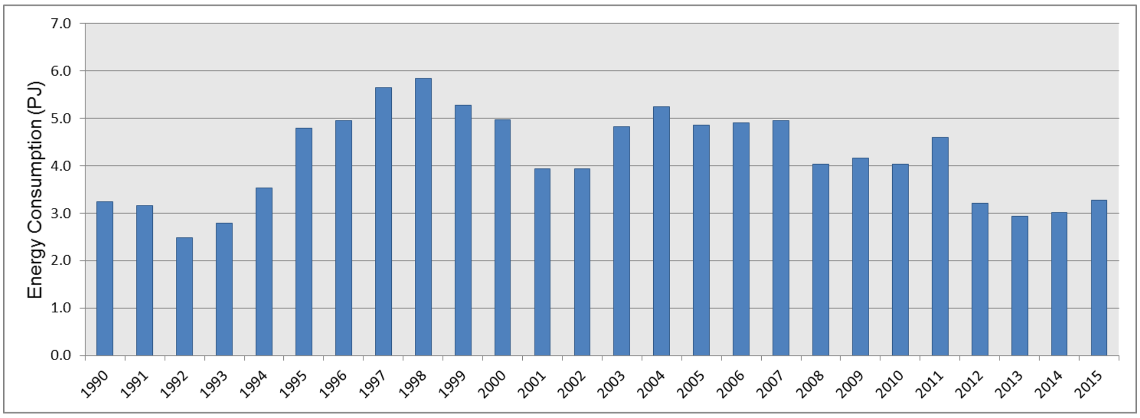
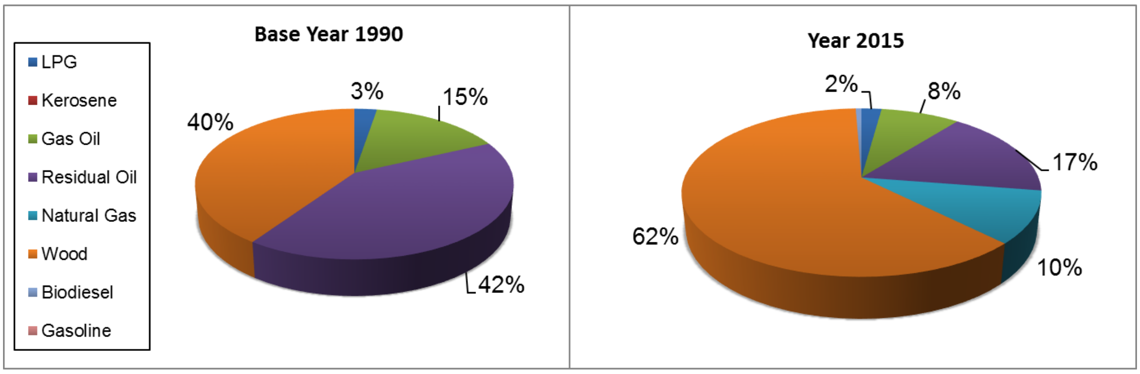


Figure 3.39 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2015.



3.3.2.2.1.2.12 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	Industrial Waste
1990	27,688	240	5,481	571,475	0	46,820	0
1995	33,286	135	13,470	270,653	0	44,393	0
2000	28,111	48	29,578	379,923	34,818	47,280	0
2005	20,546	0	1,314	27,107	419,232	0	0
2010	4,145	42	0	20,682	733,695	0	59,620
2013	4,940	0	0	1,465	858,378	21,255	144,443
2014	4,940	0	0	0	802,986	21,255	114,299
2015	6,113	0	2,088	0	808,639	19,540	98,389

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

Year	Gasoline	Gas Oil
1990	0	5,481
1995	4,728	13,470
2000	57,450	29,578
2005	48	1,314
2010	0	0
2013	0	0
2014	0	0
2015	0	2,088

The figure below shows a significant inccrease 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.

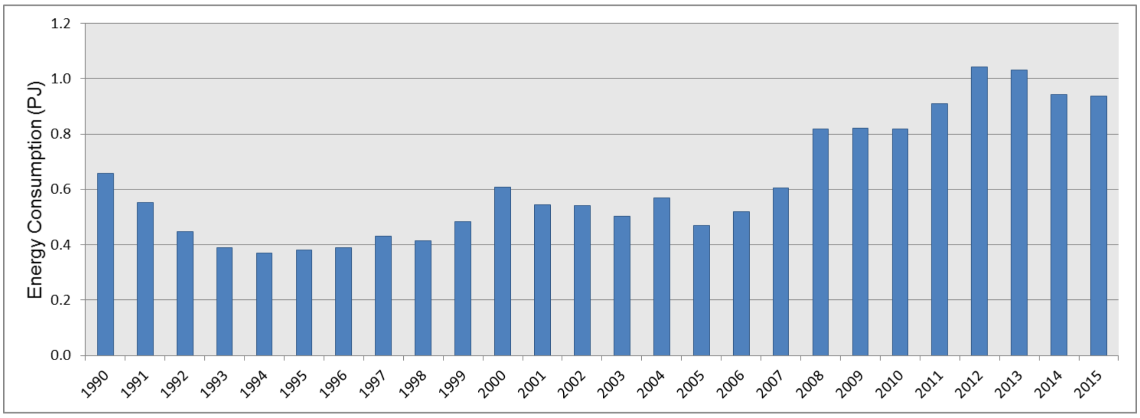
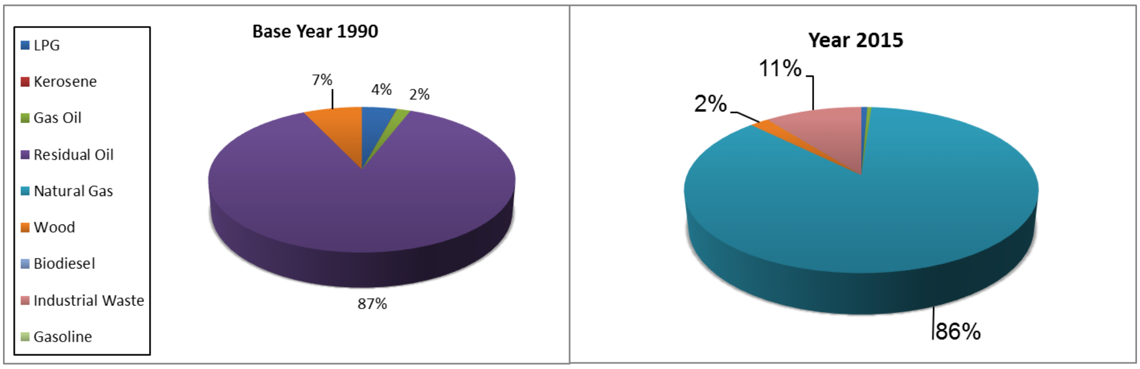


Figure 3.41 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2015.



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	Coal	Coke	Kerosene	Gas Oil	Residual Oil	Natural Gas	Wood	Biodiesel
1990	1,464,554	0	0	5,901	166,018	885,983	0	28,368	0
1995	1,606,517	0	0	77	210,899	508,561	0	26,904	0
2000	1,785,009	0	0	324	117,664	770,616	1,196,654	16,201	0
2005	1,293,735	0	0	296	142,488	215,524	2,120,737	16,992	0
2010	927,704	0	0	921	106,258	111,618	2,040,186	16,987	6,031
2013	692,449	0	0	84	99,350	4,815	2,188,943	3,849	6,302
2014	681,354	0	0	167	108,424	28,260	2,284,360	3,849	6,733
2015	715,225	1,089	4,438	544	157,190	15,491	2,382,080	22,929	11,326

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
1995	101,341	210,899	0
2000	45,687	117,664	0
2005	10,951	142,488	0
2010	90,353	106,258	6,031
2013	1,298	99,350	6,302
2014	754	108,424	6,733
2015	1,130	157,190	11,326

Figure 3.42 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry.

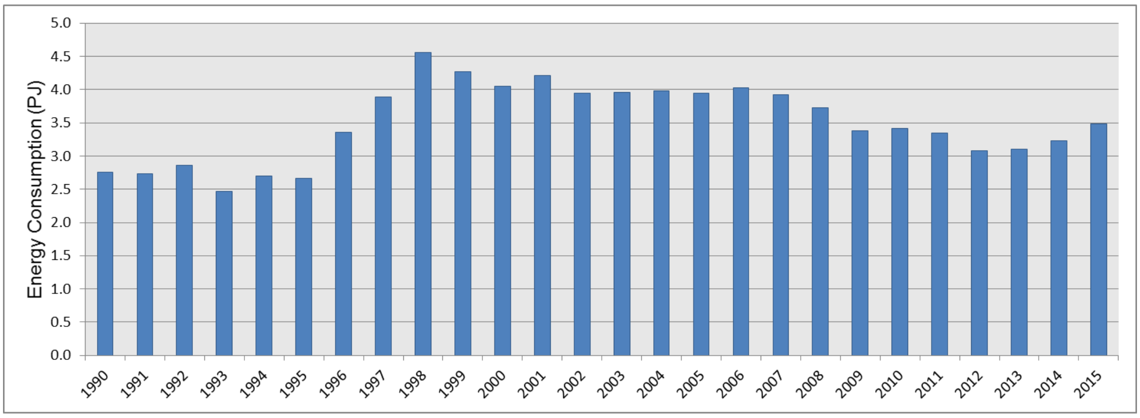
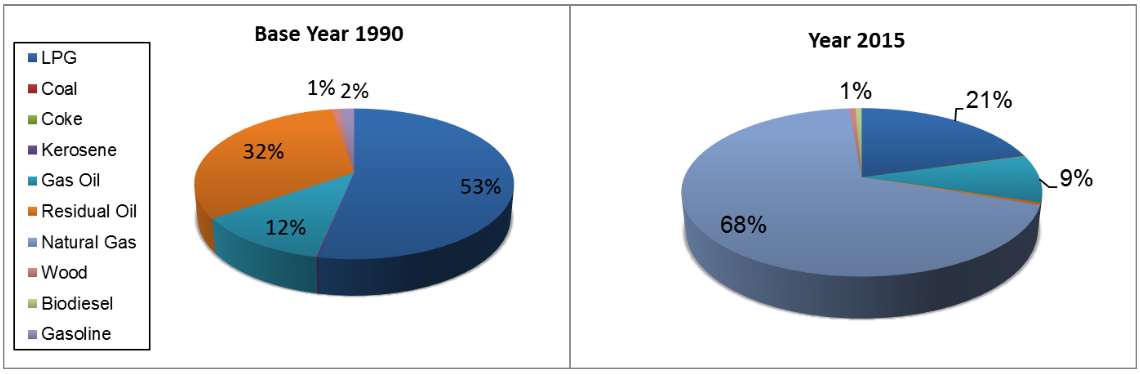


Figure 3.43 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2015.



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).

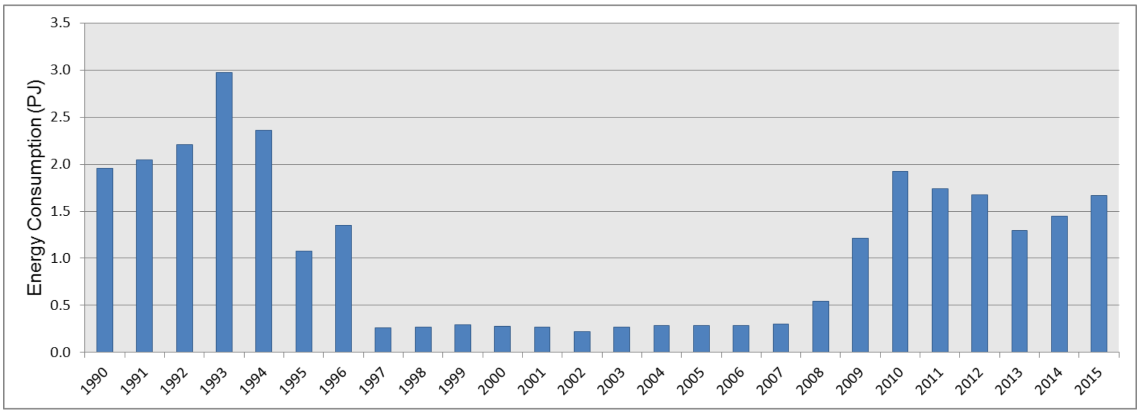
Year	Lignite	Coal	Coke	LPG	Kerosene	Gas Oil	Residual Oil	City Gas	Natural Gas	Wood	Biodiesel
1990	446	0	0	152,483	4,090	169,380	1,450,485	78	0	6,234	0
1995	0	0	0	431,055	37	180,662	168,426	55,690	0	5,900	0
2000	0	0	0	79,493	0	17,846	0	44,451	108,896	6,276	0
2005	0	0	0	33,769	0	8,023	0	0	198,239	34,984	0
2010	0	0	0	114,382	84	515,036	175,215	0	477,128	34,979	32,757
2013	0	0	0	77,455	0	341,956	47,561	0	382,255	15,774	22,123
2014	0	0	0	86,750	0	390,223	44,254	0	397,830	18,996	24,557
2015	0	5,987	1,717	104,418	84	511,792	56,563	0	318,322	7,197	37,258

Table 3.55 – Fuel consumption in Other Transformation Industry – Static Engines (GJ).

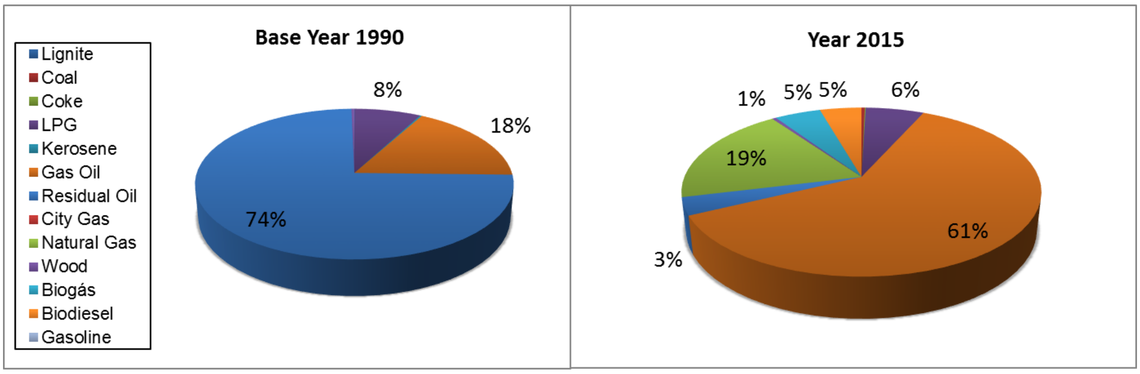
Year	Gasoline	Gas Oil	Biogás	Biodiesel
1990	307	169,380	0	0
1995	51,541	180,662	0	0
2000	2,621	17,846	0	0
2005	2,706	8,023	0	0
2010	0	515,036	26,347	32,757
2013	0	341,956	41,855	22,123
2014	0	390,223	73,238	24,557
2015	0	511,792	82,758	37,258

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 2015.



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	Coal	LPG	Gasoline	Kerosene	Gas Oil	Residual oil	Natural Gas	Biodiesel
1990	2,402	77,429	0	1,929	496,778	119,777	0	0
1995	0	106,523	0	625	497,405	53,492	0	0
2000	0	176,933	28,632	0	1,054,333	103,471	14,990	0
2005	0	72,128	2,881	0	971,618	435,410	287,341	0
2010	0	89,764	0	0	849,610	40,153	332,892	55,253
2013	0	55,296	0	0	555,998	37,757	189,913	35,304
2014	0	48,540	0	0	580,857	18,206	173,417	35,967
2015	0	56,286	0	0	663,017	22,074	169,858	47,495

Table 3.58 – Fuel consumption in the Extractive Industry – Static Engines (GJ).

Year	Gasoline	Gas Oil	Biodiesel
1990	16,254	466,146	0
1995	2,037	495,098	0
2000	20,681	756,662	0
2005	22,469	880,964	0
2010	20,181	849,610	55,253
2013	0	555,998	35,304
2014	0	580,857	35,967
2015	0	663,017	47,495

Figure 3.46 – Total Energy Consumption in the Extractive Industry.

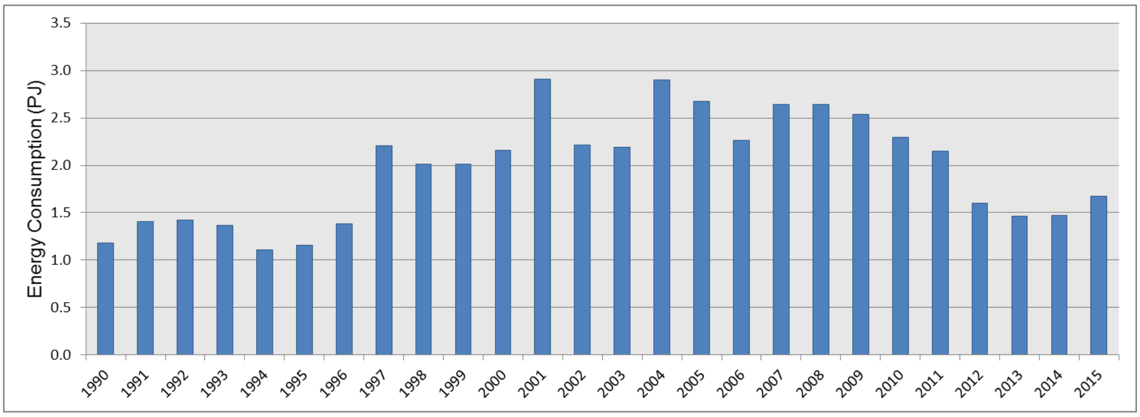
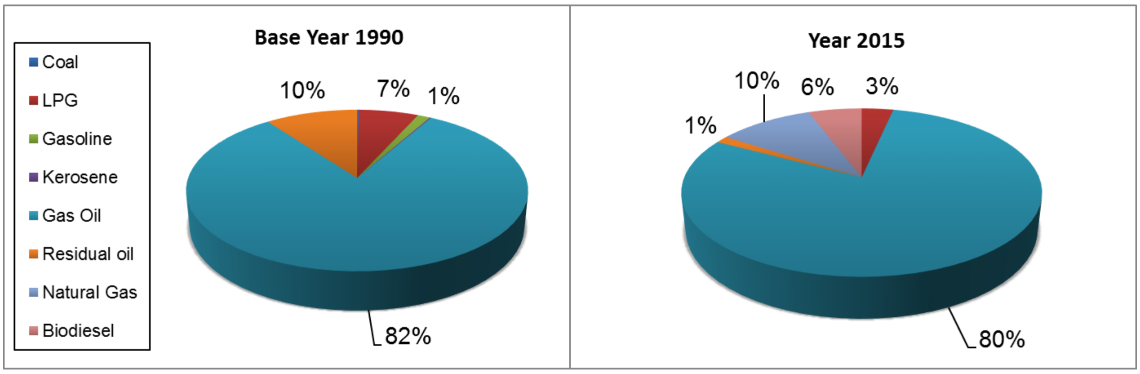


Figure 3.47 – Fuel consumption per fuel type in the Extractive Industry in 1990 and 2015.



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
1995	887,678	447,712	640	7,580,456	1,756,467	0	0
2000	545,639	72,532	130	7,548,443	1,467,006	8,455	0
2005	412,087	67,399	184	9,135,498	1,717,788	891,143	0
2010	484,791	91,783	126	5,583,764	1,072,740	1,202,436	353,676
2013	326,030	0	42	2,690,402	537,500	1,291,775	172,695
2014	317,888	0	42	2,682,988	401,792	1,076,367	165,666
2015	334,131	0	126	3,251,010	593,125	1,105,649	232,300

Figure 3.48 – Total Energy Consumption in the Construction and Building Industry.

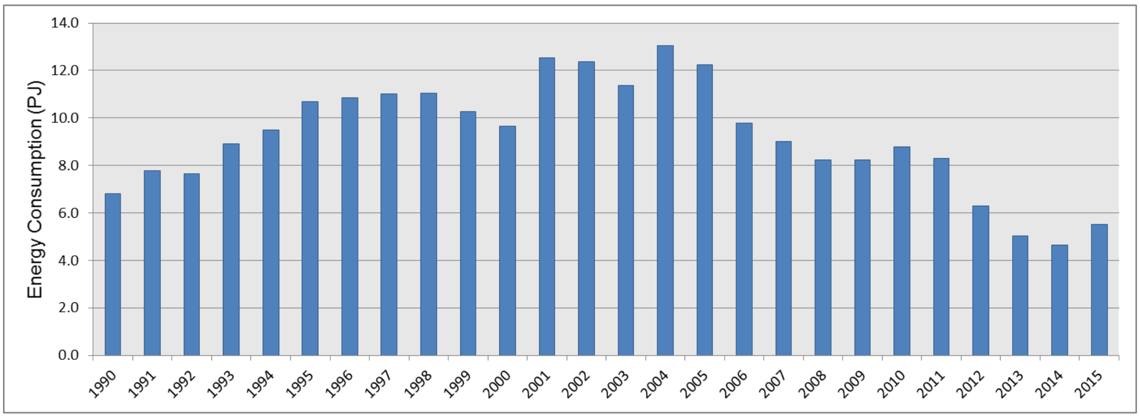
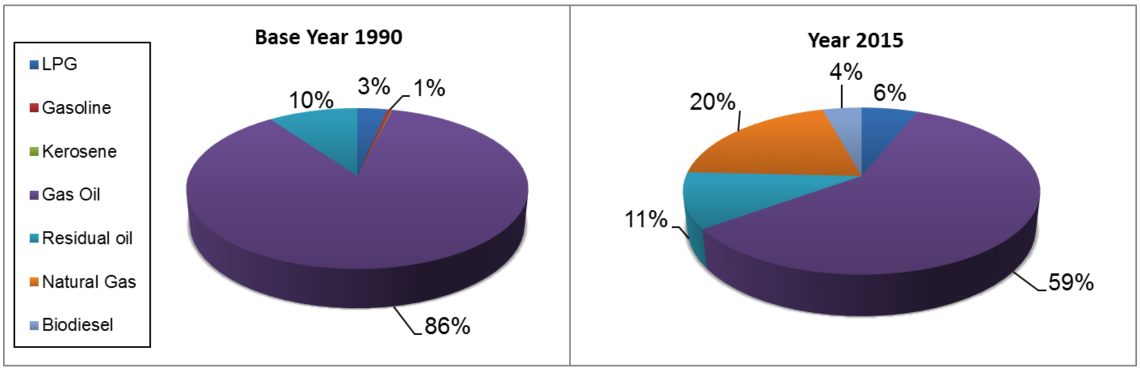


Figure 3.49 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2015.



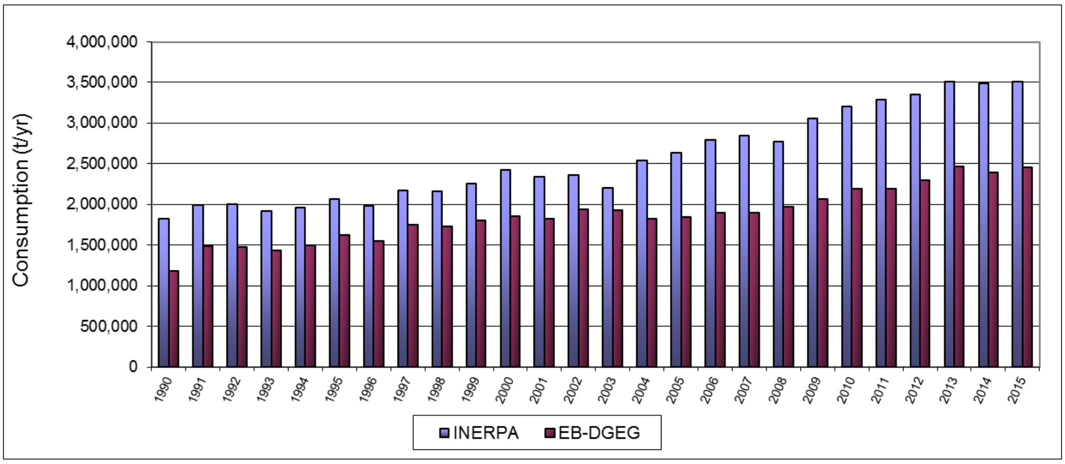
3.3.2.2.1.3 Comparison of LPS data vs. Energy Balance

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.

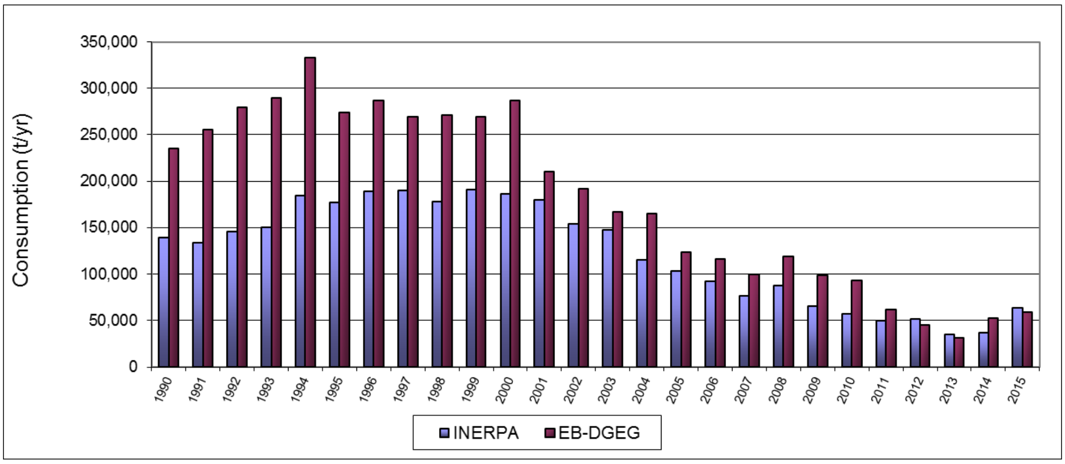
Before hand, it must be realized that to conclude for consistency between both distinct datasets, the comparison should result in higher or equal consumption in the EB than in the inventory, because apart from specific fuels (black liquor in the paper and pulp industry, coke oven gas and blast furnace 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".

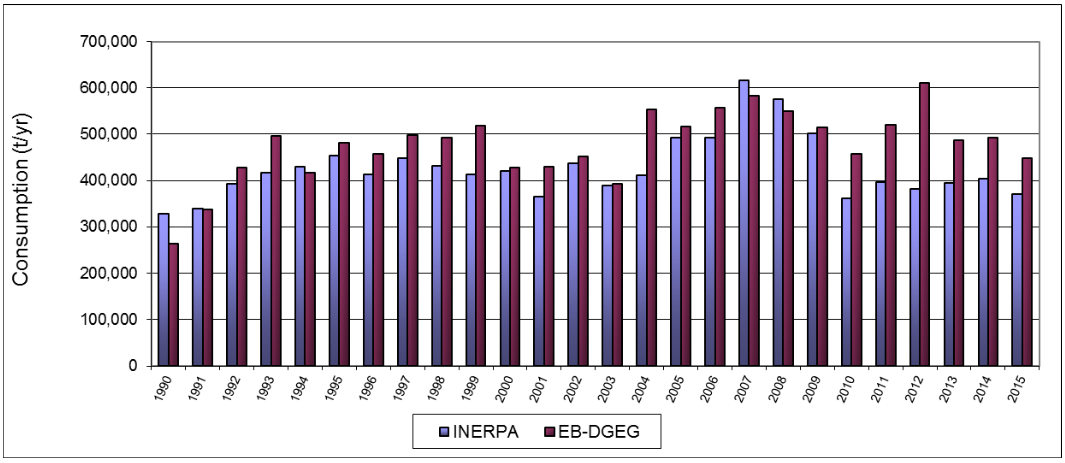
Black Liquor



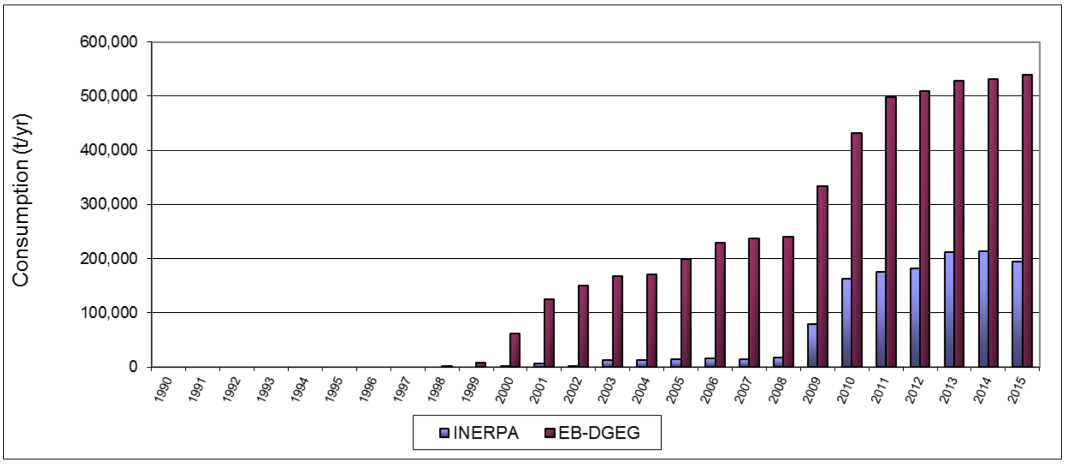
Residual Fuel Oil



Biomass

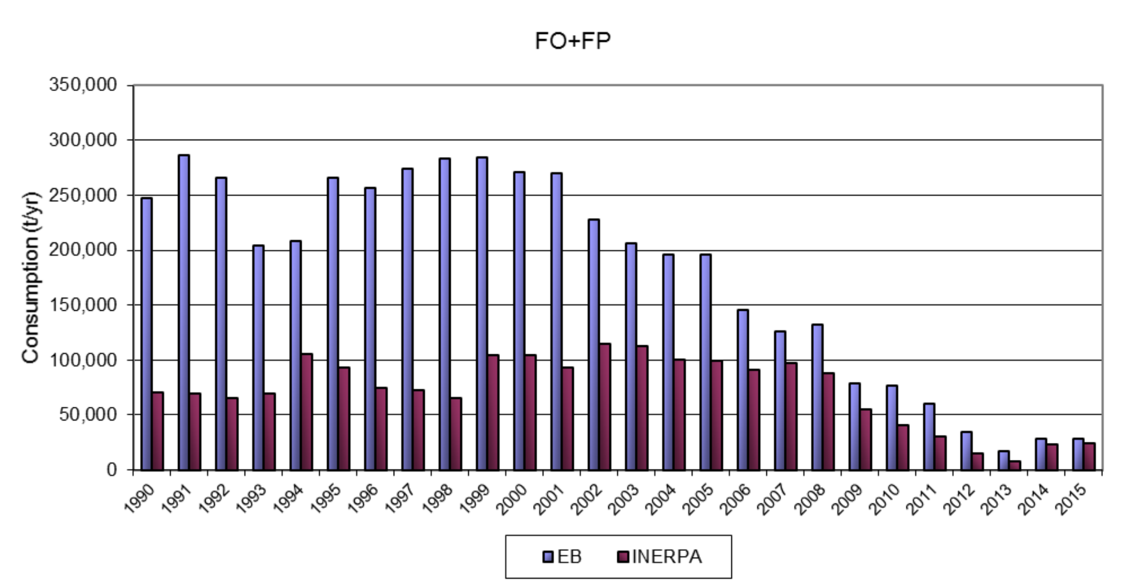


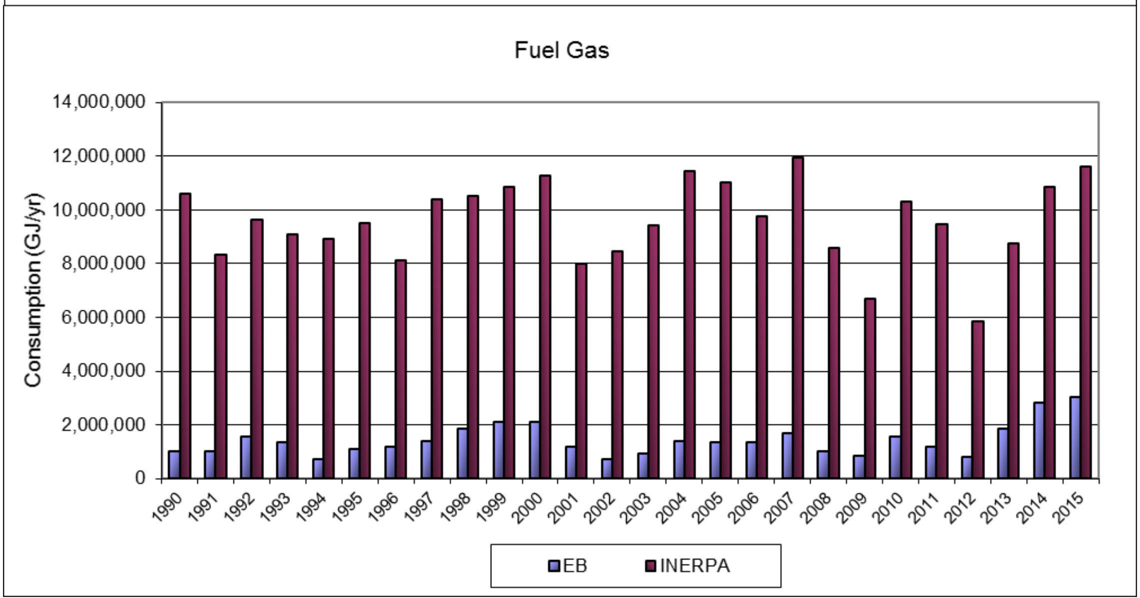
Natural Gas



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 3.50 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector "Chemical and Plastics"[17].





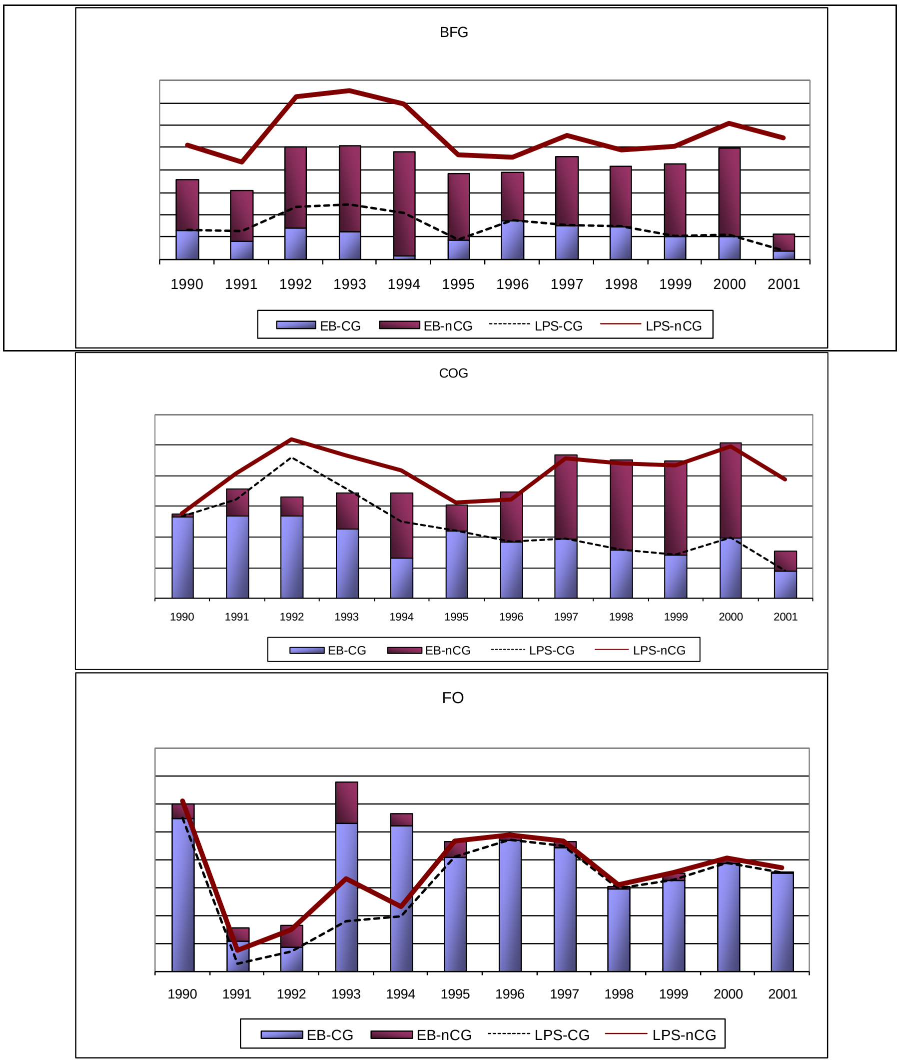
For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil[18] is about 50 % until 2005. The two values show a tendency to converge in the later years. Also important to note that in 2012 LPS values surpasse energy balance data by 8 %. Consumption 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.

[17] Units in the vertical axis are not indicated due to confidentiality issues.

[18] This category includes residual fuel oil, a traded fuel, and fuel pyrolisis, a non-traded by product fuel, used inside the industrial unit that produces it.

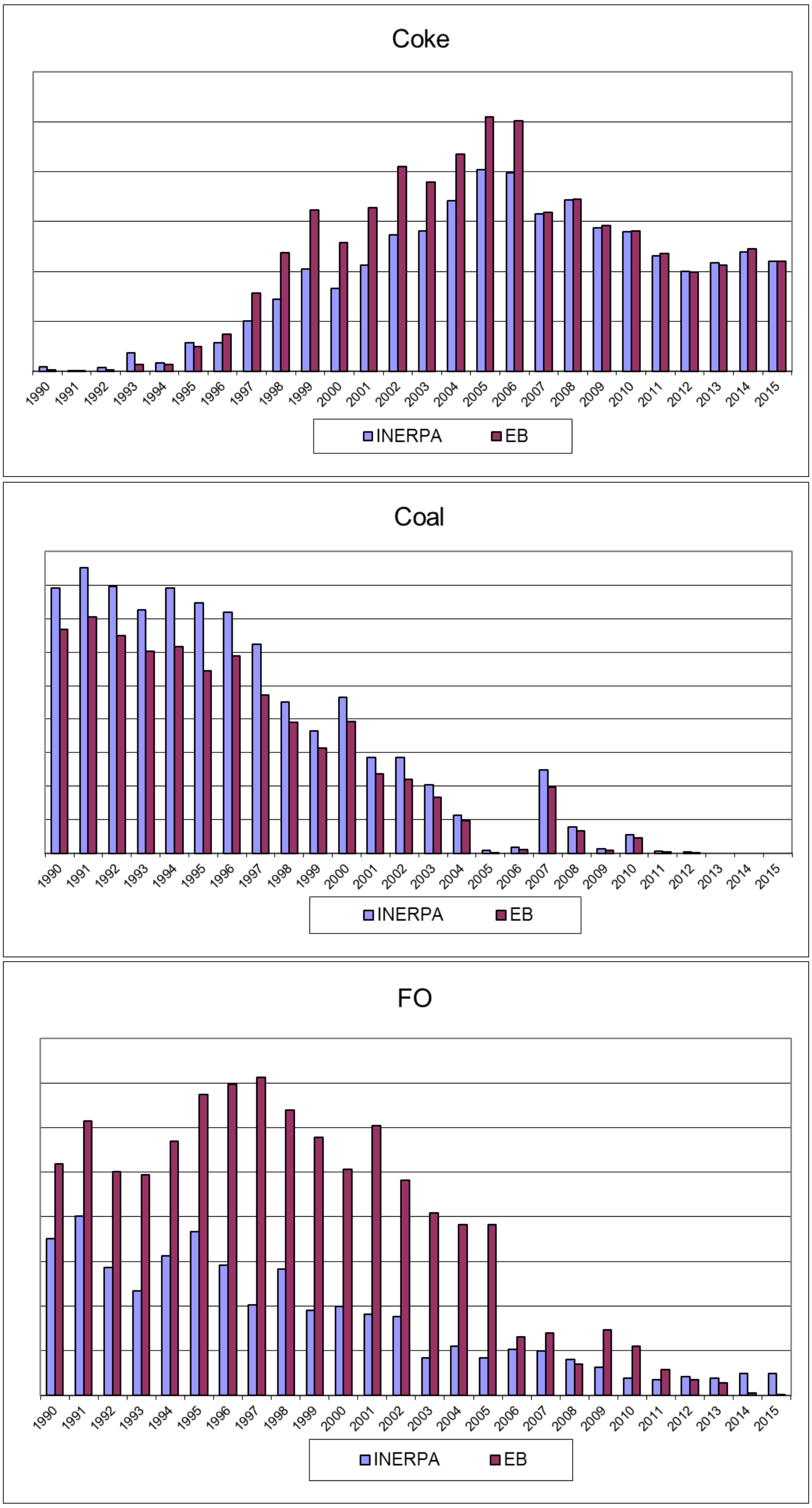
The match for the iron and steel industry show a good consistency, except for intermediate years, and for the slightly higher consumption of Blast Furnace Gas. This last difference may result from the use of different LHV values.

Figure 3.51 – 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"[19] (1990-2001).



[19] Units in the vertical axis are not indicated due to considenciality issues.

Figure 3.52 – 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 fro the following data sources:

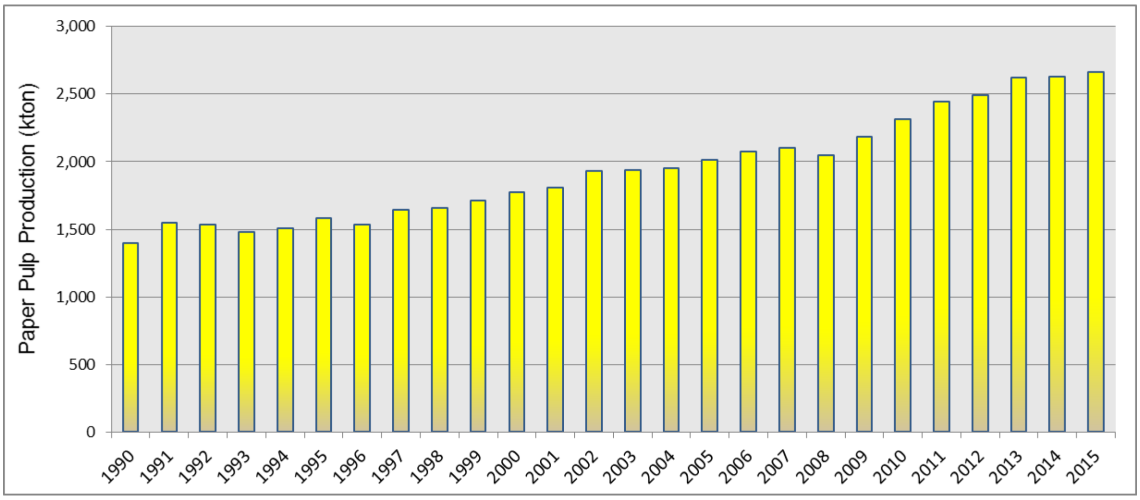
- LCP Directive – 1990 to 2000;
- CELPA – 2003 to 2009 (Kraft paper pulp);
- INE industrial production data – 2003 to 2009 (Acid sulphite paper pulp);
- EU-ETS – 2010 onwards.

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).

Product	Unit	1990	1995	2000	2005	2010	2013	2014	2015
Pulp Production	kt	1,398	1,581	1,774	2,010	2,316	2,620	2,631	2,664

Figure 3.53 – Total paper pulp production: Kraft and sulphide paper pulp.



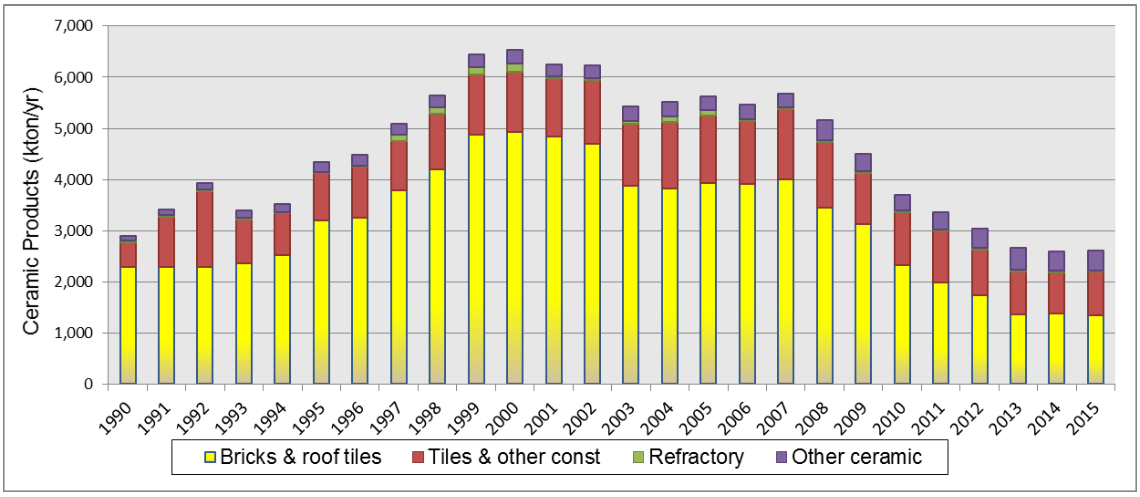
Clinker production values cannot be shown in this reported because of confidentiality issues.

Data on annual manufacturing of ceramic products is available from 1990 to 2015 from INE statistical database. The time series for total production is shown in Table 3.62 and Figure 3.54, according to type of ceramic.

Table 3.62 – Ceramic Production according to type of ceramic (kt).

Product	Unit	1990	1995	2000	2005	2010	2013	2014	2015
Bricks & roof tiles	kt	2,290	3,200	4,932	3,923	2,321	1,360	1,374	1,338
Tiles & other const	kt	478	921	1,170	1,327	1,043	841	816	859
Refractory	kt	31	27	167	100	25	27	24	24
Other ceramic	kt	104	185	260	278	310	428	384	384

Figure 3.54 – Ceramic Production according to type of ceramic.



The production values for container glass and lead crystal glass are presented in Figure 3.55 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 3.55 - Glass production by glass type (excluding flat glass production).

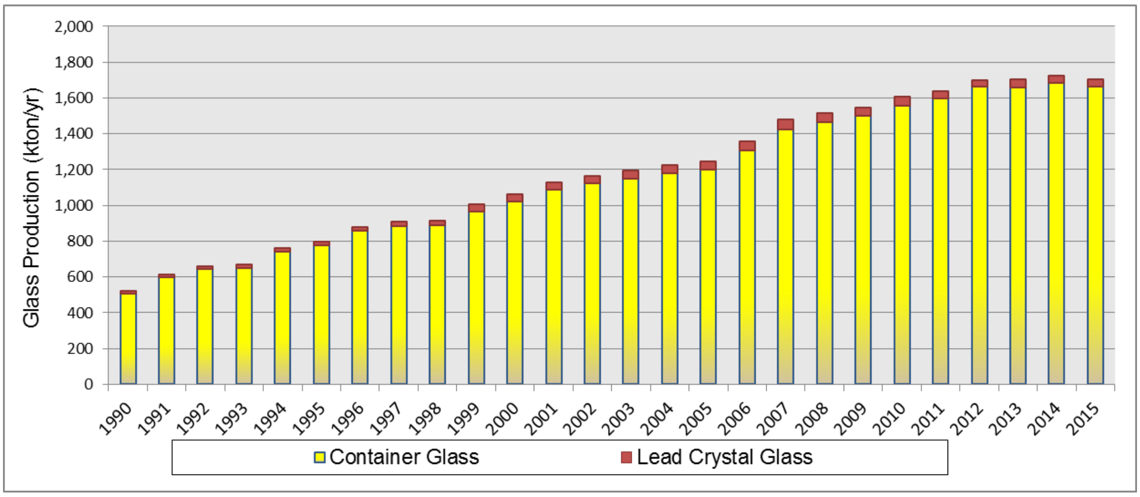


Table 3.63- Glass production by glass type (kt/yr) excluding flat glass production.

Product	Unit	1990	1995	2000	2005	2010	2013	2014	2015
Container Glass	kt	508	776	1,019	1,201	1,558	1,660	1,682	1,666
Lead Crystal Glass	kt	16	22	44	45	52	42	44	39

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_2 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_2 (i) (kg/GJ)	Oxidation factor (i) (ratio)	% C fossil	CH_4 (i) (g/GJ)	N_2O (i) (g/GJ)
Boilers	Steam Coal	S	102	98.3	1.00	100	10.0	1.5
	Brown Coal/Lignite	S	105	101.0	1.00	100	10.0	1.5
	Coke from Coal	S	107	94.6	1.00	100	10.0	1.5
	LPG	L	303	63.1	1.00	100	0.9	4.0
	City Gas	G	308	44.4	1.00	100	1.0	0.1
	Coke Oven Gas	S	304	44.4	1.00	100	1.0	0.1
	Blast Furnace Gas	S	305	260.0	1.00	100	1.0	0.1
	Fuel Gas, Hydrogen	G	399	63.1	1.00	100	0.9	4.0
	Biomass Wood	B	111	112.0	1.00	0	11.0	7.0
	Kerosene	L	206	71.9	1.00	100	3.0	0.6
	Diesel Oil	L	204	74.1	1.00	100	3.0	0.6
	Residual Oil	L	203	77.4	1.00	100	3.0	0.6
	Natural Gas	G	301	56.1	1.00	100	1.0	1.0
	Biodiesel	B	223	70.8	1.00	0	3.0	0.6
Static Engines	Gasoline	L	208	69.3	1.00	100	3.0	0.6
	Gas Oil	L	204	74.1	1.00	100	3.0	0.6
	Biogas	B	309	54.6	1.00	0	1.0	0.1
	Biodiesel	B	223	70.8	1.00	0	3.0	0.6

(i) IPCC (2006);

Table 3.65 – Emission factors of Greenhouse gases in the extractive industry.

Equipment	Fuel		NAPFUE	CO_2 (kg/GJ)	Oxidation factor (ratio)	% C fossil	CH4 (g/GJ)	N_2O (g/GJ)
Boilers	LPG	L	303	63.1	1.00	100	1.5	1.4
	Gasoline	L	208	68.6	1.00	100	0.1	0.6
	Kerosene	L	206	71.9	1.00	100	0.6	0.6
	Diesel Oil	L	204	74.1	1.00	100	0.6	0.6
	Residual Oil	L	203	76.6	1.00	100	1.4	0.6
	Natural Gas	G	301	56.1	1.00	100	1.4	1.4
	Lignite	S	105	101.2	1.00	100	2.4	0.7
Static Engines	Gasoline	L	208	69.3	1.00	100	60	0.6
	Gas Oil	L	204	74.1	1.00	100	60	0.6

(i) IPCC (2006);

Table 3.66 – Emission factors for Greenhouse gases in the building and construction industry.

Fuel		NAPFUE	LHV	CO_2			CH_4	N_2O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.17	77.4	1.00	100	3.0	0.6
Gas Oil	L	204	43.31	74.1	1.00	100	3.0	0.6
Kerosene	L	206	43.72	71.9	1.00	100	5.0	0.6
Motor Gasoline	L	208	44.77	69.3	1.00	100	9.9	0.6
LPG	L	303	47.28	63.1	1.00	100	1.0	0.1
Natural Gas	G	301	45.97	56.1	1.00	100	1.0	0.1

(i) IPCC (2006);

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_2			CH_4 (g/GJ)	N_2O (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/t Sinter)	NMVOC (kg/t 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_2			CH_4 (g/GJ)	N_2O (iii) (g/GJ)	CO (g/GJ)	NMVOC (g/GJ)
		kg/GJ	Oxidation Factor (ratio)	% C fossil				
Natural gas	G	55.74-57.43 (i)	0.995 (ii)	100	CRF 2.C.1	0.6	CRF 2.C.1	CRF 2.C.1
Gasoil	L	74.1 (ii)	0.990 (ii)	100	CRF 2.C.1	0.6	CRF 2.C.1	CRF 2.C.1
Residual oil	L	78.9 (ii)	0.993	100	CRF 2.C.1	0.6	CRF 2.C.1	CRF 2.C.1
LPG	L	63.1 (ii)	0.995 (ii)	100	CRF 2.C.1	0.1	CRF 2.C.1	CRF 2.C.1

(i) ETS data
(ii) Revised 1996 IPCC Guidelines
(iii) 2006 IPCC Guidelines

Table 3.70 – Emission factors for use in Area emissions in the Iron and steel Industry.

Fuel		CO_2			CH_4 (g/GJ)	N_2O (g/GJ)	CO (g/GJ)	NMVOC (g/GJ)
		kg/GJ (i)	Oxidation Factor (ratio) (i)	% 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

(i) Revised 1996 IPCC Guidelines

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

Equipment	Fuel		NAPFUE	CO_2 (kg/GJ)	Oxidation Factor (ratio)	% C fossil	CH_4 (g/GJ)	N_2O (g/GJ)
Boilers	Residual Fuel Oil	L	203	77.4	0.990 – 0.993	100	3	0.6
	Pyrolisys Fuel Oil	L	203	77.4	1.00	100	3	0.6
	Fuel Gas	L	307	47.6 – 50.7	1.00	100	1.0	0.1
Furnaces	Fuel Gas	L	307	47.6 – 50.7	1.00	100	1.0	0.1
	Propane	L	303	63.1	1.00	100	1.5	1.4
Static Engines	Residual Fuel Oil	L	203	77.4	0.990 – 0.993	100	3	0.6
	Diesel Oil	L	204	74.1	1.00	100	3	0.6
Flares	Flare Gas	L	307	55.0 – 74.4	1.00	100	1.0	0.1

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		CO2(i)		CH4	N2O
				EF (kg/GJ)	%C fossil	EF (g/GJ)	EF (g/GJ)
Auxiliary Boilers	Residual Oil	L	203	77.4	0	3.0	0.6
	Natural Gas	G	301	56.1	0	1.4	1.4
Biomass Boilers	Wood Waste	B	111	112.0	100	30.0	4.3
	Residual Oil	L	203	77.4	0	3.0	0.6
	Natural Gas	G	301	56.1	0	1.4	1.4
	LPG	L	303	63.1	0	1.4	1.4
Recovery Boilers	Residual Oil	L	203	77.4	0	3.0	0.6
	Natural Gas	G	301	56.1	0	-	1.4
	Gas Oil	L	204	74.1	0	-	0.6
	Bisulfite Liquor	B	215	95.3	100	30.0	0.6
	Black Liquor	B	215	95.3	100	-	0.6
	Methanol	B	111	63.1	100	-	1.4
Flare	LPG	L	303	63.1	0	1.4	1.4
Lime Kiln	Gasified Biomass	B	111	112.0	100	-	4.3
	Residual Oil	L	203	77.4	0	-	0.6
	Natural Gas	G	301	56.1	0	-	1.4
	Gas Oil	L	204	74.1	0	-	0.6
	NCG	B	111	56.1	100	-	1.4
	Tall-oil	B	111	74.1	100	-	0.6
Static Engine	Gas Oil	L	204	74.1	0	9.9	0.6
Gas Turbine	Natural Gas	G	301	56.1	0	1.4	1.4

(i)The CO_2 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	CH4(i)
	EF (kg/t 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 Date chapter for more explanations).Most emission factors result from plant specific emission factors developed from monitoring at each installation, as reported to EPER exercise.

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

Ceramic	CO_2 [(b)] (kg/t)	CH_4 [(a)] (kg/t)
Bricks and roof tiles	0.14	0.029
Tiles & other construction materials	18.57	0.022
Refractory	-	0.029
Other ceramic	-	0.022

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

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

Type of Glass	SO_x	NO_x	NMVOC	CO
Flat Glass	1.5	4	0.1	0.1
Container Glass	1.7	3.1	4.5	0.1
Lead Crystal Glass	2.8	4.3	4.7	0.1
Other Glass	2.8	4.3	4.7	0.1

Source: USEPA (1986)

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

Type of Glass	CO_2 kg/t	CH_4 kg/t
Flat Glass	126	0.01
Container Glass	130	0.45
Lead Crystal Glass	239	0.47
Other Glass	239	0.47

Source: CH4 USEPA (1986); CO2 EUTS data

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

3.3.2.4 Uncertainty Assessment

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

- when fuel consumption was obtained directly from a Large Point Source (LPS) the uncertainty of activity data was set at 3 % for energy intensive industrial sectors (iron and steel, cement, paper pulp, glass and ceramics) and 5 % for all other sources;
- if fuel consumption, other than biomass, results from statistical information gathered from the National Energy balances then uncertainty is 5 % for energy intensive sectors and 10 % for all other sectors;

- the uncertainty in biomass consumption is always higher, at least because the moisture content is always doubtful, and the uncertainty was set in all area sources as 60 %.

The uncertainty of CO_2 emission factors is 5 % for all situations, which is consistent with GPG recommendations. Finally the uncertainty for methane is 150 % and an order of magnitude for N_2O.

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

Revisions were made in the Chemical sector, namely updating of the time series of activity data and revision of some emission factors

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 2015 emissions from Civil Aviation in Portugal amounted to 3,539 Gg CO_2e, from which 369 Gg CO_2e are from domestic flights and 3,170 Gg CO_2e 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_2 e).

Source Category/Pollutant	1990	1995	2000	2005	2010	2013	2014	2015
Domestic Aviation	**180.28**	**221.27**	**323.17**	**393.06**	**404.91**	**338.64**	**344.28**	**369.36**
CO_2	177.82	218.41	319.75	389.14	401.08	335.51	341.05	365.96
CH_4	0.98	1.04	0.75	0.67	0.49	0.33	0.38	0.35
N_2O	1.48	1.82	2.67	3.24	3.34	2.80	2.84	3.05
International Aviation*	**1,548.61**	**1,647.31**	**2,021.42**	**2,300.43**	**2,660.96**	**2,851.60**	**3,029.05**	**3,169.47**
CO_2	1,532.67	1,630.47	2,002.31	2,279.59	2,637.08	2,826.18	3,001.84	3,141.38
CH_4	3.16	3.24	2.43	1.84	1.89	1.86	2.18	1.90
N_2O	12.78	13.59	16.69	19.00	21.98	23.56	25.02	26.19

*Memo item. Emissions not included in national totals.

For the elaboration of the greenhouse gases emissions inventory which is reported to the EU[20] and to the UNFCCC, emissions from flights to and from the autonomous regions of Azores and Madeira islands are included in national totals.

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

Table 3.78 – 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.

[20] Decision 2004/280/CE

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:

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

where:

EmissionLTO (p,d,a,s,y) – Emissions of pollutant p from origin/destiny d in airport a performed by aircraft s during year y (t/yr);

EmissionArrival(p,d,a,s,y), EmissionDeparture(p,d,a,s,y) – Arrival and departure emissions of pollutant p from, respectively, origin and destiny d in airport a performed by aircraft s during year y (t/yr);

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

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

EFDeparture(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;

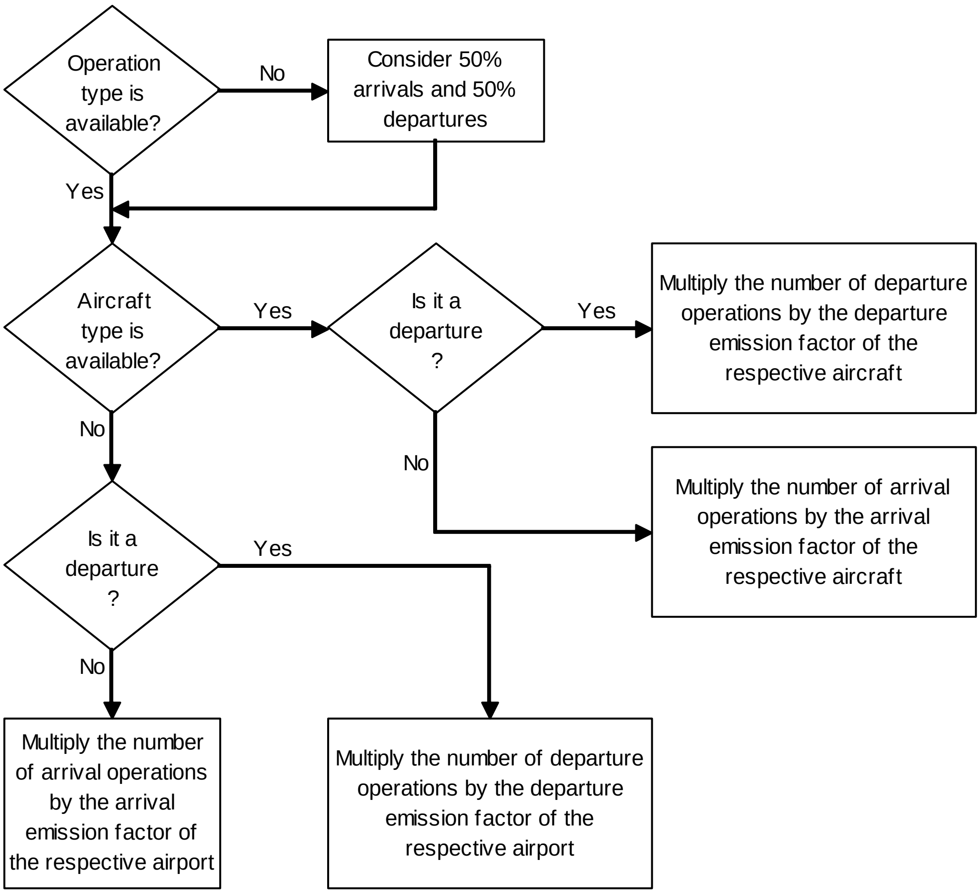
y – year.

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

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

Figure 3.56 outlines the process whereby LTO emissions are estimated.

Figure 3.56 – 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.

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

where:

Emissioncruise(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 (t/yr);

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

EFcruise(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
Beechcfrat 1900/1900C	131.6	16.2	16.2	1.5	1.2	60.5	6.8	8.7	0.4	0.6
Aerospatiale Fennec (AS-550)	94.1	1.5	3.4	1.3	1.0	94.1	1.5	3.4	1.3	1.1
Dassault (Breguet Mystere) Falcon	42.2	0.4	2.0	0.9	0.4	34.1	0.4	2.4	0.3	0.3
Airbus A340 all models	1376.4	11.8	74.4	106.1	12.8	557.3	4.4	28.6	18.2	6.1
Boeing 767 all pax models	996.1	4.7	20.7	37.3	9.4	421.2	1.9	8.9	6.9	4.7
Mooney M-20	3.0	0.1	3.1	0.0	0.0	2.1	0.0	2.5	0.0	0.0

3.3.3.1.3.1.2 Airport Based LTO Emission Factors

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

Table 3.80 – Airport based LTO emission factors (kg/movement).

Airport	Operation	Parameter	1990	1995	2000	2005	2010	2013	2014	2015
Lisboa (LIS)	Take-off	Fuel Consur	670.2	608.9	567.4	452.6	451.6	447.0	462.5	468.4
		VOC	16.4	14.9	15.2	9.3	2.8	2.4	2.3	2.3
		CO	37.1	33.7	35.4	21.5	13.8	12.2	12.3	12.8
		NOx	26.3	23.9	23.6	16.2	15.9	16.1	16.0	17.1
		PM_{10}	6.2	5.6	5.2	4.2	4.2	4.2	4.3	4.4
	Landing	Fuel Consur	291.0	264.4	240.2	204.2	206.6	201.0	178.6	223.7
		VOC	7.0	6.4	6.0	4.4	1.5	1.3	1.3	1.2
		CO	17.8	16.2	16.3	11.1	7.0	6.2	6.2	6.5
		NOx	4.9	4.4	4.3	3.3	3.4	3.3	2.9	3.8
		PM_{10}	3.1	2.8	2.6	2.2	2.2	2.2	1.9	2.4
Porto (OPO)	Take-off	Fuel Consur	530.0	481.5	401.1	374.4	427.6	342.9	423.7	358.1
		VOC	8.2	7.5	6.5	4.1	3.3	3.0	2.9	2.6
		CO	26.3	23.9	23.0	13.7	12.8	11.4	12.7	10.7
		NOx	19.1	17.3	15.0	11.9	14.7	11.6	14.3	11.9
		PM_{10}	4.9	4.5	3.7	3.5	4.0	3.2	3.9	3.3
	Landing	Fuel Consur	236.2	214.6	181.3	172.9	191.7	156.8	160.6	171.1
		VOC	3.7	3.3	2.9	2.2	1.6	1.4	1.7	1.4
		CO	12.7	11.5	11.1	7.2	6.3	5.7	6.7	5.8
		NOx	3.8	3.5	3.0	2.6	3.2	2.5	2.7	2.8
		PM_{10}	2.5	2.3	1.9	1.9	2.1	1.7	1.7	1.8
Faro (FAO)	Take-off	Fuel Consur	514.8	467.7	443.6	348.7	339.1	274.3	319.6	263.5
		VOC	5.3	4.8	4.9	3.0	2.4	2.2	2.0	2.1
		CO	19.2	17.4	17.2	12.2	11.0	9.0	9.3	8.5
		NOx	17.4	15.8	16.0	11.0	10.0	8.0	9.6	7.7
		PM_{10}	4.8	4.3	4.1	3.2	3.1	2.5	3.0	2.4
	Landing	Fuel Consur	231.8	210.6	198.9	158.2	161.1	134.9	117.5	139.3
		VOC	2.7	2.5	2.5	1.7	1.4	1.4	1.4	1.4
		CO	10.0	9.1	9.0	6.5	5.9	5.1	5.0	5.0
		NOx	3.5	3.2	3.1	2.3	2.4	2.0	1.6	2.0
		PM_{10}	2.5	2.3	2.1	1.7	1.7	1.4	1.3	1.5

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
	6482	32 223	408	4223	17790
Airbus A318/319/320/321	0	0	0	0	0
	232	842	17	149	1096
	463	1 695	27	267	1742
	926	2 858	45	508	3108
	1389	3 903	56	684	3571
	1852	5 225	73	915	4688
	2778	7 530	99	1311	6166
	3704	10 064	130	1747	7849
	4630	12 639	159	2189	9532
Boeing 727 all pax models	0	0	0	0	0
	231.5	1303.9	11	907	3459
	463	2341.8	17	2206	5869
	926	4247.3	43	2311	8837
	1389	6080.4	58	3072	11842
	1852	8058.3	74	3746	14568
	2778	12131.4	108	5279	20688
	3704	16459.4	147	6871	27075
	4630	20825.2	185	8477	33515

Source: EMEP/CORINAIR

3.3.3.1.3.2.2 Airport Based Cruise Emissions

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

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

3.3.3.1.3.2.3 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 2 in ANNEX D: ENERGY (CRF 1.A.3, 1.A.4 and 1.A.5) shows the correspondence between aircrafts and representative aircrafts for LTO and cruise emissions factors.

3.3.3.1.3.3 Fuel dependent emission factors

Fuel dependent emission factors were set for CO_2 and N_2O. Emission factors for CO_2 and N_2O are IPCC default. The LHV were obtained from the national energy authority (DGEG).

Table 3.82 – Fuel dependent emission factors

Pollutant	Aviation Gasoline	Jet Fuel
LHV (MJ/kg)	44.0	43.0
CO_2 (t/TJ)	70	71.5
N_2O (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 2015 was provided by the *Autoridade Nacional da Aviação Civil* (ANAC). 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 ANAC.

Table 3.83 – LTO per airport.

Region	Airport Code	1990	1995	2000	2005	2010	2013	2014	2015
Mainland	LIS	30,862	34,932	56,073	68,168	73,783	74,378	79,898	84,385
	OPO	11,574	13,348	23,280	25,910	28,502	30,131	32,016	35,248
	FAO	11,252	13,067	18,243	20,397	22,359	21,896	22,484	22,330
	TOTAL	53,688	61,347	97,596	114,475	124,643	126,405	134,398	141,963
Region	**Airport Code**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**	**2014**	**2015**
Islands	FNC	6,475	9,460	12,040	15,952	12,697	12,198	11,988	12,442
	TER	3,801	4,049	4,501	4,875	4,988	4,676	4,670	4,755
	PDL	2,954	3,382	4,134	7,196	8,182	7,608	7,665	8,499
	PXO	2,403	4,243	3,788	3,688	2,325	1,703	2,051	2,103
	HOR	1,237	1,542	1,756	2,964	2,919	2,353	2,272	2,331
	SMA	634	893	1,557	1,649	1,275	922	974	1,073
	FLW	281	357	552	1,101	1,136	846	954	1,002
	TOTAL	17,785	23,924	28,327	37,425	33,521	30,305	30,572	32,204

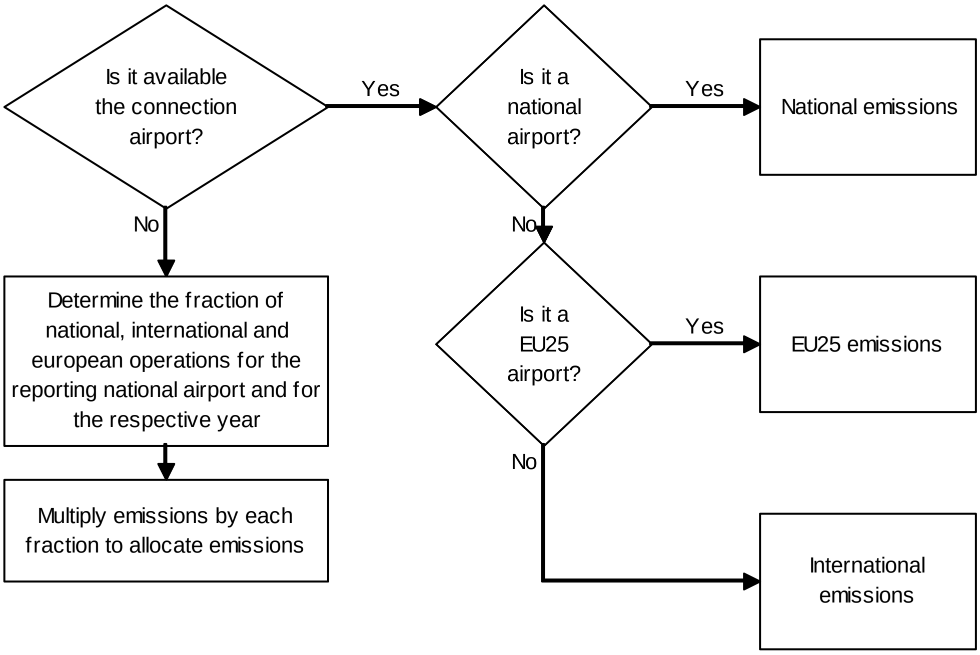
Source: ANAC

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 worst 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.

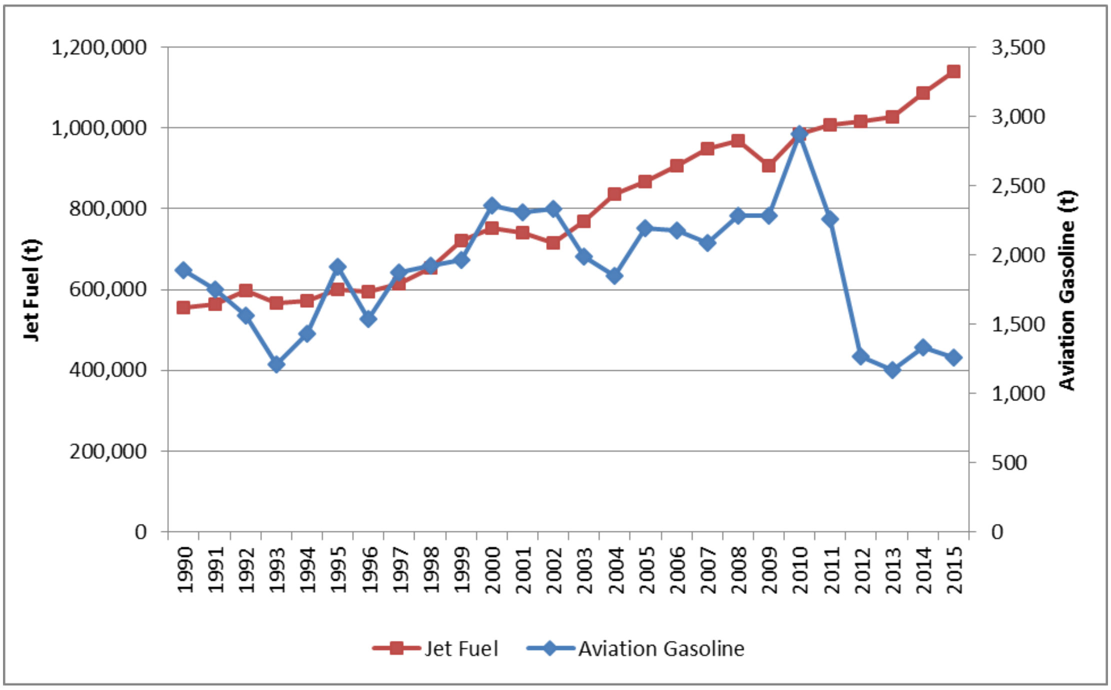
Figure 3.57 – Decision tree for distinction between domestic and international emissions.



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 3.58 – 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 wich was estimated for LTO and Cruise separately according with the following couple equations.

$$U_{cruise} = \sqrt{U^2_{movements} + U^2_{time} + U^2_{FCcruise}}$$
$$U_{lto} = \sqrt{U^2_{movements} + U^2_{FClto}}$$

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:

Ecruise, Elto = domestic energy consumption under cruise and LTO (GJ).

Table 3.84 – Aviation activity level uncertainty.

Source	Parameter	Unit	1990	1995	2000	2005	2010	2013	2014	2015
All	Uglobal	%	71	72	35	36	35	36	36	35
Cruise	Ucruise	%	99	99	47	49	48	48	48	47
LTO	Ulto	%	100	100	48	49	48	48	47	47

The uncertainties of emissions factors were set at 5% for CO_2, 100% for methane and one order of magnitude for N_2O, 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

No recalculations were made.

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_2), methane (CH_4) and nitrous oxide (N_2O).

Exhaust greenhouse gases emissions from road transportation were estimated at about 15,515 Gg CO_2e in 2015, representing an increase of 64.7% when compared to 9,422 Gg CO_2e estimated for 1990.

Emissions of N_2O 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_2 and NH_3 emissions which contribute to climate change and acid deposition. It is difficult to assess the extent to which CO_2 emissions have increased as a result of fitting catalytic converters, because improvements in fuel economy have been made at the same time as development of the engine management systems that are required to minimize NO_x and VOC emissions.

Table 3.85 – Estimated emissions from road transport (Gg CO_2e).

Source Category/Pollutant	1990	1995	2000	2005	2010	2013	2014	2015
Road Transportation	**9,422.3**	**12,824.3**	**18,479.1**	**18,897.8**	**18,055.6**	**15,048.7**	**15,362.5**	**15,514.7**
CO_2 Fossil	9,256.3	12,409.4	18,184.1	18,633.3	17,848.5	14,884.3	15,196.9	15,352.3
CO_2 Biomass*	0.0	0.0	0.0	0.0	880.8	754.2	756.7	880.6
CH_4	101.6	109.1	94.8	62.2	39.6	29.3	27.5	26.7
N_2O	64.3	305.7	200.2	202.2	167.5	135.0	138.1	135.7

*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 11.4 - September 2016). 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_2 emissions from urea-based catalytic converters which were estimated using the COPERT IV. In 2015, emissions from urea-based catalytic converters represented 0.001% of the total CO_2 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_2 emissions and Tier 3 for non-CO_2 emissions.

Figure 3.59 – General scheme of methodology applied for road transport emissions estimates (Passenger cars, light duty vehicles and motorcycles).

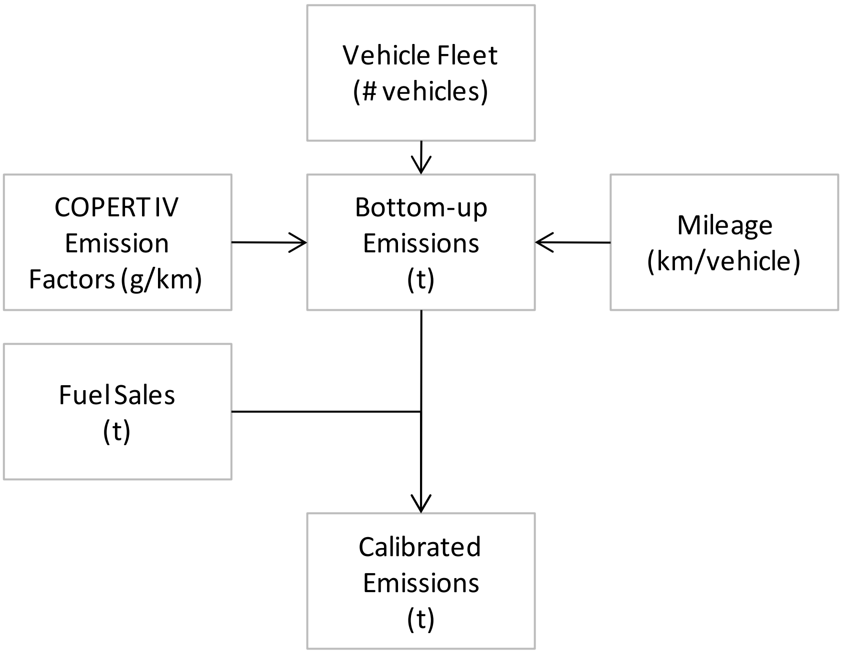
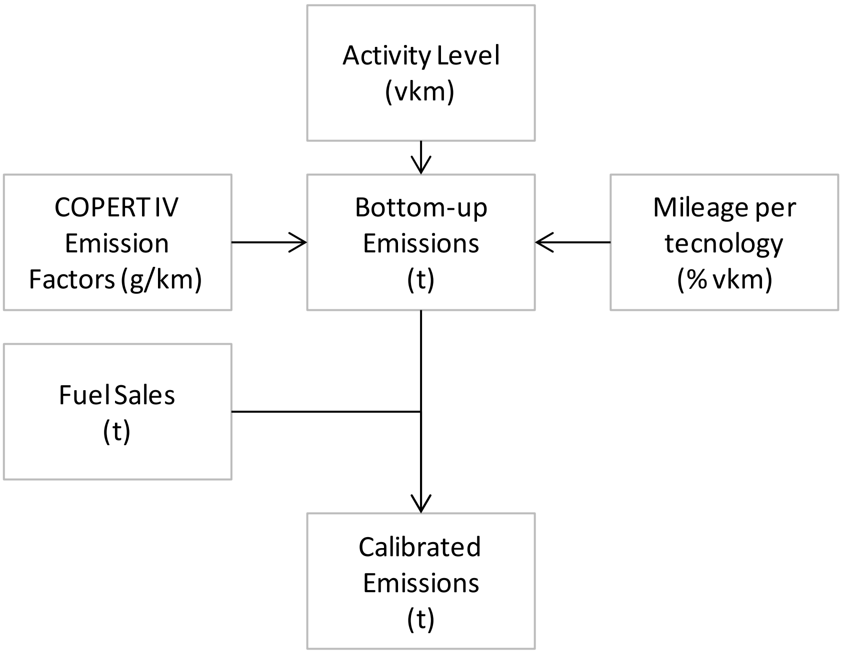


Figure 3.60 – General scheme of methodology applied for road transport emissions estimates (Heavy duty vehicles, buses and coaches).



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:

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

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

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 disagregated 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 centers.

Mopeds and motorcycles are excluded from the vehicle maintenance program therefore it was assumed an average mileage of 12000 km/year for motorcycles (Bennetts, 2009) and 5000 for mopeds.

Table 3.86 – Km per year per vehicle as function of vehicle age for passenger cars and light duty vehicles.

Vehicle Category	Sub Categories	Mileage Function	Parameters
Passenger Cars	Gasoline <1,4 l Hybrid Gasoline <1,4 l	km/year = A2 + (A1 - A2) / (1 + (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	km/year = y0 + A * Exp(-0.5 * ((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	km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p)	A1 = 13354.66789 A2 = 737.09264 x0 = 19.69152 p = 2.4209
	Diesel <2,0 l	km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p)	A1 = 19241.06557 A2 = 6603.86725 x0 = 17.45625 p = 2.53695
	Diesel >2,0 l	km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p)	A1 = 20445.94606 A2 = 9728.01464 x0 = 14.25834 p = 3.25053
Light Duty Vehicles	Diesel <3,5 t	km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p)	A1 = 20800.21535 A2 = 2597.42606 x0 = 15.44257 p = 2.32592

Table 3.87 – Km per year per vehicle type.

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2013	2014	2015
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	4,553	4,276	3,999
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	6,144	5,718	5,305
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	0	0	11,036	10,541	9,134	7,932	7,501	7,063
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	10,982	10,252	9,368	9,004	8,615
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	11,059	10,949	10,588	10,396	10,169
Passenger Cars	Gasoline <1,4 l	PC Euro 5 (post 2005)	0	0	0	0	11,059	11,032	11,007	10,954
Passenger Cars	Gasoline <1,4 l	PC Euro 6	0	0	0	0	0	0	0	11,059
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	5,611	5,273	4,976
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	7,546	6,977	6,438
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	0	0	12,880	12,430	11,172	9,852	9,326	8,770
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	12,803	12,173	11,364	10,996	10,579
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	12,937	12,758	12,422	12,254	12,052
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 (post 2005)	0	0	0	0	12,937	12,898	12,874	12,823
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6	0	0	0	0	0	0	0	12,937

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2013	2014	2015
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	6,184	5,946	5,714
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	0	13,331	12,735	11,050	8,816	7,544	7,156	6,791
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	0	0	13,312	12,549	10,726	9,376	8,925	8,482
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13,211	12,109	10,959	10,521	10,072
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13,355	13,171	12,638	12,372	12,069
Passenger Cars	Gasoline >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	13,355	13,318	13,285	13,210
Passenger Cars	Gasoline >2,0 l	PC Euro 6	0	0	0	0	0	0	0	13,355
Passenger Cars	Diesel <2,0 l	Conventional	18,516	18,089	16,360	14,000	11,863	10,910	10,660	10,434
Passenger Cars	Diesel <2,0 l	PC Euro 1 - 91/441/EEC	0	19,198	18,445	16,380	13,803	12,447	12,051	11,687
Passenger Cars	Diesel <2,0 l	PC Euro 2 - 94/12/EEC	0	0	19,196	18,299	16,092	14,515	14,005	13,513
Passenger Cars	Diesel <2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	19,127	17,943	16,608	16,091	15,566
Passenger Cars	Diesel <2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	19,241	19,031	18,369	18,034	17,652
Passenger Cars	Diesel <2,0 l	PC Euro 5 (post 2005)	0	0	0	0	19,241	19,191	19,142	19,041
Passenger Cars	Diesel <2,0 l	PC Euro 6	0	0	0	0	0	0	0	19,241
Passenger Cars	Diesel >2,0 l	Conventional	18,690	17,521	15,735	13,871	12,317	11,661	11,497	11,351
Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	0	20,428	19,808	17,394	14,327	12,960	12,604	12,293
Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	0	0	20,433	19,762	17,201	15,267	14,676	14,132
Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	20,381	19,230	17,603	16,955	16,303
Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	20,446	20,333	19,770	19,425	19,001
Passenger Cars	Diesel >2,0 l	PC Euro 5 (post 2005)	0	0	0	0	20,446	20,426	20,397	20,331
Passenger Cars	Diesel >2,0 l	PC Euro 6	0	0	0	0	0	0	0	20,446

Sector	Subsector	Technology	1990	1995	2000	2005	2010	2013	2014	2015
Passenger Cars	LPG	Conventional	13,109	12,455	10,806	8,689	6,816	5,947	5,709	5,485
Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	0	13,294	12,546	10,769	8550.609733	7,327	6,960	6,621
Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	0	0	13,295	12,442	10,554	9,197	8,749	8,311
Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	0	0	0	13,166	11,942	10,735	10,289	9,833
Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	0	0	0	13,355	13,330	13,044	12,852	12,611
Passenger Cars	LPG	PC Euro 5 (post 2005)	0	0	0	0	13,355	13,223	13,094	12,914
Passenger Cars	LPG	PC Euro 6	0	0	0	0	0	0	0	0
Passenger Cars	2-Stroke	Conventional	0	0	0	0	0	13,341	13,323	13,297
Passenger Cars	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	10,228	9,879	9,134	9,121	10,174	10,876	10,914	10,930
Passenger Cars	Hybrid Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	12,937	12,914	12,843	12,859	12,847	12,831
Passenger Cars	Hybrid Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	13,355	13,242	13,191	13,201	13,198	13,190
Light Duty Vehicles	Gasoline <3,5t	Conventional	10,433	8,828	6,292	4,092	2,460	1,237	1,189	1,143
Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	0	13,331	12,735	11,050	8,816	7,544	7,156	6,791
Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	0	0	13,312	12,549	10,726	9,376	8,925	8,482
Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	13,211	12,109	10,959	10,521	10,072
Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	13,355	13,171	12,638	12,372	12,069
Light Duty Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards	0	0	0	0	13,355	13,318	13,285	13,210
Light Duty Vehicles	Gasoline <3,5t	LD Euro 6	0	0	0	0	0	0	0	13,355
Light Duty Vehicles	Diesel <3,5 t	Conventional	17,571	16,481	13,978	11,295	9,067	8,077	7,811	7,557
Light Duty Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	0	20,733	19,497	16,114	12,248	10,346	9,803	9,307
Light Duty Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	0	0	20,741	19,246	15,618	13,224	12,483	11,782
Light Duty Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	20,649	18,597	16,392	15,581	14,763
Light Duty Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	0	20,491	19,344	18,760	18,102
Light Duty Vehicles	Diesel <3,5 t	LD Euro 5 - 2008 Standards	0	0	0	0	0	20,740	20,661	20,546
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 IMT by the highway service providers. The remaining vkm are allocated to urban and rural driving modes according with the population living in each area.

3.3.3.2.2.4 Speed

Three driving modes where individualized in accordance with source categories SNAP97 from CORINAIR/EMEP methodology: urban, rural and highway. For each driving mode average speeds had to be set by vehicle type whereas vehicle fuel consumption and exhaust emissions are strongly dependent on speed.

Table 3.88 – Assumed vehicle speeds by driving mode and vehicle type.

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

3.3.3.2.2.5 Fuel consumption

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

$$FC_{(f,y)} = \sum_{m}\sum_{c}\sum_{t}\left[vkm_{(c,t,m,f,y)} \times FC_{(c,t,m,f)}\right] \times 10^{-6}$$

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 driing 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.

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

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_2 emission factors where established according with IPCC guidelines.

Energy content was first estimated using national specific LHV provided by DGEG.

Table 3.89 – National specific LHV.

Fuel	LHV (GJ/t)
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_2 emission factors ($kgCO_2/GJ$) were multiplied by the energy consumption.

Table 3.90 - CO_2 emission factors.

Fuel	EF_{CO2} (kg CO_2/GJ)
Gasoline	69.30
Diesel	74.10
Liquefied Petroleum Gases	63.10
Compressed Natural Gases	56.10

Source: IPCC, 2006

Emissions factors for CH_4 and N_2O, expressed in g/km, were determined using COPERT IV (version 11.4 - September 2016).

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 cilinder capacity greater than 50 cc;
- Fuel type: gasoline, diesel and LPG;
- Technology standard;
- Vehicle dimensions: motor size (cubic centimetres) for light vehicles and two wheelers and vehicle weight for heavy vehicles;
- Average vehicle speed under each driving mode.

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

Table 3.91 – Technology classification according to built year.

Vehicle Category	Legislation	Built year	
		from	to
Passenger Cars	PRE ECE	…	1971
	ECE 15/00-01	1972	1977
	ECE 15/02	1978	1980
	ECE 15/03	1981	1985
	ECE 15/04	1986	1991
	Euro 1	1992	1996
	Euro 2	1997	2000
	Euro 3	2001	2004
	Euro 4	2005	2008
	Euro 5 ([21])	2009	2014
	Euro 6 ([1])	2014	…
Light Duty Vehicles	Conv	…	1991
	Euro 1	1992	1997
	Euro 2	1998	2001
	Euro 3	2002	2006
	Euro 4	2006	2009
	Euro 5 ([1])	2010	2015
	Euro 6 ([1])	2015	…
Heavy Duty Vehicles	Conv	…	1991
	Euro I	1992	1995
	Euro II	1996	2000
	Euro III	2001	2005
	Euro IV	2006	2008
	Euro V	2009	…
Mopeds	Conv	…	1999
	Euro 1	2000	2002
	Euro 2	2003	2005
	Euro 3	2006	…
Motorcycles	Conv	…	1999
	Euro 1	2000	2003
	Euro 2	2004	2005
	Euro 3	2006	…

[21] 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 ltrip for Portugal. Therefore it was decided to use an European average value of 12 km (L_{trip}) as proposed by COPERT IV. The European average value is closed to the value for Spain which is assumed to be adequate also for Portugal.

Emissions factors for SO_2 and heavy metals were estimated from the fraction S and heavy metals in the fuel. For LPG, CNG and Biodiesel it was assumed a 0% sulphur content.

Table 3.92 – Sulphur content in gasoline and diesel (%).

Fuel	1990-1999	2000-2004	2005-2008	2009-2015
Gasoline	0.100	0.015	0.005	0.001

Fuel	1990-1994	1995	1996-1999	2000-2004	2005-2008	2009-2015
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 nº 235/2004, Decreto-Lei nº 142/2010));

For evaporative emission calculations, monthly maximum and minimum average ambient temperatures were inputed into COPERT IV. Meteorological data was received from 9 climatological stations of the *Portuguese Sea and Atmosphere Institute* (IPMA). The data concerns a long period average from 1971 to 2000 and is the most updated long period average available from the IPMA. The same values were used for all years in analysis.

Table 3.93 – Monthly average ambient temperatures (ºC).

Month_	Max.	Min.
January	14.0	6.6
February	15.2	7.4
March	17.3	8.5
April	18.4	9.7
May	20.8	11.9
June	24.5	14.7
July	27.7	16.8
August	28.0	16.8
September	26.0	15.6
October	21.6	12.8
November	17.5	9.8
December	14.9	7.3

Source: IM (http://www.meteo.pt/pt/oclima/normais/)

Monthly values of fuel volatility (RVP - Reid Vapour Pressure) were established from Portuguese legislation (Decreto-lei n.º 104/2000; Portaria 1489/95; Portaria 125/89). RVP values considered in national legislation 104/2000 are applicable since the beginning of year 2000 although the regulatory document was valid only after May 2000. The new national regulation, Decreto-Lei nº 142/2010, keeps the same RVP values.

Table 3.94 – Reid Vapour Pressure (kPa).

Month	1990 to 1995	1996 to 1999	2000 to 2015
January	98	95	90
February	98	95	90
March	98	95	90
April	83	80	90
May	83	80	60
June	70	70	60
July	70	70	60
August	70	70	60
September	70	70	60
October	83	95	90
November	98	95	90
December	98	95	90

Emissions from biofuels

Use of biodiesel as a blend with diesel may also lead to some change in emissions. The following table proposes differences in emissions caused by different fuel blends on fossil diesel and correspond to a Euro 3 vehicle/engine technology.

Table 3.95 – Effect of biodiesel blends on diesel vehicles emissions.

Pollutant	Vehicle Type	B10	B20	B100
CO_2	Passenger Cars	-1.5%	-2.0%	
	Light duty vehicles	-0.7%	-1.5%	
	Heavy duty vehicles	0.2%	0.0%	0.1%
NO_x	Passenger Cars	0.4%	1.0%	
	Light duty vehicles	1.7%	2.0%	
	Heavy duty vehicles	3.0%	3.5%	9.0%
PM	Passenger Cars	-13.0%	-20.0%	
	Light duty vehicles	-15.0%	-20.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-47.0%
CO	Passenger Cars	0.0%	-5.0%	
	Light duty vehicles	0.0%	-6.0%	
	Heavy duty vehicles	-5.0%	-9.0%	-20.0%
HC	Passenger Cars	0.0%	-10.0%	
	Light duty vehicles	-10.0%	-15.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-17.0%

Source: (EEA/EMEP, 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_x, CO_2 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 7.33% in 2015 (Table 3.96), emission factors from biodiesel use were assumed to be the same as for diesel.

Table 3.96 – National biodiesel blends with diesel (%v/v).

2006	2007	2008	2009	2010	2013	2014	2015
1.51	2.93	2.90	4.85	6.97	7.06	6.91	7.83

Source: (DGEG)

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

3.3.3.2.3 Implied Emission Factors

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

Table 3.97 – Road transportation emission factors (kg/GJ).

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010	2013	2014	2015
CO_2 (kg/Gj)	Passenger Cars	Gasoline	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30
		Diesel	74.07	74.07	74.07	74.07	74.07	74.07	74.07	74.07
		LPG	63.07	63.07	63.07	63.07	63.07	63.07	63.07	63.07
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-	-	-
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-	-	-
		Diesel	74.07	74.07	74.07	74.07	74.07	74.07	74.07	74.07
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-	-	-
	Heavy Vehicles	Gasoline	-	-	-	-	-	-	-	-
		Diesel	74.07	74.07	74.07	74.07	74.07	74.07	74.07	74.07
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	56.10	56.10	56.10	56.10	56.10	56.10
		Biodiesel	-	-	-	-	-	-	-	-
	Motorcycles	Gasoline	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30
		Diesel	-	-	-	-	-	-	-	-
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-	-	-
CH_4 (kg/Gj)	Passenger Cars	Gasoline	0.044	0.036	0.026	0.019	0.014	0.011	0.010	0.009
		Diesel	0.006	0.005	0.003	0.002	0.001	0.001	0.001	0.000
		LPG	0.021	0.022	0.020	0.018	0.015	0.013	0.012	0.011
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.0009	0.0006	0.0006	0.0005
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-	-	-
		Diesel	0.004	0.004	0.003	0.002	0.001	0.001	0.001	0.000
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.0011	0.0007	0.0006	0.0005
	Heavy Vehicles	Gasoline	-	-	-	-	-	-	-	-
		Diesel	0.007	0.007	0.007	0.006	0.005	0.005	0.005	0.005
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	0.095	0.097	0.092	0.092	0.092	0.092
		Biodiesel	-	-	-	-	0.005	0.005	0.005	0.005
	Motorcycles	Gasoline	0.179	0.169	0.145	0.100	0.074	0.058	0.054	0.050
		Diesel	-	-	-	-	-	-	-	-
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-	-	-

Pollutant	Vehicle	Fuel	1990	1995	2000	2005	2010	2013	2014	2015
N2O (kg/Gj)	Passenger Cars	Gasoline	0.003	0.012	0.006	0.005	0.002	0.002	0.002	0.001
		Diesel	0.000	0.001	0.001	0.002	0.003	0.003	0.003	0.003
		LPG	0.000	0.004	0.005	0.005	0.004	0.003	0.003	0.002
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.003	0.003	0.003	0.003
	Light Duty Vehicles	Gasoline	-	-	-	-	-	-	-	-
		Diesel	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.002
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	0.002	0.002	0.002	0.002
	Heavy Vehicles	Gasoline	-	-	-	-	-	-	-	-
		Diesel	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	0.000	0.000	0.000	0.000	0.000	1.000
		Biodiesel	-	-	-	-	0.001	0.001	0.001	0.001
	Motorcycles	Gasoline	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		Diesel	-	-	-	-	-	-	-	-
		LPG	-	-	-	-	-	-	-	-
		CNG	-	-	-	-	-	-	-	-
		Biodiesel	-	-	-	-	-	-	-	-

The implied emission factors expressed in grams per kilometer were also derived.

Table 3.98 – Road transportation distance based implied emission factor (MJ/km; g/km).

Pollutant	Fuel	Vehicle Type	1990	1995	2000	2005	2010	2013	2014	2015
Energy Consumption (Mj/km)	Diesel	Passenger Cars	2.69	2.63	2.68	2.58	2.53	2.52	2.51	2.51
		Light Duty Vehicles	3.52	3.42	3.28	3.20	3.17	3.16	3.15	3.15
		Heavy Vehicles	9.99	9.86	11.62	11.61	11.24	11.61	11.76	11.80
	Gasoline	Passenger Cars	2.73	2.68	2.65	2.58	2.56	2.56	2.56	2.56
		Light Duty Vehicles	-	-	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-	-	-
		Mopeds	1.10	1.10	1.08	0.97	0.90	0.89	0.88	0.88
		Motorcycles	1.72	1.75	1.76	1.66	1.60	1.55	1.54	1.53
	CNG	Heavy Vehicles	-	-	21.57	21.62	21.51	21.51	21.51	21.51
	LPG	Passenger Cars	2.60	2.63	2.64	2.60	2.58	2.57	2.57	2.57
		Light Duty Vehicles	-	-	-	-	-	-	-	-
CO2 (g/km)	Diesel	Passenger Cars	199.20	194.67	198.86	191.13	187.53	186.46	186.01	185.73
		Light Duty Vehicles	260.57	253.62	242.61	237.04	234.56	233.70	233.48	233.33
		Heavy Vehicles	740.16	730.63	860.93	859.56	832.37	859.88	871.15	874.02
	Gasoline	Passenger Cars	189.09	185.66	183.96	179.11	177.33	177.26	177.22	177.44
		Light Duty Vehicles	-	-	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-	-	-
		Mopeds	76.23	76.23	74.51	66.92	62.54	61.43	61.24	61.12
		Motorcycles	119.30	121.41	121.79	115.17	110.79	107.72	106.74	105.96
	CNG	Heavy Vehicles	-	-	1210.33	1213.03	1206.94	1206.94	1206.94	1206.94
	LPG	Passenger Cars	164.12	166.17	166.72	164.17	162.72	162.29	162.16	162.06
		Light Duty Vehicles	-	-	-	-	-	-	-	-
CH4 (g/km)	Diesel	Passenger Cars	0.017	0.014	0.009	0.005	0.002	0.002	0.001	0.001
		Light Duty Vehicles	0.014	0.014	0.010	0.006	0.003	0.002	0.002	0.001
		Heavy Vehicles	0.068	0.067	0.077	0.073	0.054	0.055	0.055	0.054
	Gasoline	Passenger Cars	0.121	0.097	0.069	0.048	0.035	0.028	0.026	0.024
		Light Duty Vehicles	-	-	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-	-	-
		Mopeds	0.219	0.219	0.199	0.106	0.045	0.028	0.025	0.023
		Motorcycles	0.192	0.192	0.188	0.159	0.131	0.106	0.097	0.089
	CNG	Heavy Vehicles	-	-	2.05	2.11	1.98	1.98	1.98	1.98
	LPG	Passenger Cars	0.054	0.058	0.053	0.046	0.040	0.033	0.031	0.029
		Light Duty Vehicles	-	-	-	-	-	-	-	-
N2O (g/km)	Diesel	Passenger Cars	0.000	0.002	0.003	0.006	0.007	0.007	0.007	0.007
		Light Duty Vehicles	0.000	0.001	0.003	0.004	0.006	0.006	0.006	0.006
		Heavy Vehicles	0.019	0.019	0.019	0.019	0.014	0.015	0.014	0.014
	Gasoline	Passenger Cars	0.008	0.033	0.015	0.012	0.006	0.005	0.004	0.004
		Light Duty Vehicles	-	-	-	-	-	-	-	-
		Heavy Vehicles	-	-	-	-	-	-	-	-
		Mopeds	0.001	0.001	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	0.002	0.002
	CNG	Heavy Vehicles	-	-	0.002	0.002	0.002	0.002	0.002	0.002
	LPG	Passenger Cars	0.000	0.010	0.012	0.012	0.011	0.008	0.007	0.006
		Light Duty Vehicles	-	-	-	-	-	-	-	-

3.3.3.2.4 Activity Data

3.3.3.2.4.1 Vehicle Fleet

The following table, that shows the number of vehicles between 1990 and 2015, was based in data available from ACAP, *Instituto de Seguros de Portugal* (ISP) and INE.

Table 3.99 – Vehicle fleet synthesis.

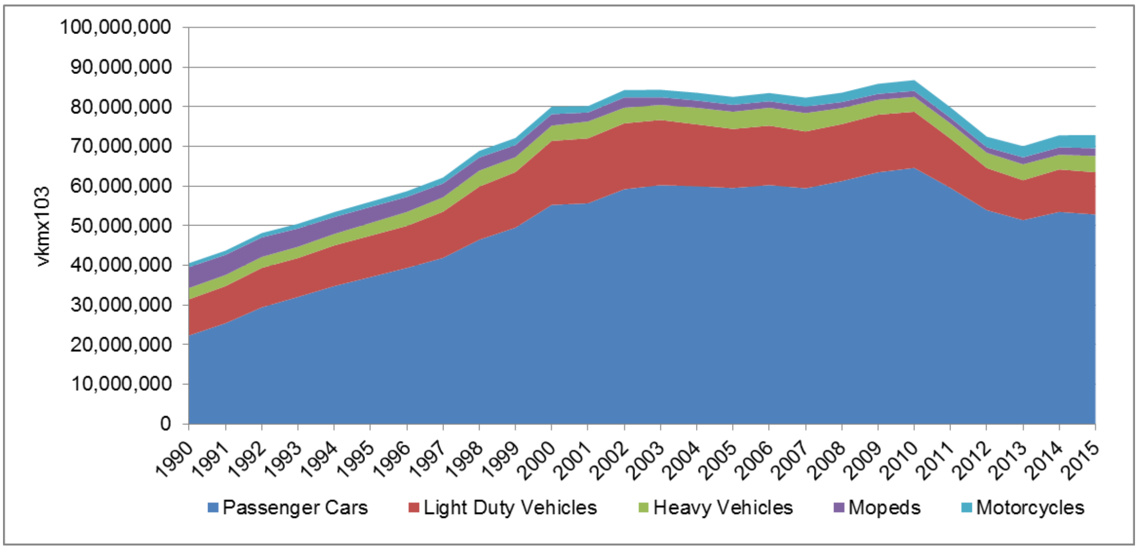
Vehicle Type	1990	1995	2000	2005	2010	2013	2014	2015
Passenger Cars	1,616,141	2,702,221	3,743,315	4,185,542	4,191,286	3,803,363	3,690,706	3,612,644
Light Duty Vehicles	449,918	545,091	684,953	751,144	718,869	628,816	600,572	576,986
Mopeds	834,675	682,031	529,387	330,528	283,369	277,354	271,861	271,713
Motorcycles	66,129	92,239	144,595	157,055	215,987	231,095	237,807	255,863

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 79.57% between 1990 and 2015.

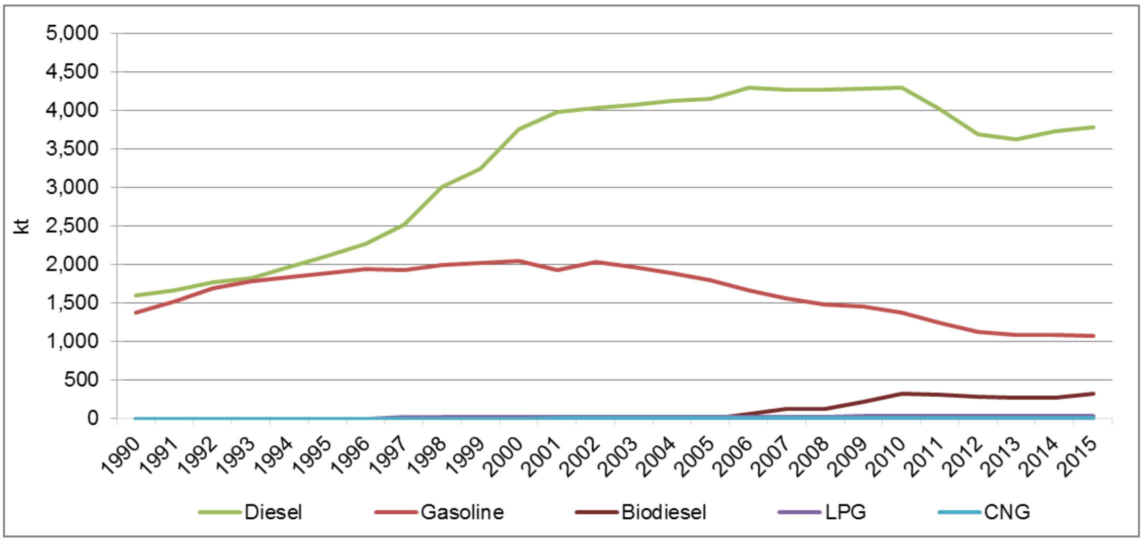
Figure 3.61 – Kilometers travelled by vehicle type (vkmx10₃).



3.3.3.2.4.3 Fuel Consumption

Fuel consumption from road transport sector is available from the revised energy balances from DGEG and is presented in the following figure and ANNEX E: Energy Balance Sheet for 2015.

Figure 3.62 – 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_2 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 2015 the estimated fuel consumption compared to sales are: Gasoline -8%; Diesel 5%; LPG -84%; 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_2 emissions are corrected as well.

3.3.3.2.7 Recalculations

Recalculations for this source category comprise:

- Revision of 2012, 2013 and 2014 vkm values for Heavy duty trucks by INE;
- Revision of the incorporation rate of biodiesel from 2006 until 2015;

- Correction of CO2 emissions calculation since CO2 emissions from the use of urea-based additives in catalytic converters are now reported under 2.D.3.c as recommended by the ESD and UNFCCC reviews 2016;

- Revision of the 2013 Energy Balances data by DGEG;

- Report of CO2, CH4 and N2O emissions for lubricants used in 2-stroke engines under 1.A.3.b.iv as recommended by the ESD review 2016.

3.3.3.2.8 Further Improvements

Continue with the efforts to develop 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 3.100 – Estimated emissions from Railways (Gg CO_2e).

Source Category/Pollutant	1990	1995	2000	2005	2010	2013	2014	2015
Railways	**197.80**	**192.46**	**151.31**	**91.84**	**52.88**	**33.96**	**35.70**	**33.93**
CO2 Fossil	177.19	172.39	135.53	82.26	47.05	30.21	31.77	30.16
CO2 Biomass*	0.00	0.00	0.00	0.00	3.02	1.96	2.01	2.20
CH4	0.25	0.24	0.19	0.12	0.07	0.05	0.05	0.05
N2O	20.37	19.83	15.59	9.46	5.76	3.70	3.88	3.72

*Information item. Emissions not included in national totals.

3.3.3.3.2 Methodology

Emissions to atmosphere of ultimate CO_2 from fossil origin were estimated from CO_2 total emissions by:

$$Fossil_{CO2(y)} = \Sigma_f \left[EF_{CO2\ (f)} * Fac_{OX\ (f)} * C_{Fossil(f)} * Cons_{Fuel(f,y)} * LHV_{(f)}\right] * 10^{-5}$$

where:

$Fossil_{CO2(y)}$ - Emissions of carbon dioxide to atmosphere from combustion of fossil fuel f (t);

$EF_{CO2\ (f)}$ – Total carbon content of fuel expressed in total CO_2 emissions (kgCO_2/GJ);

C_{Fossil} - 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 (t/yr);

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

For all other pollutants the following formula was used:

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

where

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

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

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

3.3.3.3.3 Emission Factors

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

Table 3.101 - 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 3.102 - Oxidation factor and Percentage of carbon from fossil origin in fuels – Railways.

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

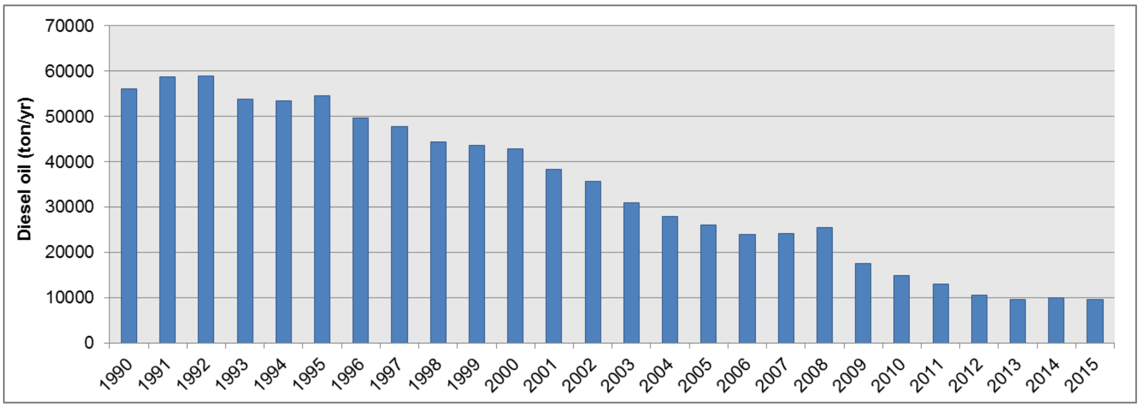
Table 3.103 - Emission factors for Greenhouse gases in Railways.

Fuel	CO_2			CH_4			N_2O		
	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 2015 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[22]. The quantities that were consumed have been decreasing steadily since 1992 due to electrification of the power lines, as can be seen in Figure 3.63.

Figure 3.63 - 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 %. In a similar way the uncertainties in methane and nitrous oxide emission factors were set at 40 % and 50 % respectively, the same values that were used for road traffic. The general error of 5 %, set for most combustion sources, was used for the calculation of uncertainties of carbon dioxide emissions.

3.3.3.3.6 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

No recalculations were made.

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.

[22] Gas oil represents no less than 93 % of total annual use of combustible energy.

Table 3.104 – Estimated emissions from Water-Borne Navigation (Gg CO_2e).

Source Category/Pollutant	1990	1995	2000	2005	2010	2013	2014	2015
Domestic Water-Borne Navigation	**265.2**	**229.6**	**203.4**	**211.3**	**231.5**	**252.0**	**266.0**	**269.1**
CO_2	262.5	227.3	201.4	209.2	229.1	249.5	263.4	266.4
CH_4	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.6
N_2O	2.0	1.8	1.6	1.6	1.8	1.9	2.1	2.1
International Water-Borne Navigation*	**1,414.1**	**1,130.1**	**1,683.8**	**1,568.7**	**1,650.9**	**2,232.3**	**1,980.8**	**2,121.0**
CO_2	1,400.0	1,118.8	1,667.0	1,553.1	1,634.5	2,210.2	1,961.2	2,099.9
CH_4	3.2	2.6	3.8	3.5	3.7	5.0	4.5	4.8
N_2O	10.9	8.7	13.0	12.1	12.7	17.1	15.2	16.3

*Memo item. Emissions not included in national totals

3.3.3.4.2 Methodology

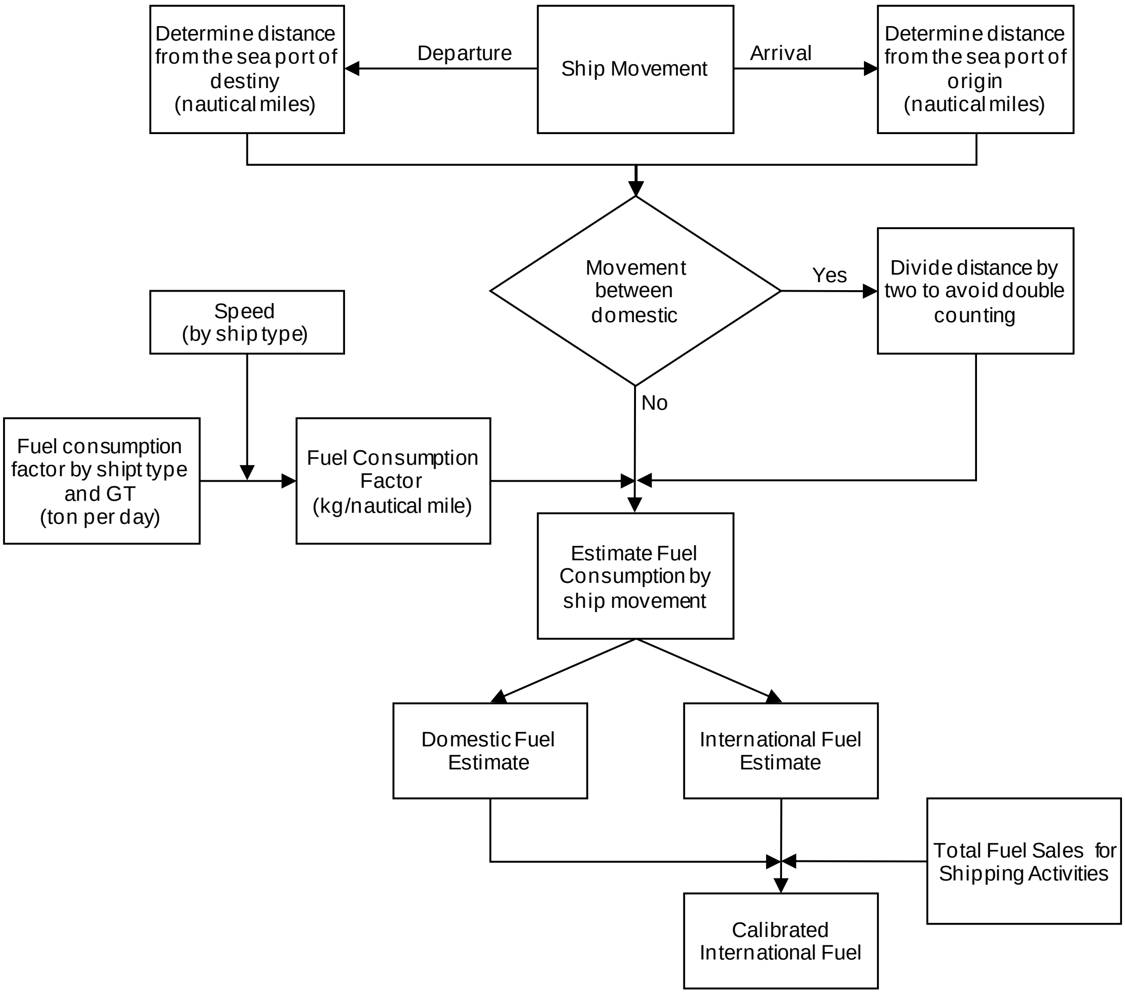
Statistics on fuel used in shipping activities are available at national level as an aggregated figure provided in the energy balance from the energy authority. Detailed ship movements are also available, as well as some technical information on the ships such as gross tonnage and ship type.

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).

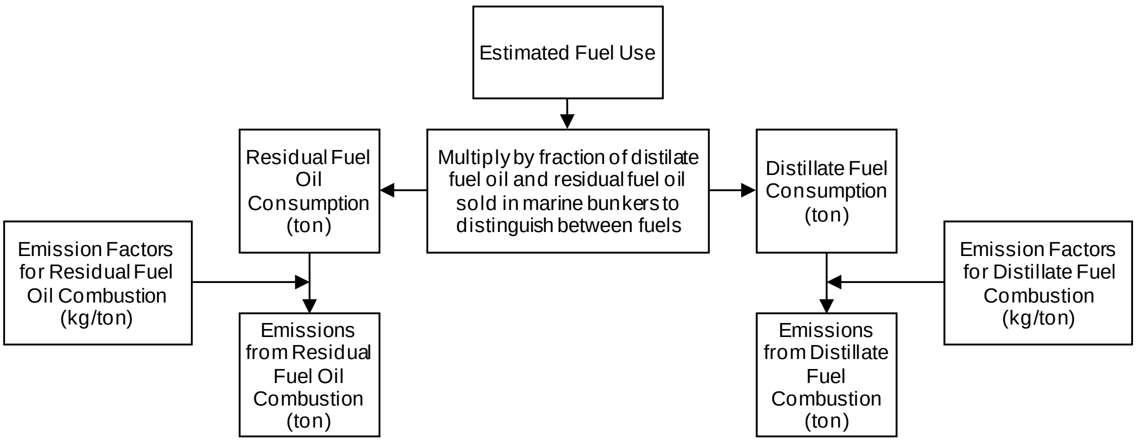
The methodology takes into account the fuel used as well as the type of ship, the distance travelled and the speed of vessel. Therefore, according with IPCC Guidelines, this approach consists in a detailed method (tier 2 or 3). Since fuel consumption is used for top-down calibration, tier 2 method could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

The general approach could be described as follows:

Figure 3.64 – Generic methodology flowchart.



Emissions factors vary according with the type of fuel used. To distinguish between residual and distillated 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 t/TJ, and the CH_4 and N_2O emission factors were obtained from IPCC 2006 Guidelines.

Table 3.105 - 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 3.106 – 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 3.107 - Emission factors for Greenhouse gases – Navigation.

Fuel	CO_2			CH_4			N_2O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Gas-oil	74.1	t /TJ	IPCC 2006	7.0	kg/TJ	IPCC 2006	2.0	kg/TJ	IPCC 2006
Residual Fuel-oil	77.4	t /TJ	IPCC 2006	7.0	kg/TJ	IPCC 2006	2.0	kg/TJ	IPCC 2006

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 3.108 – Consumption factors.

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

Legend:
gt – gross tonnage
[a] – a factor of 0.8 was applied to obtain consumption for cruise.
Source: (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 2015. 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.

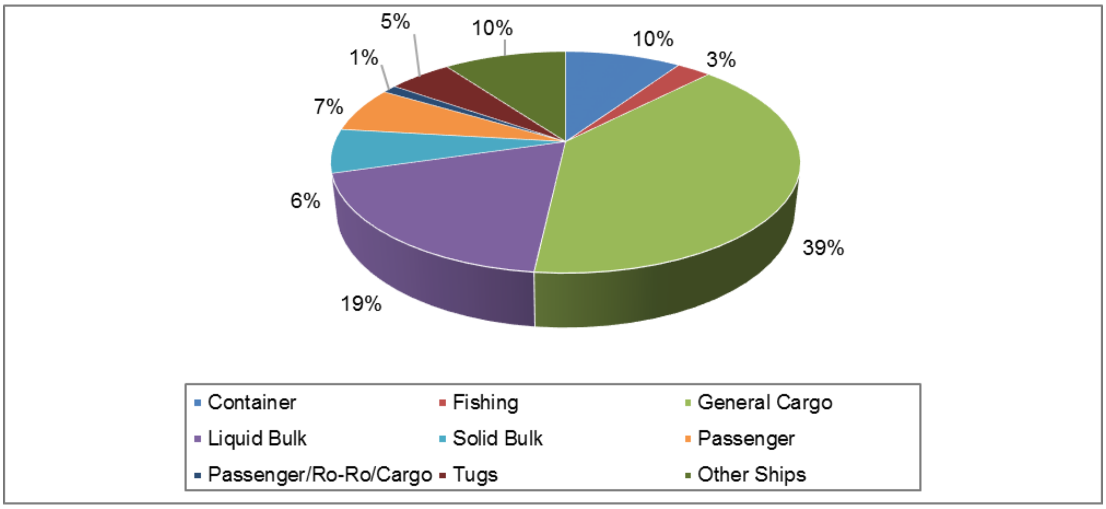
Table 3.109 – Ship docks.

Sea Port	Location	Unit	1990	1995	2000	2005	2010	2013	2014	2015
Aveiro	Mainland	docks	876	1,098	1,009	1,028	961	922	988	1,025
Caniçal	Madeira	docks	76	76	76	178	390	283	274	241
Faro	Mainland	docks	163	163	163	32	12	35	79	85
Figueira da Foz	Mainland	docks	315	297	307	321	476	523	528	496
Funchal	Madeira	docks	1,063	1,063	1,063	948	758	719	640	664
Leixões	Mainland	docks	2,742	2,896	3,050	2,814	2,612	2,564	2,627	2,735
Lisboa	Mainland	docks	5,586	4,993	3,869	3,474	3,129	2,658	2,709	2,605
Ponta Delgada	Azores	docks	1,080	1,080	1,080	1,078	1,035	886	810	831
Portimão	Mainland	docks	34	34	37	42	136	105	50	70
Porto Santo	Madeira	docks	402	402	402	400	392	368	349	348
Setúbal	Mainland	docks	1,453	1,453	1,699	1,592	1,632	1,426	1,576	1,627
Sines	Mainland	docks	1,038	979	808	1,124	1,632	1,991	1,994	901
Viana do Castelo	Mainland	docks	254	293	348	214	179	214	227	198

3.3.3.4.4.2 Ship Fleet

The fleet from the figure below refers to all ships that docked in national seaports irrespective of domestic or international movements.

Figure 3.65 – Ship fleet.



3.3.3.4.4.3 Fuel consumption

Fuel consumption is estimated with a bottom-up approach using fuel consumption factors combined with a top-down calibration with the energy balance. In a first step, domestic and international consumption are estimated with the bottom up approach. Then the international consumption is re-calculated by subtracting the estimated domestic consumption from the total sales reported in the energy balance, this is considered the top down calibration. This calibration does not affect the domestic fuel consumption calculated with the bottom-up approach.

$$FuelConsumption_{International} = FuelSales - FuelConsumption_{Domestic}$$

Table 3.110 – Total fuel sales (ton).

Fuel Sales		NAPFUE	1990	1995	2000	2005	2010	2013	2014	2015
Gas-oil	L	204	126,903	141,272	125,554	110,197	94,064	95,729	92,625	158,232
Residual Fuel-oil	L	203	407,823	290,920	475,743	457,115	506,320	697,217	624,401	603,295

Source: DGEG

Table 3.111 – Estimated fuel consumption (ton).

Fuel	Region	1990	1995	2000	2005	2010	2013	2014	2015
Residual Fuel-oil	Domestic	61,244	53,023	46,988	48,804	53,458	58,204	61,448	62,143
Residual Fuel-oil	International	431,554	448,716	430,253	411,428	515,738	710,727	746,122	545,529
Residual Fuel-oil	**Total**	492,797	501,739	477,242	460,233	569,196	768,931	807,570	607,672
Gas-oil	Domestic	23,132	20,027	17,748	18,434	20,192	21,984	23,209	23,472
Gas-oil	International	163,002	169,485	162,511	155,401	194,799	268,449	281,818	206,052
Gas-oil	**Total**	186,135	189,512	180,259	173,835	214,991	290,433	305,027	229,524

Table 3.112 – Estimated fuel consumption after top-down calibration (ton).

Fuel	Region	1990	1995	2000	2005	2010	2013	2014	2015
Residual Fuel-oil	Domestic	61,244	53,023	46,988	48,804	53,458	58,204	61,448	62,143
Residual Fuel-oil	International	346,579	237,897	428,754	408,311	452,862	639,013	562,954	541,152
Residual Fuel-oil	**Total**	407,823	290,920	475,743	457,115	506,320	697,217	624,401	603,295
Gas-oil	Domestic	23,132	20,027	17,748	18,434	20,192	21,984	23,209	23,472
Gas-oil	International	103,770	121,244	107,806	91,763	73,872	73,745	69,416	134,760
Gas-oil	**Total**	126,903	141,272	125,554	110,197	94,064	95,729	92,625	158,232

3.3.3.4.4.3.1 Tugs Fuel consumption

Data concerning tugs assistance operations within the national seaports allowed the incorporation of these emissions in the inventory. Tug fuel consumption was estimated for each manoeuvering ship in a seaport following the criteria shown in the Table 3.113. Specific tug fuel consumption factors were supplied by DGRM.

Table 3.113 – 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 3.114 – 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:

$$U_{global} = \sqrt{U_{movements}^{2} + U_{dis\tan ce}^{2} + U_{FC}^{2}}$$

Movement's uncertainty was assumed to be 5% as suggested in IPCC Good Practice Guidance and Uncertainty Management. The distance uncertainty was calculated assuming that ships speeds were constant between origin and destiny seaports. This allows the indirect assessment of the uncertainty trough the travelling time between seaports. For the same OD it is possible to estimate uncertainty according with differences between travelling times performed by the same type of ships. Finally, it was assumed an uncertainty of 48% for fuel consumption factors proposed by EMEP/CORINAIR. Activity level uncertainty was estimated about 50% as referred in Table 3.115.

Table 3.115 – Navigation activity level uncertainty.

Source	Parameter	Value
All	Uglobal	50%
Movements	Umovements	5%
Distance Travelled	Udistance	15%
Fuel Consumtion Factor	Ufc	48%

Following the recommendations of GPG the uncertainties of emission factor for CH_4 and N_2O, 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. No differences were found between total fuel estimated with the described methodology and total fuel reported in the energy balance.

3.3.3.4.7 Recalculations

During the QA/QC procedure a compilation error in the 2014 data was detected. The data for this year was updated and corrected

3.3.3.4.8 Further Improvements

No further improvements are planned for this sector.

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

3.3.3.5.1 Overview

There is not much information allowing the estimation of emissions from off-road vehicles and machines, mainly because they are not individualized in the energy balances from DGEG. The only exceptions is the agriculture/forestry sector, where it is more or less evident that all gas-oil is used as energy source to vehicles and mobile machines, and the fishing vessels.

Emissions from off-road vehicles and machines from other sectors: industry, residential and institutional, are however quantified and included in emission totals but under activity-specific emission estimates. The fact that they are different equipments with different emission factors is also considered in the inventory because when emission factors were established for all those activities some assumptions were made concerning where the fuel was used. For instance, it was assumed that all petrol/gasoline and half of the diesel-oil was used in engines, and these may be either static or mobile.

Since there is very little information to completely characterize 1 A 3 e Other Transportation the notation key "Included Elsewhere" was associated with this source category:

- off-road vehicles and machines from manufacturing industries, residential and commercial/institutional are included together with the other combustion equipment of these source categories;
- emissions from off-road vehicles and machines from agriculture/forestry and fishing sectors are included in 1 A 4 c Agriculture/Forestry/Fisheries.

All methodologic descriptions associated with each of these sources are presented in the appropriate chapter (1.A.2 and 1.A.4).

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

3.3.4.1 Overview

This source category refers to combustion in stationary and mobile sources (off-road) equipments that occur in commercial/institutional, residential, and agriculture/forestry/fishing activity sectors. The following stationary combustion equipments were included in this sector: boilers, co-generation equipment, machines and static engines are included in sector. Also included in 1.A.4 are emissions from fisheries bunkers and off road-road vehicles in agriculture/ forestry sector (both will have their own sub chapter in this report). As explained in 1.A.3.e due to contrains in

DGEG's energy balance off-road vehicles and machines from commercial/institutional and residential sectors could not be individualized from stationary combustions.

Table 3.116 – Estimated emissions from Other Sectors (Gg CO_2e).

Source Category/Pollutant	1990	1995	2000	2005	2010	2013	2014	2015
Commercial/Institutional	**746.9**	**1112.5**	**2656.3**	**3161.7**	**1308.1**	**1074.6**	**1154.2**	**1140.5**
CO_2 Fossil	745.3	1110.0	2650.8	3153.8	1303.2	1066.4	1145.3	1132.5
CO_2 Biomass*	0.0	0.0	2.2	5.6	12.2	176.7	199.0	152.8
CH_4	0.6	0.8	1.7	1.8	0.7	1.1	1.2	1.2
N_2O	1.1	1.6	3.8	6.1	4.1	7.2	7.7	6.8
Residential	**2114.7**	**2366.5**	**2815.2**	**2692.8**	**2823.5**	**2256.3**	**2158.3**	**2076.5**
CO_2 Fossil	1639.1	1940.4	2432.9	2368.6	2556.7	1967.8	1871.5	1791.2
CO_2 Biomass*	6106.3	5457.5	4865.2	4100.3	3337.3	3640.3	3620.6	3603.1
CH_4	410.4	367.6	328.9	277.4	226.1	245.8	244.3	243.0
N_2O	65.3	58.5	53.3	46.8	40.7	42.6	42.5	42.3
Agriculture /Forestry /Fishing	**1820.9**	**1831.5**	**1383.1**	**1446.9**	**1172.4**	**1161.3**	**1122.6**	**1144.3**
CO2 Fossil	1678.7	1678.8	1292.6	1333.6	1080.5	1067.1	1028.3	1048.8
CO2 Biomass*	0.0	0.0	0.5	1.6	61.0	64.9	61.6	72.1
CH4	2.9	2.8	2.5	2.4	2.0	2.0	1.9	2.0
N2O	139.4	149.9	88.0	110.9	89.8	92.2	92.4	93.4

*Information item. Emissions not included in national totals.

3.3.4.2 Commercial/Institutional (CRF 1.A.4.a)

3.3.4.2.1 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.

3.3.4.2.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance (CO_2) or emission factors, according to the pollutant, and using IPCC methodology.

For Carbon Dioxide (CO_2), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO2(s,f)} = EF_{CO2\ (f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

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

where:

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

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

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

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

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

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p,s)}$ - Total emissions of pollutant p for sub-sector s (t/yr except CO_2 in kt/yr);

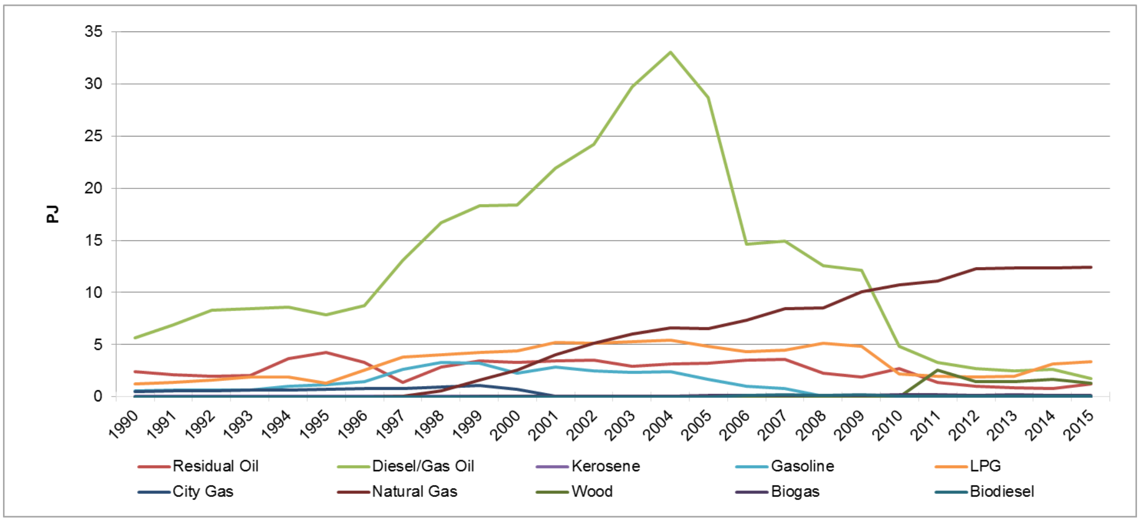
$EF_{(p,f,s,t)}$ - Emission Factor for pollutant p, specific of fuel type f, used in sub-sector s and equipment t (g/GJ except CO_2 in kg/GJ);

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

3.3.4.2.3 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: Energy Balance Sheet for 2015

Figure 3.66 – 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 3.67 – Total Energy Consumption in fuels in the commercial, services and institutional sector.

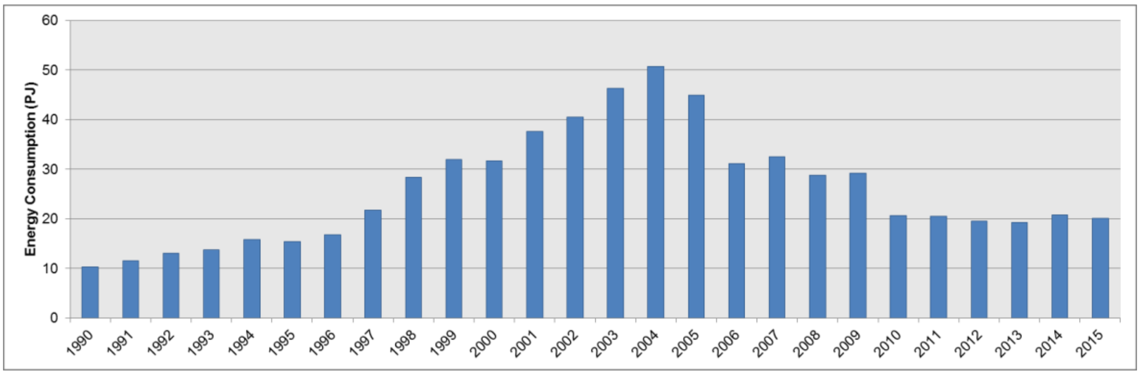
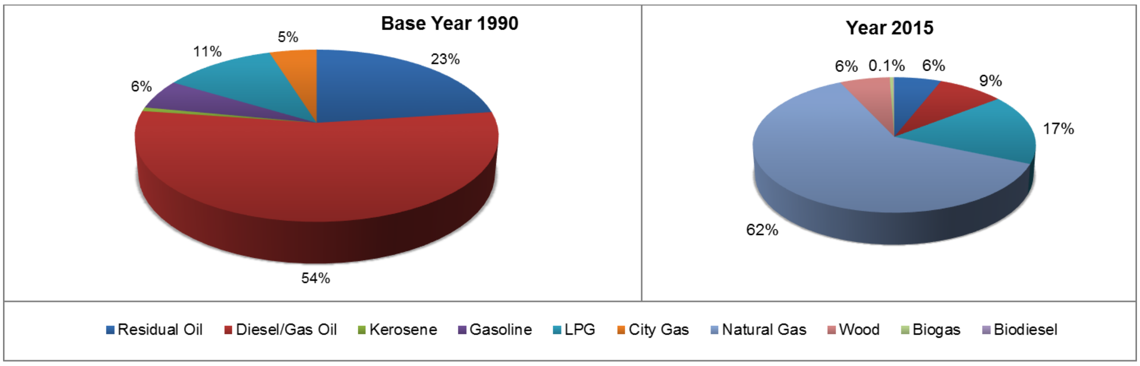


Figure 3.68 – Consumption of energy in fuels in the commercial, services and institutional sector in 1990 and 2015.



3.3.4.2.4 Emission Factors

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

Table 3.117 – 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 3.118 – 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	1.000	Ratio	100	%
Gas Oil / Diesel Oil	1.000	Ratio	100	%
Kerosene	1.000	Ratio	100	%
Motor Gasoline	1.000	Ratio	100	%
LPG	1.000	Ratio	100	%
City Gas	1.000	Ratio	100	%
Natural Gas	1.000	Ratio	100	%
Wood	1.000	Ratio	0	%
Biogas	1.000	Ratio	0	%
Biodiesel	1.000	Ratio	0	%

Table 3.119 – Emissions factors for Greenhouse gases - Commercial, services and institutional sector.

Fuel	CO_2			CH_4			N_2O		
	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	5.0	g/Gj	IPCC 2006	0.1	g/Gj	IPCC 2006
City Gas	44.0	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	112.0	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

3.3.4.2.5 Uncertainty Assessment

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

The uncertainty of CO_2 emission factors was assumed to be 5 % for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N_2O were set respectively at 150 % and an order of magnitude.

3.3.4.2.6 Category-specific QA/QA and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Only minor differences in natural gas consumption between data sources were identified for Commercial and Public Services sector (less than 10

%). For petroleum product the differences between data sources are greater than natural gas (around 30 %). DGEG reported that there were compilation errors in the information sent to IEA, which may explain the differences found.

3.3.4.2.7 Recalculations

No recalculations were made.

3.3.4.2.8 Further Improvements

No further improvements are planned for this sector.

3.3.4.3 Residential (CRF 1.A.4.b)

3.3.4.3.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in the residential sector. In this sector small other mobile sources are considered because no separation between fuel consumption is possible with DGEG's energy balance data.

3.3.4.3.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance (CO_2) or emission factors, according to the pollutant, and using IPCC methodology.

For Carbon Dioxide (CO_2), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO2(s,f)} = EF_{CO2\ (f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

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

where:

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

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

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

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

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

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p,s)}$ - Total emissions of pollutant p for sub-sector s (t/yr except CO_2 in kt/yr);

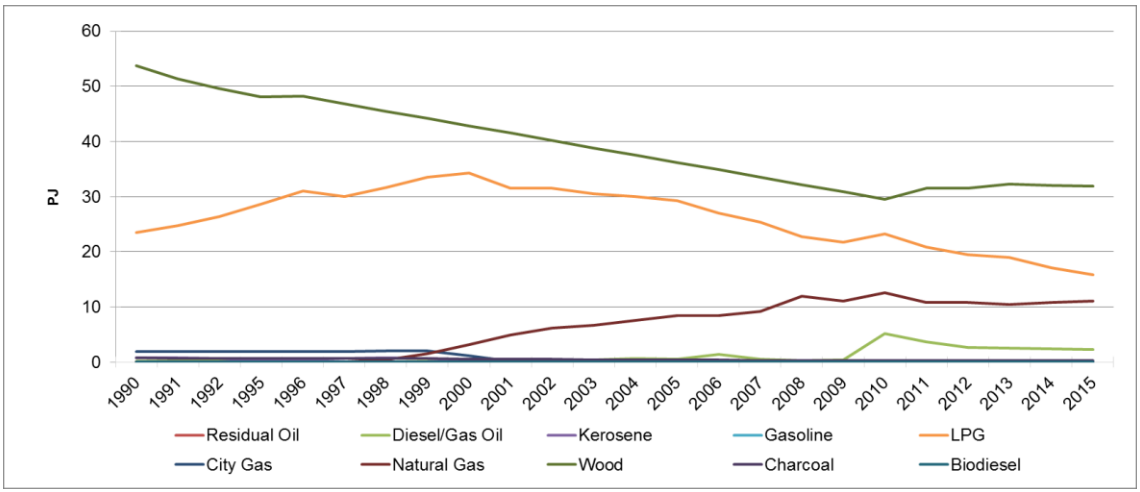
$EF_{(p,f,s,t)}$ - Emission Factor for pollutant p, specific of fuel type f, used in sub-sector s and equipment t (g/GJ except CO_2 in kg/GJ);

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

3.3.4.3.3 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: Energy Balance Sheet for 2015. Charcoal consumption was obtained from an inquiry made to the residential sector by DGEG.

Figure 3.69 – 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 3.70 – Total Energy Consumption in fuels in the residential sector.

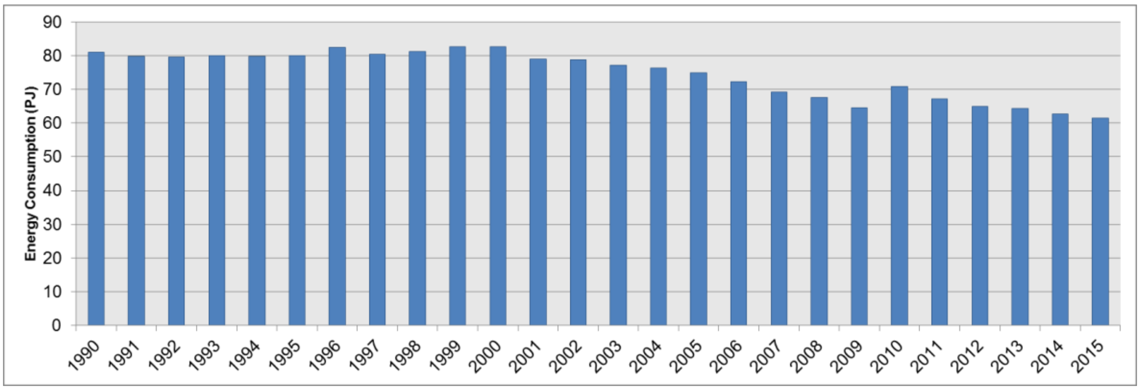
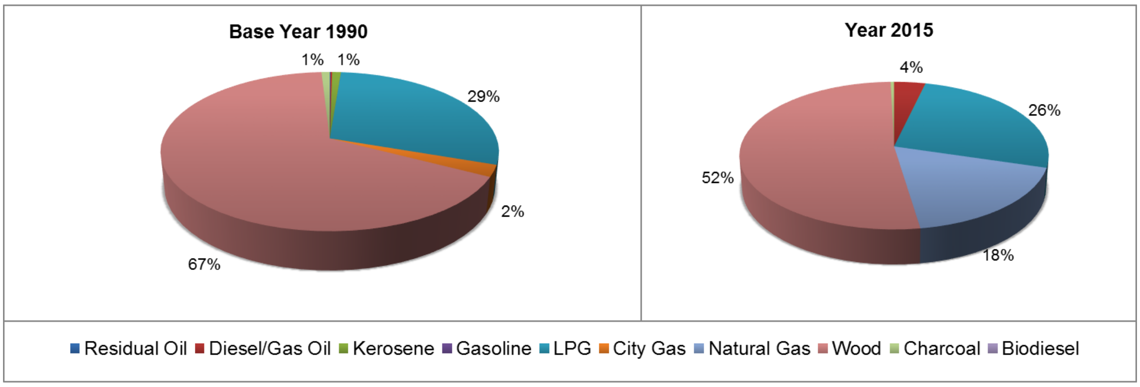


Figure 3.71 – Consumption of energy in fuels in the residential sector in 1990 and 2015.



3.3.4.3.4 Emission Factors

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

Table 3.120 – 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 3.121 – Oxidation factor and Percentage of carbon from fossil origin in fuels – Residential sector.

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

Table 3.122 – Emissions factors for Greenhouse gases - Residential sector.

Fuel	CO_2			CH_4			N_2O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Residual Oil	77.4	kg/Gj	IPCC 2006	1.4	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006
Diesel/Gas Oil	74.1	kg/Gj	IPCC 2006	0.7	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
City Gas	44.0	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	112.0	kg/Gj	IPCC 2006	300.0	g/Gj	IPCC 2006	4.0	g/Gj	IPCC 2006
Charcoal	112.0	kg/Gj	IPCC 2006	200.0	g/Gj	IPCC 2006	1.0	g/Gj	IPCC 2006
Biodiesel	70.8	kg/Gj	IPCC 2006	0.7	g/Gj	IPCC 2006	0.6	g/Gj	IPCC 2006

3.3.4.3.5 Uncertainty Assessment

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

The uncertainty of CO_2 emission factors was assumed to be 5 % for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N_2O were set respectively at 150 % and an order of magnitude.

3.3.4.3.6 Category-specific QA/QA and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). There is a general agreement between data source for this source category.

3.3.4.3.7 Recalculations

No recalculations were made.

3.3.4.3.8 Further Improvements

No further improvements are planned for this sector.

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

3.3.4.4.1 Overview

Emission considered in this source category cover stationary combustion in the agriculture and forestry sectors. Stationary combustion in the fishing industry was included together with fishing bunker in 1.A.4.c.iii.

3.3.4.4.2 Methodology

Emissions were estimated from fuel/energy consumption using either mass balance (CO_2) or emission factors, according to the pollutant, and using IPCC methodology.

For Carbon Dioxide (CO_2), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO2(s,f)} = EF_{CO2\,(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

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

where:

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

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

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

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

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

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p,s)}$ - Total emissions of pollutant p for sub-sector s (t/yr except CO_2 in kt/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_2 in kg/GJ);

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

3.3.4.4.3 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: Energy Balance Sheet for 2015.

Figure 3.72 – Fuels consumed in the agriculture and forestry sector (excluding mobile sources).

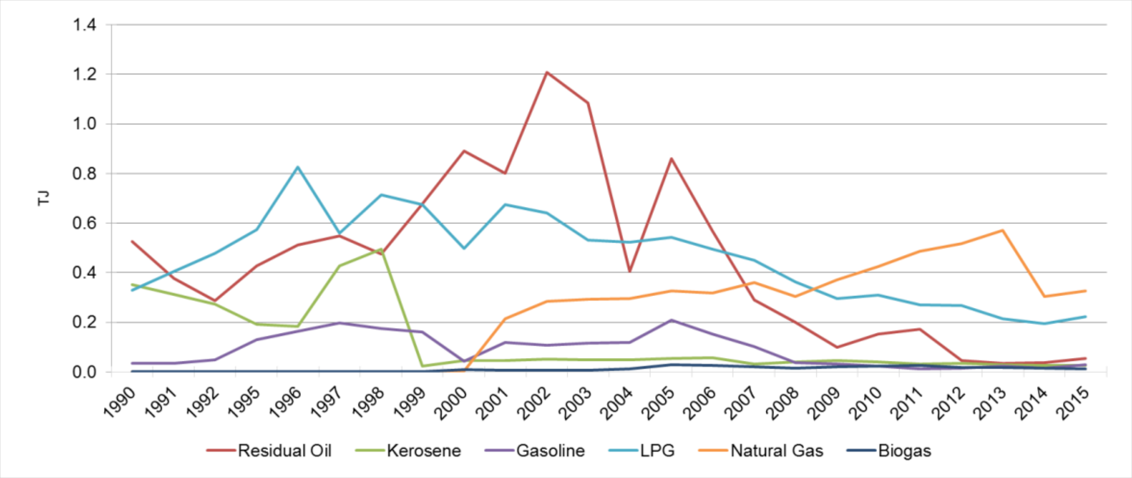


Figure 3.73 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources).

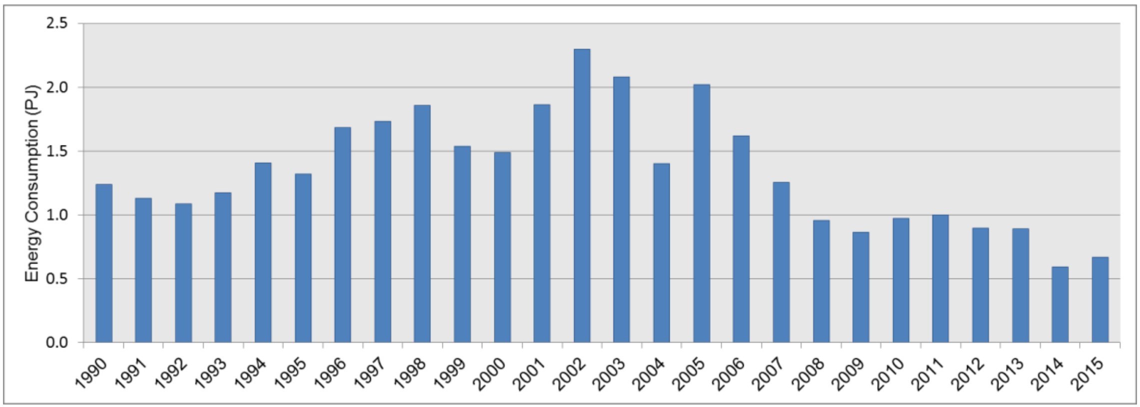
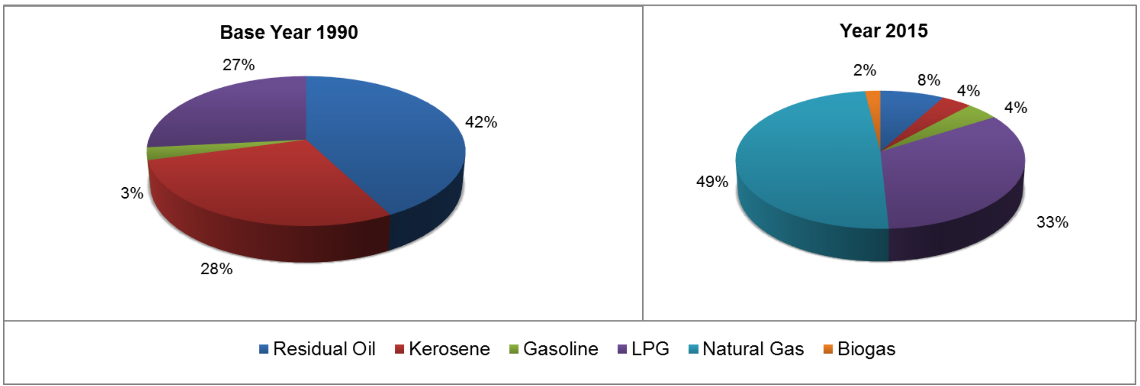


Figure 3.74 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2015.



3.3.4.4.4 Emission Factors

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

Table 3.123 – 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 3.124 – 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	1.000	Ratio	100	%
Kerosene	1.000	Ratio	100	%
Motor Gasoline	1.000	Ratio	100	%
LPG	1.000	Ratio	100	%
Natural Gas	1.000	Ratio	100	%
Biogas	1.000	Ratio	0	%

Table 3.125 – Emissions factors for Greenhouse gases - Agriculture / Forestry / Fishing – Stationary sector.

Fuel	CO_2			CH_4			N_2O		
	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	1.5	g/Gj	IPCC 2006
Biogas	54.6	kg/Gj	IPCC 2006	5.0	g/Gj	IPCC 2006	1.5	g/Gj	IPCC 2006

3.3.4.4.5 Uncertainty Assessment

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

The uncertainty of CO_2 emission factors was assumed to be 5 % for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N_2O were set respectively at 150 % and an order of magnitude.

3.3.4.4.6 Category-specific QA/QA and Verification

Following the same procedure as in other 1.A.4 source categories where energy balance was used as the main data source, a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). Only minor differences between data sources were identified for this source category.

3.3.4.4.7 Recalculations

No recalculations were made.

3.3.4.4.8 Further Improvements

No further improvements are planned for this sector.

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

3.3.4.5.1 Overview

Due to typical operation in vast land areas, agriculture and forestry activities are heavily dependent on machines and off-road vehicles: tractors from 5 kW up to 250 kW, harvesters, sprayers, mowers, tillers, chain saws, haulers, shredders and log loaders among others.

Only gas-oil is assumed to be an energy source for mobile equipments in this activity. Consumption of biodiesel with gas oil was assumed in the energy balance data, in accordance with the explained in 1A2 methodology chapter.

3.3.4.5.2 Methodology

Emissions to atmosphere of ultimate CO_2 from fossil origin were estimated from CO_2 total emissions by:

$$Fossil_{CO2(y)} = \Sigma_f \, [EF_{CO2} * Fac_{OX} * Cons_{Fuel(y)} * LHV] * 10^{-5}$$

where:

$Fossil_{CO2(y)}$ - Emissions of carbon dioxide to atmosphere from combustion of diesel oil in agriculture off road vehicles and machinery (t);

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

Fac_{OX} – Oxidation factor for diesel oil (ratio 0-1);

$Cons_{Fuel(f,y)}$ - Consumption of diesel oil in year y (t/yr);

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

Emissions for other pollutants are estimated with the following formula:

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

where:

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

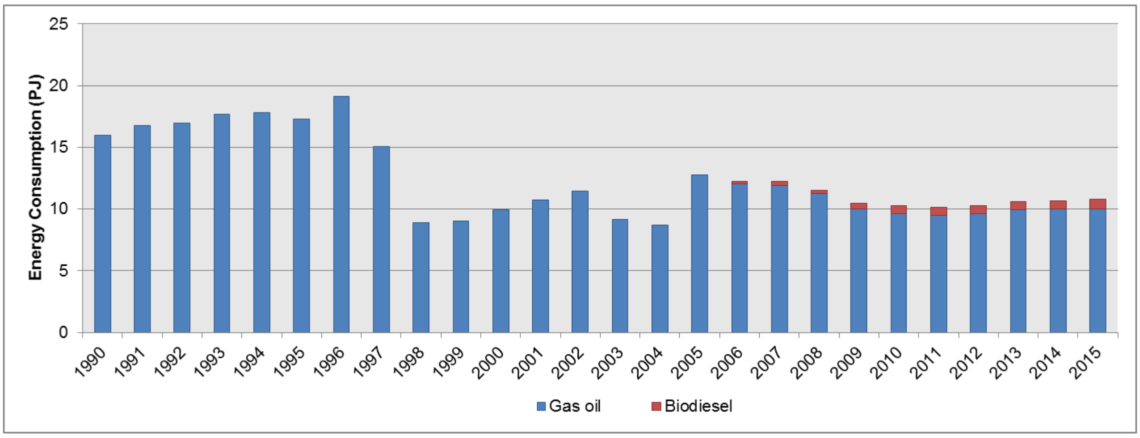
$EF_{(p)}$ - Emission factor for pollutant p (kg/t);

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

3.3.4.5.3 Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to the latest inventory year from DGEG in the energy balance. Although there is no clear specification, in the original database, in which combustion equipment each fuel is used it was assumed that all gas-oil is used in machines and other off-road vehicles. The same suppositions were made for biodiesel since both are used together. Quantities that were consumed are presented in figure below and in ANNEX E: Energy Balance Sheet for 2015.

Figure 3.75 - Consumption of gas-oil in machines and other off-road vehicles.



3.3.4.5.4 Emission Factors

The set of emission factors utilized to estimate air emissions from use of gas oil in agriculture machines and other off-road vehicles were determined as the average value of the values proposed in tables I-47 and I-49 of the Revised 1996 IPCC Guidelines (IPCC,1997). In general for biodiesel EF were considered the same as for gas oil, with the exceptions shown in the following table.

Table 3.126 – Emission factors for gas oil use in agriculture machines and other off-road vehicles.

	EF		
Parameter	**Gas oil**	**Biodiesel**	**Unit**
LHV	42.6	37.0	MJ/kg
SOx	0.3	0	%
NMVOC	8.4	8.4	g/kg
CH4 (i)	4.15	4.15	g/GJ
CO	20.7	20.7	g/kg
CO2 (i)	74.1	74.1	kg/GJ
%CO2 Fossil	100	0.0	%
Fac_{OX}	1.00	1.00	0..1
N2O (i)	28.6	28.6	g/GJ

(i) IPCC (2006);

3.3.4.5.5 Uncertainty Assessment

The time trend of diesel oil consumption in this activity shows significant annual variations. Although future developments are expected to correct this situation, in this year the uncertainty in activity data was set as the maximum inter-annual variation, 94 %. 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_2, CH_4 and N_2O.

3.3.4.5.6 Category-specific QA/QA and Verification

General revision of time series consistency for fuel consumption and emission factors was the only QA/QC procedure adopted for this sector.

3.3.4.5.7 Recalculations

Correction of a compilation error in residual fueloil consumption between 2004 and 2013.

3.3.4.5.8 Further Improvements

No further improvements are planned for this sector.

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

3.3.4.6.1 Overview

Emission in this source category include both stationary and other mobile source (fisheries bunkers). Stationary equipment included those associated with fishing industry, aquaculture or sea ports that are realized inland and not in water vessels. Fishing bunker represent emission from local costal fishing, deep-see fishing and cod-fish fishing vessels.

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

3.3.4.6.2 Methodology

3.3.4.6.2.1.1 Stationary Equipment

Emissions were estimated from fuel/energy consumption using either mass balance (CO_2) or emission factors, according to the pollutant, and using IPCC methodology.

For Carbon Dioxide (CO_2), total emissions and ultimate emissions contributing to the greenhouse gas effect, are estimated from:

$$U_{CO2(s,f)} = EF_{CO2\ (f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$
$$Fossil_{CO2(s,f)} = U_{CO2(s,f,y)} * C_{Fossil(f)} * 10^{-2}$$

where:

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

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

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

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

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

$Energy_{Cons(u,f)}$ - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions of other GHG use the following basic formula (Energy Approach):

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

where:

$Emi_{(p)}$ - Total emissions of pollutant p for sub-sector s (t/yr except CO_2 in kt/yr);

$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO_2 in kg/GJ);

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

3.3.4.6.2.1.2 Fishing Bunker

Emissions for all pollutants other than CO_2 are estimated for each ship type using the following formula:

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

where:

$Emission_{(n,p,y)}$ - Total emission of pollutant p in year y from ships of class n (t/yr);

$EF_{(n,f,p)}$ - Quantity of pollutant p emitted, variable with fuel type f and ship class n (kg/t);

$Cons_{Fuel(n,f,y)}$ - consumption by ships of type n of fuel f during year y (t/yr).

Emissions of carbon dioxide are estimated from:

$$Fossil_{CO2(n,y)} = \Sigma_f [EF_{CO2\ (f)} * Fac_{OX\ (f)} * C_{Fossil(f)} * Cons_{Fuel(n,f,y)} * LHV_{(f)}] * 10^{-5}$$

where:

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

$EF_{CO2\ (f)}$ – 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 (t/yr);

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

3.3.4.6.3 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: Energy Balance Sheet for 2015.

Figure 3.76 – Fuels consumed in fisheries (excluding consumption in fishing vessels).

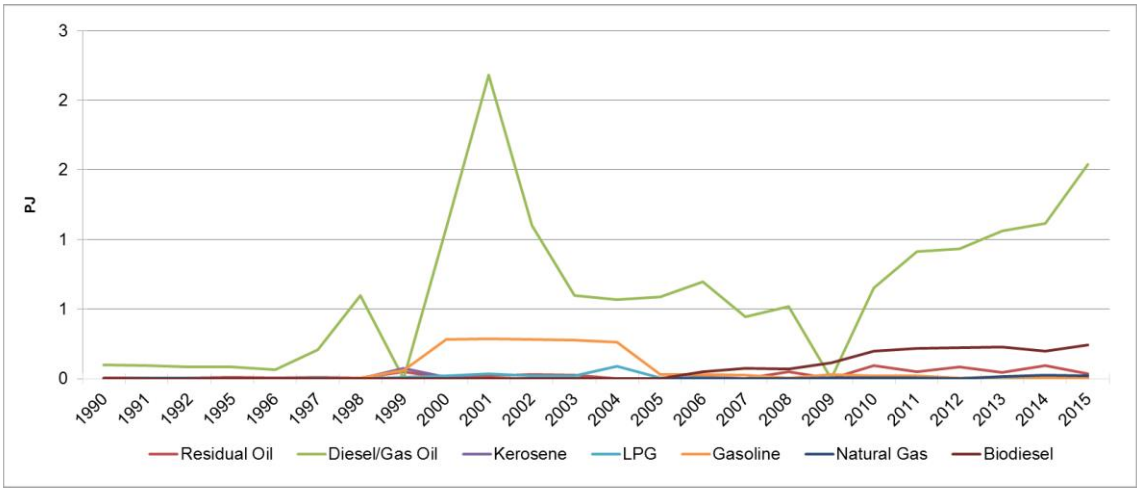


Figure 3.77 – Total Energy Consumption in fuels in fisheries (excluding consumption in fishing vessels).

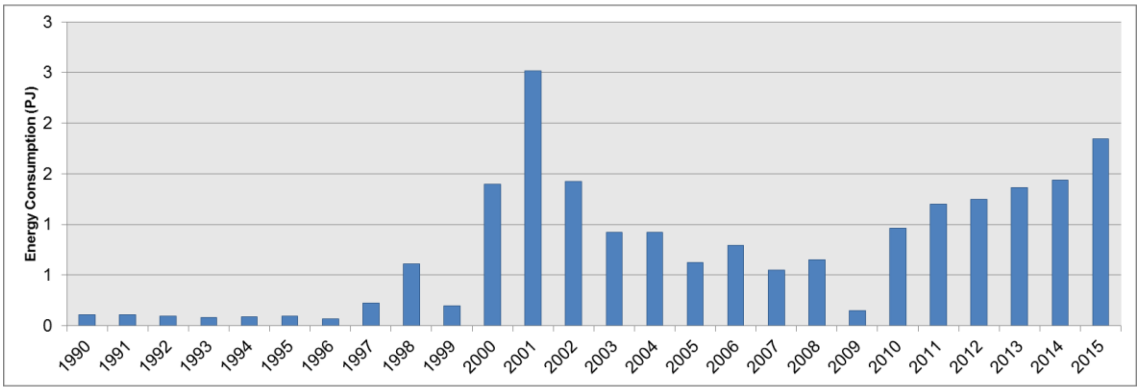
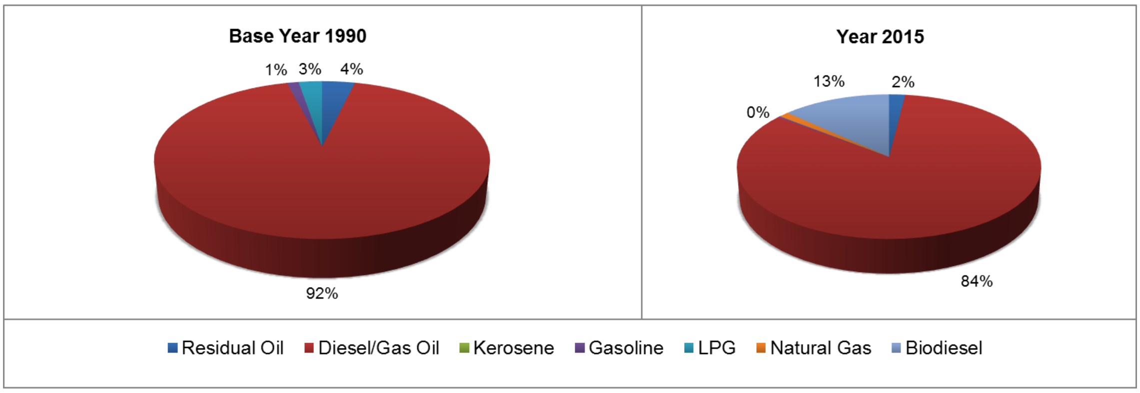


Figure 3.78 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2015.



Total fuel consumption in fishing bunkers can be seen in the following figures and ANNEX E: Energy Balance Sheet for 2015.

Figure 3.79 - Fuels consumed in fishing bunkers [23].

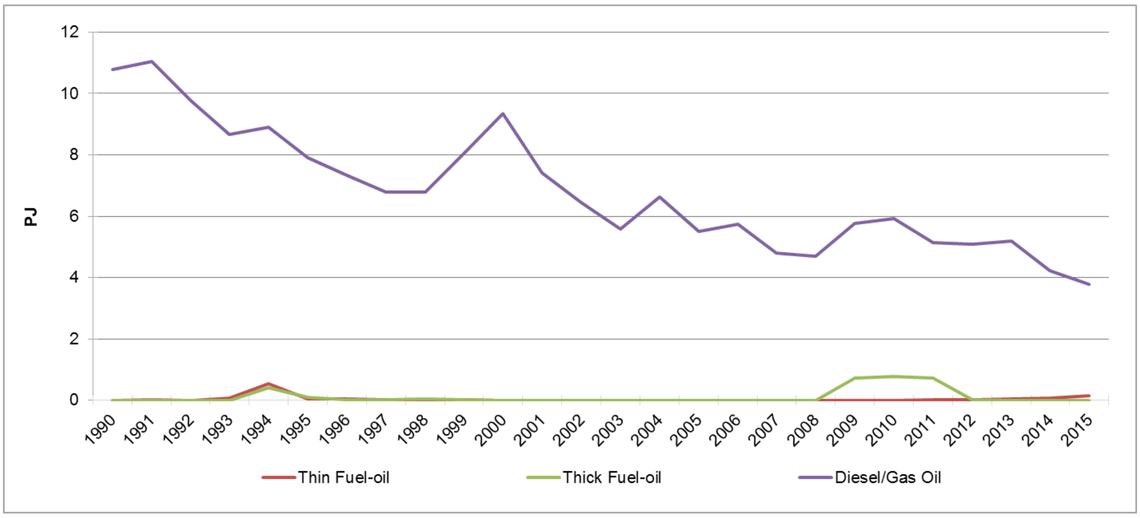
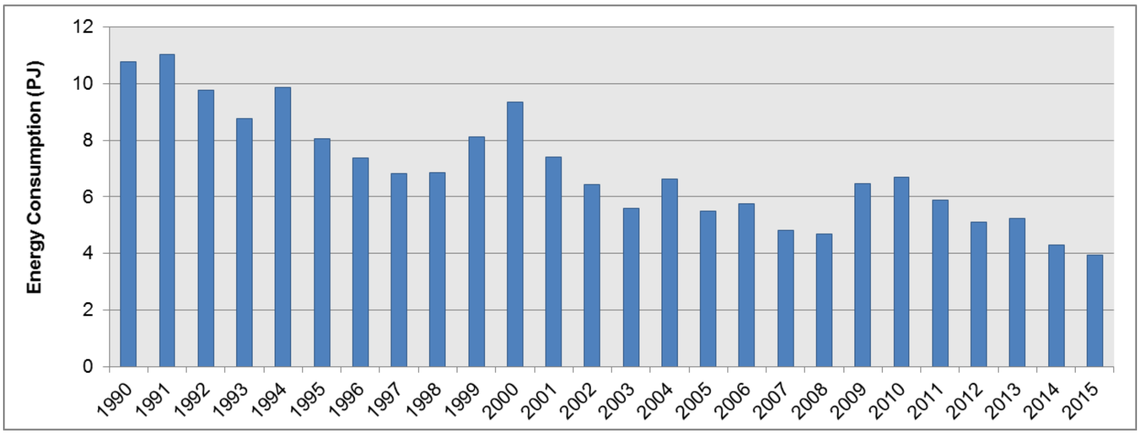


Figure 3.80 – Total Energy Consumption in fishing bunkers.

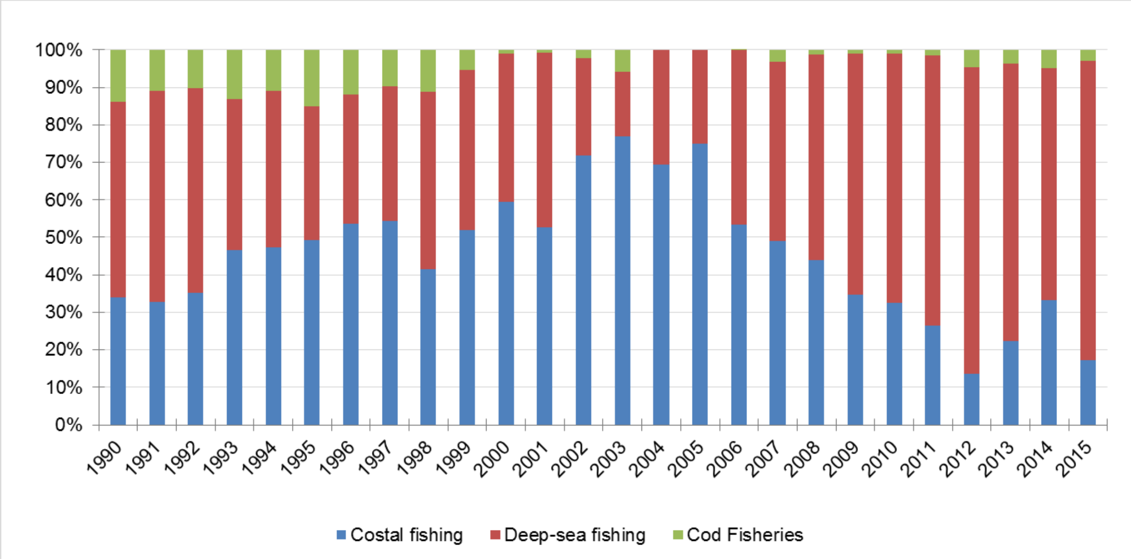


Additional information in DGEG annual reports, allows for the division of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels[24]. Percentage for each type of fisheries is presented in the next figure.

[23] 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

[24] 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.



3.3.4.6.4 Emission Factors

3.3.4.6.4.1 Stationary Equipment

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

Table 3.127 – Emissions factors for Greenhouse gases and Low Heating Value (LHV) - Fisheries – stationary equipment sector.

Fuel		NAPFUE	LHV	CO_2 (i)			CH_4 (i)	N_2O (i)
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.0	77.4	1.00	100	10.0	0.6
Gas Oil/Diesel oil	L	204	42.6	74.1	1.00	100	10.0	0.6
Kerosene	L	206	43.8	71.9	1.00	100	10.0	0.6
Motor Gasoline	L	208	44.0	69.3	1.00	100	10.0	0.6
LPG	L	303	46.0	63.1	1.00	100	5.0	0.1
Natural Gas	G	301	46.0	56.1	1.00	100	5.0	1.5
Biodiesel	B	223	37.0	70.8	1.00	0	10.0	0.6

(i) IPCC (2006);

3.3.4.6.4.2 Fishing Bunker

Except for carbon dioxide and sulphur oxide, emissions were estimated using default emission factors (kg/t) 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 3.128 – Emission factors for Water Borne Navigation and Fishing Vessels.

EF	Units	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries
		Gas-oil		Biodiesel		Fuel-oil	
LHV	MJ/kg	42.6		37.0		40.0	
SO_x	%	0.3		0.0		3	
NO_x	g/kg	67.5	87	67.5	87	67.5	87
NMVOC	g/kg	4.9					
CH_4 (i)	g/GJ	7.0					
CO	g/kg	21.3	1.9	21.3	1.9	21.3	1.9
EF_{CO2} (i)	kg/GJ	74.1		74.1		77.4	
C_{Fossil}	%	100		0.0		100	
Fac_{OX}	0..1	0.99		1.0		0.99	
N_2O (i)	g/GJ	2.0					

(i) IPCC (2006);

3.3.4.6.5 Uncertainty Assessment

3.3.4.6.5.1 Stationary Equipment

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

The uncertainty of CO_2 emission factors was assumed to be 5 % for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N_2O were set respectively at 150 % and an order of magnitude.

3.3.4.6.5.2 Fishing Bunkers

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

Following the recommendations of GPG the uncertainties of emission factors for CH_4 and N_2O, and for all types of vessels and navigation, were set respectively to 100 % and 1000 %.

3.3.4.6.6 Category-specific QA/QA and Verification

For this sector the comparison between DGED and IEA fuel consumption values was also made (please see the chapter Comparison of Energy Balance vs. IEA Energy Statistics). There are major differences between the two data sources for this source category. No precise justification for this difference was found, apart from the reported compilation errors made by DGEG in the information sent to IEA.

3.3.4.6.7 Recalculations

No recalculations were made.

3.3.4.6.8 Further Improvements

No further improvements are planned for this sector.

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

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

3.3.5.1.1 Military Use

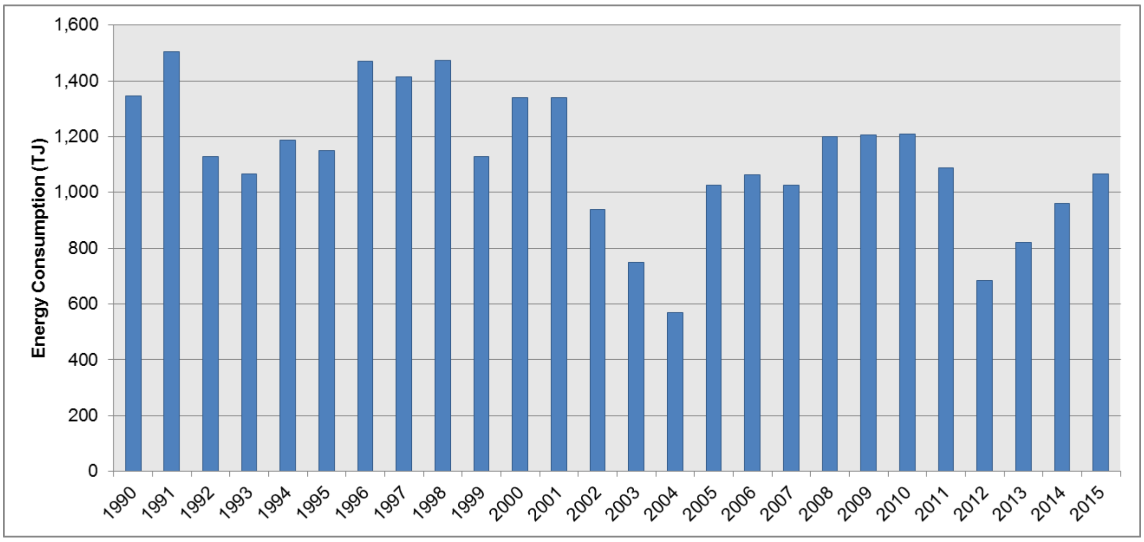
Emissions from military reported under category 1 A 5 b include only military aviation.

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 3.129 – Emission factors.

Fuel	CO_2			CH_4			N_2O		
	Value	Unit	Reference	Value	Unit	Reference	Value	Unit	Reference
Jet Fuel	71.5	tCO2/TJ	IPCC 2006	0.5	kg/TJ	IPCC 2006	2.0	kg/TJ	IPCC 2006

3.3.5.1.1.1 Uncertainty Assessment

The uncertainty of fuel consumption was set equal to the uncertainty that was considered for road traffic: 5 %.

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 % and 50 % respectively. The general error of 5 % was used for the calculation of uncertainties of carbon dioxide emissions.

3.3.5.1.1.2 Recalculations

No recalcutation were made.

3.3.5.1.1.3 Further Improvements

No further improvements are planned for this sector.

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

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

3.3.6.1.1 Coal Mining and Handling

3.3.6.1.1.1 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.

3.3.6.1.1.2 Methodology

Emission estimates include emissions occurring during extraction of coal, emissions resulting from processing and emissions from abandoned underground mines.

A simple tier 1 approach was used to estimate emissions, which is considered a sufficient approach being present the scarcity of technical information about these mines and because this emission source is no key source and has small relevance. The following equation is similar to the methodology proposed in IPCC96 (IPCC, 1997) and is used to estimate emissions related to extraction and pos-extraction activities:

$$Emi_{CH4} = [(EF_U^{ex} + EF_U^{post}) * Coal_U] * 0.67 * 10^{-3}$$

where:

Emi_{CH4} - Methane emissions in year y (t);

$Coal_U$ - quantity of coal extracted from underground mines (t/yr);

EF_U^{ex} - emission factor for extraction emissions in underground mining (m^3/t);

EF_U^{post} - emission factor for post-extraction emissions in underground mining (m^3/t);

0.67 is the conversion factor, the density of methane at 20ºC 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:

$$Emi_{CH4} = Number_{ACM} * f_{GCM} * EF * 0.67 * 10^{-3}$$

where:

Emi_{CH4} - Methane emissions in year y (t);

$Number_{ACM}$ – Number of abandoned coal mines remaining unflooded in year y (number);

f_{GCM} – Fraction of gassy Coal Mines (adimensional);

EF_{CH4} – 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 20ºC and at atmospheric pressure (kg/m^3).

$$Emi_{NMVOC} = EF_{NMVOC} * Coal_U * 10^{-3}$$

where:

Emi_{NMVOC} - NMVOC emissions in year y (t);

EF_{NMVOV} – NMVOC emission factor (kg/t of coal);

$Coal_U$ – Coal extracted from underground mines (t).

Ultimate carbon dioxide emissions, also in t/yr, are calculated from the carbon emitted as methane:

$$Emi_{CO2} = 44 / 12 * Emi_{CH4} * 12/16$$

where:

Emi_{CO2} – Ultimate carbon dioxide emissions (t);

Emi_{NMVOC} - NMVOC emissions in year y (t);

Emi_{CH4} – CH_4 emissions in year y (t).

3.3.6.1.1.3 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 3.130 – Emission Factors for coal extraction and processing.

Parameter	Type of Emission	Emission Factor	Value (kg/t)	Source
CH_4	Extraction	EF_U^{ex}	11.73	Revised 1996 IPCC Guidelines
	Post-mining	EF_U^{post}	1.64	Revised 1996 IPCC Guidelines
NMVOC	-	-	0.8	EMEP/EEA emission inventory guidebook 2013

The fraction of gassy coal mines was estimated assuming the average value of 8% (Low) and 100% (High) for underground mines abandoned in the period 1976-2010 (Table 4.1.5 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

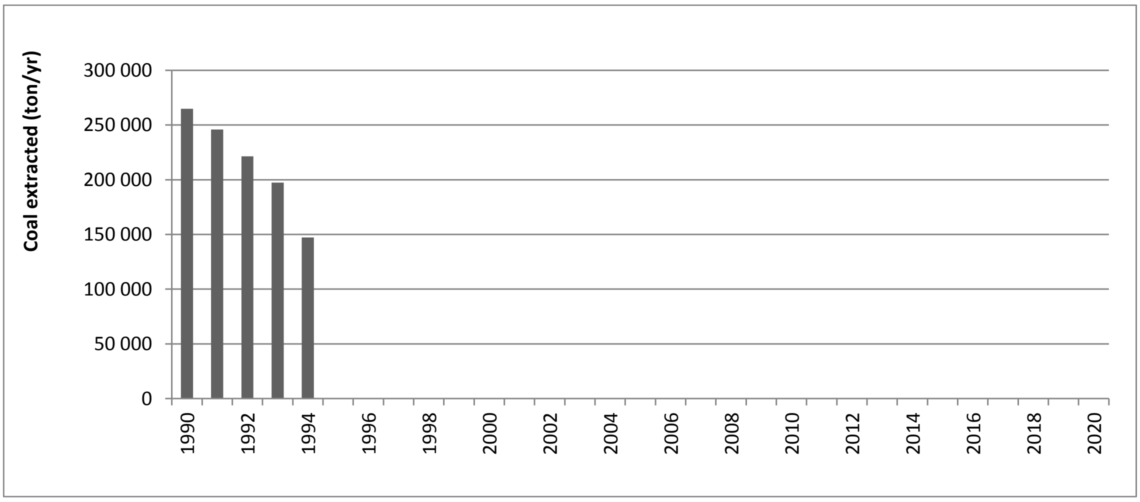
Table 3.131 – Emission Factors for abandoned underground mines.

Parameter	Unit	Value	Source
Fraction of gassy coal mines	%	54 (8-100)	2006 IPCC Guidelines
CH_4 Emission factor	10^6 m^3 CH_4/mine	0.507-1.561	2006 IPCC Guidelines

3.3.6.1.1.4 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.

3.3.6.1.1.5 Uncertainty Assessment

A value of 5 % was considered for the uncertainty of coal production (activity data) which is a conservative factor according to the proposed values by IPCC (2000). Also in accordance with table 2.14 of the GPG, the uncertainty values for methane emission factors were set at 100 % for underground mines. The uncertainties in CO_2 emission factors were set equal to uncertainties of CH_4 emission factors, considering that CO_2 emissions are simply atmospheric conversion of methane emissions.

3.3.6.1.1.6 Recalculations

No recalculations were made.

3.3.6.1.1.7 Further Improvement

No further improvements are planned for this sector.

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

3.3.6.2.1 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.

3.3.6.2.2 Fugitive emissions from oil exploration (CRF 1.B.2.a.1)

There is no oil exploration in Portugal.

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

There is no crude oil production in Portugal.

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

3.3.6.2.4.1 Overview

Emissions from this source consist mainly of volatile organic compounds, including methane, that escape to atmosphere during transport of crude oil to refineries for processing. The three oil refineries considered in the inventory where all located at a small distance from the sea coast.

Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

3.3.6.2.4.2 Methodology

Emissions of NMVOC were estimated from:

$$Emission = Source_{InFlow} * EF * 10^{-9}$$

where:

Emission - NMVOC emissions (t/y);

$Source_{InFlow}$ - is total crude oil, gasoline, naphtha, residual oil or distillate oil received at each marine terminal (L/y);

EF - emission factor for NMVOC (mg/t 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:

$$Emi_{CO2U} = 44/12 * Emi_{NMVOC} * 0.60$$

3.3.6.2.4.3 Emission Factors

Table 3.132 – Total Organic Emission Factors for Marine Vessel Loading Operations.

Loading Operations	Gasoline (mg/L)	Crude (mg/L)	Jet Naphta – JP-4 (mg/L)	Jet Kerosene (mg/L)	Distillate Oil nº2 (mg/L)	Residual Oil nº6 (mg/L)
Ships/ocean barges	215	73	60	0.63	0.55	0.004

Source: Tables 5.2-2 and 5.2-6 of USEPA AP-42 Emission Factors

The chosen Emission factor for Gasoline is the “Typical overall situation”. For other petroleum products it is used “Ships/ocean barges” emission factors.

For products for which there are not emission factors available, they were estimated using the following expression:

$$EF_{LL} = 12.46 \times \frac{F_S \times P_V \times M_V}{T} \times \left(1 - \frac{eff}{100}\right)$$

where:

EF_{LL} - Emission Factor associated to Loading Losses (lb/1000 gal);

F_S - Saturation Factor (0 to 1);

P_V - True Vapour Pressure (psia);

M_V - Molecular Weight (lb/mol);

T - Temperature of Petroleum Product (520 °R – Rankin);

eff - Overall Reduction Efficiency (Both Recovery and Collection Efficiencies);

True Vapour Pressure and Molecular Weight Values were obtained from "International Chemical Safety Cards".

3.3.6.2.4.4 Activity data

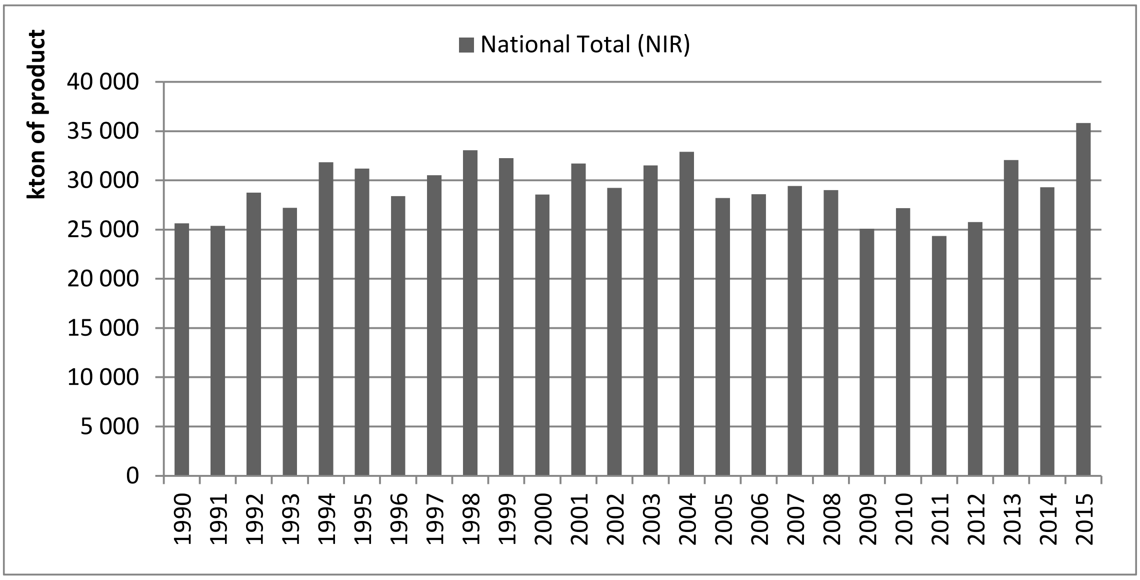
Data was obtained for year 2005, from:

- Ports Authorities (Port of Sines, Port of Lisbon, Port of Leixões, Port of Setúbal);
- Depots Companies (BP, Cepsa, CLCM, Esso, ETC, LBC Tanquipor, Petrogal, Repsol, Saaga, Sapec Química);
- Responsible company for the transport of Petroleum Products between Mainland and Madeira and São Miguel (Azores) Islands – Galpenergia;
- Responsible company for the transport of Petroleum Products between São Miguel Island (Azores) and other Azores Islands – BP (the transport is made by a ship rented by the Regional Government of Azores and is assured by BP company).

For the period 1990-2004 and from 2006 onwards data was extrapolated using Crude Oil stock changes obtained from DGEG energy balance.

It was made a cross-check between data obtained from different sources.

Figure 3.84 – Total amounts of loaded and unloaded crude and fuels in Marine Terminals (kt).



3.3.6.2.4.5 Uncertainty Assessment

An uncertainty value (3 %) similar to that that was considered for fuel consumption data in industrial LPS was also used for quantification of uncertainty of activity data for this source sector reflecting the fact that in this case data was also collected directly from refinery plants, where crude oil is uploaded, and used to build the energy balance of DGEG. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO_2 emissions, was considered to be 50 %, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases. The uncertainty of methane emission factor was set to 100 %, the double of the emission factor for CO_2/NMVOC in accordance with the fact that methane is obtained as a VOC fraction and hence with double uncertainty.

3.3.6.2.4.6 Recalculations

No recalculations were made.

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

3.3.6.2.5.1 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[25] 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.

3.3.6.2.5.2 Methodology

3.3.6.2.5.2.1 Storage and Tanks

GALP, the company operating all refineries in Portugal, made annually estimates of emissions from storage in the tanks existing inside the refineries. The estimates, relying on the TANKS4.0 model, are available from 2002 till 2005. This detailed information lead to the establishing of plant specific emission factors, and its evolution, for NMVOC losses from crude oil and oil products storage. Annual emissions of NMVOC (t/yr) for the remaining time series are estimated using the emission factor (EF in g/t) and relying in the time series of total throughput petroleum materials processed (t/yr) as an indicator of activity[26].

$$Emission_{NMVOC} = EF_{(y)} * Throughput * 10^{-6}$$

3.3.6.2.5.2.2 Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations where estimated from:

$$Emission_{(p,r)} = ActivityRate * EF_{(p,r)} * 10^{-6}$$

where:

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

[25] Sometimes only these emissions are referred as fugitive emissions from refineries.

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

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

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

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.

3.3.6.2.5.2.3 Ultimate CO2 Emissions

All carbon in emitted compounds, such as CO, NMVOC and methane, have fossil origin and must be included in ultimate emissions inventory. Individual pollutants (t/yr) are converted into ultimate CO_2 (kt/yr) by:

$$U_{CO2} = 44/12 * (0.60 * NMVOC + 12/16 * CH_4 + 12/28 * CO) * 10^{-3}$$

3.3.6.2.5.3 Emission Factors

3.3.6.2.5.3.1 Storage/ Tanks

For the period 2002-2005, GALP, the single petroleum refinery operator in Portugal, in collaboration with APA, performed a detailed inventory of NMVOC emissions from tanks in Oporto and Sines refineries using TANKS 4.0 (USEPA, 1990). The inventory has been extended to marketing terminal storage tanks (including data from all companies operating in the Portuguese territory). For the period 1990-2001 and from 2006 onwards, data was estimated using stock changes values from DGEG's energy balance.

TANKS4.0 software was designed to estimate air emissions from organic liquids in storage tanks, according to the methodology proposed in "Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources" (AP-42), Section 7.1, Organic Liquid Storage Tanks (USEPA, 1997).

Determination of emission factors for Oporto and Sines refineries were performed for each tank, considering the following detailed information:

- Site information: meteorological data such as the daily average ambient temperature, the annual average minimum and maximum temperatures, the annual average wind speed, the annual average solar insolation factor, and the atmospheric pressure;

- Liquid characterization: For individual substances the model requires chemical nomenclature, average liquid temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. For mixtures, the information may be as detailed as the mixture name, average, minimum and maximum liquid surface temperatures, bulk temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights;

- Tank information is slightly different according to tank type, but in general terms comprehends: shell and roof colour and condition, height, diameter, average and maximum liquid height, working volume, turnover rate and net output, heating conditions and pressure and vacuum settings and the existence and type of seals[27].

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

Tank Type	Description	Oporto	Sines (a)
External Floating Roof Tank	cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid	55	170
Horizontal Tank	above-ground or underground storage with the axis parallel to the foundation	4	0
Internal Floating Roof Tank	permanent fixed roof and a floating deck	30	58
Vertical Fixed Roof Tank	cylindrical shells with permanently affixed roofs; the tank axis is perpendicular to the foundation. The fixed roof may be dome-shaped or cone shaped	206	235
Domed External Floating Roof.	external floating roof tank that has been retrofit with a domed fixed roof	0	0

(a) Inventory covers only tanks for storage of liquids with Vapour Pressure above 27kPa

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

Table 3.134 – 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

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

Finally the resultant emission factors, obtained dividing total tank emissions by total throughput [28]in each refinery, are presented in next table. From 2006 onwards the emission factors were forecasted based on total throughput.

Table 3.135 – Final emission factor for evaporation of NMVOC from storage and tank in refineries.

Refinery	Emission Factor (g NMVOC/t throughput)			
	2002 and before	2003	2004	2005
Sines	0.118	0.198	0.205	0.222
Oporto	0.057	0.041	0.040	0.039
Lisbon	0.088 [(a)]	NA	NA	NA

(a) Average value from Sines and Oporto refineries

3.3.6.2.5.3.2 Fugitive Emissions

The following emission factors where used to estimate emissions from other processes, mainly leaks. These emission factors were still established from Corinair90 Emission Factor Handbook (EMEP/CORINAIR 3rd ed).

Table 3.136 – Emission Factors for fugitive emissions of NMVOC in operation processes in petroleum refineries.

Pollutant	EF kg NMVOC/ t crude
NMVOC	0.9
CH_4	0.1

3.3.6.2.5.3.3 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_x emission factor in both information sources (monitoring data and USEPA). Carbon dioxide emission factor was set assuming that coke is 92 % carbon. Final emission factors may be verified in the next table.

This set of emission factors was also applied to coke burning in the platforming unit, also in Sines refinery, and regeneration of catalysts at Oporto refinery.

[28] Crude oil input added to input of other materials.

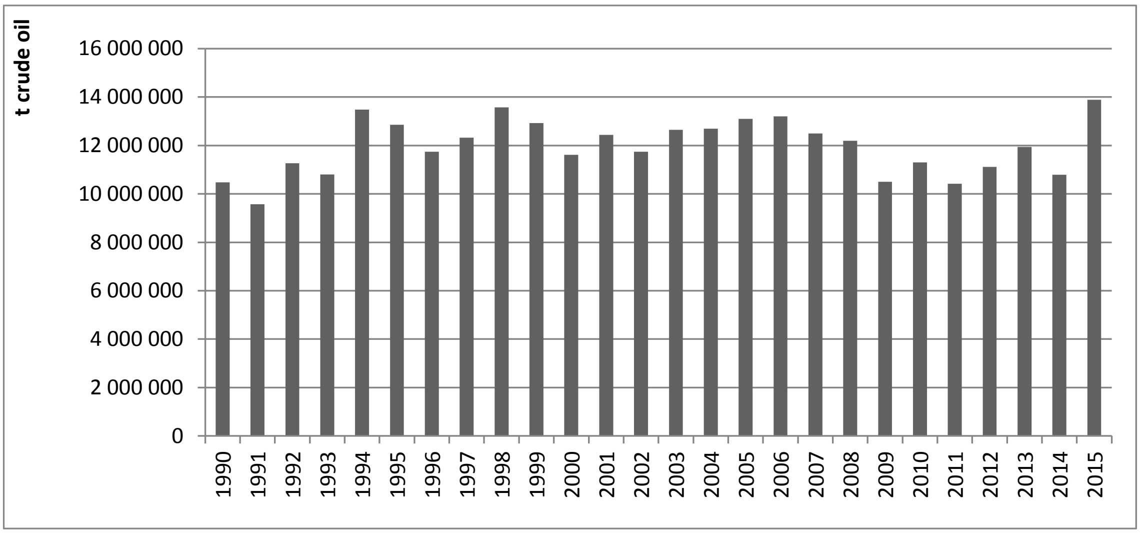
Table 3.137 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned).

Parameter	Emission Factor kg/t coke
UCO_2	3 373

3.3.6.2.5.4 Activity data

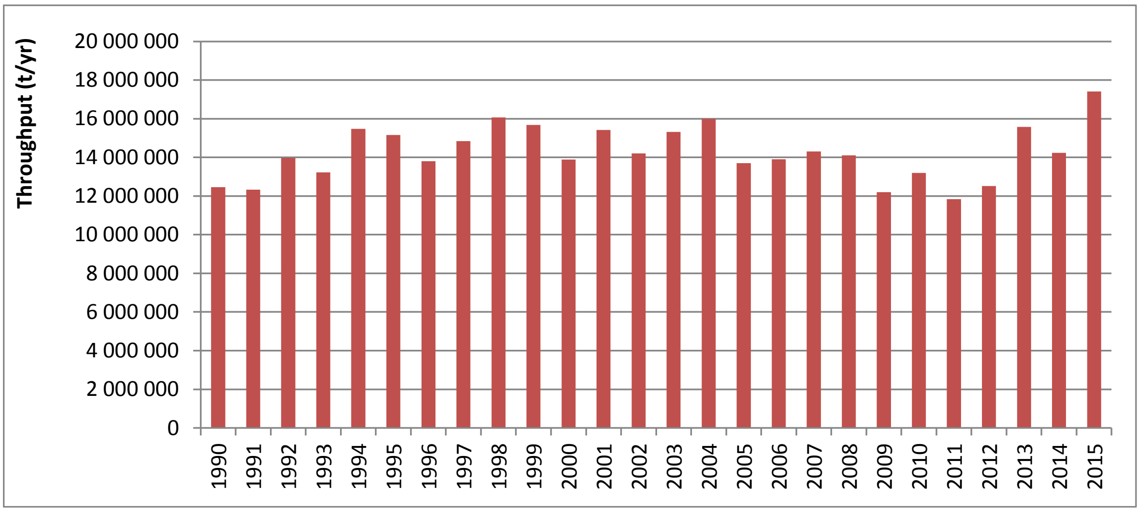
The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed (see next figure).

Figure 3.85 – Total Crude Oil Processed in Refineries (t).



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 (t).



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.

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

Uncertainty of emission factors for NMVOC[29] were set as 50 %, at the higher range of possible uncertainties proposed by IPCC (2000), although the fact that some emission factors use plant specific information. Estimates of methane emissions were assumed to have the double uncertainty that was determined for CO_2 (100%).

3.3.6.2.5.6 Recalculations

No recalculations were made.

3.3.6.2.5.7 Further Improvements

No further improvements are planned for this sector.

3.3.6.2.6 Distribution of Oil Products (CRF 1.B.2.a.5)

3.3.6.2.6.1 Overview

This sub-source sector includes emissions of volatile organic compounds resulting from distribution of refinery products, mainly gasoline:

[29] The uncertainty of NMVOC was considered to be the uncertainty of CO_2 emission factor.

- (1) Terminal Dispatch Stations in Refineries. Emissions of volatile organic compounds occurring inside refineries during filling of transport vehicles - trucks, rail cars - when dispatching products of the refining unit. Most emissions occur when light products with high level of volatile compounds are dispatched;
- (2) Transport and Depots, occurring in storage tanks outside the refineries and over the country;
- (3) Service Stations, including emissions from tank loading from trucks and when refuelling consumer cars.

Emissions may result from:

- Leakage. Evaporation of liquid products by flaws and seal leakage, pumps and valve systems;
- Displacement emissions, due to displacement of air in tanks by the incoming liquid;
- Breathing emissions in tanks;
- Vapours emitted when filling vehicles in result of displacement of filling air and from splashing and turbulence during filling;
- Unwanted spillage.

3.3.6.2.6.2 Methodology

Ultimate carbon dioxide emissions, are calculated assuming that emitted VOC have on average 60 % of carbon:

$$Emi_{CO2} = 0.60 * Emi_{NMVOC}$$

3.3.6.2.6.2.1 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^3)

$EF_{StageIB}$ - Emission Factor for Filling Underground Tanks at Service Stations with Stage IB (kg/m^3/kPa TVP)

V_{ohter} - Gasoline throughput at Service Stations without Stage IB (m^3)

EF_{other} – Emission Factor for Filling Underground Tanks at Service Stations without Stage IB (kg/m^3/kPa TVP)

Since 2005, the emissions estimates are based on:

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

where:

E_{FUT} - Emissions Filling Underground Tanks (kg)

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

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

3.3.6.2.6.3 Emission Factors

3.3.6.2.6.3.1 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 3.138 – Filling Underground Tanks NMVOC Emission Factors

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

3.3.6.2.6.3.2 Underground Tank Breathing and Emptying

The NMVOC emission factor source is "Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1" (=$3.30E^{-03}$ kg/m^3/kPa TVP).

3.3.6.2.6.3.3 Vehicle Refueling Operations

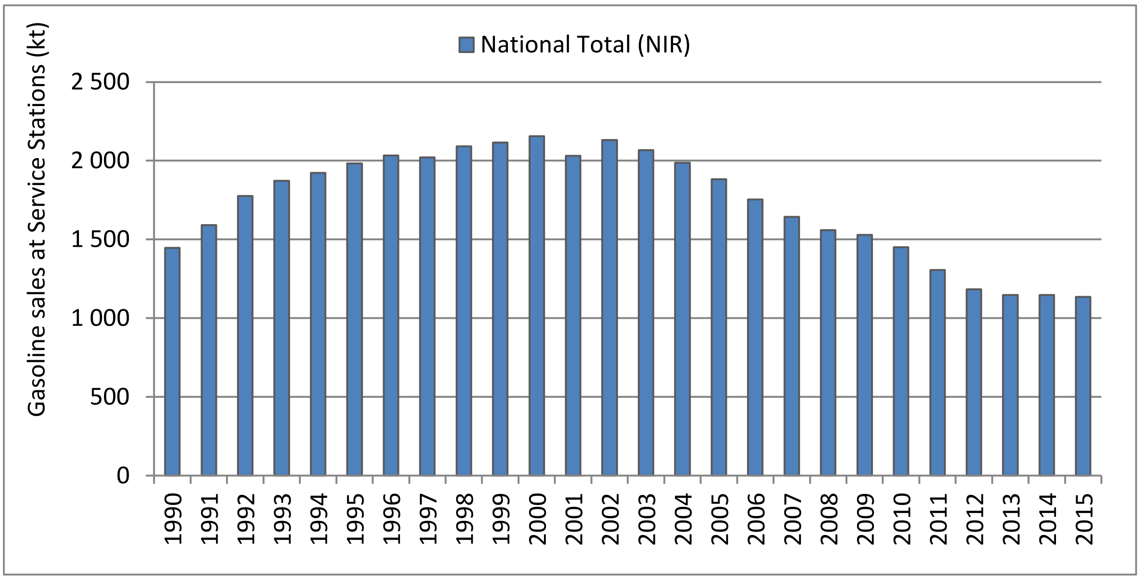
Table 3.139 – Vehicle Refueling Operations NMVOC Emission Factors.

Vehicle Refuelling Operations	Emission Factor (kg/m³/kPa TVP)
Drips and Minor Spillage	2.20E-03
Refuelling with no emission controls in operations (without Stage II measures)	3.67E-02

3.3.6.2.6.4 Activity data

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

Figure 3.87 – Fuel Sales at Service Stations.



3.3.6.2.6.5 Uncertainty Assessment

An uncertainty value (3 %) 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 %. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO_2 emissions, was considered to be 50 %, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases.

3.3.6.2.6.6 Recalculations

3.3.6.2.6.7 A correction was made in a compilation error.Further Improvements

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

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

3.3.6.3.1 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 became 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.

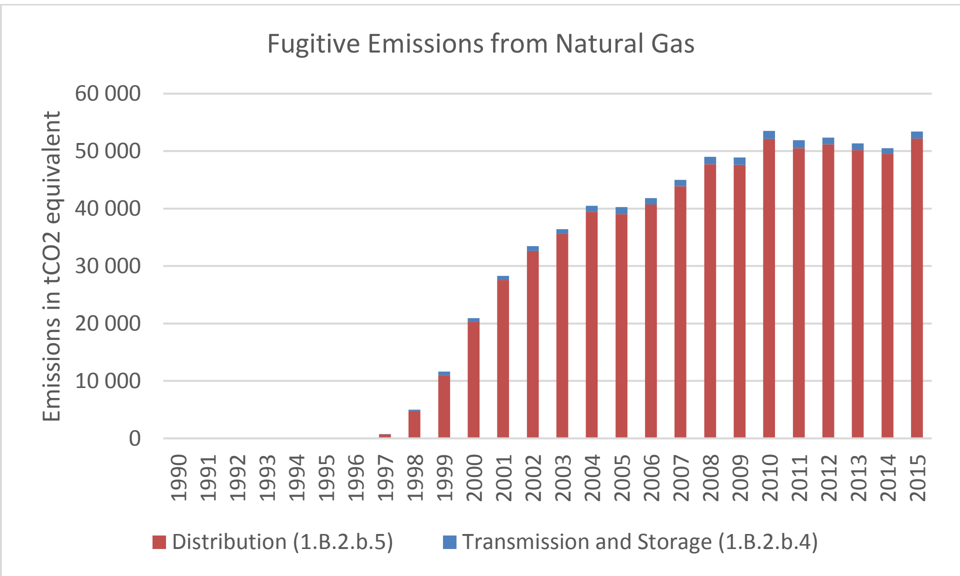
Natural gas pipelines may be classified in two different sub-groups:

- 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.

Figure 3.88 – Fugitive Emissions from Natural Gas..



3.3.6.3.2 Methodology

Estimates of fugitive emissions related to the transport of natural gas are separated into two categories. One relates to fugitive emissions during transport of Natural Gas to High Pressure and is reported in code CRF *1.B.2.b.4. - Transmission and Storage*. The other refers to the distribution networks operating medium and low pressure, these are reported in code CRF *1.B.2.b.5. – Distribution*.

Losses of natural gas through leaks are estimated through adjustment factors published by ERSE - National regulatory body of the Natural Gas market. The CO2 and CH4 emissions are estimated taking into account the composition of Natural Gas imported by Portugal

Transmission and Storage (1.B.2.b.4)

The adjustment factor considered for the National Natural Gas Transportation Network at High Pressure simultaneously considers the transmission processes and storage processes.

In order to obtain the amount of Natural Gas circulating in a year in the National High-Pressure Natural Gas Transport Network, it is necessary to remove from the total imported NG the one that arrives in the country via trucks directly to autonomous units that intrude the gas directly into the networks of distribution.

NG Transmission Network HP = NG Imported – NG from Autonomous units

NG Transmission Network Leaks = NG Transmission Network HP * Adjustment Factor HP

Transmission CH4 Fugitive Emissions = NG Transmission Network HP Leaks * % of CH4 in National NG

Transmission CO2 Fugitive Emissions = NG Transmission Network HP Leaks * % of CO2 in National NG

Distribution (1.B.2.b.5)

ERSE publishes differentiated adjustment factors for medium and low pressure distribution networks. Thus the natural gas consumptions reported in the energy balance were divided according to the type of supply network.

NG Distribution Network Leaks = NG Distribution MP Leaks + NG Distribution LP Leaks

The quantities of Natural Gas distributed by the two types of network are obtained through the Energy balance, which differentiates consumption by sector. Therefore:

<u>NG Distribution Medium Pressure:</u> Manufacturing industries

<u>NG Distribution Low Pressure:</u> Residential, Services, Commercial, Agriculture & Fisheries

The amount of natural gas leaks is estimated as follows:

NG Distribution LP Leaks = NG Distribution MP * Adjustment Factor MP

NG Distribution MP Leaks = NG Distribution HP * Adjustment Factor LP

Distribution CH4 Fugitive Emissions = NG Transmission Distribution Leaks * % of CH4 in National NG

Distribution CO2 Fugitive Emissions = NG Transmission Distribution Leaks * % of CO2 in National NG

3.3.6.3.3 Emission Factors

The adjustment factors for losses and self-consumption are applied for the purpose of determining the quantities of natural gas that market agents must place at the entrance of the Portuguese Natural Gas Network infrastructures, in order to guarantee the delivery of the natural gas necessary to supply the expected consumption for the Customers. These adjustment factors derived from the losses and self-consumption recorded by the different operators.

Table 3.140 – Ajustment Factor for Natural Gas Leaks.

Adjustment Factor	Value	Unit
Leaks in Natural Gas Transportation Network (high pressure)	0.0015	% of Natural Gas Transmitted
Leaks in Natural Gas Distribution Network (medium pressure)	0.07	% of Natural Gas Distributed (med)
Leaks in Natural Gas Distribution Network (low pressure)	0.34	% of Natural Gas Distributed (low)

The leakage values in the high pressure transport network are low because in this system the total losses are marginal (0.11% of all Natural Gas transmitted) and only a small part are NG leaks (1.33% of all losses), the remaining losses Are self-consumption that are considered in the chapter of the combustion of energy.

In the NG distribution network, leaks are associated with leaks in mechanical elements such as valves, purges, reduction stations, reduction and counting stations, mechanical connections, etc. In addition, losses are also associated with the network operation resulting from the purge for commissioning of new sections, the commissioning of new customers, gas emissions into the air resulting from the operation of safety systems, network maintenance operations, etc.. Also included in the technical losses are the possible leakages of natural gas, in the particular installations of the consumers, upstream of the meters.

The verification of natural gas characteristics is carried out by ORT - Transmission System Operator (REN Gasoduto), which periodically publishes the parameters on reference natural gas distributed in Portugal. The final composition of the natural gas varies according to its provenance and mixture, and the national average values are presented according to the following table.

Table 3.141 – Characteristics of natural gas.

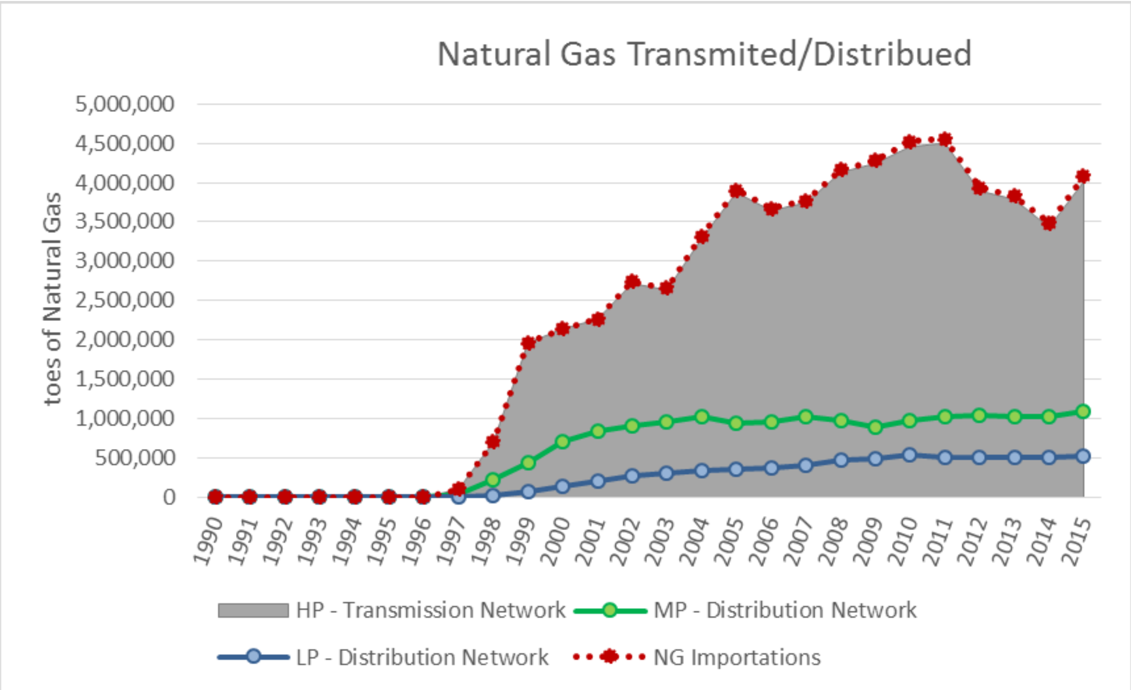
	Unit	value
Methane	mole %	90.05
Ethane (COVNM)	mole %	6.45
Propane (COVNM)	mole %	1.74
i-butane (COVNM)	mole %	0.23
n-butane (COVNM)	mole %	0.27
i-pentane (COVNM)	mole %	0.02
n-pentane (COVNM)	mole %	0.01
n-hexane (COVNM)	mole %	0.01
Nitrogen	mole %	0.58
CO2	mole %	0.63

3.3.6.3.4 Activity data

According to the above explained methodology, activity data comprehends:

- importation of natural gas, obtained from the DGEG's Energy Balances;
- consumption of Natural Gas.

Figure 3.89 – Natural Gas transported by High, Medium and Low Pressure Networks



3.3.6.3.5 Uncertainty Analysis

The uncertainty in activity data was considered to be 5 %, the value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in CH_4 emission factor, considering a low quality inventory, was assumed to be 150 %, and the same value was considered for CO_2 emissions which were determined simply from simple conversion of emissions in methane form.

3.3.6.3.6 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.

3.3.6.3.7 Recalculations

This sector has undergone a profound revision, having substantially altered the calculation methodology. The emissions of this category have been considerably reduced.

3.3.6.3.8 Further Improvements

We intend, if possible, to obtain information on leaks in the transportation and distribution of Natural Gas related to the period prior to 2009.

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

3.3.6.4.1 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_4 and CO.

3.3.6.4.2 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_2 according to:

$$U_{CO2} = EndofPipe_{CO2} + 44/12 * (0.60 * NMVOC + 12/16 * CH_4 + 12/28 * CO) * 10^{-3}$$

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_2 emissions are estimated from:

$$Emis_{CO2(y)} = Flare_{Gas(y)} * LHV_{Gas(y)} * EF_{CO2} * OF_{Gas(y)} * 10^{-3}$$

where:

$Emis_{CO2(y)}$ – Emission of CO_2 in year y (t/yr);

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

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

EF_{CO2} – Emission factor of CO_2 (kg/GJ);

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

CH_4 and NMVOC emissions are estimated from:

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

where:

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

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

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

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

N_2O emissions are estimated from:

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

where:

$Emis_{(y)}$ – Emission of N_2O in year y (t/yr);

$EF_{(p)}$ – Emission factor (t/m^3 crude);

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

$Dens_{Crude}$ – Density of the crude oil processed in the refinery in year y (t/m^3).

3.3.6.4.3 Emission Factors

Emission factors for CO_2 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_4 were set from "Concawe – Air pollutant emission estimation methods for E-PRTR reporting by refineries – report no. 1/09".

Emission factor for N_2O was set from IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Feed density was assumed equal to 0.85 t/m³.

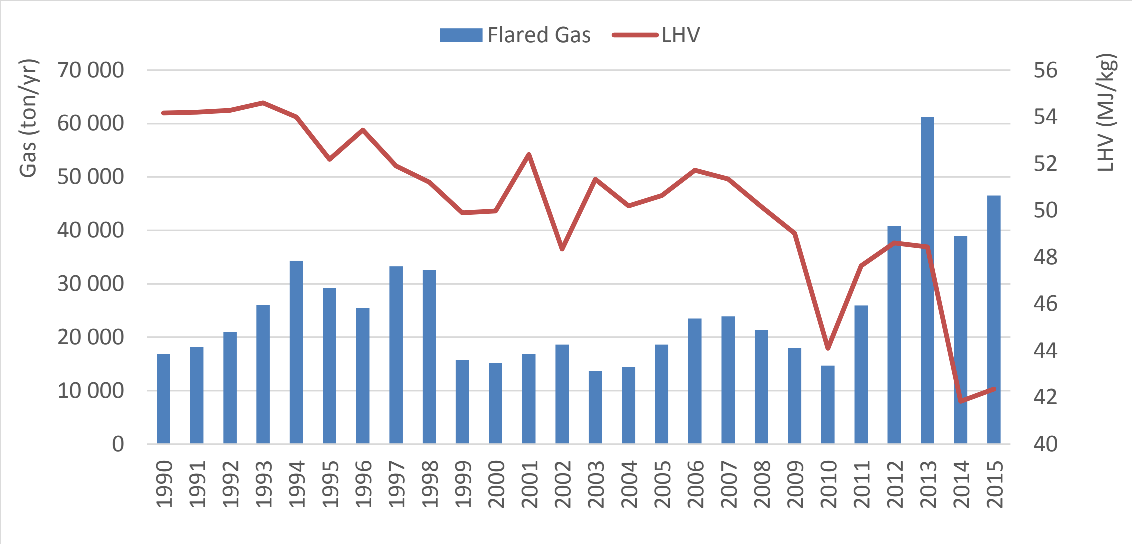
Table 3.142 – Emission Factors for flaring in refineries.

Pollutant	EF Unit	EF
CO2 (kg/GJ)	Kg/GJ	46.6 - 62.6
NMVOC	kg/t gas	5
CH_4	kg/t gas	5
N_2O[30]	t/m³ oil	$6.4x10^{-7}$

3.3.6.4.4 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.

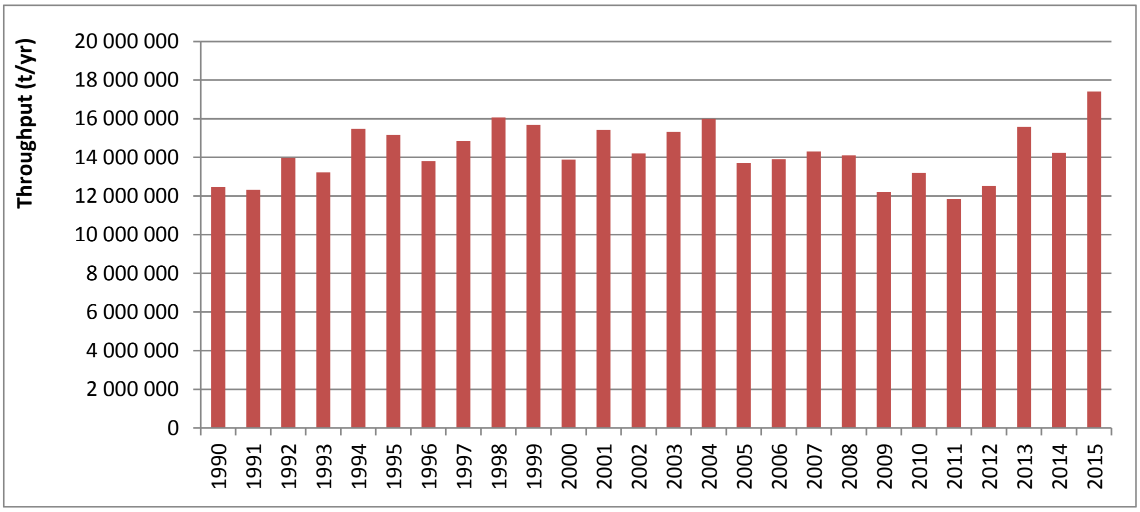
Figure 3.90 – Total consumption of flare gas in Portuguese refineries and Low Heating Value.



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

[30] 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.



3.3.6.4.5 Uncertainty Assessment

The uncertainty in activity data was considered to be 3 %, the value used when activity data refer data directly collected from the units. The uncertainty in NMVOC/CO_2 emission factor is 50 % and the double of that value for methane emissions.

3.3.6.4.6 Recalculations

No recalculations were made.

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

3.3.6.5.1 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_2 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.

3.3.6.5.2 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 CO2 mass released to the atmosphere and the calculation of a CO2 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 2003emissions of CO2 were estimated from electricity production reported by DGEG.

3.3.6.5.3 Emission factors

Measurements of carbon dioxide emissions available from Ribeira Grande and Pico Vermelho from 2008 till 2011, presented in next table, were provided by the regional authority of the Autonomous Region of Azores[31]. These results were used to estimate an average emission factor applied to the whole period on both plants (Ribeira Grande and Pico Vermelho).

The calculation of the amount of Co2 released by a geothermal power station is based on point-by-point chemical analyzes carried out on the gas fraction of the geothermal fluid, the results of which are extrapolated for the year.

Thus, the calculation of the CO2 emission is significantly influenced by the exploration effort of the plants, being directly affected by the unavailability of the geothermal wells of the production and of the auxiliary generating groups in the presence of maintenance needs.

In order to minimize the influence of these factors in the determination of the emission factor, a period of 3 years was defined for this calculation, considering that it is a reasonable time horizon to represent the evolution of the extraction effort and consequently of the Co2 emissions in the course Of the operation of the Ribeira Grande and Pico Vermelho geothermal plants

[31] Secretaria Regional dos Recursos Naturais – Direcção Regional do Ambiente.

Table 3.143 – Emission Factors for Gheotermal Electricity Production.

	2008	2009	2010	2011
Production (GWh)	171	162	174	186
CO_2 (t)	19 573	28 206	36 054	40 094
Emission Factor observed **(t/GWh)**	115	174	207	215
Emission Factor to Geothermal Electricity Production (tCO2/GWh) (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 CO2 emitted by each geothermal well and flexible operating regime of the geothermal plants. The CO2 emission factor adopted for geothermal power plants is the average of the last three years, 199 tCO2/GWh.

3.3.6.5.4 Activity Data

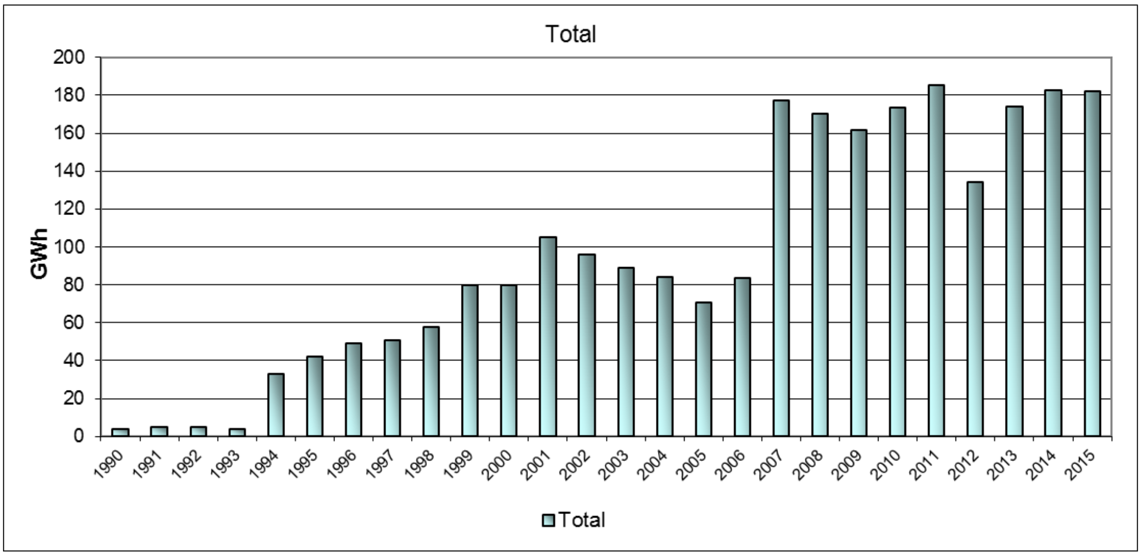
Activity data consists of geothermal production. The time series was constructed using data from the regional authority in Azores:

- Pico Vermelho – from 2000 to 2015;

- Ribeira Grande – from 1994 to 2015.

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 instalation that almost tripled the installed power (from 5MW to 13 MW).

3.3.6.5.5 Uncertainty Analysis

The uncertainty of the activity data is 5 % 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 % on the basis of the variation of the EF (measured data).

3.3.6.5.6 Recalculations

No recalculations were made.

3.3.6.5.7 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 CO2 emissions was implemented to the Energy Sector, the goal of this activity was to bring closer the estimation process in this sector.

CO2 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.

CO2 Emission Factor:

In the inventory the CO2 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 PDM 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 (SOx and NOx) from monitoring data collected from the Autocontrolo program and CO2 emission factors for information collected under carbon market;

- Consistency Checks on Refining/Storage timeseries.

3.6 Reference Approach

3.6.1 Overview

The reference approach consists in the estimate of CO_2 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"[32] for estimation of CO_2 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 CO2 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

[32] This does not mean that a "bottom-up" approach should not be followed for estimating CO_2 emissions but the total emissions must be compared with those obtained from the Reference Approach.

allow a country to produce a second independent estimate of CO_2 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_2 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.

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_2 Emissions.

3.6.2.1 Fuel consumption

Apparent consumption was estimated from energy balances from DGEG according to:

Apparent Consumption = Production + Imports - Exports- Stock Change.

for primary fuels and,

Apparent Consumption = Imports - Exports- Bunkers - 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[33]), 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:

[33] Ton of oil equivalent

$$\text{Apparent Consumption}_{(Gg\ C)} = \text{Apparent Consumption}_{(TJ)} * \text{Carbon Content}_{(MgC\ /\ TJ)} * 10^{-3}$$

The carbon content of fuels was determined using the Carbon Emission Factors used in the sectoral approach, which are presented in Table 3.144.

Table 3.144 – Carbon content of fuels and Oxidation Factor used in the Reference Approach.

Fuel			C content	Fac$_{ox}$
			(t C/TJ)	**0 - 1**
Liquid Fossil	Primary Fuels	Crude Oil	20.0	1.00
		Orimulsion	21.0	1.00
		Natural Gas Liquids	-	-
	Secondary Fuels	Gasoline	18.9	1.00
		Jet Kerosene	19.5	1.00
		Other Kerosene	19.6	1.00
		Shale Oill	-	-
		Gas / Diesel Oil	20.2	1.00
		Residual Fuel Oil	21.1	1.00
		LPG	17.2	1.00
		Ethane	-	-
		Naphtha	20.0	1.00
		Bitumen	22.0	1.00
		Lubricants	20.0	1.00
		Petroleum Coke	26.6	1.00
		Refinery Feedstocks	20.0	1.00
		Other Oil	20.0	1.00
Solid Fossil	Primary Fuels	Anthracite (a)	26.8	1.00
		Coking Coal	25.8	1.00
		Other Bit. Coal	25.8	1.00
		Sub-bit. Coal	26.2	1.00
		Lignite	27.6	1.00
		Oil Shale and tar sand	29.1	1.00
	Secondary Fuels	BKB & Patent Fuel	22.0	1.00
		Coke Oven/Gas Coke	29.2	1.00
		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 amout 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.

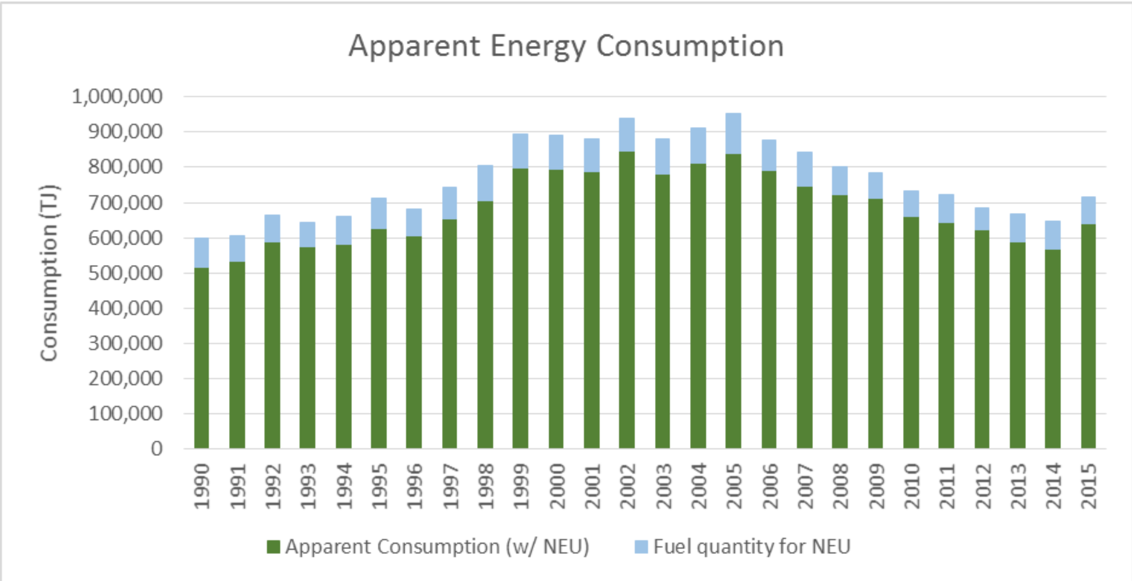
Non-energy products use – The Inventory excludes consumptions of bitumen, lubricants, paraffin, solvents and propylene, these are classified as non-energy oil in the National Energy Balance.

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

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

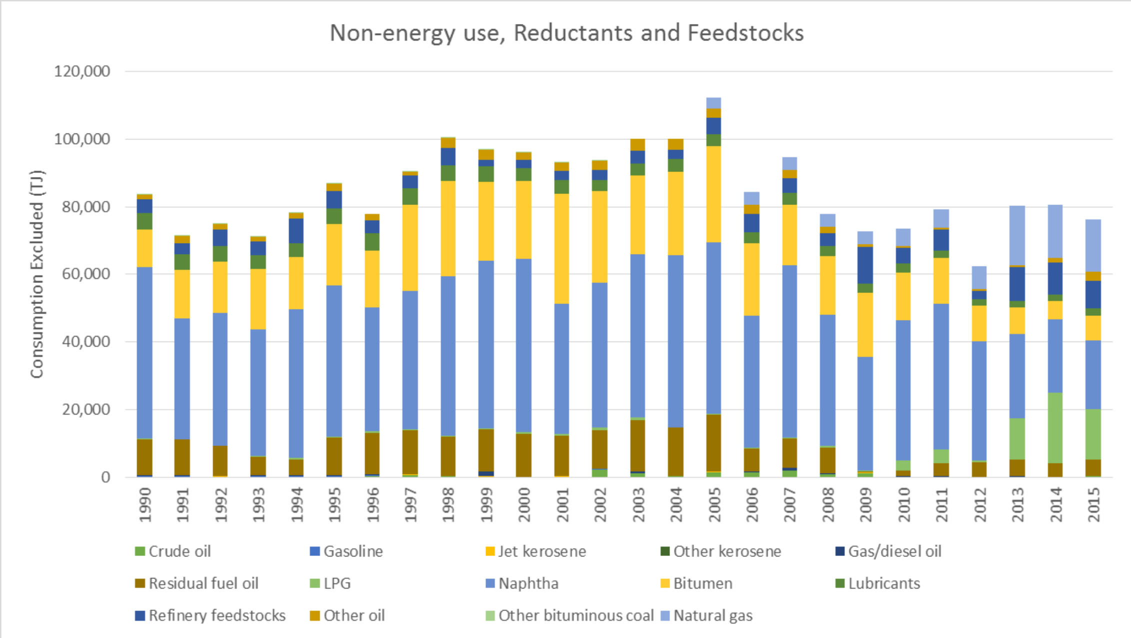
In the figure below it is possible to observe the total energy excluded from apparent consumption during the time series.

Figure 3.93 – Apparent energy consumption



This excluded energy concerns mainly the consumption as a feedstock of Naphtha and more recently LPG and Natural Gas in the Industrial Processes sector and non-energetic use of Bitumen, Lubricants and Other oil. Some losses associated with oil refining were also excluded from the reference approach, since these were not classified as energy consumptions.

Figure 3.94 – Fuel consumption exclueded from Apparent Consumption



3.6.3 Actual Carbon Dioxide Emissions

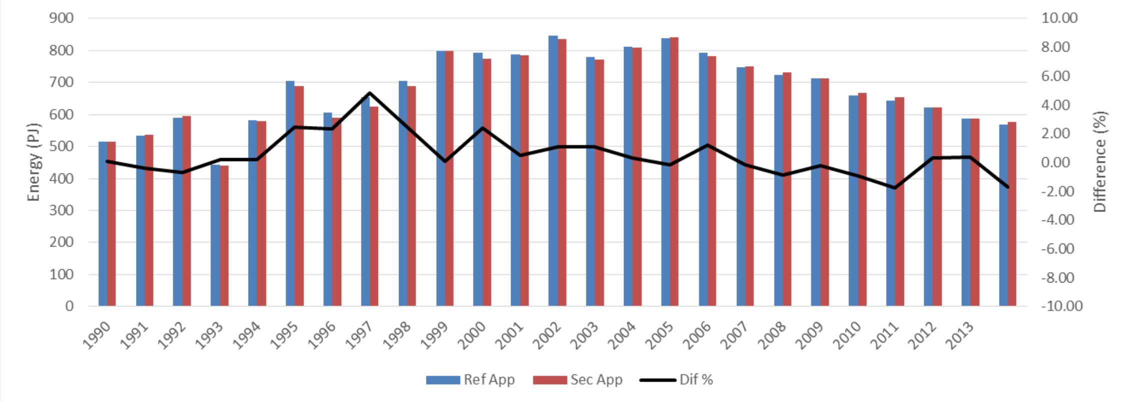
Estimated simply from:

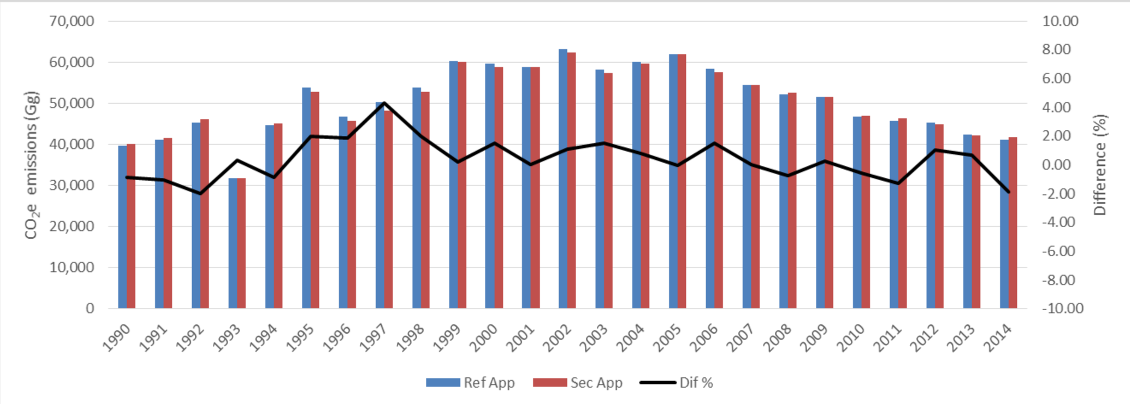
$$CO_2 \text{ Emission} = 44/12 * (\text{Apparent Consumption - Excluded Carbon}) * \text{Oxidation Factor}$$

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 3.95.

Figure 3.95 – Comparison of Energy Consumption and CO_2 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 % of feed-stocks which carbon is stored in products are default values and not specific of the national conditions reflected in the inventory;
- the energy balance as been updated in order to follow the IPCC criteria to distinguish between domestic and international fuel use. This improvement contributes to decrease the difference between the reference and the sectoral approach. Portugal is still developing efforts to further improve the split between domestic and international consumption in the energy balance;

The difference between the approaches in terms of CO_2, 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

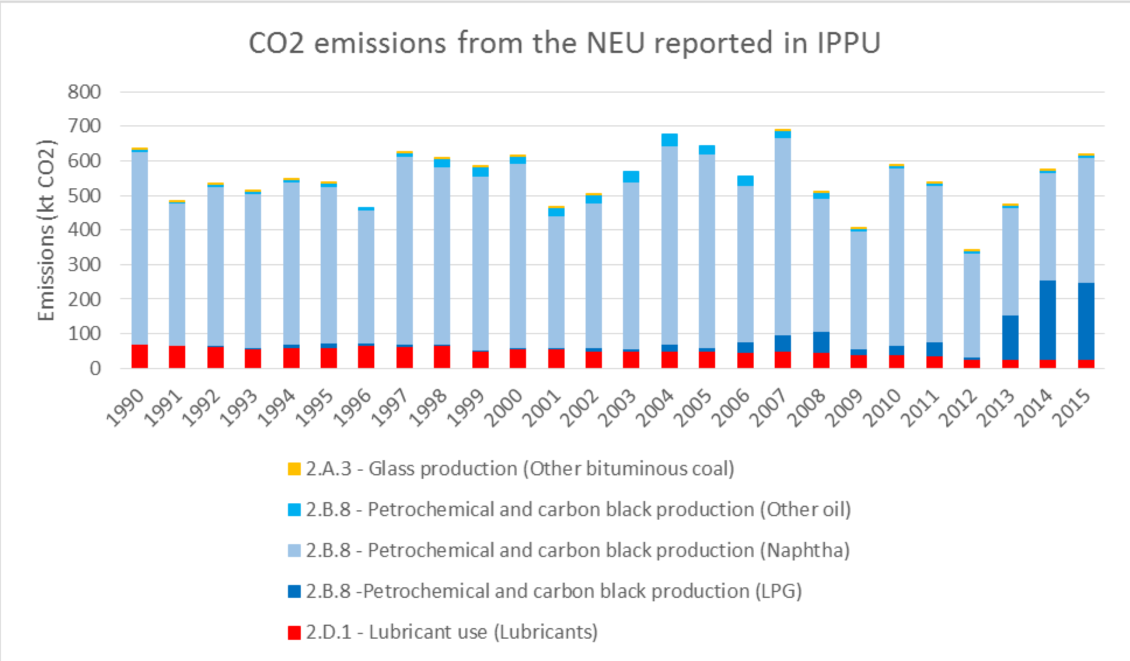
Emissions of greenhouse gas emissions from feedstock use are only clearly accounted in the inventory in the following situations:

- emission of CO_2 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_2 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.

Figure 3.96 – Carbon dioxide (CO2) emissions from non-energy use by sector



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[34]. According to UNFCCC reporting guidelines, also are included in this sector the emissions of fluorinated compounds (HFC, PFC and SF_6) 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_x, NMVOC and SO_x. Industrial processes are also relevant sources of particulate matter (PM, PM_{10}, $PM_{2.5}$ and PM_1) 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[35].

In terms of total GHG, emissions from the industrial production sector have increased from about 5.8 Mt CO_2e in 1990 to 7.6 Mt CO_2e in 2015, as may be seen from the figure below, i.e. emissions estimated for 2015 changed 29.8 % when compared to emissions estimated for 1990[36]. The majority of emissions, expressed in CO_2e, are associated with mineral industry, responsible for 62.8 % of total emissions from this sector in 1990, and 50.1 % of total emissions from this sector in 2015, as may be seen in Figure 4-2. The remaining sub-source sectors (2B, 2C, 2D, 2E, 2F, 2G and 2H[37])contribute to 49.9 % of total emissions in 2015. There is a relevant increase in sub-category 2F, consumption of Halocarbons and SF6, which represents in 2015 about 35.9 % of total GHG emissions from this source sector, and shows a fast grow over years.

[34] 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.

[35] 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.

[36] Base year for F-gases is however 1995.

[37] No emissions were allocated to sub-category 2H – Other. Emissions for category. Sector 2 F - Production of Halocarbons and SF6 does not occur in Portugal.

Figure 4-1 – Total GHG emissions from Industrial Processes per source sub-sector.

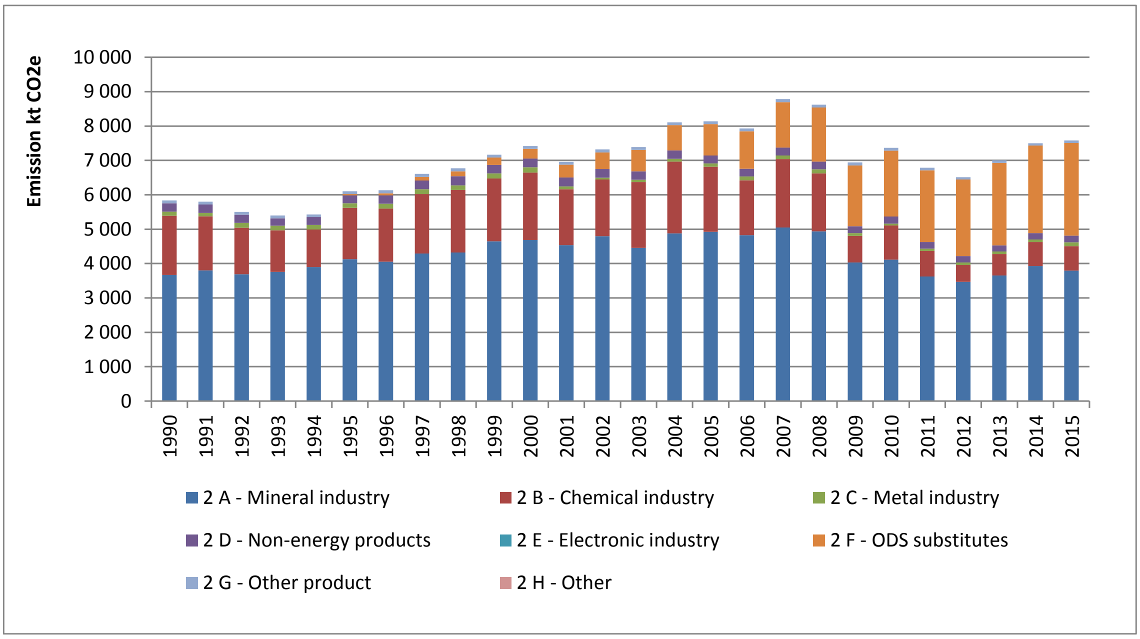
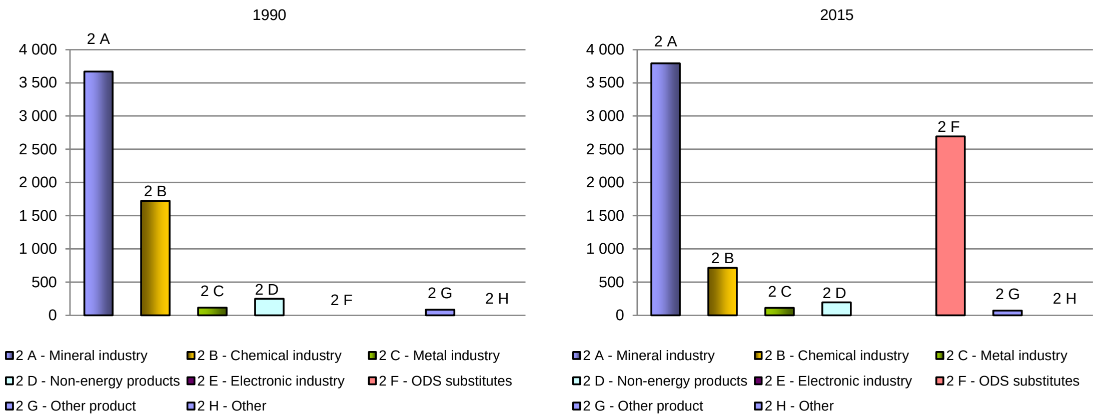
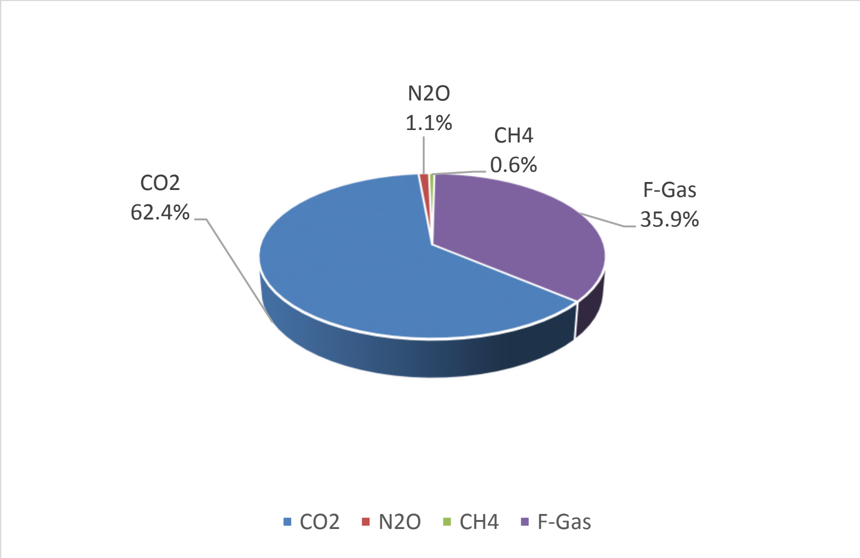


Figure 4-2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2015 (kt $CO2_e$).



The major part of greenhouse gas emissions are released directly as CO_2; while N_2O represents a smaller proportion of emissions and methane emissions are a non-relevant part, as may be seen in the figure below for year 2015. 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 2015.



4.2 Recalculations

- Uses of Carbonates in Ceramics (2.A.4.a): Following the Inventory review, biomass consumption values have been corrected in the period 1990-2010;
- Ammonia Production (2.B.1): We implemented the deduction of the CO_2 used for the urea production. This led to a decrease of 29.7 kt of CO_2 in 1990 and 20.7 kt of CO_2 in 2008 (last year with ammonia production);
- Ethylene Production (2.B.8.b): We started estimating direct CO_2 emissions from ethylene production. CH_4 emission factor has been revised;
- Ethylene Dichloride and Vinyl Chloride Monomer (VCM) Production (2.B.8.c): We started applying the 2006 IPCC Guidelines;
- Solvent Use (CRF 2.D.3.a): Correction of solvents use activity data based on national statistics (paint applications, dry cleaning, chemical products, fat edible and non-edible oils);
- Product Uses as Substitutes for ODS (CRF 2.F): Complete revision of this sector (methodologies, activity data and emission factors).

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[38] 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

[38] 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.

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[39].

Carbon dioxide emissions from cement production process result from the conversion of $CaCO_3$ and $MgCO_3$, the main constituents of limestone, to lime (CaO) and MgO, while leaving CO_2 as by product to atmosphere (Decarbonization).

Only emissions of 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. CO_2 emissions from liberation of carbon in fuel during combustion are reported also in Energy sector 1A2. However, although emissions are estimated separately from carbon originally present in fuel and carbon present in raw materials, they are in fact emitted at same place and are inseparable in concept.

4.3.1.2 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:

$$Emi_{CO2} = \text{Raw meal} * EF * CF$$

where:

Emi_{CO2} – emissions of CO_2 from cement production, originated from carbon in raw meal (kt/yr);

Raw meal – Net amount of relevant kiln input (t/yr);

EF – emission factor (kt CO_2/t of raw meal);

CF – Conversion factor (0 to 1).

We have estimated plant specific average ratio between CO_2 emissions and clinker production for each facility in the period 2005-2009 and used this average value to back cast CO_2 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:

$$Emi_{CO2,\,x} = \text{Clinker Production}_{,\,x} * EF_{(2005\text{-}2009)}$$

where:

$Emi_{CO2,\,x}$ – emissions of CO_2 from cement production in year “x” of the period 1990-2004 (kt CO_2);

[39] One calciner is a false pre-calciner.

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

EF – average emission factor (kt CO2/t clinker) in the period 2005-2009;

4.3.1.3 Emission Factors

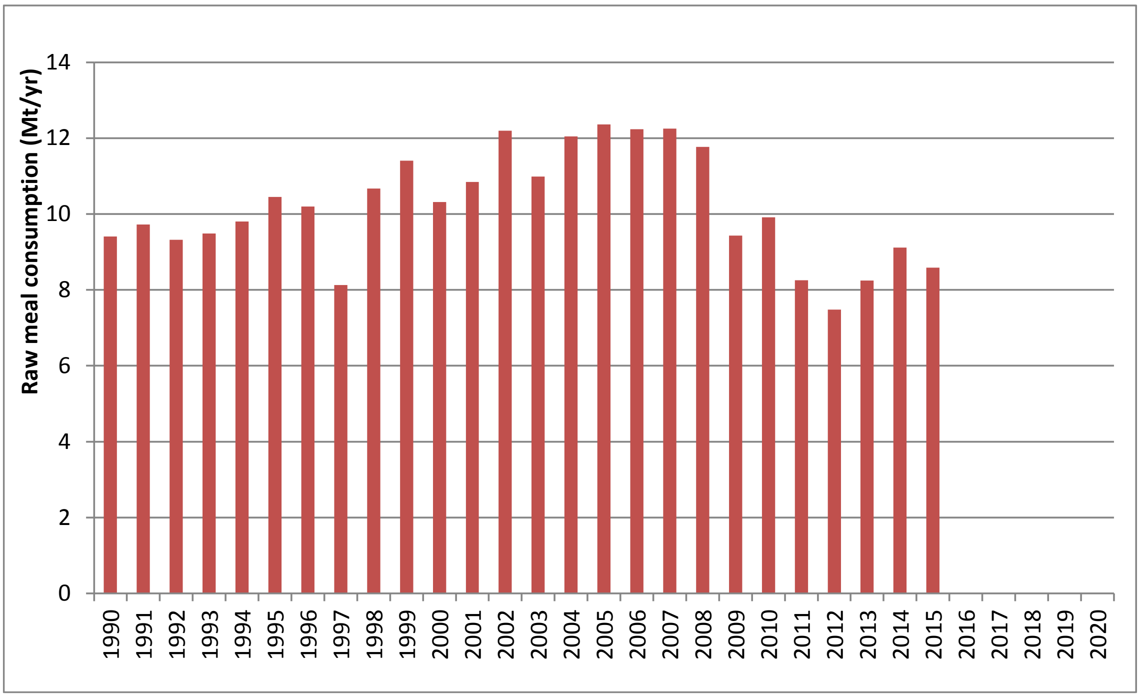
From 2005 onwards we have used raw meal carbon content characterization to estimate CO_2 emissions based on raw meal consumption in the kilns. We have estimated plant specific average ratio between CO_2 emissions and clinker production for each facility in the period 2005-2009 and used this average value to back cast CO_2 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

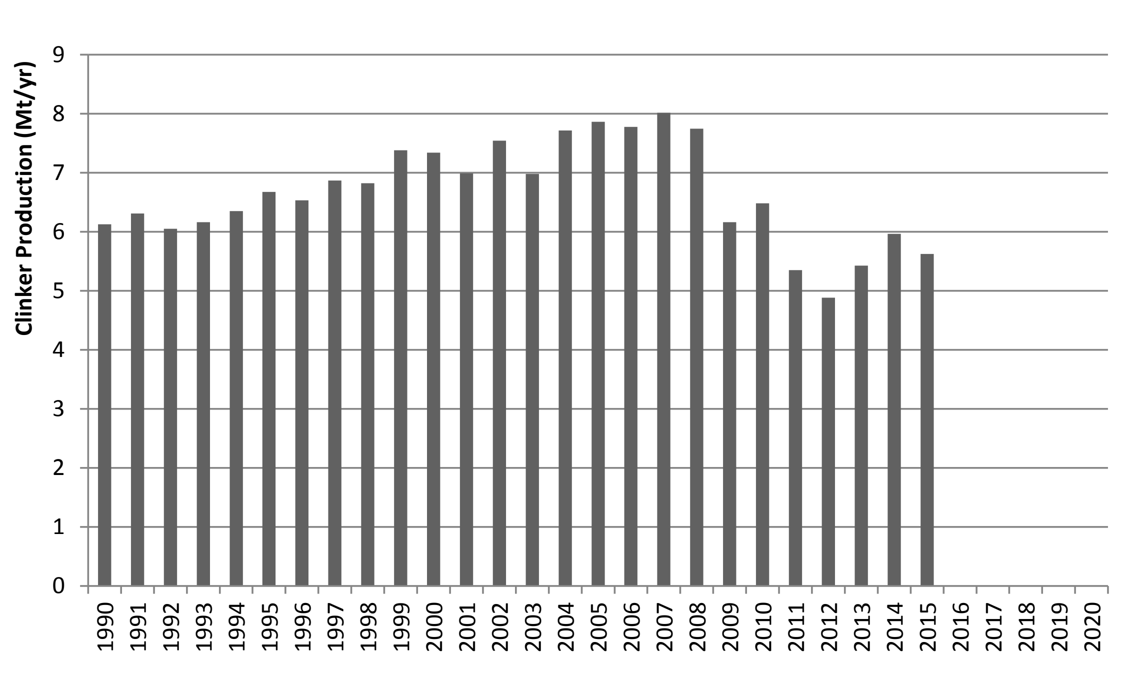
EU-ETS data on raw meal consumption is used from 2005 onwards. From 1990-2004, raw meal consumption was obtained directly from the plants.

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 Mt and is due to a demand decrease in Portugal, Spain and North Africa market. From 2013 to 2014 there is an overall increase in clinker production of 0.54 Mt due to exports rise to Africa and South America. In 2015 there is a decrease of 0.34 Mt of clinker produced, due to a contraction of external market sales, related both to supply excess in the Mediterranian area and to a consumption decrease in Africa.

4.3.1.5 Uncertainty assessment

Table 4.1 – Uncertainty values related to emissions reported under CRF 2.A.1.

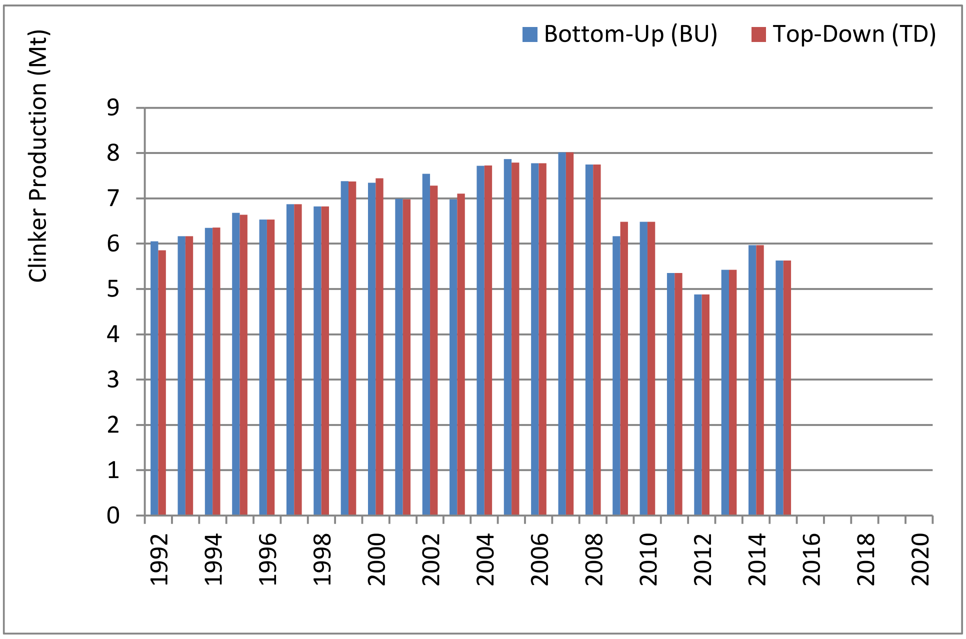
Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Composition	7.0%	Table 2.3 of "Chapter 2: Mineral Industry Emissions" de "2006 IPCC Guidelines for National Greenhouse Gas Inventories": • 2% - Kerogen (or other non-carbonate carbon) determination; • 2% - Overall chemical analysis pertaining to carbonate content (mass) & type; • 3% - Assumption that carbonate species is 100% CaCO3.
Activity Data	Uncertainty of plant-level weighing of raw materials	2.0%	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
Activity Data	Uncertainty on CKD	30.0%	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories":
Activity Data	Combined Uncertainty	30.9%	-
CO_2 EF	Combined Uncertainty	1.4-5.4%	Uncertainty = [(Highest-Lowest)/Average/2]*100 Data on CO2 emissions obtained from ETS.

Uncertainty estimates based on fuel consumption are reported under CRF 1.A.2.f.

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 (IAPI) from 1992 onwards. There are slight differences using the two different approaches, but, generally, data is consistent.

Figure 4-6 – Emissions estimates – comparison of approaches.



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 in dedicated plants (CRF 2.A.2.)

4.3.2.1 Overview

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200ºC) 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.

$$CaCO_3 \text{ (limestone)} + \text{heat} \rightarrow CaO + CO_2$$

$$CaCO_3.MgCO_3 \text{ (dolomite)} + \text{heat} \rightarrow CaO.MgO + 2CO_2$$

Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy $CaCO_3$ content (at least 50 %) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of Na_2CO_3, NAOH, steel, refractory material, SO_2 absorption, CaC_2, glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;

- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45 % in content). Dolomite quicklime is a mixture of CaO and MgO;

- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime: $Ca(OH)_2$ It is produced from CaO and water. When an equivalent quantity of water is used is called slaked lime, when an excess water is used is milk of lime and a clear solution of $Ca(OH)_2$ in water is limewater. It is used as an industrial alkali and in the preparation of mortar (slaked lime plus sand) which sets to solid by reconversion of the hydroxide to CaCO3 (Sharp, 1981);

- Hydraulic Lime. A mixture of calcium oxide (CaO) and silicates, it is an intermediate product between lime and cement.

There are 5 dedicated lime production plants under ETS in Portugal (7 until 2008 and 6 until 2013).

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:

$$Emi_{CO2} = \text{Kiln input} * EF * CF$$

where:

Emi_{CO2} – emissions of CO_2 from lime production, originated from carbon in kiln input materials (kt/yr);

Kiln input – Net amount of relevant kiln input (t/yr);

EF – emission factor (kt CO2/t 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 (t CO2/t lime) based on ETS CO_2 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

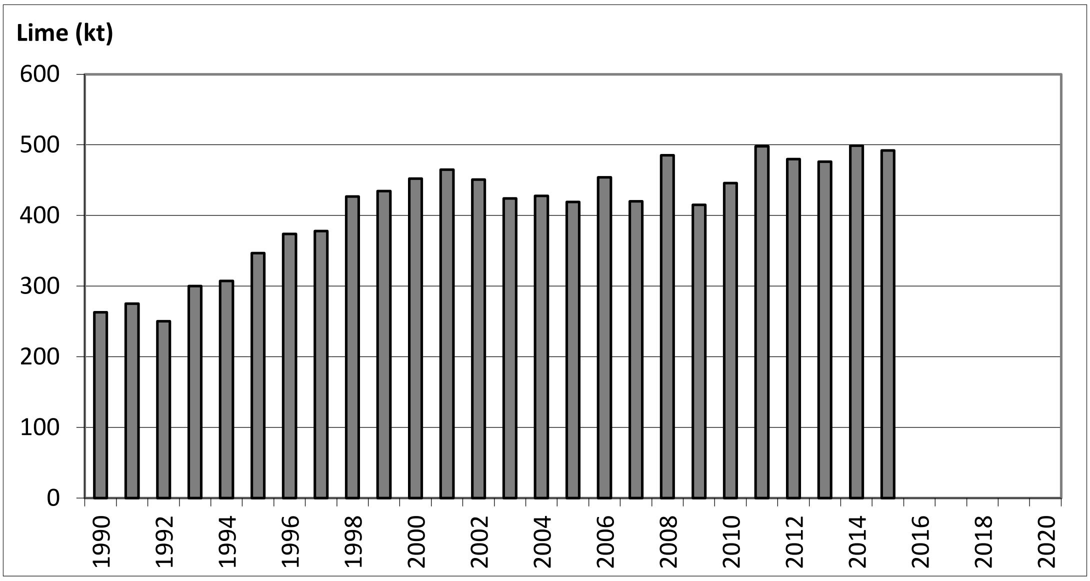
The CO2 emission factors were estimated by converting kiln input materials composition data, using the following stoichiometric ratios (Table 1 of Annex VIII of Decision 2007/589/EC):

Substance	Unit	Stoichiometric ratios
$CaCO_3$	t CO_2/t $CaCO_3$	0.440
$MgCO_3$	t CO_2/t $MgCO_3$	0.522

4.3.2.4 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.

Figure 4-7 – Lime Production.



The Lime production values in 2015 are 1.9 times higher than in 1990.

4.3.2.5 Uncertainty assessment

Table 4.2 – Uncertainty values related to emissions reported under CRF 2.A.2.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Lime production data	1.5% (average of 1.0-2.0% range)	Average of the range 1.0-2.0% of Table 2.5 of Chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Activity Data	Lime Production	35% (highest of 25-35% range)	Highest value of the range (25-35%) of "Default Values" of CKD/LKD in Table 2.3 of Chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Activity Data	Combined Uncertainty	35.03%	-
CO_2 EF	CaO in lime	6.0% (average of 4.0-8.0% range)	Average of the range 4.0-8.0% of "Table 2.5" of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	EF of High Calcium Lime	2.0%	"Emission factor high calcium lime" (2%) of "Table 2.5" of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	Combined Uncertainty	6.3%	-

Table 4.3 – Uncertainty values related to emissions reported under CRF 1.A.2.f.

Parameter	Fuel Type/	1990-2004	2005-2007	2008 onwards
Activity Data	L	10% (i)	3% (ii)	2% (iii)
	S	10% (i)	3% (ii)	2%
	G	10% (i)	3% (ii)	2%
	B	10% (i)	3% (ii)	2%
	O	10% (i)	3% (ii)	2%
CO_2 EF	L	3% (iv)	3% (iv)	3% (iv)
	S	7% (v)	7% (v)	7% (v)
	G	7% (v)	7% (v)	7% (v)
	B	7% (v)	7% (v)	7% (v)
	O	7% (v)	7% (v)	7% (v)
CH_4 EF	L	100% (vi)	100% (vi)	100% (vi)
	S	100% (vi)	100% (vi)	100% (vi)
	G	100% (vi)	100% (vi)	100% (vi)
	B	100% (vi)	100% (vi)	100% (vi)
	O	100% (vi)	100% (vi)	100% (vi)
N_2O EF	L	150% (vii)	150% (vii)	150% (vii)
	S	150% (vii)	150% (vii)	150% (vii)
	G	150% (vii)	150% (vii)	150% (vii)
	B	150% (vii)	150% (vii)	150% (vii)
	O	150% (vii)	150% (vii)	150% (vii)

(i) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value of the range 5-10% of "Extrapolation" in "Less developed statistical systems".

(ii) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value of the range 2-3% of "Surveys" in "Well developed statistical systems".

(iii) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Lowest value of the range 2-3% of "Surveys" in "Well developed statistical systems".

(iv) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value for "Oil" in "Table 2.13".

(v) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Average value for "Coke, oil, gas" in "Table 2.13".

(vi) Highest value of Table 2.14 of "Volume 2: Energy" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

(vii) Average UK value in "Table 2.14" of "Volume 2: Energy" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

4.3.2.6 Recalculations

No recalculations were made.

4.3.2.7 Further Improvements

No further improvements are expected.

4.3.3 Lime Production in Paper Pulp and in Iron and Steel Sectors (CRF 2.A.2)

4.3.3.1 Overview

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.

4.3.3.2 Methodology

4.3.3.2.1 Methodology - Lime Production in Iron and Steel Industry

Emissions were estimated based on lime production time series, on stoichiometric ratios between CO_2 and CaO (0.785 t CO_2/t CaO), and assuming a correction factor for CaO in lime (95%).

$$CaCO_3 \rightarrow CaO + CO_2 \qquad (Reaction\ in\ the\ Lime\ Kiln)$$

$$Emi(CO_2) = m(Lime) \times Cont(CaO) \times \frac{m(CO_2)}{m(CaO)} \times 10^{-3}$$

where:

Emi(CO_2) - emission of carbon dioxide (kt CO_2);

m(Lime) – Lime production in lime kilns (t);

Cont(CaO) – CaO content in Lime (0.95);

m(CO_2)/m(CaO) – stoichiometric ratio of CO_2 in lime kilns (0.785 t CO_2/t CaO).

4.3.3.2.2 Methodology - Lime Production in Paper Pulp Production

We estimate both $CaCO_3$ used to produce lime in lime kilns and Na_2CO_3 used in causticisers to convert green liquor in white liquor. The $CaCO_3$ produced in the causticiser from Na_2CO_3 is subsequently transformed in CaO in the lime kilns.

$$CaCO_3 \rightarrow CaO + CO_2 \qquad (Reaction\ in\ the\ Lime\ Kiln)$$

$$Ca(OH)_2 + Na_2CO_3 \rightarrow 2NaOH + CaCO_3 \qquad (Reaction\ in\ the\ Causticiser)$$

CO_2 emissions are estimated from the quantification of carbon in $CaCO_3$ and Na_2CO_3, and making a mass balance for the quantities of CO_2 that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

$$Emi_{CO2\ (y)} = Mat_{Carb\ (m,y)} * C_{content\ (m)} * 10^{-3}$$

where:

$Emi_{CO2\ (y)}$ - emission of carbon dioxide in year y (kt CO_2/yr);

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

$C_{content\ (m)}$ - carbon content of material m consumed in year y (t CO_2/t material m).

4.3.3.3 Emission Factors

4.3.3.3.1 Emission Factors – Lime Production in Iron and Steel Industry

Table 4.4 – Emission Factors.

Parameter	Unit	Carbon Content	Source
CO_2/CaO	t CO_2/t CaO	0.785	Table 2.4 of Volume 3: Industrial Processes and Product Use of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
CaO content in High-Calcium Lime	t CaO/t Lime	0.950	Table 2.4 of Volume 3: Industrial Processes and Product Use of 2006 IPCC Guidelines for National Greenhouse Gas Inventories

4.3.3.3.2 Emission Factors – Lime Production in Paper Pulp Industry

Table 4.5 – Carbon content of raw materials.

Raw Material	Unit	Carbon Content
$CaCO_3$	t CO_2/t $CaCO_3$	0.440
Na_2CO_3	t CO_2/t Na_2CO_3	0.415

4.3.3.4 Activity Data

4.3.3.4.1 Activity Data - Lime Production in Iron and Steel Industry

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.

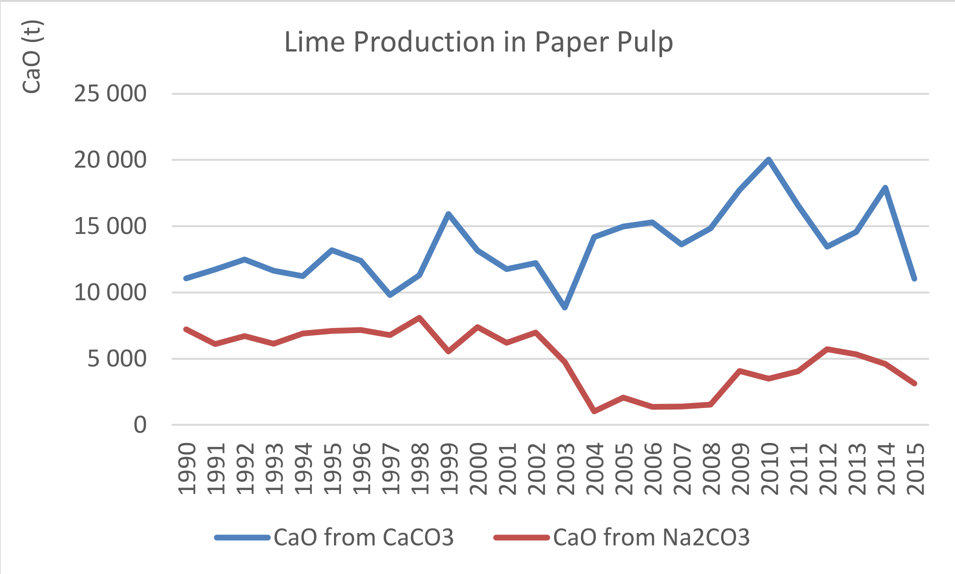
4.3.3.4.2 Activity Data - Lime Production in Paper Pulp Industry

In paper pulp industry, data on consumption of $CaCO_3$ (in lime kilns) and Na_2CO_3 (in causticisers) was obtained from all the facilities from 1990 onwards. In the estimates of CaO. We only consider additional $CaCO_3$ that is bought to produce CaO. The amounts of carbonaceous sludge consumed ($CaCO_3$) are not considered since they correspond to a closed cycle of carbon in the liquors cycle.

Table 4.6 – Carbon content of raw materials.

Raw Material	Unit	Carbon Content
$CaCO_3$	t CO_2/t $CaCO_3$	0.440
Na_2CO_3	t CO_2/t Na_2CO_3	0.415

Figure 4-8 – Lime Production in Paper Pulp.



4.3.3.5 Uncertainty Assessment

Table 4.7 – Uncertainty values related to emissions reported under CRF 2.A.2.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Lime production data	1.5% (average of 1.0-2.0% range)	Average of the range 1.0-2.0% of Table 2.5 of Chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Activity Data	Lime Production	35% (highest of 25-35% range)	Highest value of the range (25-35%) of "Default Values" of CKD/LKD in Table 2.3 of Chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Activity Data	Combined Uncertainty	35.03%	-
CO_2 EF	CaO in lime	6.0% (average of 4.0-8.0% range)	Average of the range 4.0-8.0% of "Table 2.5" of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	EF of High Calcium Lime	2.0%	"Emission factor high calcium lime" (2%) of "Table 2.5" of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	Combined Uncertainty	6.3%	-

4.3.3.6 Recalculations

No recalculations were made.

4.3.3.7 Further Improvements

No further improvements are expected.

4.3.4 Glass Production (CRF 2.A.3.)

4.3.4.1 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[40].

4.3.4.2 Methodology

Carbon dioxide emissions from glass production were estimated from:

$$Emission_{CO2(t,y)} = EF_{CO2(t)} * Carbonate_{(t,y)}$$

where:

$Emission_{CO2(t,y)}$ - annual emission of carbon dioxide from consumption of specific carbonate (t/yr);

$Carbonate_{(t,y)}$ - Carbonate of type t consumed in a given year y (t/yr);

$EF_{CO2(t)}$ - emission factor from consumption of carbonate t (t CO_2/t carbonate).

From 2005 onwards, carbonates consumption was obtained from ETS data. In the period 1990-2004, carbonates consumption in each glass production plant was estimated based on 2005 carbonates consumption in the same plant and on the ratio of glass production between each year and the glass production of year 2005:

$$Carbonate_{(y)} = Carbonate_{(2005)} * Glass\ Production_{(y)} / Glass\ Production_{(2005)}$$

where:

Carbonate (y) – Carbonate consumption in year y;

[40] They were not used to derive the country specific emission factors for instance.

Carbonate (2005) – Carbonate consumption in year 2005;

Glass Production (y) – Glass Production in year y;

Glass Production (2005) – Glass Production in year 2005.

4.3.4.3 Emission Factors

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

Table 4.8 – Stoichiometric CO_2 Emission Factors for each carbonate.

Carbonate	EF	Unit EF
$CaCO_3$	0.440	t CO_2/t carbonate
$MgCO_3$	0.522	t CO_2/t carbonate
Na_2CO_3	0.415	t CO_2/t carbonate
$BaCO_3$	0.223	t CO_2/t carbonate
Li_2CO_3	0.596	t CO_2/t carbonate
K_2CO_3	0.318	t CO_2/t carbonate
$NaHCO_3$	0.524	t CO_2/t carbonate
$X_Y(CO3)_Z$	var	t CO_2/t carbonate

4.3.4.4 Activity Data

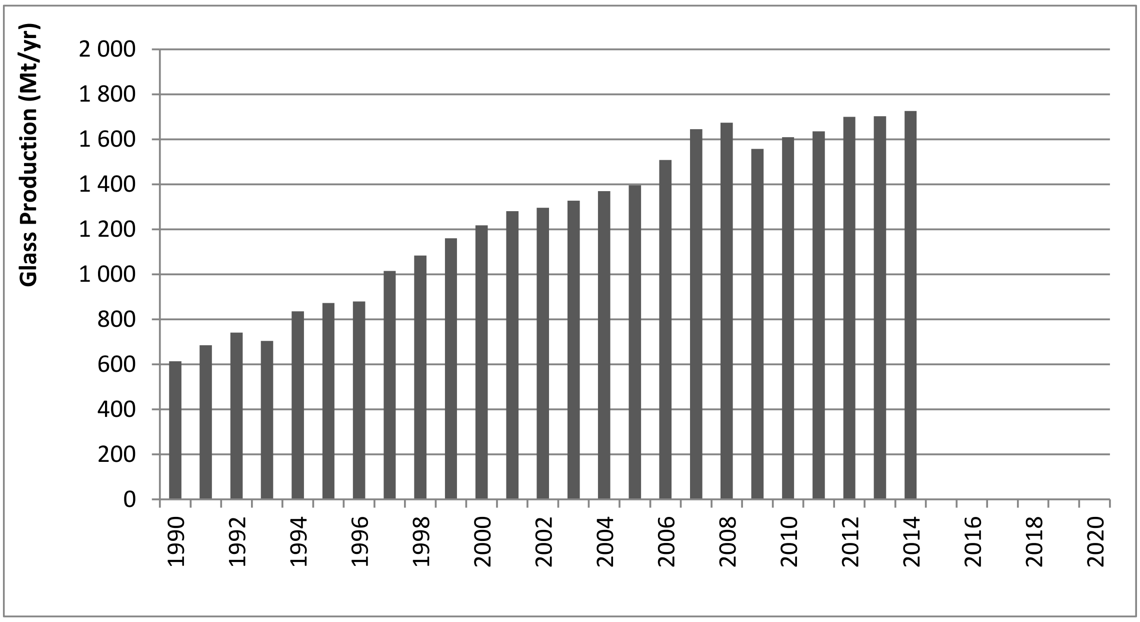
We don't use data from INE because not all products are reported in weight, but instead are measured in area-units (m^2) or number of produced pieces.

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

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

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

Figure 4-9 - Glass production.



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

From 2005 onwards it is used ETS data on Na_2CO_3, $MgCO_3$, $CaCO_3$, $BaCO_3$, coal and other carbonate raw materials consumption in the kilns.

For flat glass and container glass the facilities that report data under ETS correspond to the national total.

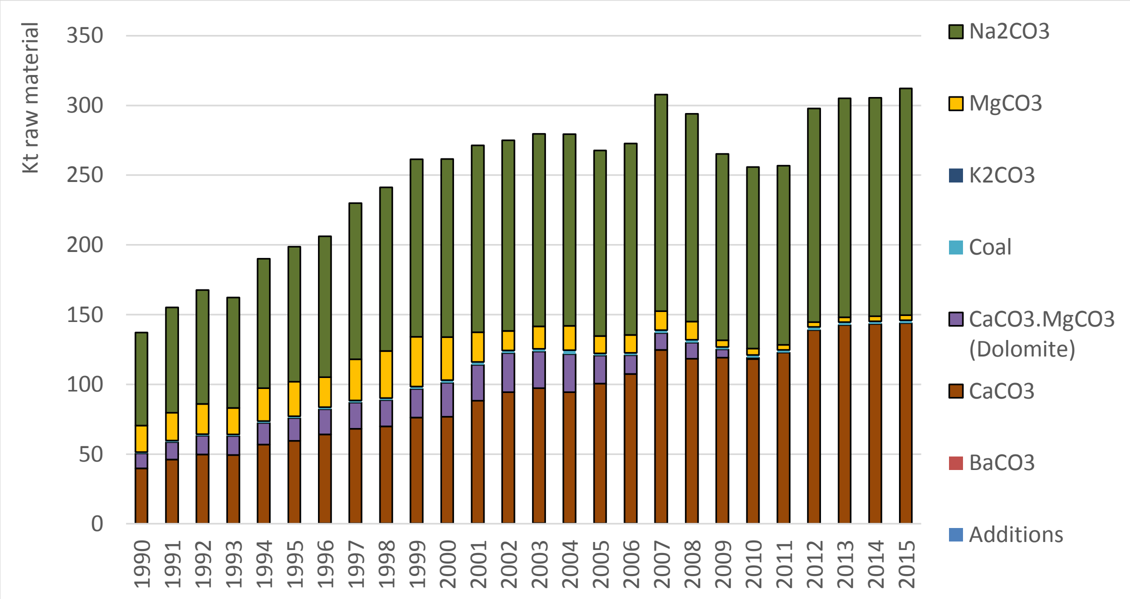
For crystal glass it is used the ETS data from the largest facility that reports data under ETS and data is extrapolated for the remaining crystal glass facilities based on crystal glass production.

Stoichiometric CO_2 emission factors for each carbonate from the Annex IX of Directive 2003/87/EC are used.

Glass production data by type of glass (flat, container, crystal) is used to estimate emissions on the period 1990-2004, since there is no detailed data on carbonate raw material consumption from ETS in that period.

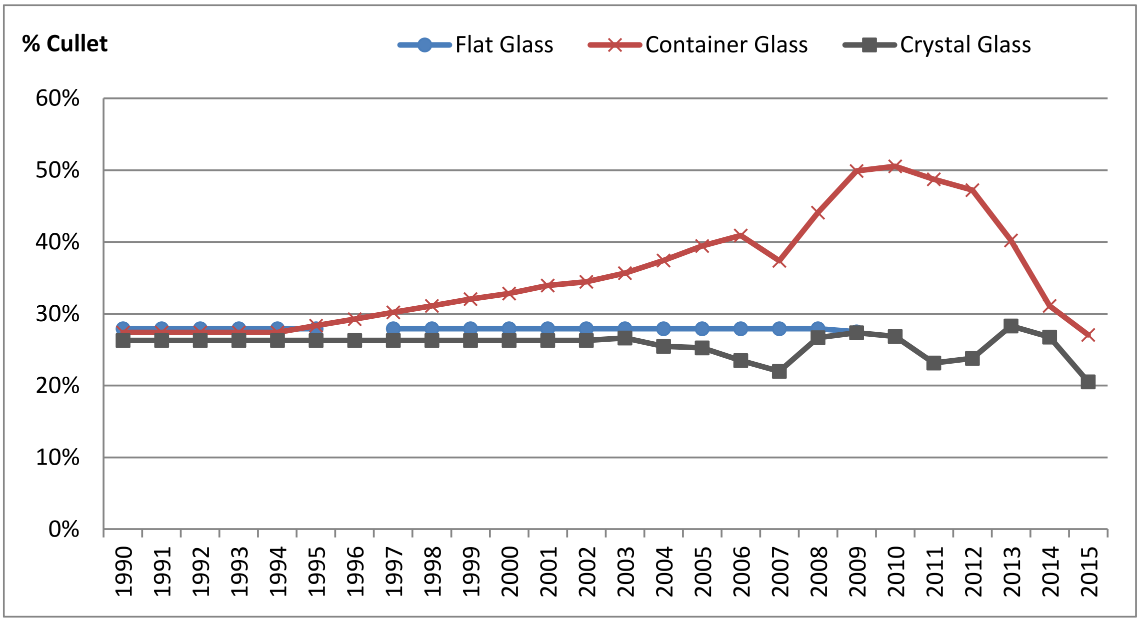
Raw materials consumption could be checked in the next figure.

Figure 4-10 – Raw materials consumption.



Cullet incorporation ratio could be checked in the next figure.

Figure 4-11 - Percent of Cullet incorporation by type of glass.



4.3.4.5 Uncertainty Assessment

Table 4.9 – Uncertainty values related to emissions reported under CRF 2.A.3.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Weighing or proportioning raw materials	2.0% (average of 1.0-3.0% range)	Subchapter 2.4.2.2 of chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Activity Data	Glass Production	5.0%	Subchapter 2.4.2.2 of chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Activity Data	Combined Uncertainty	5.4%	-
CO_2 EF	Stoichiometric ratio	2.0% (average of 1.0-3.0% range)	Subchapter 2.4.2.1 of chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CO_2 EF	Calcination of the carbon input	1.0%	Subchapter 2.4.2.1 of chapter 2: Mineral Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CO_2 EF	Combined Uncertainty	2.2%	-

Table 4.10 – Uncertainty values related to emissions reported under CRF 1.A.2.f.

Parameter	Fuel Type/	1990-2004	2005-2007	2008 onwards
Activity Data	L	10% (i)	3% (ii)	2% (iii)
	S	10% (i)	3% (ii)	2%
	G	10% (i)	3% (ii)	2%
	B	10% (i)	3% (ii)	2%
	O	10% (i)	3% (ii)	2%
CO_2 EF	L	3% (iv)	3% (iv)	3% (iv)
	S	7% (v)	7% (v)	7% (v)
	G	7% (v)	7% (v)	7% (v)
	B	7% (v)	7% (v)	7% (v)
	O	7% (v)	7% (v)	7% (v)
CH_4 EF	L	100% (vi)	100% (vi)	100% (vi)
	S	100% (vi)	100% (vi)	100% (vi)
	G	100% (vi)	100% (vi)	100% (vi)
	B	100% (vi)	100% (vi)	100% (vi)
	O	100% (vi)	100% (vi)	100% (vi)
N_2O EF	L	150% (vii)	150% (vii)	150% (vii)
	S	150% (vii)	150% (vii)	150% (vii)
	G	150% (vii)	150% (vii)	150% (vii)
	B	150% (vii)	150% (vii)	150% (vii)
	O	150% (vii)	150% (vii)	150% (vii)

(i) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value of the range 5-10% of "Extrapolation" in "Less developed statistical systems".

(ii) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value of the range 2-3% of "Surveys" in "Well developed statistical systems".

(iii) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Lowest value of the range 2-3% of "Surveys" in "Well developed statistical systems".

(iv) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value for "Oil" in "Table 2.13".

(v) Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Average value for "Coke, oil, gas" in "Table 2.13".

(vi) Highest value of Table 2.14 of "Volume 2: Energy" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

(vii) Average UK value in "Table 2.14" of "Volume 2: Energy" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

4.3.4.6 Recalculations

No recalculations were made.

4.3.4.7 Further Improvements

No further improvements are expected.

4.3.5 Glass Wool and Rock Wool (CRF 2.A.3.)

4.3.5.1 Overview

There is no glass wool production in Portugal.

There are two plants in Portugal producing rock wool. 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.

4.3.6 Uses of Carbonates in Ceramics (CRF 2.A.4.a)

4.3.6.1 Overview

Process-related emissions from ceramics result from the calcination of carbonates in the clay, as well as additions. In Portugal, part of the ceramics sector is considered in the Emissions trading scheme (ETS) and from 2013 onwards, there is a good characterization of raw materials consumption in the ceramic plants under ETS.

4.3.6.2 Methodology

For year 2015:

$$Total\ Mat_{Carb(m)} = ETS\ Mat_{Carb(m)} \times \frac{EB\ Fuel\ Cons_{(Ceramics)}}{ETS\ Fuel\ Cons_{(Ceramics)}}$$

where:

$Total\ Mat_{Carb(m)}$ – Raw material m consumption for all national ceramics (t raw material) – both ETS (Emissions Trading Scheme) and non-ETS plants;

$ETS\ Mat_{Carb(m,y)}$ – Raw material m consumption for ceramic plants under ETS (t raw material);

$EB\ Fuel\ Cons_{(Ceramics)}$ – Energy Balance Ceramics fuel consumption (GJ) - both ETS and non-ETS plants;

$ETS\ Fuel\ Cons_{(Ceramics)}$ – Fuel consumption (GJ) for Ceramic plants under ETS.

CO_2 emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of CO_2 that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

$$Emi_{CO2\ (y)} = Mat_{Carb\ (m,y)} * C_{content\ (m)} * 10^{-3}$$

where:

$Emi_{CO2\ (y)}$ - emission of carbon dioxide in year y (kt CO_2/yr);

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

$C_{content\ (m)}$ - carbon content of material m consumed in year y (t CO_2/t material m).

For the period 1990-2014:

$$ETS\ Mat_{Carb(m,y)} = ETS\ Mat_{Carb(m,2015)} \times \frac{Year_x EB\ Fuel\ Cons_{(Ceramics)}}{2015\ EB\ Fuel\ Cons_{(Ceramics)}}$$

where:

ETS $Mat_{Carb(m,y)}$ – Raw material m consumption in year t for ceramic plants under ETS (t raw material);

ETS $Mat_{Carb(m,\ 2015)}$ – Raw material m consumption in year 2015 for ceramic plants under ETS (t raw material);

$Year_x$ EB Fuel $Cons_{(Ceramics)}$ – Energy Balance Ceramics fuel consumption (GJ) in year 2015 - both ETS and non-ETS plants;

$Year_x$ EB Fuel $Cons_{(Ceramics)}$ – Energy Balance Ceramics fuel consumption (GJ) in year x - both ETS and non-ETS plants;

$$Total\ Mat_{Carb(m)} = ETS\ Mat_{Carb(m)} \times \frac{EB\ Fuel\ Cons_{(Ceramics)}}{ETS\ Fuel\ Cons_{(Ceramics)}}$$

where:

Total $Mat_{Carb(m)}$ – Raw material m consumption for all national ceramics (t raw material) – both ETS (Emissions Trading Scheme) and non-ETS plants;

ETS $Mat_{Carb(m,y)}$ – Raw material m consumption for ceramic plants under ETS (t raw material);

EB Fuel $Cons_{(Ceramics)}$ – Energy Balance Ceramics fuel consumption (GJ) - both ETS and non-ETS plants;

ETS Fuel $Cons_{(Ceramics)}$ – Fuel consumption (GJ) for Ceramic plants under ETS.

$$Emi_{CO2\ (y)} = Mat_{Carb\ (m,y)} * C_{content\ (m)} * 10^{-3}$$

where:

$Emi_{CO2\ (y)}$ - emission of carbon dioxide in year y (kt CO_2/yr);

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

$C_{content\ (m)}$ - carbon content of material m consumed in year y (t CO_2/t material m).

4.3.6.3 Emission Factors

Table 4.11 – Carbon content of raw materials.

Raw Material	Unit	Carbon Content
Clay	t CO_2/t Clay	0.0244
$BaCO_3$	t CO_2/t $BaCO_3$	0.2230
$CaCO_3$	t CO_2/t $CaCO_3$	0.4400
Kaolin	t CO_2/t Kaolin	0.0049
Dolomite	t CO_2/t Dolomite	0.4778
$MgCO_3$	t CO_2/t $MgCO_3$	0.5220
Na_2CO_3	t CO_2/t Na_2CO_3	0.4150
Other Carbonates	t CO_2/t Other Carbonates	0.0295
Ceramic Paste	t CO_2/t Ceramic Paste	0.0036
Polystyrene	t CO_2/t Polystyrene	3.3850

4.3.6.4 Activity Data

From 2015 onwards, both raw materials consumption and carbon content of raw materials have been obtained from ETS data.

Since, not all ceramics are covered under ETS, raw materials consumption have been extrapolated based on fuel consumption in ceramics reported both under ETS (just ETS plants) and in Energy Balance (both ETS and non-ETS plants), as described in the methodology.

Figure 4-12 – Raw materials consumption (t) – ETS plants.

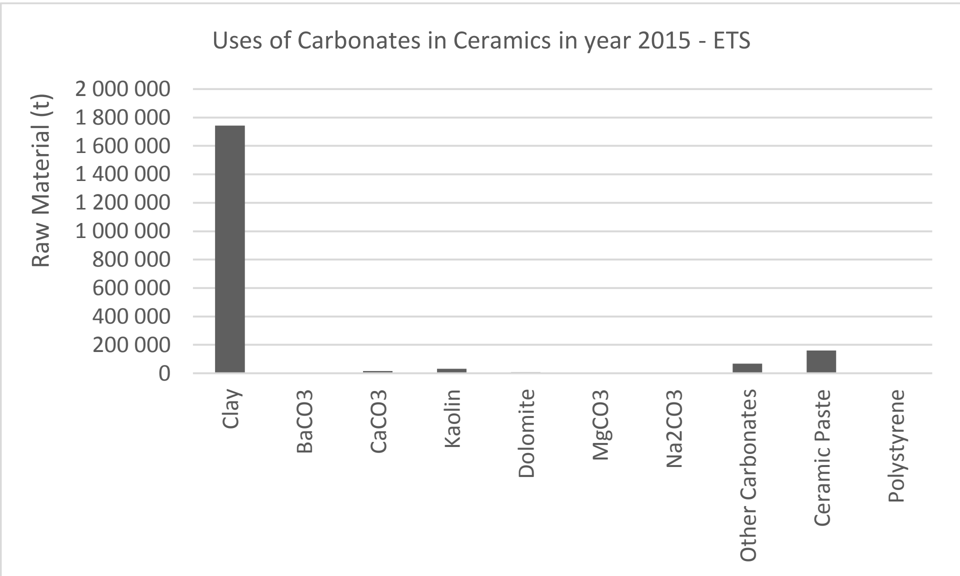


Figure 4-13 – Fuel consumption in Ceramics by type (GJ).

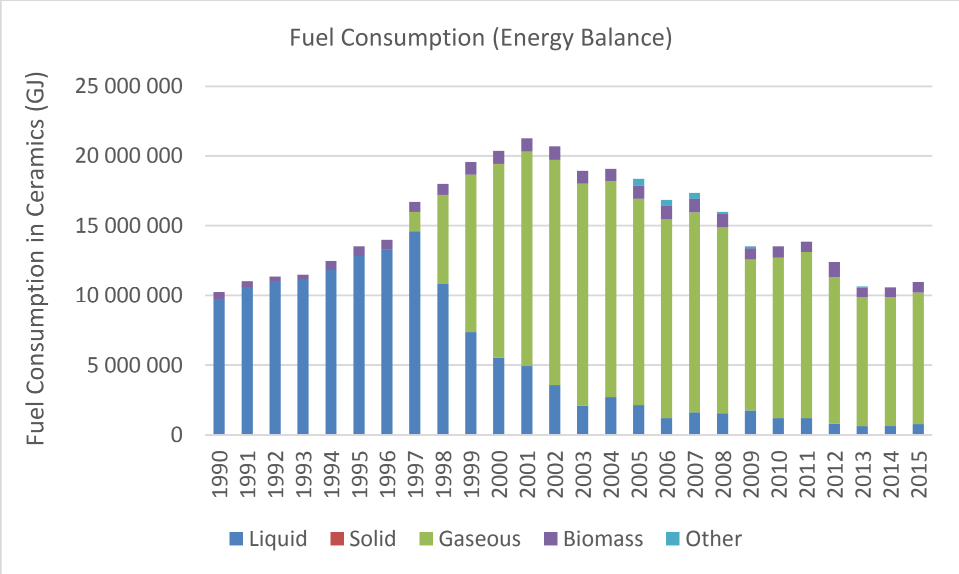


Figure 4-14 – Fuel Consumption in Ceramics – Energy Balance vs ETS data (GJ).

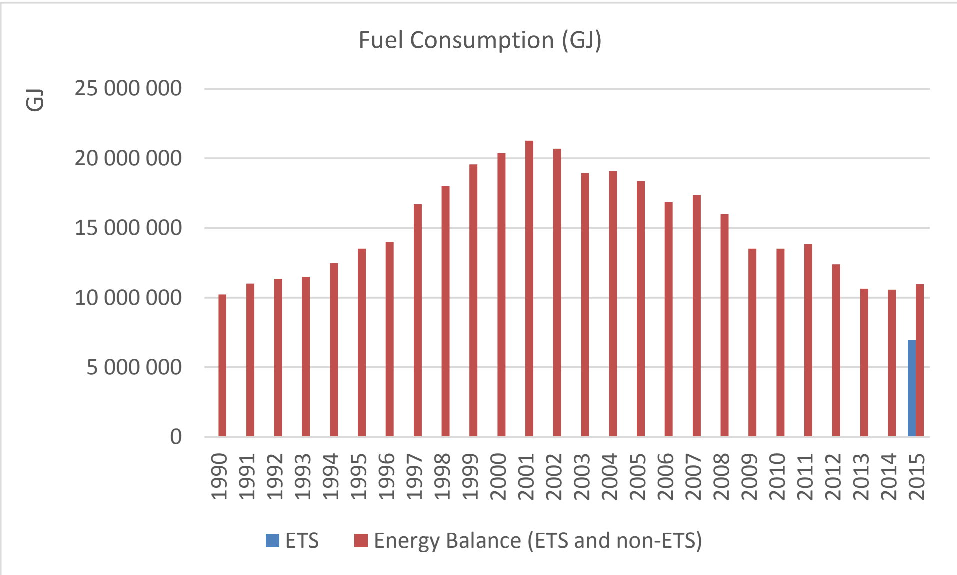
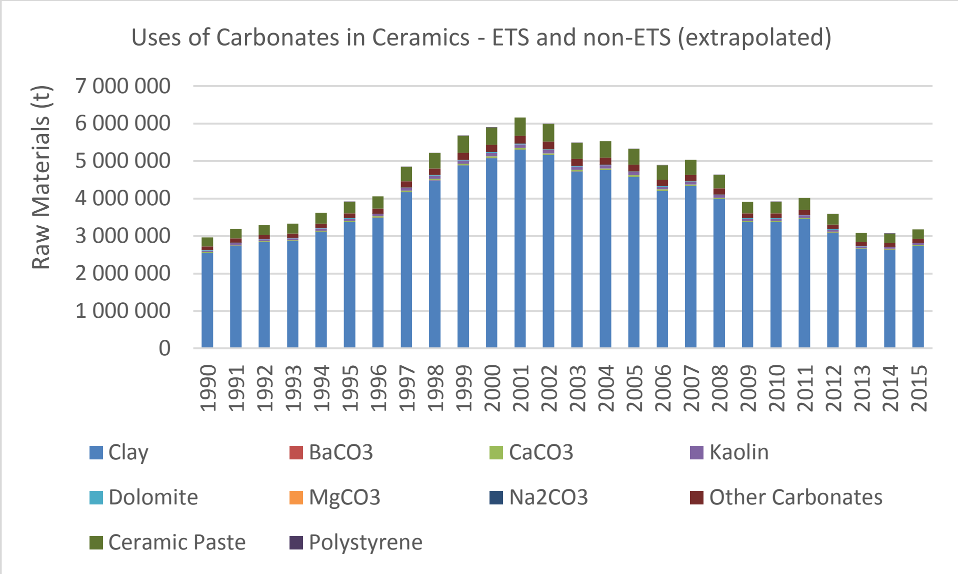


Figure 4-15 – Uses of Carbonates in Ceramics – both ETS and non-ETS plants (extrapolated).



4.3.6.5 Uncertainty Assessment

Table 4.12 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Weighing or proportioning raw materials	2.0% (average of 1.0-3.0% range)	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
Activity Data	Carbon content	2.0%	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
Activity Data	Combined Uncertainty	2.8%	-
CO_2 EF	Fractional purity	3.0% (average of 1.0-5.0% range)	Average value of the range 1-5% of chapter 2.5.2.1 of Volume 3: Industrial Processes and Product Uses of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.3.6.6 Recalculations

Following the Inventory review, biomass consumption values have been corrected in the period 1990-2010.

4.3.6.7 Further Improvements

No further improvements are expected.

4.3.7 Soda Ash Consumption (CRF 2.A.4.b)

4.3.7.1 Overview

Soda Ash (Na_2CO_3) is consumed as a raw material in the Glass Production (CRF 2.A.3), in paper pulp production (CRF 2.H.1), ceramics and other sectors with less consumption relevance.

4.3.7.2 Methodology

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

Apparent Consumption = National Production + Imports - 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).

Apparent Consumption (other sectors) = AC (total) – AC (Glass) – AC (Paper and Pulp)

where:

Apparent Consumption (other sectors) – soda ash apparent consumption in sectors other than Glass Production or Paper Pulp Production (t Na_2CO_3);

AC (Total) – soda ash national total apparent consumption (t Na_2CO_3);

AC (Glass) – soda ash consumption in Glass Production (t Na_2CO_3);

AC (Paper and Pulp) – soda ash consumption in Paper and Pulp Production (t Na_2CO_3).

4.3.7.3 Emission Factors

Carbon content of soda ash was set from molecular stoichiometry:

Table 4.13 - Carbon content of soda ash.

Material	Ccontent
Sodium Carbonate (Soda Ash)	0.415

4.3.7.4 Activity Data

Estimates are based on soda ash apparent consumption (National Production + Imports – Exports). Soda Ash imports, exports and national production data were obtained directly from National Statistis. From 1990 to 2014, there was only one facility producing soda ash in Portugal. Therefore, due to confidentiality constraints, activity data for the entire time series is presented as an index value related to 1990 data. Since 2005, there is no soda ash production. In CRF 2.A.4.b, it is introduced a notation key (IE) and the emissions are reported in CRF 2.A.4.d along with “Other Process Uses of Carbonates”.

Figure 4-16 – Soda Ash apparent consumption.

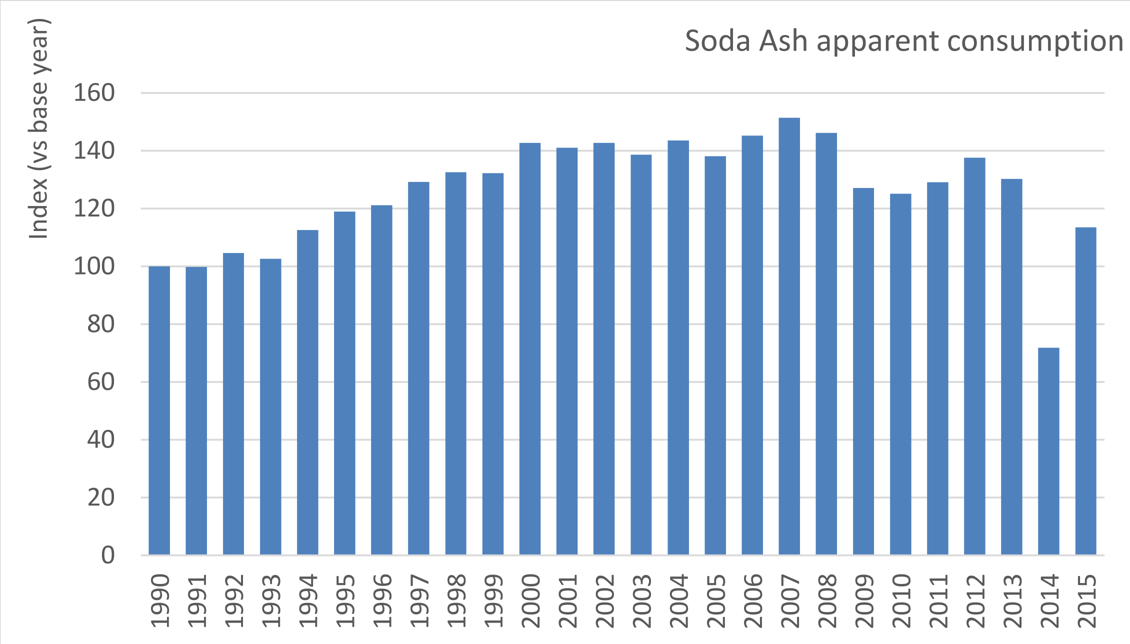
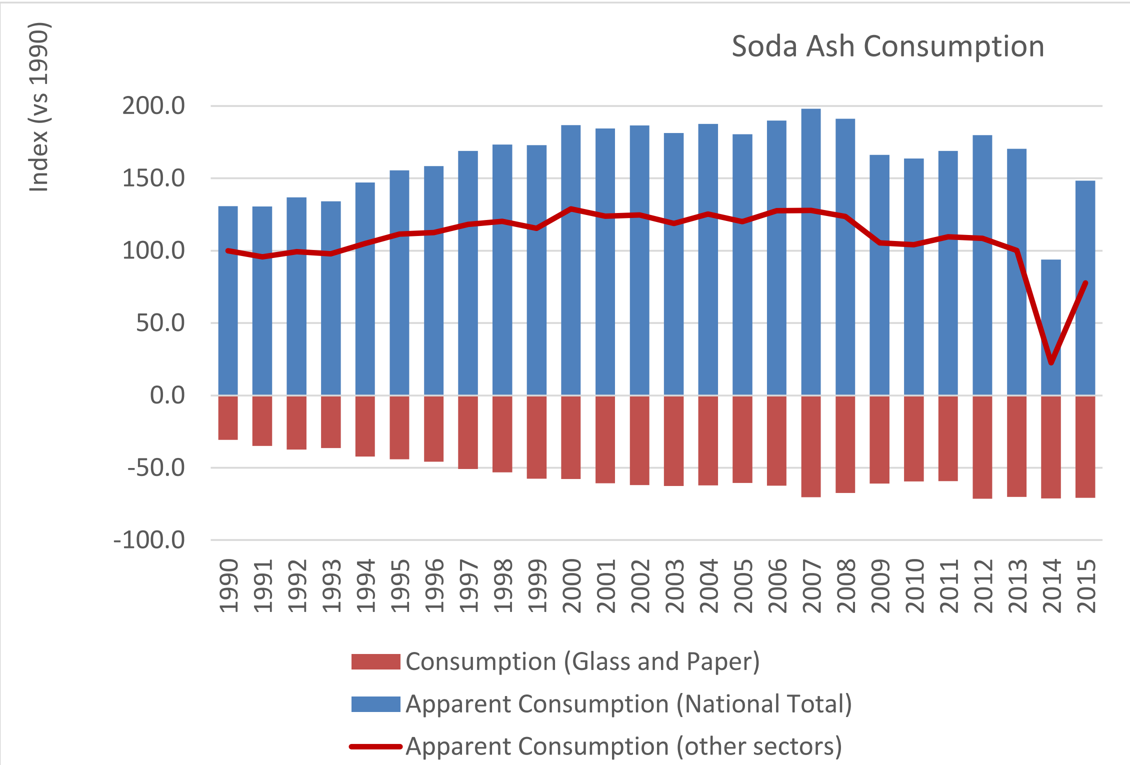


Figure 4-17 – Soda ash apparent consumption for the remaining sectors (after subtraction of soda ash consumption from Glass, Pulp and Paper sectors).



4.3.7.5 Uncertainty Assessment

Table 4.14 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Weighing or proportioning raw materials	2.0% (average of 1.0-3.0% range)	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
Activity Data	Carbon content	2.0%	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
Activity Data	Combined Uncertainty	2.8%	-
CO_2 EF	Fractional purity	3.0% (average of 1.0-5.0% range)	Average value of the range 1-5% of chapter 2.5.2.1 of Volume 3: Industrial Processes and Product Uses of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.3.7.6 Recalculations

No recalculations were made.

4.3.7.7 Further Improvements

No further improvements are expected.

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

There is no non-metallurgical magnesium production in Portugal.

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

4.3.9.1 Overview

Carbon dioxide liberation to atmosphere occurs from several industrial activities that use limestone ($CaCO_3$), dolomite rock ($CaCO_3.MgCO_3$) or other carbonates, but only when original materials are not incorporated as inert components but suffer a chemical removal of carbon., as for example when calcium carbonate is added to nitric acid to form calcium nitrate:

$$2\ HNO_3 + CaCO_3 \rightarrow Ca\ (NO_3)_2 + H_2O + CO_2$$

Presently, are considered in CRF 2.A.4.d carbonates uses in Fertilizers production, carbonates uses in carbon electrodes and soda ash consumption (due to confidentiality constraints is not reported in CRF 2.A.4.b).

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. There are dedicated lime production facilities and there is also lime production in lime kilns in paper pulp industry and in iron and steel industry. 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.

4.3.9.2 Methodology

CO_2 emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of CO_2 that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

$$Emi_{CO2\ (y)} = 44/12 * Mat_{Carb\ (m,y)} * C_{content\ (m)} * 10^{-3}$$

where:

$Emi_{CO2\ (y)}$ - emission of carbon dioxide in year y (kt/yr);

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

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

4.3.9.3 Emission Factors

Carbon content of materials consumed in Portugal was set from molecular stoichiometry[41]:

Table 4.15 - Carbon content of carbonate materials.

Material	Carbon content
Limestone*	0.44
Dolomite #	0.48
Coal (Electrodes) to be removed	3.67

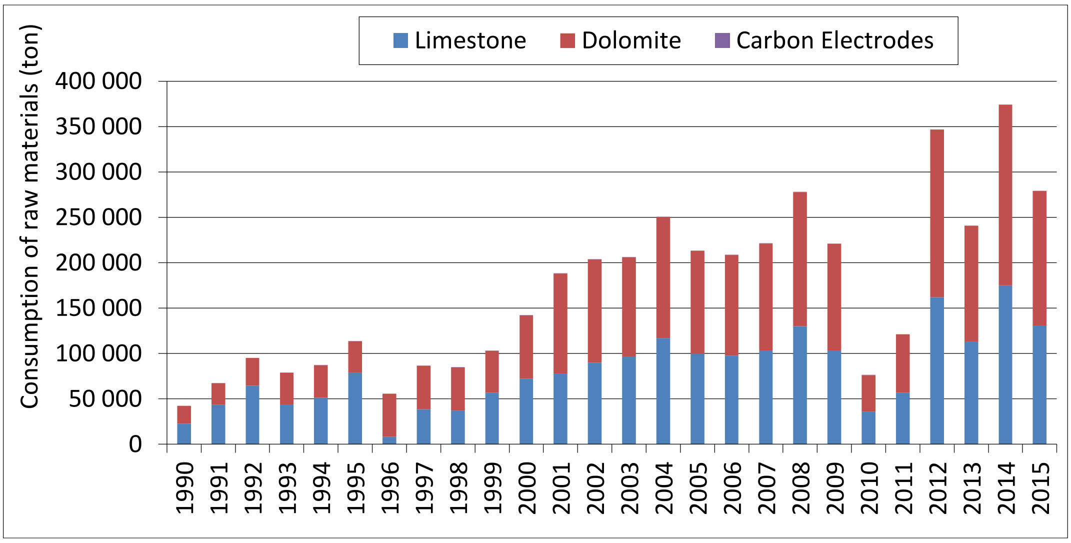
* assumed pure calcium carbonate;# Ca and Mg carbonate in equal share

4.3.9.4 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 $CaCO_3$ or $MgCO_3$. Fertilizer production data was also available from INE database from 1990 onwards. Final total consumption of carbonaceous materials is presented in the figure below. In the period 2010-2011 there is a strong decrease in limestone and dolomite consumption related to a decrease in calcium nitrate production.

[41] It was assumed that limestone was totally pure, which causes over-estimated emissions.

Figure 4-18 - Consumption of carbonate materials in industry.



4.3.9.5 Uncertainty Assessment

Table 4.16 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Weighing or proportioning raw materials	2.0% (average of 1.0-3.0% range)	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
Activity Data	Carbon content	2.0%	Table 2.3 of "Chapter 2: Mineral Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories"
Activity Data	Combined Uncertainty	2.8%	-
CO_2 EF	Fractional purity	3.0% (average of 1.0-5.0% range)	Average value of the range 1-5% of chapter 2.5.2.1 of Volume 3: Industrial Processes and Product Uses of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.3.9.6 Recalculations

No recalculations were made.

4.3.9.7 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 1990 there were two plants producing ammonia in Portugal, but one of the plants has stopped activity already in the beginning of that year.From 1991-2008, there was only one plant producing ammonia. In 2009, this plant was closed and the ammonia production has been relocated to India.

Ammonia is synthesized from nitrogen and hydrogen, by the following reaction:

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

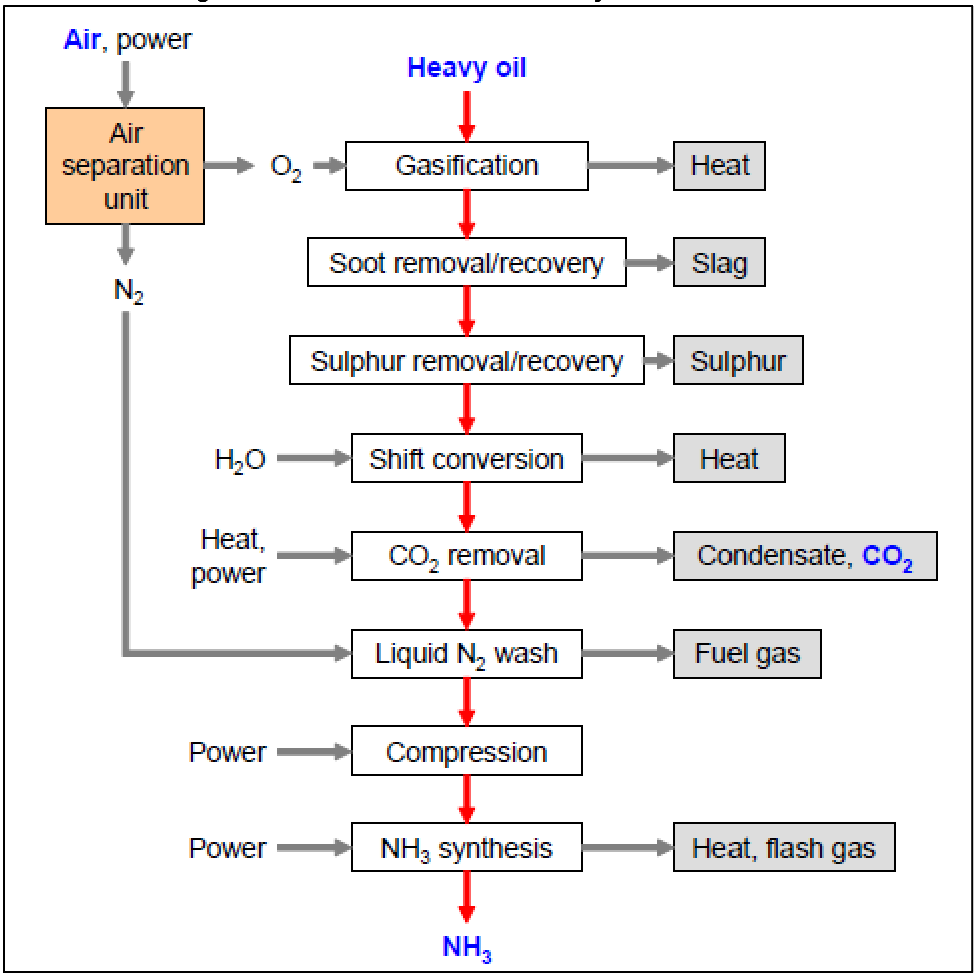
Nitrogen is obtained from atmospheric air.

Depending on the type of fossil fuel, two different methods are applied to produce the hydrogen for ammonia production: steam reforming or partial oxidation. In Portugal, hydrogen is obtained from partial oxidation of heavy hydrocarbons.

Gasification of heavy hydrocarbons follows the reaction:

$$2CH_n + O_2 \rightarrow 2CO + nH_2$$

Figure 4-19 – Ammonia Production by Partial Oxidation



Source: Best available techniques Reference document developed under the IPPC Directive and the IED

After cooling the exit gas from the shift conversion, the process condensate is separated. The gas is chilled and scrubbed with chilled methanol, which absorbs CO_2 and H_2S. Pure CO_2, may be used for urea production, and these amounts need to be subtracted to CO_2 emissions estimated based on NH_3 production in order to avoid double counting.

Other pollutants result from the process, either from escape of ammonia (NH_3) or either from release of products from feedstock: CO and NMVOC.

Urea is synthesized from ammonia and carbon dioxide, which are fed into the reactor at high pressure and temperature, following the two step reaction below:

$$2NH_3 + CO_2 \leftrightarrows NH_2COONH_4 \ (Ammonium\ Carbamate)$$

$$NH_2COONH_4 \leftrightarrows H_2O + NH_2CONH_2 \ (Urea)$$

4.4.1.2 Methodology

Carbon dioxide emissions were estimated using a Tier 2 methodology based on feedstock consumption:

$$E_{CO_2} = Feedstock_{CO2} - R_{CO_2}$$

where:

E_{CO2} – Emissions of CO_2 (kt CO_2);

$Feedstock_{CO2}$ – CO_2 from feedstocks (kt CO_2);

R_{CO2} – CO_2 recovered for downstream use in urea production (kt CO_2).

$$Feedstock_{CO2} = Feedstock_{cons} \times EF_{CO_2}$$

where:

$Feedstock_{CO2}$ – CO_2 from feedstocks (kt);

$Feedstock_{cons}$ – Feedstock consumption (kt);

EF_{CO2} – Plant specific CO_2 emission factor based on feedstock consumption (kt CO_2/kt feedstock).

$$R_{CO_2} = UP \times \frac{M(CO_2)}{M(Urea)}$$

where:

R_{CO2} – CO_2 recovered for urea production (kt);

UP – Urea production (kt);

$M(CO_2)$ – Molar mass of CO_2 (44 g/mol);

M(Urea) – Molar mass of Urea (60 g/mol).

4.4.1.3 Emission Factors

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

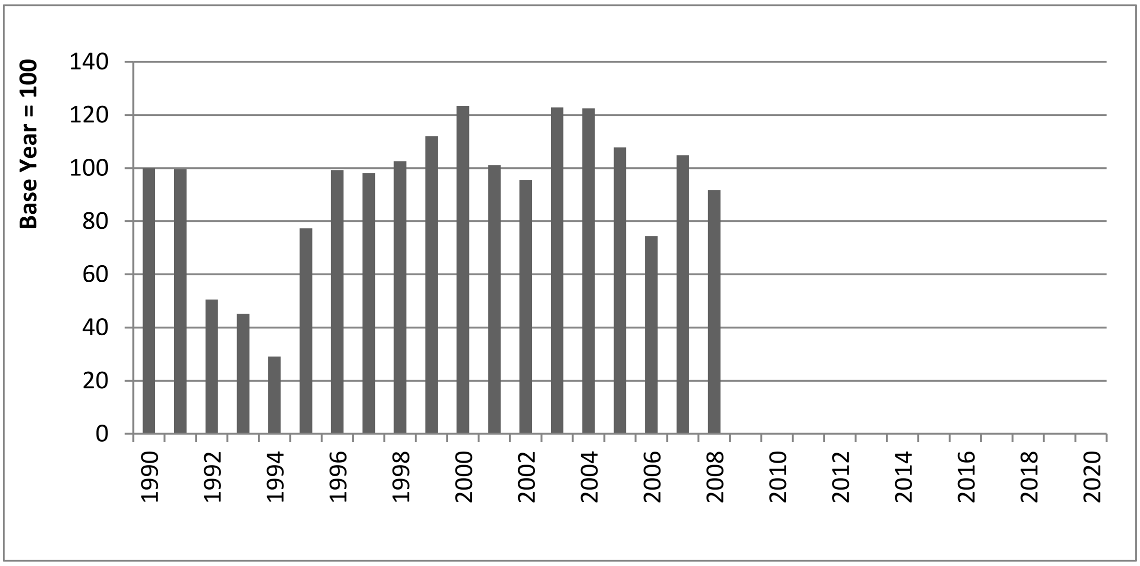
4.4.1.4 Activity Data

In 1990 there were two plants producing ammonia in Portugal, but one of the plants has stopped activity already in the beginning of that year. From 1991-2008, there was only one plant producing ammonia. In 2009, this plant was closed and the ammonia production has been relocated to India.

Due to confidentiality constraints, it is not possible to present any absolute information concerning activity data for this source activity, neither ammonia nor urea production.

The overall trend in the amount of ammonia produced in the period may be depicted in the Figure 4-20, from where it is evident the significant inter-annual changes in the period 1991-1996. The reason for the low emission values in the period 1992-1994 is the 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.

Figure 4-20 - Trend in Ammonia production.



Ammonia and urea production data were obtained from the facilities for the period 1990-2008. From 2009 onwards there is no ammonia production. This data is consistent with national statistics ammonia production data.

The CO_2 amounts recovered and used in the urea production were estimated based on urea production and on molar mass of CO_2 and Urea (please check "Methodology" section).

4.4.1.5 Uncertainty Assessment

Table 4.17 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Ammonia Production	2%	Subchapter 3.2.3.2 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CO_2 EF	CO_2 emission factor	7%	Table 3.1 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Ammonia production data was obtained directly from the plant (2% uncertainty).

4.4.1.6 Recalculations

We implemented the deduction of the CO_2 used for the urea production. This led to a decrease of 29.7 kt of CO_2 in 1990 and 20.7 kt of CO_2 in 2008 (last year with ammonia production).

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 %) is produced from ammonia, using catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to 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 NO_x (NO and NO_2), trace amounts of HNO_3 acid mist, ammonia (NH_3) and Nitrous Oxide (N_2O). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of NO_x are controlled by catalytic reduction. Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

4.4.2.2 Methodology

For all pollutants emissions are estimated using the following equation:

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

where:

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

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

$EF_{(p)}$ - emission factor for pollutant p (kg/ t).

4.4.2.3 Emission Factors

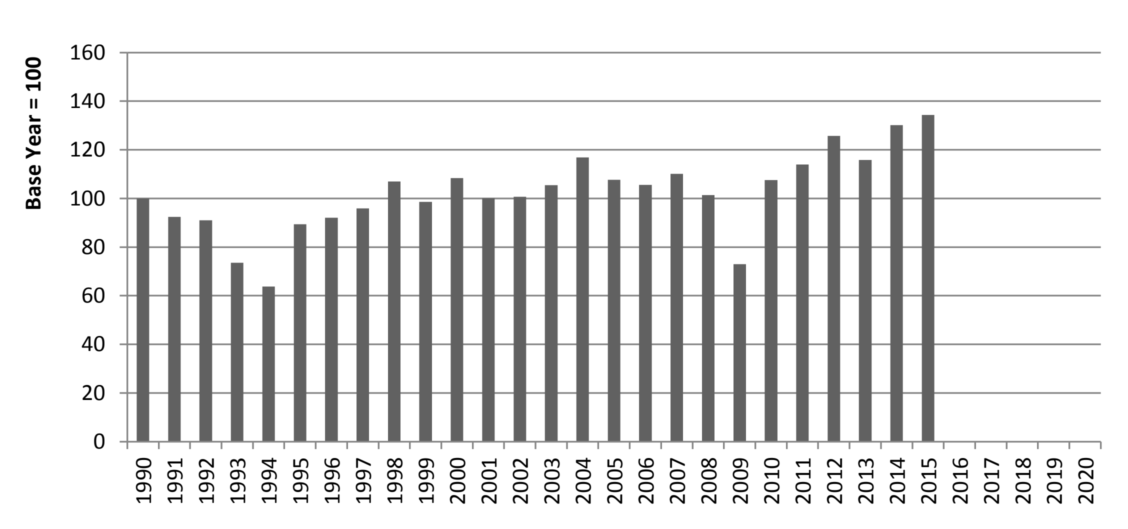
Due to confidentiality constraints it is not possible to publish the chosen emission factors. They were estimated based on monitoring data from the facilities.

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 4-21 - Trend in Nitric Acid production.



4.4.2.5 Uncertainty Analysis

Table 4.18 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Nitric Acid Production	2%	Subchapter 3.3.3.2 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
N_2O EF	N_2O emission factor	20%	Table 3.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Nitric Acid production data was obtained directly from the plants (2% uncertainty).

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_2 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_2 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_2 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:

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

where:

$Emission_{(p,y)}$ - annual emission of pollutant p in year y (t/yr);

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

$EF_{(p)}$ - emission factor (kg/ t).

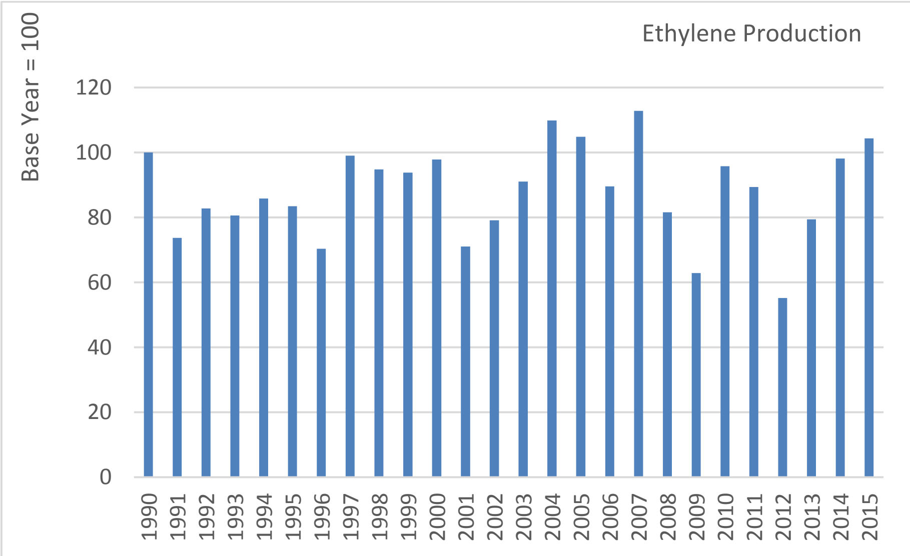
4.4.9.3 Emission Factors

There is only one plant producing ethylene in Portugal. Due to confidentiality constraints, it is not possible to present the emission factors considered in the estimates.

4.4.9.4 Activity Data

There is only one plant producing ethylene in Portugal. Activity data was obtained directly from the facility and cross-checked with national statistics data (QA/QC).

Figure 4-22 - Trend in Ethylene production.



4.4.9.5 Uncertainty Assessment

Table 4.19 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	Ethylene Production	10%	Subchapter 3.9.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CO_2 EF	CO_2 emission factor for ethylene production	10%	Subchapter 3.9.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CH_4 EF	CH_4 emission factor for ethylene production	10%	Subchapter 3.9.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.4.9.6 Recalculation

We started estimating direct CO_2 emissions from ethylene production. CH_4 emission factor has been revised.

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 (VCM) Production (CRF 2.B.8.c)

4.4.10.1 Overview

We consider that vinyl chloride monomer is produced from ethylene by a balanced process, as follows:

$$2C_2H_4 + Cl_2 + \frac{1}{2}O_2 \rightarrow 2CH_2CHCl + H_2O \qquad (Ethylene\ Dichloride - VCM\ Reaction)$$

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O \qquad (Feedstock\ Oxidation\ Reaction)$$

4.4.10.2 Methodology

Following the 2006 IPCC Guidelines, the total CO2 emissions result from the sum of noncombustion CO2 emissions from process vent and CO2 emissions from plant combustion sources.

$$Emis_{CO_2} = CO_2(noncombustion) + CO_2(combustion)$$

where:

$Emis_{CO2}$ – CO_2 emissions (kt CO_2);

CO_2 (noncombustion) – CO_2 emissions from process vent (kt CO_2);

CO_2 (combustion) – CO_2 emissions from plant combustion sources (kt CO_2). Includes combustion of both process waste gas and auxiliary fuel in the process waste gas thermal incinerator, however does not include emissions from flares.

$$CO_2(noncombustion) = VCM_{Prod} \times (EF_{CO_2} \times 10^{-3})$$

where:

CO_2 (noncombustion) – CO_2 emissions from process vent (kt CO_2);

VCM_{Prod} – Vinyl Chloride Monomer Production (t VCM);

EF_{CO2} – CO_2 emission factor (t CO_2/t VCM).

$$CO_2(combustion) = VCM_{Prod} \times FCF \times \left(FCC \times \frac{44}{12} \times 10^{-3}\right)$$

where:

CO_2 (combustion) – CO_2 emissions from plant combustion sources (kt CO_2);

VCM_{Prod} – Vinyl Chloride Monomer Production (t VCM);

FCF – Feedstock (Ethylene) Consumption Factor (t ethylene/t VCM);

FCC – Feedstock (Ethylene) Carbon Content (t C/t Ethylene).

The CH_4 emissions estimates are based on vinyl chloride monomer production and on the use of emission factor, as proposed by the 2006 IPCC Guidelines.

$$Emis_{CH_4} = VCM_{Prod} \times \left(EF_{CH_4} \times 10^{-3}\right)$$

where:

$Emis_{CH4}$ – CH_4 emissions (t);

VCM_{Prod} – Vinyl Chloride Monomer Production (t VCM);

EF_{CH4} – CH_4 emission factor (kg CH_4/t VCM).

4.4.10.3 Emission Factors

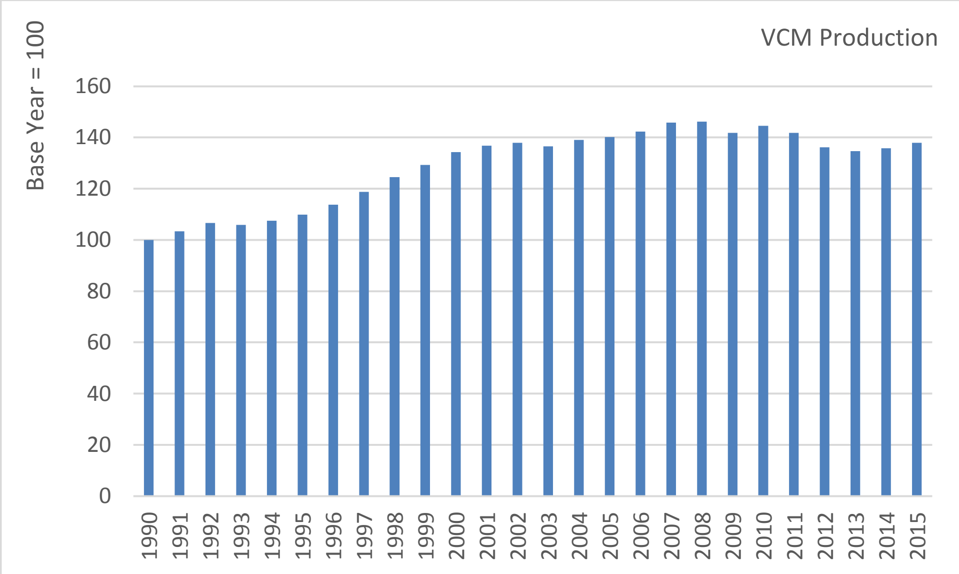
Table 4.20 – Emission Factors

Description	Unit	Value	Source
Non Combustion CO_2 (Balanced Process) Emission Factor	t CO_2/ t VCM	0.294	Table 3.17 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines
Feedstock (Ethylene) Consumption Factor (Balanced Process)	t ethylene/ t VCM	0.470	Table 3.18 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines
Feedstock (Ethylene) Carbon Content	t C/ t ethylene	0.856	Table 3.10 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines
CH_4 Emission Factor	kg CH_4/ t VCM	0.0226	Table 3.19 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines

4.4.10.4 Activity Data

Activity data for year 1990 is from national production statistics. From 1991 onwards, data is estimated based on gross domestic product trend.

Figure 4-23 - Trend in VCM production.



4.4.10.5 Uncertainty Assessment

Table 4.21 – Uncertainty values.

Parameter	Type of Uncertainty	Uncertainty	Source
Activity Data	VCM Production	10%	Subchapter 3.9.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CO_2 EF	CO_2 emission factor for VCM production	10%	Subchapter 3.9.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
CH_4 EF	CH_4 emission factor for VCM production	10%	Subchapter 3.9.3 of Chapter 3: Chemical Industry Emissions of 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.4.10.6 Recalculation

We started applying the 2006 IPCC Guidelines.

4.4.10.7 Further Improvements

Chemical sector associations will be contacted in order to obtain better quality information related to VCM production in Portugal.

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:

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

where:

$Emission_{(p,y)}$ - annual emission of pollutant p in year y (t/yr);

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

$EF_{(p)}$ - emission factor (kg/ t).

Where CO_2 emissions result from liberation of carbon in tail gas to atmosphere, emissions were estimated using a simple mass balance:

$$44 / 12 * C_{TailGas} = C_{Feedstock} + C_{AuxFuels} – C_{CarbonBlack}$$

where:

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

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

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

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

4.4.13.3 Emission Factors

The carbon black industrial unit was subjected, for period 2009 - 2012, to a detailed 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 4.22 – Emission Factors in calculation of Carbon Black process emissions.

Pollutant	Process Emissions (kg/t carbon black)	EF Source
CO2	2,379	Carbon Balance Approach
CH4	0.060	IPCC 2006 Guidelines
NOx	9.390	EMEP Guidebook 2016
CO	1.160	Instalation Data
NMVOCs	0.540	Instalation Data
SOx	10.96	Sulphur Balance Approach
TSP	0.148	Instalation Data
PM10	0.133	Instalation Data
PM2.5	0.130	Instalation Data
BC	0.013	EMEP Guidebook 2016

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 %.

4.4.13.6 Recalculations

Review of the time series of activity data and emission factors for the Carbon Black sector.

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)

There are no direct CO_2, CH_4 and N_2O emissions to report in this subsector in Portugal. There are however indirect CO_2 emissions related to NMVOC.

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)

There are no direct CO_2, CH_4 and N_2O emissions to report in this subsector in Portugal. There are however indirect CO_2 emissions related to NMVOC.

4.4.17 Solvent Use in Plastic Products Manufacturing (CRF 2.B.10.d)

There are no direct CO_2, CH_4 and N_2O emissions to report in this subsector in Portugal. There are however indirect CO_2 emissions related to NMVOC.

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_2 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_2 emissions from decarbonizing.

Emissions of ultimate fossil CO_2 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_2 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 2002 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:

$$Emission_{(p,y)} = \Sigma_a[EF_{(p,a)} * Activity_{Indicator\ (p,a,y)}] * 10^{-3}$$

and,

> $Emission_{(p,y)}$ - Emission of pollutant p in a specific year y from all sector activities and equipments (t/yr);
>
> $Activity_{Indicator\ (p,act,y)}$ - Most suitable indicator for emissions of a particular pollutant p resulting from a specific source activity or equipment a (t/yr);
>
> $EF_{(p,act)}$ - Emission factor specific of pollutant and activity/ equipment a (kg/t).

Emissions from sintering were also estimated using similar equation and reported in source code 2.C.1.d.

Emissions from lime production are described in chapter 4.3.3.2.1.

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_2 emissions are reported under source "1.A.2.a" and process related CO_2 emissions are reported under source "2.C.1.a". CH_4, CO and NMVOC emissions are based on monitoring data and reported under source code "2.C.1.a".

We do a cross-check between data received from the two plants and the energy balance data. Part of the differences (coke and coal consumption) is considered under source "1.A.2.a". The differences related to other fuels are reported under source "1.A.2.g.i", since this could be a misallocation from the energy balance.

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/t are present in next table.

Table 4.23 - Emission Factors for Iron and Steel Production in the period 1990-2001.

Pollutant	Coke Oven (kg/t coke)	Sintering (kg/t sinter)	Blast Furnace (kg/t steel)	BOF (kg t/steel)	EAF (kg/t steel)	Rolling Mills (kg/t steel)
CO_2	151[(a)]	200[(b)]	-	98.3[(d)]	71.6[(e)]	-
NMVOC	0.09[(a)]	0.14[(c)]	-	-	0.11[(f)]	0.007[(c)]
CH_4	0.10[(a)]	0.07[(b)]	-	-	0.32[(f)]	-
CO	15.4[(a)]	22.9[(d)]	0.03[(d)]	3.5[(c)]	0.51[(f)]	-

(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_2 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_2 stoichiometric emission factors from carbon bearing materials could be checked in next table.

Table 4.24 – Carbon bearing materials CO_2 stoichiometric EF.

Material	EF	Unit EF
$CaCO_3$	0.440	t CO_2/t material
$MgCO_3.MgCO_3$	0.477	t CO_2/t material
$FeCO_3$	0.380	t CO_2/t material
EAF Carbon Electrodes	3.00	t CO_2/t material
EAF Charge Carbon	3.04	t CO_2/t material
Petroleum Coke	3.19	t CO_2/t material
Scrap Iron	0.15	t CO_2/t material
Steel	0.04	t CO_2/t material

From 2002 onwards, CH_4, 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 4.25 – CH_4, CO and NMVOC emission factors

Pollutant	EF	Unit EF
CH_4	0.323	t CH_4 / 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

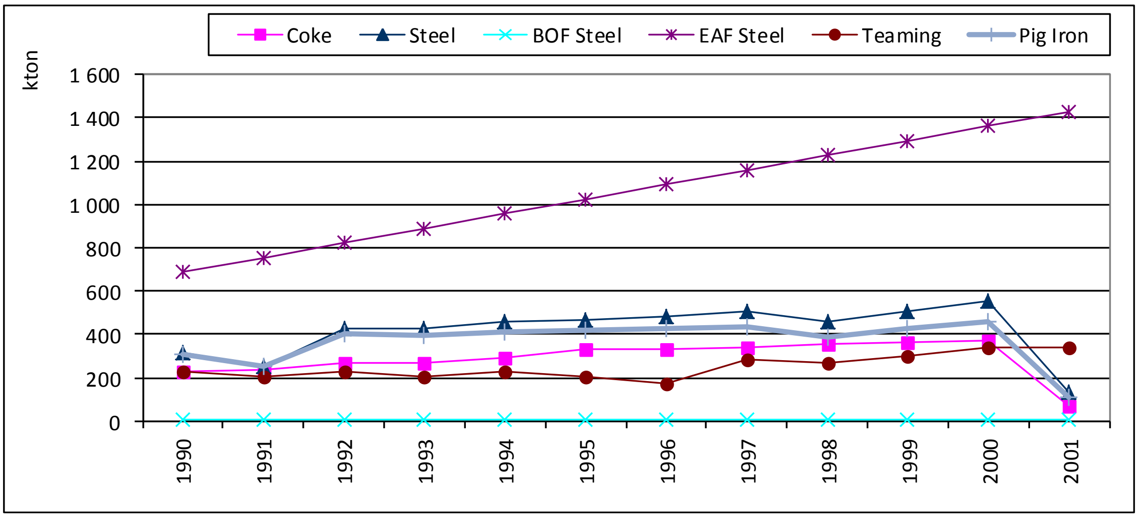
There are differences in the activity data used in estimates for the period 1990-2001 and from 2002 onwards.

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 4-24 - 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_2 emissions from iron and steel production from 2002 onwards comprehends fuel consumption, raw materials consumption and carbon content of raw materials.

Figure 4-25 - Production of secondary steel from 2002 onwards.

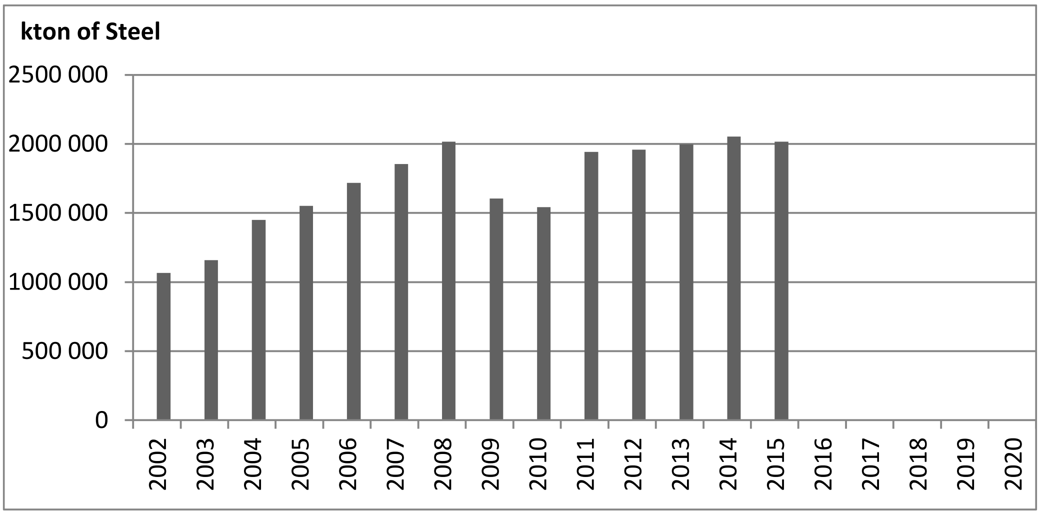
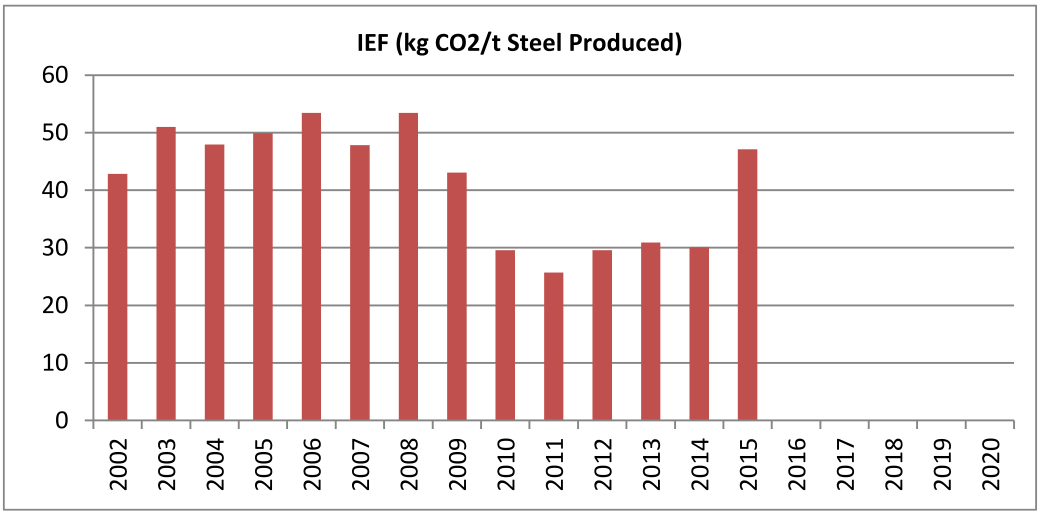


Figure 4-26 – CO_2 implied emission factor from 2002 onwards.



From 2014 to 2015, there is a sharp increase in scrap iron consumption (EF=0.15 t CO2/t scrap iron) and a decrease in scrap steel consumption (EF= 0.04 t CO_2/t scrap steel). There is also a sharp increase in coal consumption (EF=2.92-3.11 t CO_2/t coal). The combination of these 3 factors lead to a substantial increase in CO_2 emissions from 2014 to 2015.

4.5.1.5 Uncertainty Assessment

Table 4.26 – Uncertainty values related to emissions reported under CRF 2.C.1.

Parameter	Uncertainty	Source
Activity Data	10%	Chapter 4.2.3 of "Volume 4: Metal Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	10%	Chapter 4.2.3 of "Volume 4: Metal Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". "Material-specific default carbon contents".
CH_4 EF	5%	Chapter 4.2.3 of "Volume 4: Metal Industry Emissions" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories". "Company-specific emission factors" based on plant-specific measurements.

Table 4.27 – Uncertainty values related to emissions reported under CRF 1.A.2.a.

Parameter	Type of Fuel	Uncertainty	Source
Activity Data	All	2.5-5.0%	Table 2.15 of "Chapter 2: Stationary Combustion" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	L	3%	Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Highest value for "Oil" in "Table 2.13".
	S	7%	Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Average value for "Coke, oil, gas" in "Table 2.13".
	G	7%	Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Average value for "Coke, oil, gas" in "Table 2.13".
	B	7%	Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Average value for "Coke, oil, gas" in "Table 2.13".
	O	7%	Chapter 2: Stationary Combustion of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Average value for "Coke, oil, gas" in "Table 2.13".
CH_4 EF	All	50%	Average value of Table 2.14 of "Volume 2: Energy" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
N_2O EF	All	150%	Average UK value in "Table 2.14" of "Volume 2: Energy" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

4.5.1.6 Recalculations

We did a cross-check between data received from the two plants and the energy balance data. Part of the differences (coke and coal consumption) is now considered under source “1.A.2.a”. The differences related to other fuels are reported under source “1.A.2.g.i”, since this could be a misallocation from the energy balance.

4.5.1.7 Further Improvements

Streamline between fuel consumption reported by the plants and the nergy balance data for iron and steel sector. The results from this streamline could lead to emissions reallocation,

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_2 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_2 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.

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

4.5.7 Lubricants Use (CRF 2.D.1)

4.5.7.1 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.

4.5.7.2 Methodology

$$Lubricants_{Cons}\ (2D1) = Lubricants_{Cons}\ (Total) - Lubricants_{Cons}\ (Two\text{-}stroke\ engines)$$

where:

$Lubricants_{Cons}$ (2D1) – Consumption of Lubricants except for two-stroke engines (GJ);

$Lubricants_{Cons}$ – Total Consumption of Lubricants (GJ);

$Lubricants_{Cons}$ (Two-stroke engines) – Consumption of Lubricants in two-stroke engines (GJ).

CO_2 emissions related to lubricants consumption (reported under CRF 2.D.1), except for two-stroke engines:

$$CO_2\ Emissions = Lubricants_{Cons}\ (2D1) * (DCC * 44/12 * 10^{-3}) * ODU$$

where:

CO_2 Emissions – CO_2 emissions (t);

$Lubricants_{Cons}$ (2D1) – Consumption of Lubricants except for two-stroke engines (GJ);

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

ODU – Oxidized During Use factor (=0.2).

CO_2 emissions related to lubricants consumption in two-stroke engines (reported under CRF 1.A.3.b.iv):

$$CO_2 \text{ Emissions} = Gasoline_{Cons} * \%Lubricant * Carbon\ Content * 10^{-3}$$

where:

CO_2 Emissions – CO_2 emissions (t);

$Gasoline_{Cons}$ – Gasoline Consumption in two-stroke engines (GJ);

%Lubricant - % of lubricant in the mixture gasoline/lubricant used in two-stroke engines;

Carbon Content – Lubricant carbon content (kg CO_2/GJ).

4.5.7.3 Emission Factors

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

Table 4.28 – Emission Factors for Lubricant Use (2.D.1).

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

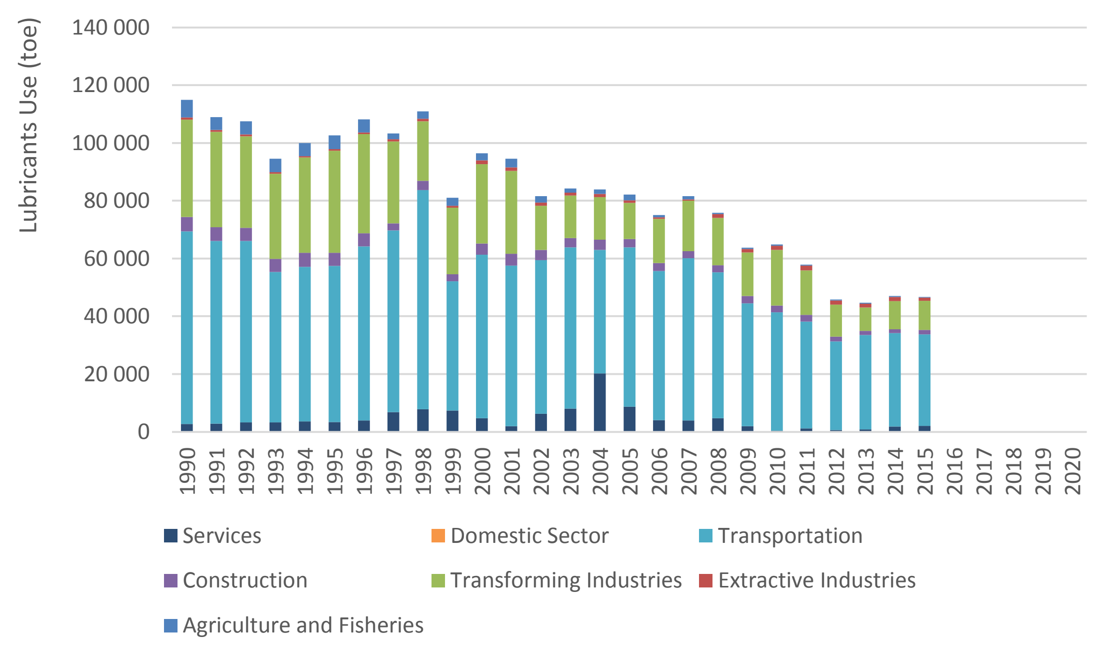
Table 4.29 – Emission Factors for Lubricant Use in two-stroke engines (1.A.3.b.iv).

Parameter	Unit	Value	Source
Default Carbon Content	Kg CO_2/GJ	73.3	2006 IPCC Guidelines
% Lubricant in the mixture	%	4.0	2006 IPCC Guidelines
CH_4 EF	g/GJ	33	2006 IPCC Guidelines
N_2O EF	g/GJ	3.2	2006 IPCC Guidelines

4.5.7.4 Activity Data

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

Figure 4-27 – Amounts of Lubricants used in Portugal.



4.5.7.5 Uncertainty Assessment

Table 4.30 – Uncertainty values.

Parameter	Uncertainty	Source
Activity Data	5.0%	"Well-developed energy statistics" in "subchapter 5.2.3.2" of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF – ODU Factor	50.0%	Subchapter 5.2.3.1 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF – Carbon Content	3.0%	Subchapter 5.2.3.1 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF – Combined	50.1%	-

4.5.7.6 Recalculations

Emissions related to lubricant consumption in two-stroke engines have been relocated to CRF 1.A.3.b.iv. The remaining lubricant consumption have been reported in CRF 2.D.1.

4.5.7.7 Further Improvements

No further improvements are expected.

4.5.8 Paraffin Wax Use (CRF 2.D.2)

4.5.8.1 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.

4.5.8.2 Methodology

CO_2 emissions are estimated based on:

$$CO_2 \text{ Emissions} = PW * (CC_{Wax} * 44/12 * 10^{-3}) * ODU_{Wax}$$

where:

CO_2 Emissions – CO_2 emissions (t);

PW – Consumption of Paraffin Waxes (GJ);

CC_{Wax} – Paraffin Waxes Default Carbon Content (= 20 kg C/GJ);

ODU_{Wax} – Paraffin Waxes Oxidized During Use factor (=0.2).

4.5.8.3 Emission Factors

Both default carbon content and oxidized during used factor were obtained from 2006 IPCC Guidelines (chapter 5.3.2.2.).

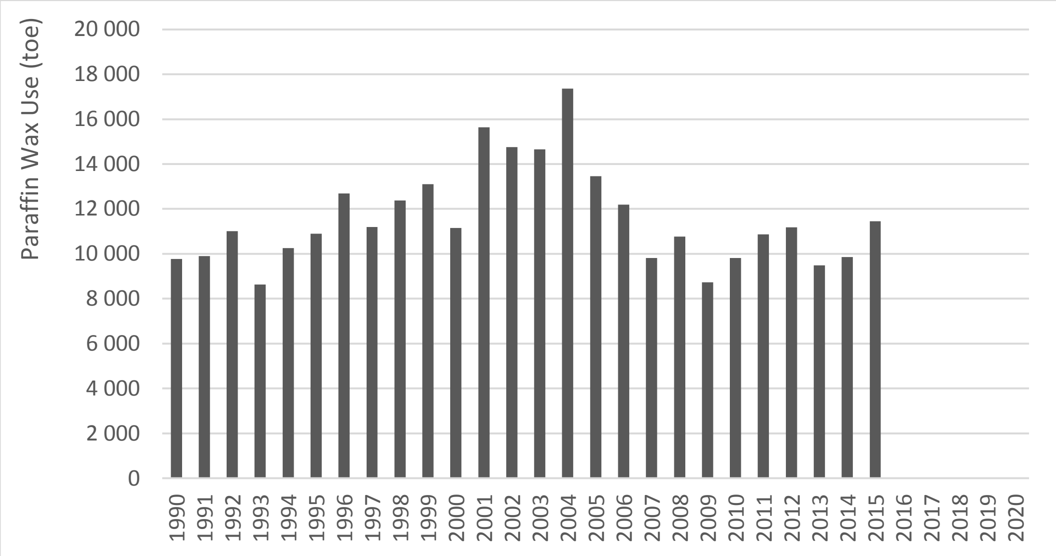
Table 4.31– Emission Factors for Paraffin Waxes Use.

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

4.5.8.4 Activity Data

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

Figure 4-28 – Amounts of Paraffin Waxes used in Portugal.



4.5.8.5 Uncertainty Assessment

Table 4.32 – Uncertainty values.

Parameter	Uncertainty	Source
Activity Data	5.0%	"Well-developed energy statistics" in "subchapter 5.3.3.2" of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF – ODU Factor	100.0%	Subchapter 5.3.3.1 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF – Carbon Content	5.0%	Subchapter 5.3.3.1 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF – Combined	100.1%	-

4.5.8.6 Recalculations

No recalculations were made.

4.5.8.7 Further Improvements

No further improvements are expected.

4.5.9 Solvent Use (CRF 2.D.3.a)

4.5.9.1 Overview

Solvents and related compounds are a significant source of emissions of non-methane volatile organic compounds (NMVOC). Emissions of N_2O from the use of anesthesia are also included in this sector. No emissions of methane are included in this source sector.

Some peculiarities apply to this source sector. In first place not all emissions occur directly to atmosphere when the production or use action takes place, as some solvents remain in product or are conveyed into wastewater. However, because eventually sooner or later these solvent fractions are liberated to atmosphere, all solvent losses may be assumed to contribute to air emissions. On the other hand, emissions of solvent may occur in three phases: during production of products containing solvents, during actual use of products containing solvent and during disposal.

NMVOC emissions estimates must be converted in CO_2 emissions whenever the carbon that is present in organic compounds has fossil fuel origin (originated from feedstocks from petroleum, coal or natural gas), and being assumed that NMVOC compounds are fully oxidized in air to carbon dioxide contributing thence to the atmospheric pool.

4.5.9.2 Paint Application

4.5.9.2.1 Overview

This sub-source sector covers NMVOC emissions resulting from the use of coating materials – interpreted as the application of a continuous layer in a surface with the objective of protecting the surface or enhancing its appearance[42] – 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 NMVOC emissions except if they are recovered and treated by any control equipment such as incineration or absorption.

All emissions from paint activity are included here, such as those arising from car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities and domestic use.

The distinction between coating operations in construction and building and domestic use is not very relevant because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

4.5.9.2.2 Methodology

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \Sigma_a \Sigma_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

where:

[42] Non continuous applications of coatings is printing industry and is included in other sub-source category. Application of continuous layers for gluing materials, by the use of glues or adhesives is also considered elsewhere.

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from use/application of coating substances during year y (t/yr);

$Coating_{CONS(a,p,y)}$ – Use of coating substance p in economic activity a during year y (t coater/yr);

$EF_{(p)}$ – NMVOV emission factor (solvent content) resulting from application of substance p (kg/t).

For specific sectors were 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.

$$Emi_{NMVOC(p,y)} = \Sigma_a \Sigma_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

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_2 emissions were calculated assuming that 60 % 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_2 emissions are included in the inventory as CO_2e.

$$U_{CO2} = NMVOC * 0.60 * (44/12)$$

where:

U_{CO2} - Ultimate CO_2 (t/yr);

NMVOC - Global emissions of NMVOC (t/yr).

4.5.9.2.3 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 4.33 – 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)

4.5.9.2.3.1 Construction and buildings (SNAP 060103)

Table 4.34 – Default emission factor.

SNAP	Unit	NMVOC
Construction and buildings	g/kg paint	230

Source: (EEA/EMEP, 2013)

Table 4.35 – 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 4.36 – Control strategy.

Technology	Unit	1990	1995	2000	2005	2010	2015
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 4.37 – Final emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
Final EF	g/kg paint applied	221	170	140	105	69	69

4.5.9.2.3.2 Wood (SNAP 060107)

Table 4.38 – Default emission factor.

SNAP	Unit	NMVOC
Wood	g/kg paint applied	800

Source: (EEA/EMEP, 2013)

Table 4.39 – 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 4.40 – Control strategy.

Technology	Unit	1990	1995	2000	2005	2010	2015
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 4.41 – Final emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
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

4.5.9.2.3.3 Manufacture of automobiles (SNAP 060101)

Table 4.42 – Default emission factor.

SNAP	Unit	NMVOC
Manufacture of automobiles: Car coating	kg/car	8

Source: (EEA/EMEP, 2013)

Table 4.43 – 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 4.44 – Control strategy.

Technology	Unit	1990	1995	2000	2005	2010	2015
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 4.45 – Final emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
Final EF Car coating	kg/car	8.0	6.2	4.4	2.6	0.8	0.8

4.5.9.2.3.4 Truck cabin coating (SNAP 060108)

Table 4.46 – Default emission factor.

SNAP	Unit	NMVOC
Industrial coating application: Vehicle refinishing	kg/vehicle	8

Source: (EEA/EMEP, 2013)

Table 4.47 – 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 4.48 – Control strategy.

Technology	Unit	1990	1995	2000	2005	2010	2015
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 4.49 – Final emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
Final EF truck cabin coating	kg/vehicle	8.0	8.0	8.0	8.0	8.0	8.0

4.5.9.2.3.5 Leather finishing (SNAP 060108)

Table 4.50 – Default emission factor.

SNAP	Unit	NMVOC
Industrial coating application: leather finishing	g/kg leather	200

Source: (EEA/EMEP, 2013)

Table 4.51 – 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 4.52 – Control strategy.

Technology	Unit	1990	1995	2000	2005	2010	2015
Use of water based products (30 wt-% solvent content)	%	0	0	0	10	30	50
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	45

Source: (IIASA, 2009)

Table 4.53 – Final emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
Final EF leather finishing	g/kg leather	200.0	200.0	200.0	187.0	152.9	126.9

4.5.9.2.4 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:

$$Total_{Cons(y)} = Production_{(y)} + Imports_{(y)} - Exports_{(y)}$$

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 4.53.

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 4.54.

Total consumption of paints was calculated and the resultant time series is presented in Table 4.55.

Table 4.54 – National production of paints (t).

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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	154 992

Parameter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Produced paints	155 081	154 221	149 706	148 908	165 048	161 165	135 826	155 209	133 748	119 692	121 150	128 383	161 593

Table 4.55 – Paint import and export (t).

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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	37 990
Exports	5 336	5 626	5 785	5 415	7 534	8 130	12 854	11 614	14 670	13 622	13 823	16 171	20 545

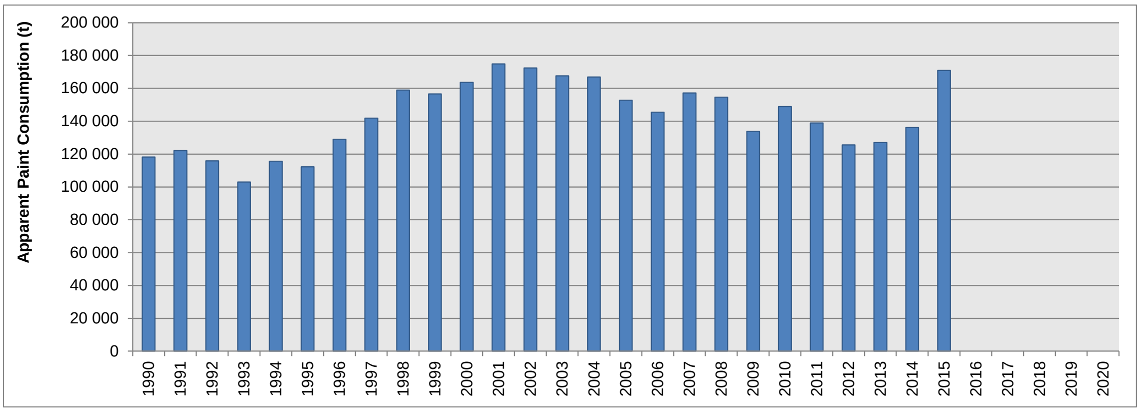
Parameter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Imports	36 398	38 680	37 097	37 371	35 624	35 883	34 466	33 044	45 556	41 781	41 308	43 525	46 687
Exports	23 827	25 973	34 089	40 749	43 510	42 435	36 546	39 398	40 338	35 838	35 433	35 770	37 364

Table 4.56 – Estimated paint consumption (t).

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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	172 437

Parameter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Apparent Consumption	167 651	166 928	152 714	145 530	157 162	154 612	133 746	148 855	138 965	125 635	127 026	136 138	170 916

Figure 4-29 - 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 4.56. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction[43].

[43] No further disaggregation by this uses is possible from available statistical information

Table 4.57 - 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	2002
60103	Decorative coating	Paint application:	10 738	10 326	9 248	8 388	8 760	8 486	9 447	9 225	7 761	7 069	8 399	7 866	7 524
60104	Decorative coating	Paint application:	91 969	95 902	92 001	79 659	92 249	90 715	102 421	111 519	129 668	125 779	130 608	147 593	147 528
60101	Industrial coating	Paint application:	111	111	111	111	111	249	709	1 142	1 143	1 130	2 595	1 528	1 528
60107	Industrial coating	Paint application:	6 508	6 824	5 583	5 917	5 567	4 061	4 813	5 057	4 626	3 849	2 836	3 862	3 872
60108	Industrial coating	Other industrial	8 475	8 475	8 475	8 475	8 475	8 475	11 609	15 400	16 351	19 319	20 891	14 867	12 827
60108	Industrial coating	Other industrial	391	391	391	391	391	391	562	523	381	433	631	534	534
60108	Industrial coating	Other industrial	154	154	154	154	154	154	154	154	154	137	330	201	152

SNAP	NFR Title	SNAP Title	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
60103	Decorative coating	Paint application:	7 328	8 613	9 242	10 373	10 374	11 120	8 385	9 846	7 390	6 658	8 117	8 116	8 258
60104	Decorative coating	Paint application:	145 161	144 863	129 412	115 964	130 607	123 686	108 092	119 610	114 339	102 732	102 239	110 388	145 548
60101	Industrial coating	Paint application:	1 528	1 274	1 232	1 346	1 540	1 441	911	1 212	1 190	1 142	1 129	1 139	1 157
60107	Industrial coating	Paint application:	3 740	4 333	4 493	5 078	5 257	5 402	4 244	5 018	3 918	3 464	4 033	4 884	4 372
60108	Industrial coating	Other industrial	10 787	8 746	9 074	13 489	10 061	13 324	11 952	13 110	12 069	11 583	11 452	11 555	11 524
60108	Industrial coating	Other industrial	534	320	363	489	242	158	99	113	110	106	105	106	107
60108	Industrial coating	Other industrial	102	52	130	137	621	923	973	1 159	1 138	1 092	1 079	1 089	1 106

Table 4.58 - Final activity data used for paint application emission calculation.

SNAP Title	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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	7 524
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	147 528
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	193 917
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	3 872
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	12 827
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	6 378
Other industrial paint application: leather finishing	t leather	834	834	834	733	651	534	603	806	1 480	2 098	2 386	7 399	10 718

SNAP Title	Unit	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Paint application: construction and buildings	t paint	7 328	8 613	9 242	10 373	10 374	11 120	8 385	9 846	7 390	6 658	8 117	8 116	8 258
Paint application: domestic use (except 060107)	t paint	145 161	144 863	129 412	115 964	130 607	123 686	108 092	119 610	114 339	102 732	102 239	110 388	145 548
Paint application: manufacture of automobiles	n vehicles	171 207	161 465	146 340	152 884	173 864	173 054	125 965	157 552	185 370	158 278	154 743	158 715	153 189
Paint application: w ood	t paint	3 740	4 333	4 493	5 078	5 257	5 402	4 244	5 018	3 918	3 464	4 033	4 884	4 372
Other industrial paint application	t paint	10 787	8 746	9 074	13 489	10 061	13 324	11 952	13 110	12 069	11 583	11 452	11 555	11 524
Other industrial paint application: truck cabin coating	n vehicles	5 576	6 687	6 203	6 101	5 935	5 789	4 202	4 396	3 788	3 657	3 951	4 019	3 929
Other industrial paint application: leather finishing	t leather	10 611	8 758	8 932	13 122	16 043	13 171	12 431	14 854	11 946	9 010	7 987	7 148	7 936

Table 4.59 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	2002
Paint application: construction and buildings	g/kg paint app	220.8	210.7	200.6	190.4	180.3	170.2	164.2	158.2	152.3	146.3	140.3	133.2	126.0
Paint application: domestic use (except 060107)	g/kg paint app	220.8	210.7	200.6	190.4	180.3	170.2	164.2	158.2	152.3	146.3	140.3	133.2	126.0
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	3.7
Paint application: w ood	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	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	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	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	194.8

SNAP Title	Unit	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Paint application: construction and buildings	g/kg paint app	118.9	111.8	104.7	97.5	90.4	83.3	76.1	69.0	69.0	69.0	69.0	69.0	69.0
Paint application: domestic use (except 060107)	g/kg paint app	118.9	111.8	104.7	97.5	90.4	83.3	76.1	69.0	69.0	69.0	69.0	69.0	69.0
Paint application: manufacture of automobiles	kg/car	3.3	3.0	2.6	2.2	1.9	1.5	1.2	0.8	0.8	0.8	0.8	0.8	0.8
Paint application: w ood	g/kg paint	439.9	439.9	439.9	406.6	373.3	340.0	306.7	273.4	273.4	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	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	8.0
Other industrial paint application: leather finishing	g/kg leather	192.2	189.6	187.0	180.2	173.4	166.5	159.7	152.9	147.7	142.5	137.3	132.1	126.9

4.5.9.2.5 Uncertainty Assessment

The uncertainty factor of the emission factor for NMVOC and CO_2 was calculated from information obtained from EEA/CORINAIR Guidebook. The uncertainty value for CO_2/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.

4.5.9.2.6 Recalculations

Paint production, imports and exports data related to year 2014 have been revised based on national statistics.

4.5.9.2.7 Further Improvements

No further improvements are planned for this sector.

4.5.9.3 Degreasing and Dry Cleaning

4.5.9.3.1 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[44], 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.

4.5.9.3.2 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.

[44] Emissions from degreasing in this industry are included under rubber processing

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several sources (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

CO_2 emissions are derived by assuming that 60 % of the mass emissions of NMVOC is carbon:

$$U_{CO2} = NMVOC * 0.60 * (44/12)$$

where:

U_{CO2} - Ultimate CO_2 (t);

NMVOC - Global emissions of NMVOC (t).

4.5.9.3.3 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 4.59, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

Table 4.60 - Solvent use in degreasing operations in metal and plastic industries (t).

Sub-Sector / Year	1990	1991	2005	2015
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)[45] consumed in Portugal is used in dry-cleaning[46] activity and that all PER used is imported (no national production). Annual apparent consumption was estimated from INE's statistical databases on external trade from 1990 onwards and assumed as equal to solvent use.

Table 4.61 - Annual consumption of PER (Tetra-chloro-ethylene) (t).

Parameter	1990	1995	2000	2005	2010	2015
Imports	2 172	1 155	1 649	0	1 108	882
Exports	0	0	0	0	49	39
Apparent Consumption	2 172	1 155	1 649	0	1 059	843

Source: INE.

4.5.9.3.4 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.

[45] 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.

[46] There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

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.

4.5.9.3.5 Recalculations

PER production, imports and exports data related to year 2014 have been revised based on national statistics..

4.5.9.3.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.4 Chemical Products, Manufacture and Processing

4.5.9.4.1 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.

4.5.9.4.2 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 (t/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 (t/yr);

EF - emission factor (kg/ t).

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:

$$Emi_{CO2} = Emi_{NMVOC} * 0.60 * (44 / 12)$$

4.5.9.4.2.1 Polyester processing

4.5.9.4.2.1.1 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:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{POYESTER(y)} \times 10^{-3}$$

where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from polyester processing (t/yr);

EF_{NMVOC} – NMVOC emission factor for polyester processing (g/kg monomer used);

$Prod_{FOAM(y)}$ – Quantity of monomer used y (t/yr).

4.5.9.4.2.1.2 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 4.62 – 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:

$$Emi_{CO2} = Emi_{NMVOC} * 0.60 * (44 / 12)$$

4.5.9.4.2.1.3 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 4.63 –Polyester processed.

SNAP Title	Unit	1990	1995	2000	2005	2010	2015
Polyester processing	t monomer	5	57	870	405	1 061	1767

Source: INE

4.5.9.4.2.1.4 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%.

4.5.9.4.2.1.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO2 species that oxidizes to CO2 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.

4.5.9.4.2.1.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.4.2.2 Polyvinylchloride processing

4.5.9.4.2.2.1 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:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RESIN(y)} \times 10^{-3}$$

where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from polyvinylchloride processing (t/yr);

EF_{NMVOC} – NMVOC emission factor for polyvinylchloride processing (g/kg resin);

$Prod_{RESIN(y)}$ – Quantity of polyvinylchloride resin (t/yr).

4.5.9.4.2.2.2 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 4.64 – 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:

$$Emi_{CO2} = Emi_{NMVOC} * 0.60 * (44 / 12)$$

4.5.9.4.2.2.3 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 4.65 – Polyvinylchloride processed.

SNAP Title	Unit	1990	1995	2000	2005	2010	2015
Polyvinylchloride processing	t PVC	95 993	102 618	138 944	74 862	60 512	57780

Source: INE

4.5.9.4.2.2.4 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%.

4.5.9.4.2.2.5 Recalculation

Differences in estimated emissions, from carbon emitted in the form of non-CO2 species that oxidizes to CO2 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.

4.5.9.4.2.2.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.4.2.3 Polyurethane and polystyrene foam processing

4.5.9.4.2.3.1 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:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{FOAM(y)} \times 10^{-3}$$

where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from foam processing (t/yr);

EF_{NMVOC} – NMVOC emission factor for foam processing (g/kg foam processed);

$Prod_{FOAM(y)}$ – Quantity of foam processed in year y (t/yr).

4.5.9.4.2.3.2 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 4.66 – 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:

$$Emi_{CO2} = Emi_{NMVOC} * 0.60 * (44 / 12)$$

4.5.9.4.2.3.3 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 4.67 –Foam processed.

SNAP Title	Unit	1990	1995	2000	2005	2010	2015
Polyurethane processing	t foam	5 700	6 322	11 704	16 989	10 038	17456
Polystyrene processing	t foam	11 222	14 454	22 212	16 561	16 995	22652

Source: INE

4.5.9.4.2.3.4 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%.

4.5.9.4.2.3.5 Recalculations

Differences in estimated emissions, from carbon emitted in the form of non-CO2 species that oxidizes to CO2 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.

4.5.9.4.2.3.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.4.2.4 Rubber processing

4.5.9.4.2.4.1 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:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RUBBER(y)} \times 10^{-3}$$

where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from rubber processing (t/yr);

EF_{NMVOC} – NMVOC default emission factor for rubber processing (g/kg rubber produced);

$Prod_{RUBBER(p,y)}$ – Production of rubber in year y (t/yr).

4.5.9.4.2.4.2 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 4.68 – 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

4.5.9.4.2.4.3 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 4.69 –Rubber processed.

SNAP Title	Unit	1990	1995	2000	2005	2010	2015
Rubber processed	t rubber	26 871	24 484	29 915	32 818	68 442	18136

Source: INE

4.5.9.4.2.4.4 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%.

4.5.9.4.2.4.5 Recalculations

No recalculations were made.

4.5.9.4.2.4.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.4.2.5 Paints, Inks and Glues Manufacturing

4.5.9.4.2.5.1 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.

4.5.9.4.2.5.2 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;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

Table 4.70 – Default emission factor (Source: EMEP/CORINAIR 2013).

SNAP	Unit	NMVOC
Paints, Inks and Glue Manufacturing	g/kg product	11

Table 4.71 – Abatement technology (Source: EMEP/CORINAIR 2013).

Abatement Technology	Unit	Efficiency
Use of good practices	%	27

Table 4.72 – Control strategy (Source: IIASA, 2009).

Technology	Unit	1990	1995	2000	2005	2010	2015
Use of good practices	%	0	0	0	50	100	100
No control	%	100	100	100	50	0	0

Table 4.73 – Final emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
Final EF	g/kg product	11.0	11.0	11.0	9.5	8.0	8.0

4.5.9.4.2.5.3 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 4.74 – Production of paints, inks and glue.

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2015
060307	Paints manufacturing	t paint	117 961	96 320	146 854	158 181	169 908	178 268
060308	Inks manufacturing	t ink	3 677	1 166	3 266	2 262	3 485	2 269
060309	Glues manufacturing	t glue	29 666	23 451	79 466	60 524	61 882	43 596

Source: INE

4.5.9.4.2.5.4 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%.

4.5.9.4.2.5.5 Recalculations

No recalculations were made.

4.5.9.4.2.5.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.4.2.6 Manufacture of Tyres

4.5.9.4.2.6.1 Methodology

Emissions from tyre manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the number of tyres produced according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC\ (y)} \times Tyres_{(y)} \times 10^{-6}$$

where:

$Emi_{NMVOC(y)}$ – NMVOC emissions from manufacturing of tyres during year y (t/yr);

$EF_{NMVOC(y)}$ – NMVOC emission factor for manufacturing of tyres in year y (g/tyre);

$Tyres_{(y)}$ – Number of tyres produced in year y (n./yr);

y – year.

4.5.9.4.2.6.2 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 4.75 – Default emission factor (Source: EMEP/CORINAIR 2013).

SNAP	Unit	NMVOC
Tyre production	g/kg tyre	10

Table 4.76 – 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 4.77 – Control strategy (Source: IIASA, 2009).

Technology	Unit	1990	1995	2000	2005	2010	2015
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 convertion factor was used to obtain emission factor expressed in g/tyre in order to use the activity data provided by INE. A convertion factor of 15kg/tyre was used.

Table 4.78 – Final NMVOC emission factor.

Parameter	Unit	1990	1995	2000	2005	2010	2015
Final EF	g/kg tyre	10	7	4	4	4	4
Final EF	g/tyre	150	108	67	67	67	67

4.5.9.4.2.6.3 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 4.79 – Production of tyres.

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2015
060314	Manufacture of tyres	tyres	4 218 714	5 891 971	11 605 755	14 748 990	15 595 153	18 105 066

Source: INE

4.5.9.4.2.6.4 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%.

4.5.9.4.2.6.5 Recalculations

No recalculations were made.

4.5.9.4.2.6.6 Further Improvements

No further improvements are planned for this sector.

4.5.9.5 Other use of solvents and related activities

4.5.9.5.1 Overview

In this chapter are included emission calculations for different activities, such as:

- printing;
- edible and non edible oil extraction;
- use of glues and adhesives;
- ewood preservation;
- domestic solvent use including fungicides.

4.5.9.5.2 Printing

4.5.9.5.2.1 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).

4.5.9.5.2.2 Methodology

Emissions from printing industry was estimated according with Tier 1 methodologly 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_2 emissions are calculated assuming that 60 % 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_2 emissions are included in the inventory.

$$U_{CO2} = NMVOC * 0.60 * (44 / 12)$$

where:

U_{CO2} - Ultimate CO_2 (t/yr);

NMVOC - Global emissions of NMVOC (t/yr).

4.5.9.5.2.3 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 4.80 – NMVOC emission factor for printing activities.

SNAP	Unit	NMVOC
Printing	g/kg ink	500

Source: EMEP/CORINAIR 2013

4.5.9.5.2.4 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 2015 values were forecasted based on 1990-2010 values and on GDP trend.

Table 4.81 – Consumption of inks in printing industry.

SNAP	SNAP Title	Unit	1990	1995	2000	2005	2010	2015
060403	Printing Industry	t ink	5 372	5 372	9 290	8 722	9 336	8 914

Source: INE

4.5.9.5.2.5 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%.

4.5.9.5.2.6 Recalculations

No recalculations were made.

4.5.9.5.2.7 Further Improvements

No further improvements are planned for this sector.

4.5.9.5.3 Edible and non edible oil extraction

4.5.9.5.3.1 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[47]. 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 though vents or leaks or indirectly though water and residues.

4.5.9.5.3.2 Methodology

Emissions of NMVOC were estimated considering that the annual hexane consumption by the industrial plant, hexane make-up, is due to losses to the air, and hence:

$$Emi_{NMVOC}(y) = MakeUp_{Solvents(y)}$$

where:

$Emi_{NMVOC}(y)$ - Emissions of NMVOC (t/yr);

$MakeUp_{Solvents(y)}$ - annual consumption of solvent in edible and non-edible oil industry, to replenish losses (t/yr).

Ultimate CO_2 emissions are calculated assuming that 60 % of the mass emissions of NMVOC is carbon[48] and is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO_2 emissions are included in the inventory.

$$U_{CO2} = NMVOC * 0.60 * (44 / 12)$$

where:

U_{CO2} - Ultimate CO_2 (t/yr);

NMVOC - Global emissions of NMVOC (t/yr).

[47] Classified as virgin olive oil

[48] From hexane chemical formula

4.5.9.5.3.3 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 4.81, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole covered period.

Table 4.82 – Calculation of the National emission factor for edible and non-edible oils extraction (kg/t).

Oil Type	Parameter	1989	1990	1991	Average
Edible	Oil refined (t)	93 401	90 686	107 163	
non-edible		113 749	110 883	113 509	
Total		207 150	201 569	220 672	
Edible	Solvent Use (t)	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/t)	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

4.5.9.5.3.4 Activity Data

Oil refining data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter.Annual values are reported in Table 4.82. Production of olive oil by mechanical pressure does not cause NMVOC emissions.

Table 4.83 - Refining of edible and non-edible oils in Portugal.

Parameter	1990	1995	2000	2005	2010	2015
Oil refining	201 569	220 672	184 406	280 430	186 238	276 003

Source: National Statistics Institute (INE)

4.5.9.5.3.5 Uncertainty Analysis

The activity data time trend is reasonably complete and an uncertainty of 10% was considered. The uncertainty of NMVOC/CO_2 emission factor was established by comparison of the emission factors determined from the several available years: 26%.

4.5.9.5.3.6 Recalculations

Production, imports and exports from national statistics have been revised for year 2014.

4.5.9.5.4 Industrial application of glues and adhesives

4.5.9.5.4.1 Methodology

$$NMVOC = Cons_{Nat} \times FE_{Nat} + Imp \times FE_{imp}$$

where:

NMVOC = Global emissions of NMVOC (t);

$Cons_{Nat}$ = Domestic consumption of glues and adhesives produced in Portugal (t);

FE_{Nat} = Emission factor for glues and adhesives produced in Portugal (kg NMVOC/t Ink);

Imp = Imported glues and adhesives (t);

FE_{imp} = Emission factor associated with the use of imported glues and adhesives.

$$Cons_{Nat} = Prod_{Nat} - Exp$$

where:

$Cons_{Nat}$ = Consumed glues and adhesives produced in Portugal (t);

$Prod_{Nat}$ = National production of glues and adhesives (t);

Exp = Exported glues and adhesives (t).

4.5.9.5.4.2 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 4.83 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 4.84). 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 4.84 - Solvents consumption in glue and adhesives manufacture (t).

	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 4.85 - National emission factors (kg/t).

	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/t. It is considered that natural based glue does not contribute to NMVOC emission.

4.5.9.5.4.3 Activity Data

Table 4.86 - Activity Data for non-natural glues and adhesives (t).

Year	1990	1991	2015
National Production (t)	36 297	35 769	35 473
Importation (t)	2 192	2 328	2 260
Exportation (t)	707	532	620

Source: National Statistics Institute (INE)

4.5.9.5.4.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

4.5.9.5.4.5 Recalculations

No recalculations were made for this source sector.

4.5.9.5.5 Wood Preservation

4.5.9.5.5.1 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.

4.5.9.5.5.2 Methodology

$$Emi_{NMVOC\ (y)} = Consumption_{(y)} * FE_{Consumption}$$

where:

$Emi_{NMVOC(y)}$ - Emissions of NMVOC associated to consumption of wood preservation products (t);

$Consumption_{(y)}$ - Consumption of wood preservation products (t);

$FE_{Consumption}$ - Emission factor associated to the consumption of wood preservation products.

4.5.9.5.5.3 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/t of product applied for creosote; 900 kg/t 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.

4.5.9.5.5.4 Activity Data

Table 4.87 - Wood preservation products consumption (t).

Year	1990	1991	Average
Wood Preservation products Consumption (t)	2083	2900	2491

Source: National Statistics Institute (INE)

4.5.9.5.5.5 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.

4.5.9.5.5.6 Recalculations

No recalculations were made for this source sector.

4.5.9.5.6 Domestic solvent use including fungicides (CRF 3.D.5)

4.5.9.5.6.1 Methodology

This secotr 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:

$NMVOC_i$ - Emissions of NMVOC associated to the use of domestic products containing solvents [t];

$Population_i$ – inhabitants in year i;

EF_{NMVOC} - Emission factor associated with the use of domestic products containing solvents [kg/person/year].

4.5.9.5.6.2 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 4.88 – Default emission factor.

Description	Unit	Value
Emission factor for domestic solvent use including fungicides	kg/person/year	2.7

4.5.9.5.6.3 Activity Data

Table 4.89 - Activity data (inhabitants).

Description	1990	1995	2000	2005	2010	2015
Inhabitants	9 970 441	10 043 180	10 256 658	10 569 592	10 636 979	10 374 822

Source: National Statistics Institute (INE)

4.5.9.5.6.4 Uncertainty Assessment

The uncertainty associated with the emission factor for domestic solvent use was based on information collected from EEA/CORINAIR Guidebook. An uncertainty of 125% was estimated for the emission factor and an uncertainty of 10% was assumed for the activity data. The overall uncertainty was calculated to be 125%.

4.5.9.5.6.5 Recalculations

No recalculations were made.

4.5.10 Road Paving with Asphalt (CRF 2.D.3.b)

4.5.10.1 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 (150º-160º)[49]. 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 (40-60º).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers[50]. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphtha (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12 % of solvents. Hot mix asphalts in the other hand, result in minimum NMVOC emissions during application, because the organic component has high molecular weight and low 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 % 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)[51]. Emission estimates for hot-mix are only made here for pollutants NMVOC and PM, while emission of other pollutants are covered in emission estimates made for Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity[52].

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible[53].

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

[49] That are needed to fluidize the asphalt cement.

[50] And also a solvent in several emulsion types.

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

[52] It is not possible to distinguish fuel combustion in hot mix production activity.

[53] Some emissions do occur in fact during mixing and stockpiling operations. However, because the methodology is based on mass balance, these emissions are in fact quantified under application of asphalt.

production of asphalts – except emissions from fuel combustion – are included in this source category.

4.5.10.2 Methodology

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100 % composed of VOC (USEPA, 2001) and that emitted VOC have on average 60 % of carbon[54]:

$$Emi_{CO2} = 44 / 12 * 0.60 * Emi_{NMVOC}$$

Different methodologies were used to estimate emissions of NMVOC during asphalt application or from asphalt production.

4.5.10.2.1 Application of Asphalt Concretes and Liquefied Asphalts

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA, 1997; USEPA, 2001):

$$Emi_{NMVOC\ (y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where:

$Emi_{NMVOC\ (y)}$ - Emissions of NMVOC from asphalt application during year y (t/yr);

Binder (y) – Total quantity of asphalt binder used in road paving during year y (t/yr);

SLV_{Fac} - Fraction of distillate (solvent) in asphalt (m^3/m^3);

d_{Slv} - density of solvent added to liquefied asphalt (kg/l);

d_{BIN} - density of bitumen binder mixture (kg/l);

$Cure_{FC}$ - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

4.5.10.2.2 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:

[54] 2006 IPCC Guidelines.

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

$Hotmix_{Batch\ (y)}$ and $Hotmix_{Drum\ (y)}$ – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (t/yr);

$EF_{(p)}$ and $EF_{(p)}$ – Emission Factors for pollutant p used respectively in discontinuous (batch) and continuous (drum) plants (t/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.

4.5.10.2.3 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 4.90 - Emission Parameters for road paving with asphalt.

Parameter	Cutback	Emulsions
SLV_{Fac}	25 %	3 %
d_{SLV}	0.95 kg/l	0.85 kg/l
d_{Bin}	0.95 kg/l	0.85 kg/l
Cure type	Medium Cure (MC)	-
$Cure_{FC}$	0.75 kg/kg	1 kg/kg

Emission factors used to estimate NMVOC and PM emissions from hot mix plants are from USEPA (2000) and are presented in next table.

Table 4.91 - Emission Parameters for Hot Mix asphalt production.

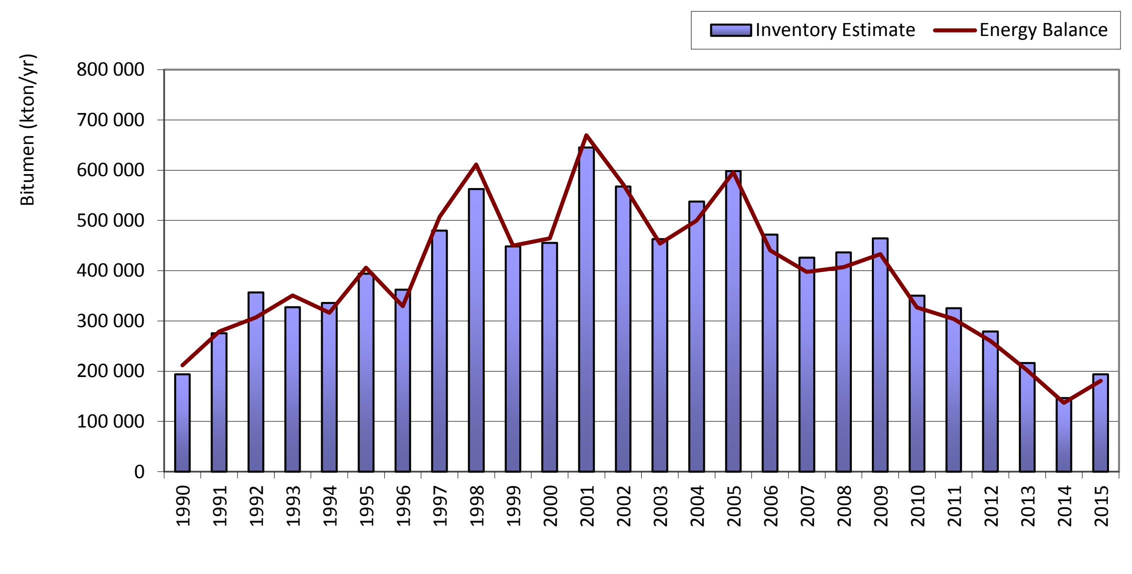
Pollutant	Continuous	Batch	Unit EF
NMVOC	32.0	22.1	g/t
CH4	12.0	7.4	g/t

Source: USEPA (2000)

4.5.10.2.4 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[55], 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 4-30 - Total consumption of bitumen in the construction sector according to sales from DGEG Energy Balance and sum of values of asphalt used according to the inventory.



Cutback asphalt is seldom used in Portugal and it is sold only by two companies, according to information gathered at APORBET, the Portuguese Association of Producers of Bitumen Materials. Annual sales were assumed equal to annual consumption and may be seen in the table below and in the figure above. Total emulsions applied are available from EAPA for 1997 and beyond. For previous years, use of emulsions was estimated from the total quantity of asphalt materials applied as road pavement, also from EAPA, and considering a percentage of that bitumen that is emulsions. It was also assumed that this percentage was zero in 1990 and has increased to 19 % 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 % 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 4.92 – Amounts of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (t).

Asphalt	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cutback	ton	4 100	3 500	2 700	3 100	2 600	676	407	1 232	933	162	576	824	501
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	116 000

Asphalt	Unit	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cutback	ton	340	0	0	0	0	0	0	0	0	0	0	0	0
Emulsified	ton	112 665	93 600	65 000	40 500	36 556	37 441	39 824	30 049	27 934	23 934	18 560	12 595	16 650

[55] Original data from DGEG is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGEG

Figure 4-31 - Amounts of asphalt binders (cutback and emulsified asphalts) consumed in Portugal.

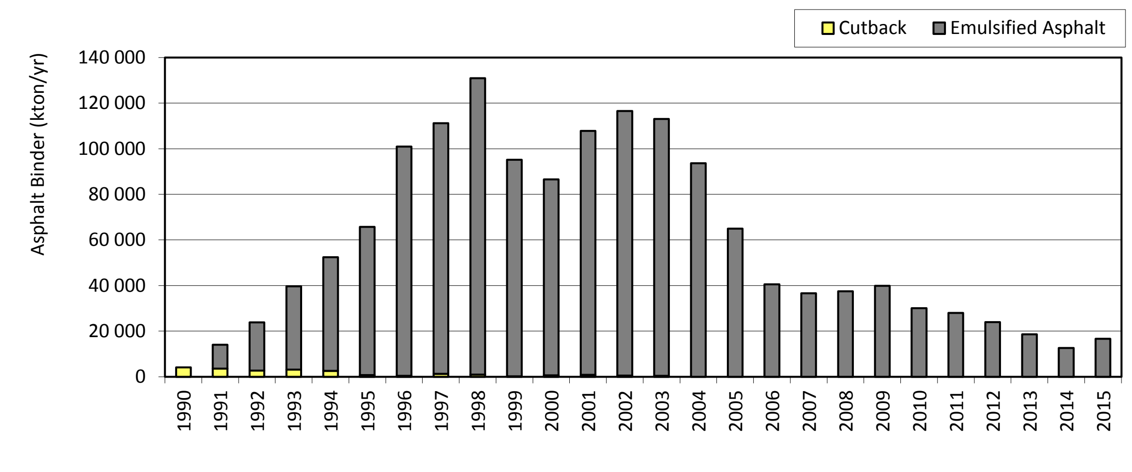
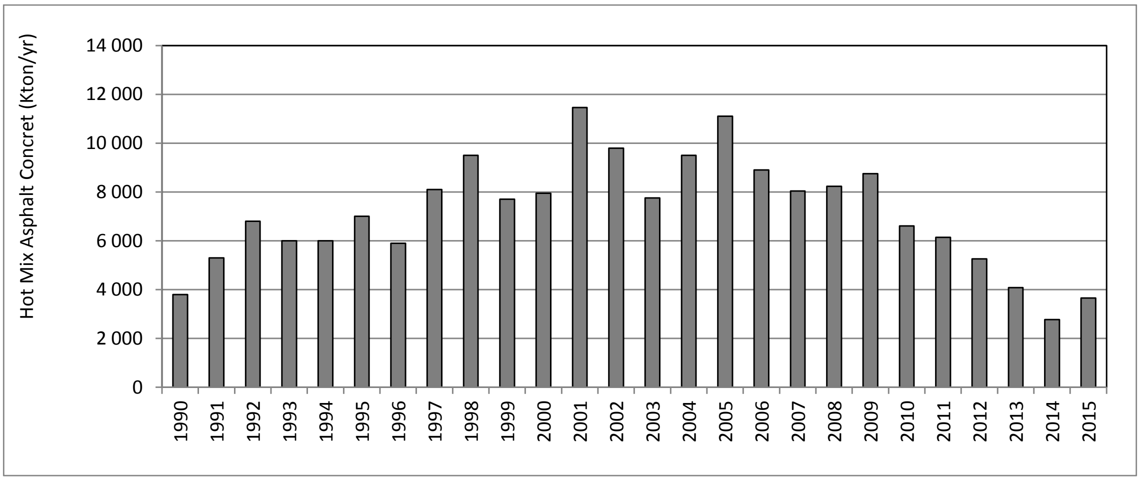


Figure 4-32 – Total Production of Hot Mix Asphalt.



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 % continuous equipment and 54 % batch, which is an expert guess (PTEN, 2002).

4.5.10.3 Uncertainty Assessment

Table 4.93 – Uncertainty values.

Parameter	Uncertainty	Source
Activity Data	100%	Chapter 5.4.4 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CO_2 EF	100%	Chapter 5.4.4 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".
CH_4 EF	100%	Chapter 5.4.4 of "Volume 3: Industrial Processes and Product Use" of "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

4.5.10.4 Recalculations

No recalculations were made.

4.5.10.5 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.

4.6 Electronics Industry (CRF 2.E)

4.6.1 Integrated Circuit or Semiconductor (CRF 2.E.1)

This sector will be fully addressed in future NIR submissions.

4.6.2 TFT Flat Panel Display (CRF 2.E.2)

This sector will be fully addressed in future NIR submissions.

4.6.3 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.

4.6.4 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.

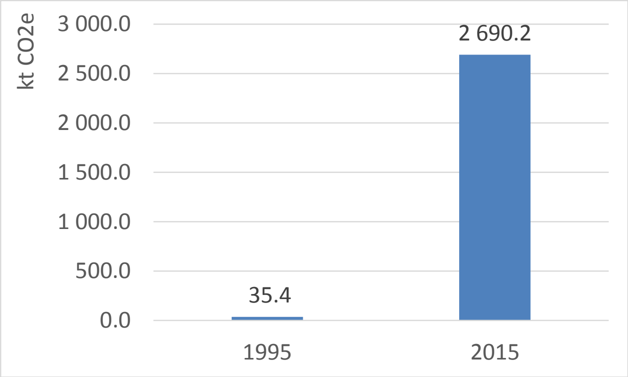
4.7 Product Uses as substitutes for ODS (CRF 2.F)

4.7.1 Overview

The category Product uses as substitutes for ODS (2.F) includes :

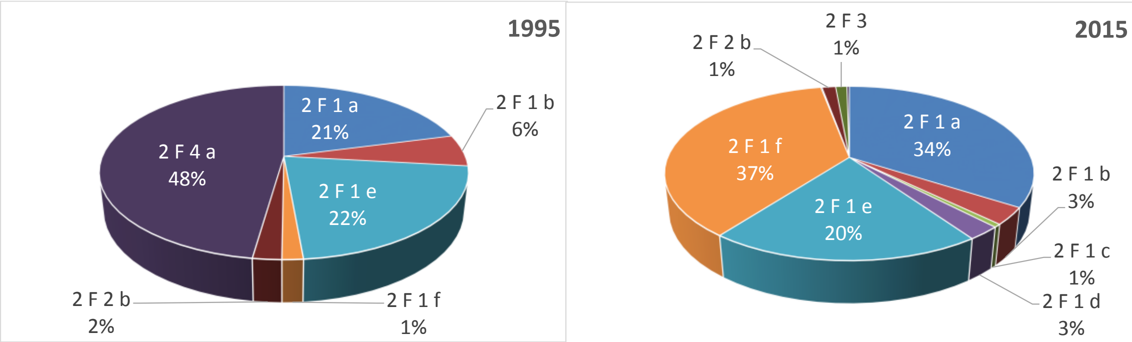
- Commercial Refrigeration (CRF 2.F.1.a) ;
- Domestic Refrigeration (CRF 2.F.1.b) ;
- Industrial Refrigeration (CRF 2.F.1.c) ;
- Transport Refrigeration (CRF 2.F.1.d) ;
- Mobile Air Conditioning (CRF 2.F.1.e) ;
- Stationary Air Conditioning (CRF 2.F.1.f) ;
- Foam Blowing (CRF 2.F.2) ;
- Fire Protection (CRF 2.F.3) ;
- Metered Dose Inhalers (CRF 2.F.4.a).

Figure 4-33 – Emissions from product uses as substitutes for ODS



There is a strong increase in emissions from product uses as substitutes for ODS (7945% increase from 1995 to 2015).

Figure 4-34 – Share of emissions by subcategory



In 2015, the most relevant subcategories are stationary air conditioning (37%), commercial refrigeration (34%) and mobile air conditioning (20%).

It was developed a national reporting tool (https://formularios.apambiente.pt/GasesF/) where national operators report the use of fluorinated gases, as proposed in article 6 of Regulation (EU) No. 517/2014. It has data from 10000 national operators. This tool gives us information from 2014 onwards, and is used in the national inventory to establish the share of each gas/blend for each type of equipment.

4.7.2 Commercial Refrigeration (CRF 2.F.1.a)

4.7.2.1 Methodology

CFC, HCFC and F-Gases emissions from operation and disposal of Commercial Refrigeration Equipments were estimated using a bottom-up approach Tier 2a.

a) Sources of emissions when charging new equipment:

$$E_{charge\ (t,y)} = N_t \times m_t \times \frac{HFC_y}{100} \times \frac{k}{100}$$

Where:

$E_{charge\ (t,y)}$ – emissions of fluid y during system manufacture/assembly in year t, t of fluid;

Nt – number of equipments charged in year t;

m_t – amount of refrigeration fluid charged into each equipment in year t, t of fluid;

HFC_y – HFC y charged in new equipments, percent;

K – emission factor of assembly losses of the HFC charged into new equipment, per sub-application, percent.

b) Sources of emissions during equipment lifetime:

$$E_{lifetime\ (t,y)} = B_t \times \frac{HFC_y}{100} \times \frac{x}{100}$$

Where:

$E_{lifetime,t}$ – emissions of fluid y during system lifetime in year t, t of fluid;

Bt – amount of fluid banked in existing systems in year t;

HFC_y – HFC y banked in existing equipments, percent;

x – annual emission rate of HFC of each sub-application bank during operation, accounting for average annual leakage and average annual emissions during servicing, percent.

c) Emissions at system end-of-life (Disposal)

$$E_{end-of-life,t} = B_{t-d} \times \frac{HFC_y}{100} \times \frac{Disp}{100} \times \frac{P}{100} \times \left(1 - \frac{\eta_{rec,d}}{100}\right)$$

Where:

$E_{end-of-life,t}$ – amount of HFC emitted at system disposal in year t, t of fluid;

B_{t-d} – amount of fluid banked in existing systems in year (t-d);

HFC_y – HFC y banked in existing equipments in year (t-d), percent;

Disp – annual disposal rate of equipments, percent;

P – residual charge of HFC in equipment being disposed of, expressed in percentage of full charge, percent;

$\eta_{rec,d}$ – recovery efficiency at disposal, percent.

4.7.2.2 Emission Factors

4.7.2.2.1 Emission Factors - Assemblage

Table 4.94 – Emission Factors considered in assemblage

Description	Unit	Value
First charge (m_i)	kg/unit	0.87
First charge emissions (k)	%	1.75

4.7.2.2.2 Emission Factors – Operation and Servicing

Table 4.95 – Emission Factors for F-gas emissions from commercial refrigeration equipments (hypermarkets not included)

Type of Equipment	Charging -kg/unit-	Lifetime Emissions -%-	Residual Charge of HFC in equipment being disposed (P) -%-	Recovery Efficiency at disposal (η_{rec}) -%-	Annual disposal rate -%-	Lifetime
Mini-Fridge	0.05	0.20	80	60	8.3	12
Fridge	0.11	0.20	80	60	8.3	12
Horizontal Freezer	0.87	5.50	80	60	8.3	12
Congelation Chamber	1.20	5.50	80	60	8.3	12
Refrigeration Chamber	1.20	5.50	80	60	8.3	12
Supermarket Vertical Freezer Showcase	0.87	5.50	80	60	8.3	12
Vertical Freezer	0.87	5.50	80	60	8.3	12
Under Bench Refrigerator	1.31	5.50	80	60	8.3	12
Supermarket Horizontal Freezer Showcase	1.31	5.50	80	60	8.3	12
Fridge (Bottles)	1.31	5.50	80	60	8.3	12
Wine Fridge Showcase	0.87	5.50	80	60	8.3	12
Ice Machine	0.05	5.50	80	60	8.3	12
Juice Machine	0.05	5.50	80	60	8.3	12
Ice Cream Machine	0.05	5.50	80	60	8.3	12
Chantilly Machine	0.05	5.50	80	60	8.3	12
Tap drink cooler	0.05	5.50	80	60	8.3	12
Can Vendor	0.11	0.20	80	60	8.3	12
Tap beer cooler	0.05	5.50	80	60	8.3	12

Table 4.96 – Emission Factors for F-gas emissions in hypermarkets

Area (m²)	Category	Positive Temperature	Negative Temperature	Initial Emission (k) - % of Initial Charge/year	Operation Emissions (x) - % of Initial Charge/year	p (residual charge at disposal) -%	η (recovery efficiency at disposal) - %
		Initial Charge (kg)	Initial Charge (kg)				
Area >4500	Big	1800	1250	1.75	22.5	80	60
1000 ≤ Area ≤ 4500	Medium	550	350	1.75	22.5	80	60
Area < 1000	Small	350	250	1.75	22.5	80	60

4.7.2.3 Activity Data

4.7.2.3.1 Activity Data - Assemblage

The number of units for 1990 and 1991 was estimated concerning the Gross Domestic Product (GDP) values for each year. Data on the assemblage of commercial and industrial refrigeration units from national statistics Industrial Survey (IAPI) is only available from 1992 to 2007 and refers to refrigeration units with a viewing monitor. From 2008 onwards, data was estimated based on GDP values.

Figure 4-35 – Number of commercial refrigeration assembled units in Portugal

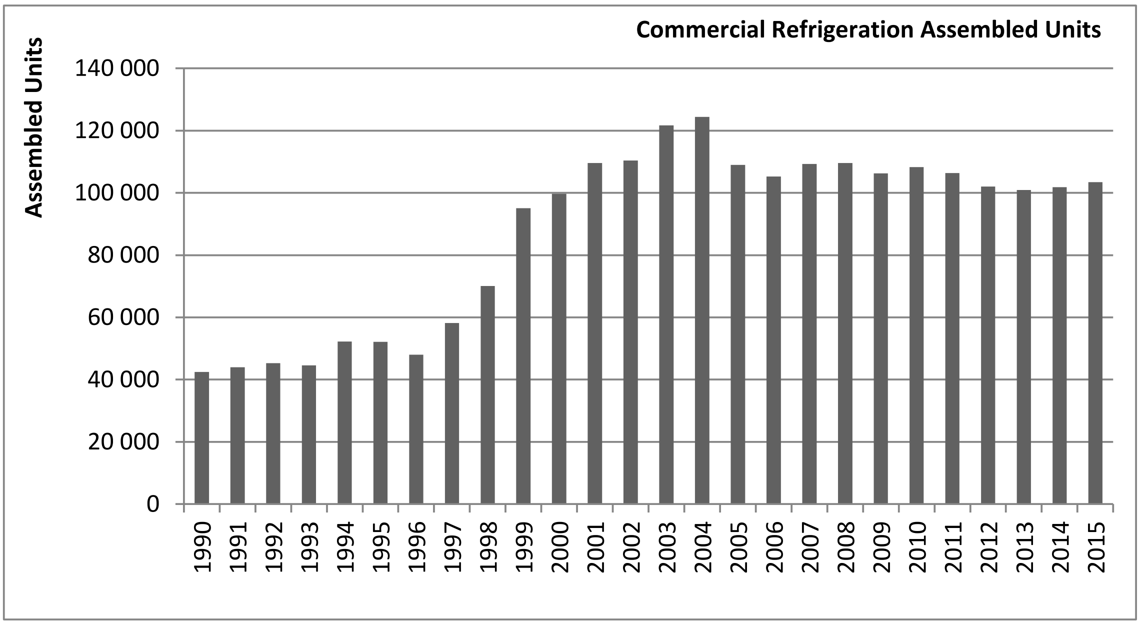


Table 4.97 – Use of each Gas/Mixture in the assembled units (percent)

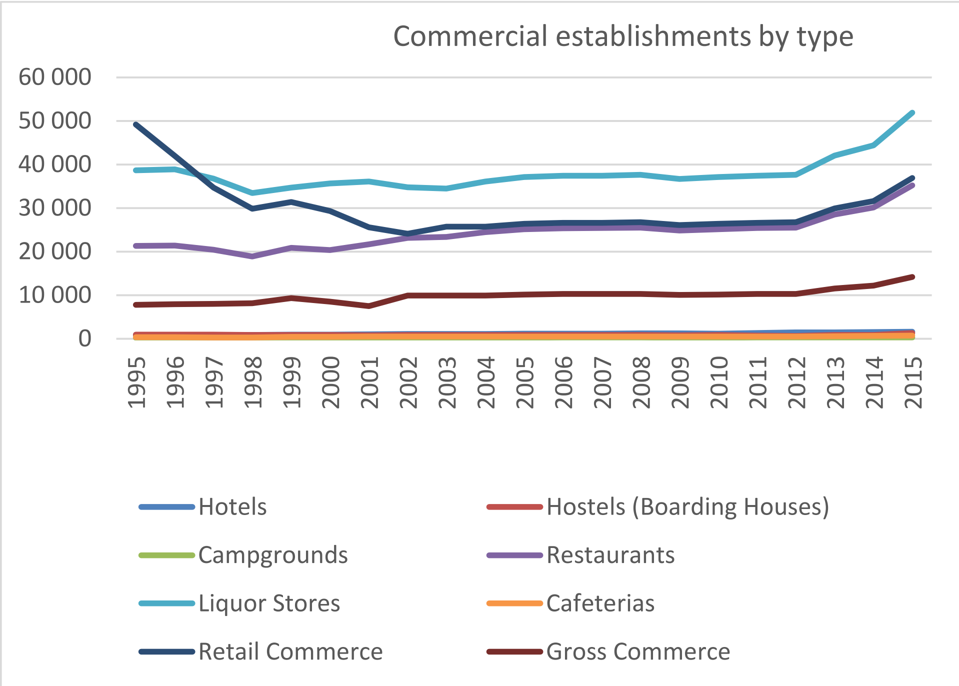
% of Fluid	Unit	1995	2000	2005	2010	2011	2012	2013	2014	2015
CFC-12	%	33.6	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCFC-22	%	66.4	42.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R-404A	%	0.0	6.5	15.2	28.7	31.4	34.2	36.9	39.6	39.6
HFC-134A	%	0.0	48.2	84.8	57.8	52.4	47.0	41.6	36.2	36.2
R-407C	%	0.0	0.0	0.0	4.4	5.3	6.1	7.0	7.9	7.9
R-410A	%	0.0	0.0	0.0	3.5	4.2	4.9	5.5	6.2	6.2
R-422D	%	0.0	0.0	0.0	2.2	2.6	3.0	3.5	3.9	3.9
R-417A	%	0.0	0.0	0.0	1.4	1.7	2.0	2.2	2.5	2.5
R-422A	%	0.0	0.0	0.0	1.1	1.3	1.5	1.7	1.9	1.9
R-507A	%	0.0	0.0	0.0	1.0	1.2	1.4	1.6	1.8	1.8

4.7.2.3.2 Activity Data – Operation and Servicing

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, Fluorinated Gases Distributors 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:

Figure 4-36 – Number of commercial establishments by type



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 4.98 – 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"

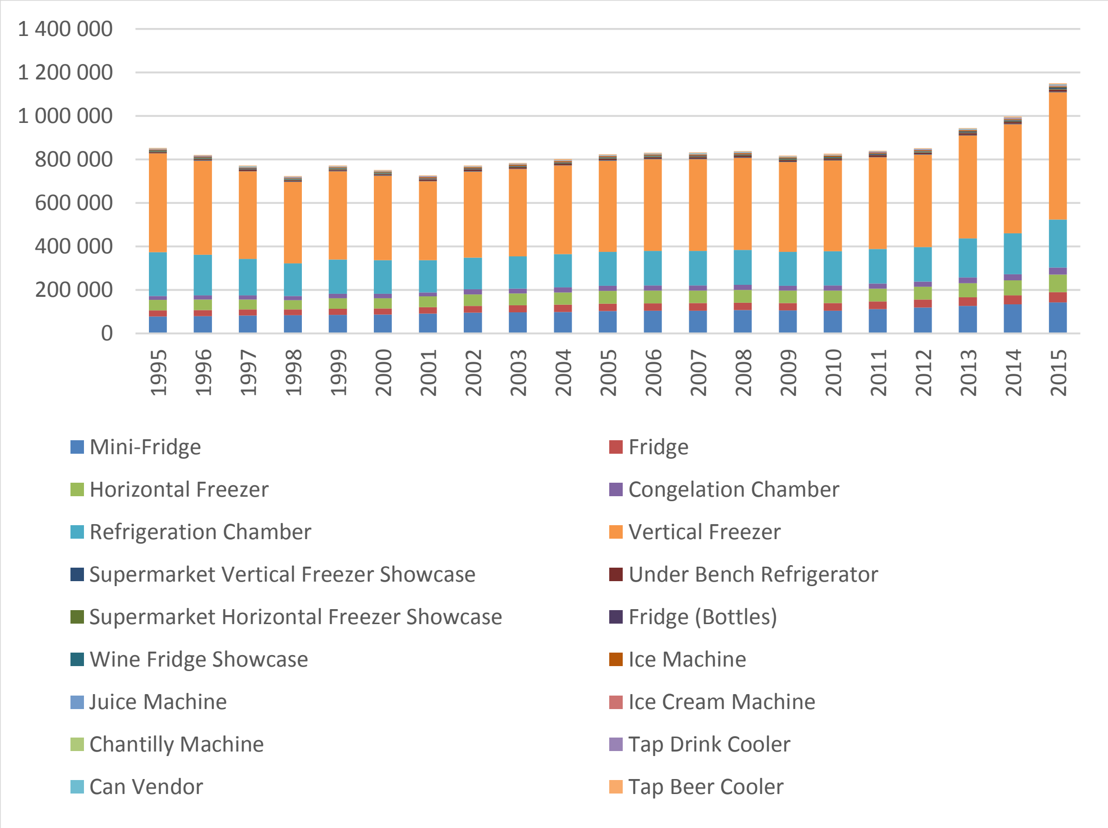
When it was not possible to use real data, the number of equipments per activity was set by expert judgement and through visits to some installations, according to the following table:

Table 4.99 – 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

Figure 4-37 – Number of commercial refrigeration equipments



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 4.100 – Classification of refrigeration equipments by area.

Area (m^2)	Category	Showcase Fridge/Freezer (m)		Refrigeration Chambers (m^2)	Congelation Chambers (m^2)
		Positive Temp.	Negative Temp.		
Area >4500	Big	218	110	550	180
1000 ≤ Area ≤ 4500	Medium	96	48	75	82
Area < 1000	Small	40	38	10	20

Source: Hypermarket Company

The number of disposed equipments in each year was assumed equal to the number of assembled equipments 12 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[56]. It was assumed an average lifetime of 12 years.

[56] In consequence no emissions of HFC from disposal are estimated for the reported period.

4.7.2.4 Recalculations

The entire sector has been revised.

4.7.2.5 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.101 – Stand-alone commercial units (equipments of Hypermarkets not included)

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments per commercial place	0	391	71.2	112.0%
Initial Charge	0.40	0.46	0.44	2.8%
AD Combined Uncertainty	**-**	**-**	**-**	**112.5%**
Lifetime	10	15	12	8.5%
Initial Emission	0.5	3	1.75	29.2%
Lifetime Emission	1	15	8	35.7%
Residual charge remaining at disposal	0	80	80	20.4%
Recovery efficiency at disposal	0	70	60	23.8%
EF Combined Uncertainty	**-**	**-**	**-**	**56.4%**

Table 4.102 – Medium & Large commercial units (equipments of Hypermarkets)

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of commercial places	-	-	-	10%
Initial Charge	350	1800	550	53.8%
% HFC	-	-	-	30%
AD Combined Uncertainty	**-**	**-**	**-**	**62.4%**
Lifetime	10	15	12	8.5%
Initial Emission	0.5	3	1.75	29.2%
Lifetime Emission	10	35	22.5	22.7%
Residual charge remaining at disposal	50	100	80	12.8%
Recovery efficiency at disposal	0	70	60	23.8%
EF Combined Uncertainty	**-**	**-**	**-**	**46.6%**

4.7.3 Domestic Refrigeration (CRF 2.F.1.b)

4.7.3.1 Methodology

It was used the same methodology as for Commercial Refrigeration (CRF 2.F.1.a). Please check sector 4.7.2.1.

4.7.3.2 Emission Factors

Prior to 1993 no F-gas was used in the assembling of refrigeration units.

The amount of Refrigeration Fluid charged into the equipment was assumed to be 0.11 kg/equipment for combined equipments (fridge+freezer) and 0.18 kg/equipment unit for freezers, which are well within the range (0.05-0.5 kg/equipment) set in Table 7.9 of chapter 7 of the 2006 IPCC Guidelines.

The following emission factors were considered for this activity corresponding to the average values from the proposed range in Table 7.9 of chapter 7 of the 2006 IPCC Guidelines.

Table 4.103 - Emission Factors of F-gases from Domestic Refrigeration.

Initial Emission (k), % of Initial Charge/year	Operation Emissions (x), % of Initial Charge/year	Lifetime, years	Disposal rate, %	p (residual charge at disposal), %	η (recovery efficiency at disposal), %
0.6	0.2	12	8.3	80.0	60.0

4.7.3.3 Activity Data - Assemblage

Time series on the number of assembled domestic refrigeration units in Portugal for the period 1990-2003 was provided by National Statistics (INE) and is presented in next figure. Values from 2004 onwards were forecasted by APA based on gross domestic product trend and on the average value for the period 1990-2003.

Figure 4-38 – Number of assembled refrigeration units.

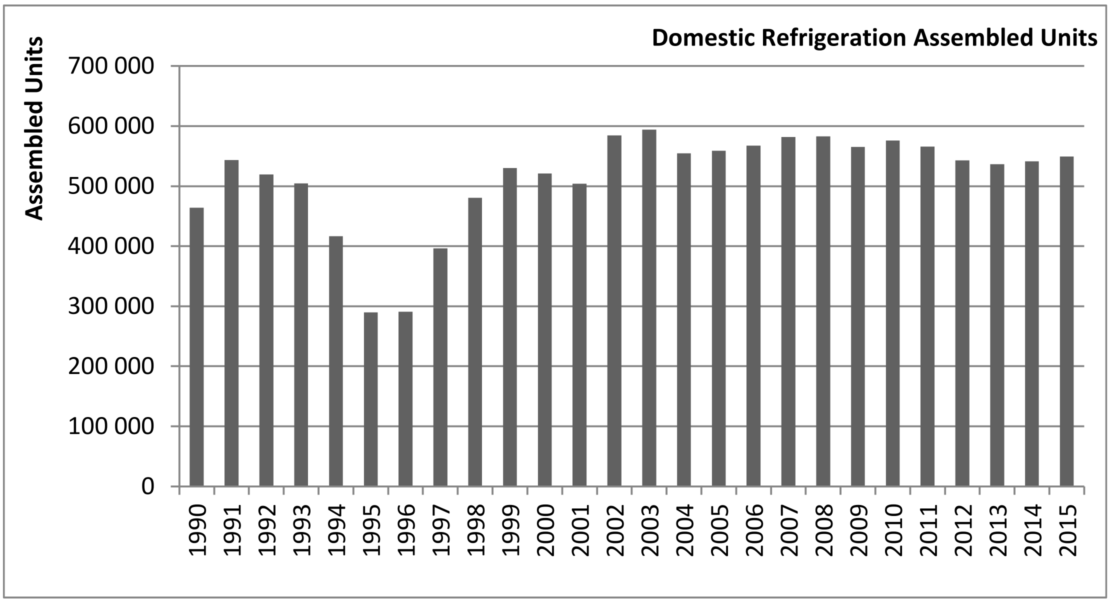


Table 4.104 – Use of each Gas/Mixture in the assembled units (percent)

% of Fluid	Unit	1995	2015
CFC-12	%	14.29	0.00
HFC-134A	%	42.86	58.57
R-404A	%	42.86	23.68
R-410A	%	0	4.52
R-422D	%	0	3.43
R-407C	%	0	3.12
R-417A	%	0	1.71
R-507A	%	0	1.40
R-422A	%	0	1.25
R-143A	%	0	0.93
R-437A	%	0	0.78
R-434A	%	0	0.62

4.7.3.4 Activity Data – Operation and Servicing

The stock of domestic refrigeration equipments was estimated from the number of households and from the percentage of households with refrigeration equipments (available for 1987-1995 and 2000, according to an unpublished report from INE). From year 2000 onwards, the evolution on the percentage of equipments per household was forecasted by APA based on expert judgement. The number of households refers to INE annual publication “Estatísticas da Construção e Habitação”.

Figure 4-39 – Number of Households.

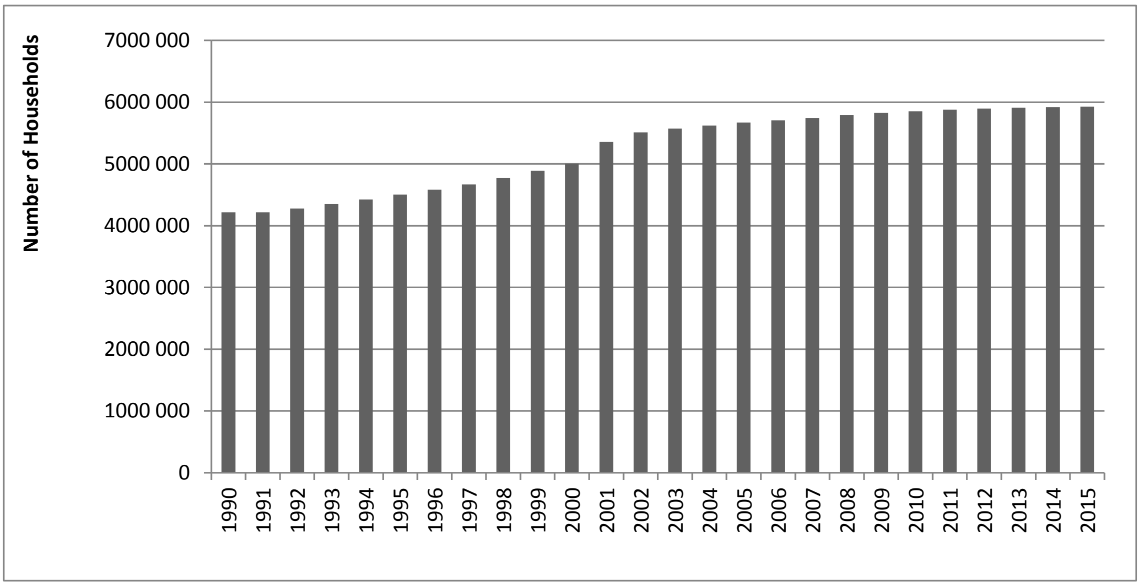


Table 4.105 - Percentage of households in Portugal provided with refrigeration equipments.

Equipment	1990	1995	2000	2005 onwards
Combined (Fridge and Freezer)	91.9	95.7	97.1	100.0
Freezers	34.4	49.5	53.5	55.0

Table 4.106 – Use of each Gas/Mixture in the equipments in operation (percent)

% of Fluid	Unit	1995	2015
CFC-12	%	66.67	0.00
HFC-134A	%	16.67	38.95
R-404A	%	16.67	36.89
R-407C	%	0.0	7.17
R-410A	%	0.0	5.91
R-422D	%	0.0	3.75
R-417A	%	0.0	2.37
R-422A	%	0.0	1.78
R-507A	%	0.0	1.74
R-427A	%	0.0	0.73
R-437A	%	0.0	0.71

4.7.3.5 Recalculations

This sector has been completely revised.

4.7.3.6 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.107 – Domestic Refrigeration - Fridge

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	0.10	0.12	0.11	3.8%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**31.8%**
Lifetime	12	20	12	13.6%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	0.1	0.5	0.2	40.8%
Residual charge remaining at disposal	0	80	80	20.4%
Recovery efficiency at disposal	0	70	60	23.8%
EF Combined Uncertainty	**-**	**-**	**-**	**59.8%**

Table 4.108 – Domestic Refrigeration - Freezer

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	0.10	0.26	0.18	18.3%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**36.5%**
Lifetime	12	20	12	13.6%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	0.1	0.5	0.2	40.8%
Residual charge remaining at disposal	0	80	80	20.4%
Recovery efficiency at disposal	0	70	60	23.8%
EF Combined Uncertainty	**-**	**-**	**-**	**59.8%**

4.7.4 Industrial Refrigeration (CRF 2.F.1.c)

4.7.4.1 Methodology

Emissions from Industrial Refrigeration Equipments were estimated using a bottom-up approach Tier 2a.

a) Sources of emissions when charging new equipment:

$$E_{charge\ (t,y)} = N_t \times m_t \times \frac{HFC_y}{100} \times \frac{k}{100}$$

Where:

$E_{charge\ (t,y)}$ – emissions of fluid y during system manufacture/assembly in year t, t of fluid;

Nt – number of equipments charged in year t;

m_t – amount of refrigeration fluid charged into each equipment in year t, t of fluid;

HFC_y – HFC y charged in new equipments, percent;

K – emission factor of assembly losses of the HFC charged into new equipment, per sub-application, percent.

b) Sources of emissions during equipment lifetime:

$$E_{lifetime\ (t,y)} = B_t \times \frac{HFC_y}{100} \times \frac{x}{100}$$

Where:

$E_{lifetime,t}$ – emissions of fluid y during system lifetime in year t, t of fluid;

Bt – amount of fluid banked in existing systems in year t;

HFC_y – HFC y banked in existing equipments, percent;

x – annual emission rate of HFC bank during operation, accounting for average annual leakage and average annual emissions during servicing, percent.

c) Emissions at system end-of-life (Disposal)

$$E_{end-of-life,t} = N_{t-d} \times m_{t-d} \times \frac{HFC_y}{100} \times \frac{P}{100} \times \left(1 - \frac{\eta_{rec,d}}{100}\right)$$

Where:

$E_{end\text{-}of\text{-}life,t}$ – amount of HFC emitted at system disposal in year t, t of fluid;

$N_{t\text{-}d}$ – number of equipments charged in year t-d;

$m_{t\text{-}d}$ – amount of refrigeration fluid charged into each equipment in year t-d, t of fluid;

HFC_y – HFC y banked in existing equipments in year (t-d), percent;

P – residual charge of HFC in equipment being disposed of, expressed in percentage of full charge, percent;

$\eta_{rec,d}$ – recovery efficiency at disposal, percent.

4.7.4.2 Emission Factors

Table 4-109 – Industrial Refrigeration emission factors

	Unit	Emission Factor
Initial Emission (k)	%	1.75
Lifetime Emission (x)	%	22.5
Lifetime	Years	12
p (residual charge at disposal)	%	80
η (recovery efficiency at disposal)	%	60

4.7.4.3 Activity Data

Activity data was obtained from companies that use industrial refrigeration equipments in their activity.

4.7.4.4 Recalculations

The entire subsector has been revised.

4.7.4.5 Further Improvements

Efforts will be made to gatter information from the most relevant industrial refrigeration plants, reported under Regulation (EC) No. 517/2014. This will allow a better characterization of the most relevant fluorinated gases used in this subsector.

4.7.4.6 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4-110 – Industrial Refrigeration

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of industrial plants	-	-	-	10.0%
Initial Charge	350	1800	550	53.8%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**62.4%**
Lifetime	10	15	12	8.5%
Initial Emission	0.5	3	1.75	29.2%
Lifetime Emission	10	35	22.5	22.7%
Residual charge remaining at disposal	50	100	80	12.8%
Recovery efficiency at disposal	0	70	60	23.8%
EF Combined Uncertainty	**-**	**-**	**-**	**46.6%**

4.7.5 Transport Refrigeration (CRF 2.F.1.d)

4.7.5.1 Methodology

Emissions from Transport Refrigeration Equipments were estimated using a bottom-up approach Tier 2a.

d) Sources of emissions when charging new equipment:

$$E_{charge\ (t,y)} = N_t \times m_t \times \frac{HFC_y}{100} \times \frac{k}{100}$$

Where:

$E_{charge\ (t,y)}$ – emissions of fluid y during system manufacture/assembly in year t, t of fluid;

Nt – number of equipments charged in year t;

m_t – amount of refrigeration fluid charged into each equipment in year t, t of fluid;

HFC_y – HFC y charged in new equipments, percent;

K – emission factor of assembly losses of the HFC charged into new equipment, per sub-application, percent.

e) Sources of emissions during equipment lifetime:

$$E_{lifetime\ (t,y)} = B_t \times \frac{HFC_y}{100} \times \frac{x}{100}$$

Where:

$E_{lifetime,t}$ – emissions of fluid y during system lifetime in year t, t of fluid;

Bt – amount of fluid banked in existing systems in year t;

HFC_y – HFC y banked in existing equipments, percent;

x – annual emission rate of HFC bank during operation, accounting for average annual leakage and average annual emissions during servicing, percent.

f) Emissions at system end-of-life (Disposal)

$$E_{end-of-life,t} = N_{t-d} \times m_{t-d} \times \frac{HFC_y}{100} \times \frac{P}{100} \times \left(1 - \frac{\eta_{rec,d}}{100}\right)$$

Where:

$E_{end-of-life,t}$ – amount of HFC emitted at system disposal in year t, t of fluid;

N_{t-d} – number of equipments charged in year t-d;

m_{t-d} – amount of refrigeration fluid charged into each equipment in year t-d, t of fluid;

HFC_y – HFC y banked in existing equipments in year (t-d), percent;

P – residual charge of HFC in equipment being disposed of, expressed in percentage of full charge, percent;

$\eta_{rec,d}$ – recovery efficiency at disposal, percent.

4.7.5.2 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).

Table 4.111 – Transport Refrigeration emission factors

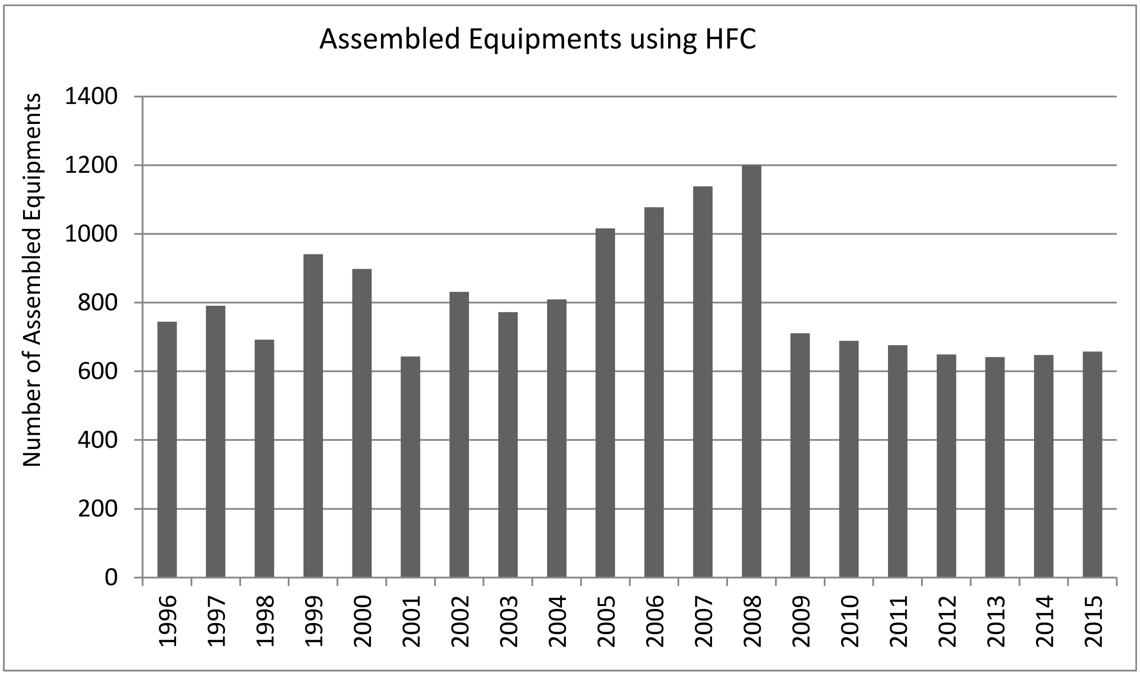
	Unit	Emission Factor
Initial Charge	Kg/equipment	5.35
Initial Emission (k)	%	0.60
Lifetime Emission (x)	%	32.50
Lifetime	Years	10
p (residual charge at disposal)	%	90.00
η (recovery efficiency at disposal)	%	70.00

4.7.5.3 Activity Data - Assemblage

It was assumed that, before 1996, CFC-12 was used instead of HFC as Refrigeration Fluid in Portugal. From 1996 onwards it is assumed that 50% of the equipments are assembled with HFC-134a and the remaining 50% with R-404A.

Data on the number of equipments assembled in Portugal was collected from equipment manufacturers in the period 1996-2010. From 2011 onwards, this number was estimated based on year 2010 value and on Gross Domestic product trend.

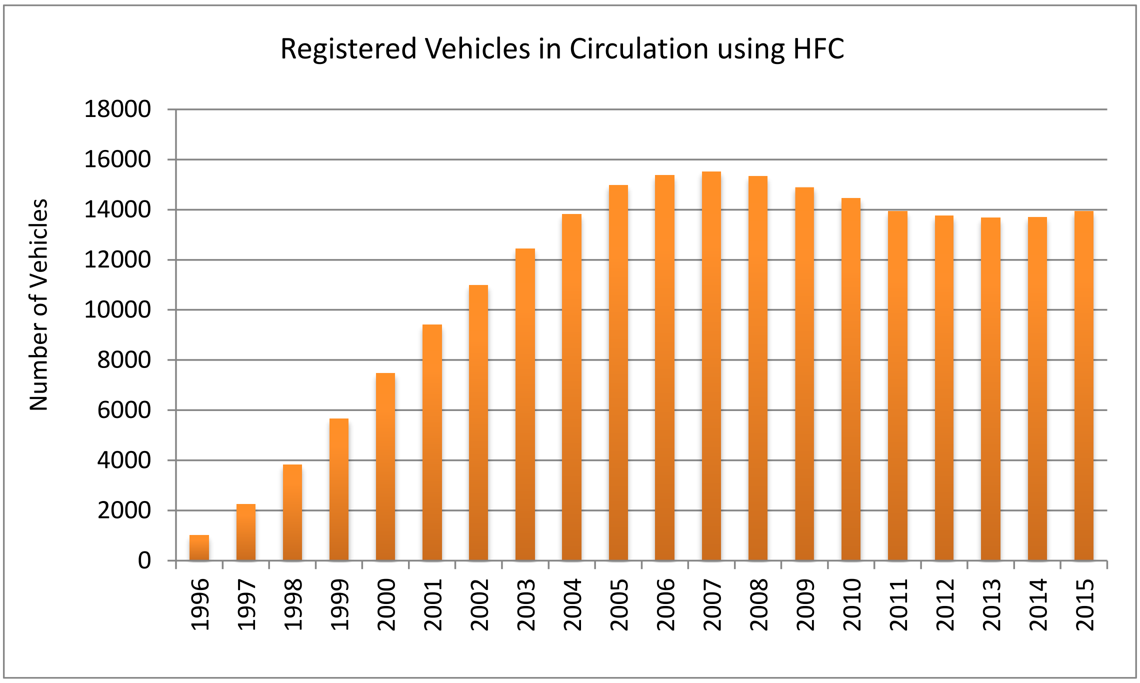
Figure 4-40 – Number of Equipments assembled in Portugal.



4.7.5.4 Activity Data – Operation and Servicing

Data on the number of registered vehicles was provided by the Portuguese Authority on Vehicles (ex-DGV) in the period 1996-2005. From 2006 onwards, this value was estimated based on the average number of registered vehicles in the period 2002-2005.

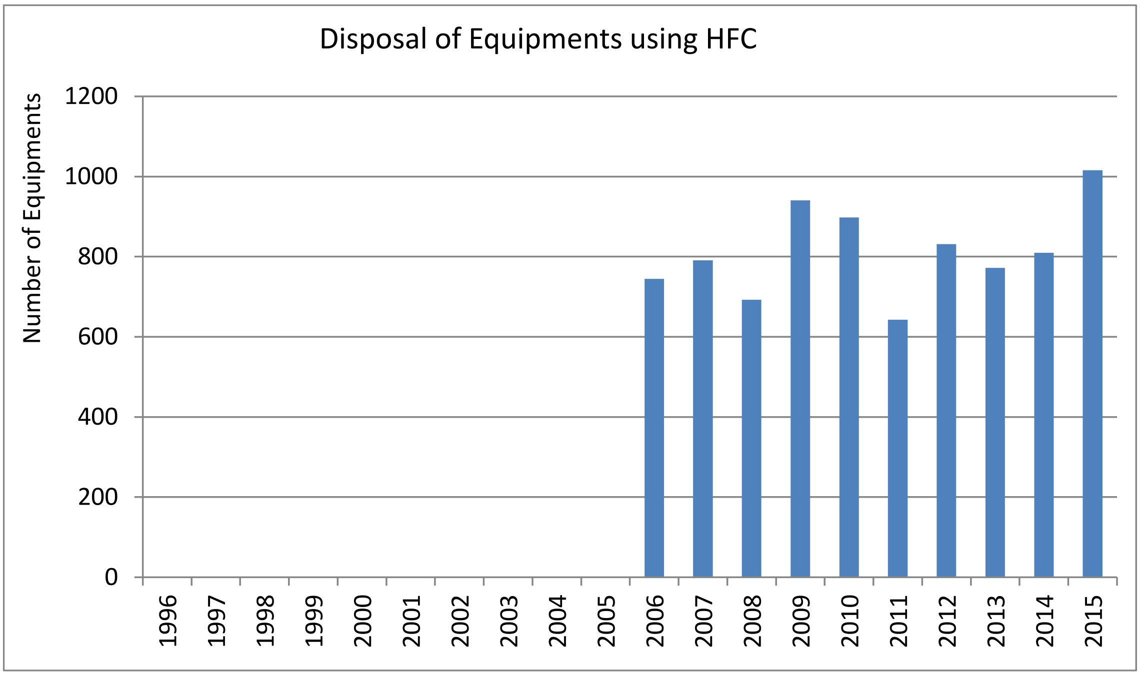
Figure 4-41 – Number of Registered Vehicles in circulation in Portugal using HFC.



4.7.5.5 Activity Data – Disposal

It was assumed a lifetime of 10 years.

Figure 4-42 – Disposal of equipments using HFC.



4.7.5.6 Recalculations

The entire subsector has been revised.

4.7.5.7 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.112 – Transport Refrigeration

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	1.57	10.00	5.35	32.2%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**45.1%**
Lifetime	6	10	10	8.2%
Initial Emission	0.2	1.0	1.0	16.3%
Lifetime Emission	15	50	32.5	22.0%
Residual charge remaining at disposal	0	50	50	20.4%
Recovery efficiency at disposal	0	70	70	23.8%
EF Combined Uncertainty	**-**	**-**	**-**	**42.4%**

4.7.6 Mobile Air Conditioning (CRF 2.F.1.e)

4.7.6.1 Methodology

It was used the same methodology as for Transport Refrigeration (sector 4.7.5.1).

4.7.6.2 Emission Factors

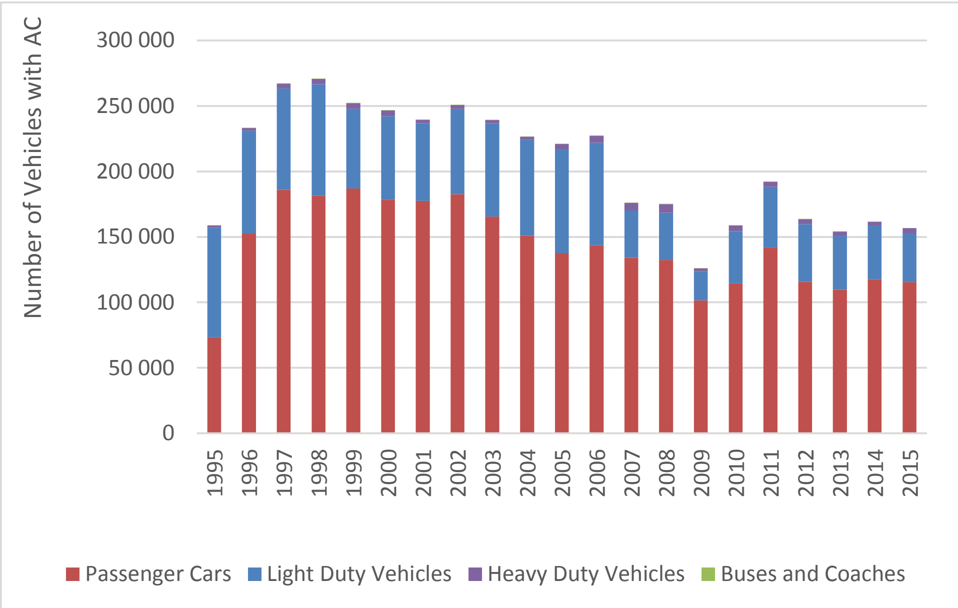
Table 4.113 – Mobile Air Conditioning emission factors

	Unit	Passenger Cars	Light Duty Vehicles	Heavy Duty Vehicles	Buses and Coaches
Initial Charge	Kg/equipment	0.77	0.77	1.20	7.50
Initial Emission (k)	%	0.35	0.35	0.35	0.35
Lifetime Emission (x)	%	15	15	15	15
Lifetime	Years	16	16	16	16
p (residual charge at disposal)	%	40	40	40	40
η (recovery efficiency at disposal)	%	35	35	35	35

4.7.6.3 Activity Data – Road Transportation

Estimates for Road Transportation and Railways were made separately.

Figure 4-43 – Assemblage of Vehicles equipped with AC systems.



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 4-44 – Fleet of Vehicles equipped with AC systems.

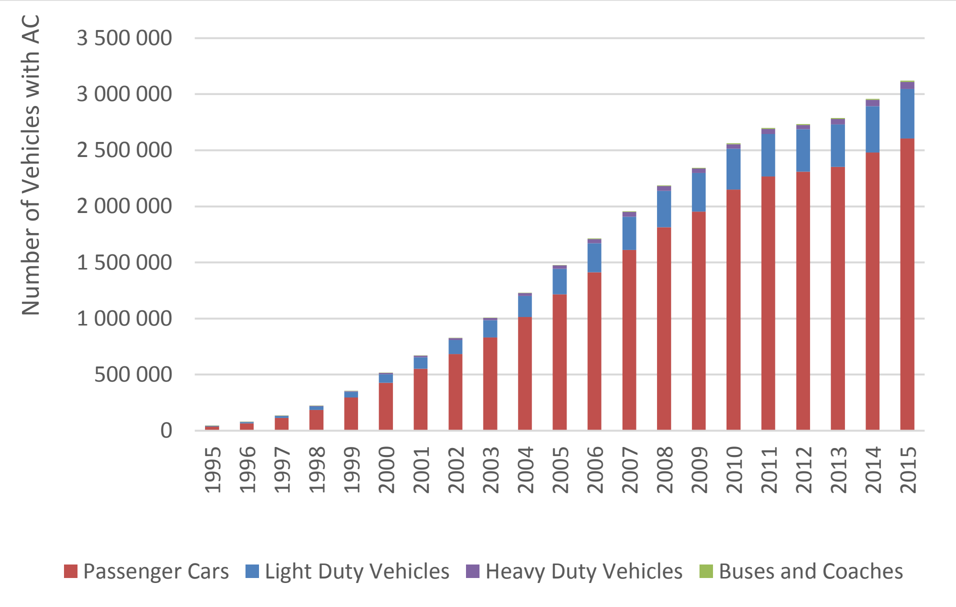
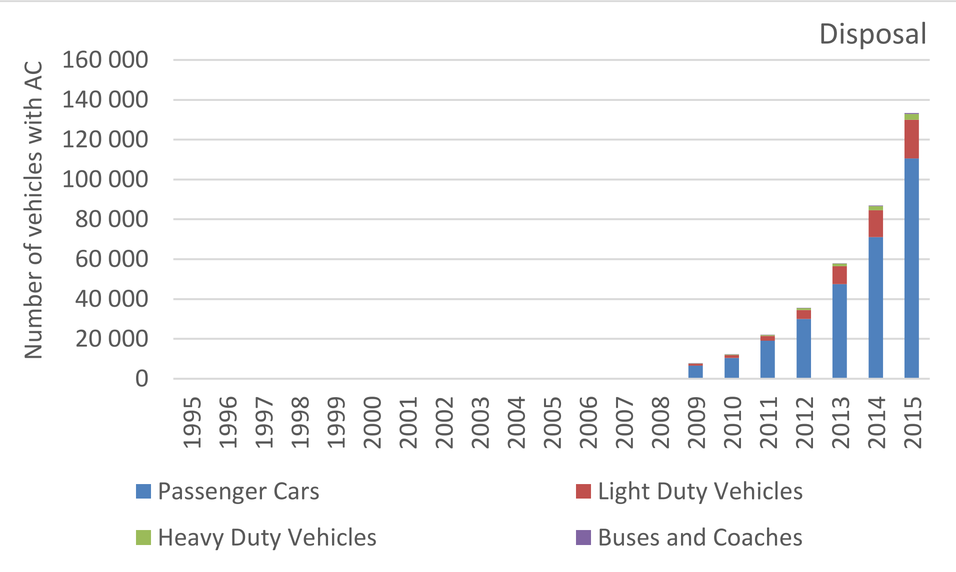


Figure 4-45 – Disposal of Vehicles equipped with AC systems.



4.7.6.4 Activity Data - Railways

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.

4.7.6.5 Recalculations

This subsector has been completely revised.

4.7.6.6 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.114 – Passenger cars and light duty vehicles

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	0.59	0.90	0.77	8.3%
% HFC				10.0%
AD Combined Uncertainty	**-**	**-**	**-**	**16.4%**
Lifetime	9	16	16	8.9%
Initial Emission	0.20	0.50	0.35	17.5%
Lifetime Emission	10	20	15	13.6%
Residual charge remaining at disposal	0	50	40	25.5%
Recovery efficiency at disposal	0	50	35	29.2%
EF Combined Uncertainty	**-**	**-**	**-**	**45.5%**

Table 4.115 – Heavy duty vehicles

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	0.50	1.50	1.20	17.0%
% HFC				10.0%
AD Combined Uncertainty	**-**	**-**	**-**	**22.1%**
Lifetime	9	16	16	8.9%
Initial Emission	0.20	0.50	0.35	17.5%
Lifetime Emission	10	20	15	13.6%
Residual charge remaining at disposal	0	50	40	25.5%
Recovery efficiency at disposal	0	50	35	29.2%
EF Combined Uncertainty	**-**	**-**	**-**	**45.5%**

Table 4.116 – Buses and Coaches

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	4.50	10.00	7.50	15.0%
% HFC				10.0%
AD Combined Uncertainty	**-**	**-**	**-**	**20.6%**
Lifetime	9	16	16	8.9%
Initial Emission	0.20	0.50	0.35	17.5%
Lifetime Emission	10	20	15	13.6%
Residual charge remaining at disposal	0	50	40	25.5%
Recovery efficiency at disposal	0	50	35	29.2%
EF Combined Uncertainty	**-**	**-**	**-**	**45.5%**

Table 4.117 – Railways

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	-	-	-	10.0%
% HFC				10.0%
AD Combined Uncertainty	**-**	**-**	**-**	**17.3%**
Lifetime	20	30	25	8.2%
Initial Emission	0.2	1.0	0.5	32.7%
Operation Emission	1	10	6	30.6%
EF Combined Uncertainty	**-**	**-**	**-**	**45.5%**

4.7.7 Stationary Air conditioning (CRF 2.F.1.f)

4.7.7.1 Methodology

It was used the same methodology as for Transport Refrigeration (sector 4.7.5.1).

Annual stocks were estimated from assemblage data, using the formula:

$$\mathbf{Stocks_y = Stocks_{y-1} + Assemblage_y + Disposal_y}$$

Where:

$Stocks_y$ – stocks of the year y;

$Stocks_{y-1}$ – stocks of the year y-1;

$Assemblage_y$ – Equipments assembled in year y;

$Disposal_y$ – Disposal of equipments in year y.

4.7.7.2 Emission Factors

Table 4.118 – Stationary Air Conditioning emission factors

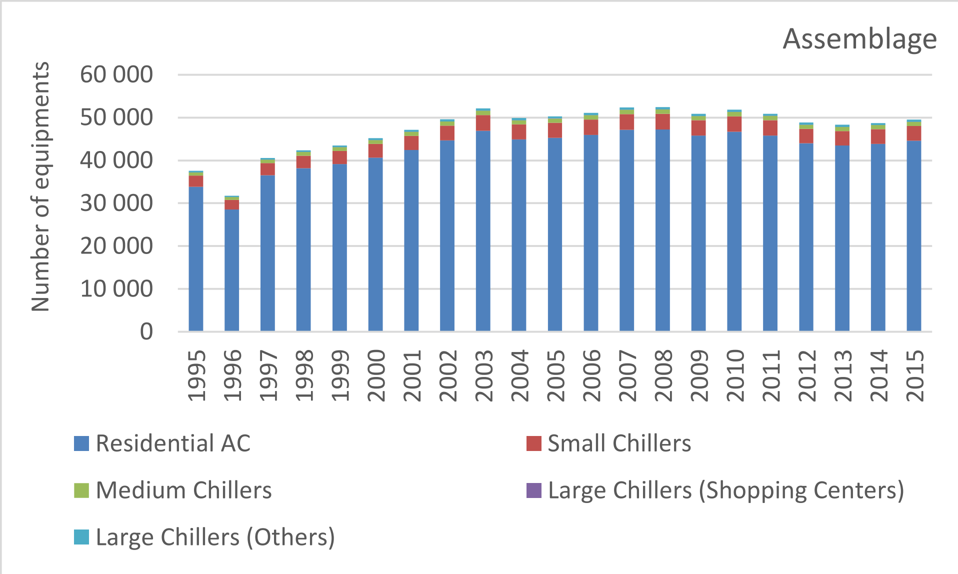
	Unit	Residential AC	Small Chillers	Medium Chillers	Large Chillers (Shopping Centers)	Large Chillers (Other)
Initial Charge	Kg/equipment	0.3	100.0	200.0	441.0	300.0
Initial Emission (k)	%	0.6	0.6	0.6	0.6	0.6
Lifetime Emission (x)	%	5.5	5.5	5.5	5.5	5.5
Lifetime	Years	13	20	20	20	20
p (residual charge at disposal)	%	75	90	90	90	90
η (recovery efficiency at disposal)	%	40	60	60	60	60

4.7.7.3 Activity Data - Assemblage

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 number of assembled stationary air conditioning equipments was available from unpublished information received from IST-UTL (see next figure) from 1990 to 2004. From 2005 onwards, data was estimated based on gross domestic product trend.

Figure 4-46 - Number of Stationary Air Conditioning Equipments assembled in Portugal.



By expert judgment it was assumed the following share between classes of stationary air conditioning equipments:

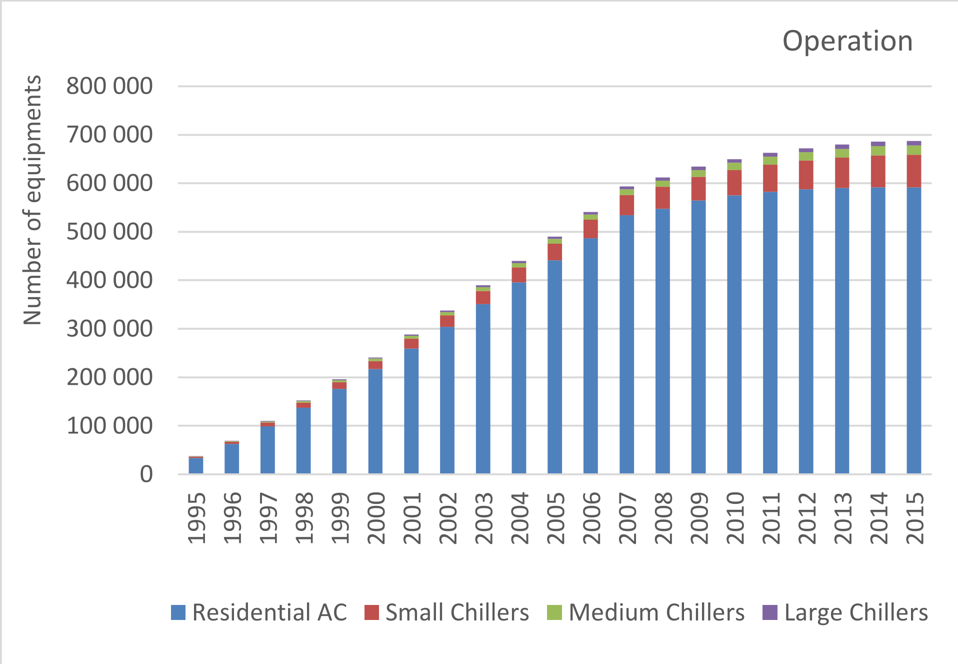
- Residential AC: 90%;
- Small Chillers: 7%;
- Medium Chillers: 2%;
- Large Chillers: 1%.

Table 4.119 – Use of each Gas/Mixture in the assembled equipments (percent)

% of Fluid	Unit	1995	2015
HCFC-22	%	99.0	0.0
R-410A	%	0.3	58.6
R-407C	%	0.3	25.9
HFC-134A	%	0.5	5.7
R-417A	%	0.0	5.0
R-422D	%	0.0	2.7
R-404A	%	0.0	2.0

4.7.7.4 Activity Data – Operation and Servicing

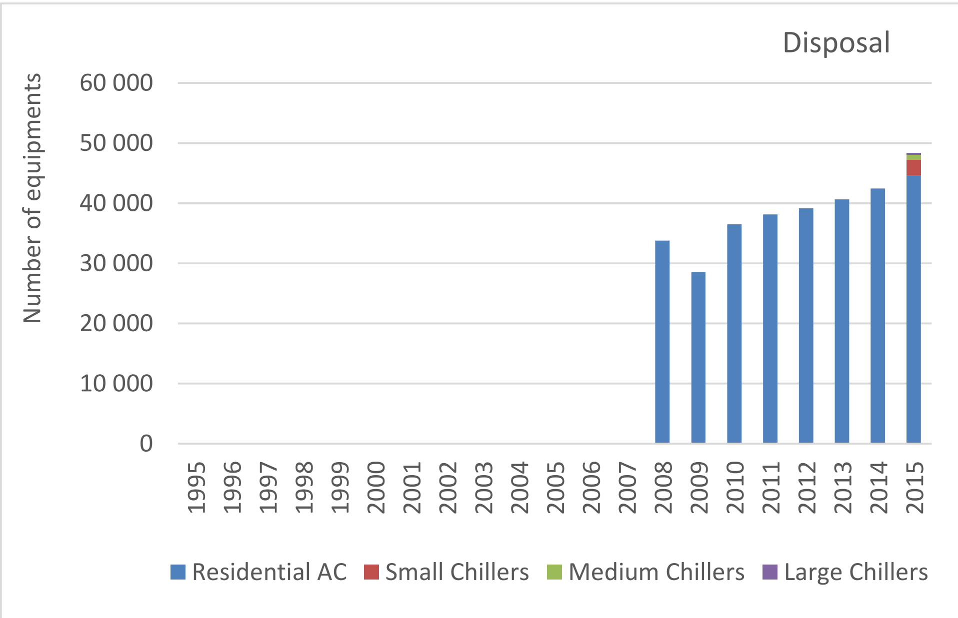
Figure 4-47 - Annual Stock of Stationary Air Conditioning Equipments in Portugal.



4.7.7.5 Activity Data – Disposal

Assuming a lifetime of 13 years for residential AC, disposal emissions started in 2008. For chillers we assumed a lifetime of 20 years and disposal emissions started in 2015.

Figure 4-48 - Disposal of Stationary Air Conditioning Equipments in Portugal.



4.7.7.6 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 2011. From 2012 onwards it was assumed the same annual trend verified in 2011.

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.

4.7.7.7 Recalculations

This sector has been completely revised.

4.7.7.8 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.120 – Residential AC

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	0.2	1.0	0.3	54.4%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**63.0%**
Lifetime	10	20	13	15.7%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	1.0	10.0	5.5	33.4%
Residual charge remaining at disposal	0	80	75	21.8%
Recovery efficiency at disposal	0	80	40	40.8%
EF Combined Uncertainty	**-**	**-**	**-**	**65.1%**

Table 4.121 – Small Chillers

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	30.0%
Initial Charge	50	100	100	10.2%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**43.6%**
Lifetime	15	30	20	15.3%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	2.0	15.0	5.5	48.2%
Residual charge remaining at disposal	80	100	90	4.5%
Recovery efficiency at disposal	0	95	60	32.3%
EF Combined Uncertainty	**-**	**-**	**-**	**66.1%**

Table 4.122 – Medium Chillers

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	30.0%
Initial Charge	150	250	200	10.2%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**43.6%**
Lifetime	15	30	20	15.3%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	2.0	15.0	5.5	48.2%
Residual charge remaining at disposal	80	100	90	4.5%
Recovery efficiency at disposal	0	95	60	32.3%
EF Combined Uncertainty	**-**	**-**	**-**	**66.1%**

Table 4.123 – Large Chillers (Shopping Centers)

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	10.0%
Initial Charge	210	791	441	26.9%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**41.5%**
Lifetime	15	30	20	15.3%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	2.0	15.0	5.5	48.2%
Residual charge remaining at disposal	80	100	90	4.5%
Recovery efficiency at disposal	0	95	60	32.3%
EF Combined Uncertainty	**-**	**-**	**-**	**66.1%**

Table 4.124 – Large Chillers (Other)

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Number of equipments	-	-	-	30.0%
Initial Charge	250	1000	300	51.0%
% HFC				30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**66.4%**
Lifetime	15	30	20	15.3%
Initial Emission	0.2	1.0	0.6	27.2%
Lifetime Emission	2.0	15.0	5.5	48.2%
Residual charge remaining at disposal	80	100	90	4.5%
Recovery efficiency at disposal	0	95	60	32.3%
EF Combined Uncertainty	**-**	**-**	**-**	**66.1%**

4.7.8 Foam Blowing (CRF 2.F.2)

4.7.8.1 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.

4.7.8.2 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[57];

K - first year loss emission factor;

X - annual loss emission factor.

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.

4.7.8.3 Emission Factors

Due to unavailability of country-specific information, default emission factors shown in the following table were used:

Table 4.125 - 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

4.7.8.4 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 from 1995 to 2010. From 2011 onwards, data was estimated assuming the average trend of the period 2008-2010.

[57] For the time being the stock is restricted to foam filled in Portugal;

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.

4.7.8.5 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.126 – Foam Blowing (Closed Cell)

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Amount of foam produced	-	-	-	50.0%
% HFC	-	-	-	30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**58.3%**
Lifetime	12	50	20	38.8%
Emission in first year	7.5	12.5	10.0	10.2%
Emission in subsequent years	0.5	4.5	4.5	18.1%
EF Combined Uncertainty	**-**	**-**	**-**	**44.0%**

Table 4.127 – Foam Blowing (Open Cell)

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Amount of foam produced	-	-	-	50.0%
% HFC	-	-	-	30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**58.3%**
Emission in first year	100	100	100	0.0%
EF Combined Uncertainty	**-**	**-**	**-**	**0.0%**

4.7.9 Fire Protection (CRF 2.F.3)

4.7.9.1 Overview

The consumption of HFC in fire protection systems in Portugal started only in year 1999. The fire protection equipments used in Portugal contain HFC-227ea and HFC-236fa.

4.7.9.2 Methodology

$$\text{Emissions} = \text{F-gas}_{a.s.} - (\text{F-gas}_{n.e} - \text{F-gas}_{r.e.})$$

where:

$\text{F-gas}_{a.s.}$ – F-gas annual sales (t);

$\text{F-gas}_{n.e.}$ – F-gas used to charge new fire protection equipments (t);

F-gas$_{r.e.}$ – F-gas used to charge retiring fire protection equipments (t).

4.7.9.3 Emission Factors

Table 4.128 – Fire protection emission factors

	Unit	Residential AC
Lifetime Emission (x)	%	4
Lifetime	Years	18
p (residual charge at disposal)	%	100
η (recovery efficiency at disposal)	%	0

4.7.9.4 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 the average of the period 2005-2010. It was made a streamline with the national enquiry on fluorinated gases consumption. These equipments contain HFC-227ea and HFC-236fa 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. In the 2005-2009 period there is a decrease in consumption values associated to market saturation.

Figure 4-49 – HFC consumption in new Fire protection Equipments by type of gas (t).

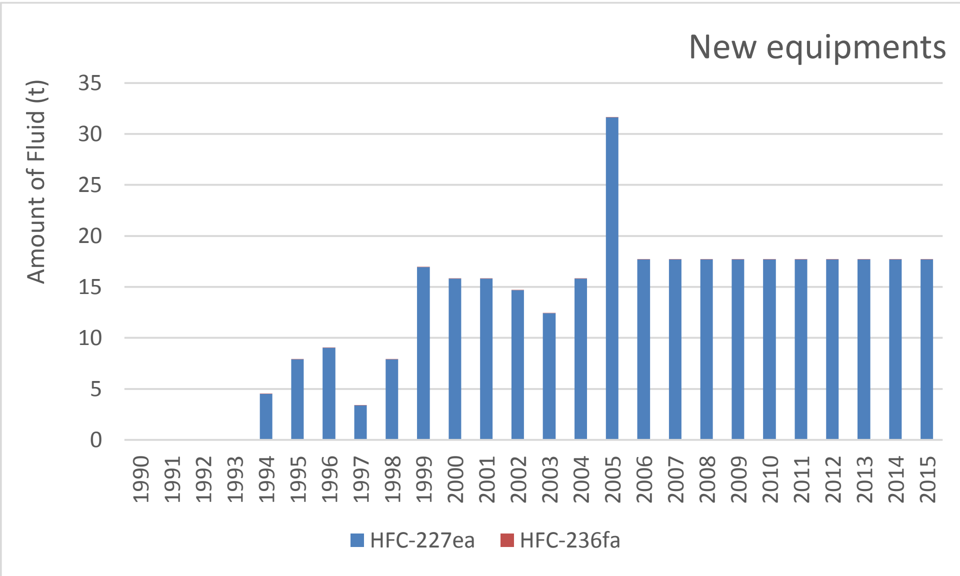
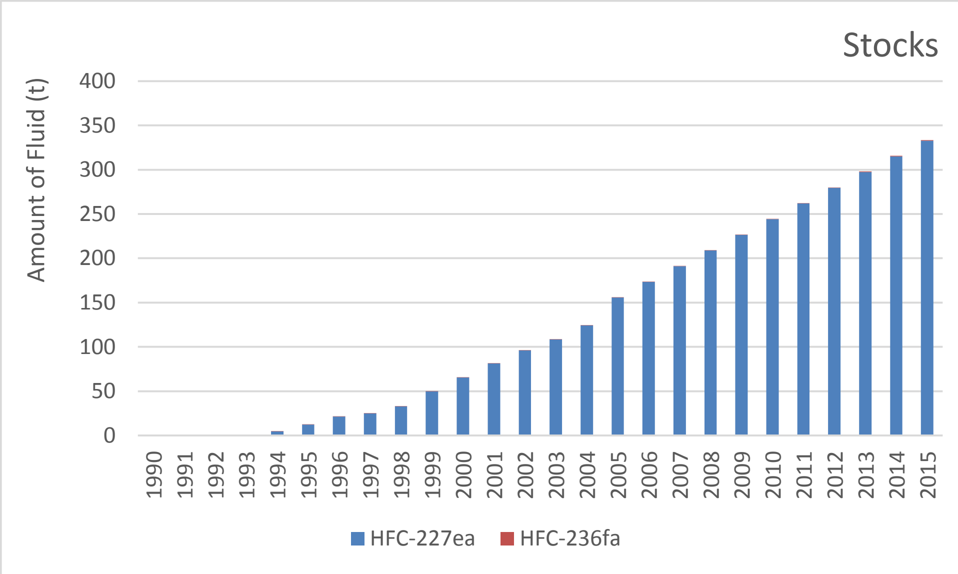


Figure 4-50 – Stocks of HFC in Fire protection Equipments by type of gas (t).



4.7.9.5 Uncertainty Assessment

We used a triangular distribution to estimate uncertainty values based on the minimum and maximum of the range proposed by the guidelines and the more probable value (expert judgment).

Table 4.129 – Fire protection

Parameter	Minimum Value	Maximum Value	Selected Value	U(%)
Charge amount	-	-	-	30.0%
% HFC	-	-	-	30.0%
AD Combined Uncertainty	**-**	**-**	**-**	**42.4%**
Lifetime	15	20	18	5.7%
Lifetime emissions (%)	2	6	4	20.4%
EF Combined Uncertainty	**-**	**-**	**-**	**21.2%**

4.7.10 Further Improvements

No further improvements are expected.

4.7.11 Metered Dose Inhalers (CRF 2.F.4.a)

4.7.11.1 Overview

Fluorinated gases are used as propellants in pressurized solutions (metered dose inhalers) in the treatment of asthma.

4.7.11.2 Methodology

It is assumed that the gas is partly emitted during the same year the inhaler is sold and in the subsequent year.

$$Emi_{HFCt} = [\Sigma(Sold\ MDI_{t-1} * K_{t-1}) + \Sigma\ (Sold\ MDI_t * K_t)] / 2 * 1*10^{-6}$$

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.

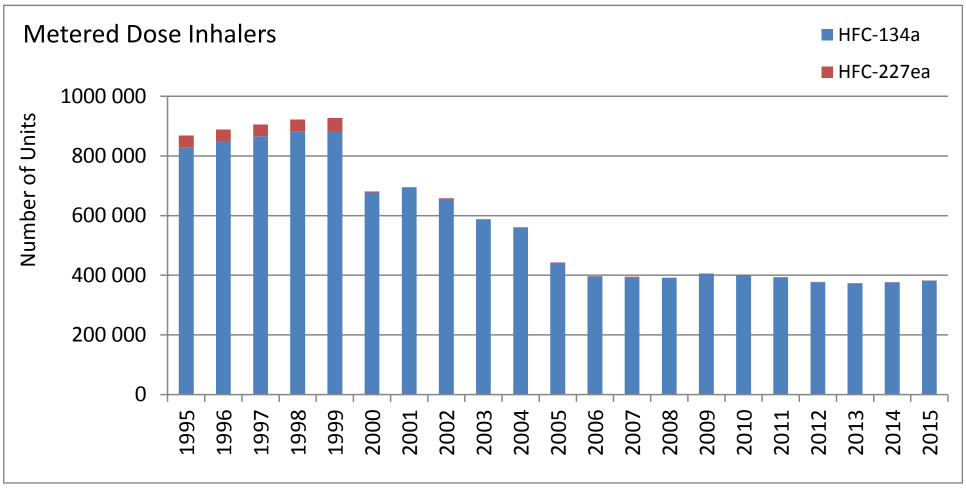
4.7.11.3 Emission Factors

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.

4.7.11.4 Activity Data

Information was gathered on the amounts of sold inhalers charged with F-gases in the period 1990-2010. From 2011 onwards, data was estimated based on gross domestic trend. Information on the % of propellant (F-gas) for each type of inhaler was also provided. The two F-gases in inhalers are HFC-134a and HFC-227ea.

Figure 4-51 – Sold Metered Dose inhalers using F-gases as propellant.



4.7.11.5 Further Improvements

MDI charge values will be further analyzed with the Portuguese Association for Pharmaceutical Products.

4.7.11.6 Uncertainty Analysis

Table 4.130 – Metered Dose Inhalers

Parameter	U(%)
AD Combined Uncertainty	30%
EF Combined Uncertainty	50%

4.8 Other Product Manufacture and Use (CRF 2.G)

4.8.1 Electrical Equipment Manufacturing (CRF 2.G.1)

4.8.1.1 Overview

This chapter will be completely revised in May submission. For 2013 and 2014, it was assumed the same trend verified for each subsector between 2011 and 2012 emissions. The charts and tables in NIR have not been revised.

In Portugal, sulphur hexafluoride (SF_6) 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.

4.8.1.2 Methodology

It is used a Tier 1 methodology based on SF_6 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:

$$SF_6 \text{ emission}_{(y)} = EF * SF_6 \text{ consumption}_{(y)}$$

where

SF_6 emission $_{(y)}$ - annual SF_6 emission in year y (t/yr);

SF_6 consumption $_{(y)}$ – annual SF_6 consumption in year y (t/yr);

EF – Fraction of SF_6 emitted during electrical equipment manufacturing.

4.8.1.3 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.

4.8.1.4 Activity Data

Activity data on SF_6 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.

4.8.1.5 Uncertainty Assessment

The uncertainty in activity data was set at 10 percent, since SF_6 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.

4.8.1.6 Further Improvements

No further improvements are expected.

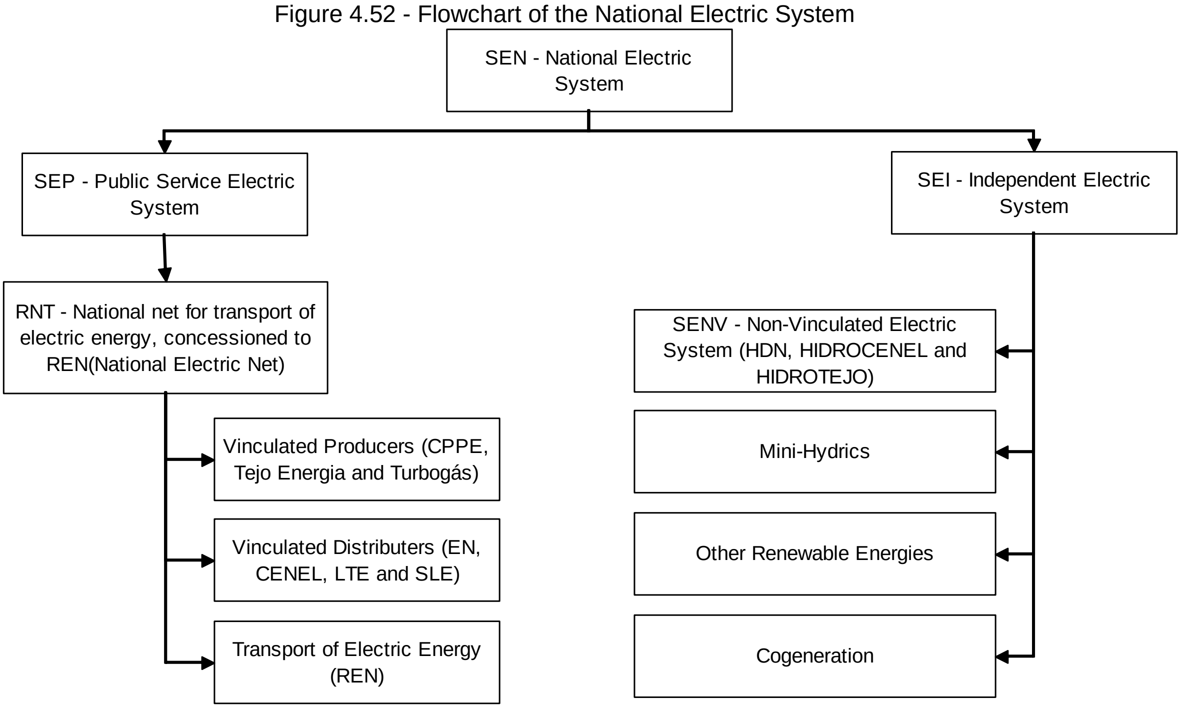
4.8.2 Electrical Equipment Use (CRF 2.G.1)

4.8.2.1 Overview

In Portugal, sulphur hexafluoride (SF_6) 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 4.52 - Flowchart of the National Electric System



In SEP (Public Service Electric System), "REN (National Electric Net)" is responsible for electricity distribution at Very High Voltage (>110 kV), "EDP Distribuição" is responsible for distribution at Low (≤1 kV), Medium (>1 kV and ≤45 kV) and High Voltage (>45 kV and ≤110 kV) and includes vinculated distributors. "EDP Produção" includes vinculated producers "CPPE" units and great part of SEI (Independent Electric System). "Tejoenergia" and "Turbogás" are SEP (Public Service Electric System) vinculated producers.

Figure 4.53 – Map of National Network of Electric Energy Transport

4.8.2.2 Methodology

There are different estimates methodologies for:

- REN;
- EDP Distribuição, EDP Produção, Tejoenergia and Turbogás;
- Other Companies.

4.8.2.2.1 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)

where:

Ti and Pi - Measured Temperature and Pressure at the beginning of reposition of lost SF_6;

Tf and Pf - Measured Temperature and Pressure at the end of reposition of lost SF_6;

R - Gases Constant;

V - Compartment volume filled with SF_6 inside the equipment;

Zi - Compressibility Factor at Pressure Pi and Temperature Ti;

Zf - Compressibility Factor at Pressure Pf and Temperature Tf;

ni - Mole number of SF_6 at pressure Pi and Tf before the reposition of gas;

nf - Mole number of SF_6 at pressure Pf and Tf after the reposition of gas;

M - SF_6 molecular mass;

m - SF_6 mass emitted;

There are two alarm situations that require an intervention and reposition of SF_6:

- Loss of SF6 slightly above Service Pressure (≈70 percent of Maximum Pressure);
- Loss of SF6 below Service Pressure (<70 percent of Maximum Pressure) - in this situation the equipment doesn't work at all;

Besides these two situations there is a team that does regular gas repositions (each 15 days) after temperature and pressure measurements on containers. Each intervention is registered in a database and the equipment used is identified.

4.8.2.2.2 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_6 from electrical equipment were estimated with a tier T3b, based on data provided by "EDP Distribuição", excluding the details in life-cycle and using a country-specific emission factor. Emissions were determined using the following equation:

$$Emi_{SF6\ (t)} = Stock_{SF6\ (t)} * (EF/100)$$

where:

$Emi_{SF6\ (t)}$ - Equipment use emissions, including leakage emissions, servicing and maintenance;

$Stock_{SF6\ (t)}$ - total SF_6 gas in existence at year t in all electrical equipments;

EF – Emission Factor, corresponding to the percentage of SF_6 in stock at year t that is emitted to atmosphere.

4.8.2.2.3 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.

4.8.2.3 Emission Factors

There are different emission factors for:

- REN;
- EDP Distribuição;
- EDP Produção;
- Tejoenergia;
- Turbogás;
- Other Companies.

4.8.2.3.1 REN

The database on SF_6 repositions by equipment was available for the period 2003-2010. For the period 1995-2002 and from 2011 onwards, an average of the estimated loss (0.38 percent) for the period 2003-2010 was considered.

4.8.2.3.2 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 “Cloased 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”;

4.8.2.3.3 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 SF6 stock amounts in “Closed Pressure” equipments from 2000 onwards. There is no data related to SF6 stock in the period 1995-1999 and it is used an average emission factor of 0.93 percent based on 2000-2006 data period.

4.8.2.3.4 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”.

4.8.2.3.5 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”.

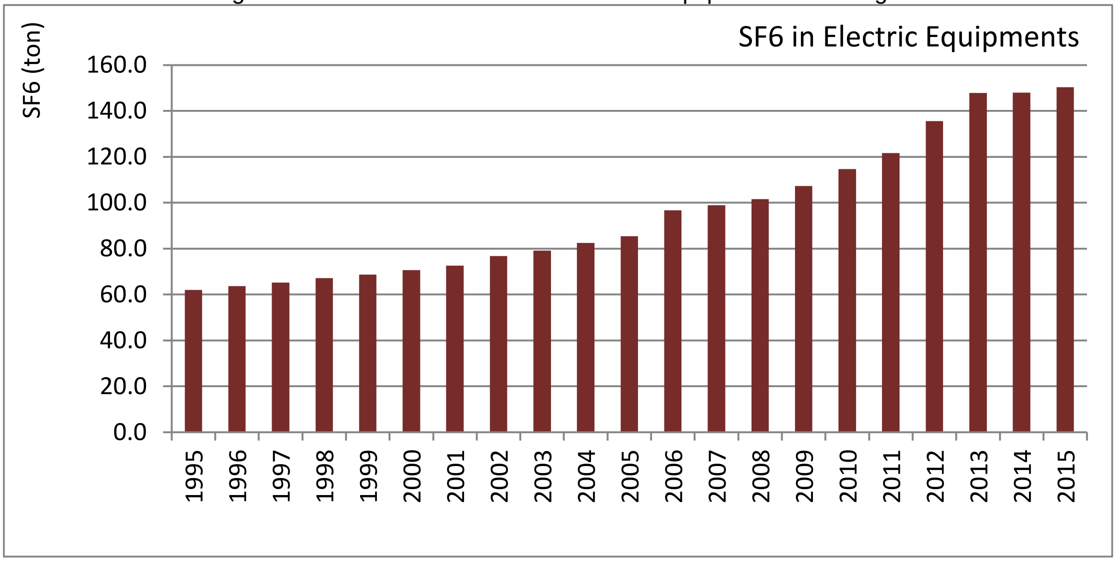
4.8.2.4 Activity Data

Although it is not possible to differentiate activity data in this report, the information on the yearly total amount of SF_6 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 4.131 – Average SF_6 charge for each kind of equipment

Equipment	**SF_6 (kg)**
Gas Circuit Breaker	1.200
Outdoor Gas Insulated Switchgear	0.720
Gas Insulated Switchgear	0.484

Figure 4.54 - Total SF6 in stock in electric equipments in Portugal



4.8.2.5 Uncertainty Assessment

Table 4.132 – Electric Equipment

Parameter	U(%)
AD Combined Uncertainty	**10.0%**
Manufacture	30.0%
Use (Includes leakage, major failures/arc faults and maintenance losses)	30.0%
Lifetime EF	40.0%
EF Combined Uncertainty	**58.3%**

4.8.2.6 Recalculations

The activity data for manfacture of electric equipment has been revised.

4.8.2.7 Further Improvements

No further improvements are expected.

4.8.3 SF6 and PFCs from Other Product Use (CRF 2.G.2)

There are no other product uses of SF_6 and PFCs in Portugal.

4.8.4 N_2O from Product Use – Medical Applications (CRF 2.G.3.a)

4.8.4.1 Overview

Evaporative emissions of nitrous oxide (N_2O) 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.

4.8.4.2 Medical Applications (CRF 2.G.3.a)

4.8.4.2.1 Methodology

The N_2O 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_2O emissions from data of quantity of N_2O supplied that are obtained from manufacturers and distributors of N2O products”. There will be a time delay between manufacture, delivery and use but this is probably small in the case of medical applications because hospitals normally receive frequent deliveries to avoid maintaining large stocks. Therefore, it is reasonable to assume that the N2O products supplied will be used in one year.

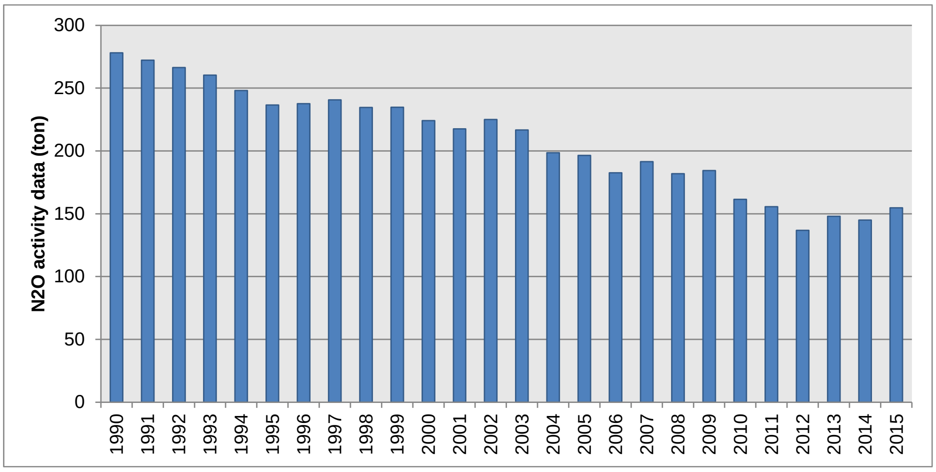
4.8.4.2.2 Emission Factors

It is assumed that none of the administered N2O is chemically changed by the body, and all is returned to the atmosphere. It is reasonable to assume an emission factor of 1.0.

4.8.4.2.3 Activity Data

Consumption of N_2O emissions are calculated from data collected from enterprises. This set of activity data includes estimatives due to lack of data.

Figure 4.4 – N_2O activity data (t).



4.8.4.2.4 Uncertainty Assessment

The uncertainty is associated with the activity data which refers to information collected from the productors/importers and include estimates for the previous years. Values considered are: 1990-2000: 25 %; 2001-2007: 10 %; from 2008 onwards: 1 %.

4.8.4.2.5 Category-specific QA/QC and verification

No category-specific QA/QC has been made for this category.

4.8.4.2.6 Recalculations

No recalculations were made for this category.

4.8.4.2.7 Further Improvements

No further improvements are under consideration at this time.

4.8.4.3 Other (CRF 2.G.3.b)

4.8.4.3.1 Propellant for pressure and aerosol products

Emissions from this category are not occurring.

4.9 Other (2.H)

4.9.1 Paper pulp production (CRF 2.H.1)

4.9.1.1 Overview

In Portugal there were in 1990 six paper pulp plants using the kraft process and two units using the acid sulphide process. Later, in 1993, one of the smaller of the acid sulphide plants was decommissioned and nowadays only 6 plants remain in operation.

Kraft pulping is essentially a digestion process of wood by a solution of sodium sulphide (Na_2S) and sodium hydroxide (NaOH) (white liquor) at elevated temperature and pressure that dissolves lignin and leaves cellulose fibbers 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_2S, occur in digester and blow tank relieves, in evaporators, and in the lime kiln. In the recovery furnace sulphur compounds are oxidized to SO_x, 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_2 absorbed in a base solution. Washing, drying and recovery of chemicals are also part of this production process.

Emissions of CO_2, CH_4 and N_2O 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).

4.9.1.2 Methodology

Air emissions (t/yr) for each pollutant are estimated from production of air dried paper pulp ($Pulp_{PROD}$ - t AD/yr) after applying emission factors (EF - kg/t AD) specific of each pollutant:

$$Emission_{(p,y)} = EF_{(p)} * Pulp_{PROD\ (y)} * 10^{-3}$$

4.9.1.3 Emission Factors

The following emissions factors (kg/ t 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 4.133 – Emission Factors for paper pulp production (non-combustion).

Process	SO_x	NO_x	NMVOC
Kraft	0.31	1.95	2.74
Sulphide	35.5	NA	NA

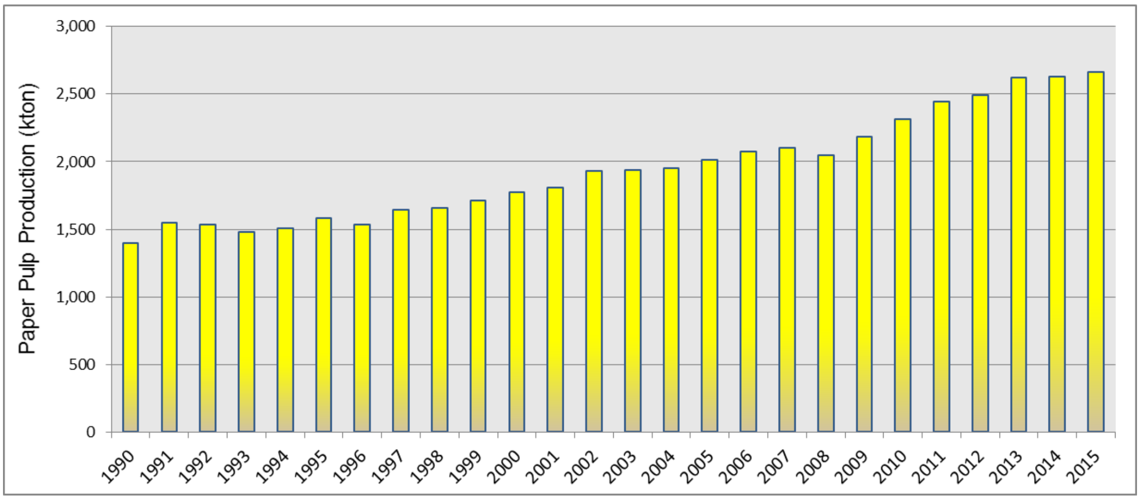
4.9.1.4 Activity Data

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[58] but may not be published individualised due to confidentiality constraints. However, sulphide production is about 5 to 8 % 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.

[58] Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

Figure 4-55 – Total production of paper pulp - Kraft and semi-sulphide.



4.9.1.5 Uncertainty Assessment

This information will be provided in future submissions.

4.9.1.6 Recalculations

No recalculations were made.

4.9.2 Food Manufacturing (CRF 2.H.2)

4.9.2.1 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.

4.9.2.2 Methodology

Emissions where estimated by a Tier 2 methodology using EMEP/EEA emission inventory guidebook 2009 default emission factors multiplied by the quantity of material produced:

$$Emission_{NMVOC\ (y)} = EF_{NMVOC} * ActivityRate_{(y)} * 10^{-3}$$

where:

$Emission_{NMVOC}$ - annual emission of NMVOC in year y (t/yr);

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

EF_{NMVOC} - emission factor (kg/ t).

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60 % of carbon:

$$Emi_{CO2} = 44 / 12 * 0.60 * Emi_{NMVOC} / 1000$$

where:

Emi_{CO2} – annual emission of CO_2 in year y (kt/yr);

$Emission_{NMVOC}$ - annual emission of NMVOC in year y (t/yr).

4.9.2.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (2.D.2. Food and Drink).

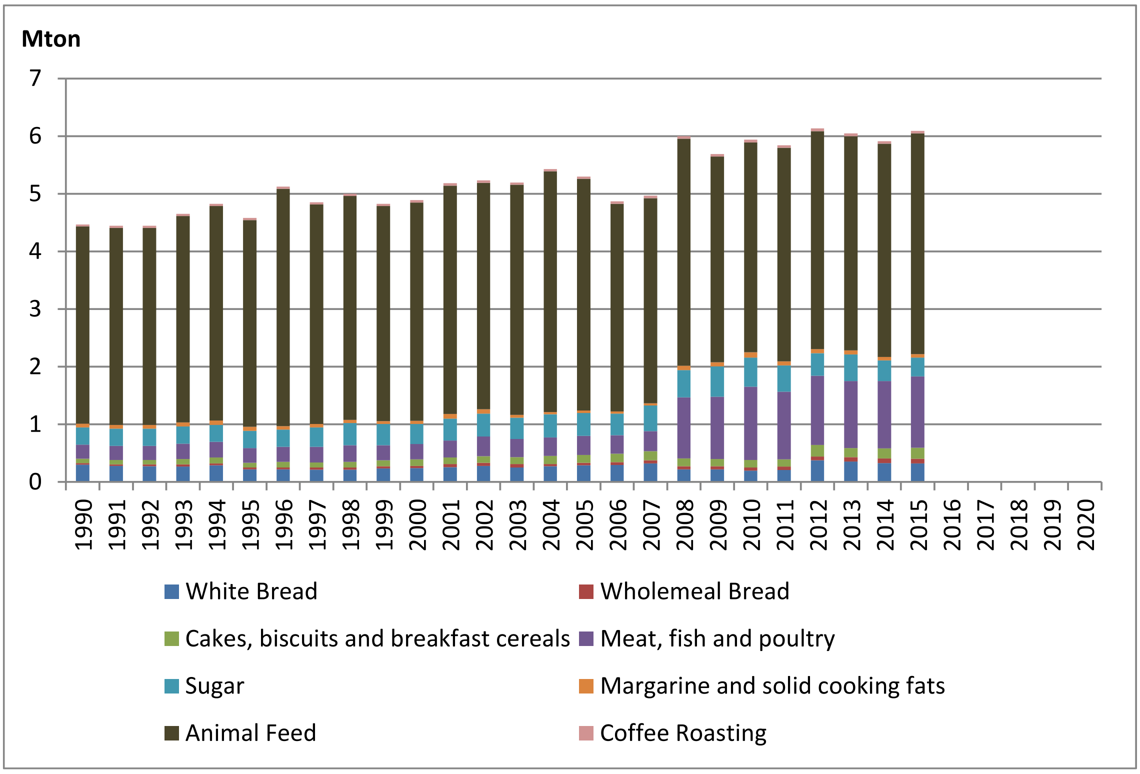
Table 4.134 – Emission Factor for each food product.

Food Product	Unit	EF
White Bread	Kg/t	4.50
Wholemeal Bread	Kg/t	3.00
Cakes, biscuits and breakfast cereals	Kg/t	1.00
Meat, fish and poultry	Kg/t	0.30
Sugar	Kg/t	10.00
Margarine and solid cooking fats	Kg/t	10.00
Animal feed	Kg/t	1.00
Coffee roasting	Kg/t	0.55

4.9.2.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4-56 – Food manufacturing by food product.



4.9.2.5 Recalculations

No recalculations were made.

4.9.2.6 Further Improvements

No further improvements are planned.

4.9.3 Drink Manufacturing (CRF 2.H.2)

4.9.3.1 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.

4.9.3.2 Methodology

We used the same methodology described in Food Manufacturing sector.

4.9.3.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (2.D.2. Food and Drink).

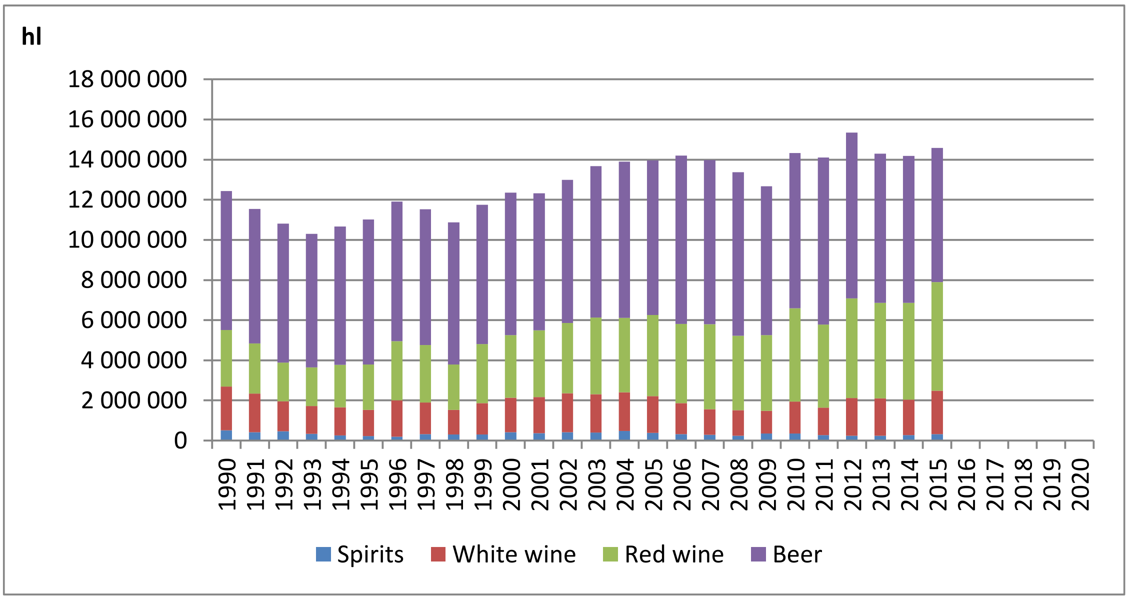
Table 4.135 – Emission Factor for each alcoholic beverage.

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

4.9.3.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4-57 – Drink manufacturing by alcoholic beverage.



4.9.3.5 Recalculations

No recalculations were made.

4.9.3.6 Further Improvements

No further improvements are planned.

4.9.3.7 Wood Chipboard Production (CRF 2.H.3.a)

4.9.3.8 Overview

Chipboard manufacturing involves solvent emission but it is included in this source sector.

4.9.3.9 Methodology

We used the same methodology described in Food Manufacturing sector.

4.9.3.10 Emission Factors

NMVOC emission factor is 0.9 kg/t, from Corinair90 Default Emission Factor Handbook.

4.9.3.11 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.

4.9.3.12 Recalculations

No recalculations were made.

4.9.3.13 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_4 emissions from enteric fermentation (3.A); CH_4 and N_2O emissions from manure management (3.B); direct and indirect N_2O emissions from agriculture soils (3.D); CH_4 from rice cultivation (3.C); CH_4 and N_2O emissions from field burning of agriculture residues (3.F) and CO_2 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_2 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 11.75 % in 1990 to 9.64 % in 2015.

Total GHG emissions from agriculture sector decreased by 5.12 % from 1990 to 2015: 6.98 Mt of CO_2e in 1990 and 6.62 Mt CO_2e in 2015 (Table 5.1). Most significant reduction occurred with nitrous oxide emissions, 10.03 %, while methane emissions reduced 2.83 %.

Table 5.1 – Total Greenhouse Gas Emissions from Agriculture MtCO₂e.

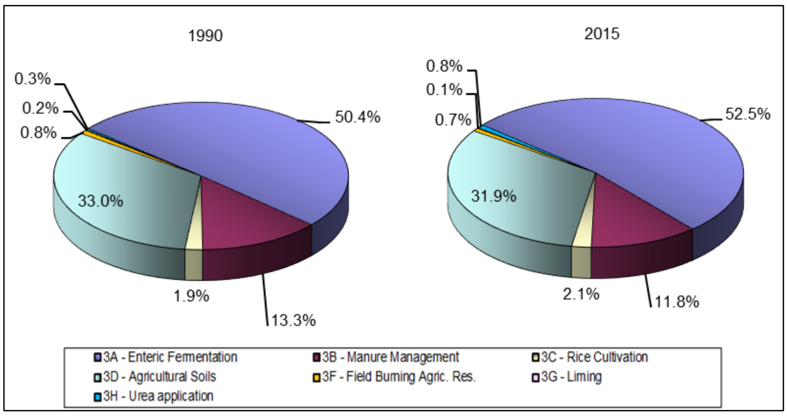
Gas/Source	1990	1995	2000	2005	2010	2013	2014	2015
CH4	**4.37**	**4.39**	**4.57**	**4.36**	**4.26**	**4.17**	**4.19**	**4.24**
Enteric Fermentation	3.52	3.57	3.75	3.60	3.51	3.42	3.45	3.48
Manure Management	0.67	0.68	0.67	0.58	0.58	0.57	0.58	0.59
Rice Cultivation	0.13	0.10	0.12	0.15	0.14	0.14	0.14	0.14
Field Burning of Agricultural Residues	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N2O	**2.58**	**2.49**	**2.73**	**2.22**	**2.17**	**2.27**	**2.33**	**2.32**
Manure Management	0.25	0.25	0.26	0.23	0.22	0.20	0.19	0.19
Agricultural Soils Management	2.31	2.22	2.45	1.98	1.94	2.06	2.12	2.11
Field Burning of Agricultural Residues	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CO2	**0.03**	**0.02**	**0.05**	**0.03**	**0.03**	**0.03**	**0.05**	**0.06**
Liming and Urea application	0.03	0.02	0.05	0.03	0.03	0.03	0.05	0.06
Total	**6.98**	**6.90**	**7.34**	**6.61**	**6.47**	**6.47**	**6.57**	**6.62**

Note: Totals may not sum due to independent rounding.. Emissions values are presented in CO_2e mass units using IPCC AR4 GWP values (CH_4 -25; N_2O- 298).

In 2015, the contribution of each GHG emissions in the total emissions from agriculture, expressed in CO_2e is: CH_4 emissions 64.0% (62.5 in 1990); N_2O emissions 35.1 % (37.0 in 1990) and CO_2 emissions 0.9 % (0.5 in 1990).

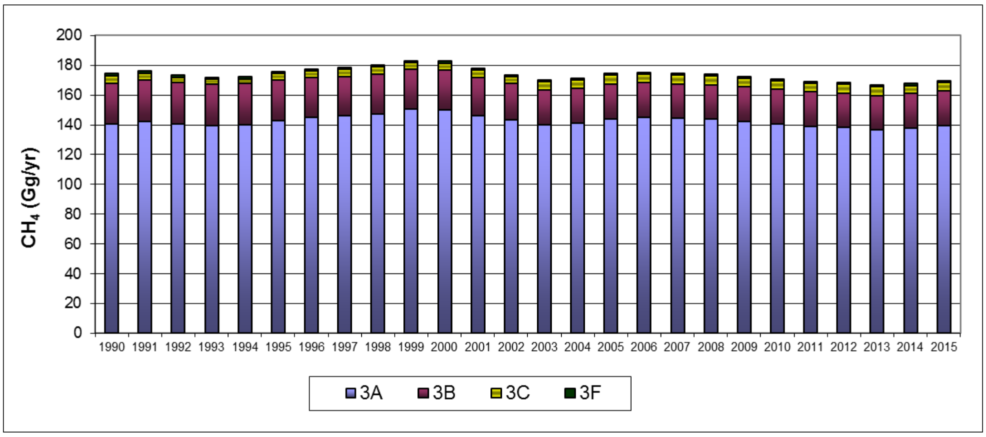
The majority of emissions from agriculture in 1990 and 2015 are the result of three main 3 sub-sources (figure below): Enteric Fermentation, Agriculture Soils and Manure Management (hierarchically listed in order of the most prevalent). Rice cultivation, Field burning of crop residues and Liming and Urea application are minor sub-sources representing all together no more than 3.8 % of the total emissions from agriculture.

Figure 5-1 - Importance of agriculture sub-sectors GHG emissions in 1990 and 2015.



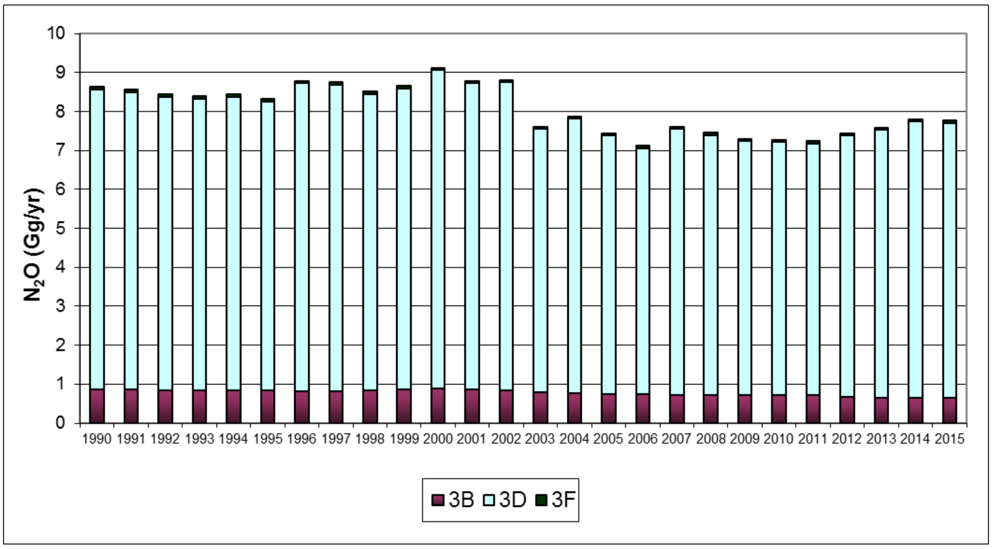
Annual emissions of CH_4 from agriculture have decreased (2.83 %) from 1990 to 2015 (Figure 5-2). The Enteric Fermentation was responsible, in 2015, for 82.02 % of the sectorial methane emissions and Manure Management accounted for 13.4 % of the sectorial emissions in the same year. The remaining 4.04 % of emissions result mainly from Rice Cultivation, with only a very small contribution from Field Burning of Crop Residues, 0.69 %, of total CH_4 emissions in the same year.

Figure 5-2 - Methane emissions from agriculture – trend by source.



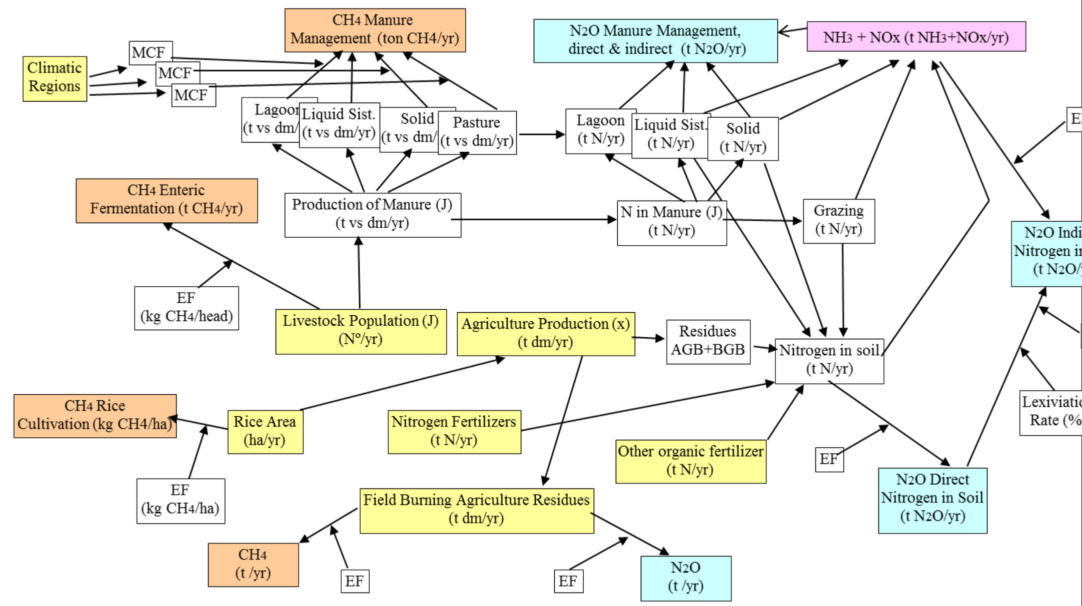
Following the same trend, N_2O emissions have decreased by 10.03 % from 1990 to 2015 (Figure 5-3). The great majority of emissions in 2015 were associated with direct and indirect emissions from Agricultural Soils (90.99 %), Manure Management is responsible for 8.29 % of emissions, while the small remaining fraction results from Field Burning of agricultural crop residues (0.72 %).

Figure 5-3 - Nitrous Oxide emissions from Agriculture – trend by source.



Emissions were estimated following as far as possible the methodology recommended by *IPCC 2006 Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) and were done in a consistent way: the same activity data is used and balanced for all source categories. A general overview of methodology is presented in the figure below.

Figure 5-4 - Overview of Methodology.



This integration of calculus means that changes in methodology are done also in a consistent and coherent way among the several source sectors. Improvements in methodology in each source sector are reflected in changes in other related sources.

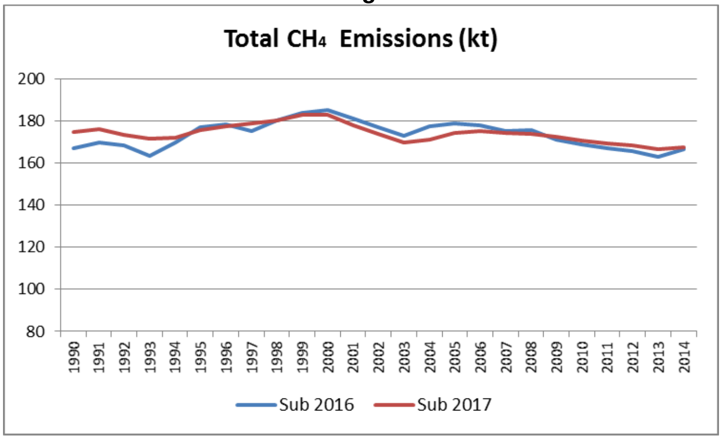
5.2 Recalculations

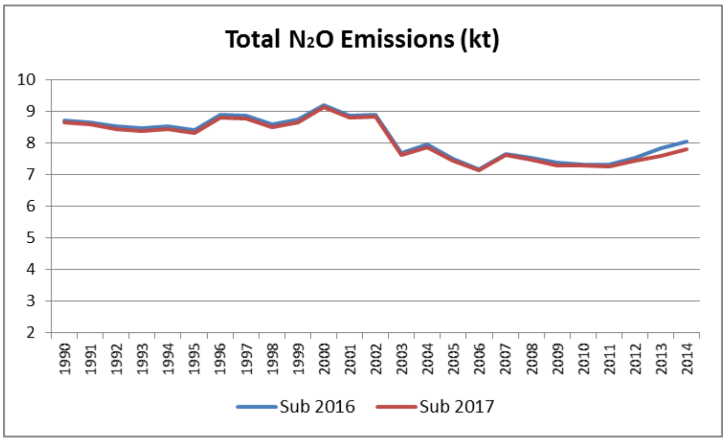
The major changes between submissions (2016 and 2017) result from the following actions:

- revision of 2013 and 2014 values for apparent consumption of inorganic N fertilizers updated by the National Statistical Institute (INE);
- implementation of the tier 2 methodology of EMEP/EEA Guidebook 2016 to estimate NH_3 emissions from inorganic N fertilizers, including the new default emission factors. These calculations also affect N_2O indirect emissions;
- enteric fermentation EF of non-dairy cattle, sheep and goats: it was withdrawn the correlation factor used (centered in 1998) to correct parameters in the time serie. This was a recommendation of UNFCCC review 2016;
- revision of 2013 and 2014 values for sewage sludge applied to agricultural sector updated by the waste sector;

The differences between last year submission and this year submission are graphically represented in the figures below for the total methane emissions and for the total nitrous oxide emissions from agriculture sector.

Figure 5-5 - Differences between submission 2016 and submission 2017 for CH_4 and N_2O emissions from agriculture sector.





5.3 CH_4 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 presented the estimates of CH_4 emission from enteric fermentation.

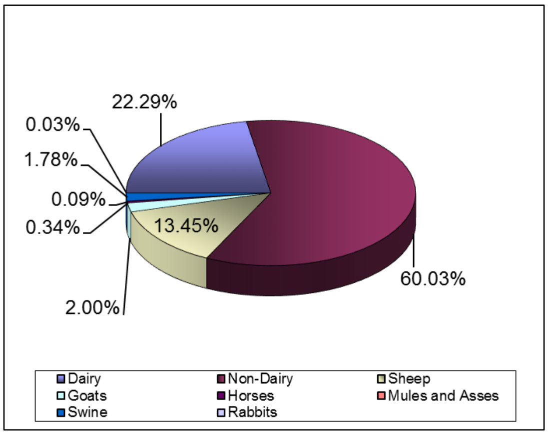
Table 5.2 – CH4 emissions from enteric fermentation (kt).

Livestock type	1990	1995	2000	2005	2010	2013	2014	2015
Dairy cattle	38.19	37.34	39.95	35.57	32.71	30.69	31.46	31.02
Non- dairy cattle	60.19	61.39	67.36	74.96	79.40	80.68	81.49	83.54
Sheep	31.77	34.07	33.86	26.45	22.07	19.44	18.95	18.72
Swine	3.09	3.07	2.79	2.32	2.31	2.34	2.39	2.47
Goats	5.69	4.93	4.35	3.33	3.07	2.93	2.85	2.78
Horses	0.59	0.86	1.05	0.93	0.68	0.48	0.47	0.47
Mules and asses	1.18	1.03	0.69	0.40	0.22	0.15	0.14	0.13
Rabbits	0.13	0.11	0.09	0.08	0.07	0.05	0.05	0.04
Total	**140.83**	**142.79**	**150.12**	**144.05**	**140.53**	**136.76**	**137.80**	**139.18**

Note: Totals may not sum due to independent rounding

CH_4 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, 22.3% to 227.1% of total CH_4 emissions from Enteric Fermentation, while non-dairy cattle represents about 42.7 to 60.0 % of total CH_4 from enteric fermentation. Together, in 2015, cattle were responsible for about 82.3 % of total CH_4 emissions from enteric fermentation.

Figure 5-6 - Relative Importance of emissions of CH_4 from Enteric Fermentation per each animal species in 2015.



Sheep is also an important source of methane, for which emissions have oscillated in the time series between 13.5 and 24.0 % of total CH_4 from enteric fermentation. Emissions from goats were 2.0 to 4.0 % and from swine were 1.6 to 2.3 % of total enteric fermentation emissions. Total emissions of methane for all other species varied between 0.5 and 1.4 %, for the same period and have less importance.

5.3.2 Methodology

Emissions were estimated for each animal type[59] by multiplication of the number of animals by the respective emission factor, in accordance to equation 10.19 of the IPCC 2006 (vol 4, Chapter 10).

$$Emi_{CH_4\,(y)} = \Sigma_t\,[EF_{(i,y)} * N_{(i,y)}]$$

where, for each specie:

Emi_{CH_4} - methane emissions from enteric fermentation in year y, kg CH_4/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 used, by animal type and subcategoy, may be seen in Table 5.3, where is also indcated the corresponding methodology level used to calculate each one. Methodological approach 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. In Portugal.There are no livestock populations of Buffalo, Camels or Lamas .

The default emission factors proposed by IPCC 2006 in table 10.10 (vol 4, chapter 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 charactheristics allowed the use of a higher level methodology, tier 2.

[59] 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_4/head/year). Comparison with the defaults IPCC 2006

Animal type	sub-class	EF (kg CH_4/hd/yr)		
		Country estimates (T2)		Default[2] (T1)
Dairy-Cattle	Dairy Cows	131.8	T2	128
Non-dairy cattle	Beef calfs (<1 yr)	21.7	T2	57 / 58
	Calfs, Males for Replacements (<1 yr)	47.2	T2	
	Calfs, Females for Replacements (<1 yr)	40.3	T2	
	Males 1-2 yrs	67.3	T2	
	Beef Females 1-2 yrs	45.9	T2	
	Females for Replacemet 1-2 yrs	57.0	T2	
	Steers (>2 yrs)	90.6	T2	
	Heifers for Beef (>2 yrs)	61.1	T2	
	Heifers for Replacements (>2 yrs)	61.1	T2	
	Non-dairy cows	91.8	T2	
Swine	Piglets (<20 kg)	0.3	T2	1.5
	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	9.8	T2	8
	Other: rams and young males	12.5	T2	
	Lambs	3.2	T2	
Goats	Does	7.8	T2	5
	Other: bucks and young males	5.2	T2	
	kids	3.0	T2	
Equidae	Horses	18.0	T1	18
	Asses & Mules	10.0	T1	10
Other	Rabbits[1]	0.3	T2	--

1Per female cage; 2 – from tables 10.10 and 10.11 of IPCC 2006, volume 4, chapter 10

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_{CH4} - emission factor, kg CH_4/hd/yr;

GE - gross energy intake, MJ/hd/day;

Y_m - methane conversion factor (% of gross energy in feed that is converted to methane).

The factor 55.65 (MJ/kg CH_4) 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[60] 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[61] and 365 days. Therefore, lactating and non – lactating periods are included in the estimation of the CH_4 dairy cattle emission factor.

Livestock numbers, annual milk production and fat content of milk are published by National Statistical Institute (INE) disaggregated by region.

The majority of cows used for milk production in Portugal belong to the Frisians race. The average weight of 600 kg for mature Frisian cows was supplied by experts[62] 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 (1999-2015) of National Animal Registration (SNIRA)[63] . 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 - 2015) for the relevant country[64] specific parameters used to estimated CH_4 dairy cow emissions from enteric fermentation.

[60] Dra Olga Moreira e Engª Teresa Dentinho - Unit of Animal Production and Health

[61] The same time series used in the inventory but not averaged over 3 years.

[62] Dr Vicente de Almeida - Animal Genetic Resources Department ; Dr José Neves – Unit of Animal Identification, Registration and Movement

[63] Provided by Funding Institute for Agriculture and Fisheries (IFAP),

[64] 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^{-1})	Average Milk production (kg hd^{-1} d^{-1})	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	74.80	22.14	73.34
1996	600	13.00	3.91	74.78	22.61	73.33
1997	600	13.19	3.90	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	21.95	3.75	75.36	38.67	72.85
2014	600	23.42	3.76	76.43	38.17	72.84
2015	600	22.70	3.76	73.62	37.58	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 1993/1994, 2003/2004, 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_4 Emission Factor (kg CH_4/hd/yr) from dairy cows enteric fermentation, which were calculated based on the equations described in IPCC 2006[65] (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).

[65] Volume 4, Chapter 10

A constant methane conversion factor of 6.5% (IPCC2006 value from table 10.12) of gross energy intake was applied.

Table 5.5 - Methane Emission Factors from enteric fermentation - dairy cattle.

Year	NEm	NEa	NEg(1)	NEl	NEw	NEp	REM	GE (Mj hd-1 d-1)	CH_4 EF (kg CH_4 hd-1yr-1)
1990	46.80	1.70	0.00	37.44	0.00	3.52	0.54	227.17	96.85
1991	46.80	1.77	0.00	37.22	0.00	3.52	0.54	226.75	96.71
1992	46.80	1.69	0.00	36.90	0.00	3.51	0.54	225.89	96.27
1993	46.80	1.71	0.00	34.33	0.00	3.51	0.54	219.43	93.53
1994	46.80	1.74	0.00	36.03	0.00	3.51	0.54	223.74	95.43
1995	46.80	1.76	0.00	37.94	0.00	3.50	0.54	228.67	97.52
1996	46.80	1.80	0.00	39.49	0.00	3.50	0.54	232.72	99.25
1997	46.80	1.88	0.00	39.97	0.00	3.50	0.54	234.17	99.92
1998	46.80	2.01	0.00	41.23	0.00	3.51	0.54	237.81	101.52
1999	46.80	2.23	0.00	47.35	0.00	3.52	0.54	254.32	108.50
2000	46.80	2.25	0.00	51.77	0.00	3.52	0.54	265.49	113.35
2001	46.80	2.42	0.00	53.56	0.00	3.53	0.54	270.83	115.57
2002	46.80	2.57	0.00	58.05	0.00	3.60	0.54	283.29	120.73
2003	46.80	2.58	0.00	55.58	0.00	3.52	0.54	277.36	118.01
2004	46.80	2.58	0.00	55.92	0.00	3.51	0.54	278.03	118.37
2005	46.80	2.70	0.00	59.61	0.00	3.51	0.54	288.06	122.54
2006	46.80	2.77	0.00	60.09	0.00	3.53	0.54	288.98	123.23
2007	46.80	2.79	0.00	60.33	0.00	3.49	0.54	289.61	123.48
2008	46.80	2.78	0.00	62.90	0.00	3.47	0.54	295.54	126.24
2009	46.80	2.92	0.00	64.08	0.00	3.46	0.54	299.83	127.78
2010	46.80	2.99	0.00	64.50	0.00	3.47	0.54	300.87	128.39
2011	46.80	2.99	0.00	64.65	0.00	3.54	0.54	302.13	128.67
2012	46.80	3.10	0.00	66.65	0.00	3.58	0.54	307.61	131.14
2013	46.80	3.08	0.00	65.29	0.00	3.53	0.53	305.04	129.34
2014	46.80	3.04	0.00	69.71	0.00	3.58	0.53	316.28	134.27
2015	46.80	2.99	0.00	67.53	0.00	3.45	0.54	309.15	131.80

(1)Assumed no gain weight as definition of dairy cows category are mature cows.

For the year 2015 the estimated EF is 131.80 (kg CH_4 / hd /yr) which is higher than the default value 128 (kg CH_4 / hd /yr) but not much different.

5.3.3.1.2 Non-dairy Cattle

The Ministry of Agriculture (MAM[66]) 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 pure breed animals represents about 20 % of total reproductive animals. Most of the animals in the remaining livestock population are the result of cross-breeding and t 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:

[66] 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[67]. 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 equations10.3, 10.4, 10.8, 10.13, 10.6 and 10.11, respectively.

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[67]).

Finally Gross Energy Intake (GE), expressed in energy, was calculated using equation 10.16 (IPCC 2006)[67].

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[68]. 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.

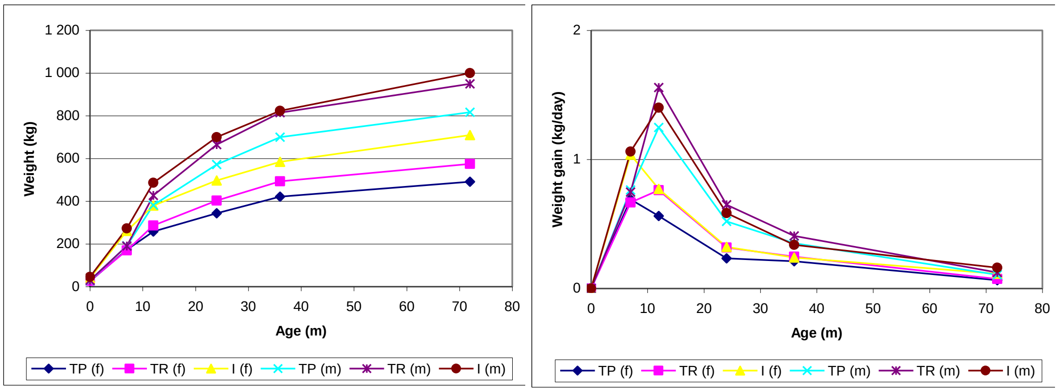
The evolution pattern of growth, represented in the next Figures, was built based on the weights at birth, weaning age (7 months) and adult age (72 months) collected directly from the database information and on the weights at intermediate ages (12,24,36 months) calculated in relation to the adult weight (%) [69].

[67] Volume 4, Chapter 10

[68] Imported breeds are Charolês; Limousine; Simmental Fleckvieh and Salers. Breeds in traditional pasture are: Arouquesa, Barrosã, Marinhoa, Maronesa, Minhota/ Galega, Cachena, Ramo Grande and Mirandesa. Traditional range breeds are: Alentejana, Garvonesa, Brava, Mertolenga and Preta.

[69] References obtained from french traditional and beef animals, Jarrige (1988)

Figure 5-7 – Evolution pattern growth for cattle: (I) Imported breeds; (Tp) Traditional Pasture and (Tr) Traditional Range, for males (m) and females (f).



(a) (b)

(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 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[i]	NEa (Mj/ d)	Cg	NEg (Mj/ d)	Work (h/d)	NEw (kg/d)
Beef calfs (<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	0.040	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[ii]	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)[i]	8.000
F (Fat content of Milk) (%)	4.000
NE_l (MJ/ day)	12.615
$C_{pregnancy}$	0.100
NE_p (MJ /d)	2.787

i) Value considered for non-diary 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	599

Table 5.10 – Non dairy cattle estimated Gross Energy (GE) and CH_4 Emission Factor (EF) from enteric fermentation. Weighted averages from individual breeds.

sub-class	∑ NE (MJ/d)	REM (ratio)	REG (ratio)	DE (%)	GE (MJ/d)	Ym (%)	EF CH4 (kg/hd/y)
Beef calfs (<1 yr)	29.196	0.514	0.308	65.0	104.5	6.5	21.7
Calfs, Males for Rep. (<1 yr)	31.075	0.514	0.308	65.0	110.8	6.5	47.2
Calfs, 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 (i)	67.3
Beef Fem. 1-2 yrs	36.014	0.495	0.278	60.0	133.7	5.2 (i)	45.9
Females for R. 1-2 yrs	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

Methane implied emission factors for non-dairy cattle category in the complete time series are presented in the following table.

Table 5.11 – Methane implied emission factor (IEF) of non dairy cattle category in the time series.

Year	IEF Kg CH_4/hd/yr
1990	61.52
1991	61.38
1992	61.09
1993	61.34
1994	61.77
1995	62.45
1996	63.17
1997	63.74
1998	64.06
1999	63.86
2000	63.81
2001	63.62
2002	63.61
2003	63.55
2004	63.45
2005	63.51
2006	63.89
2007	64.30
2008	64.58
2009	64.76
2010	64.67
2011	64.35
2012	63.96
2013	64.11
2014	64.22
2015	64.12

In 2015, the non-dairy cattle implied emission factor (IEF) was 64.12 kg CH_4/hd/yr, which is higher but not much different, than the default IPCC 2006 values of 57/58 kg CH_4/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[70] native Portuguese breeds of sheep and the five native Portuguese breeds of goats[71]. Three imported breeds of sheep[72] 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[73] for sheep was used.

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.

[70] 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.

[71] Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

[72] Assaf, Ile de France and Merino Precoce.

[73] Volume 4, Chapter 10

Table 5.12 – Parameters used in determination of Net Energy for sheep and goats (weighted averages of individual breed per sub-class animal type).

	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
Cfi[i]	0.250	0.217	0.254	0.250	0.217	0.254
NEm (MJ/day)	6.58	4.30	2.28	3.79	2.68	1.43
Ca[ii]	0.017	0.017	0.017	0.024	0.024	0.024
NEa (MJ/day)	1.39	0.93	0.33	0.90	0.68	0.24
WG (kg/day)	-	-	0.064	-	-	0.160
NEg (MJ/day)	-	-	0.90	-	-	1.08
Wool (kg/yr)	6.5	3.6	-	-	-	-
NEwool (MJ/day)	0.43	0.23	-	-	-	-
Milk Production (kg/day)	-	0.184	-	-	1.238	-
Energy Value of Milk (Mj/kg)[iii]	-	4.60	-	-	2.80	-
NEl (Mj/day)	-	0.96	-	-	3.47	-
Cpregnancy	-	0.077	-	-	0.077	-
NEp (MJ/day)	-	0.33	-	-	0.20	-

i – For Ram and Bucks Cfi value was increased by 15% for intact males; for lambs and kids Cfi 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 5.13 – Sheep and goats estimated Gross Energy (GE) and CH_4 Emission Factor from Enteric Fermentation (weighted averages of individual breeds).

	Sheep			Goats		
	Ram	Ewe	Lamb	Buck	Doe	Kid
REM	0.495	0.495	0.529	0.495	0.495	0.529
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 CH4/hd/yr)	12.53	9.81	3.23	5.18	7.78	3.00

Methane implied emission factors for sheep and goats categories in the complete time series are presented in the next two tables.

Table 5.14 – Methane implied emission factor (IEF) for sheep category in the time series

Year	IEF Kg CH_4/hd/yr
1990	9.74
1991	9.76
1992	9.82
1993	9.86
1994	9.92
1995	9.92
1996	9.89
1997	9.87
1998	9.89
1999	9.88
2000	9.78
2001	9.58
2002	9.35
2003	9.25
2004	9.25
2005	9.29
2006	9.31
2007	9.25
2008	9.21
2009	9.23
2010	9.26
2011	9.25
2012	9.20
2013	9.20
2014	9.17
2015	9.13

Table 5.15 – Methane implied emission factors (IEF) goats category in the time series

Year	IEF Kg CH_4/hd/yr
1990	7.02
1991	6.97
1992	6.93
1993	6.93
1994	6.94
1995	6.94
1996	6.95
1997	6.95
1998	6.92
1999	6.92
2000	6.98
2001	7.10
2002	7.19
2003	7.22
2004	7.19
2005	7.19
2006	7.16
2007	7.15
2008	7.16
2009	7.17
2010	7.20
2011	7.22
2012	7.23
2013	7.23
2014	7.23
2015	7.24

In 2015, the implied emission factors (IEF) for sheep enteric fermentation was 9.13 (kg CH_4/hd/yr) and the IEF for goats enteric fermentation was 7.44 (kg CH_4/hd/yr). Both IEFs are higher than the respectives 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:

$$GE = Feed_{ED} / (DE / 100)$$

where:

GE – gross energy, MJ/day;

$Feed_{ED}$ – Recommended feed ingestion, expressed in digestible energy, MJ ED/day;

DE - digestible energy expressed as a percentage of gross energy, %.

The characteristics of each animal class as they were used to derive final emission factors for CH_4 emissions from enteric fermentation were obtained from INRA (1984) for each animal sub-class and are presented in Table 5.16.

Table 5.16 – Parameters used in determination of Gross Energy (GE) and enteric fermentation methane emission factor by swine and rabbits (values INRA (1984).

sub-class	Weight (kg)	ED (MJ/day)	DE (% GE)	EF (kg CH_4/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 (r2 - 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[1]	per female cage.

(1)From Italian NIR

In 2015, the IEF from enteric fermentation by swine was 1.2 (kg CH_4/hd/yr) which is lower than the default IPCC 2006 but not so different.

5.3.3.1.5 Poultry[74]

The methodology that was used to derive Gross Energy ingestion is similar to that used for swine and rabbits, albeit Metabolic Energy (ME) is used as indicator of feed ingestion, and digestibility is replaced by Metabolisability (McDonald et al, 2002; INRA, 1985):

$$GE = Feed_{ME} / [(EM/GE) / 100]$$

where:

GE – gross energy, MJ/day;

$Feed_{ME}$ – Recommended metabolic energy ingestion, MJ/day;

EM/GE - Metabolisability, metabolic energy expressed as a percentage of gross energy, %.

Table 5.17 – 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
Turkeys	3.23	68.0	4.75	NA
Ducks[#]	1.46	65.8	2.22	NA

used as reference for other poultry

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 on agriculture[75] 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 several Quality Control measures by INE. The complete National Methodological Report is available at Eurostat website http://ec.europa.eu/eurostat/web/agriculture/national-methodology-reports.

[74] CH_4 emissions from Enteric Fermentation are not estimated for Poultry. Nevertheless GE is estimated for these animal types for the estimate of CH_4 emissions from Manure Management. GE is reported here for better comparison to the GE values for other animal types

[75] In portuguese Recenseamento Geral Agrícola (RGA 1989 and RGA 1999), Recenseamento Agrícola (RA 2009)

Also, through Farm Structure Survey about 40 000 farms (production units) were surveyed, every two years. From 2010 the interval between surveys has been extended[76] to 3 years. The complete National Methodological Report of 2013 farm structure survey is also available at Eurostat website (same link).

Annually livestock numbers[77] for cattle, swine, sheep and goats are estimated through the National Animal Registration database (SNIRA).

Using these data sources, INE built consistent time series of annual livestock numbers from 1987 to 2015 for cattle, swine, sheep, goats, disaggregated per region[78], age and sex.

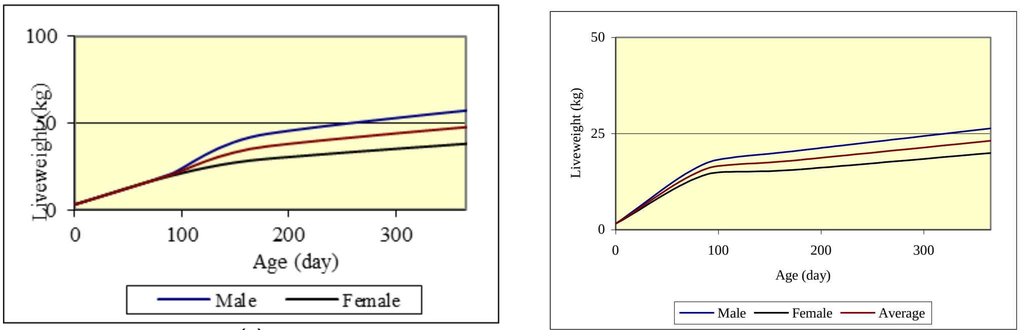
All original figures in statistical database represent the annual average population.

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[79] for both species, Figure 5-8, using the weight at slaughter as published by INE, which values are presented in Figure 5-9. Resultant average ages vary from 107 to 128 days for sheep and 69 to 104 days for kids.

Figure 5-8 – Evolution pattern growth for Sheep (a) and Goats (b).



(a) (b)

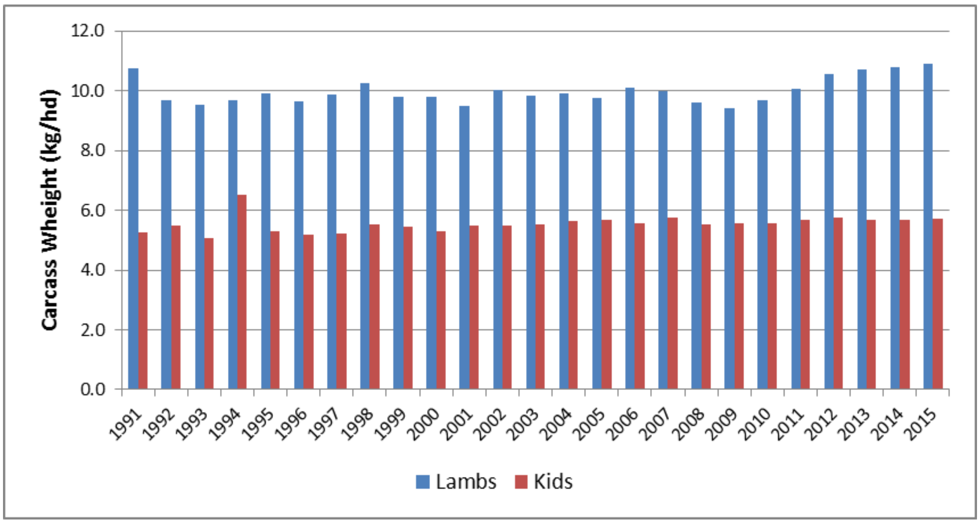
[76] Regulation (EC) nº 1166/2008, on Farm Structure Surveys and the Survey on Agricultural Production methods, repealing Regulation (EEC)nº 571/88.

[77] Regulation (EC) nº 1165/2008, concerning livestock and meat statistics and repealing Council Directives 93/23/EEC, 93/24/EEC and 93/25/EEC:

[78] A total of 7 regions were available: the 5 regions in mainland Portugal (NUT II level), Norte, Centro, Lisboa e Vale do Tejo, Alentejo and Algarve and the two Autonomous regions of Azores and Madeira.

[79]Set up from the information on existing breeds in Portugal, complemented by information of Jarrige (1988) related with growth patterns.

Figure 5-9 – Lambs and Kids: average carcass weight at slaughtering.



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.

The population of horses, mules and asses, poultry and rabbits (reproductive females) is established from the results of the Agricultural Census and the Farm Structure Survey. The disaggregation of hens for industrial egg production and hens for production of chicks was obtained from the Annual Survey of eggs production and the Annual Survey of Industrial Poultry, published by 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 5.18 is presented the annual livestock numbers (1990, 1995, 2000, 2005, 2010, and the three last years) that are activity data for CH_4 emission estimates from enteric fermentation (CRF 3A). In a consistent way same activity data are used to estimate CH_4 emissions and N_2O emissions from manure management systems (CRF 3B) and N_2O emissions from animal manure applied to soil and from urine and dung deposited by grazing animals (CRF 3D). The complete time series data is included in the ANNEX F: Agriculture.

Table 5.18 - Livestock Population (Thousands).

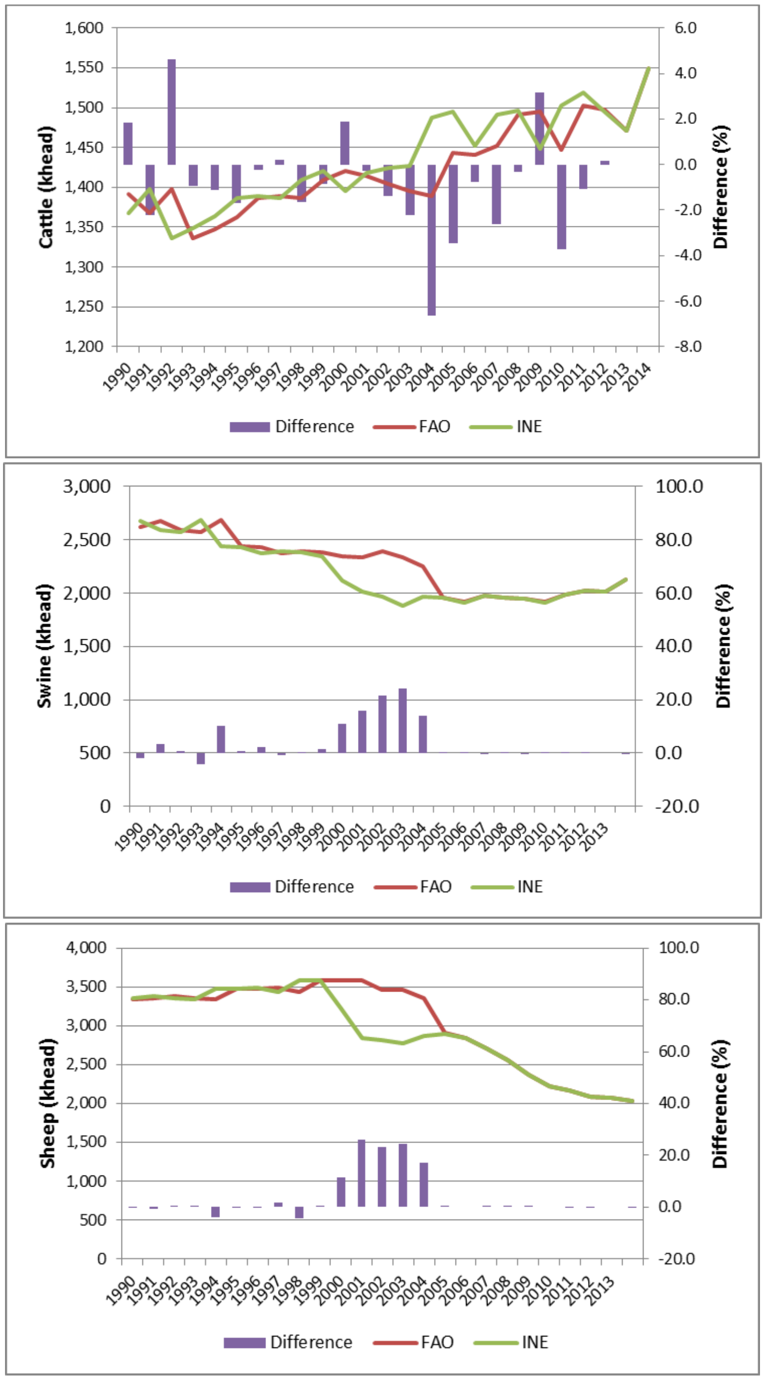
Animal class	Sub-class	1990	1995	2000	2005	2010	2013	2014	2015
Dairy-Cattle	Dairy cows	394	383	353	290	255	236	233	235
Non-dairy cattle	Beef calfs (<1 yr)	46	60	67	104	114	119	113	112
	Calfs M.Rep. (<1 yr)	186	162	144	136	123	136	142	152
	Calfs F Rep. (<1 yr)	177	158	174	183	171	191	198	209
	Males 1-2 yrs	112	103	82	81	66	54	53	58
	Beef Fem. 1-2 yrs	18	22	17	17	20	19	17	15
	Females rep. 1-2 yrs	111	109	127	135	137	135	139	148
	Steers (>2 yrs)	38	33	26	25	38	42	39	37
	Heifers Beef (>2 yrs)	4	10	6	9	12	14	15	15
	Heifers rep. (>2 yrs)	45	52	67	94	110	105	103	96
	non-dairy cows	242	273	345	397	438	443	450	461
Swine	Piglets (<20 kg)	727	726	663	574	597	658	681	713
	Fatt. Pigs (20-50 kg)	662	660	585	467	448	464	472	485
	Fatt. Pigs (50-80 kg)	525	525	483	368	360	366	369	380
	Fatt. Pigs (80-110 kg)	218	198	174	214	244	263	273	285
	Fatt. Pigs (> 110 kg)	44	44	38	41	36	25	28	30
	Boars (>50 kg)	26	26	20	12	7	5	5	6
	Sows, pregnant	210	211	195	191	179	159	159	162
	Sows, non-pregnant	124	132	124	68	66	68	69	71
Sheep	Ewes	2 292	2 339	2 410	2 293	1 915	1 683	1 638	1,620
	Other Ovine	663	817	733	234	191	167	162	155
	Lambs	307	278	319	322	277	263	267	275
Goats	Does	614	517	460	380	356	342	333	324
	Other Caprine	149	151	129	57	40	36	36	37
	kids	47	41	33	26	29	27	25	23
Equidae	Horses	33	48	58	52	38	27	26	26
	Asses & Mules	118	103	69	40	22	15	14	13
Poultry	Hens, reproductive	3 421	3 271	2 644	3 056	3 453	3 179	3 060	2,960
	Hens eggs	7 539	7 745	9 060	7 349	7 867	7 138	6 887	6,803
	Broilers	18 524	18 813	24 374	18 686	19 207	17 847	17 313	17,045
	Turkeys	1 149	945	1 208	798	1 445	956	831	769
	Other poultry	1 667	1 648	1 707	1 353	1 522	1 178	1 084	1,038
Other	Rabbits[1]	475	401	336	289	255	193	177	169

[1]Female reproductive

5.3.4.1 Quality Assessment of Livestock Numbers

Livestock numbers used in the inventory, as collected from National Statistics, were compared to FAO livestock numbers for years 1990-2014 (2015 not available), and results are presented in the Figure 5-10 for cattle, swine and sheep.

Figure 5-10 – Livestock numbers: comparison between National Statistics and FAO database.



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

Uncertainties estimates of livestock numbers are based on the information provided by the National Statistical Institute (INE) and are presented in Table 5.19.

Table 5.19 – Livestock population uncertainty estimates.

Animal Type	U (%)
Dairy Cattle	7
Non-dairy cattle	4
Sheep	10
Goats	9
Pigs	9
Equidae	15
Poultry	16
Rabbits	20

The uncertainty for digestibility estimates was assumed 20 % where tier 2 was used, which is in line with the IPCC 2006.

The uncertainty of the emission factor was assumed to be 20 % for all animals where tier 2 was used and 50 % when tier 1 emission factors were used, in accordance with the 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:

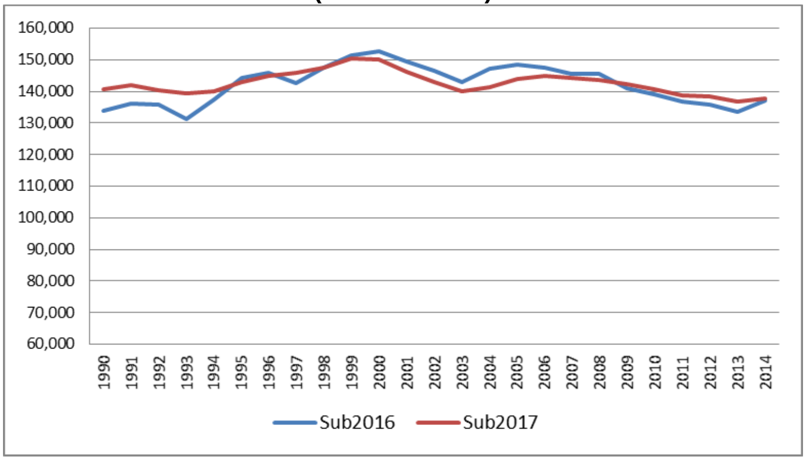
- Comparison between data from Agricultural General Census (every 10 year) and data from Farm Structure Survey (every two or three years) concerning horses, mules & asses, poultry and rabbits to check any outliers;
- Comparison between livestock data obtained from INE and FAO numbers for cattle, sheep, goats and swine population.

QA/QC also included a series of checks: calculation formulas verification, data and parameters verification and the information provided in this report.

5.3.7 Recalculations

Following recommendation of 20016 UNFCCC review it was withdrawn the correlation factor used (centered in 1998) to correct non dairy cattle, sheep and goats parameters in the time serie. In previous submission the estimated values of parameters, centered in 1998, were corrected by an exponencial function (equation of table 10.10) of the carcass weight variation (yearly average).Differences between submissions are graphcically represented in the figure below.

Figure 5-11– Total Enteric Fermentation Emissions (t CH_4), differences between submissions (2016 and 2017)



5.3.8 Further Improvements

It is planned update the database information (MAM, 1998) used for non dairy cattle, sheep and goats enteric fermentation estimates. We already begin work on that but it will be needed some time to gather the complete and validated information.

5.4 CH_4 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[80].

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_4 emission from manure management.

[80] Nitrous oxide emissions from manure deposited in soil during grazing and pasture are nevertheless included in source category N_2O from agricultural soil: Animal production, in accordance with UNFCCC reporting guidelines.

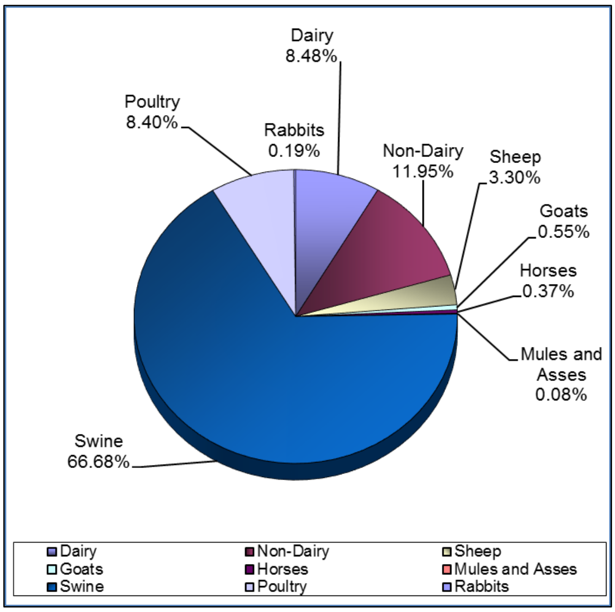
Table 5.20 – CH4 emissions from manure management (kt).

Livestock type	1990	1995	2000	2005	2010	2013	2014	2015
Dairy cattle	1.89	1.93	2.22	2.12	2.09	1.98	2.04	2.00
Non- dairy cattle	2.18	2.22	2.36	2.63	2.72	2.74	2.76	2.83
Sheep	1.34	1.42	1.42	1.11	0.91	0.80	0.79	0.78
Swine	18.51	18.79	17.33	14.64	14.76	14.96	15.25	15.77
Goats	0.26	0.22	0.20	0.15	0.14	0.14	0.13	0.13
Horses	0.12	0.18	0.22	0.19	0.14	0.09	0.09	0.09
Mules and asses	0.18	0.16	0.10	0.06	0.03	0.02	0.02	0.02
Poultry	2.33	2.31	2.72	2.15	2.46	2.14	2.04	1.99
Rabbits	0.13	0.11	0.09	0.08	0.07	0.05	0.04	0.04
Total	**26.95**	**27.35**	**26.66**	**23.13**	**23.32**	**22.92**	**23.16**	**23.65**

Note: Totals may not sum due to independent rounding

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 66.68 % of emissions in 2015, as may be seen in Figure 5-12, and according to the good practice rule of thumb this specie is the only significant source.

Figure 5-12 - Relative Importance of emissions of CH_4 from Manure Management per each animal species in 2015



5.4.2 Methodology

Following the IPCC 2006, emission estimates are calculated based on the equation 10.22[81] 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

[81] Volume 4, chapter 10

and the storage conditions are included in the determination of the emission factor, and will be discussed thereafter.

$$Emi_{CH_4} = \Sigma_t \Sigma_c.[EF_{(i,k)} * N_{(i,k)}]$$

where, for each specie:

Emi_{CH_4} = methane emissions from manure management, kg CH_4/year;

$EF_{(i,k)}$ = emission factor for the specific population of animal type i, living in climate region k, kg/head/year;

$N_{(i,k)}$ = total number of animals of type i, living in climate region k, head.

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), 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:

$$EF_{(i)} = (VS_{(i)} * 365) *[Bo_{(i)} * 0.67 * \Sigma_{jk} MCF_{(jk)}/100*MMS_{(ijk)}]$$

$EF_{(i)}$ - 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 k, %;

$MMS_{(ijk)}$ - 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 were 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 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 %;

(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 (Bo) 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 of GE.

Table 5.21 – Parameters used in the estimate of Volatile Solids and EF per animal.

Animal Class	sub-class	DE (%)	ASH	B_o (m^3/kg VS)
Dairy-Cattle	Dairy Cows	73»	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 #	0.045*	0.45
	Fattening Pigs	83 #	0.045*	0.45
	Sows and Boars	78 #	0.045*	0.45
Sheep	Ewes & other ovine	60	0.080	0.19
Goats	Does & other caprine	60	0.080	0.18
Equidae	Horses	70	0.040	0.30
	Asses & Mules	70	0.040	0.33
Poultry	Hens Reproductive	64 #	0.048 #	0.39
	Hens eggs	64 #	0.048 #	0.39
	Broilers	68 $	0.020 #	0.36
	Turkeys	68 #	0.026 #	0.36
	Other poultry	66 #	0.020 #	0.36
Other	Rabbits (per female cage)	59 #	0.034 #	0.32

Note: all values IPCC default, except: »-Country specific (Table 5.4); # - INRA (1984); $- McDonnald et al (2002); * INIAV82

Expert guess[83], based on survey data and field knowledge of technical personnel of the Ministry of Agriculture was used to establish the % 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

[82] Animal Nutrition expertise. Drº Olga Moreira

[83] Information received from Eng. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005, and in 7, October 2009, following update.

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 2015 we assume the 2010 distribution.

The values for the fraction of manure handled in each MMS in 1990 and in 2015 are presented in Table 5.22. The annual variation of the share of each MMS in the period 1990 – 2010 is shown in Table 5.23.

Table 5.22 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990 and 2015 (%).

Animal Type	1990					2015*				
	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
Other poultry	-	-	100.0	-	100.0	-	10.0	90.0	-	100.0
Rabbits	-	-	100.0	-	100.0	-	-	100.0	-	100.0
Equidae	-	-	60.0	40.0	100.0	-	-	60.0	40.0	100.0

*equal to 2010

Table 5.23 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type (1990 – 2010).

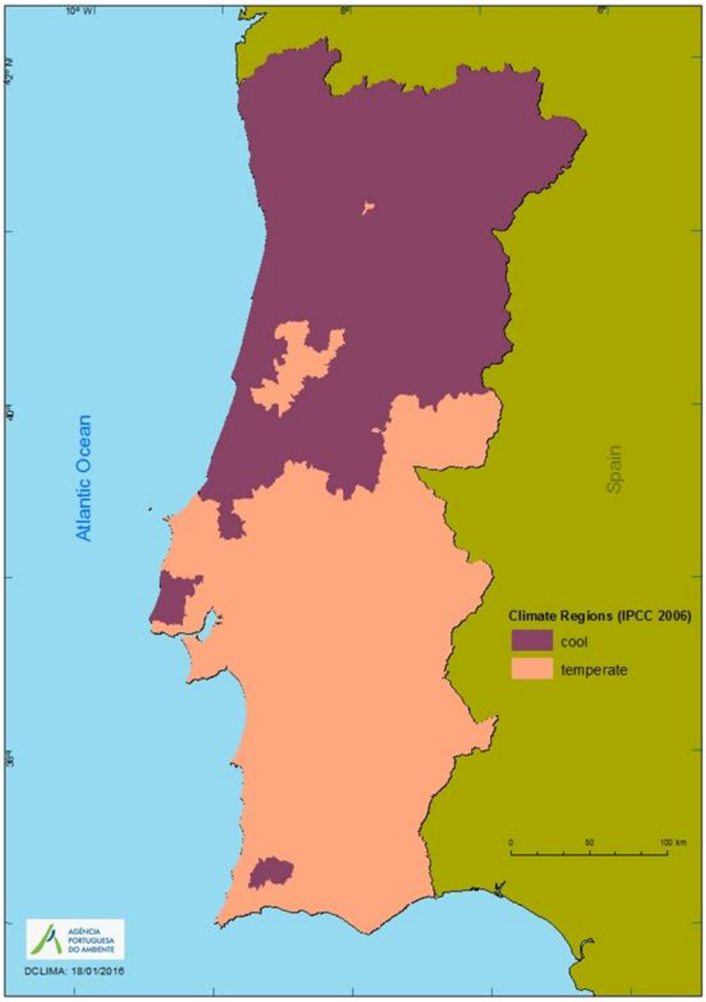
Animal Type	Lagoons	Tanks	Solid Storage	Pasture
Dairy Cows	0.100	-0.850	0.750	-
non-dairy cows	-	-	-	-
Other cattle	-	-	-1.500	1.500
Ewes	-	-	-	-
Other ovine	-	-	-	-
Does	-	-	-	-
Other caprine	-	-	-	-
Sows	0.250	-0.450	-0.100	0.300
Other Swine	0.250	-0.350	-0.050	0.150
Hens	-	-	-	-
Broilers	-	-	-0.195	0.195
Turkeys	-	-	-0.005	0.005
Other poultry	-	0.500	-0.500	-
Rabbits	-	-	-	-
Equidae	-	-	-	-

Note: values represent the annual increment in the % of MMS use. Positive values represent increment in the % of the MMS. Negative values represent decrease in use

Two climate regions occur in Portugal, in accordance with reporting table[84] classification: temperate (annual average temperature between 15ºC and 25ºC) and cool (annual average temperature below 15ºC). In next Figure is presented the map with the representation of the two climate regions in the mainland territory. Both Arquipelagos Azores and Madeira are only in one climate region, temperate.

[84] CRF 3B classification of climate regions is different than IPPC 2006 Guidelines (page 3.39 of volume 4, chapter 3 and page G.11 of the Glossary).

Figure 5-13 – Climate regions representation.



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[85] and for each animal sub-type;
- livestock numbers per animal type were available at c*oncelho* level from three Agriculture General Census (1989, 1999 and 2009)[86]. Data for 1999 and 2009 were available for all animal types and sub types and for 1989 only for dairy cattle, other cattle, ewes, other sheep, female goats and other goats, sows and other swine;

[85] 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^2.

[86] Recenseamento Geral da Agricultura 1989, Recenseamento Geral da Agricultura 1999 and Recenseamento Agrícola 2009, extensive agriculture census made by INE each 10 years.

- the average annual temperature of each *concelho* area was provided by the national authority in the fields of meteorology and climate, IPMA[87], based on the results of 30 years observations, climatological normal 1971 – 2000. The classification of each *concelho* in climate region cool or temperate was done according to the respective mean annual temperature provided by IPMA. The same source was used to produce the map above;

- livestock numbers in each *concelho* area were allocated to each climate region, for the years 1999 and 2009, according to the IPMA data and to the Census data for the same territorial unit. For 1989 it was assumed the livestock distribution of each sub type animal equal to 1999 given the unavailability of disaggregated animal information in the 1989 Agriculture Census;

- the information at *concelho* level, number of animals allocated at each climate region, was then grouped at a higher level territorial unit corresponding to NUT II[88] region. For each NUT II region, based on the data of the set of *concelhos* included in that NUT, was established the share (in %) of animals (by sub type) allocated at each climate region for the years 1989, 1999 and 2009;

- for the intermediate years, 1990 to1998 and 2000 to 2008 the animal share (by sub type) allocated to each climate region, result from the interpolation of the values of 1989 and 1999 and of the values of 1999 and 2009 respectively. From 2010 to 2015 were assumed the 2009 values until the data of the next Agriculture Census in 2019 will be available;

- livestock population in each climate region and by NUT II was estimated annually from total livestock population in NUT, considering the share values established for the NUT.

For the complete time series the percentage of livestock population (by sub type animal) living in cool climate regions, calculated in accordance with the above explained procedure, is presented in ANNEX F: Agriculture.

In Table 5.24, is presented the percentage of national livestock population living in cool climate regions, for major animal types, 1990 and 2015.

[87] IPMA, Instituto Português do Mar e da Atmosfera

[88] Region NUT – Nomenclature of territorial units for statistics. There are 7 NUT II regions in Portugal, 5 in mainland Portugal, 1 for whole Archipelago of Azores and 1 for whole Archipelago of Madeira

Table 5.24 – Share of livestock population in climate cool regions (%), 1990 and 2015.

Animal Type	1990	2015
Dairy Cows	64.4	47.1
Other Cattle	52.8	28.3
Sheep	30.8	33.7
Goats	57.1	51.8
Horses	41.7	59.7
Mules and Asses	68.0	71.0
Swine	46.9	33.4
Poultry	66.2	68.1
Other	75.3	88.6

Methane Conversion Factors (MCF) for each MMS are the default[89] ones from IPCC 2006, shown in Table 5.25, considering a mean annual temperature of 17º C for temperate climate region and a mean annual temperature of 14ºC for the cool climate region:

Table 5.25 - Methane Conversion Factors (MCF), %, for determination of CH_4 emissions from Manure Management.

MMS	Temperate	Cool
Lagoons	32	25
Tanks[1]	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 F: 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_4/ 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 lagoons systems. A small number of explorations still have short retention pits;

[89] 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 5.26 – Manure management CH_4 Implied Emission Factors (IEF) and comparison with IPCC 2006 default emission factors (kg/hd/yr).

Livestock	1990	1995	2000	2005	2010	2013	2014	2015	Default * (cool – temperate)
Dairy cattle	4.79	5.05	6.29	7.33	8.19	8.40	8.73	8.52	15-22 (*Solid based systems are used for the majority of the manure (EE)*. Portugal also has a significant % of manure directly deposited on pasture,table 5-25 of this report)
Non-dairy cattle	2.23	2.24	2.24	2.23	2.22	2.18	2.17	2.17	1-2 (*Non-dairy manure is usually managed as solid and deposited on pastures (NAm).* Portugal has the same situation. See table 5-25 of this report)
Swine	7.30	7.45	7.59	7.57	7.62	7.44	7.42	7.40	8-15 *Liquid /slurry and pit storage systems are commonly used (WE).* Portugal has more than 90 % of swine manure managed in lagoons/tanks and about 5% deposited on pasture. See table 5-25 of this report)
Sheep	0.41	0.41	0.41	0.39	0.38	0.38	0.38	0.38	0.19-0.28
Goats	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.34	0.13-0.20
Horses	3.77	3.77	3.75	3.63	3.63	3.45	3.41	3.38	1.56-2.34
Mules & Asses	1.55	1.55	1.51	1.48	1.43	1.48	1.50	1.52	0.76-1.10
Poultry	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.02-0.09
Rabbits[1]	0.28	0.28	0.27	0.26	0.26	0.25	0.25	0.25	0.08 *(The default value is per animal. Emission estimates in Portugal are done per female cage. See tables 5.19; 5.21; 5.24 and 5.37 of this report)*

*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; NAm – North America:WE – Western Europea.

[1]Per female cage

5.4.4 Activity Data

In a consistent manner livestock numbers are the same that were used in previous source category: CH_4 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_4 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 uncertainty for the average annual mean temperature of each *concelho* estimated by IPMA;

- uncertainty for the quantity excreted, VS parameter, was set at 20 %, considering the use of an enhanced livestock characterization, similar to that used in the derivation of the emission factor of CH_4 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 latest revised patterns[90]. This error was combined with the error associated with the MCF parameter: the uncertainty was assumed to be 80 % for Anaerobic Lagoons, given the possible range in the IPCC defaults (IPCC,2006), for Liquid and solid storage and pasture, the uncertainty values of 50 % reflect the variation of this parameter;

- the error associated with the parameters B_o is specie dependent and was establish from the range of possible values in the IPCC 2006, for developed and developing nations. Uncertainty values vary from 10.61 % for horses, mules and asses up to 26.74 % for non-dairy cattle. The uncertainty of the biogas density was assumed not to be determinant of the overall uncertainty value;

- the evaluation of the errors associated with the territorial distribution of the annual mean temperature was done by IPMA. The values of the standard errors calculated for each *concelho* territorial unit shows that 17.6 % of them a change in climate region classification could occur in either direction, cool or temperate, nevertheless the maximum error is always lower than 1ºC (0.52 ºC) Considering the modification that could exert in the percentage of livestock numbers allocated as either in cool or temperate region was assumed 20 % as a representative value of uncertainty for this factor.

[90] 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.

The individual uncertainty values are presented in next table (using as base value 1990).

Table 5.27 – Uncertainty Values (in %) of the Emission Factors of CH_4 emissions from Manure Management.

Specie	Σ MMS*MCF	VS	Bo	Region	EF
Dairy Cows	31.77	20.00	22.92	20.00	53.74
Non-dairy cows	61.64	20.00	26.47	20.00	76.26
Other cattle	45.61	20.00	26.47	20.00	64.00
Sheep	44.73	20.00	15.79	20.00	60.43
Goats	44.73	20.00	13.89	20.00	59.74
Swine	64.38	20.00	21.11	20.00	77.31
Poultry	60.09	20.00	20.83	20.00	79.03
Rabbits	50.64	20.00	20.83	20.00	68.54
Equidae	50.64	20.00	10.61	20.00	64.82

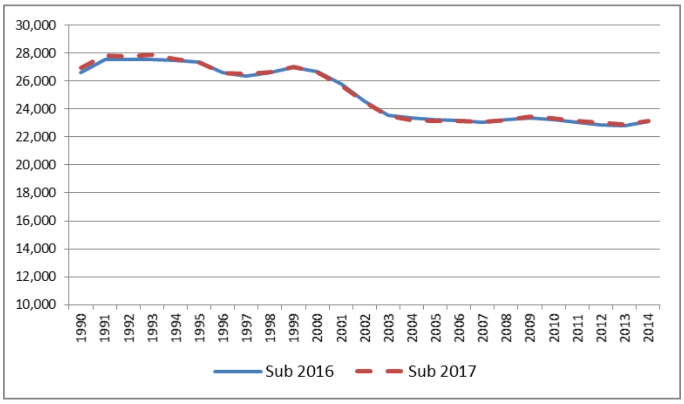
5.4.6 Category-specific QA/QC and verification

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, 2016 and 2017, are shown in the figure below. Only minor corrections were done in result of QA/QC verifications with no significant impact in the total CH_4 emissions from this source category.

Figure 5-14 – Manure Management emissions (t CH_4), differences between submissions (2016 and 2017).



5.4.8 Further Improvements

It is planned to revisit the characterization of the manure management systems, framed by the new national law[91] related with livestock farming.

5.5 CH_4 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_4 emission from rice cultivation.

Table 5.28 – CH4 emissions from Rice cultivation (kt).

	1990	1995	2000	2005	2010	2013	2014	2015
Rice cultivation	5.36	4.16	4.70	6.08	5.53	5.77	5.46	5.68

5.5.2 Methodology

Methane emissions from rice production were estimated following the equation 5.1 of IPCC 2006,[92] 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:

$$E\_Rice_{CH4(y)} = EF * Rice_{Area\ (y)} * 10^{-3}$$

where:

$E\_Rice_{CH4(y)}$ - emission from rice production estimated for year y (ton/yr);

EF - final emission factor seasonally integrated and adjusted for management practices (kg/ha/yr);

$Rice_{Area\ (y)}$ - 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:

$$EF = EF_{ct} * SF_w * SF_p * SF_o * SF_s$$

[91] Decree-Law nº 81/2013

[92] Volume 4, chapter 5

where

EF - final emission factor seasonally integrated and adjusted for management practices (kg/ha/yr);

$EF_{c\ (t)}$ – 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;

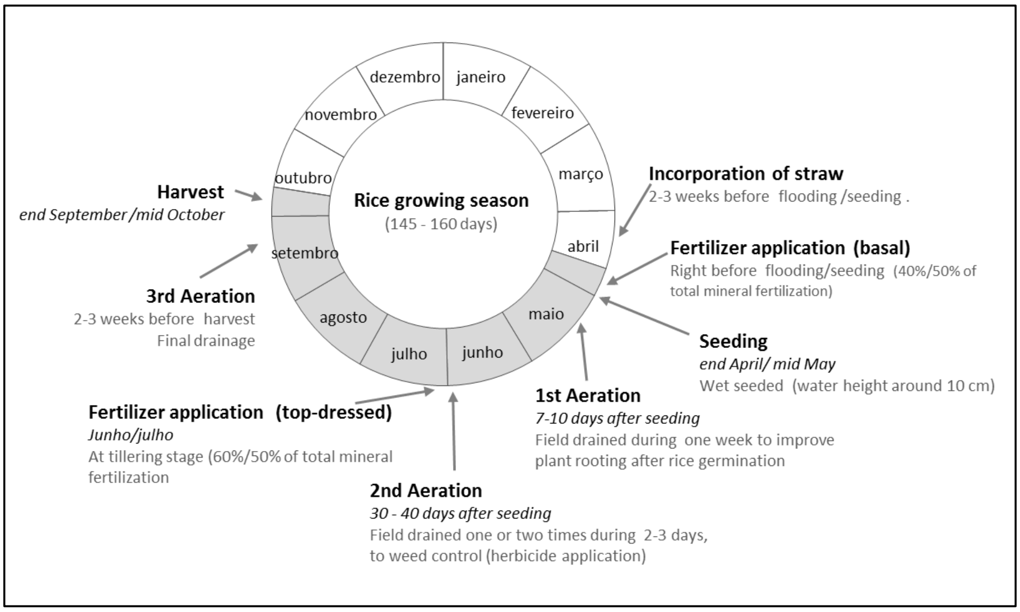
SF_s - scaling factor for soil type.

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 [93]because a country specific EF_c 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 5-15 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_w was set as 0.60 based on Table 5.12 of IPCC 2006, and for parameter SF_p the value considered was 0.68 (table 5.13, IPCC 2006).

[93] 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

Figure 5-15 – 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[94] limits. In these situations the practice of burning crop residues is forbidden[95] , 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[96] all rice cultivation areas subjected to “Techniques of Integrated Production and Protection[97]” 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.

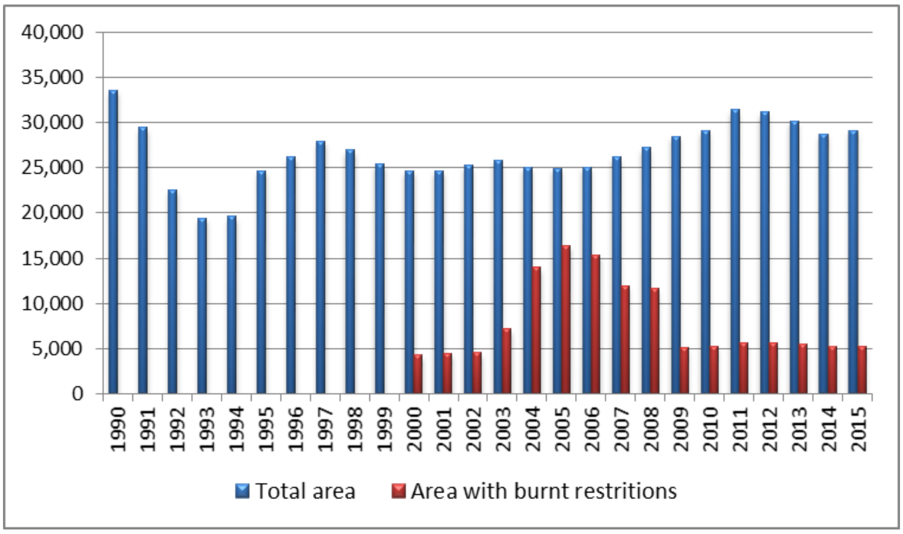
[94] Natura 2000 network includes Special Zones for Conservation (ZPC) established under Habitats Directive (92/43/ CEE) and Special Protection Zones (ZPE) established under Birds Directive (last revision 2009/147/CE). http://www.icnf.pt/portal/naturaclas/rn2000

[95] National Laws: DL 140/99 artº 11º (revised by DL 49/2005); RCM 177/2008 artº 21º; RCM 182/2008 artº 8º.

[96] From 2009 onwards the limitation of residues burnt was removed (Circular / DSPFSV/ 08 from Directorate General of Agriculture and Rural Development -DGADR)

[97] “Modos de protecção e produção integrada” in the original in Portuguese.

Figure 5-16 – Rice areas cultivated (ha) in Portugal.



Source: Ministry of Agriculture

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 Sf_o, 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 5.29 are summarized the parameters and emissions factors used to estimate methane emissions from rice cultivation in Portugal, for the full time series.

Table 5.29 – Parameters and Emission Factor used to estimated CH4 emissions from rice paddies in Portugal.

Year	EF_{ct} (kg CH_4/ha/yr)	SFw	SFp	SFo	SFs	EF (kg CH_4/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
2014	198.90	0.60	0.68	2.34	1	189.78
20015	198.90	0.60	0.68	2.40	1	194.90

5.5.4 Activity Data

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 5-16. 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

For activity data, the standard deviation of inter-annual area under rice cultivation was considered: 10.2 %.

Totall 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 Factor:

- the error associated with the parameters SFw and SFp were establish from the range of possible errors for each scaling factor(IPCC 2006);
- the error associated with the scaling factor SFo was obtained by the combination of the uncertainties of the parameters ROA and CFOA and the exponent of the SFo equation;
- the error associated with the baseline Efc was obtained from the range of possible error values.

The individual uncertainty values are presented in next table.

Table 5.30 –Uncertainty Values (in %) of the Emission Factor of CH_4 emission from Rice cultivation

SFw	SFp	Sfo	Efc	EF
28.3	16.2	8.5	53.8	63.5

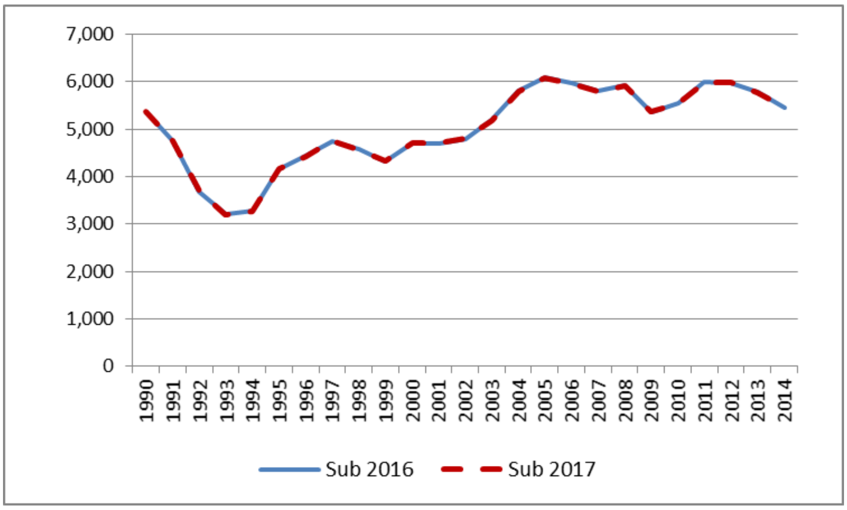
5.5.6 Category-specific QA/QC and verification

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

No recalculations were done in this source category. There are no differences between submissions as shown in figure below.

Figure 5-17 – Rice cultivation CH_4 emissions estimation (t CH_4/yr), differences between submissions 2016 and 2017.



5.5.8 Further Improvements

No further improvements planned

5.6 N_2O Emissions from Manure Management (CRF 3.Bb)

The estimates of total N_2O emissions from manure management, direct and indirect emissions, are present in the table below. In the following chapters 5.6.1 – Direct N_2O emissions from manure management and 5.6.2 – Indirect N_2O emissions from manure management further details will be developed.

Table 5.31 – N_2O emissions from manure management (kt).

Livestock type	1990	1995	2000	2005	2010	2013	2014	2015
Direct emissions	**0.47**	**0.46**	**0.49**	**0.42**	**0.40**	**0.36**	**0.35**	**0.35**
Dairy cattle	0.13	0.13	0.16	0.15	0.13	0.12	0.12	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	0.02
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	0.14	0.13	0.12	0.12
Rabbits	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01
Indirect emissiona	**0.38**	**0.38**	**0.39**	**0.33**	**0.32**	**0.30**	**0.29**	**0.29**
Total	**0.85**	**0.83**	**0.88**	**0.75**	**0.72**	**0.66**	**0.65**	**0.65**

Note: Totals may not sum due to independent rounding

5.6.1 Direct N_2O 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_2O during management or during storage of manure, before application to soil, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen.

Emissions of N_2O that occur during manure application on soil and urine and dung deposited directly into soil by grazing are reported in the category N_2O from managed soils (CRF 3D) following the UNFCCC reporting guidelines.

In a short description, this is a biological based process where emission of N_2O 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_2 and nitrous oxide).

In terms of the importance of each Manure Management System, observable in Figure 5 20, the great majority of emissions result from solid storage totalizing in 2015, 94.2 % of direct N_2O emissions from Manure Management. The remaining 5.8 % N_2O emissions are from liquid systems. There is no direct N_2O emission estimates from manure managed in anaerobic lagoons because nitrification, which is a necessary prerequisite for the emission of N_2O from stored animal manure, does not occur under anaerobic conditions. In terms of origin by animal type, emissions are dominated by dairy cattle (35.5 %) and poultry (34.2 %) which together comprehend about 69.7 % of total emissions, as may be seen in Figure 5-19 for the year 2015.

Figure 5-18 – Distribution of direct N_2O emissions from Manure Management per System in year 2015.

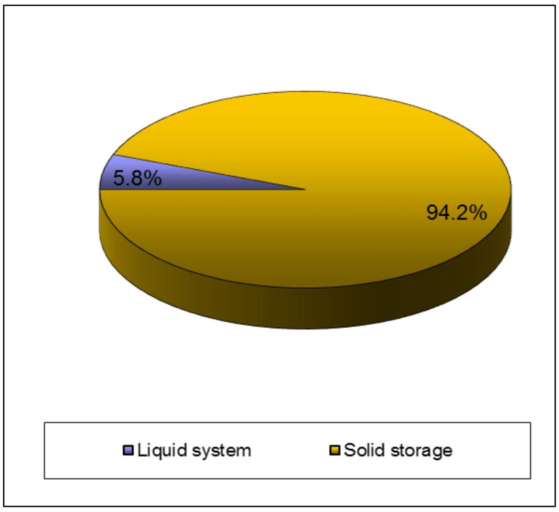
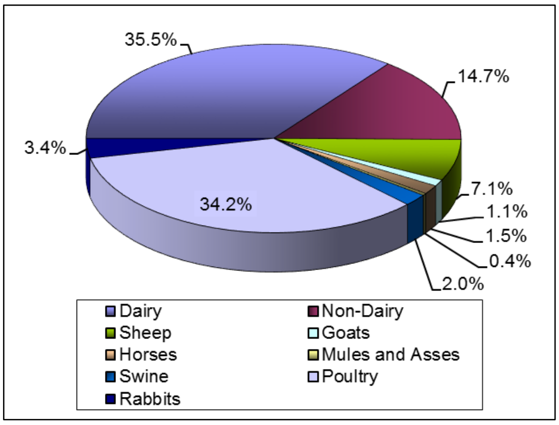


Figure 5-19 – Distribution of direct N_2O emissions from manure managed per livestock category in year 2015.



5.6.1.2 Methodology

Direct N_2O emissions from manure for each Manure Management System (MMS) were estimated from the following formula:

$$EN_2O_{(s)} = \Sigma_i[N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)} * 44/28$$

where:

$EN_2O_{(s)}$ - N_2O emissions from manure in Manure Management System s;

s - Manure Management System;

i - Animal/species category of livestock;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s;

$EF3_{(s)}$ - N_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 5.22 of chapter 5.4 of this report).

Table 5.32– Classification of Manure Management Systems in Portugal.

MMS	CRF classification
Lagoons	Liquid system
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 5.33 – N_2O from Manure Management: Emission Factors per Manure Management System.

MMS	EF_3 (kg N_2O-N/kg N)
Lagoons	0.000
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[98]. 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_4 emissions from Enteric Fermentation and Manure Management).

The final Nex rates used in the inventory (Table 5.35) 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[99] nº 259/2012, 8th 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 % for every 1000 kg less of milk production;
- The Nex increases 2 % for every 1000 kg extra of milk production.

Milk production and Nex are presented in Table 5.34.

[98] Drª Fátima Calouro, director of the Laboratório Químico Agricola 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)

[99] 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 5.34 – 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	8 000	117.3
2014	8 548	118.6
2015	8 287	118.0

b) Final Nex for all livestock categories

The following table presents the nitrogen excretion rates applied in the estimation of N_2O emissions 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 5.35 – N excretion rate per head and by animal species/category (Nex).

Animal Class	Animal sub class	Nex			
		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	118.00**	600	0.48	105.12
Non-dairy cattle	Beef calfs (<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 [1]	9.00	-	-	8.10

*Average weight in the time series; ** The Nex value for dairy-cattle associated with Sub 2017 represents the value for latest year reported in that submission (2015); [1]Per female cage

Values for piglets (< 20kg), lambs and goat kids, are 0 kg N/hd/yr because the Nex is included in the Nex of their respective mothers.

The Nex values for rabbits correspond to a breeding female with 40 young animals with a final weight of 2.7/3.0 kg per rabbit per year.

There is an acceptable agreement between country-specific values and IPCC 2006 defaults for all species other than sheep and goats. These two categories nitrogen excretion rate appears to be low, when in comparison with default values, but it has similarities to those used by other parties.

The total quantity of nitrogen in manure produced (including deposition on pasture) per animal type, and its annual variation in the period 1990 to 2015, is presented in the ANNEX F: Agriculture. For the year of 2015 the distribution of N manure by manure management system and deposition on pasture is shown in Figure 5-20. The major contributors to total nitrogen from livestock manure in Portugal in 2015 were non-dairy cattle and dairy cattle, as may be seen in Figure 5-21 .

Figure 5-20 – Distribution of total Nitrogen in manure produced in 2015 (%).

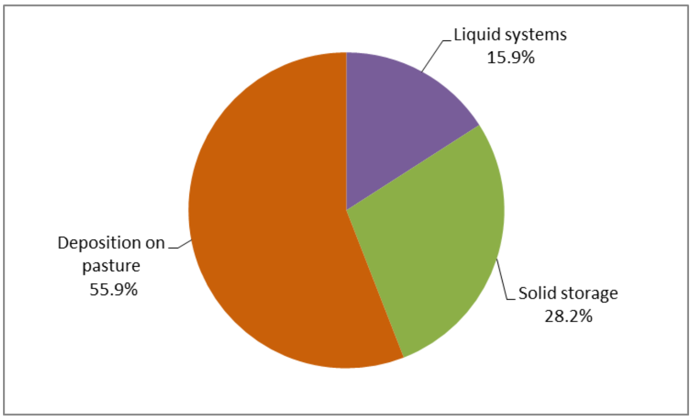
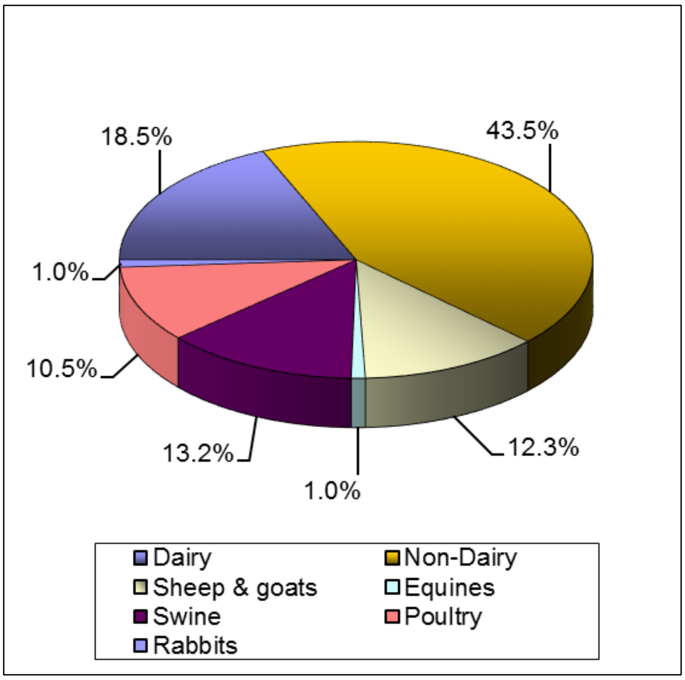


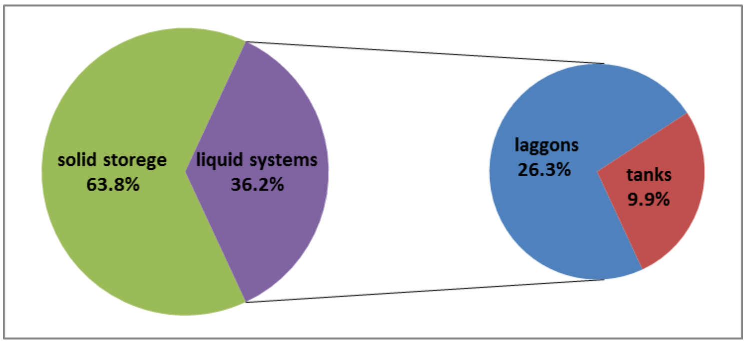
Figure 5-21 – Origin of total nitrogen in manure produced in 2015, per animal type.



The N_2O emissions estimates from urine and dung directly deposited on pasture are included in chapter 5.7 – “N_2O 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.

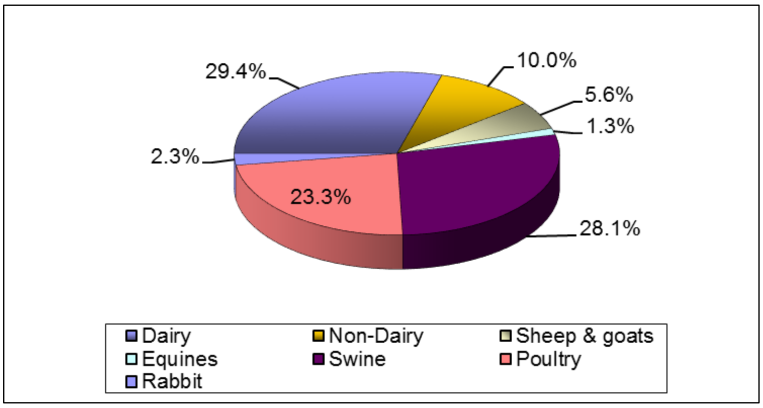
The percentage of nitrogen in manure stored and treated, per manure management system, is presented in the next figure for the year 2015.

Figure 5-22 – Share of nitrogen in manure per MMS, in 2015.



The major contribution for stored and treated manure in 2015, were dairy cattle, swine and poultry, as it is shown in figure below.

Figure 5-23 – Origin, by livestock class, of nitrogen in manure stored and treated in 2015.



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_4 emissions from Manure Management (Table 5.22 and Table 5.23 of this report).

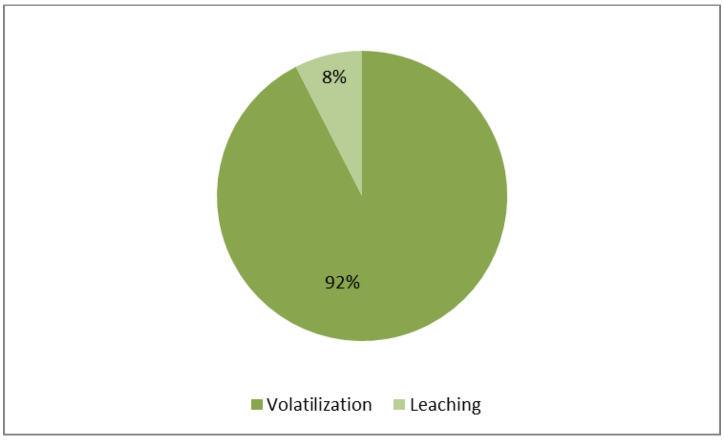
5.6.2 Indirect N_2O emissions from manure management

5.6.2.1 Overview

Indirect N_2O emissions result from volatile nitrogen losses, in forms of NH_3 and NO_x, 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_2O emissions from manure management is shown in figure below for the 2015 year.

Figure 5-24 – Relative importance of the losses of volatile nitrogen and of nitrogen leached in total indirect N_2O emissions, 2015.



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 2016, chapter 3B – Manure management, in coherence with UNECE/CLRTAP emissions 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 5.36 – 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 o N lost due to volatilisation and due to leaching and runoff for the time series is presented in the next table.

Table 5.37 – Amount of N lost due to volatilisation (NH_3+NO_x) and leaching during animal housing and manure storage (t N/yr).

Year	Volatilisation	Leaching
1990	23 035	2 095
1991	23 264	2 104
1992	23 095	2 083
1993	22 924	2 051
1994	22 773	2 083
1995	22 581	2 142
1996	22 178	2 176
1997	22 034	2 181
1998	22 300	2 198
1999	23 197	2 318
2000	23 383	2 364
2001	22 721	2 315
2002	21 811	2 305
2003	20 670	2 203
2004	20 075	2 202
2005	19 642	2 235
2006	19 171	2 218
2007	18 703	2 167
2008	18 728	2 146
2009	18 970	2 129
2010	18 940	2 088
2011	18 607	2 023
2012	18 047	1 976
2013	17 517	1 926
2014	17 292	1 914
2015	17 323	1 915

5.6.3 Uncertainty Assessment

5.6.3.1 N_2O Direct emissions

Uncertainty in activity data is the result of the combined uncertainties in livestock number, nitrogen excretion rates and the distribution by each manure management system. The values for uncertainty in livestock numbers are the same that were for sector CH_4 emissions from enteric fermentation. The uncertainty in N-excretion rate was set at 37.5 %, considering an intermediate situation between the uncertainty values recommended by IPCC 2006 for default N-excretion rates (50 %) and the lower uncertainty when country-specific values are based on accurate national statistics (25 %). Uncertainty in MMS share was determined as the maximum difference in total excretion for each MMS considering the initial allocation per MMS used in the first submissions (Seixas et al, 1999) and the last revised share of MMS by the Ministry of Agriculture. The values vary from 37.5 % for liquid systems to 38.8 % for solid systems. Individual values and the overall uncertainty values for activity data are presented in the next table.

Table 5.38 –Uncertainty Values (in %) of the activity data for N2O emissions from manure management.

Specie	Livestock numbers	Nexc	MMS allocation	Total U_AD
Dairy cattle	7.31	37.50	38.00	53.9
Non- dairy cattle	3.93	37.50	38.00	54.3
Sheep	10.12	37.50	38.00	54.2
Goats	9.29	37.50	38.00	54.1
Swine	9.04	37.50	38.00	55.4
Poultry	15.69	37.50	38.00	55.4
Rabbits	20.00	37.50	38.00	61.2
Equidae	15.00	37.50	38.00	57.0

The uncertainty of N_2O emission factor was set from the error range considered in IPCC 2006, resulting 75 % for all MMS.

5.6.3.2 Indirect N_2O emissions

The uncertainty of activity data is the same discussed above in direct N_2O emissions. Emission factors uncertainties were set based on the error ranges referred in IPCC2006. Given that the uncertainty of EF_4 was estimated in 135.0 % and the uncertainty of EF_5 in 163.3 %.

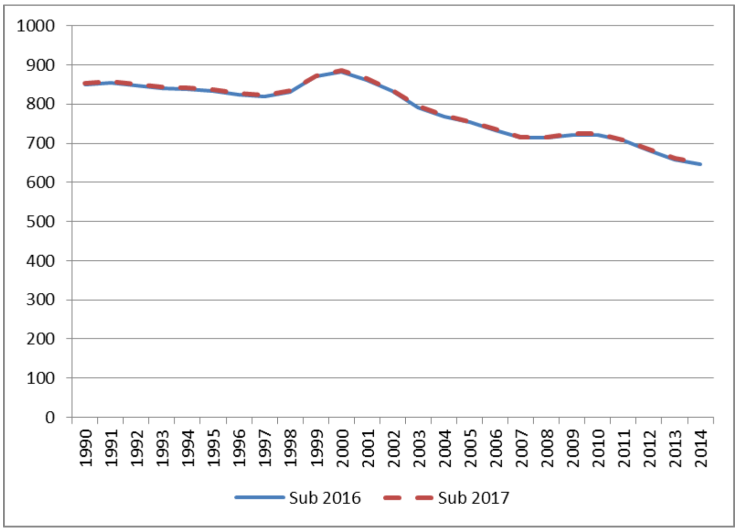
5.6.4 Category-specific QA/QC and verification

For this source category QA/QC procedures included the comparison between inventory Nex values and the corresponding IPCC default (Table 5.35) and a series of checks: calculation formulas verification, data and parameters verification and the information provided in this report.

5.6.5 Recalculations

Differences between submissions, 2016 and 2017, are graphically represented in the figure below. Only minor corrections were done in result of QA/QC verifications with no significant impact in the total N_2O emission estimates of this source category.

Figure 5-25 – Total (direct and indirect) N_2O emissions from manure management systems. Differences between 2016 and 2017 submission (t N_2O).



5.6.6 Further Improvements

It is planned to revisit the characterization of the manure management systems, framed by the new national law[100] related with livestock farming.

5.7 N_2O Emissions from Managed Soils (CRF 3.D)

The estimates of total N_2O emissions from managed soils, direct and indirect emissions, are present in the table below. In the following chapters 5.7.1 – Direct N_2O emissions from managed soils and 5.7.2- Indirect N_2O emissions from managed soils further details will be developed.

Table 5.39 – N2O emissions from managed soils (kt).

Gas/Source	1990	1995	2000	2005	2010	2013	2014	2015
Direct emissions	**6.07**	**5.85**	**6.47**	**5.31**	**5.23**	**5.55**	**5.70**	**5.67**
Synthetic fertilizers	2.49	2.29	2.67	1.61	1.58	1.74	1.93	1.90
Organic Fertilizers	0.95	0.92	0.93	0.78	0.73	0.69	0.67	0.69
Urine and dung deposited by grazing animals	1.81	1.92	2.18	2.29	2.36	2.33	2.35	2.39
Crop residues	0.82	0.72	0.69	0.63	0.57	0.79	0.75	0.69
Indirect emissions	**1.67**	**1.59**	**1.74**	**1.35**	**1.28**	**1.35**	**1.41**	**1.42**
Total	**7.74**	**7.44**	**8.21**	**6.66**	**6.52**	**6.90**	**7.12**	**7.09**

Note: Totals may not sum due to independent rounding

[100] Decree –Law nº81/2013

5.7.1 Direct N_2O emissions from managed soils

5.7.1.1 Overview

In agricultural soils, emission of N_2O 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_2O, there are no available sound estimate techniques and consequently these were not estimated in this inventory.

Direct emissions of N_2O 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 other organic fertilizers);
- urine and dung deposited on pasture, range and paddock by grazing animals;
- N input from incorporation of crop residues into soils.

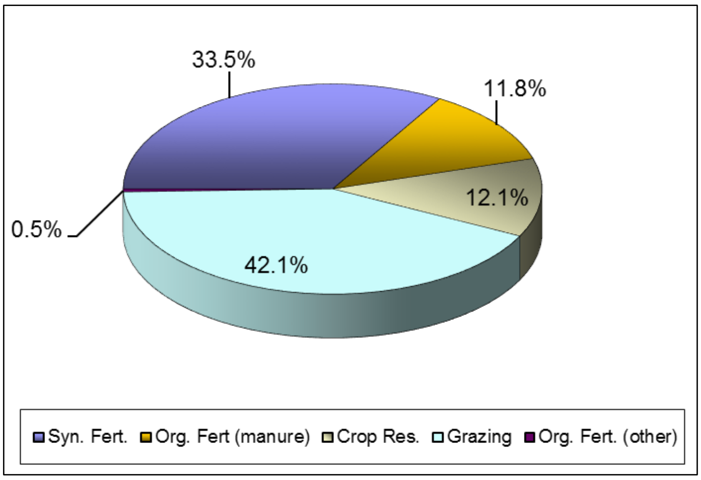
Most effort was placed to made estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources: N_2O, CH_4, NH_3 and NO_2.

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.

The comparative importance of the several sub-source activities for 2015 to direct N_2O emissions from managed soils is shown in Figure 5-26, from where it is evident the major contribution from direct deposition of urine and dung on pasture (Grazing) 42.1 % and synthetic fertilizers (Syn. Fert.) with 33.5%, which may be considered significant sources in accordance with the IPCC rule of thumb. Crop residues (Crop Res) source is responsible for 12.1 % and organic fertilizers (Org. Fer. manure) are also an important source, representing 11.8 % of the direct N_2O emissions from managed soils. The remaining 0.5 % are from oyher organic fertilizers (sewage sludge+ compost MSW)

Figure 5-26– Contribution of the various sub-sources to total N2O emissions from direct managed soil emissions in 2015.



5.7.1.2 Methodology

The approach used to estimate direct N_2O emissions from managed soils follow the IPCC 2006 Tier 1 methodology with country specific activity data.

Final N_2O emissions are estimated with a formulation derived from equation 11.1 of IPCC 2006:

$$EN_2O_{Direct} = (N_2O - N_{N\ inputs} + N_2O - N_{N\ prp}) * 44/28$$

$$N_2O - N_{N\ inputs} = (F_{SN} + F_{AM} + F_{SEW} + F_{MSW} + F_{CR}) * EF_1$$

$$N_2O - N_{N\ prp} = (F_{prp,\ cpp} * EF_{3\ prp,cpp}) + (F_{prp,\ so} * EF_{3\ prp,so})$$

where:

EN_2O_{Direct} – total direct emission of N_2O from managed soils, kg N_2O/yr;

$N_2O - N_{N\ inputs}$ – annual direct N_2O-N emissions from N inputs to managed soils, kg N_2O-N/yr;

$N_2O - N_{N\ prp}$ – annual direct N_2O-N emissions from urine and dung directly deposited by grazing animals, kg N_2O-N/yr;

44/28 – conversion of N_2O-N emissions to N_2O emissions;

F_{SN} - annual amount of synthetic fertilizer nitrogen applied to soils, kg N/yr;

F_{AM} - annual amount of animal manure nitrogen applied to soils, kg N/yr;

F_{SEW} – annual amount of nitrogen in sludge applied to agriculture soils, kg N/yr;

F_{MSW} – annual amount of nitrogen in compost from biological treatment of municipal solid waste that is applied to agriculture soils, kg N/yr:

F_{CR} – annual amount of nitrogen in crop residues returned to soils, kg N/yr;

EF_1 - emission factor for N_2O emissions from N inputs to soil, kg N_2O-N/kg N input;

$F_{prp, cpp}$ – annual amount of urine and dung N deposited by grazing cattle, poultry and pigs (cpp) on pasture, kg N /yr;

$F_{prp, so}$ - annual amount of urine and dung N deposited by grazing sheep and other animals (so) on pasture, kg N /yr;

$EF_{3\ prp,cpp}$ - emission factor for N_2O emissions from urine and dung N deposited by grazing animals (cpp) on pasture, kg N_2O-N/kg N input;

$EF_{3\ prp,so}$ - emission factor for N_2O emissions from urine and dung N deposited by grazing animals (so) on pasture, kg N_2O-N/kg N input.

The annual amount of nitrogen in mineral soils that is mineralised (F_{SOM}) with loss of C soil from soil organic matter as a result of changes to land use (cropland remaining cropland) and the direct and indirect emissions of N_2O are reported in CRF 3D but estimates are done in LULUCF sector. Methodologies, emission factors and activity data used are described in LULUCF chapter (6.11 and 6.12 of this report).

5.7.1.3 Emissions factors

The emissions factors used for N_2O emissions from N_{inputs} to soil (EF_1) and for N2O emissions from urine and dung N deposited by grazing animals on pasture ($EF_{3\ prp,\ cpp}$ and $EF_{3\ prp,so}$) were the default values of IPCC 2006, table 11.1.

In the next table are shown the values used for EF_1, $EF_{3\ prp,\ cpp}$ and $EF_{3\ prp,so}$.

Table 5.40 – Emission Factors used to estimate direct N2O emissions from managed soils.

Emission Factor	Value (Kg N2O-N/kg Ninput)
EF_1	0.01
$EF_{3\ prp,\ cpp}$	0.02
$EF_{3\ prp,so}$	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_2O emissions, are shown in Table 5.41 and in ANNEX F: Agriculture for the complete time series.

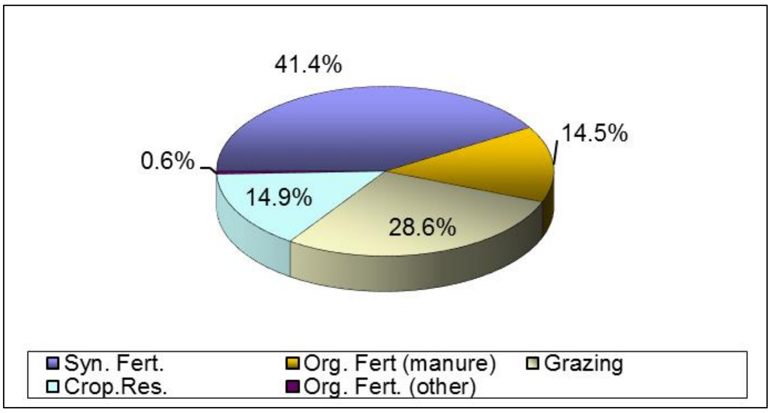
Total nitrogen added to soil was in 2015 about 14.4 % lower than what it was applied in 1990.

Table 5.41 - Total amounts of Nitrogen (t N/yr) added to managed soils: activity data for direct N2O emissions.

Sources	1990	1995	2000	2005	2010	2013	2014	2015
Synthetic Fertilizer	158 500	145 815	170 009	102 663	100 249	110 643	122 842	121 028
Organic Fertilizer (manure)	59 921	58 384	58 699	48 989	45 922	42 735	42 335	42 547
Pasture	70 561	74 447	82 538	83 729	84 097	82 253	82 468	83 692
Crop Residues	52 258	45 925	43 910	40 151	36 371	50 002	47 837	43 602
Organic Fertilizer (sewage & compost)	319	319	263	366	491	1 246	489	1 648
Total	341 598	324 898	355 419	275 897	267 130	286 879	295 971	292 516

For the last year in the inventory there are two categories that represent the majority of nitrogen added to soil: synthetic fertilizers (41.4 %) and direct droppings during grazing in Pasture (28.6 %) as shown in next figure.

Figure 5-27 – Sources of direct input of Nitrogen to agricultural soil in 2015.



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[101] and ADP[102], 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[103] and international market information data. The fertilizer consumption data reported by INE are obtained by the following methodology:

$$Consumption_{(f)} = Production_{(f)} + Import_{(f)} - Export_{(f)}$$

where,

$Consumption_{(f)}$ – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

$Production_{(f)}$ – Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

$Import_{(f)}$ – Annual imports in Portugal of nitrogen fertilizer f (ton N/yr);

$Export_{(f)}$ - Annual exports in Portugal of nitrogen fertilizer f (ton N/yr).

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.

The ACFA time series data produced by INE are only available from 1995, 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).

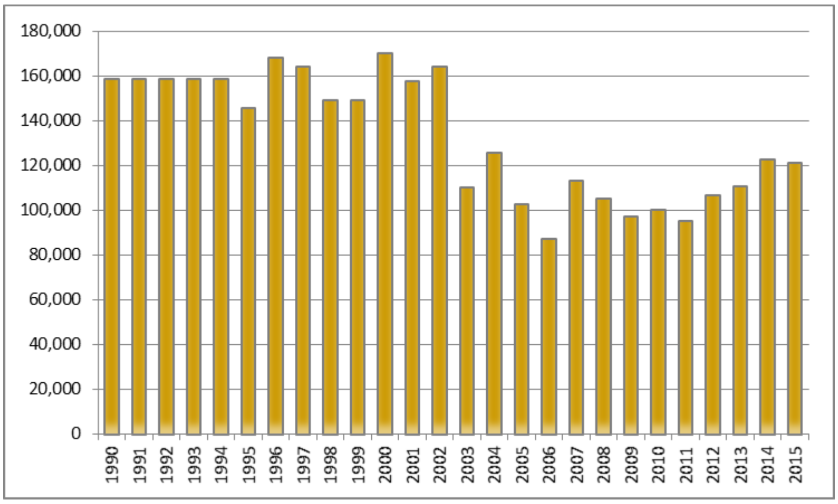
The available time series is presented in Figure 5-28. It shows a period until 2002 with a higher consumption of synthetic fertilizers and then a sharp decrease in 2003 closely linked with the significant change, at that time, of the direct support schemes under the common agricultural policy (Council 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.

[101] 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).

[102] ADP, Adubos de Portugal, S.A., is the main producer of fertilizers in Portugal, and responsible for about 75% of fertilizer sales (INE,2004)

[103] IAPI – Annual censos made by INE to the Manufacturing Industry.

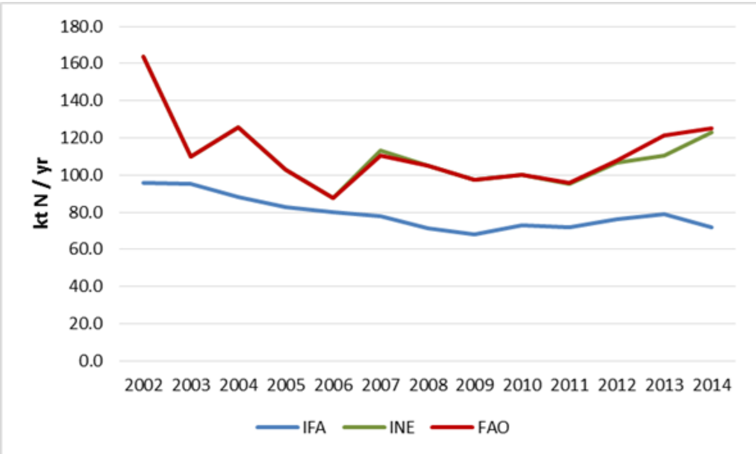
Figure 5-28- Use of Nitrogen Fertilizers (t N/yr) in Portugal, estimated from INE data (1995-2015) - Using a simple average value for 1990-1994.



In ANNEX F: 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) and the databases of FAO (http://www.fao.org/faostat/en/#data/RF) and of IFA[104] (http://ifadata.fertilizer.org/ucSearch.aspx) for the period 2002 – 2014. For previous years (1990-2001) FAO database archive has no data registers. In both databases (FAO and IFA) 2014 is the last year available. Comparison results are shown in Figure 5-29.

Figure 5-29 – Data bases comparison of N inorganic fertilizers use.



FAO and INE series agree quite well. The difference for 2013 is due to a recent update done by INE to the previous value that should then be transmitted by Eurostat to FAO, what apparently has not been done yet.

IFA data are lower than INE ones because IFA consumption statistics, follow the IFA definition "*relate, to the extent possible, to real consumption*" and not the apparent consumption concept. The restriction access to detailed information about the construction of IFA data set prevented a

[104] International Fertilizers Association

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 5.43 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 3-7 of EMEP/EEA Guidebook 2016, chapter 3 B – Manure management, and are shown in table below.

Table 5.42 – 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	1596.88	6.39
Other cattle	475.55	1.90
Sheep & goats	47.69	0.19
Sows	566.64	2.27
Other swine	192.42	0.77
Horses & asses	608.30	2.43

.

Table 5.43 – Estimates of the amount of manure managed nitrogen available for application to soils (t N/yr).

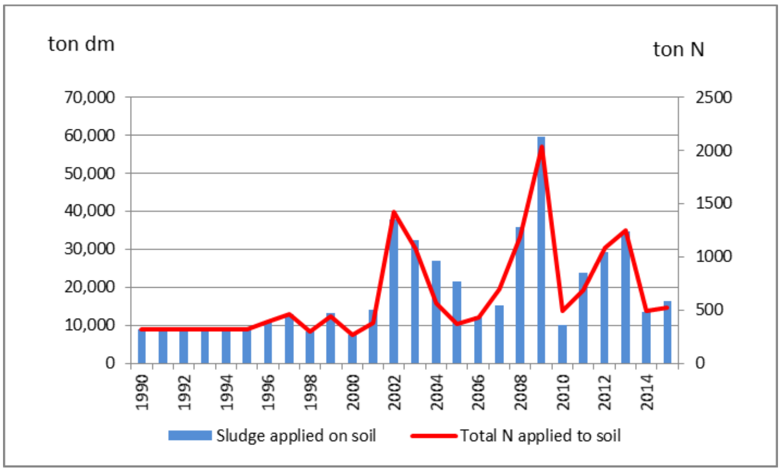
Year	N_ manure managed MS	N_bedding MS	N_total losses MS	NMS_available for application to soils
1990	89 659	1 606	31 344	59 921
1991	90 473	1 614	31 637	60 450
1992	89 690	1 591	31 439	59 843
1993	88 917	1 591	31 216	59 292
1994	88 342	1 572	31 091	58 822
1995	87 742	1 571	30 929	58 384
1996	86 267	1 559	30 525	57 301
1997	85 647	1 539	30 372	56 814
1998	86 379	1 515	30 830	57 064
1999	89 507	1 491	32 236	58 762
2000	89 930	1 449	32 680	58 699
2001	87 139	1 386	31 895	56 630
2002	83 600	1 322	30 778	54 144
2003	79 144	1 272	29 235	51 180
2004	77 039	1 253	28 450	49 842
2005	75 658	1 234	27 903	48 989
2006	73 974	1 210	27 248	47 936
2007	72 066	1 174	26 573	46 667
2008	71 792	1 144	26 619	46 318
2009	72 277	1 115	26 987	46 405
2010	71 830	1 076	26 985	45 922
2011	70 456	1 037	26 473	45 019
2012	68 446	1 007	25 627	43 827
2013	66 562	982	24 810	42 735
2014	65 805	969	24 439	42 335
2015	65 990	974	24 417	42 547

5.7.1.4.3 Other organic ferilizers applied to soil

a) Sewage sludge applied to soil

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 5-30 – 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 5.44 – Estimates of annual amounts of N sewage sludge applied in agriculture soils.

Year	Sewage sludge applied (t dm)	N content (kg N/kg dm)	Total N (t N)
1990	8 800	0.0363	319
1991	8 800	0.0363	319
1992	8 800	0.0363	319
1993	8 800	0.0363	319
1994	8 800	0.0363	319
1995	8 800	0.0363	319
1996	10 626	0.0363	386
1997	12 852	0.0363	467
1998	8 283	0.0363	301
1999	13 309	0.0330	440
2000	7 435	0.0354	263
2001	13 971	0.0270	377
2002	37 952	0.0374	1 419
2003	32 479	0.0330	1 072
2004	27 006	0.0210	567
2005	21 533	0.0170	366
2006	12 282	0.0349	429
2007	15 154	0.0458	693
2008	35 739	0.0333	1 191
2009	59 609	0.0341	2 035
2010	5 647	0.0493	278
2011	23 088	0.0287	663
2012	29 172	0.0371	1 082
2013	34 651	0.0360	1246
2014	13 451	0.0364	489
2015	16 508	0.0318	525

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.

b) Compost from municipal solid waste applied to soil

The compost resulting from biological treatment of municipal solid waste (MSW) was only recognized as a fertilizer from June 2015 (Decree Law 103/2015). The decree establishes quality standards and control measures including the monitoring of the compost applied to agricultural soils. Therefore the accounting of this type of N amendment begins in 2015 and emisions from this source category are estimate at the first time in this year submission.

In 2015 a total amount of 56 156 t of MSW compost was applied to agricultural soils which corresponds to the N amount application of 1 123 t.

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_2O emissions from Manure Management (CRF 3Bb). The fraction of total annual N excretion deposited on pasture for each livestock species are presented in Table 5.22 and Table 5.23 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 5.41 above and in the ANNEX F: Agriculturefor 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 ($Frac_{remove}$) and for the % of crop area with residues burnt *in situ* ($Area_{burnt}$), 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 $Frac_{remove}$ 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[105] for some legumes and N content of above ground residues (N_{AG}) for cereals, potatoes and some legumes.[106] 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_{BG-BIO}) and for N content of below-ground residues (N_{BG}).

[105] "In "Manual de Culturas Hortícolas", Volume I e II de Domingos Almeida

[106] 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 5.45 – Parameters used to estimate nitrogen from crop residues returned to soil.

Crop	dm_{Frac}	$Frac_{Removed}$	NAG (kg N/kg dm)	RBG-BIO (ratio)	NBG (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
Tobacco	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
Cereals 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 5.46. The final amounts of Nitrogen added to soil from crop residues returned to soil are shown in Table 5.41 and in ANNEX F: Agriculture for the complete time series.

Table 5.46 – Crop Yield _Fresh (kg/ha).

Crop	1990	1995	2000	2005	2010	2013	2014	2015
Wheat	1 858	1 679	1 366	1 504	1 430	1 753	2 066	2 023
Triticale	1 478	1 388	1 295	1 262	1 057	1 543	1 562	1 693
Maize grain	3 083	4 375	5 793	5 293	6 929	8 315	8 333	8 452
Barley	1 430	1 464	1 345	1 675	1 514	1 774	2 209	2 097
Rye	1 020	815	965	914	859	865	891	856
Oats	911	902	1 092	1 064	1 071	1 245	1 334	1 212
Rice	4 665	5 787	5 940	5 747	5 845	5 970	5 819	6 345
Tobacco	2 066	2 454	2 755	2 940	3 188	2 471	2 447	2 682
Sunflower	639	313	486	473	544	639	1 056	1 242
Potatoes	11 671	14 644	14 831	16 000	15 034	18 224	19 838	19 771
Other root crops	36 998	42 619	57 666	72 334	31 403	29 007	37 812	45 198
Peas fresh	5 333	5 980	7 129	6 427	6 335	6 400	10 300	16 488
Beans fresh	7 781	9 472	10 013	12 741	15 344	15 400	16 313	16 979
Dry beans	524	541	512	446	582	575	578	567
Broad beans	6 616	6 616	6 225	6 132	6 008	7 828	8 562	7 778
Peanuts	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
Other legumes	1 661	2 428	2 711	2 098	2 740	2 977	4 419	2 303
Tomatoes	46 169	56 378	69 746	78 137	83 096	75 914	75 819	92 714
Maize for forage	34 005	37 978	38 363	37 750	35 517	40 720	42 020	39 022
Cereals for forage	24 568	21 224	21 818	21 942	22 162	17 860	18 036	16 032
Other forage	11 800	9 593	9 779	9 752	9 563	22 970	23 073	21 861

5.7.2 Indirect N_2O emissions from managed soils

5.7.2.1 Overview

In addition to direct N_2O emissions from managed soils, emissions of N2O also occur through two indirect pathways: via volatilisation NH_3 and NO_x 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_3 and NO_x. A fraction of the N volatilised returns to the ground and is then re-emitted as N_2O. 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_2O.

Share of indirect N_2O emissions from managed soils, by pathway and by source, is shown in the next two figures for 2015.

Figure 5-31 – Share of indirect N_2O emissions from managed soils by pathway: volatilisation and leaching and runoff, 2015.

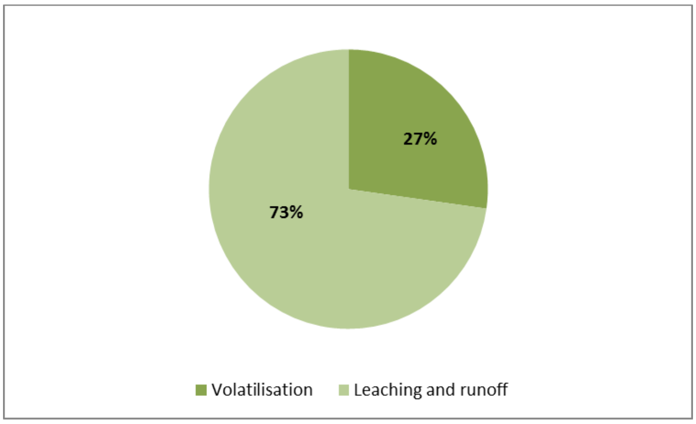
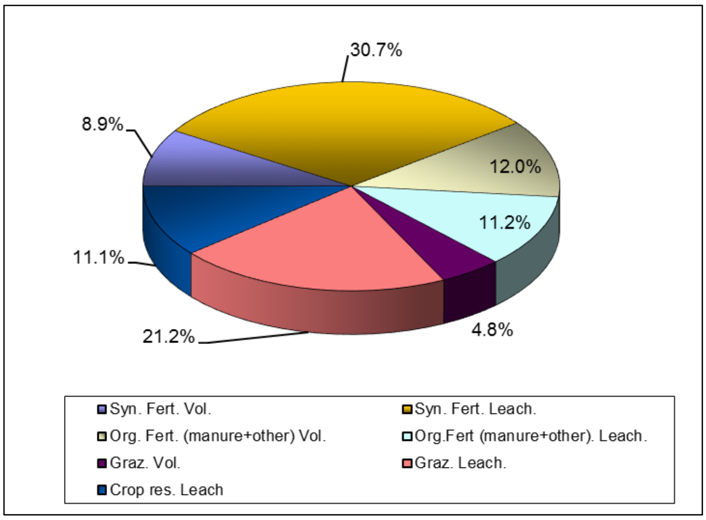


Figure 5-32 – Share of indirect N_2O emissions from managed soils by source, 2015.



5.7.2.2 Methodology

Volatilisation/atmospheric deposition

Indirect N_2O emissions due to volatilisation/atmospheric deposition of N added to soils were estimated based on equation 11.9 of IPCC 2006.

$$N_2O_{(ATD)} = [(F_{SN}*Frac_{GASF})+(F_{ON}+F_{PRP})*Frac_{GASM})]*EF_4*44/28$$

where:

$N_2O_{(ATD)}$ –N_2O emissions indirectly produced from atmospheric deposition of N volatilized from managed soils, kg N_2O/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+compost$_{MSW}$) applied t 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 +sewage sludge+$compost_{MSW}$) and from urine and dung deposited by grazing animals that volatilises as NH3 and NOx, kg N volatilised/kg N applied and deposited;

EF_4 – emission factor for N2O 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.

For all source categories of managed soils the annual amounts of N that volatilized in form of NH_3 and NO_x are estimated using the methodologies described, for each one, in EMEP/EEA Guidebook 2016, in consitence with UNECE/CLRTAP emissions inventory.

The amount of N from synthetic fertilizers application that volatilized as NH_3 was estimated using the tier 2 approach[107], which provides different emissions factors[108] by type of fertilizer and emission region (combination of the soil pH and the climate zone as defined in IPCC 2006).

The amount of N from synthetic fertilizers application that volatilized as NO_x was estimated using a tier 1 methodology[109] (no tier 2 available).

The amount of N from manure application and from urine and dung deposited on soil by grazing animals that volatilized as NH_3 and NO_X was estimated using the tier 2 methodology[110] (N_flow approach).

The amount of N from sewage sludge and compost additions on soils that volatilized as NH_3 and NO_x was estimated using a tier 1 methodology[111].

In the next table are presented the estimated annual amounts of N, expressed in tonnes, volatilized as NH_3 and NO_x ,disaggregated by source input.

[107] Chapter 3D-Crop production and agricultural soils, page 14 of EMEP/EEA Guidebook 2016.

[108] Table 3-2 of Chapter 3D – Crop production and agricultural soils, page 15 of EMEP/EEA Guidebook 2016.

[109] Chapter 3D – Crop production and agricultural soils, page 15 of EMEP/EEA Guidebook 2016.

[110] Chapter 3B – Manure management, page 20 of EMEP/EEA Guidebook 2016.

[111] Chapter 3D – Crop production and agricultural soils, page 15 of EMEP/EEA Guidebook 2016.

Table 5.47 – Annual N amounts (t) that volatilized as NH_3 and NO_X, disaggregated by source input.

Year	Synthetic fertilizers	Animal manure	Grazing animals	Other organic additions
1990	9 981	12 553	3 677	45
1991	9 981	12 232	3 736	45
1992	9 981	12 122	3 715	45
1993	9 981	12 004	3 715	45
1994	9 981	11 915	3 779	45
1995	9 307	11 792	3 890	45
1996	10 897	11 535	3 989	54
1997	10 246	11 454	4 058	65
1998	8 421	11 580	4 129	42
1999	9 330	12 044	4 223	62
2000	11 298	12 088	4 245	37
2001	10 295	11 671	4 172	53
2002	10 052	11 134	4 111	199
2003	6 501	10 478	4 051	150
2004	6 943	10 152	4 086	79
2005	6 815	9 933	4 159	51
2006	6 862	9 684	4 195	60
2007	8 090	9 405	4 195	97
2008	7 557	9 354	4 168	167
2009	6 437	9 429	4 118	285
2010	5 545	9 392	4 067	69
2011	6 381	9 263	4 002	95
2012	6 069	9 038	3 966	152
2013	5 800	8 832	3 913	174
2014	7 535	8 765	3 916	68
2015	8 497	8 817	3 967	168

In the table below are presented the annual calculated values of $Frac_{GASF}$ and $Frac_{GASM}$ according to report requirements (CRF 3 D – Aditional information).

Table 5.48 -- $Frac_{GASF}$ and $Frac_{GASM}$ annual values.

Year	$Frac_{GASF}$	$Frac_{GASM}$*
1990	0.063	0.20
1991	0.063	0.20
1992	0.063	0.20
1993	0.063	0.20
1994	0.063	0.20
1995	0.064	0.19
1996	0.065	0.20
1997	0.062	0.19
1998	0.056	0.18
1999	0.063	0.18
2000	0.066	0.20
2001	0.065	0.19
2002	0.061	0.19
2003	0.059	0.16
2004	0.055	0.16
2005	0.066	0.16
2006	0.079	0.16
2007	0.072	0.16
2008	0.072	0.16
2009	0.066	0.15
2010	0.055	0.15
2011	0.067	0.15
2012	0.057	0.15
2013	0.052	0.15
2014	0.061	0.16
2015	0.070	0.17

* $Frac_{GASM}$, (manure, applied, excreta deposited on pasture and other organic fertilizers applied)

The annual variation of $Frac_{GAS}$ is mostly related with the amount and type of N synthetic fertilizers comsunption in each year. In ANNEX F: Agriculture is presented, for the time series, the annual amounts of N synthetic fertilizers used by type of fertilizer.

The annual variation of $Frac_{GASM}$ is associated with the livestock population in each year and the proportion of manure managed (housing and storage) and manure not managed (urine and dung deposited on soils).

For both cases, $Frac_{GAS}$ and $Frac_{GASM}$, the calculated values are within the range of possible values, table 11.3 of chapter 11, volume 4 of IPCC 2006.

Leaching and runoff

Indirect N2O 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 N2O emissions from managed soils.

The value used for $Frac_{LEACH}$ is the default value of 0.30 kg N/kg N additions or deposition by grazing animals proposed in table 11.3 of chapter 11, volume 4 of IPCC 2006.

N losses through runoff and leaching occurs not only during the rainy season as a result of rainfall but also during the irrigation season as a result of irrigated systems and practices. In Portugal the rainy season (October to March) is the period when the autumn/winter crops, such as wheat, barley, rye, triticale, potatoes and some legumes, are sowed and grown and the irrigation season (April to September) is the period when the spring/summer crops, such as maize, rice, tomato and other legumes, are cultivated and need to be irrigated because in normal weather conditions there is no rain during this period. Permanents crops, such as pastures, vinyeards, olive groves and orchards are subjected to different agricultural practices along the two seasons. At the end of the day the N inputs into agriculture soils, including those related to livestock activities, occur in a continuous along the agricultural year and national territory.

The national river basins[112] management plans (aggregated in eight hidrographic regions[113] in the continental territory, and one hydrographic region in each of the archipelagos of Azores and Madeira) were recently approved[114]. They includ estimates of N losses to the water bodies through runoff/leaching of the total N inputs resulting from all the agricultural activities, at the order of 17 - 17.5% for water surface and 12-12.4% for groundwater bodies. These means that for every unit of N applied to the soil or deposited by grazing animals, 29 – 29.9 % is lost to the water bodies through runoff and leaching, which is very close to the default value kept for inventory calculations.

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.

[112] http://snirh.pt/snirh/_atlasagua/galeria/mapasweb/pt/aa1002.pdf, continental territory; http://servicos-sraa.azores.gov.pt/grastore/DRA/PGRHA_20162021/PGRH-A_2016-2021_RT_Parte2.pdf , archipelago of Açores; http://www.madeira.gov.pt//Portals/12/Documentos/Ambiente/RecHidricos/PGRH/PGRH10_Parte%202%20-%20Caraterizacao%20e%20Diagnostico.pdf, archipelago of Madeira.

[113] https://www.apambiente.pt/index.php?ref=16&subref=7&sub2ref=9&sub3ref=848

[114] September 2016, continental river basins plans; December 2016, Madeira river basins plans and February 2017 Açores river basins plans.

Table 5.49 – Emission factors used for calculation of indirect N_2O emissions from managed soils.

Emission Factor	Value
EF_4	0.010 Kg N_2O-N/kg NH_3-N+NO_X-N
EF_5	0.0075 Kg N_2O-N/kg N leaching/runoff

5.7.2.4 Activity data

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 and the annual N amounts added to soil, by source, are summarized in Table 5.41 and in ANNEX F: Agriculture for the complete time series.

5.7.3 Uncertainty Assessment

5.7.3.1 Direct N2O emissions

The IPCC 2006 presents no information concerning the uncertainty in activity data, and therefore, the values were set in the following mode:

- Synthetic Fertilizers: the uncertainty value was estimated by comparison of the data (N amount in fertilizers) of apparent consumption of N fertilizers produced by INE with the consumption data of N fertilizers produced by IFA. A maximum uncertainty of 26.1 % was obtained;

- For nitrogen in animal manure applied to soil the uncertainty value of 56.0% was set based in the same uncertainty values that were used for activity data in N_2O from Manure Management;

- An uncertainty error of 35.5 % in crop residues production was considered in accordance with the range of errors of equation to estimate the above ground residue dry matter (table 11.2 IPCC 2006) for the most relevantt crops contributing to N returned to soil;

- For urine and dung deposited on pasture by grazing animals the uncertainty value of 38.8 % was set based in the same methodology used to determine uncertainty values in MMS used in the N_2O direct emissions from manure management.

The uncertainties of emission factors EF_1 for N additions from mineral, organic and crop residues and EF_3 for urine and dung deposited on pasture by grazing animals were determined from the possible range of errors of the default values. The calculated uncertainty values are: EF_1 135.0 % and EF_3 133.2 %.

5.7.3.2 N2O indirect emissions

Uncertainties in estimates of indirect N2O emissions from managed soils are the result of combined uncertainties related to the fractions of N volatilized from mineral fertilizers applications ($Frac_{GASF}$), from organic fertilizers amendments and urine and dung deposited on pasture ($Frac_{GASM}$), and to the fraction o N lost by leaching/runoff ($Frac_{Leach}$) and the uncertainties related with the emission factors EF_4 (volatilization and re-deposition) and EF_5 (leaching and run off).

The individual uncertainty values are presented in next table.

Table 5.50 – Uncertainty Values (in %) of Fractions N volatilized and N leached and of the Emission Factors of N_2O indirect emissions from managed soils.

$Frac_{GASF}$	$Frac_{GASM}$	$Frac_{Leach}$	EF_4	EF_5
135.0	112.5	116.7	135.0	163.3

5.7.4 Category-specific QA/QC and verification

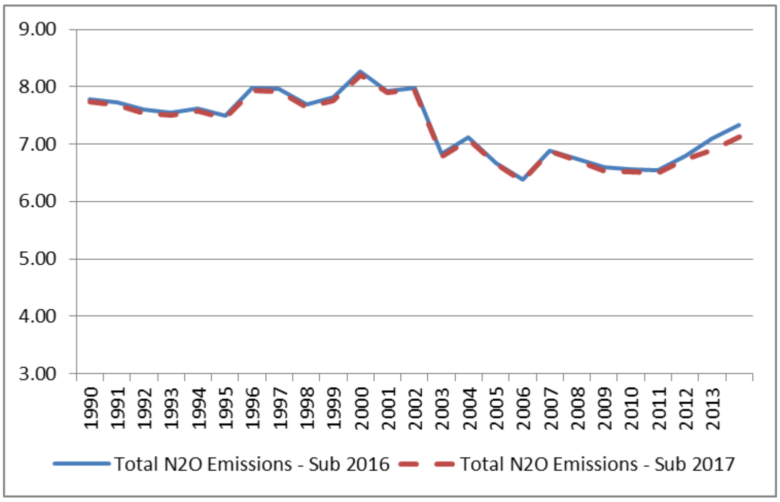
The QA/QC procedures applied in this source category comprehend a comparison between FAO and IFA available data with INE values concerning the use of nitrogen fertilizers in Portugal. The results are presented in Figure 5-29 of this report.

iThe QA/QC procedures also included a series of checks: calculation formulas verification, data and parameters verification and the information provided in this report.

5.7.5 Recalculations

Differences between last year and this year submission are graphically represented in figure below.

Figure 5-33 – Differences between submissions, 2016 and 2017 for N_2O emissions (direct and indirect) from managed soils (kt N_2O).



Changes result mainly from the following reasons:

– Downward revision of 2013 and 2014 values for apparent consumption of N synthetic fertilizers, updated by INE;

- Downward revision of 2013 and 2014 values of sewage sludge applied to agricultural soils, updated by the waste sector;

- implementation of the tier 2 methodology of EMEP/EEA Guidebook 2016 to estimate NH_3 emissions from N synthetic fertilizers application, which includes new default emission factors (lower than the previous one). Less N volatilized in form of NH_3 less N_2O indirect emissions from atmospheric deposition.

5.7.6 Further Improvements

As referred in the sources categories related with manure management (CRF 3.B.a and CRF 3.B.b) it is planned to revisit the characterization of the manure management systems, framed by the new national law[115] related with livestock farming. It is likely that the possible outcome will also have impact in the N_2O emissions from manure applied to soil.

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 5.51 – Methane and Nitrous Oxide estimates emissions from field burning of agriculture residues (kt).

Gas/Source	1990	1995	2000	2005	2010	2013	2014	2015
CH_4	**1.49**	**1.36**	**1.27**	**1.07**	**1.14**	**1.17**	**1.16**	**1.17**
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	0.03	0.03	0.02
Rice	0.31	0.26	0.23	0.10	0.26	0.28	0.26	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	0.85	0.86	0.86	0.86
N_2O	**0.07**	**0.07**	**0.06**	**0.06**	**0.05**	**0.06**	**0.06**	**0.06**
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

Note: Totals may not sum due to independent rounding

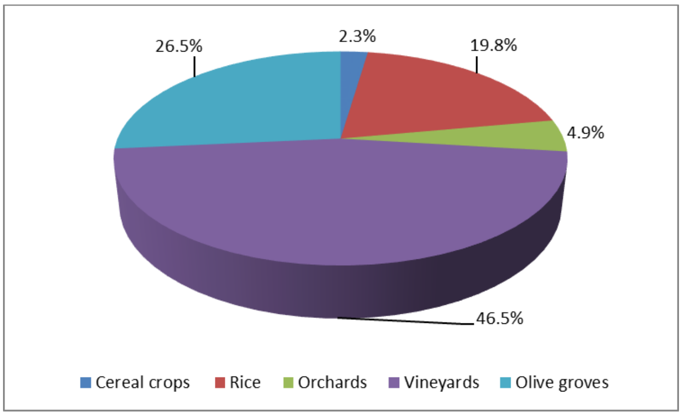
5.8.1 Overview

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 5-34), burning of residues from vineyards is the most significant source of this non-key source.

[115] Decree –Law nº81/2013

Figure 5-34 – Importance of GHG emissions from field burning of agriculture residues by crop in 2015.



5.8.2 Methodology

Emissions of in-site burning of agriculture residues were estimated based on equation 2.27[116] from the IPCC 2006 which is summarized in the following equation:

$$Emission_{(p,crop)} = A_{(crop)} * M_{B(crop)} * C_f * EF_{(p,crop)} * 10^{-3}$$

where:

$Emission_{(p,crop,y)}$ - 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_4, N_2O, CO, NMVOC and NO_X emissions from field burning agricultural residues are the default values from IPCC 2006 (table 2.5[117]) and from EMEP/EEA Guidebook 2013 (chapter 3F). They are presented in the following table with source indication by crop and pollutant.

[116] Volume 4, chapter 2, pg 2.42

[117] Volume 4, chapter 2,pg.2.47

Table 5.52 – Emission factors for field burning of agricultural residues, g/kg dm burnt.

Crop	CH_4	N_2O	NO_x	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#	0.5#	66.7#
Orchards	4.7"	0.26"	3.0"	0.7»	107.0"
Vineyard	4.7"	0.26"	3.0"	0.6»	107.0"
Olive grove	4.7"	0.26"	3.0"	1.4»	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;» Table 2.5-5 AP_ 42 USEPA.

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.

In chapter 5.5– CH_4 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 5-16 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[118] values presented in Table 5.53.

Activity data and parameters used to estimate emissions from cereal and permanent crops residues burnt on field are summarized in table below for 2015. Combustion factors used for cereals are the default values from Table 2.6 of IPCC 2006[119]. For pruning material from

[118] Dias, J.J. Mestre (2002), "Utilização da biomassa: avaliação dos resíduos e utilização de pellets em caldeiras domésticas".

[119] Volume 4, chapter 2, page 2.49

permanent crops the combustion factor considered was made equal to 1, following the recommendation of the EMEP/EEA Guidebook 2013[120].

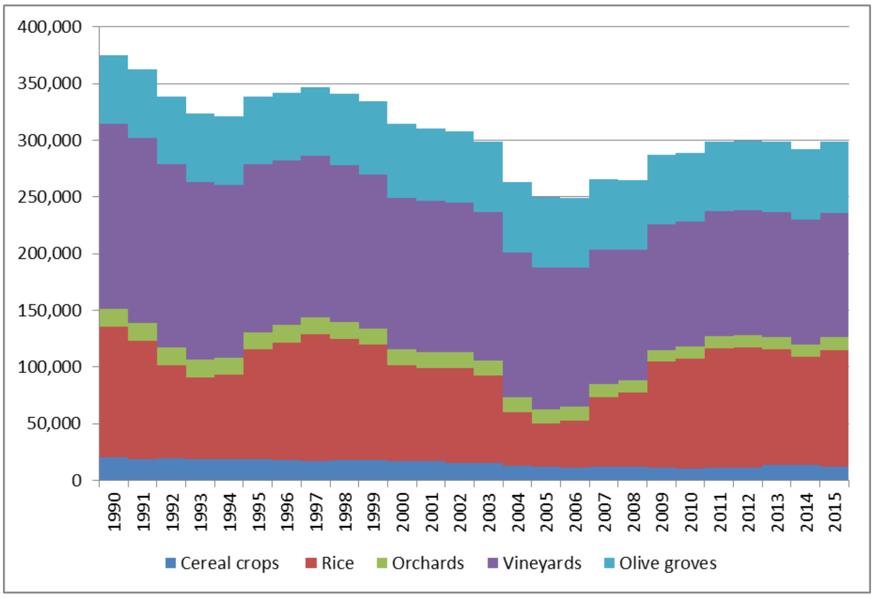
Table 5.53 – Activity data and parameters used to estimate emissions from field burning of agricultural residues, 2015.

Crop	Area burnt* (kha)	Biomass available for combustion (t dm /ha)	Combustion factor
Wheat	0.40	3.24	0.9
Barley	0.21	2.42	0.9
Maize	1.37	8.18	0.8
Rice	16.42	7.83	0.8
Other cereals	0.81	2.01	0.9
Orchards	9.16	2.27	1.0
Vineyard	92.16	1.19	1.0
Olive grove	228.38	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 1990-2015.

Figure 5-35 – Annual biomass burnt (tdm/yr) for the time series.



5.8.5 Uncertainty Assessment

The uncertainty in activity data was obtained from the combined uncertainties related with the areas burned and with the crop biomass available for combustion. The individual uncertainties and the final value for activity data uncertainty is presented in next table.

[120] Chapter 3F, page 6

Table 5.54 – Uncertainty values (in %) of the activity data from on field burning of crop residues.

Crop	Area burned	Biomass available	AD
Cereals	25.0	35.5	43.4
Perennial woody crops[1]	25.0	25.0	35.4

1Pruning material

The uncertainty of the emission factors were calculated considering the uncertainties ranges in IPCC 2006, and are presented below.

Table 5.55 – Uncertainty values (in %) of the emission factors, CH_4 and N_2O, from on field burning of crop residues.

Crop	EF CH_4	EF N_2O
Cereals	39.1	47.6
Perennial woody crops[1]	40.4	26.9

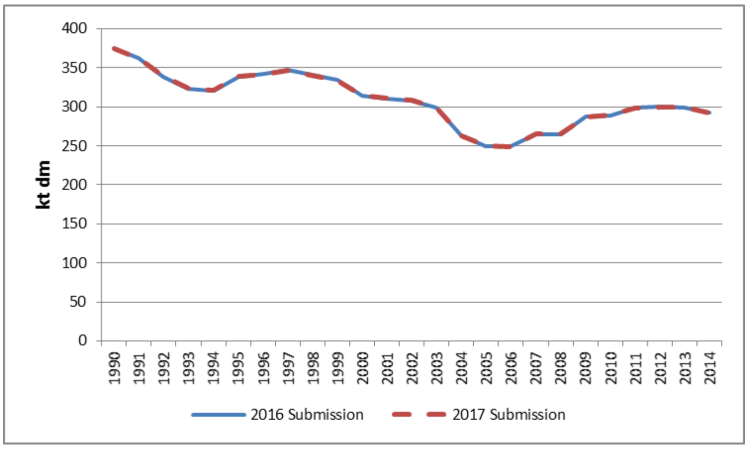
5.8.6 Category-specific QA/QC and verification

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

No recalculations to signalize as shown in the figure below.

Figure 5-36 - Amount of biomass burnt (kt dm) - differences between submission 2016 and submission 2017.



5.8.8 Further improvements

No specific improvements are planned.

5.9 CO_2 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 2015, emissions from liming were estimated in 7.3 kt CO_2, corresponding to a decrease of 41.8% compared to 1990 emissions (12.6 kt CO_2).

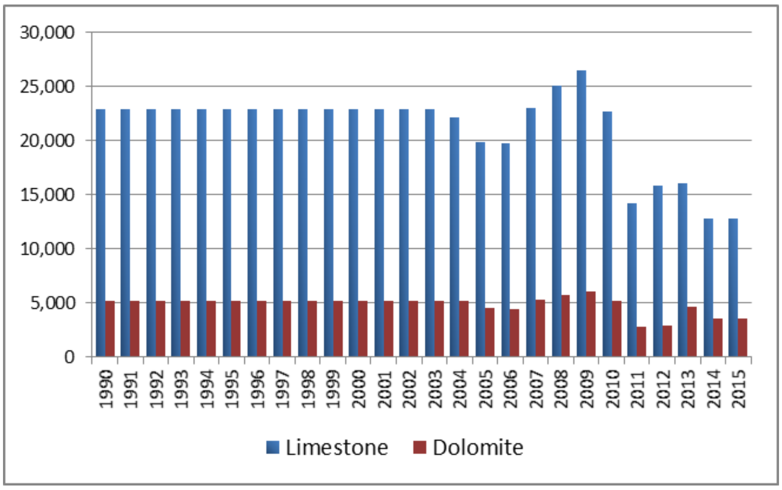
5.9.2 Methodological issues

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 $CaCO_3$, 13% for $CaMg(CO_3)_2$).

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 5-37 – Limestone and dolomite use on agricultural land (t/yr).



5.9.4 Uncertainty Assessment

Under the IPCC 2006 Tier 1 methodology, the default emission factor was used, which assume conservatively that all carbon from liming is emitted as CO_2 into the atmosphere. The default emission factor represents the absolute maximum emissions associated with liming added to soils so is assumed certain.

Activity data uncertainty was considered of 50 %.

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 were done in this source category.

5.9.7 Further improvements

No specific improvements are planned.

5.10 CO_2 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 2015 it accounts about 26.6% of the N synthetic fertilizers applications to the soil, more than double than 1990 (8,4%).

CO_2 emissions from urea application produced 51.31 kt CO_2 in 2015. This represents an increase of 141.2% compared to 1990 CO_2 emissions from urea applied to agricultural soils.

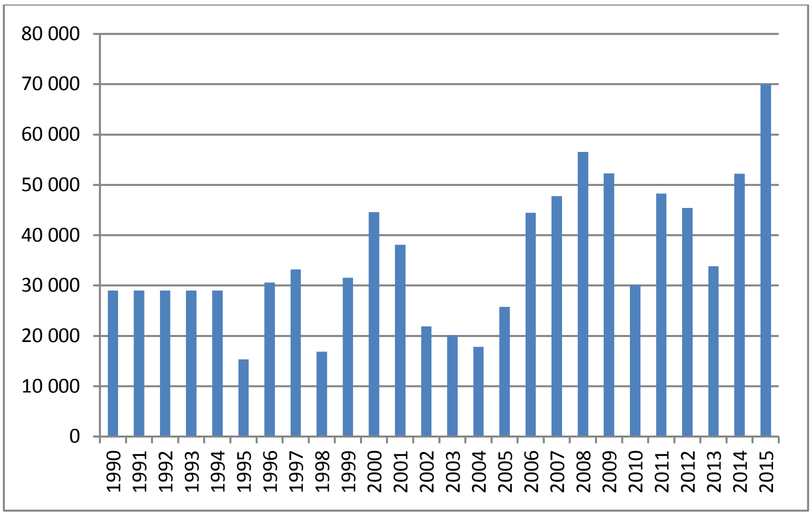
5.10.2 Methodological issues

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 5-38 – 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_2 into the atmosphere. The default emission factor represents the absolute maximum emissions associated with urea fertilization so is assumed certain.

The uncertainty of activity data, apparent consumption of urea, was assumed the same that was considered for N synthetic fertilizers in direct N2O emissions from managed soils, i.e., 26.1 %.

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

Changes between last year submission and this year submission result from the INE update of N synthetic fertilizers values for 2013 and 2014, including the amounts of urea.

5.10.7 Further improvements

No specific improvements planned

6 LAND USE, LAND USE CHANGE AND FORESTRY (CRF 4.)

6.1 Overview of LULUCF

6.1.1 LULUCF Inventory Framework

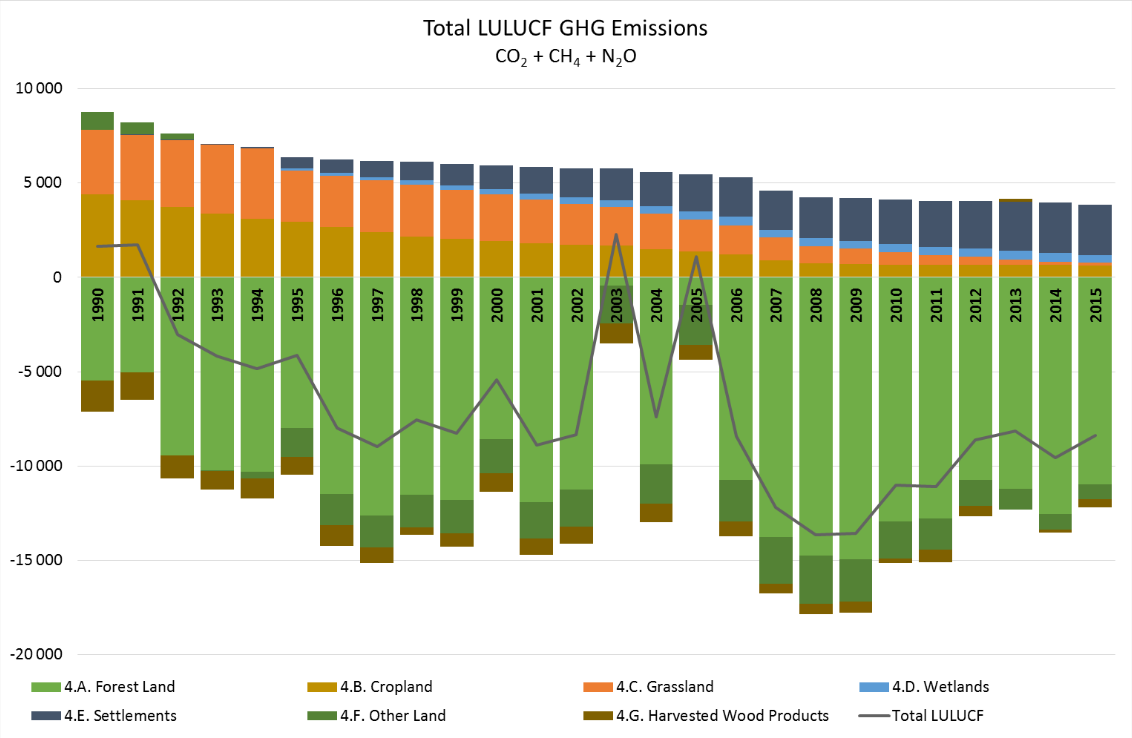
When considered in its entirety, the LULUCF sector is estimated as a net-sink for the whole time series period, except for the years 1990, 1991, 2003 and 2005, as represented in Figure 6-1.

In 2015 the carbon sink resulting from LULUCF is estimated at 8.8Mt CO_2e. In the period 1990-2015 the average sink was 7.4Mt CO_2e, with a tendency for increasing net-sequestration over time.

The main contributors for this increase 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, largely 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_2e).

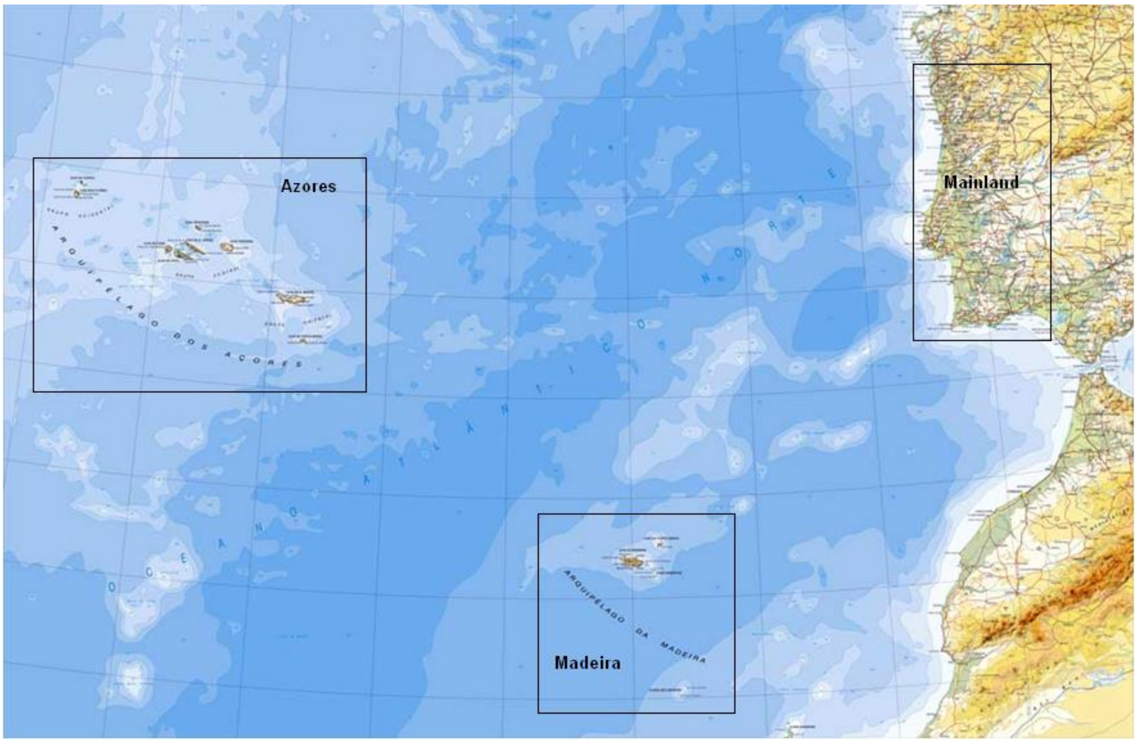


6.1.2 Representation of Land-Areas and Land-Use Changes

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
Forest Land	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
Cropland	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[121]
	Other permanent crops	Includes all areas used for cultivation of all other species of woody crops, including fruit orchards[122]
Grassland	All grasslands	Includes all lands covered in permanent herbaceous cover
Wetlands	Wetlands	Includes all lands permanently or temporarily covered in water, such as natural wetlands, water reservoirs and inland natural lagoons, lakes and estuaries
Settlements	Settlements	Includes all artificial territories, including cities and villages, industry, roads and railway, ports and airports
Other Land	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 1970-2015 was divided into two different time periods: 1970-1995 and 1995-2015.

This separation was needed due to the quality of available information, where the period 1995-2015 can be estimated using an approach type 3 (spatially-explicit land-use conversion data),

[121] Olive trees used for the production of olive oil and/or olives. The Wild Olive Tree (sub-species Olea europea sylvestrys) is reported as Forest Land / Other Broadleaves

[122] 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.

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 1995-2015

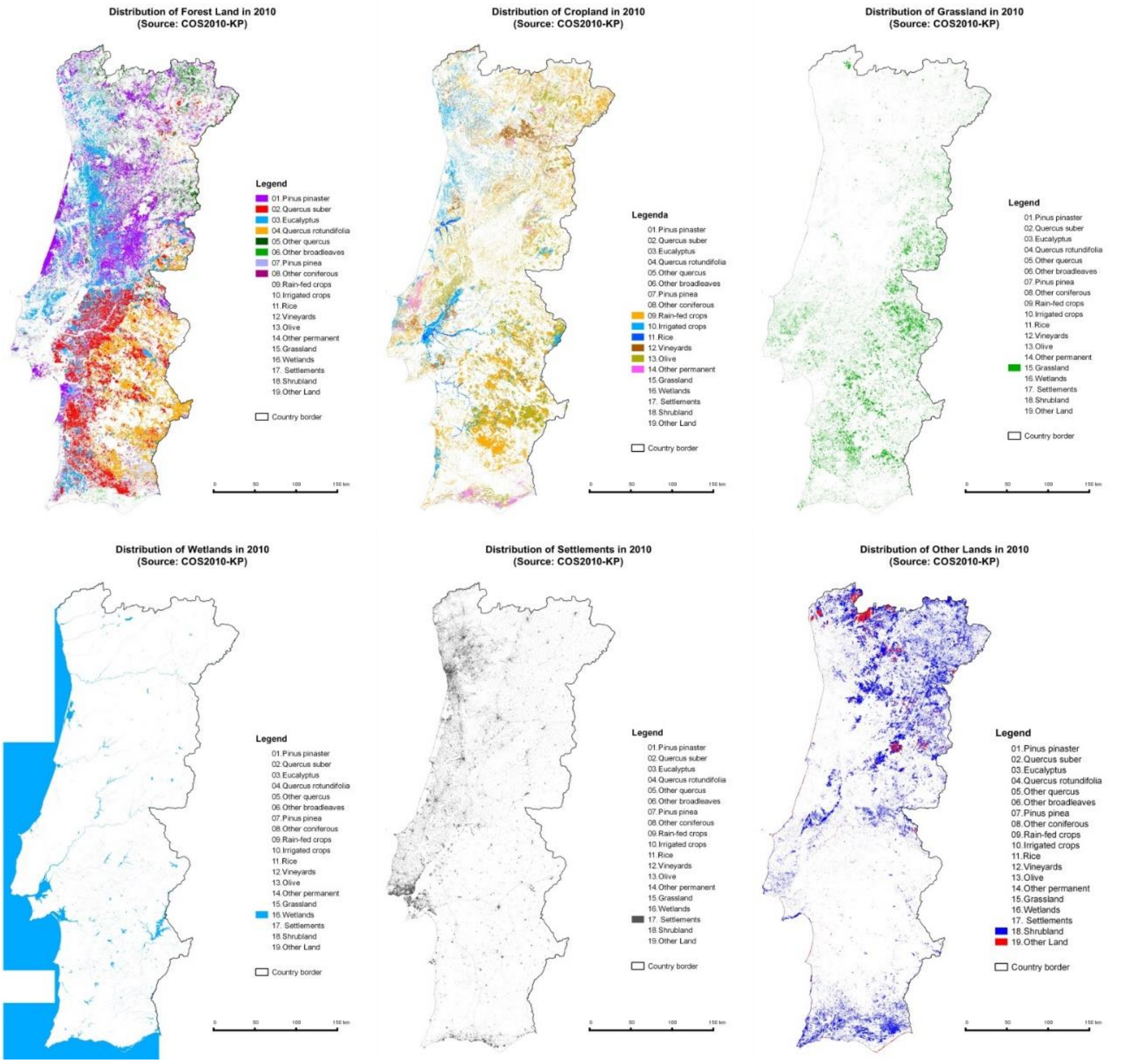
The main information source for this period is the Cartografia de Ocupação de Solo[123] (COS). COS was produced during 2013, based on an earlier version of 2007. COS (2007) was revised and used as a basis to derive COS (1995) and COS (2010), using the full aerial photography cover of mainland Portugal available for the respective years.

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 tree 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.

[123] 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 2007-2015 and equal to the annual land-use changes derived in those periods.

Equation 6-1 - Estimation of annual land-use change 1995-2015

$$LUC_{x\rightarrow y[Y_i]} = \frac{LUC_{x\rightarrow y[1995-2007]}}{12}$$, Y_i = any year in [1995-2007[

$$LUC_{x\rightarrow y[Y_i]} = \frac{LUC_{x\rightarrow y[2007-2010]}}{3}$$, Y_i = any year in [2007-2015]

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:

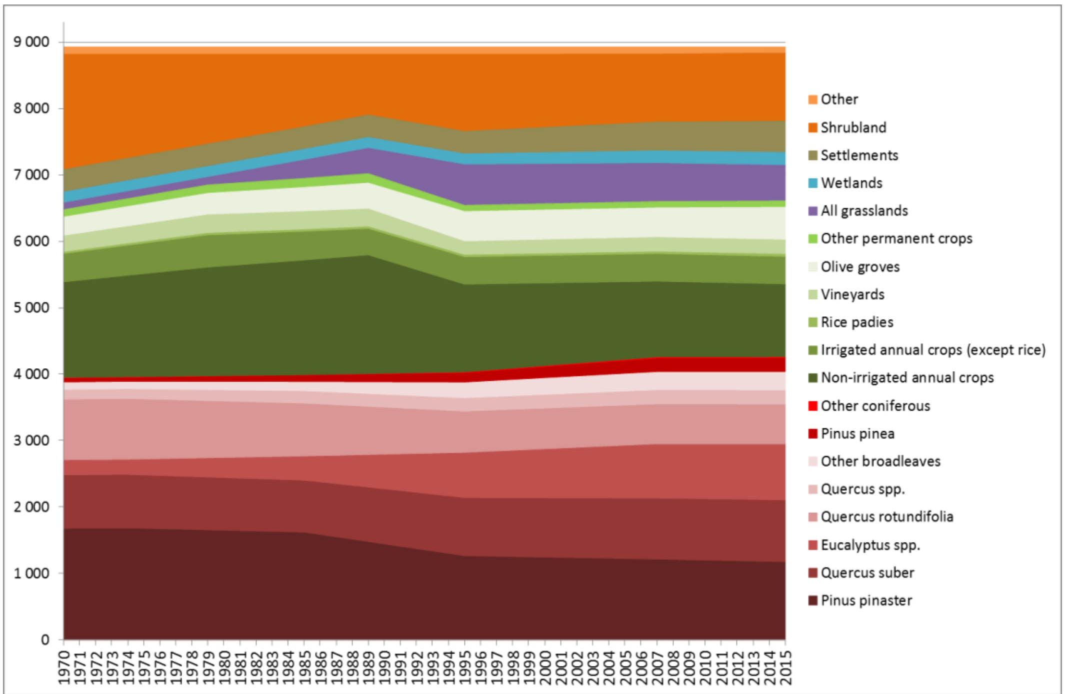
5. the total area of cropland + grassland (in hectares) from COS (1995) was taken as a starting point for 1995;

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 1970-2015 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→Y (e.g. gross afforestation) and Y→X (e.g. gross deforestation), as the only information available is the total of net-changes in area in each period, i.e. X→Y plus Y→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.

$$LUC_{x \to y, Y_i} = \sum LUC_{x \to all, Y_i} \times \frac{\sum LUC_{all \to y, Y_i}}{\sum LUC_{all, Y_i}}$$

where:

$LUC_{x \to y, Y_i}$ = Land-use change from land-use x to land-use y in Year i (ha);

Y_i = Any year in the period [1970-1995[;

$\sum LUC_{x \to all, Y_i}$ = Net area loss of land-use type x in Year i (ha);

$\sum LUC_{all \to y, Y_i}$ = 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. Com	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	1,147	0	**1,147**	2,696
Q. suber	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	156	0	**156**	
Q. rotundifolia	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	101	0	**101**	
O. broadleaves	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	42	0	**42**	
O. coniferous	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	21,989	0	**21,989**	38,759
Irrigated crops	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	467	0	**467**	
Vineyards	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	4,361	0	**4,361**	
O. permanent	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	1,547	0	**1,547**	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**	
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	
	0								0						0	0	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**	21,854
Q. suber	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
Eucalyptus	1,138	419		2,142	0	0	0	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**	
O. Quercus	330	122	0	622		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	20	0	0	0	0	0	0	0	0	0	1,732	0	**2,504**	
P. pinea	320	118	0	602	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**	
Rain-fed crops	2,031	748	0	3,826	0	0	0	172		0	0	0	0	0	0	0	0	15,212	0	**21,989**	38,759
Irrigated crops	602	222	0	1,135	0	0	0	51	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	323	0	**467**	
Vineyards	344	127	0	648	0	0	0	29	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	3,017	0	**4,361**	
O. permanent	157	58	0	295	0	0	0	13	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	1,070	0	**1,547**	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**	
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**	
	19,158								**0**						**0**	**0**	**0**	**43,002**			

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**	21.854	2.696
Q. suber	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**		
Eucalyptus	985	363		1.855	0	0	0	83	0	1.507	0	147	0	0	0	0	0	7.375	0	**12.314**		
Q. rotundifolia	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**		
O. Quercus	286	105	0	539		0	0	24	0	438	0	43	0	0	0	0	0	2.141	0	**3.576**		
O. broadleaves	200	74	0	377	0		0	17	0	306	0	30	0	0	0	0	0	1.500	0	**2.504**		
P. pinea	277	102	0	521	0	0		23	0	423	0	41	0	0	0	0	0	2.072	0	**3.460**		
O. coniferous	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	**0**		
Rain-fed crops	1.208	445	0	2.275	0	0	0	102		1.849	0	181	0	0	0	0	0	9.046	0	**15.105**	23.316	13.669
Irrigated crops	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	18	0	**30**		
Vineyards	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	3.928	0	**6.560**		
O. permanent	130	48	0	244	0	0	0	11	0	198	0	19	0		0	0	0	970	0	**1.620**		
Grasslands	2.130	785	0	4.012	0	0	0	180	0	3.260	0	318	0	0		0	0	15.952	0	**26.637**	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	-43.002
O. land	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
	19.158								**9.647**						**0**	**0**	**0**	**43.002**				

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 crps	Ir crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1985-1989		Net Gains
P. pinaster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	57.154	4.323
Q. suber	3.100		0	1.520	0	0	0	0	0	769	0	75	0	0	0	0	0	3.903	0	**9.367**		
Eucalyptus	10.421	0		5.112	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**		
O. Quercus	416	0	0	204		0	0	0	0	103	0	10	0	0	0	0	0	524	0	**1.257**		
O. broadleaves	3.268	0	0	1.603	0		0	0	0	810	0	79	0	0	0	0	0	4.114	0	**9.874**		
P. pinea	1.390	0	0	682	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	79	0	8	0	0	0	0	0	402	0	**964**		
Rain-fed crops	4.999	0	0	2.452	0	0	0	0		1.239	0	121	0	0	0	0	0	6.294	0	**15.105**	23.316	13.669
Irrigated crops	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	**0**		
Rice	10	0	0	5	0	0	0	0	0	2		0	0	0	0	0	0	13	0	**30**		
Vineyards	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	**0**		
Olive	2.171	0	0	1.065	0	0	0	0	0	538	0	53		0	0	0	0	2.733	0	**6.560**		
O. permanent	536	0	0	263	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	2.186	0	214	0	0		0	0	11.099	0	**26.637**	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	-44.629
O. land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**		
Annual Losses 1985-1989	**35.445**	**0**	**0**	**17.387**	**0**	**0**	**0**	**0**	**0**	**8.788**	**0**	**859**	**0**	**0**	**0**	**0**	**0**	**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 crps	Ir crps	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**	57.154	4.323
Q. suber	2.216		0	1.087	0	0	0	0	4.870	0	0	675	0	519	0	0	0	0	0	**9.367**		
Eucalyptus	7.449	0		3.654	0	0	0	0	16.374	0	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**		
O. Quercus	297	0	0	146		0	0	0	653	0	0	91	0	70	0	0	0	0	0	**1.257**		
O. broadleaves	2.336	0	0	1.146	0		0	0	5.134	0	0	711	0	547	0	0	0	0	0	**9.874**		
P. pinea	994	0	0	487	0	0		0	2.185	0	0	303	0	233	0	0	0	0	0	**4.201**		
O. coniferous	228	0	0	112	0	0	0		501	0	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**	13.020	-83.998
Irrigated crops	588	0	0	288	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	35	0		5	0	4	0	0	0	0	0	**67**		
Vineyards	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	**0**		
Olive	2.476	0	0	1.214	0	0	0	0	5.442	0	0	754		580	0	0	0	0	0	**10.467**		
O. permanent	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	**0**		
Grasslands	9.090	0	0	4.459	0	0	0	0	19.981	0	0	2.769	0	2.130		0	0	0	0	**38.429**	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	21.446	0	0	2.972	0	2.287	0	0	0		0	**41.247**	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**		
Annual Losses 1989-1995	**35.445**	**0**	**0**	**17.387**	**0**	**0**	**0**	**0**	**77.914**	**0**	**0**	**10.797**	**0**	**8.307**	**0**	**0**	**0**	**0**	**0**	149.850		0
	52.831								97.018						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 crps	Ir crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 1995-2007		Net Gains
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**	30.044	-14.062
Irrigated crops	209	71	177	56	4	34	21	0	3.591		229	619	180	183	666	1	10	106	4	**6.161**		
Rice		0	0	0		1	0		8	368		1	0	2	10	1	1	0	0	**392**		
Vineyards	213	40	87	50	34	45	5	1	1.822	521	2		468	146	449	0	2	352	2	**4.240**		
Olive	76	47	52	78	11	27	2	0	2.870	294	14	169		58	676	0	3	390	2	**4.769**		
O. permanent	74	2	19	4	7	57	2	0	943	232	3	139	144		178		2	187	0	**1.992**		
Grasslands	103	526	86	899	14	31	30	4	6.846	777	34	507	493	204		5	42	2.338	330	**13.271**	13.271	-3.187
Wetlands	16	81	58	966	9	43	6		272	82	6	8	81	7	326		18	203	9	**2.192**	2.192	2.139
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				

Table 6.8 – Annual land-use changes (ha) in the period [2005-2015].

2010 \ 2007	P. pin	Q. sub	Eucal	Q. rot	O. Que	O. Br	P. pnea	O. Com	Rf crps	Ir crps	Rice	Vine	Olive	O. Perm	Grassl	Wetl	Settl	Shrub	O. land	Annual Gains 2007-2010		Net Gains
P. pinaster		94	1.175	162	58	359	88	41	224	17		18	23	49	189	0	18	1.664	97	**4.275**	17.962	278
Q. suber	529		257	310	25	67	107	6	262	6		0	17	0	610		0	273	1	**2.472**		
Eucalyptus	5.577	217		10	27	196	28	4	122	36	0	31	12	5	154		37	629	53	**7.140**		
Q. rotundifolia	6	124	170		23	29	58		234	1		0	6	3	321	2	2	93		**1.073**		
O. Quercus	66	5	22	3		49	0	1	56	4		1	1	1	22		2	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. coniferous	49	2	11	2	7	48	5		15	3		1		2	18		4	25	1	**192**		
Rain-fed crops	235	76	146	86	107	102	8	1		477	1	783	702	259	3.288	0	22	694	2	**6.990**	22.733	827
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**		
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**	6.877	-4.818
Wetlands	4	18	10	46	3	32	3	0	71	31	3		57	1	206		202	61	1	**750**	750	731
Settlements	905	78	745	92	55	161	175	8	699	263	2	79	196	56	632	8		846	45	**5.046**	5.046	4.556
Shrubland	400	51	665	15	26	84	1	105	498	32		54	255	40	2.887	1	61		2.563	**7.739**	8.499	-1.574
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		0
	17.683								21.906						11.694	19	490	10.073				

6.1.2.4 Autonomous Region of Azores

For the Azores, the main sources of information available were:

1. COS (2007) – full wall-to-wall map
2. IFRAA (1987) and IFRAA (2007) – Regional Forest Inventory
3. RGA (1999) and RGA (2009) – General Census of Agriculture

The basis for the estimation of land-use and land-use change in the Azores was COS (2007) combined with growth rates estimated using the IFRAA and RGA, respectively for forest land and cropland and grassland.

For "Forest Land" the following estimation methodology was used:

1. The total area of forest (in hectares) COS (2007) was used directly.
2. For the period 1970-2015 the following assumptions were made:
    a. total forest area increased (in % annual change) from 1970 to 2015 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 2007-2015 was considered the same as 2007.

For "Cropland" and "Grassland" the following estimation methodology was used:

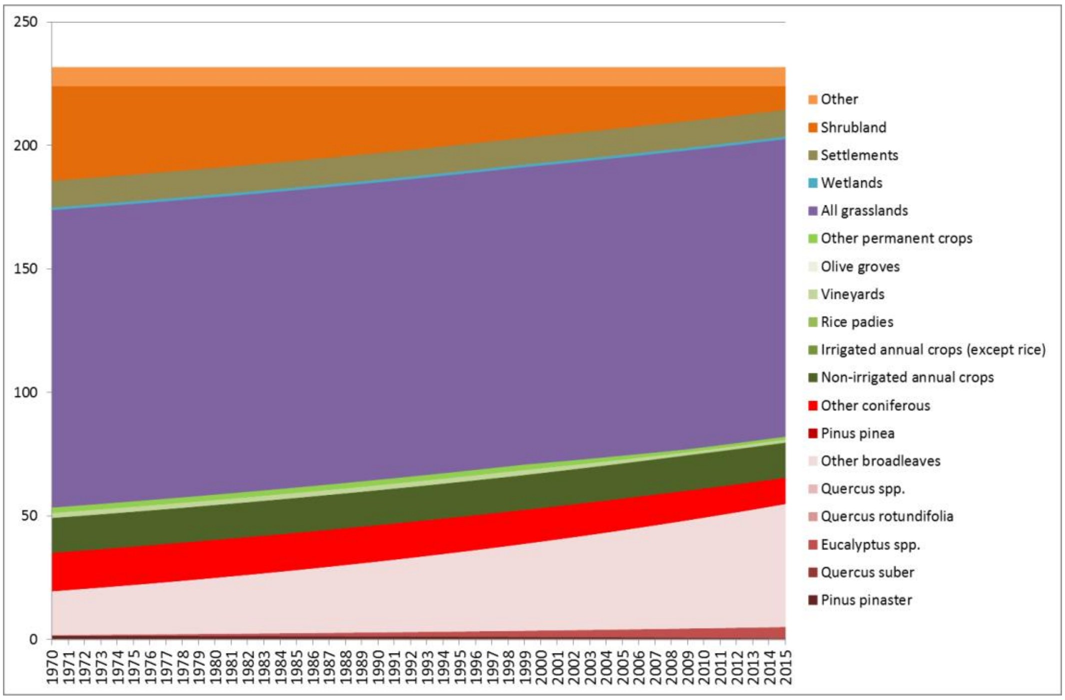
1. The total area of cropland + grassland (in hectares) COS (2007) was used directly.
2. For the period 1970-2015 the following assumptions were made:
    a. total cropland + grassland area increased (in % annual change) from 1970 to 2015 at the same rate as RGA (1999) and RGA (2009);
    b. the share 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 2009-2015 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 1970-2015 the following assumptions were made:
    a. The total area for the Autonomous Region of the Azores was maintained constant in the period 1970-2015 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 1970-2015 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 1970-2015 cannot be estimated separately for X→Y (e.g. gross afforestation) and Y→X (e.g. gross deforestation), as the only information available is the total of net-changes in area in each period, i.e. X→Y plus Y→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 2015 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 1970-2015 was considered the same as in IFRAM (2004).

For “Cropland” and “Grassland” the following estimation methodology was used:

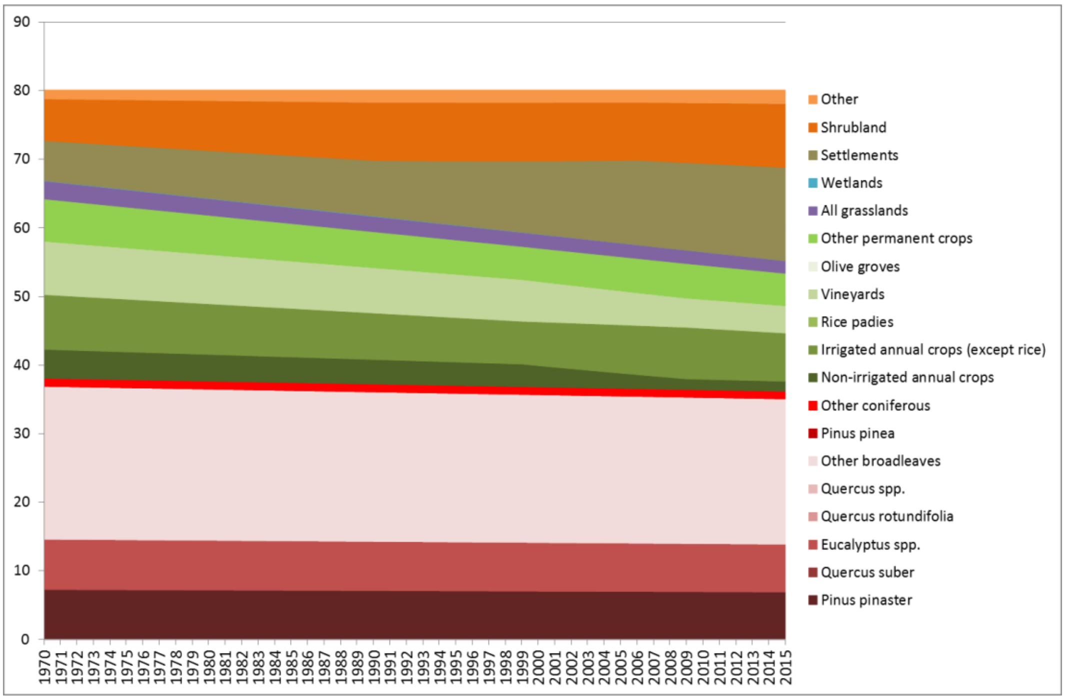
1. The total area of cropland + grassland (in hectares) of CLC (1990) and CLC (2006) was used directly.
2. For the period 1970-2015 the following assumptions were made:
    a. total cropland + grassland area increased (in annual change) from 1970 to 2015 at the same rate as CLC 1990-2006;
    b. the 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 2009-2015 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 1970-2015 the following assumptions were made:
    a. total wetlands + settlements + other land area increased (in annual change) from 1970 to 2015 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 2006-2015 was considered the same as CLC (2006).

The results for the full time series 1970-2015 for Madeira are presented in Figure 6-6.

Figure 6-6 – Changes in Total Land-Use in the Region of Madeira (1000 ha).



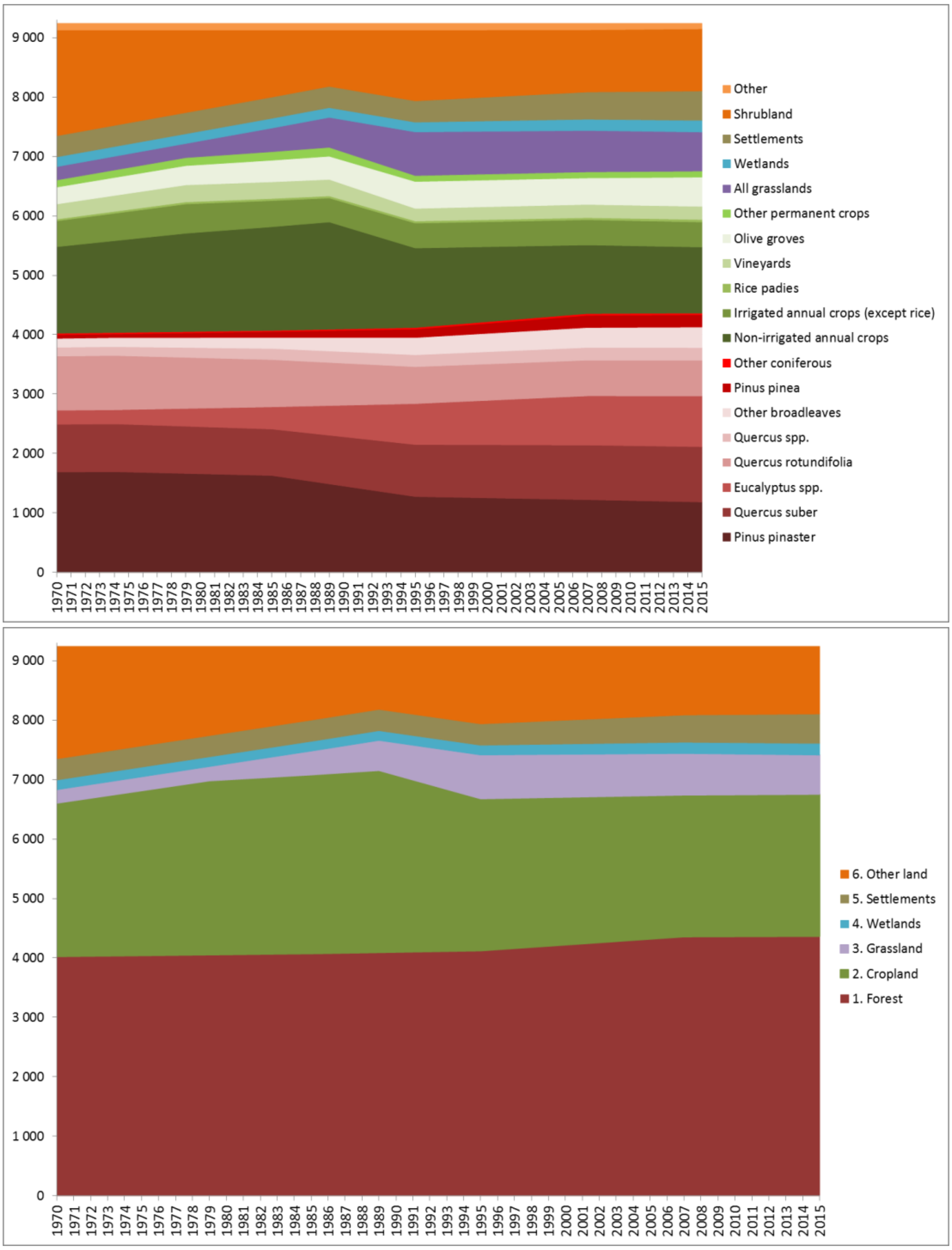
As mentioned above for the case of mainland Portugal, land use changes for the period 1970-2015 cannot be estimated separately for X→Y (e.g. gross afforestation) and Y→X (e.g. gross deforestation), as the only information available is the total of net-changes in area in each period, i.e. X→Y plus Y→X (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 Reportin.

$$LC_{y\rightarrow x,\,RY_i} = \sum_{i-20}^{i} ALUC_{y\rightarrow x,i}$$

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:

$\mathrm{LRL_{x,\,RY_i}}$ = Land Y remaining Land X in reporting year i (ha);

$\mathrm{TA_{x,\,RY_i}}$ = Total Reported Area of land-use X in reporting year I, as shown in Figure 6-7 (ha);

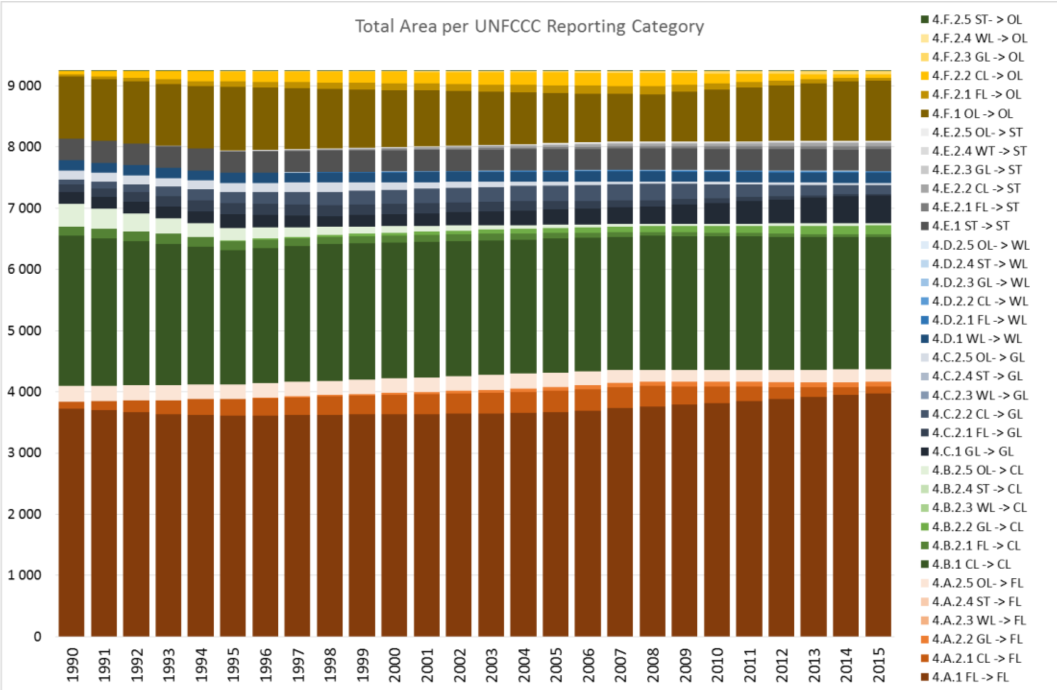
$\mathrm{LC_{y\rightarrow x,\,RY_i}}$ = Land Y converted to Land X in reporting year i (ha).

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.

$$AR_{RY_i} = \sum_{1990}^{i} \sum_{\substack{all\ y \\ all\ x}} ALC_{NFLU_y \to FLU_x, i}$$

where:

AR_{RY_i} = Area of Afforestation and Reforestation in reporting year i (ha);

$ALC_{NFLU_y \to FLU_x, i}$ = Annual Land-use change from Non-Forest Land-use Y to Forest Land Use X in reporting year i (i ≥ 1990) (ha).

For Deforestation all lands converted from forest to other land-uses "since 1990" were considered, as shown in Equation 6-6.

Equation 6-6 – Estimation of KP Areas under Deforestation.

$$D_{RY_i} = \sum_{1990}^{i} \sum_{\substack{all\ y \\ all\ x}} ALC_{FLU_y \to NFLU_x, i}$$

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 6-7.

Equation 6-7 – 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 6-8.

Equation 6-8 Estimation of KP Areas under Cropland Management.

$$CM_{RY_i} = TA_{CL, RY_i} - \sum_{1990}^{i} \sum_{\substack{all\ y \\ all\ x}} ALC_{FLU_y \rightarrow CL_x, i} + \sum_{2008}^{i} \sum_{\substack{all\ y \\ all\ x}} ALC_{CL_y \rightarrow NR_x, i}$$

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).

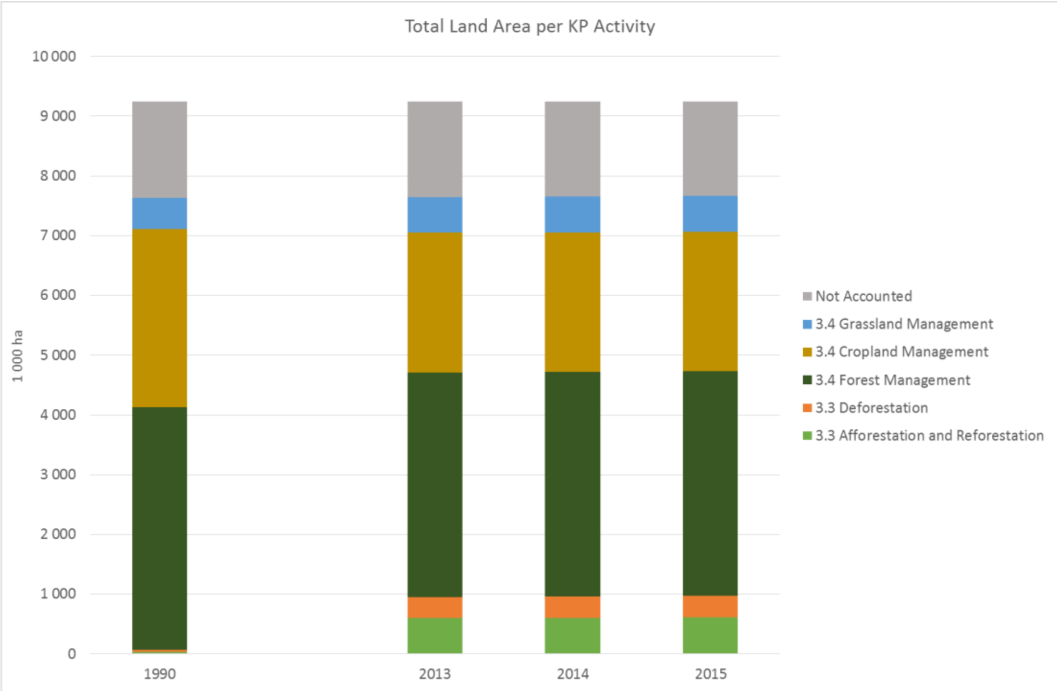
Conversions from cropland to grassland were reported as “Grazing land management”. Conversions between different cropland types were estimated and used in estimating emissions and removals, but the relevant conversion areas were included as “cropland management”.

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:

$$BEF_f = \frac{AGB_f}{Vol_f} \qquad\qquad RTS_f = \frac{BGB_f}{AGB_f}$$

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_f ktdm	BGB_f ktdm	Vol_f km^3	BEF_f tdm/m^3	RTS_f ad	$C_{f\,LB}$ %	$C_{f\,litter}$ %	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 "Scrubland", page 10
(8) Values from EMEP/EEA emission inventory guidebook 2009, Chapter 11b forest fires, table 3.2 "Grassland (Steppe)", page 10
(9) Living biomass per ha from NIR Spain 2012, Tabla 7.3.3, page 7.59. Unit values of ABG 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[124]. The values used in the NIR are presented in Table 6.10.

[124] 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 6.10 – Mean Annual Increment per Forest Type (in pure and dominant stands).

Forest species	MAI_{ff} m^3/ha.y
Pinus pinaster	5,6
Quercus suber	0,5
Eucalyptus spp.	9,5
Quercus rotundifolia	0,5
Quercus spp.	2,9
Other broadleaves	2,9
Pinus pinea	5,6
Other coniferous	5,0

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.

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^3/ha		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	91,6	1,5	7,3	0,2	8,3	16,1	6,9	0,9
	Quercus suber	0,7	30,5	0,4	4,8	0,5	1,0	8,6	0,3
	Eucalyptus spp.	5,1	0,2	46,9	0,0	1,0	2,6	0,2	0,2
	Quercus rotundifolia	0,1	1,3	0,0	16,0	0,0	0,1	0,0	0,9
	Quercus spp.	1,2	0,2	0,2	0,1	23,3	2,6	0,4	0,8
	Other broadleaves	1,4	0,4	0,4	0,1	5,9	32,9	0,2	2,6
	Pinus pinea	1,0	2,1	0,1	0,1	0,2	0,4	30,4	0,0
	Other coniferous	0,2	0,4	0,0	1,2	0,2	1,0	0,2	24,1
Total		**101,1**	**36,5**	**55,4**	**22,5**	**39,5**	**56,7**	**46,8**	**29,7**

Table 6.12 – Average volume per hectare and per tree species by forest type (NFI5/2005).

Mixed forests IFN (2005)		Forest Type							
average volume m^3/ha		Pinus pinaster	Quercus suber	Eucalyptus spp.	Quercus rotundifolia	Quercus spp.	Other broadleaves	Pinus pinea	Other coniferous
Dominated species	Pinus pinaster	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^3/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 m^3/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 (m3/ha.year) used for each Forest Type.

annual increment m^3/ha.year - Pinus pinaster		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Quercus suber		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Eucalyptus spp.		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Quercus rotundifolia		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Quercus spp.		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Other broadleaves		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Pinus pinea		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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^3/ha.year - Other coniferous		1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2015
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 6-9 - 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 Anual 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 [125]

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.

[125] For references of the sources of data for these values please check Table 6.17.

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 6-10 to Equation 6-12.

Equation 6-10 - 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 6-11 - Estimation of Above Ground Living Biomass in Forests.

$$AGB_f = \sum_y AVol_{yf} \times BEF_y \times CF_y$$

Equation 6-12 - 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^3/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 6-13 - Estimation of Above Ground Living Biomass in Shrubland.

$$AGB_s = 18.86 \times (1 - e^{-0.23t}) \times CF_s$$

where:

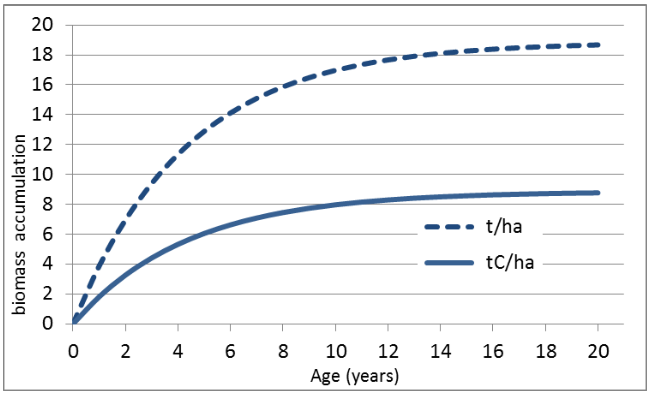
AGB_s = Average Above Ground Biomass of shrubs (tC/ha);

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 NFI4 (1995), NFI5 (2005) and NFI6 (2010). NFI6 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 6-14.

Equation 6-14 - Estimation of Litter Emission Factors.

$$LEF_{x \to y} = \frac{ALC_y - ALC_x}{20}$$

where:

$LEF_{x \to y}$ = 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				
	LUCAS	ICP/Biosoil			Total
Legenda KP	2009	1995/99	2005	Total	
01. Pinus pinaster	54	41	12	53	**107**
02. Quercus suber	57	42	37	79	**136**
03. Eucalyptus	46	21	8	29	**75**
04. Quercus rotundifolia	30	25	23	48	**78**
05. Other quercus	10	4	4	8	**18**
06. Other broadleaves	5	19	17	36	**41**
07. Pinus pinea + 08. Other coniferous	4	2	1	3	**7**
09. Rain-fed crops	78	21		21	**99**
10. Irrigated crops + 11. Rice	22	26		26	**48**
12. Vineyards	22	14		14	**36**
13. Olive	39	12		12	**51**
14. Other permanent	11	11		11	**22**
15. Grassland	42	18		18	**60**
17. Settlements	7				**7**
18. Shrubland	36	5	1	6	**42**
Total	463	261	103	364	828

No. Plots C(20-40cm) (measured)	Source				
	LUCAS	ICP/Biosoil			Total
Legenda KP	2009	1995/99	2005	Total	
01. Pinus pinaster	0	1	12	13	**13**
02. Quercus suber	0	3	35	38	**38**
03. Eucalyptus	0		8	8	**8**
04. Quercus rotundifolia	0		21	21	**21**
05. Other quercus	0		4	4	**4**
06. Other broadleaves	0	1	17	18	**18**
07. Pinus pinea + 08. Other coniferous	0	1	1	2	**2**
09. Rain-fed crops	0	21		21	**21**
10. Irrigated crops + 11. Rice	0	25		25	**25**
12. Vineyards	0	14		14	**14**
13. Olive	0	12		12	**12**
14. Other permanent	0	11		11	**11**
15. Grassland	0	15		15	**15**
17. Settlements	0				
18. Shrubland	0	5	1	6	**6**
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 only 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				
	LUCAS	ICP/Biosoil			Total Average
Legenda KP	2009	1995/99	2005	Average	
01. Pinus pinaster	70	73	72	72	71
02. Quercus suber	46	43	40	41	43
03. Eucalyptus	75	41	41	41	62
04. Quercus rotundifolia	41	43	45	44	43
05. Other quercus	58	51	52	52	55
06. Other broadleaves	71	66	63	64	65
07. Pinus pinea + 08. Other coniferous	74	25	64	38	58
09. Rain-fed crops	40	27		27	37
10. Irrigated crops + 11. Rice	39	39		39	39
12. Vineyards	36	24		24	31
13. Olive	49	33		33	45
14. Other permanent	44	26		26	35
15. Grassland	43	30		30	39
17. Settlements	55				55
18. Shrubland	70	52	88	58	68
Média global	52	44	50	46	49

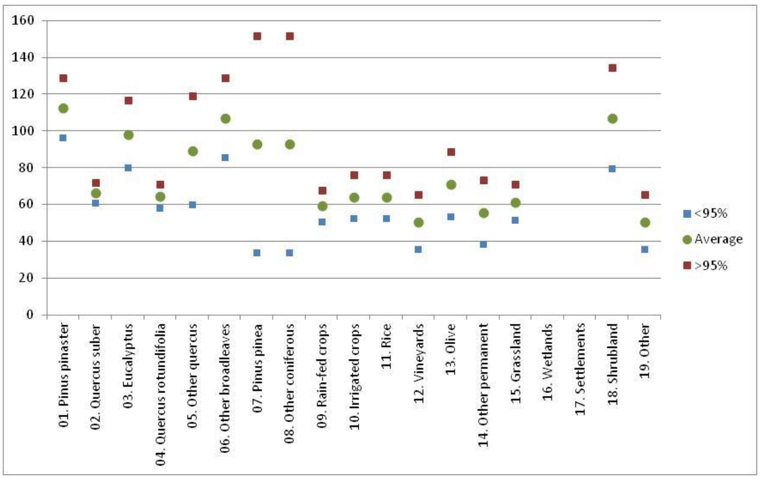
Average C (0-40cm) ton/ha (measured)	Source				
	LUCAS	ICP/Biosoil			
Legenda KP	20-40cm	0-20cm	20-40cm	0-40cm	40/20cm
01. Pinus pinaster		77	45	122	59%
02. Quercus suber		38	15	53	40%
03. Eucalyptus		41	26	67	63%
04. Quercus rotundifolia		44	15	59	35%
05. Other quercus		52	39	91	74%
06. Other broadleaves		60	45	105	75%
07. Pinus pinea + 08. Other coniferous		46	28	74	62%
09. Rain-fed crops		27	19	46	71%
10. Irrigated crops + 11. Rice		37	28	65	74%
12. Vineyards		24	16	40	69%
13. Olive		33	20	53	61%
14. Other permanent		26	16	42	61%
15. Grassland		33	18	51	54%
17. Settlements					
18. Shrubland		58	33	91	58%
Grand Total		41	24	64	58%

For all 208 plots for which both 0-20 cm and 20-40 cm was available the ratio of Carbon between the 2 depths was calculated and used to estimate the missing information for all the plots for which only 0-20 cm samples had been collected. The average C stock per land use is presented in Table 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 Average
Legenda KP	2009	1995/99	2005	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 6-15 only where the difference between average C stocks of the respective land-uses was deemed 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 6-15.

Equation 6-15 - Estimation of Soil Emission Factors.

$$SEF_{x \to y} = \frac{ASC_y - ASC_x}{20}$$

where:

$SEF_{x \to y}$ = 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 6-15** 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[126].

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.

[126] 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.

Table 6.22 – Estimated Annual Emission/Sequestration Factors (tC/ha) for Soil.

Soil Emission Factors			TO																		
			Forest land								Cropland						Grassl	Wetl.	Setlm	Other Land	
			01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
FROM	Forest land	01. Pinus pinaster	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 -1.2 Mt CO_2e and -15.0 MtCO_2e.

Figure 6-12 – Areas of Forest Land per UNFCCC Reporting Category (1000 ha)

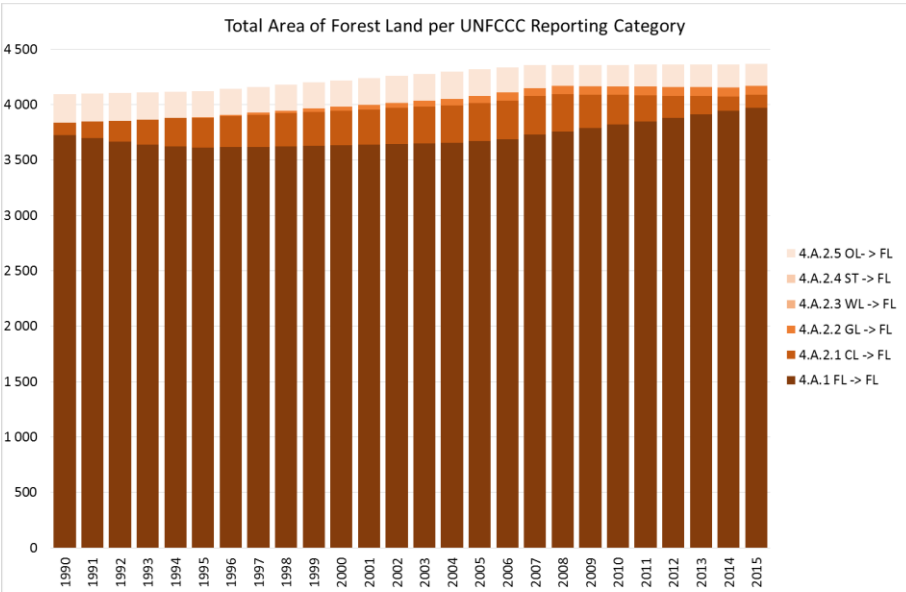
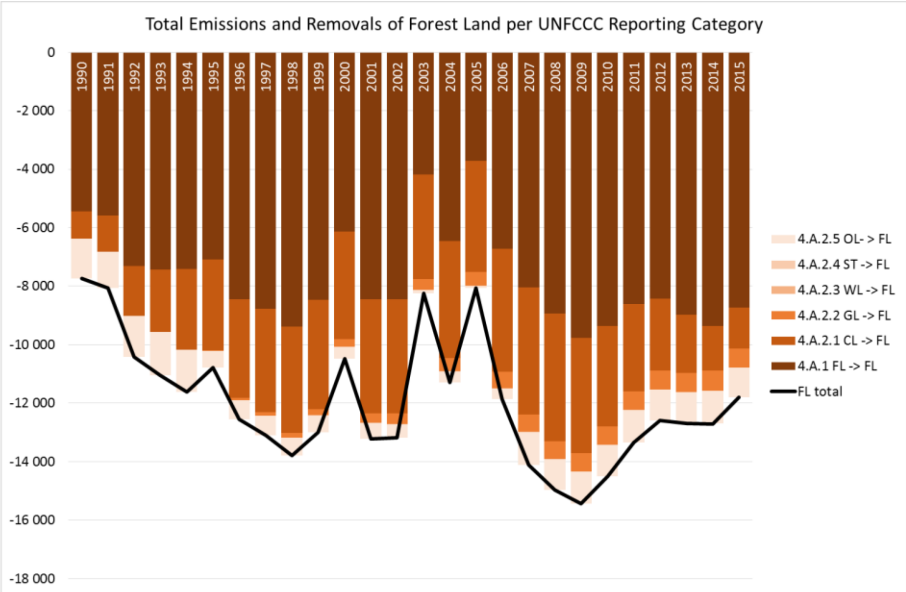


Figure 6-13: Total Emissions and Removals in Forest Land (kt CO2e)



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 6-16. 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 6-16 – 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 has harvesting before the end of the transition period. Allocated based on share of L->Eucalyptus / total Eucalyptus area 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 per 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	Reported as "fire emissions" not as "losses" 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)	Reported as "losses" from FL->L in the respective land-use and not as Forest land emissions

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[127] 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 share of lands converted to eucalyptus to total eucalyptus area,

[127] Lands are moved from the category "Land converted to Forest" to "Forest Land Remaining Forest Land" 20 years after the afforestation took place.

the remaining of the industrial consumption of eucalyptus wood was assumed to come from forest land remaining forest land.

Harvested areas under the Kyoto Protocol's Article 3.3 Afforestation and Reforestation (reporting category A.1) 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 harvesting in 3.3AR land is reported only from 2001 onwards. The harvesting under 3.3 AR was estimated based share of 3.3AR eucalyptus to total eucalyptus area, the remaining of the industrial consumption of eucalyptus wood was assumed to come from Artcile 3.4 Forest Management.

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 6-17: Estimation of losses in living biomass in Forest Land Remaining Forest Land.

$$LBL_{RY_i} = LBLH_{RY_i} + LBLOWU_{RY_i} + LBLSW_{RY_i} + LBLNM_{RY_i} + LBLFC_{RY_i}$$

$$LBLH_{RY_i} = \sum_{FS_y} (HARV_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y$$

$$LBLOWU_{RY_i} = \sum_{FS_y} (OWU_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y$$

$$LBLSW_{RY_i} = \sum_{FS_y} (SW_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y$$

$$LBLNM_{RY_i} = \sum_{FS_y} (NM_{y,RY_i} \times BEF_y \times (1 + RTS_y) \times CF_y$$

$$LBLFC_{RY_i} = \sum_{f \to x} AFC_{f \to x,RY_i} \times (AGB_f + BGB_f)$$

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;

$\sum_{f \to x}$ = Sum for all conversions between forest types;

$HARV_{y,RY_i}$= Volume of industrial harvesting of forest species y in reporting year i (m^3);

OWU_{y,RY_i}= Volume of other wood use harvesting of forest species y in reporting year i (m^3);

SW_{y,RY_i}= Volume of salvaged wood harvesting of forest species y in reporting year i (m^3);

NM_{y,RY_i}= Volume of natural mortality volume of forest species y in reporting year i (m^3);

$AFC_{f \to x,RY_i}$= 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.

6.2.2 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 6-16 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[128] 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 share of the area of “land converted to eucalyptus” to “total eucalyptus area” in the respective year; the remaining of the industrial consumption of eucalyptus wood was assumed to come from forest land remaining forest land.

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.

[128] Lands are moved from the category “Land converted to Forest” to “Forest Land Remaining Forest Land” 20 years after the afforestation took place.

6.2.2.4 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 4.1 Mt CO_2/year and with clear trend for decreasing emissions.

Figure 6-14 – Areas of Cropland per UNFCCC Reporting Category (1000 ha)

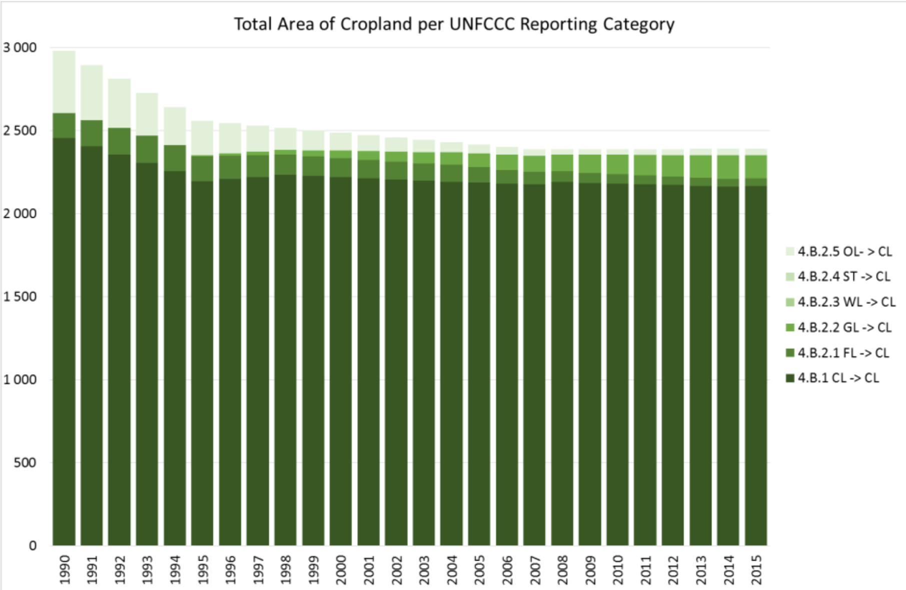
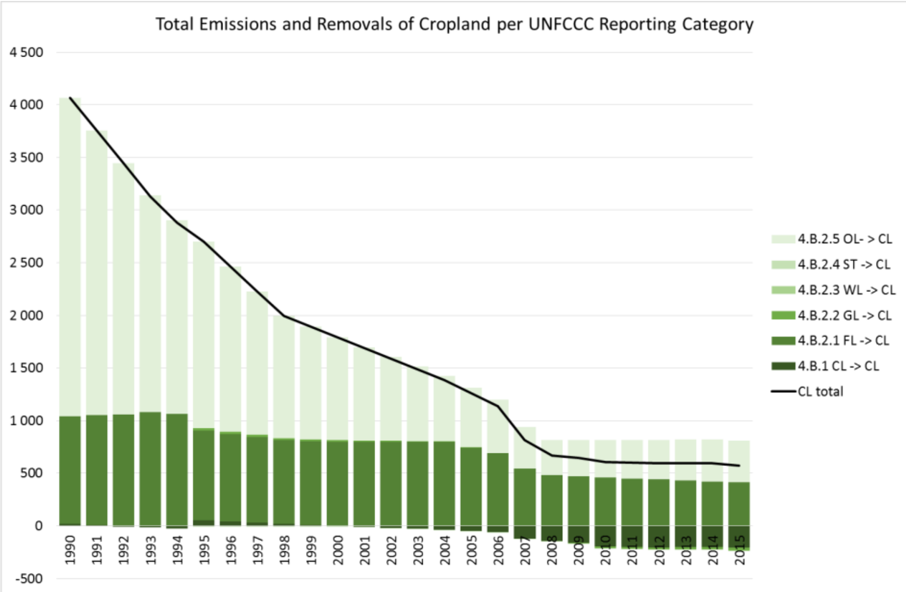


Figure 6-15 – Total Emissions and Removals in Cropland (kt CO2e)



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).

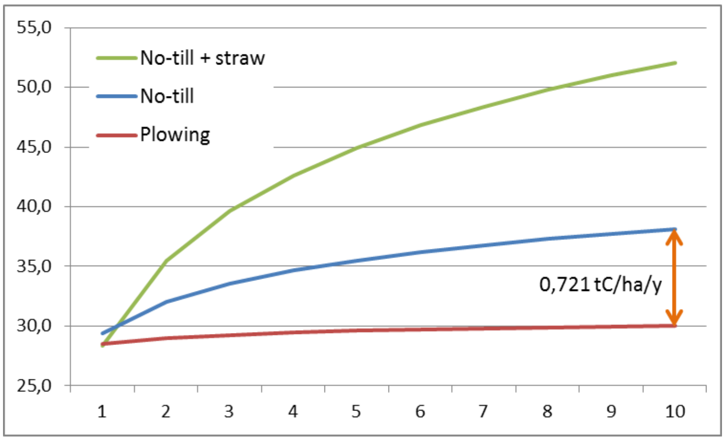
6.3.1.5 Activity in Cropland: No tillage

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 0.1 and 3.5 Mt CO_2/year and with clear trend for decreasing emissions.

Figure 6-17 – Areas of Grassland per Reporting Category (1000 ha)

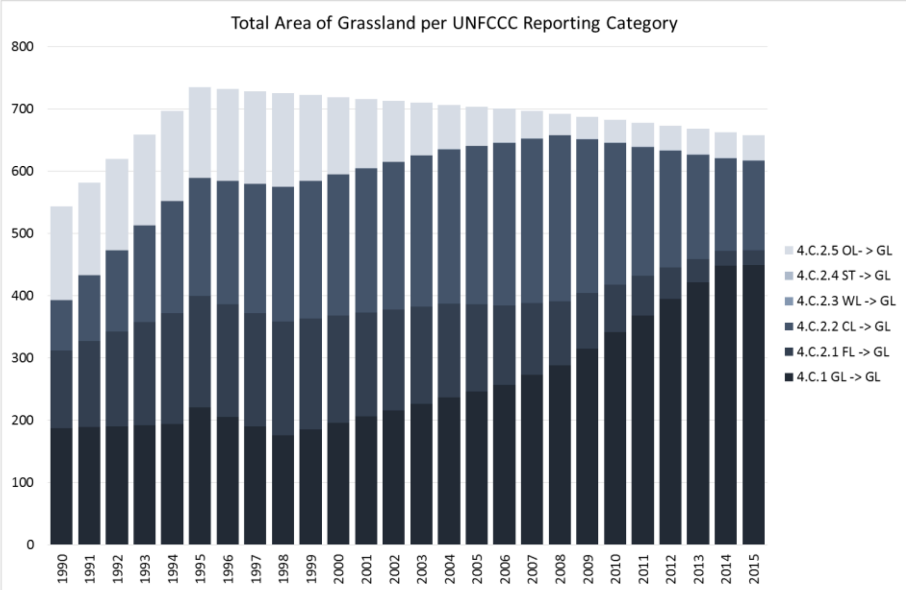
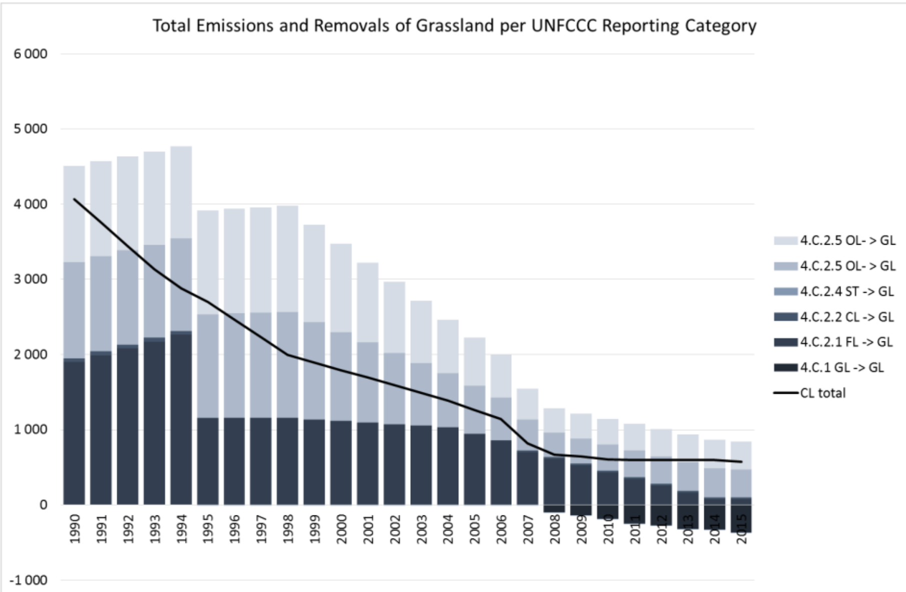


Figure 6-18 – Total Emissions and Removals in Grassland (kt CO2e)



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 $tCO_2.ha^{-1}.yr^{-1}$** 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.

Following the practice in previous years, “wetlands” are still considered as a single category. Efforts are ongoing to adapt reporting to 2006 IPCC guidelines and separate the current single category in “flooded lands”, “peat extraction” and “other wetlands”.

Emissions in the period have ranged between 0 and 0.4 Mt CO_2/year and with trend for increasing emissions.

Figure 6-19 – Areas of Wetlands per Reporting Category (1000 ha).

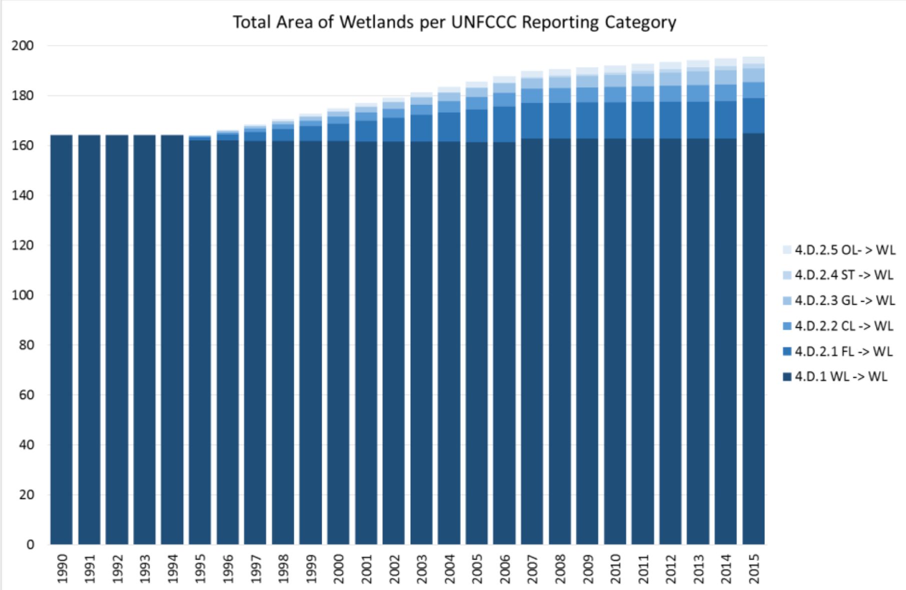
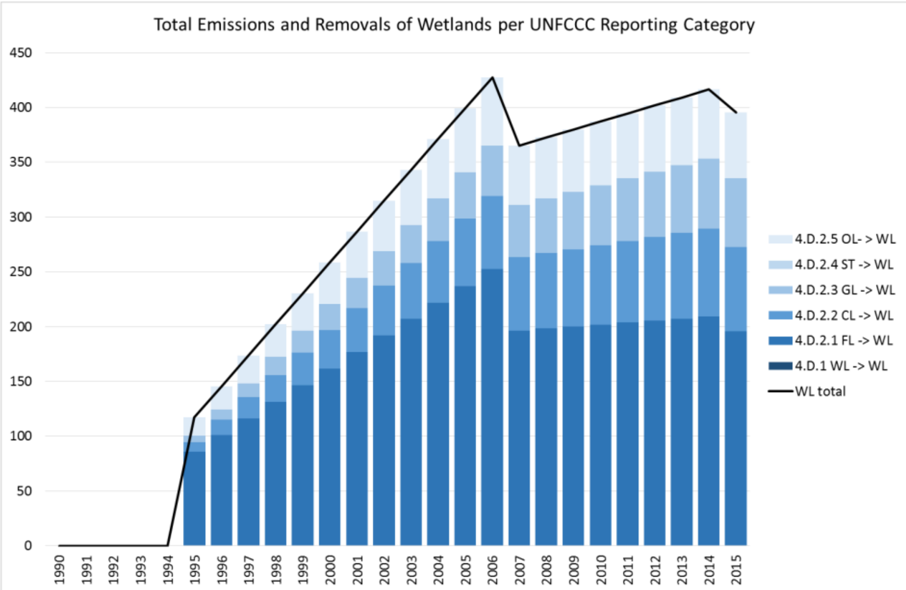


Figure 6-20 – Total Emissions and Removals in Wetlands (kt CO2e).



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 2.5 Mt CO_2/year and with a trend for increasing emissions.

Figure 6-21 – Areas of Settlements per Reporting Category (1000 ha)

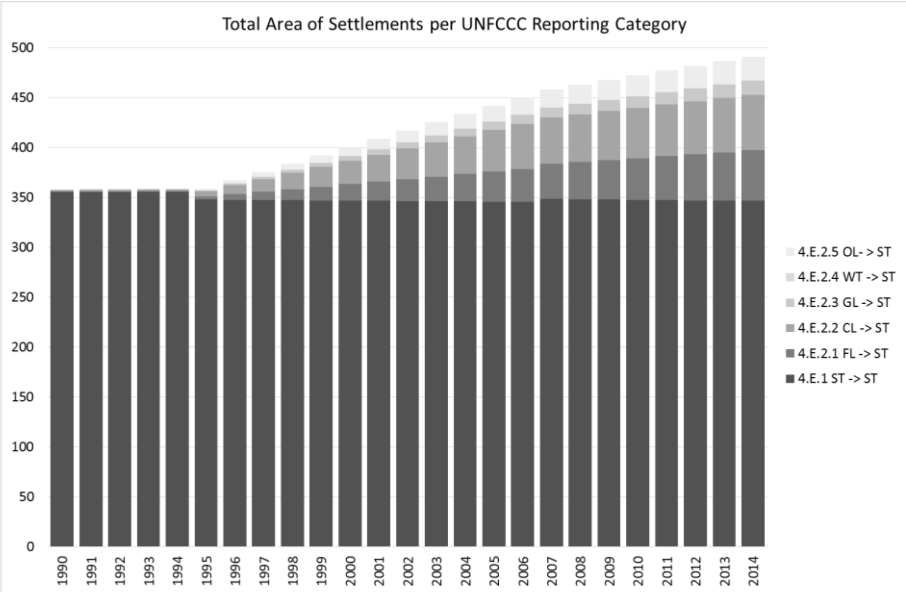
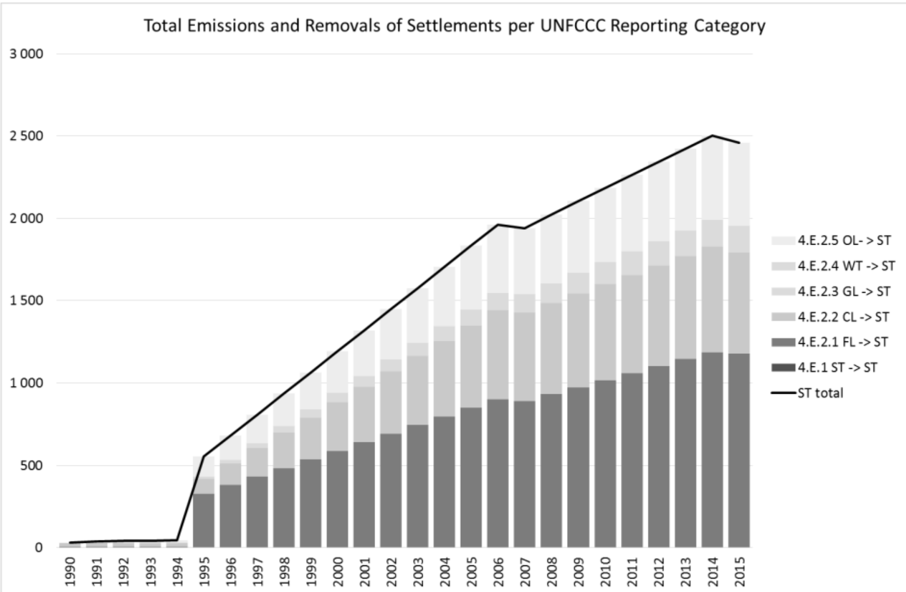


Figure 6-22 – Total Emissions and Removals in Settlements (kt CO2e)



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 4.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 0.8 $MtCO_2e$ in 2015.

Emissions in the period have ranged between -2.6 and +0.9 Mt CO_2/year and with a more recent trend for decreasing sequestration.

Figure 6-23 – Areas of Other Land per Reporting Category (1000 ha)

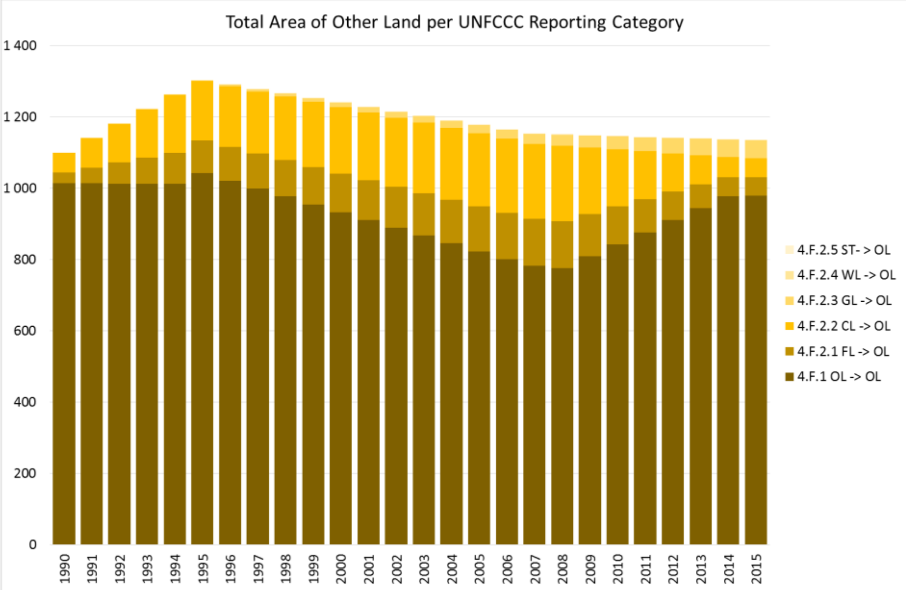
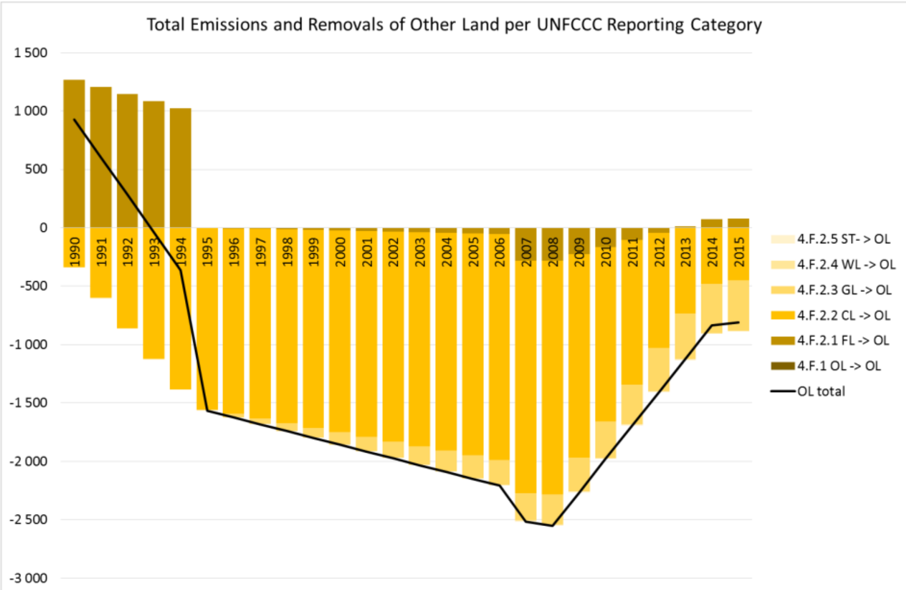


Figure 6-24 – Total Emissions and Removals in Other Land (kt CO2e)



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 1964-2015. Production estimates from 1900-1963 were produced using IPCC equation 12.6. The production of HWP that came from domestic harvest was estimated using IPCC 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

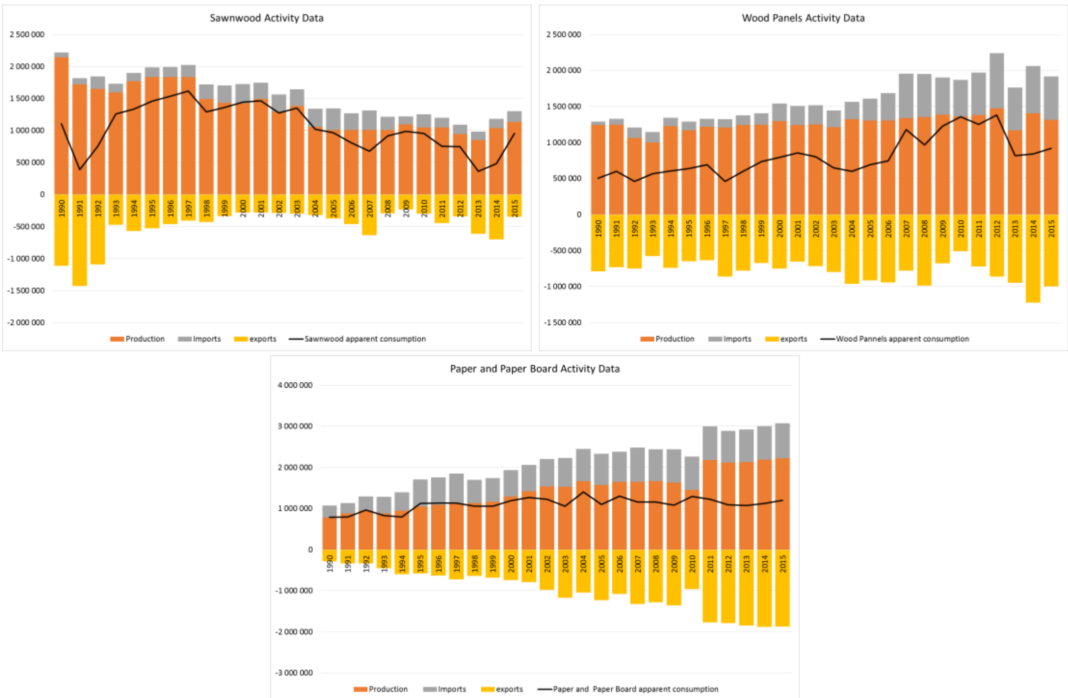
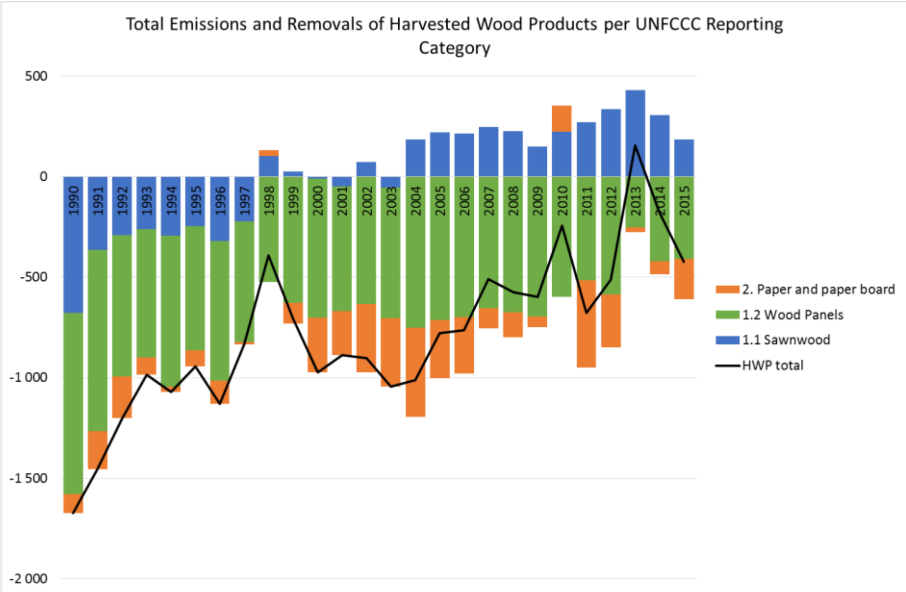


Figure 6-26 – Evolution of Carbon Stocks and Carbon Stock Changes in Harvested Wood Products



6.9 Direct N2O 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”.

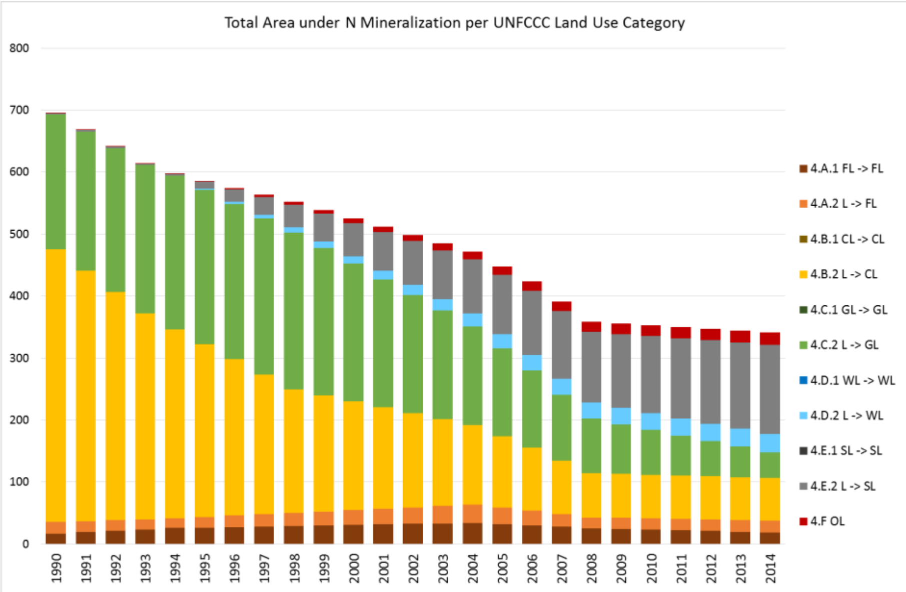
6.11 Direct N2O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter resulting from change of LU or management of Mineral Soils (CRF 4(III))

6.11.1 Activity Data

For the purposes of calculating this category, only the areas associated with land-use transitions where mineral soil C is being lost were considered (i.e. land-use transitions with negative soil emission factors see Table 6.22). The result is presented in Figure 6-27.

As per IPCC guidance, emissions from “cropland remaining cropland” are reported in CRF 3.D.1.5, whereas all N mineralization taking place in other Land Use Categories is reported under CRF 4(III).

Figure 6-27 – Total Area under N Mineralization (kha)



6.11.2 Emission estimation

Emissions from N2O 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 IPCC - equation 11.8:

$$N_2O - N_{CLoss} = EF_1 \times \Delta C_{LCMineral} \times \frac{1}{C{:}N\ ratio} \times 10^{-6}$$

where:

$N_2O\text{-}N_{CLoss}$ = N_2O emissions associated with a Soil Carbon Loss, Gg N_2O-N.yr[-1;]

EF_1 = IPCC default emission factor used to calculate emissions from agricultural land caused by added N, whether in the form of mineral fertilizers, manures, crop residues and N mineralized from mineral soils as a result of loss of soil C, kg N_2O-N.kg^{-1} N. (The default value used is 0.01 kg N_2O-N.kg^{-1} N, IPCC table 11.1);

$\Delta C_{LCMineral}$ = C emissions from land use change.

The same methodology was applied to estimate emissions from N mineralization in mineral soils in CRF 3.D.1.5.

6.12 Indirect N2O Emissions from managed soils (CRF 4(IV))

Indirect emissions reported in this section consider only:

1. Infdirect emissions from leaching and runoff resulting from the loss of SOM (CRF 4(III))
2. Indirect emissions from atmospheric deposition resulting from emissions of NO_x and NH_3 from forest fires (CRF 4(V))

The methodologies and emission factors used are described in section “5.7.2 Indirect N_2O Emissions from Managed Soils” in the Chapter 5 (Agriculture).

Figure 6-28 – Total N Lost per Source

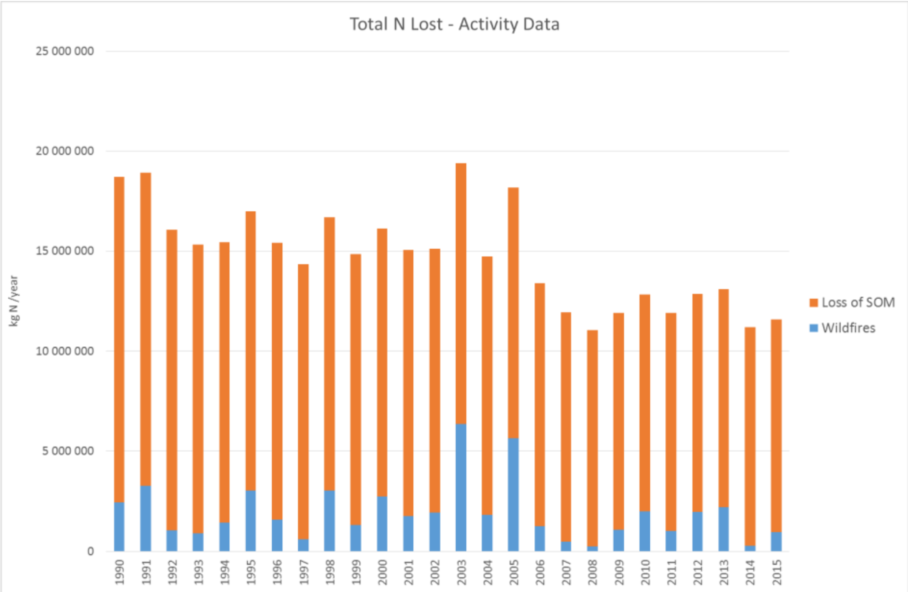
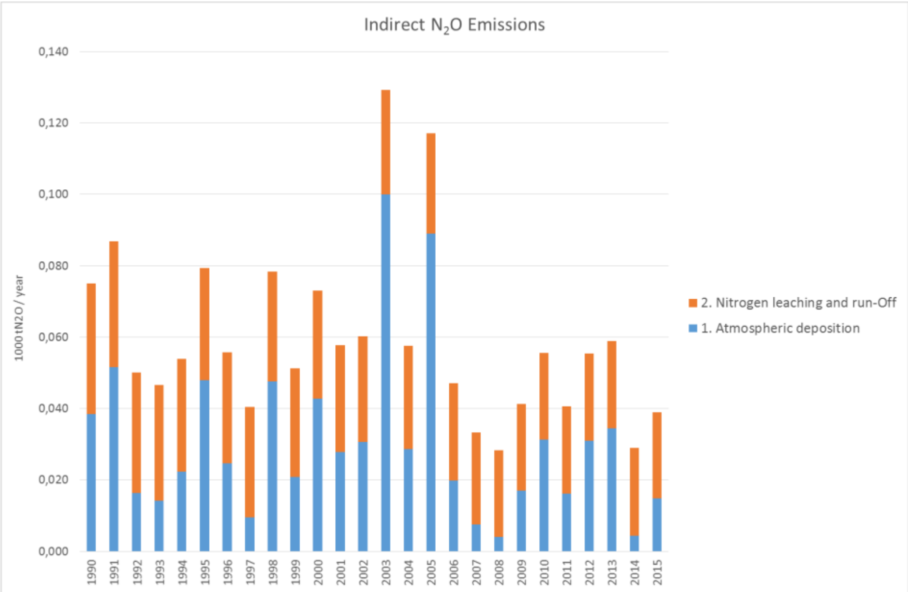


Figure 6-29 – Total Indirect N_2O Emissions



6.13 Emissions from Biomass Burning (CRF 4(V))

Forest Fire Emissions are estimated as the sum of:

- Direct CO_2 emissions, i.e., CO_2 emissions that occur *during the fire*
- Direct non-CO_2 emissions, i.e., CH_4 and N_2O emissions that occur *during the fire*

- Indirect CO_2 emissions, i.e., CO_2 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.

<table>
<tr><th>Land use</th><th>GHG → / Pool ↓</th><th>Direct emissions CO_2</th><th>Direct emissions N_2O and CH_4</th><th>Indirect emissions CO_2</th></tr>
<tr><td>Forest</td><td>Tree above ground biomass</td><td>Yes</td><td>Yes</td><td>Yes (dead trees)</td></tr>
<tr><td>Forest</td><td>Tree below ground biomass</td><td colspan="2">Considered negligible</td><td>Yes (dead trees)</td></tr>
<tr><td>Forest</td><td>Shrub below and above ground biomass</td><td rowspan="6">Land-remaining-land
No gains/losses are considered
⇒
No fire emissions reported</td><td>Yes</td><td rowspan="6">Land-remaining-land
No gains/losses are considered
⇒
No fire emissions reported</td></tr>
<tr><td>Forest</td><td>Litter</td><td>Yes</td></tr>
<tr><td>Agriculture</td><td>Above ground biomass</td><td>Yes</td></tr>
<tr><td>Grasslands</td><td>Above ground biomass</td><td>Yes</td></tr>
<tr><td>Other land</td><td>Above ground biomass</td><td>Yes</td></tr>
<tr><td>Other land</td><td>Litter</td><td>Yes</td></tr>
</table>

6.13.1 Estimation of Burnt Areas

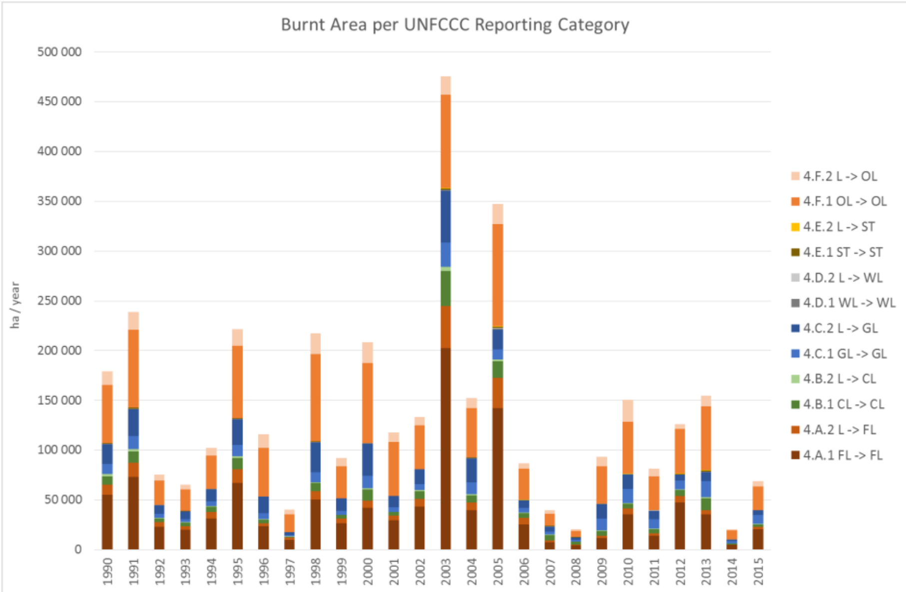
The main sources of burnt areas are the fire reports issued every year by the National Forest Authority, currently the Institute for Nature Conservation and Forestry (ICNF 1990-2012). The reports are derived from satellite imagery and the results cover all burnt areas.

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 (RAM) were provided by the Secretaria de Recursos Naturais, 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 6-30 – 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.

	Share of AG Tree Biomass		Combustion Factor				
Land-use Type	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 CO2 Emissions from Fires

Direct CO2 emissions from fires were estimated using Equation 6-18.

Equation 6-18 - Estimation of Direct CO_2 Emissions from Fires.

$$E_{CO2} = \sum_x BA_x \times BLF_x \times Cf \times CtoCO2$$

where:

E_{CO2} = Emissions of CO_2 (tCO_2);

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 (%);

$CtoCO2$ = Stoichiometric conversion from Carbon to CO2 (44/12 ~ 3,67).

6.13.4 Direct CH4 Emissions from Fires

Direct CH_4 emissions from fires were estimated using Equation 6-19.

Equation 6-19 - Estimation of Direct CH_4 Emissions from Fires.

$$E_{CH4} = \sum_x BA_x \times BLF_x \times Cf \times C/CH4 \times CtoCH4$$

where:

E_{CH4} = Emissions of CH_4 (tCH_4);

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 (%);

$C/CH4$ = Carbon Lost as CH_4 (IPCC Default = 0,012);

$CtoCH4$ = Stoichiometric conversion from Carbon to CH_4 (1,33).

6.13.5 Direct N2O Emissions from Fires

Direct N_2O emissions from fires were estimated using Equation 6-20.

Equation 6-20 - Estimation of Direct N_2O Emissions from Fires.

$$E_{N2O} = \sum_x BA_x \times BLF_x \times Cf \times N/C \times N/N2O \times NtoN2O$$

where:

E_{N2O} = 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);

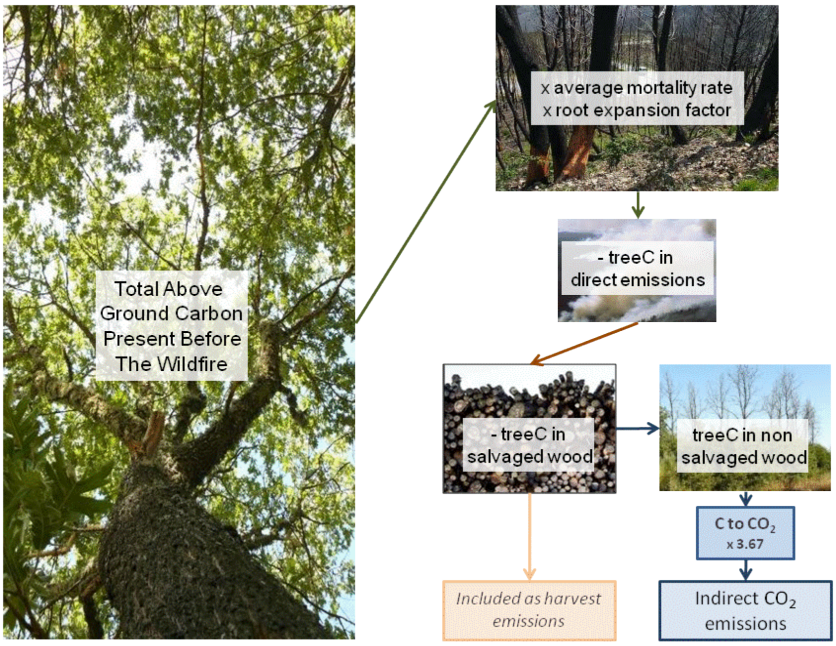
$N/N2O$ = Nitrogen Lost as N_2O (IPCC Default = 0,007);

$NtoN2O$ = 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 6-31.

Figure 6-31 – Estimation of Indirect Fire Emissions.



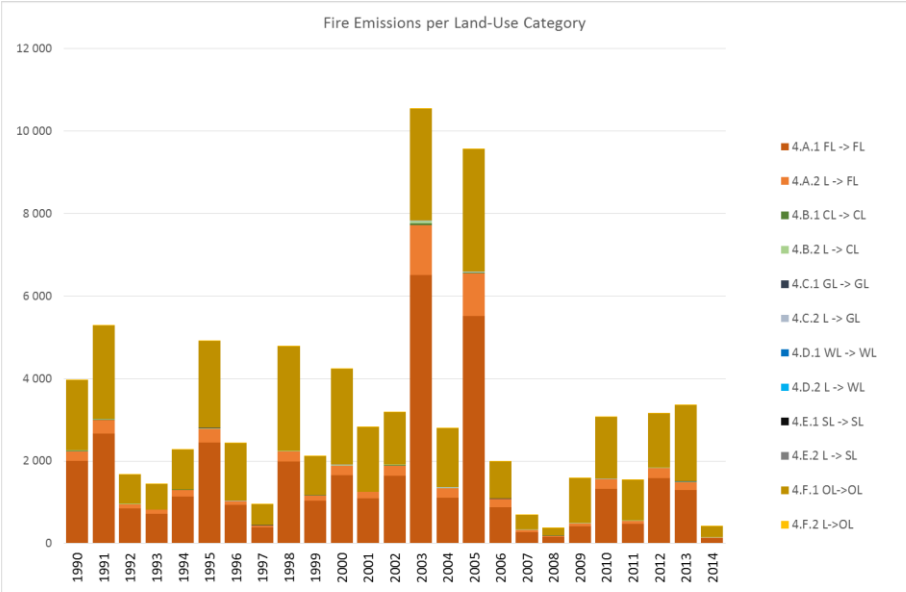
Average Mortality Rates and Salvage Wood were estimated by expert judgement, as presented in Table 6.26.

Table 6.26 – Mortality and Salvage Wood Rates.

Land-use Type	Mortality %	Non-salvage %
Pinus pinaster	70%	60%
Quercus suber	30%	60%
Eucalyptus spp.	50%	50%
Quercus rotundifolia	10%	60%
Quercus spp.	30%	60%
Other broadleaves	30%	60%
Pinus pinea	30%	60%
Other coniferous	70%	60%

The results of the estimations are presented in the figure below.

Figure 6-32 – Total Emissions from Biomass Burning per Land-use Category (kt CO2e)



6.14 Uncertainty Assessment

Uncertainties were calculated using the guidance of the IPCC 2006 guidelines, volume 1, chapter 3. Approach 1 was used for estimating uncertainties of annual estimates. For trend uncertainties, both Type A and Type B uncertainties were calculated.

Uncertainties were calculated using the same level of data disaggregation as was used for the emission estimates, i.e., for all possible land-uses and land-use changes, all pools and all gases.

Uncertaininties were later aggregated into the relevant UNFCCC categories using, as appropriate, IPCC 2006 equation 3.1 and/or equation 3.2.

EQUATION 3.1
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

EQUATION 3.2
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + \ldots + (U_n \bullet x_n)^2}}{|x_1 + x_2 + \ldots + x_n|}$$

The resulting total uncertainty per UNFCCC category is presented in Figure 6-33.

It should be recalled that uncertainties are expressed as a percentage of the absolute value of the total emissions of that category and that, as a consequence, abnormally high final estimates of uncertainty coincide with years for which annual net-emissions in that category/pool/gas are close to zero. Finally, it should be noted that estimates for categories 4.G, 4(III) and 4(V) are included in the net-emissions calculation, but the uncertainty estimates for those categories were not yet made.

Figure 6-33: LULUCF Total Uncertainty and Total Net-Emissions.

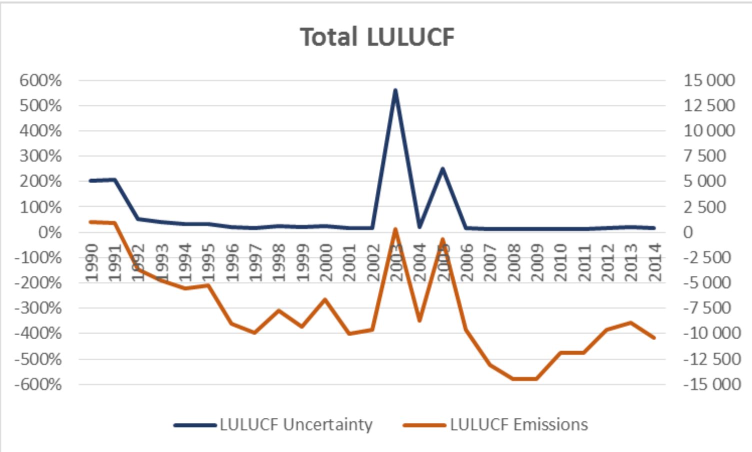


Figure 6-34 - Total Uncertainty and Total Net-Emissions per UNFCCC category.

LULUCF Area

Uncertainties for total area per land-use or per land-use change were considered to be inversely proportional to the total area, as shown in Table 6.27. This expert judgement value is based on the assumption that estimates of larger areas will generally be less uncertain than those for smaller areas.

Table 6.27 – Uncertaintiy of total area of each land-use / land-use change per class of area.

Land-use or land-use change area	Uncertainty
> 1,000,000 ha	3%
[500,000 ha – 1,000,000 ha[	5%
[50,000 ha – 500,000 ha[	10%
< 50,000 ha	25%

These individual uncertainties were assigned to each of the possible 19x19 land-use changes, according to their respective areas.

The combined uncertainty per UNFCCC category, applying the error propagation equations described above, resulted in the following uncertainty estimates:

Table 6.28 – Uncertainty estimates: total area per UNFCCC category and per year.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4.A.1 FL -> FL	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,1%	2,1%	2,1%	2,1%
4.A.2 L -> FL	6,1%	6,1%	5,3%	5,1%	5,0%	4,9%	4,7%	4,7%	4,6%	4,6%	4,7%	4,3%	4,3%	4,3%	4,3%
4.B.1 CL -> CL	2,7%	2,8%	2,8%	2,8%	2,9%	2,9%	2,9%	2,9%	2,9%	2,9%	2,9%	2,8%	2,8%	2,8%	2,8%
4.B.2 L -> CL	5,9%	5,8%	5,8%	6,4%	6,4%	6,4%	6,4%	6,4%	6,6%	6,5%	6,6%	6,7%	6,9%	8,3%	6,5%
4.C.1 GL -> GL	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
4.C.2 L -> GL	6,0%	5,1%	5,0%	4,9%	4,8%	4,8%	4,8%	4,8%	4,8%	4,8%	4,8%	4,9%	4,9%	5,0%	5,1%
4.D.1 WL -> WL	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
4.D.2 L -> WL	NO	NO	NO	NO	NO	12,4%	12,4%	12,4%	12,4%	12,4%	12,4%	12,4%	12,4%	12,4%	12,4%
4.E.1 ST -> ST	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
4.E.2 L -> ST	10,4%	9,9%	9,6%	9,5%	9,4%	8,6%	8,8%	8,9%	8,9%	9,0%	9,0%	9,0%	9,0%	9,1%	9,1%
4.F.1 OL -> OL	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%
4.F.2 L -> OL	14,4%	8,6%	8,6%	8,6%	6,8%	6,6%	6,5%	6,4%	6,3%	6,2%	6,1%	6,1%	6,0%	6,0%	5,9%

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4.A.1 FL -> FL	2,1%	2,1%	2,2%	2,2%	2,2%	1,9%	1,9%	2,0%	2,0%	2,2%
4.A.2 L -> FL	4,3%	4,3%	4,2%	4,2%	4,6%	4,6%	4,6%	5,1%	4,9%	5,0%
4.B.1 CL -> CL	2,8%	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%
4.B.2 L -> CL	6,1%	5,8%	5,6%	5,5%	5,5%	5,5%	5,5%	5,6%	5,7%	5,8%
4.C.1 GL -> GL	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
4.C.2 L -> GL	5,8%	5,9%	6,4%	6,5%	7,1%	7,0%	6,9%	6,9%	7,0%	7,3%
4.D.1 WL -> WL	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
4.D.2 L -> WL	12,4%	12,4%	12,2%	12,0%	11,8%	11,7%	11,5%	11,4%	11,3%	11,1%
4.E.1 ST -> ST	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
4.E.2 L -> ST	9,1%	9,1%	9,0%	9,0%	9,0%	8,9%	8,9%	8,9%	8,9%	8,9%
4.F.1 OL -> OL	4,5%	4,5%	4,4%	4,4%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%
4.F.2 L -> OL	5,9%	5,9%	5,9%	5,9%	5,9%	5,9%	6,1%	6,4%	10,3%	10,4%

6.14.1 Living Biomass: Gains

Uncertainties of mean annual increments in forest land-uses were considered to be low (3%) for the industrial species for which a more scientific knowledge is available, higher (5%) for all other individual species and 10% for groups of species. Where these species are growing as dominated species the uncertainty is assumed to double.

For other land-uses, a 30% incertainty was considered for growth rates in woody crops and shrubland, 40% for annual crops and grasslands and 50% for other land.

Table 6.29 – Uncertainties considered for each of factors used for calculation of Living Biomass – Gains.

Forest species/land-uses	Mean Annual Increment Where species is the dominant species	Mean Annual Increment Where species is the dominated species	BCEF	Root-to-shoot	Carbon Fraction
Pinus pinaster	3%	6%	5%	10%	5%
Quercus suber	5%	10%	10%	10%	5%
Eucalyptus spp.	3%	6%	5%	10%	5%
Quercus rotundifolia	5%	10%	10%	10%	5%
Quercus spp.	5%	10%	10%	10%	5%
Other broadleaves	10%	20%	10%	10%	5%
Pinus pinea	5%	10%	10%	10%	5%
Other coniferous	10%	20%	10%	10%	5%
Other land-uses	**Annual growth rate**			**Root-to-shoot**	
Rainfed annual crops	40%			50%	
Irrigated annual crops	40%			50%	
Rice padies	40%			50%	
Vineyards	30%			20%	
Olive groves	30%			20%	
Other permanent crops	30%			20%	
All grasslands	40%			30%	
Wetlands	NA			NA	
Settlements	NA			NA	
Shrubland	30%			30%	
Other	50%			50%	

These individual uncertainties were assigned to each of the possible 19x19 land-use changes, according to their respective areas.

The combined uncertainty per UNFCCC category, applying the error propagation equations described above, resulted in the following uncertainty estimates:

Table 6.30 – Uncertainty estimates: Living Biomass / Gains UNFCCC category and per year.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4.A.1 FL -> FL	5,6%	5,5%	5,5%	5,4%	5,3%	5,3%	5,3%	5,2%	5,2%	5,2%	5,2%	5,3%	5,3%	5,3%	5,3%
4.A.2 L -> FL	8,9%	8,7%	7,7%	7,5%	7,3%	7,1%	6,9%	6,7%	6,5%	6,4%	6,4%	6,1%	6,0%	6,0%	5,9%
4.B.1 CL -> CL	23,3%	24,9%	26,4%	27,5%	28,4%	23,5%	23,0%	22,6%	22,3%	22,3%	22,2%	19,3%	19,3%	19,3%	19,4%
4.B.2 L -> CL	18,7%	18,5%	18,3%	20,0%	20,1%	18,8%	18,8%	18,7%	18,7%	18,3%	17,8%	17,3%	16,9%	16,6%	16,2%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	32,4%	30,2%	30,2%	30,2%	30,2%	28,5%	28,5%	28,5%	28,5%	28,5%	28,5%	28,5%	28,5%	28,5%	28,5%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.F.1 OL -> OL	49,2%	49,2%	49,2%	49,2%	49,2%	44,9%	44,9%	44,9%	44,9%	44,9%	44,9%	44,9%	44,9%	44,9%	44,9%
4.F.2 L -> OL	28,4%	26,1%	26,2%	26,3%	25,8%	25,3%	24,9%	24,5%	24,1%	23,8%	23,5%	23,2%	23,0%	22,8%	22,5%

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4.A.1 FL -> FL	5,3%	5,4%	5,5%	5,5%	5,6%	5,2%	5,3%	5,3%	5,4%	5,5%
4.A.2 L -> FL	5,9%	6,2%	6,1%	6,0%	6,2%	6,1%	6,0%	6,9%	6,6%	6,6%
4.B.1 CL -> CL	19,4%	19,4%	20,1%	20,2%	19,9%	19,5%	19,2%	18,9%	18,6%	18,4%
4.B.2 L -> CL	15,8%	15,3%	15,0%	14,9%	14,6%	14,5%	14,6%	15,1%	15,8%	16,7%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	28,6%	28,6%	26,7%	26,6%	26,7%	26,6%	26,6%	26,6%	26,6%	26,6%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.F.1 OL -> OL	44,9%	44,9%	45,4%	45,7%	46,0%	46,2%	46,4%	46,5%	46,7%	46,8%
4.F.2 L -> OL	22,4%	22,2%	22,0%	21,8%	21,3%	20,7%	20,0%	19,5%	20,7%	21,0%

6.14.2 Living Biomass: Losses

As explained above the calculation of C losses are divided into diferent parcels. Uncertainty was calculated for each of the relevant parcels per land-use as explained below.

6.14.2.1 Land-use change

As outlined in sections 6.2.1.2.2, 6.2.2.2.2, 6.3.1.2.2, 6.3.2.2.2, 6.4.1.2.2, 6.4.2.2.2, 6.5.2.2.2, 6.6.2.2.2, 6.7.1.2.2 and 6.7.2.2.2, this corresponds to the loss of the C stock in biomass of the previous land-use.

Uncertainties for total forest standing volume per land-use were considered to be inversely proportional to the total volume present at the time of conversion, as shown in Table 6.31. This expert judgement value is based on the assumption that estimates of larger volume will generally be less uncertain than those for smaller volumes.

Table 6.31 – Uncertaintiy of total standing volume of each land-use per class of volume.

Forest standing volume per forest species	Uncertainty
> 20 m3/ha	5%
[5 ha – 20 m3/ha[	15%
< 5 m3/ha	30%

Based on these values, and on the uncertainties for BCEF, RTS and %C (as shown in Table 6.29), the uncertainties of standing C stock / ha per forest type were calculated.

For all other land-uses an uncertainty of 50% for standing C stock per ha was considered.

6.14.2.2 Industrial harvest

Industrial harvest was only considered only for forest land categories. The uncertainty of industrial harvest estimates (expressed in m3) is assumed to be 3%. Based on this value, and on the uncertainties for BCEF, RTS and %C (as shown in Table 6.29), the uncertainties loss of C stock / ha due to harvesting were calculated.

6.14.2.3 Other wood use harvest

Other wood use was only considered only for forest land categories. The uncertainty of individual harvesting per forest type (expressed in m3/ha) is based on the growth rate, and so it is based on the uncertainty estimates layed out in section 6.14.1. Based on these values, on the uncertainties for BCEF, RTS and %C (as shown in Table 6.29) and on the uncertainty of the use of wood factor (assumed to be 50%), the uncertainties loss of C stock / ha due to other wood use were calculated.

6.14.2.4 Natural mortality

Natural mortality was only considered only for forest land categories. The uncertainty of mortality rates per forest type was assumed to be 25%. This value was then combined with the standing volume uncertainty estimates layed out in section 6.14.2.1.

These individual uncertainties were assigned to each of the possible 19x19 land-use changes, according to their respective areas.

The combined uncertainty per UNFCCC category, applying the error propagation equations described above, resulted in the following uncertainty estimates:

Table 6.32 – Uncertainty estimates: Living Biomass / Losses UNFCCC category and per year.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4.A.1 FL -> FL	2,6%	2,9%	2,4%	2,4%	2,5%	3,2%	2,9%	2,8%	3,3%	3,0%	2,8%	3,0%	3,1%	3,2%	2,6%
4.A.2 L -> FL	17,8%	16,3%	14,4%	14,2%	13,5%	18,2%	20,0%	20,0%	18,2%	18,8%	18,0%	18,2%	17,4%	12,0%	15,8%
4.B.1 CL -> CL	12,2%	12,2%	12,2%	12,2%	12,2%	8,1%	8,1%	8,1%	8,1%	8,1%	8,0%	8,0%	8,0%	8,0%	8,0%
4.B.2 L -> CL	34,3%	34,3%	34,3%	34,3%	34,3%	9,1%	9,1%	9,0%	9,0%	9,0%	9,0%	8,9%	8,9%	9,5%	9,3%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	32,3%	32,3%	32,3%	32,3%	32,3%	11,2%	11,2%	11,1%	11,1%	11,1%	11,0%	11,0%	11,0%	10,9%	10,9%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	NO	NO	NO	NO	NO	27,2%	27,0%	26,9%	26,7%	26,6%	26,5%	26,3%	26,2%	26,0%	25,9%
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	18,2%	16,9%	16,8%	16,8%	16,9%	23,4%	23,3%	23,2%	23,1%	23,0%	22,9%	22,8%	22,7%	22,7%	22,6%
4.F.1 OL -> OL	25,0%	0,0%	0,0%	0,0%	0,0%	22,3%	22,3%	22,3%	22,3%	22,3%	22,3%	22,3%	22,3%	22,3%	22,3%
4.F.2 L -> OL	36,3%	36,3%	36,3%	36,3%	32,5%	28,3%	28,1%	28,0%	27,8%	27,7%	27,6%	27,4%	27,3%	27,2%	27,0%

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4.A.1 FL -> FL	3,1%	2,6%	2,0%	2,1%	2,2%	2,4%	2,1%	2,3%	2,3%	2,1%
4.A.2 L -> FL	12,5%	15,8%	12,0%	12,3%	12,4%	11,9%	12,9%	12,3%	19,1%	22,6%
4.B.1 CL -> CL	8,0%	7,9%	7,8%	7,8%	7,8%	8,0%	8,0%	8,0%	8,0%	8,0%
4.B.2 L -> CL	9,3%	9,3%	8,7%	8,7%	8,7%	8,7%	8,7%	8,7%	8,7%	8,7%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	11,4%	11,4%	12,1%	12,1%	12,1%	12,2%	12,2%	12,2%	12,2%	12,2%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	25,8%	25,8%	18,1%	18,1%	18,1%	18,1%	18,1%	18,1%	18,1%	18,1%
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	22,5%	22,5%	22,1%	22,1%	22,1%	22,1%	22,1%	22,1%	22,1%	22,1%
4.F.1 OL -> OL	22,3%	22,3%	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%
4.F.2 L -> OL	26,9%	26,9%	19,8%	19,8%	19,8%	19,8%	19,8%	19,8%	20,6%	20,6%

6.14.3 Litter / dead organic matter

Uncertainties of litter C stock estimates were considered to be 25% for all categories under forest land and shrubland, and 40% for all other land-uses. The uncertainty of the 20 years transition period was assumed to be 20%.

These individual uncertainties were assigned to each of the possible 19x19 land-use changes, according to their respective areas.

The combined uncertainty per UNFCCC category, applying the error propagation equations described above, resulted in the following uncertainty estimates:

Table 6.33 – Uncertainty estimates: Litter per UNFCCC category and per year.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4.A.1 FL -> FL	16,7%	16,8%	16,9%	17,0%	17,2%	17,8%	18,4%	18,9%	19,5%	20,0%	20,4%	20,9%	21,3%	21,7%	22,0%
4.A.2 L -> FL	24,5%	27,9%	32,1%	38,1%	50,2%	56,2%	64,9%	78,1%	100,1%	127,9%	179,1%	294,1%	866,5%	962,7%	318,0%
4.B.1 CL -> CL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.B.2 L -> CL	17,7%	17,4%	17,1%	17,1%	17,0%	17,0%	17,0%	17,1%	17,2%	16,9%	16,5%	16,0%	15,5%	17,1%	16,2%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	24,3%	23,7%	23,2%	22,8%	22,4%	22,4%	22,5%	22,5%	22,5%	22,2%	21,9%	21,6%	21,3%	20,9%	20,6%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	NO	NO	NO	NO	NO	24,5%	24,5%	24,5%	24,5%	24,5%	24,5%	24,5%	24,5%	24,5%	24,5%
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	16,2%	18,0%	21,3%	24,0%	26,1%	22,0%	21,8%	21,7%	21,7%	21,7%	21,7%	21,7%	21,7%	21,7%	21,7%
4.F.1 OL -> OL	38,4%	39,8%	39,8%	39,8%	39,8%	773,3%	803,5%	814,1%	819,5%	825,0%	826,8%	828,2%	830,6%	833,7%	833,9%
4.F.2 L -> OL	25,5%	21,4%	21,5%	21,5%	21,4%	21,0%	20,6%	20,2%	19,9%	19,6%	19,4%	19,1%	18,9%	18,7%	18,5%

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4.A.1 FL -> FL	22,6%	23,3%	23,9%	24,6%	25,2%	25,9%	26,7%	27,5%	28,4%	29,4%
4.A.2 L -> FL	135,3%	89,0%	61,7%	46,9%	59,5%	81,6%	133,3%	386,2%	429,1%	137,9%
4.B.1 CL -> CL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.B.2 L -> CL	15,7%	15,1%	14,3%	13,4%	13,5%	13,6%	13,8%	14,1%	14,5%	15,0%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	20,7%	20,6%	22,9%	22,5%	24,7%	25,2%	26,1%	27,8%	30,4%	34,3%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	24,5%	24,5%	24,4%	24,2%	24,1%	23,9%	23,8%	23,7%	23,6%	23,5%
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	21,7%	21,7%	21,6%	21,6%	21,5%	21,5%	21,4%	21,4%	21,3%	21,3%
4.F.1 OL -> OL	834,1%	835,3%	270,1%	175,9%	137,3%	116,4%	103,4%	94,5%	88,1%	83,2%
4.F.2 L -> OL	18,3%	18,1%	18,0%	17,9%	17,4%	16,9%	16,5%	16,1%	18,0%	18,5%

6.14.4 Mineral Soils

Uncertainties of mineral soil C stock estimates were calculated based on 95% confidance intervals of the respective measurements. The uncertainty of the 20 years transition period was assumed to be 20%.

Land-use	Uncertainty
Pinus pinaster	29%
Quercus suber	17%
Eucalyptus spp.	38%
Quercus rotundifolia	20%
Quercus spp.	66%
Other broadleaves	41%
Pinus pinea	127%
Other coniferous	127%
Rainfed annual crops	29%
Irrigated annual crops	37%
Rice padies	37%
Vineyards	59%
Olive groves	50%
Other permanent crops	62%
All grasslands	32%
Wetland	NA
Setlements	NA
Shrubland	52%
Other	59%

These individual uncertainties were assigned to each of the possible 19x19 land-use changes, according to their respective areas.

The combined uncertainty per UNFCCC category, applying the error propagation equations described above, resulted in the following uncertainty estimates:

Table 6.34 – Uncertainty estimates: Litter per UNFCCC category and per year.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4.A.1 FL -> FL	55,5%	51,6%	54,2%	56,8%	62,0%	66,8%	72,6%	79,6%	88,7%	99,1%	108,0%	134,7%	156,9%	181,0%	196,6%
4.A.2 L -> FL	33,1%	28,5%	23,7%	22,8%	22,5%	22,0%	21,6%	21,3%	21,0%	20,8%	20,7%	20,7%	20,6%	20,6%	20,6%
4.B.1 CL -> CL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.B.2 L -> CL	23,1%	22,7%	22,3%	22,0%	21,8%	21,7%	21,5%	21,4%	21,3%	20,8%	20,2%	19,5%	18,8%	19,6%	18,6%
4.C.1 GL -> GL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C.2 L -> GL	29,5%	28,6%	27,9%	27,3%	26,8%	26,9%	26,9%	26,9%	27,0%	26,6%	26,2%	25,9%	25,5%	25,1%	24,9%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	NO	NO	NO	NO	NO	19,8%	19,8%	19,8%	19,8%	19,8%	19,8%	19,8%	19,8%	19,8%	19,8%
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	22,1%	21,2%	21,0%	21,4%	22,2%	18,7%	18,8%	18,9%	18,9%	19,0%	19,0%	19,0%	19,1%	19,1%	19,1%
4.F.1 OL -> OL	51,1%	51,1%	51,1%	51,1%	51,1%	518,7%	508,8%	505,6%	504,0%	502,4%	501,9%	501,5%	500,8%	500,0%	499,9%
4.F.2 L -> OL	32,7%	29,2%	29,3%	29,3%	29,4%	29,0%	28,7%	28,4%	28,1%	27,9%	27,6%	27,4%	27,2%	27,0%	26,9%

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4.A.1 FL -> FL	176,2%	140,5%	109,5%	78,8%	64,4%	55,7%	54,5%	53,7%	56,2%	69,2%
4.A.2 L -> FL	20,1%	18,9%	18,5%	18,3%	18,9%	18,9%	19,0%	20,5%	21,4%	24,1%
4.B.1 CL -> CL	NO	NO	NO	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%
4.B.2 L -> CL	17,9%	17,2%	16,4%	15,6%	15,4%	15,4%	15,5%	15,8%	16,2%	16,7%
4.C.1 GL -> GL	NO	NO	NO	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%	18,0%
4.C.2 L -> GL	24,8%	24,8%	26,0%	25,8%	29,5%	29,4%	29,9%	31,6%	35,3%	42,7%
4.D.1 WL -> WL	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D.2 L -> WL	19,8%	19,8%	19,7%	19,6%	19,4%	19,3%	19,3%	19,2%	19,1%	19,0%
4.E.1 ST -> ST	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2 L -> ST	19,1%	19,1%	19,1%	19,1%	19,1%	19,1%	19,1%	19,1%	19,1%	19,1%
4.F.1 OL -> OL	499,8%	499,5%	28470,6%	634,4%	343,8%	248,7%	201,6%	173,6%	155,1%	141,9%
4.F.2 L -> OL	26,7%	26,5%	26,4%	26,2%	25,7%	25,2%	24,7%	24,5%	26,8%	28,9%

6.14.5 Harvested Wood Products

Uncertainties for the LULUCF sector were extensively recalculated for this submission. Due to time constraints it was not possible to present revised calculations for this category. Uncertainties for this category will be included in next year's submission.

6.14.6 N2O emissions from N inputs to managed soils

These emissions are reported as "IE / Included Elsewhere".

6.14.7 Emissions and removals from drainage and rewetting

These emissions are reported as "NO / Not Occurring".

6.14.8 N2O emissions from disturbance associated with land-use conversion to Cropland

Uncertainties for the LULUCF sector were extensively recalculated for this submission. Due to time constraints it was not possible to present revised calculations for this category. Uncertainties for this category will be included in next year's submission.

6.14.9 CO2 emissions from agricultural lime application

These emissions are reported as “IE / Included Elsewhere”.

6.14.10 Biomass burning

Uncertainties for the LULUCF sector were extensively recalculated for this submission. Due to time constraints it was not possible to present revised calculations for this category. Uncertainties for this category will be included in next year’s submission.

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.

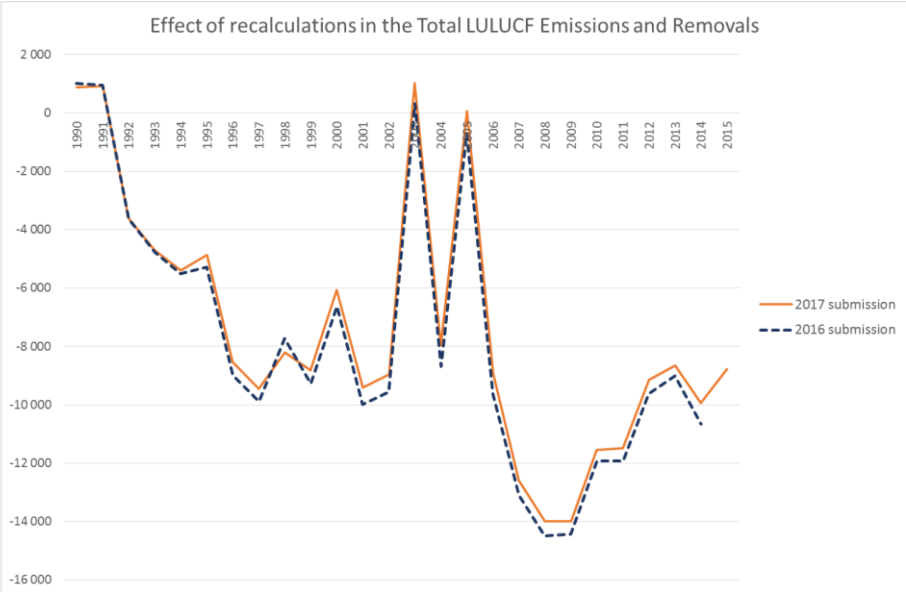
6.16 Recalculations and Data Improvements

The following recalculations were made since the last submission:

- → Data for HWP was made consistent with the most recent UNECE database
- → Category 4(IV) is now estimated
- → Mistake in C Stock levels for biomass and litter from shrubland detected and corrected
- → Change in harvest allocation between LF / FF and 3.3AR / 3.4FM introduced
- → Minor mistake in HWP estimates detected and corrected

However it should be noted that the impact of these recalculations in the final totals was small (Figure 6-35).

Figure 6-35 - Effect of recalculations in the Total LULUCF Emissions and Removals



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.

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7 WASTE (CRF 5.)

7.1 Overview

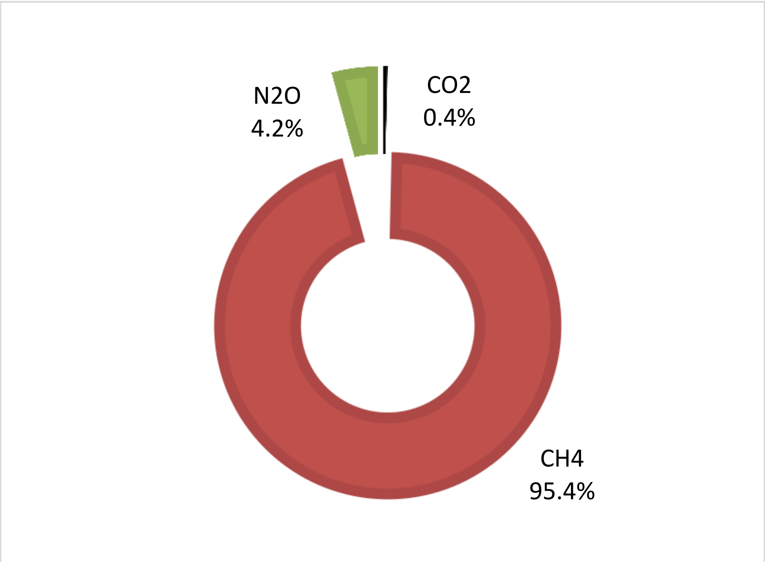
Waste management and treatment of industrial and municipal wastes are sources of GHG emissions. The inventory covers emissions resulting from landfilling, composting of organic waste, wastewater treatment, waste incineration and combustion of biogas.

The most important gas produced is CH4, resulting from the anaerobic decomposition of organic waste disposed on land and from handling of wastewater treatment under anaerobic conditions. N2O emissions are related with wastewater treatment and discharge of nitrogen into waterways.

CO2 emissions in the waste sector are associated with incineration of waste containing fossil carbon, e.g. plastics. CO2 emissions from biogenic origin are accounted as an information item.

Waste and wastewater treatment can also produce emissions of NMVOCs, NOx, CO as well as NH3 which are also estimated.

Figure 7-1 – Emissions of direct GHG from waste by gas (2015).



Emissions generated from waste activities are estimated, in 2015, as 6.4 Mt CO2e, representing 9.3 % of total GHG emissions. The biggest sub-category within the sector refers to waste disposed on land (CRF 5A) – 3.7 Mt CO2e - corresponding to approx. 58.1 % of the sector´ emissions. Waste Water Handling (CRF 5D) contributes to the majority of the remaining emissions, with 40.9% of the sector emissions (Industrial WWH 23.6% and Urban WWH 17.4%). 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 0.6% and 0.4 %, 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 (2015).

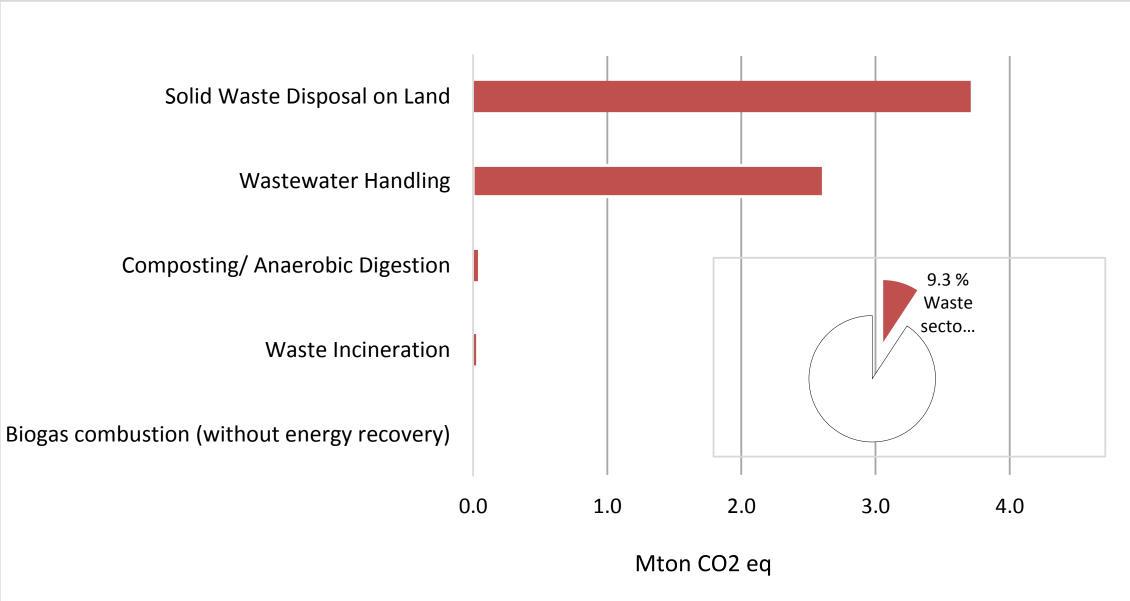


Table 7.1 – Total Greenhouse Emissions from Waste (ktCO2e).

Gas/Source	1990	1995	2000	2005	2010	2013	2014	2015
CH4	**5,132.68**	**6,288.07**	**6,947.35**	**7,398.87**	**6,618.39**	**6,287.38**	**6,045.30**	**6,089.99**
Solid waste disposal	2,728.45	3,483.76	4,499.72	4,771.53	4,383.53	3,959.22	3,731.63	3,709.04
Biological treatment of solid waste	5.03	11.04	13.74	13.07	22.18	21.97	24.13	23.07
Incineration of waste (without energy recovery)	0.27	0.28	0.26	0.37	0.15	0.14	0.15	0.15
Waste water treatment	2,398.94	2,792.99	2,433.63	2,613.88	2,212.52	2,306.05	2,289.39	2,357.72
Other (biogas burning)	NO	NO	NO	0.01	0.01	NO	NO	0.00
N2O	**221.23**	**239.49**	**262.26**	**265.63**	**286.89**	**268.61**	**268.51**	**268.51**
Solid waste disposal	-	-	-	-	-	-	-	-
Biological treatment of solid waste	3.59	7.90	9.83	9.35	15.68	13.33	12.74	13.64
Incineration of waste (without energy recovery)	0.90	0.97	1.05	1.85	0.63	0.70	0.71	0.71
Waste water treatment	216.74	230.62	251.39	254.43	270.57	254.59	255.06	254.15
Other (biogas burning)	NO	NO	NO	0.01	0.01	NO	NO	0.00
CO2	**6.86**	**7.12**	**4.99**	**9.58**	**15.99**	**18.25**	**26.02**	**22.40**
Incineration of waste (without energy recovery)	6.86	7.12	4.99	9.58	15.99	18.25	26.02	22.40
Total	**5,360.77**	**6,534.68**	**7,214.61**	**7,674.08**	**6,921.27**	**6,574.23**	**6,339.83**	**6,380.89**

In the period 1990-2015 GHG emissions from waste activities have increased 19.0 %.

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 centers 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).

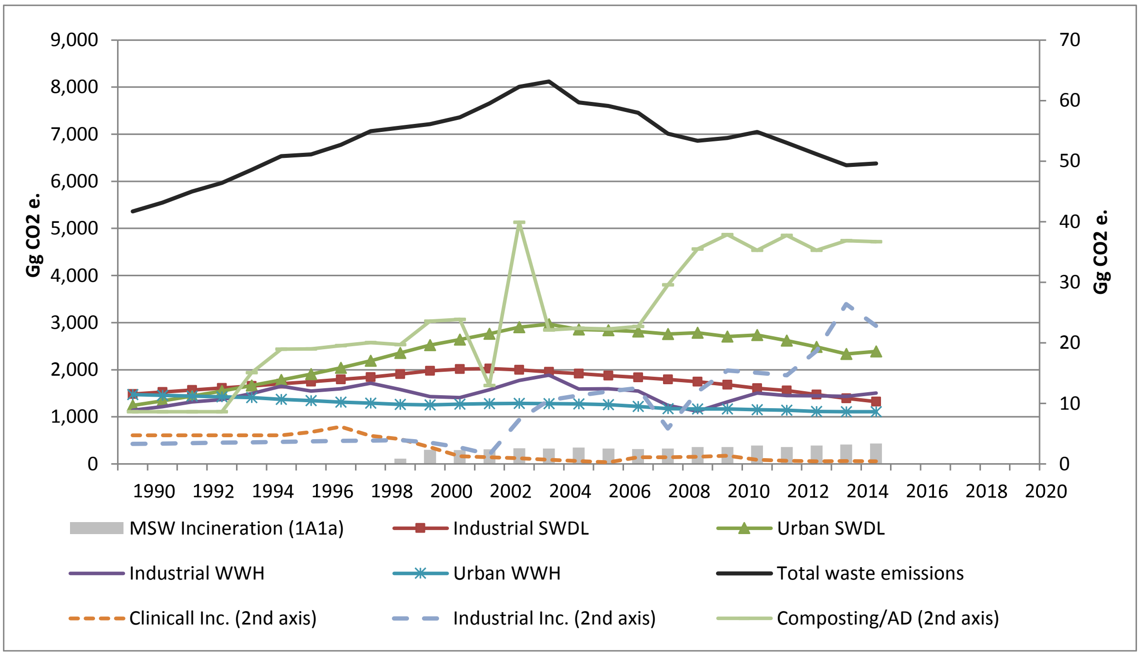
The growth of the sector emissions is related in majority to the CH4 emissions generated in Municipal Solid Waste landfilling, representing 37% of the sector emissions in 2015 and having registered a 92% increase since 1990.

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 2015, 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 municipal waste was not collected on a regular basis, and most information was available from:

- PERSU II - "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 details the different treatments: landfilling, incineration, composting/anaerobic digestion, and material recycling.

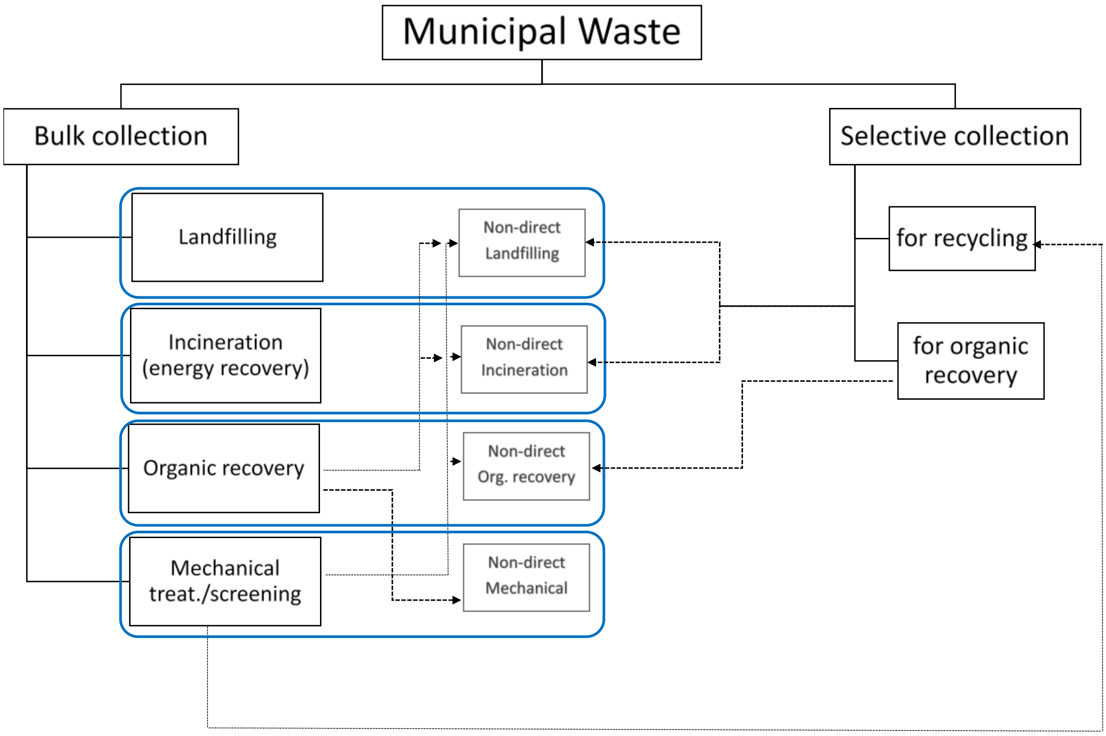
At present the National legislation (Decree-Law no. 178/2006 amended and republished in the Decree-Law no. 73/2011) defines the legal obligations related to the Waste Registry for: waste producers, management waste operators (municipal and non-municipal), waste carriers, integrated schemes for management of specific waste streams, and waste brokers and dealers.

The National entity responsible for the definition, implementation and supervising the waste policies is APA, I.P. through its Waste Department, which is also responsible for the validation and treatment of the information collected via the Integrated System for Electronic Registry on Waste (SIRER) in the SILIAMB electronic platform.

The operators should upload on different registration maps (MRRU, for municipal waste) the information regarding production, 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 data collected from the MRRU (Municipal Waste Registration Form), that 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). At present, MRRU is filled in by municipal waste management systems from Portugal Mainland and the Autonomous Region of Madeira. Information for the Autonomous Region of Azores is collected under the framework of SNIERPA (National System Inventory).

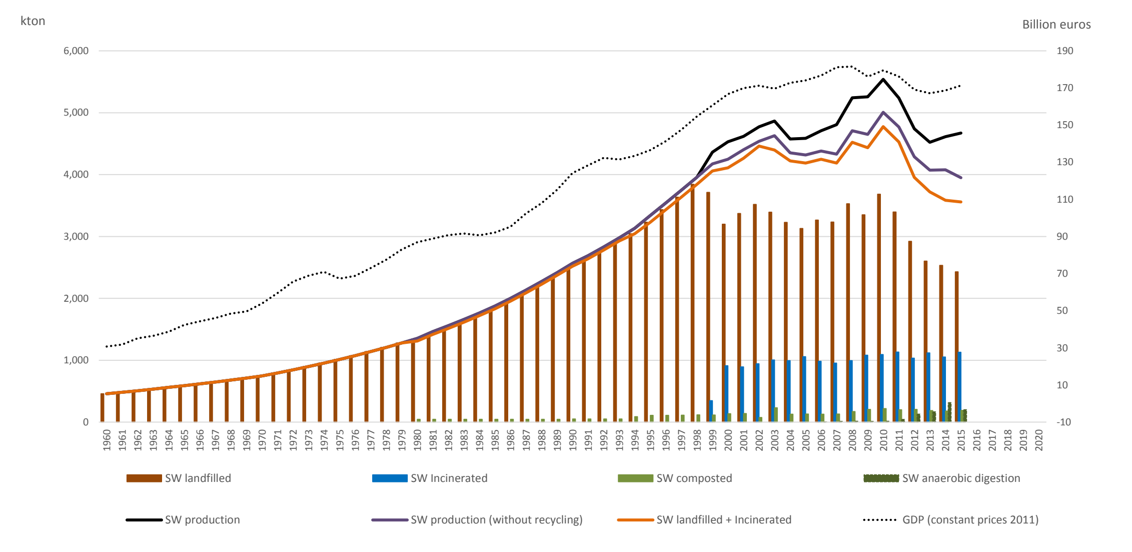
Figure 7-4 – Waste collection and waste streams by treatment type.



Although the "direct disposal of waste" represents the majority of situations, it does not reflect the actual final destination of waste. Thus, when calculating the overall fraction of waste disposed in a system, additional amounts of waste indirectly disposed should be considered, understanding the latter as rejected amounts from the previous handling processes, such as mechanical treatment and screening.

Next figure presents the trends of SW generation amounts and the quantities of waste per type of final disposal.

Figure 7-5 – Municipal waste.



Source: APA, include estimates

In the latest years, solid waste production presents a decreasing tendency, resulting from the policies on preventing, reducing and recycling of waste, but mainly due to the recent economic crisis effect on consumption.

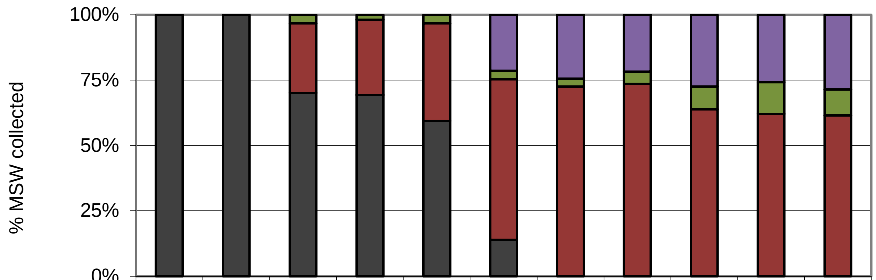
In 2015 they were produced around 4.7 million tonnes (t) of the urban waste in Portugal, approximately 1.0% more than in 2015, reversing the downward trend started in 2010. This increase may be related to an improvement of the economic situation of Portugal which registered approximately 1.6% growth in 2015 as compared to 2015.

As presented in the figure, waste start to be diverted from SWDS after 1999 corresponding to the beginning of operation of two MSW incineration units in Mainland Portugal.

Despite the fact that landfilling remains the main destination for municipal waste, the final disposal of waste in landfills have been continuously decreasing since 2010. This trend has been accompanied by the growth of importance of Mechanical and Biological treatment as well as Sorting units as foreseen in the Municipal Solid waste Strategic Plan (PERSU, PERSU II) and the National Plan for Waste Management (PGNR 2011-2020). The number of waste management infrastructures for organic recovery and biological treatment have grown expressively in the last decade, with the aim to increase the direct diversion of landfill waste and increase the quantity of recyclable waste recovered.

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 97% of total waste disposal; in 2015 this figure fall to 62%, and the percentage of waste incinerated represents 29%). Composting has been growing in importance and represents in 2015 approx. 10% of waste final disposal.

Figure 7-6 – Waste treatment.



	Early 60s	Early 70s	Early 80s	1990	1995	2000	2005	2010	2013	2014	2015
Incinerated	0	0	0	0	0	21	24	22	27	26	29
Composted/ AD	0	0	3	2	3	3	3	5	9	12	10
Managed landfills	0	0	27	29	37	61	72	74	64	62	62
Open dump sites	100	100	70	69	59	14	0	0	0	0	0

Source: APA estimates

7.2 Recalculations

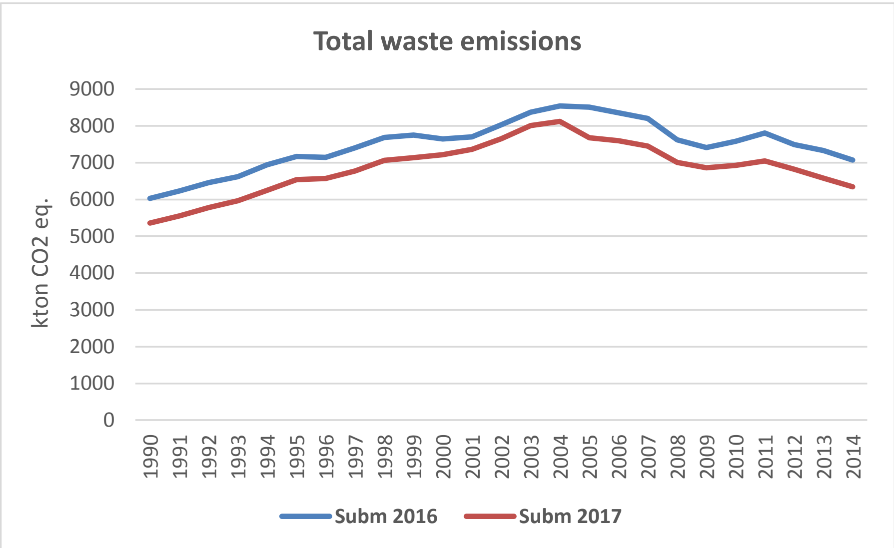
The recalculations made since last year (December 2016 resubmission in the context of the UNFCCC review) refer to:

- Wastewater treatment and discharge (CRF 5D):
  - N2O emissions from wastewater (CRF 5D1 and CRF 5D2)
    1. Emissions from industrial sources previously estimated on the basis of an emission factor (0.02 kg N2O/kg inhab-eq) from EMEP/CORINAIR (EEA, 2002) are now calculated together with domestic wastewater using the default factor (1.25) for industrial and commercial co-discharged protein into the sewer system (FIND-COM) proposed by 2006 IPCC;
    2. Correction of a calculation error in the previous estimates: instead of subtracting N from wasterwater effluent (equation 6.8) we were subtracting the N2O emissions from sludge removal in equation 6.7 and consequentely the emissions were underestimated.

  - CH4 emissions from industrial wastewater (CRF 5D2)

    Several revisions have been made for this category:
    1. Industrial treatment in septic tanks was excluded from 2005 onwards based on the knowledge that this type of treatment does not exist nowadays; treatment of IWW in textile and wood industry was not considered for the whole time series;
    2. MCF revision for situations where industrial treatment type is unknown: previous values, which referred to the MCF weighted averages for all domestic wastewater treatment types (values varying from 24% to 17%), were replaced by new figures referring to MCF weighted averages for industrial wastewater treatment types (values ranging from 10% to 14%);
    3. Compilation error related to anaerobic treatment.

Figure 7-7 – Differences between 2016 submission and 2017 submission for Municipal Waste.



7.3 Solid Waste Disposal on Land (CRF 5.A.)

7.3.1 Source category description

Decomposition of organic waste does not occur instantaneously after disposal on land, but rather over a long period of time, and CH4 is emitted at a diminishing rate. Different factors affect the generation of CH4: Waste disposal practices (degree of control of disposal sites – in general, controlled placement of waste favors anaerobic activity and consequently landfill gas formation, but the gas can be recovered and be either flared or used for energy purposes); Waste composition (quantities of degradable materials is one major element influencing biogas production); and Physical factors (e.g. moisture content and temperature).

Solid waste disposal sites (SWDS), which include both managed landfills and open dump sites, can also produce directly significant amounts of CO2. In fact, the decomposition of organic materials originates landfill gas or biogas consisting of approximately 50 % CH4 and 50 % CO2 by volume. However, this carbon dioxide results in its major part from oxidation of biomass materials and does not contribute hence to ultimate CO2. Additionally, a much smaller percentage of landfill gas is composed of NMVOC and NH3.

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 CH4, both in terms of level and trend.

Table 7.2 – CH4 (1) Emissions from Solid Waste Disposal (ktCO2e).

Source	1990	1995	2000	2005	2010	2013	2014	2015
Municipal solid waste	**1,243.2**	**1,783.1**	**2,522.9**	**2,854.7**	**2,703.6**	**2,484.7**	**2,337.5**	**2,387.4**
- managed disposal sites	359.7	656.0	1,259.4	1,908.3	2,036.7	1,944.1	1,833.4	1,917.4
- unmanaged disposal sites	883.6	1,127.1	1,263.5	946.4	666.9	540.6	504.1	470.0
Industrial solid waste	**1,485.2**	**1,700.6**	**1,976.8**	**1,916.8**	**1,679.9**	**1,474.6**	**1,394.1**	**1,321.6**
- managed disposal sites	361.9	544.4	872.0	1,108.9	1,110.5	1,013.0	963.8	920.4
- unmanaged disposal sites	1,123.3	1,156.3	1,104.8	808.0	569.4	461.5	430.3	401.2
Total	**2,728.5**	**3,483.8**	**4,499.7**	**4,771.5**	**4,383.5**	**3,959.2**	**3,731.6**	**3,709.0**

7.3.2 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).

7.3.2.1 Quantities of waste landfilled

7.3.2.1.1 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 K: Key Category Analysis). 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 municipal 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:

[Population (inhabitants) * Annual amount of municipal waste generated per capita (t/inhabitant/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.

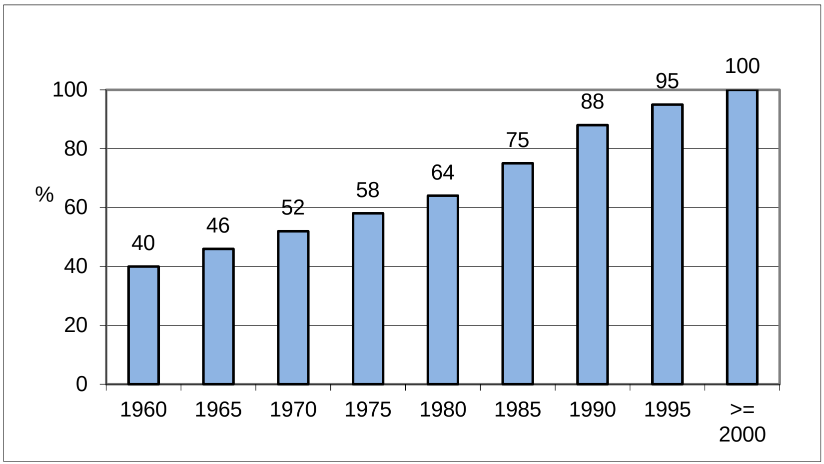
Since 1999, data on MSW are collected from management systems operators. The quantities of MSW production between 1994 and 1999 were estimated by interpolation.

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:

Waste disposed to SWDS = [Population * Annual amount of municipal waste generated per capita *

Percentage of Population served by waste collection] – Quantity of incinerated waste – Quantity of composted/digested waste

Figure 7-8 - Population served by waste collection systems.



Source: APA

7.3.2.1.2 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, and the 2004-2007 period to an interpolation of 2003 and 2008 data.

Data from 2008 onwards refer to data collected via SIRER (Integrated System for Electronic Registry on Waste) in the SILIAMB electronic platform. After data collection 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).

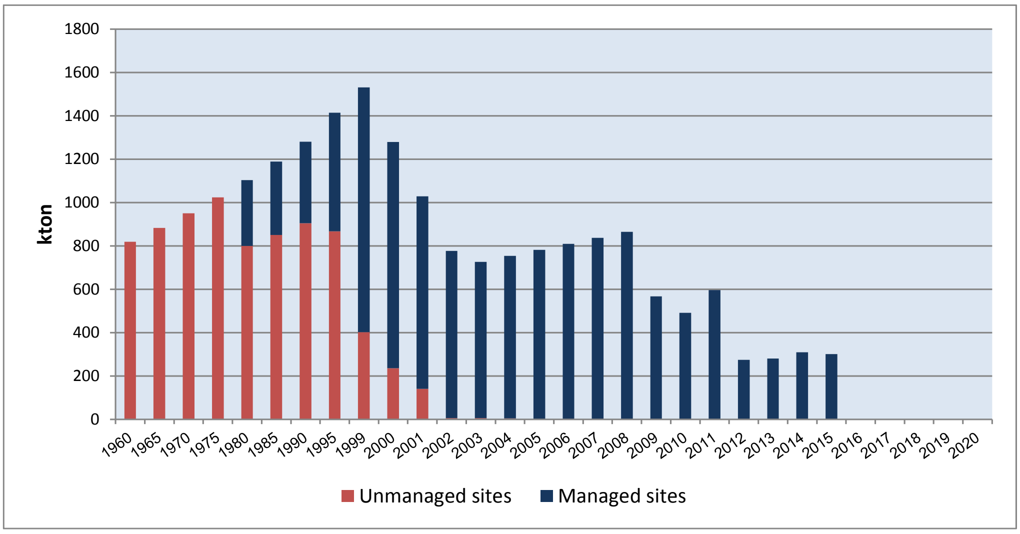
In 2012, the Statistical Office made a methodological change in the sectoral waste statistics, consisting in the harmonization of the sample used for these statistics with other statistical operations related to the Common Corporate Sector/ Business Sector, in which a set of statistical units, such as municipalities and other entities from public administrations, are excluded since 2012.

This revision is considered to have increase the quality of the waste statistics, as it was found to exist an overlap of content and double accounting between the sectoral and the municipal statistics, due to a double registry, in the MRRU and MIRR, of waste operations by many operators.

In order to make the time series more consistent, the data from 2008 has been revised to exclude the information from entities not considered from 2012 onwards. This double accounting phenomenon is more difficult to quantify for previous years.

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 municipal disposal pattern between uncontrolled and controlled SWDS.

Figure 7-9 – Quantities of fermentable industrial waste disposed to SWDS.



Source: APA

The fluctuations of industrial waste amounts 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, shipping abroad 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.

7.3.2.2 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.

7.3.2.2.1 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 composition of waste disposed in SWDS.

Table 7.7.3 – Municipal waste composition disposed to SWDS and DOC.

Fermentable fractions	DOC content	Early 60s	Early 70s	Early 80s	Early 90s	Mid 90s	2000	2010	2011	2012	2013	2014	2015
		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	13.7	13.3
Glass	-	2.5	2.5	2.5	4.4	5.1	7.4	3.7	3.6	4.0	4.5	4.4	4.3
Plastics	-	3.0	3.0	3.0	9.2	11.7	11.1	10.8	10.5	10.2	10.8	10.8	10.8
Metal	-	3.0	3.0	3.0	2.8	2.7	2.8	2.0	1.8	1.6	1.9	1.9	1.8
Food waste	15	59.9	59.9	59.9	42.0	34.8	26.5	42.8	43.0	40.9	36.6	37.5	36.7
Textiles	24	5.5	5.5	5.5	3.8	3.1	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Non-food fermentable materials 1)	20	0.0	0.0	0.0	13.4	18.7	17.4	14.3	14.3	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	1.0	1.2
Other	-	9.1	9.1	9.1	3.2	0.8	5.4	8.7	10.3	13.1	14.8	13.9	15.0
DOC	**-**	**17.1**	**17.1**	**17.1**	**18.4**	**18.9**	**18.9**	**16.0**	**15.5**	**15.0**	**14.9**	**15.0**	**14.8**

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 2010-15: APA

DOC content: 2006 IPCC defaults.

7.3.2.2.2 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 Decision - 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 the SIRER's MIRR registration map at SILIAMB electronic platform. 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 EWCStat 4.0 categories that are considered as organic waste. These data are presented in the next table.

Table 7.7.4 - Industrial organic waste composition and DOC.

waste groups	DOC (0..1)	*1960-99*	1999	2000	*2001*	2002	2003
		ton					
paper and textiles	0.40		841,899			384,713	316,538
garden w aste, park w aste or other non-food organic p	0.17		77,269			208,965	172,135
food w aste	0.15		19,209			56,455	158,286
w ood 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			1,410	2,643
TOTAL	-	*estimates*	**1,530,654**	*1,279,615*	*1,028,576*	**777,537**	**726,946**
DOC (weighted average)	-	***0.282***	**0.282**	***0.284***	***0.285***	**0.286**	**0.257**

waste groups (EWC-Stat/Version 4)	DOC (0..1)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
		ton											
03.2 + 03.3 Sluge from industrial origin	0.14					28,674	40,149	32,944	33,758	23,203	28,905	29,733	*29,919*
05 Health care and biological w astes a)	0.15					9,791	9,790	9,759	10,698	9,916	3,886	808	*2,395*
07.2 Paper and cardboard w astes	0.40					3,214	3,548	1,372	54,438	323	275	144	*214*
07.5 Wood w astes	0.30					22,776	12,758	8,197	7,848	4,713	1,053	626	*856*
07.6 Textile w astes a)	0.24					29,400	25,348	36,064	24,162	14,935	13,950	16,002	*15,282*
09.1 Animal w aste of food preparation and products	0.15					20,377	12,173	15,892	14,063	11,618	14,020	19,803	*17,257*
09.2 Vegetal w aste	0.15					24,531	13,715	9,994	15,216	3,405	2,611	4,112	*3,430*
09.3 Slurry and manure	0.15					0	20	0	0	0	0	19,167	*9,780*
10.1 Household and similar w astes b)	0.17					456,187	181,907	150,510	211,008	37,390	34,743	34,291	*35,224*
10.21 + 10.22 Mixed and undifferentiated materials	0.26					129,327	127,318	90,969	99,042	45,971	42,461	54,845	*49,649*
11 Common sludges	0.14					89,469	93,815	95,137	88,537	87,977	73,664	58,295	*67,330*
TOTAL	-	***754,633***	***782,320***	***810,006***	***837,693***	**865,380**	**566,972**	**491,447**	**596,709**	**275,080**	**281,207**	**309,581**	*301,441*
DOC (weighted average)	-	***0.241***	***0.224***	***0.208***	***0.191***	**0.175**	**0.175**	**0.171**	**0.192**	**0.155**	**0.135**	**0.139**	***0.137***

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); and 2004-2007 (interpolation of 2003 and 2008 data). The amounts of waste for the previous decades (1960-1998) were calculated considering annual growth rates as explained previously2015 data were estimated on the basis of GDP variation, taking in account the average of 2013-2015 data.

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.

7.3.2.3 Other parameters

Other parameters used in the calculation rely on some IPCC default values, and apply both to municipal and industrial waste.

Table 7.7.5 – 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

7.3.2.3.1 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 t1/2) as follows: k = ln2 / t1/2. 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.

7.3.2.3.2 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.

CH4 recovered in flares and valorized for energy purposes is estimated on the basis of average biogas flows (continuous measurement) and the number of hours of burning. The concentration of CH4 in biogas used in the estimates of the CH4 quantities refer to monitoring plans (quarterly measurements) measuring the biogas quality (generally CH4, CO2, O2, N2, H2S) at the entrance of the flares or the biogas energy recovery system.

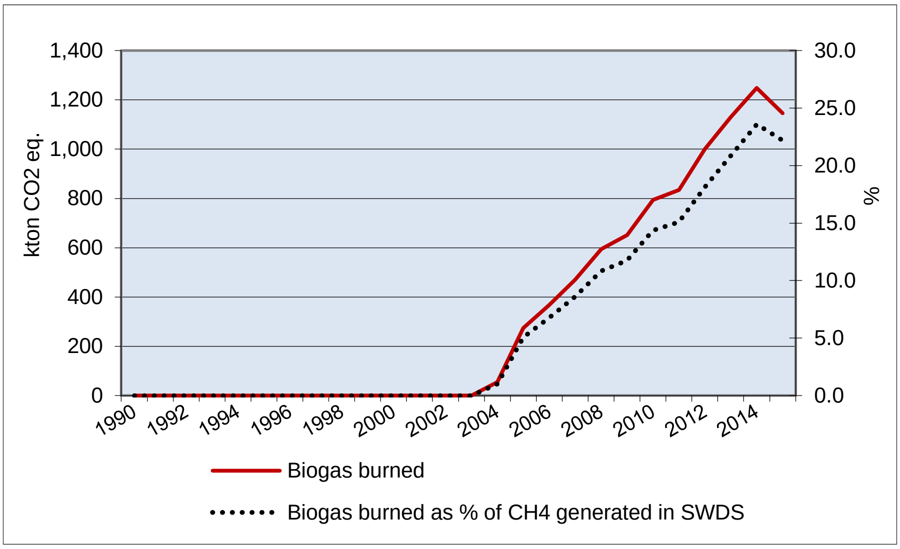
The annual quantities of biogas burnt (in flares and energy recovering units) reported by each landfill (in cubic meters) were converted into CH4 amounts considering the CH4 percentages in biogas (based on measurements) reported by management systems.

Table 7.7.6 –CH4 in landfill gas.

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Average share of CH4	%	54	51	53	52	52	52	54	51	51	*51*	*51*	*50*

Source: APA questionnaire.

Figure 7.7- – Quantities of CH4 combusted (SWDS).



Source: APA questionnaire data (flared and energy recovered quantities); 2004: DGEG data (energy recovery only).

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 CH4 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, 2006). The OX factor was applied after subtraction of CH4 recovered.

7.3.3 Uncertainty and time-series consistency

7.3.3.1 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 back cast 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 equation 3.2; AD = MSWT (Total Municipal Solid Waste produced) * MSWF (Fraction of MSWT sent to SWDS), using the proposed values from IPCC 2006. A combined uncertainty of 14% was estimated for the quantities disposed in managed SWDS in 2015. The uncertainty of the emission factor was estimated using a combination of equation 3.2 and 3.1. The default values proposed IPCC 2006 were used to calculate uncertainties for each parameter: DOC (approx. 15%), DOCF (20%), MCF (10%), F (5%) and k (28.6%). An overall error of 18 % was estimated for CH4 EF in 2015.

7.3.3.2 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 in 2015 for the deposition on land of industrial solid wastes was about 18%.

Uncertainty in the determination of the emission factor follows the rules of error propagation and were set from the default values proposed in the 2006 IPCC. The calculated uncertainties in 2015 for the parameters are: DOC (29%), DOCF (20%), MCF (10%), F (5%) and k (28.6%). An overall error of 47 % was estimated for CH4 EF in 2015.

7.3.4 Source-specific QA/QC and verification

7.3.4.1 Solid Waste Disposal on Land

7.3.4.1.1 General QC 1

General QC 1 procedures were applied following the guidance from 2006 IPCC Guidelines (Volume 1/Table 6.1) 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.

7.3.4.1.2 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, in particular those with similar natural, demographic and economic conditions.

7.3.5 Source-specific recalculations

No significant revisions were made for this category. The slight recalculation (<1% difference in 2014) refers to a revision of the percentage of CH4 in biogás for the period 2012-2014.

7.3.6 Source-specific planned improvements

No revisions are foreseen for the near future.

7.4 Biological treatment of solid waste (CRF 5.B.)

7.4.1 Source category description

This category refers to composting and anaerobic digestion of municipal organic waste. The emissions from home composting are not included as no reliable data exits on this activity.

After the period 1995-2002, characterized by a significant increase in MSW deposition capacity in landfills and incineration with energy recovery, the country has been investing in organic recovery infrastructures to meet the objectives of the Directive Landfills. In 2002 there were 5 composting units, while in 2015, the number rose to 22 organic recovery units distributed throughout the country. Anaerobic digestion started in 2006.

Table 7.7.7 – Emissions from Biological Treatment of Solid Waste (ktCO2e).

Source	1990	1995	2000	2005	2010	2013	2014	2015
CH4	5.0	11.0	13.7	13.1	22.2	22.0	24.1	23.1
N2O	3.6	7.9	9.8	9.4	15.7	13.3	12.7	13.6
Total	**8.6**	**18.9**	**23.6**	**22.4**	**37.9**	**35.3**	**36.9**	**36.7**

7.4.2 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 CH4 recovery occurs the amounts should be subtracted.

Due to lack of data, in particular for the years until 2008, some assumptions were made in order to estimate the amounts that are effectively subject to composting, i.e. the quantities that are forwarded to biological treatment minus the amounts rejected afterwards. For the latest years, the rejections from composting represent approximately 55% of the total quantities sent to composting. This percentage was used to estimate the the activity level for the past years. Data for the latest years refer to data collected from management systems, which separates entrances and rejections from biological treatment. The time series shown in the next figure presents some fluctuations which are the result of systems functioning interruptions what occurred for instance in 2002, when a composting system did not functioned in that year.

Figure 7-10 – Quantities of municipal waste Composted/ Digested and related emissions.

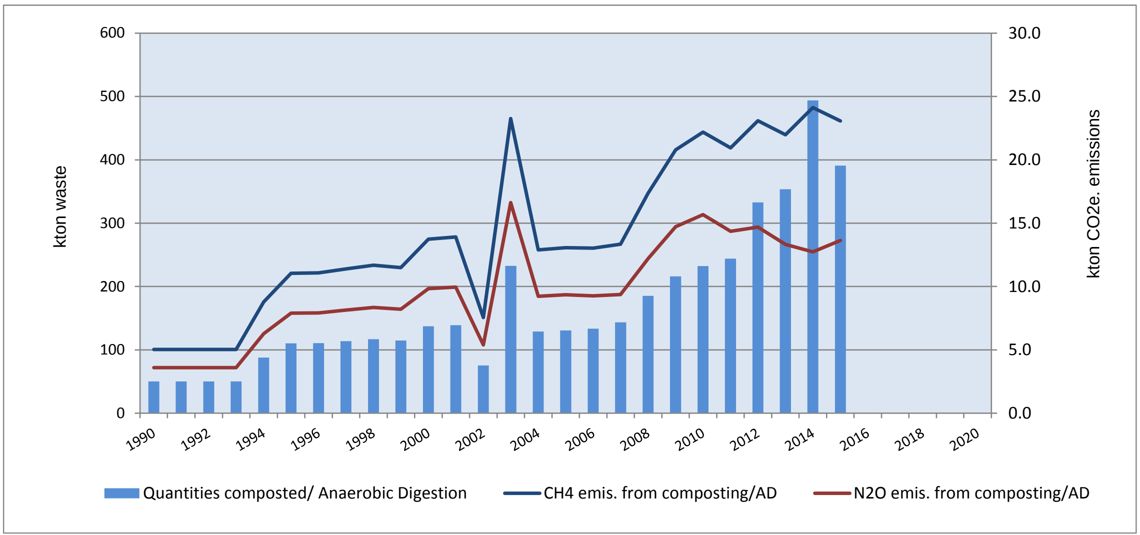


Table 7.7.8 – Default emission factors for CH4 and N2O emissions from biological treatment (wet weight basis).

	CH4 (g/kg waste treated)	N2O (g/kg waste treated)
Composting	4	0.24
Anaerobic digestion	0.8	Assumed negligible

Source: 2015 corrigenda of the IPCC 2006 GL (IPCC TFI, 31 July 2015 as published at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html).

7.4.3 Uncertainty and time-series consistency

The accuracy of the activity data on biological treatment of waste is consider to be lower for the previous years of the time series when information on waste collection and disposal was scarce. Even for the more recent years, there is still some uncertainty concerning the quantification of the amounts that are effectively subject to composting. In fact, there are considerable amounts of waste that are rejected after being forwarded to organic valorisation facilities. These amounts are well known for the latest years but information is difficult to obtain for previous years. The uncertainties estimated for the activity data varies from approx. 150% (1990) to 14% (2015). The uncertainties of the emissions factors were based on range variations considered in the 2006 IPCC for default emission factors for composting and anaerobic digestion, resulting in 120% for CH4. The uncertainty value considered for EF for N2O emissions from composting is 112.5%.

7.4.4 Source-specific QA/QC and verification

To be developed in the future.

7.4.5 Source-specific recalculations

No recalculations have been made since latest 2016 submission (UNFCCC Review resubmission made in November 2016), when EFshave been updated accordingly to the 2015 corrigenda of the IPCC 2006 GL.

7.4.6 Source-specific planned improvements

No revisions are foreseen in the near future.

7.5 Waste Incineration (CRF 5.C.)

7.5.1 Source category description

Waste incineration in Portugal includes combustion of municipal, clinical and industrial wastes.

Relevant gases emitted include CO2, CH4 and N2O. CO2 emissions are dependent to a large extent on the amount of fossil carbon in the waste burned. The non-CO2 emissions are more dependent on the technology and conditions during the incineration process.

Incineration of municipal solid wastes (MSW) takes place in three modern units where energy is recovered, and thus, according to the IPCC Guidelines, these emissions are accounted for in the energy sector (sub-category 1A(a) Public electricity and heat production). The incineration of other waste, such as clinical or industrial waste that occurs without energy recovery, is therefore allocated to the waste sector. Nevertheless, as the methodology applies for both situations (with and without energy recover), in order to avoid a double description, it is presented only once in this sub-section.

Emissions have been estimated for the non-biogenic and biogenic component of the waste. Emissions from the non-biogenic component have been reported under public electricity and heat production – other fuels. Non-CO2 emissions from the biogenic part are accounted under public electricity and heat production – biomass, and the CO2 emissions are reported as a memo item from solid biomass use.

Table 7.7.9 –Emissions from Waste Incineration (ktCO2e).

Gas/Source	1990	1995	2000	2005	2010	2013	2014	2015
CO2								
Non-biogenic								
MSW incineration (CRF 1A1a)	0.0	0.0	281.4	326.5	337.4	367.2	391.1	411.8
Industrial solid wastes	2.4	2.7	2.4	9.1	14.7	17.9	25.6	22.0
Clinical waste	4.4	4.4	2.6	0.4	1.3	0.4	0.5	0.4
Biogenic (memorandum item)								
MSW incineration (CRF 1A1a)	0.0	0.0	447.8	519.5	536.8	544.2	483.6	550.3
Industrial solid wastes	9.5	10.5	14.7	33.9	12.2	13.4	10.5	12.3
Clinical waste	13.3	13.3	7.8	1.3	3.8	1.2	1.4	1.3
CH4								
MSW incineration	0.0	0.0	5.3	6.2	6.4	6.6	6.2	6.6
Industrial solid wastes	0.1	0.2	0.2	0.4	0.1	0.1	0.1	0.1
Clinical waste	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
N2O								
MSW incineration	0.0	0.0	13.6	15.8	16.3	16.7	15.7	16.8
Industrial solid wastes	0.7	0.8	0.9	1.8	0.6	0.7	0.7	0.7
Clinical waste	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.0
Total								
Incineration with energy recovery (CRF 1A1a)	**0.0**	**0.0**	**300.4**	**348.5**	**360.1**	**390.4**	**413.0**	**435.2**
Incineration without energy recovery (CRF 5C)	**8.0**	**8.4**	**6.3**	**11.8**	**16.8**	**19.1**	**26.9**	**23.3**

7.5.2 Methodological issues

7.5.2.1 CO2 emissions

CO2 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, CO2 emissions were calculated on the basis of waste composition as following:

$$CO2\ emissions\ (Gg/yr) = MSW * \Sigma_j\ (WFj * dmj * CF_j * FCF_j * OF_j) * 44 / 12\ )$$

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);

WFj - fraction of waste type/material of component j in the MSW (as wet weight incinerated);

dmj - dry matter content in the component j of the MSW incinerated, (fraction);

CF_j - Fraction of carbon in the dry matter (i.e., carbon content) of component j;

FCF_j - Fraction of fossil carbon in the total carbon of component j;

OF_j - oxidation factor, (fraction);

44/12 = conversion factor from C to CO2.

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:

$$CO2\ emissions\ (Gg/yr) = (SW * CF * FCF * OF * 44 / 12\ )$$

where:

SW - amount of waste incinerated (Gg/yr);

CF - fraction of carbon content;

FCF - fraction of fossil carbon;

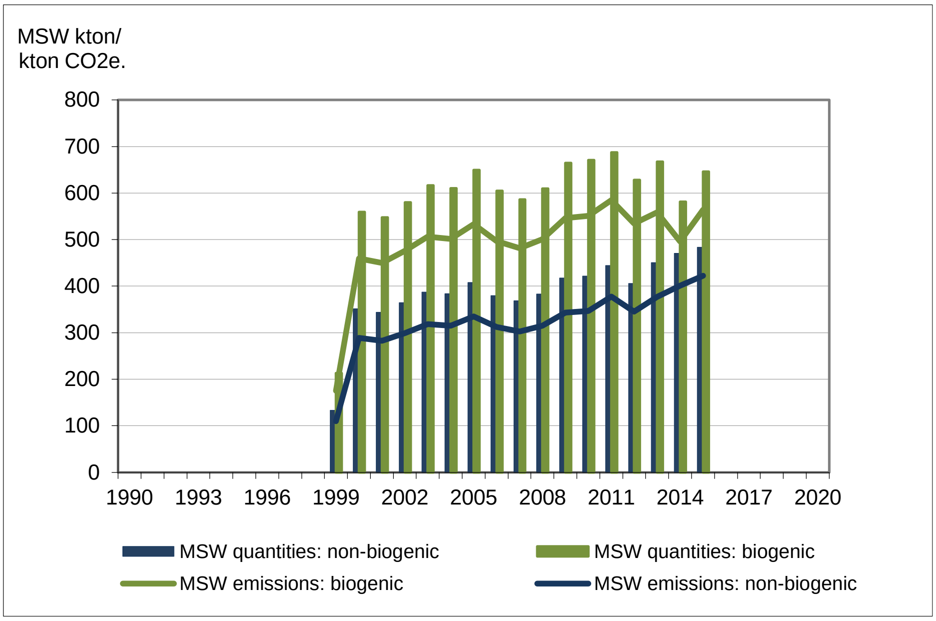
OF – oxidation factor (fraction).

7.5.2.1.1 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 incineration of MSW which includes domestic and commercial waste.

The emissions from MSW incineration occur with energy recovery and are therefore accounted in the energy sector (category 1A1a).

Figure 7-11 – Incineration of Municipal Solid Waste: quantities incinerated (kton) and related emissions (kt CO2e) (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-CO2 emissions from the combustion of organic materials (e.g. food waste, paper). CO2 emissions from the biogenic component are only reported as a memo item.

All the incineration units considered are modern units using best available technologies, either concerning the abatement technologies or the incineration techniques used, which aim at the optimization of the combustion process, and consequently the minimisation of atmospheric pollutants.

The incineration process used refers to continuous mass burning with heat recovery for steam and electricity production. The waste is burnt in a combustion grate at approximately 1000ºC. 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 850ºC. 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 NOx, acid gases, dioxins, furans, heavy metals and particulates.

Abatement technologies used include:

- NOx reduction system based on the ammonia or urea injection in the combustion chamber;
- semi-dry treatment process, consisting of a reactor, were spray fine droplets of an alkaline reagent (calcium hydroxide) are introduced to neutralise the acid gases;

- activated carbon injection to remove dioxins, furans and heavy metals;
- fabric filter for particulate removal.

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, CO2 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.

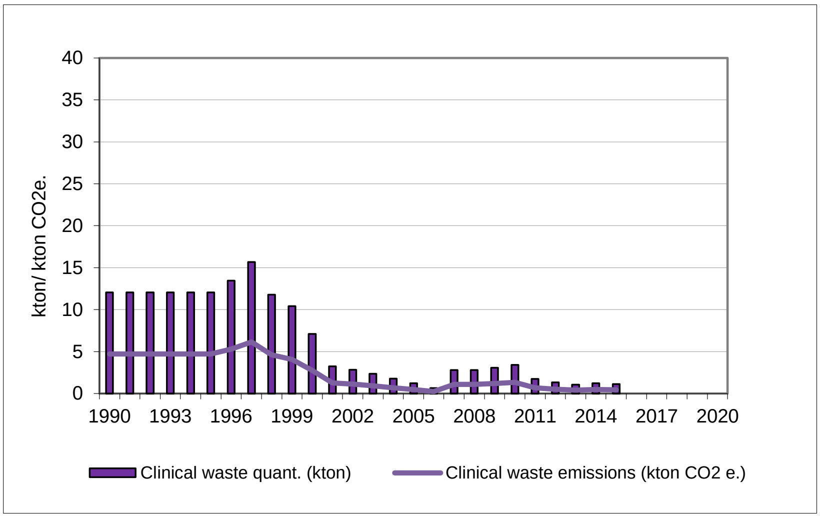
Table 7.10 – Base table for MSW C content estimation.

	Dry matter content	Carbon content	Fossil carbon	Waste composition (% of wet weight)									
	(% of wet weight)	(% of dry matter)	(% of total C)	1990	1995	1999	2000	2010	2011	2012	2013	2014	2015
Paper/ Card	90	46	1	-	-	14.3	14.3	14.3	15.6	15.6	14.5	13.6	15.3
Glass	100	NA	NA	-	-	4.7	4.7	4.7	5.7	5.7	5.1	5.1	5.1
Plastics	100	75	100	-	-	10.0	10.0	10.0	10.7	10.7	10.7	12.3	12.1
Metals	100	NA	NA	-	-	2.0	2.0	2.0	1.9	1.9	1.8	2.1	2.1
Food waste	40	38	-	-	-	42.2	42.2	42.2	39.6	39.6	40.5	38.8	39.7
Textiles	80	50	20	-	-	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Non-food fermentable materials	40	49	0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood	85	50	-	-	-	0.7	0.7	0.7	1.1	1.1	0.8	0.5	0.4
Other	90	3	100	-	-	23.4	23.4	23.4	22.8	22.8	24.0	25.0	22.8
C content in Plastics,Textiles, etc (1)						8.4	8.4	8.4	8.9	8.9	9.0	10.1	9.9
Total C of waste (2)				**-**	**-**	**21.9**	**21.8**	**21.8**	**22.6**	**22.6**	**22.2**	**22.7**	**23.2**
% non-biogenic C in waste (1)/(2) * 100				**-**	**-**	**38.6**	**38.6**	**38.6**	**39.2**	**39.2**	**40.3**	**44.7**	**42.8**

7.5.2.1.2 Clinical waste

Data on clinical waste incinerated refers to data declared in registry maps of public and private hospital units, research centers and other units (e.g. piercings, tattoos). The quantities of clinical waste incinerated decreased strongly in the years 2000 as shown in the previous figure. Twenty-five incinerators were closed in recent years in Mainland Portugal, and only one remaining clinical waste incinerator is operating since 2004. Other clinical wastes receive alternative treatment or are sent abroad.

Figure 7-12 – Incineration of Clinical Waste: quantities incinerated (kton) and related emissions (kt CO2e).



Sources: APA; DGS.

The remaining clinical waste 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 850ºC to 950ºC. The resulting gases get into a second combustion chamber or thermal reactor where the gases suffer a new combustion reaching higher temperatures (1100ºC – 1200ºC) 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 following table.

Table 7.11 - Parameters considered: clinical waste.

	Unit	Clinical waste
C content of waste	%	40 a)
Fossil carbon in waste	% total C	25 a)

Note:

a) 2006 IPCC default (wet basis).

The oxidation factor in percentage of carbon input considered is 100% (IPCC default).

7.5.2.1.3 Industrial waste

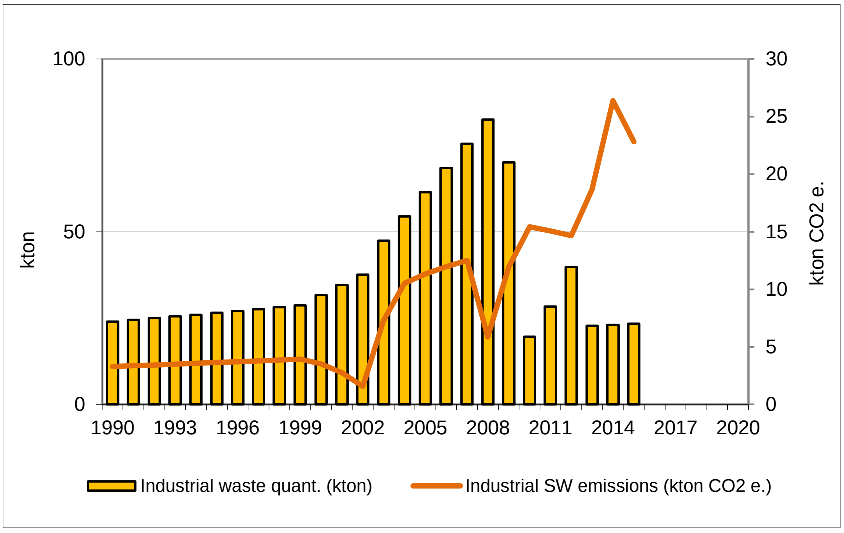
Data refer to incineration of industrial solid waste in industrial units collected in APA. Data for the years 1999, 2002 and 2003 refer to industrial units declarations. Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%.The figures for 2000 and 2001 are interpolated. Data from 2004 onwards refer to data collected under SIRER's MIRR. 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. 2015 data were estimated on the basis of GDP variation, taking in account the average of 2013-2014 data.

As previously mentioned, in 2012, the Statistical Office made a methodological change in the sectoral waste statistics, consisting in the harmonization of the sample used for these statistics with other statistical operations related to the Common Corporate Sector/ Business Sector, in which a set of statistical units, such as municipalities and other entities from public administrations, are excluded since 2012.

This revision is considered to have increased the quality of the waste statistics, as it was recognized to exist an overlap of content and double accounting between the sectoral and municipal statistics, due to a double registry, in the MRRU and MIRR, of waste operations by many operators.

In order to make the time series more consistent, the data from 2008 has been revised to exclude the information from entities not considered from 2012 onwards. This double accounting phenomenon is more difficult to quantify for previous years.

Figure 7-13 – 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.

Despite the reduction in quantities of industrial waste incinerated, the emissions raised in latest years due to the growth of the fossil carbon content fraction of waste incinerated.

Table 7.12 - Parameters considered.

	Unit	Industrial Solid Waste											
		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015
C content of w aste	%	0.14	0.14	0.15	0.19	0.19	0.23	0.37	0.33	0.28	0.37	0.43	0.40
Fraction of fossil carbon in w aste	% total C	0.20	0.20	0.14	0.21	0.05	0.16	0.55	0.41	0.32	0.57	0.71	0.64
Efficiency of combustion a)	%	100	100	100	100	100	100	100	100	100	100	100	100

Note:

a) 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. 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”.

7.5.2.2 Non-CO2 emissions

Non-CO2 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 CH4 emissions. The N2O 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.

$$\text{Non-}CO_2 \text{ emissions (Gg/yr)} = \Sigma_i \, (IW_i * EF_i) * 10^{-6}$$

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,2016) (Tier 1).

The CH4 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 CH4 emission factors for Stationary Combustion (Volume 2, Chapter 2).

For N2O 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	7.82	PROET study
CH4	g/GJ	30.00	2006 IPCC
N2O	kg/ton MSW	0.05	2006 IPCC
SOx	kg/ton MSW	0.02	Country measured data
NOx	kg/ton MSW	0.72	Country measured data
COVNM	kg/ton MSW	0.0059	2016 EEA Guidebook (Tier 1); Nielsen et al. (2010)
CO	kg/ton MSW	0.04	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)
CH4	g/GJ	30.00	2006 IPCC
N2O	kg/ton W	0.05	2006 IPCC
SOx	kg/ton W	1.09	2016 EEA Guidebook (Tier 2, Uncontroled)
NOx	kg/ton W	1.78	2016 EEA Guidebook (Tier 2, Uncontroled)
COVNM	kg/ton W	0.70	2016 EEA Guidebook (Tier 2, Uncontroled)
CO	kg/ton W	1.48	2016 EEA Guidebook (Tier 2, Uncontroled)

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)
CH4	g/GJ	30.00	2006 IPCC
N2O	kg/ton W	0.05	2006 IPCC
SOx	kg/ton W	0.09	2016 EEA Guidebook (Tier 2, Controled by various types of abatement)
NOx	kg/ton W	1.78	2016 EEA Guidebook (Tier 2, Uncontroled)
COVNM	kg/ton W	0.70	2016 EEA Guidebook (Tier 2, Uncontroled)
CO	kg/ton W	1.48	2016 EEA Guidebook (Tier 2, Uncontroled)

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
CH4	g/GJ	30.00	2006 IPCC
N2O	kg/ton MSW	0.10	Corinair 3rd version. Activity 090201. No NOx abatement
SOx	kg/ton MSW	0.05	2016 EEA Guidebook (Tier 1 default EF)
NOx	kg/ton MSW	0.87	2016 EEA Guidebook (Tier 1 default EF)
NMVOC	kg/ton MSW	7.40	2016 EEA Guidebook (Tier 1 default EF)
CO	kg/ton MSW	0.07	2016 EEA Guidebook (Tier 1 default EF)

7.5.3 Uncertainty and time-series consistency

7.5.3.1 Waste Incineration and Other

The accuracy of activity data considered for incineration of MSW was 5%. The uncertainty for CO2 emission factor was estimated on the basis of the value ranges proposed by the 2006 IPCC for the fossil carbon fraction in % of total carbon for the different fractions of waste incinerated. The estimated uncertainty for 2015 resulting from the application of equation 3.2 is 41%.

For clinical wastes an uncertainty of 30% for the years 1990 and 10% since 2006 was considered for the activity data. For industrial incineration (without energy recovery) an uncertainty of approx. 190% was estimated for the activity data for the early 1990s and 18% for the latest years.

The uncertainty of CO_2 emission factors was set as 10% for hospital wastes and 250% 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_2O and CH_4 emission factors a 100% uncertainty was considered.

7.5.4 Source-specific QA/QC and verification

7.5.4.1 Waste Incineration

7.5.4.1.1 General QC 1

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and data field relationships
- Check for consistency in data between source categories
- Verification of uncertainties estimates
- Undertake completeness checks
- Comparison of estimates to previous estimates.

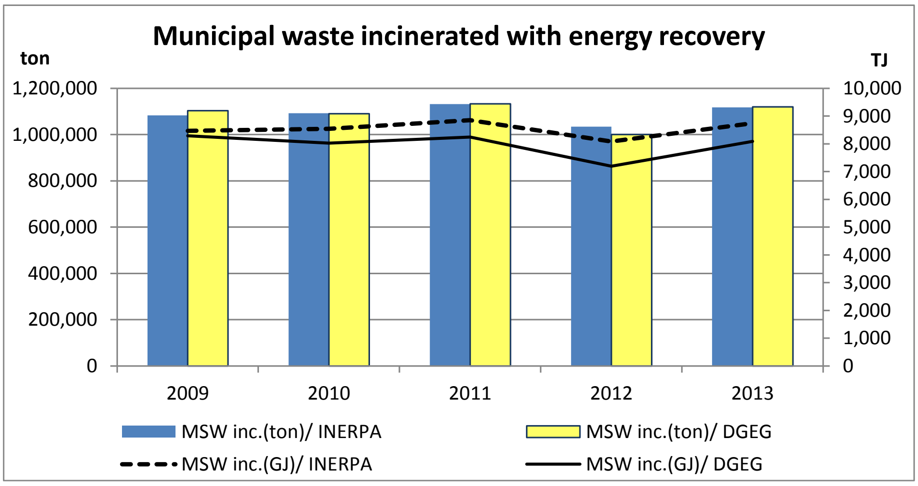
An analysis of emission trends and of IEF was performed to detect unusual trends in order to identify potential underlying problems.

7.5.4.1.2 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.

Figure 7-14 – Comparison between MSW incineration data used in the inventory and EB data.



7.5.5 Source-specific recalculations

The recalculations made refer to changes of activity data for the non-urban waste (sectoral waste) in result of the methodological revision made by INE in 2012. In this revision, the sample used for the statistics of sectoral waste was harmonized with the other statistical operations related to the Common Corporate Sector/ Business Sector, in which a set of statistical units, such as municipalities and other entities from public administrations, are excluded since 2012.

The revisions made are graphically represented in section 7.2. of this document.

7.5.6 Source-specific planned improvements

Not foreseen in the near future.

7.6 Wastewater Treatment and Discharge (CRF 5.D.)

7.6.1 Source category description

Wastewater treatment processes can produce CH4 when treated or disposed anaerobically, and N2O. CO2 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 (ktCO2e).

Gas/Source	1990	1995	2000	2005	2010	2013	2014	2015
CH4	**2,398.9**	**2,793.0**	**2,433.6**	**2,613.9**	**2,212.5**	**2,306.0**	**2,289.4**	**2,357.7**
Domestic wastewater	1,257.6	1,142.8	1,002.9	1,020.8	894.7	859.4	854.8	854.3
Industrial wastewater	1,141.3	1,650.1	1,430.7	1,593.1	1,317.8	1,446.7	1,434.6	1,503.4
N2O	**216.7**	**230.6**	**251.4**	**254.4**	**270.6**	**254.6**	**255.1**	**254.2**
Domestic and Industrial wastewater	216.7	230.6	251.4	254.4	270.6	254.6	255.1	254.2
Total	**2,615.7**	**3,023.6**	**2,685.0**	**2,868.3**	**2,483.1**	**2,560.6**	**2,544.5**	**2,611.9**

7.6.2 Methodological issues

7.6.2.1 Domestic Wastewater CH4 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).

CH4 emissions from urban wastewater handling were estimated using a methodology adapted from 2006 IPCC, which follows three basic steps:

7.6.2.1.1 Determination of the total amount of organic material originated in each wastewater handling system

The main factor determining the CH4 generation potential of wastewaster 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 organics in wastewater (TOW) is a function of human population and the amount of degradable organic component generated per person.

$$TOW_{dom} = P * D_{dom}$$

where:

TOW_{dom} - total domestic/commercial organics in wastewater in kg BOD/yr;

P - population in 1000 persons;

D_{dom} - domestic/commercial degradable organic component in kg BOD/1000 persons/yr.

The fraction of organics treated using wastewater handling system i (TOW_i) is calculated as a percentage of population served by wastewater handling system.

$$TOW_i = (TOW_{dom} * U_i) - S_i$$

where:

U_i – fraction of population served by each treatment/discharge pathway or system type i;

S_i – organic component removed as sludge in each treatment system type i.

7.6.2.1.2 Estimation of emission factors

The emission factor for each wastewater depends on the maximum CH_4 producing potential of each waste type (Bo) and a weighted average of CH_4 conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_o \times MCF_i$$

where:

EF_i - emission factor (kg CH_4 /kg DC) for wastewater handling system type i;

B_o - maximum methane producing capacity (kg CH_4/kg BOD);

MCF_i - methane correction factors of each wastewater system i.

Maximum CH4 producing capacity (B_o) is the maximum amount of CH_4 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.

7.6.2.1.3 Calculation of emissions

Emissions are a function of total organics generated and an emission factor characterizing the extent of CH_4 generation for each wastewater handling system. CH_4 that is recovered and flared or used for energy should be subtracted from total emissions, as it is not emitted into the atmosphere.

$$CH4\ emissions = \Sigma_i (TOW_i * EF_i) - R$$

where:

CH4 emissions - Total CH_4 emissions from wastewater handling in kg CH_4/yr;

TOW_i - total organics in wastewater for type i in kg BOD/yr. (Step 1);

EF_i - emission factor for waste type i in kg CH_4/kg DC (Step 2);

R - total amount of methane recovered or flared in kg CH_4.

7.6.2.1.4 Activity data and parameters

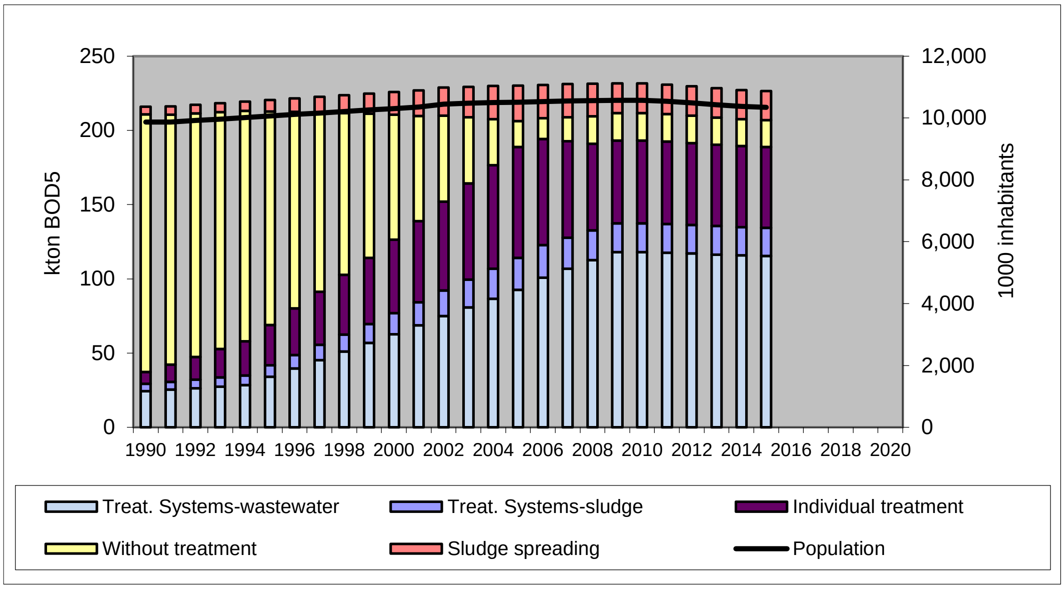
Total organic content of domestic sewage (TOW_{dom}) was determined multiplying the total population for each year by a per capita wastewater BOD_5 production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991, 2001 and 2011, and intermediate years have been estimated by interpolation. The BOD_5 factor considered was 60 g BOD_5/cap/day, which is the figure considered in the Council Directive 91/271/CEE, 21st May, 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 de Água e de Águas Residuais/ National survey on water supply and wastewater treatment 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_5 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 7-15 – Wastewater BOD produced according to handling systems (ton BOD_5) 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	2009-2015
		% 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
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
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
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
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
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
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
3.1-	**% Pop: colective 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
3.2-	**% 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
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
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
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
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
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
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
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
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
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
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
3.4.9-	Imhoff Tank	0.6	0.3	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.3	1.2	1.0	0.8
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
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
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
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
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

Source: APA

<u>Parameters: Bo and MCF</u> - The default IPCC (2006) value for Bo 0.6 kg CH4/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
			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 with anaerobic sludge digestion	c)	0.17	0.80	63%	37%	-
3.4.2-	Biodisks without anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.3-	Activated sludge with anaerobic sludge digestion	c)	0.17	0.80	63%	37%	-
3.4.4-	Activated sludge without anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.5-	Laguning, with anaerobic pond	d)	0.20	0.00	100%	-	-
3.4.6-	Laguning, without anaerobic pond		0.00	0.00	63%	-	37%
3.4.7-	Percolation beds with anaerobic sludge digestion	c)	0.17	0.80	63%	37%	-
3.4.8-	Percolation beds without anaerobic sludge digestion		0.10	0.00	63%	-	37%
3.4.9-	Imhoff Tank		0.80	0.00	100%	-	-
3.4.10-	Oxidation ponds with anaerobic sludge digestion	d)	0.20	0.00	63%	37%	-
3.4.11-	Oxidation ponds without anaerobic sludge digestion		0.00	0.00	63%	-	37%
3.4.12-	Other treatment with anaerobic sludge digestion	c)	0.17	0.80	63%	37%	-
3.4.13-	Other treatment without 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).

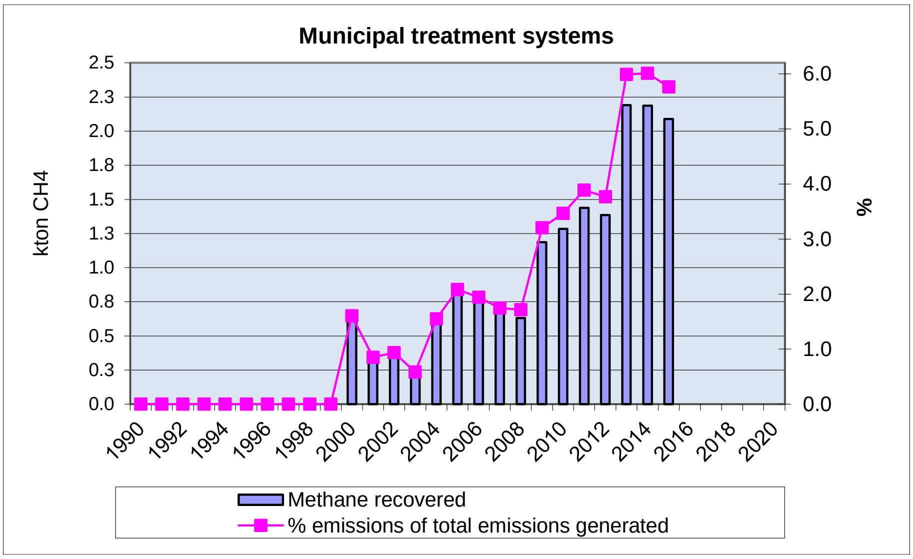
b) Expert judgment, assuming that half of the situations refer to bad conditions (stagnant sewer MCF=0.5), due to the Summer reduced flow in many sewerage, the high temperatures, and the stagnant conditions and eutrophication of inland waters in many places during that season. The other half of the situations 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 CH4: data on biogas gas recovered 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 equipment, etc. The quantities of biogas that are reported in Nm3 were converted into CH4 amounts, considering a density of 0.72 kg/m3 and a percentage of 60% of CH4 in biogas. 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 CH4 (Universidade de Coimbra, 2006).

Figure 7-16 - Methane recovery (Urban).



Source: Quantities based on data DGEG data.

7.6.2.2 Industrial Wastewater Handling CH4 Emissions

7.6.2.2.1 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:

$$Emi_{CH4} = \Sigma_j \{ (TOW_{(j)} – S_j) * \Sigma_h [WHS_{(j,h)} * MCF_{(h)}]- Rec_{CH4(j,h)}\}$$

where:

Emi_{CH4} – Total methane emissions from industrial wastewater handling, t CH_4/yr;

$TOW_{(j)}$ – Total Organic wastewater generated from industrial sector j, expressed in COD, t O_2/yr;

S_j – 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;

$Rec_{CH4(j,h)}$ – 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_4/yr.

7.6.2.2.2 Activity data

The organic wastewater load (TOW) was estimated using statistical data on industrial production (Ind_{PROD}, ton product/yr) multiplied by pollution coefficients (Pol_{COEF}, kg O_2/ton product).

$$TOW = Ind_{PROD} * Pol_{COEF}$$

The pollution coefficients that were used 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[129]. 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.

[129] -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 (m3/PU)	BOD (kg/PU)	COD (kg/PU)
Slaughter House	Meat & Poultry	ton	6	18	27
Slaughter House, swine	Meat & Poultry	ton	6	18	42
Slaughter House, Poultry	Meat & Poultry	ton	9	6	13
Meat Packing	Meat & Poultry	ton	10	20	30
Milk processing	Dairy Products	m3	1	1	2
Cheese	Dairy Products	m3 milk	8	13	20
Other dairy products	Dairy Products	m3 milk	5	7	10
Fruit and vegetables conservat	Vegetables, Fruits & Juices	ton	15	15	27
Tomato juice	Vegetables, Fruits & Juices	ton	100	19	32
Fruit Juices	Vegetables, Fruits & Juices	ton	9	45	77
Fish processing and canning	Fish Processing	ton	35	18	35
Olive oil production	-	ton olives	1	15	45
Olive oil processing	-	ton	6	1	1
Edible oils	Vegetable Oils	ton	3	13	19
Margarine	Dairy Products	ton	25	3	8
Grains milling and processing	Starch Production	ton	3	5	9
Sugar processing	Sugar Refining	ton	8	2	4
Yeast	-	ton	120	600	1,080
Ethanol	Alcohol Refining	m3	17	328	1,192
Spirits Distillation	Wine & Vinegar	m3	8	95	218
Wine Cellars	Wine & Vinegar	ton grapes	2	5	8
Beer	Beer & Malt	m3	5	4	9
Mineral water and similars	Vegetables, Fruits & Juices	ton	8	6	10
Wool production	Textiles (Natural)	ton	44	89	366
Wool processing	Textiles (Natural)	ton	537	87	347
Synthetic fibres processing	Textiles (Natural)	ton	155	155	268
Artificial fibres processing	Textiles (Natural)	ton	42	30	52
Cotton fibres processing	Textiles (Natural)	ton	317	155	268
Leather industry	-	ton	85	85	213
Cork processing	-	ton	1	2	8
Cork granulation	-	m3	1	83	1,104
Kraft pulping	Pulp & Paper (Combined)	ton	140	28	158
Acid sulphite pulping	Pulp & Paper (Combined)	ton	270	283	1,050
Kraft paper	Pulp & Paper (Combined)	ton	14	1	3
Wafer board and Strand board	-	ton	1	14	43
Chorine and alkalis	-	ton ClNa	28	0	39
Inorganic acids	-	ton	100	0	50
Cyclic Hydrocarbons	Organic Chemicals	ton	190	285	570
Aliphatic Hydrocarbons	Organic Chemicals	ton	190	285	570
Synthetic fertilizers	-	ton	15	15	38
Pesticides	Drugs & Medicines	ton	4	23	30
Polymers	Plastics & Resins	ton	15	15	45
Synthetic rubber	Plastics & Resins	ton	15	15	45
Artificial fibres production	Plastics & Resins	ton	300	150	450
Polyester fibres production	Plastics & Resins	ton	348	6	16
Acrylic fibres production	Plastics & Resins	ton	65	50	121
Paints, varnishes and lacquers	Paints	ton	0	1	9
Pharmaceutical products	-	employe	0	0	14
Soaps	Soap & Detergents	ton	4	6	12
Detergents	Soap & Detergents	ton	3	1	2
Petroleum refining	Petroleum Refineries	ton	2	1	2

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 2014. 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 cannot be delivered in this report, because of confidential restrains existing in certain sectors.

For the construction of the time series the following methodology was used:

- Identification of the industrial sectors which represented 95% of the total wastewater CH_4 emissions in the Initial Report. From a total of 51 industrial sectors 15 represent 95% of the total CH_4 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_4 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 establish from the DGEG's Energy Balance, which data is available annually from 1990 till 2015;

- 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 2015, 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[130]. The checking of the time series was based on graph plotting of the data, and basically the aim was to detected unexpected sudden changes in the magnitude of the time series from 1991 till 1992, when IAIT was changed to IAPI. In some situations the beginning years when IAPI was started had to be discarded, because a sudden and temporary drop from IAIT values was observable and after some years they rise again and continue with a trend compatible with that that existed in IAIT. It was assumed that an adaptation period to the new industrial survey lead to a temporary underestimation of industrial production statistics.

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			1990-2015	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2015	
Slaughter House, Poultry			1990-2015	Broilers, Turkeys, ducks, quails, ostrich, guinea-fowl, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200	-	
Milk processing	3112		1994-2015	
Cheese	3112	15510	-	
Other dairy products	3112		1994-2015	Cream, yugurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2015	
Tomato juice			1994-2015	
Fruit Juices	3131+3132		1994-2015	
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			1993-2015	
Ethanol	313110	159101070; 1592011	-	
Spirits Distillation	3131+3132	1591010-159101070+1592012	-	
Wine Cellars	3131+3132	15930; 15950	2001-2015	
Beer	3133	1596010	-	
Mineral water and similars			1993-2015	

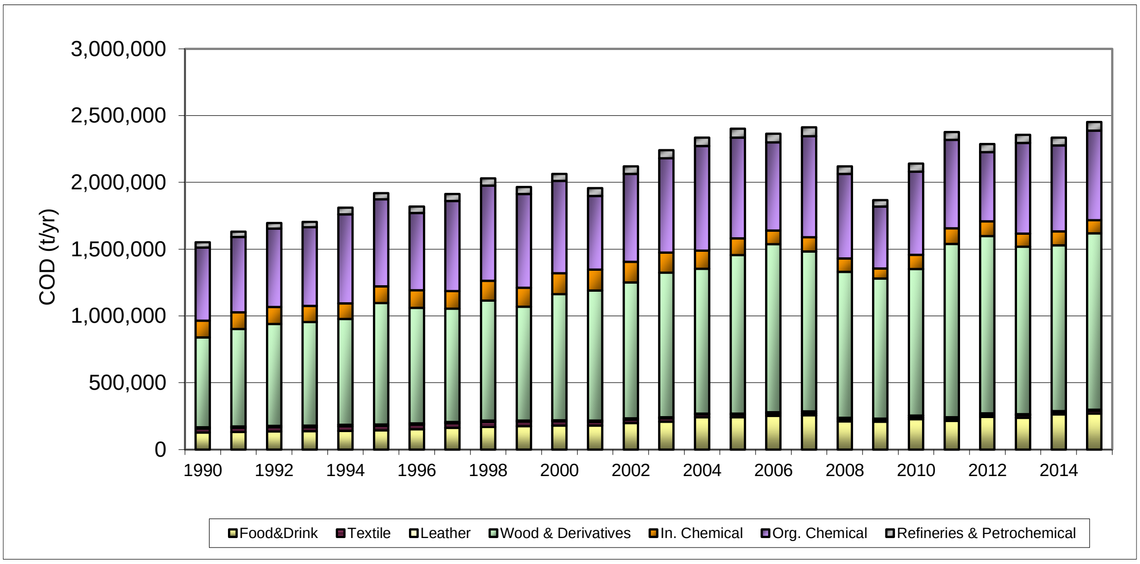
[130] It must be stressed though, that all information sources were produced by the National Statistical Institute (INE). Only methodological procedures for data collection change according to years.

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	-	
Chorine and alkalis		241301111; 2413015; 2413022	-	
Inorganic acids		2413014-241301453- 241301475- 241301477	-	
Cyclic Hydrocarbons		2414312; 2414314	-	
Aliphatic Hydrocarbons		2414311	-	
Synthetic fertilizers		2415	-	Original units is kg N, kg P2O5 and K2O and were converted to ton of fertilizer
Pesticides	3512	242	-	
Polymers	351312	24160-2416058	-	
Synthetic rubber		2417	-	
Artificial fibres production		2470023; 247003070	-	
Polyester fibres production		247001130; 247001315; 247001350	-	
Acrylic fibres production		247001150	-	
Paints, varnishes and lacquers	3521	24301	-	
Pharmaceutical products			1998-2015	
Soaps		2451131	-	
detergents		2451120/32	-	
Petroleum refining			-	Energy Balance (DGGE): 1990-2015

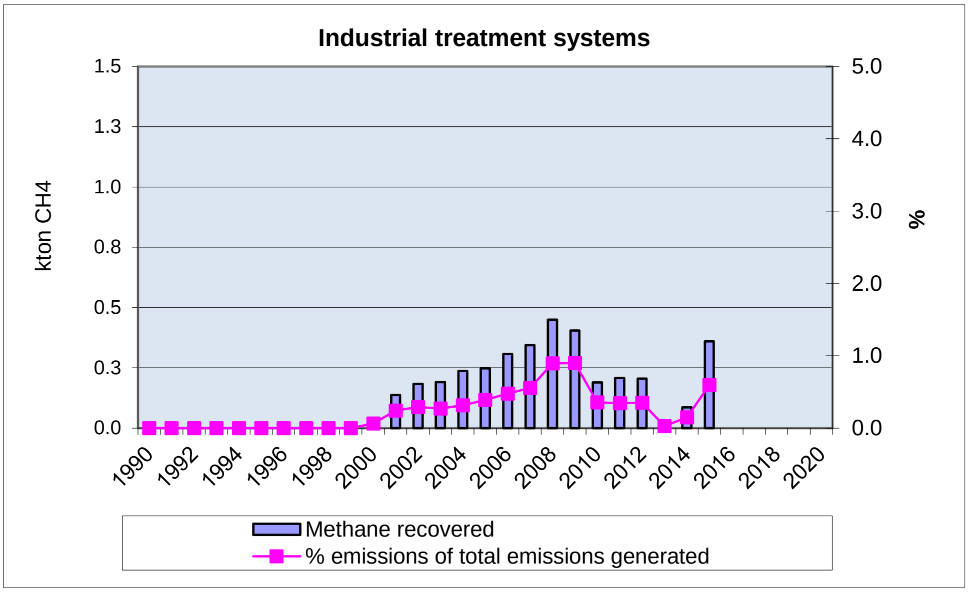
Total wastewater load aggregated per industrial group is presented in Figure7.7-17 below, from where it is evident the continuous growth of discharge from 1990 to 2007, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry. In later years the situation stabilized or even decreased in some years.

Figure7-17 - Industrial Wastewater load, expressed in COD, from major groups of industrial activity.



Biogas generated in sludge treatment systems is recovered 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_4, considering a density of 0.72 kg/m3 and a percentage of 60% of CH_4 in biogas. This figure is based on the assumption that wastewater treatment uses anaerobic digestion and that the biogas produced has a content of 60 to 70% of CH4 (Universidade de Coimbra, 2006).

Figure 7-18 – Methane recovery (Industry).



Source: Quantities based on DGEG data.

7.6.2.2.3 Emission Factors

7.6.2.2.3.1 Wastewater handling systems

As consequence of the fact that there was no available comprehensive information about the existence of each treatment system, the necessary information to determine the %s 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*[131] and a *Specific Plan of Elaboration*[132]. Eighteen sectors were involved: textile; dairy; stone quarrying and processing; vegetable oils; chemical industry; graphics and paper transformation; shoe making; rubber; ceramics; cork; wood and wood products; paper and card; electric and electronic equipment production; naval industry; crop protection industry; paint and varnishes, glues and adhesives and tomato processing. There was a specific agreement with the sector of extraction of olive oil;

- Information for individual plants or industrial associations, such as the paper pulp production industry and the oil refineries;

- Information collected from the Environmental Permits attributed to operators of installations covered by the 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;

[131] Caracterização da Situação Ambiental*, in the original Portuguese nomenclature.*

[132] Plano Específico de Adaptação*, in the original Portuguese nomenclature.*

- Secondary treatment (aerobic), well managed;
- Secondary treatment (anaerobic), no CH4 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 2015.

Information from the Environmental Permits has been collected in latest years in order to improve the characterization of the wastewater treatment systems, in particular for the industrial sectors for which no information was available (unknown treatment). Despite this effort, the information is still incomplete and refer very often to expert assumptions, so this work will continue and should be further developed in the future.

The % of total industrial load, expressed in COD, for which the treatment system and final destination of effluents was unknown, varies from 1990 to 2015 between 49% and 40% as presented in the next table.

Table 7.23 - Fraction of industrial wastewater by wastewater handling system (% of total industrial load expressed as COD).

Wastewater Handling System		1990	1995	2000	2005	2010	2013	2014	2015
No treatment, discharge in river or soil	%	11.7	14.3	10.0	11.8	10.5	11.7	11.8	12.2
Primary	%	5.7	5.1	5.3	6.4	1.0	0.8	0.9	0.8
Secondary treatment: Aerobic, well managed	%	17.1	14.2	15.0	14.1	25.0	23.9	24.1	23.8
Secondary treatment: Aerobic, not well managed	%	2.6	2.3	2.2	2.8	2.5	2.1	2.1	2.1
Secondary treatment: Anaerobic, no CH4 recovery	%	0.0	0.0	0.1	1.1	1.4	1.3	1.3	1.2
Septic Tank	%	4.8	6.4	5.8	0.0	0.0	0.0	0.0	0.0
Municipal Sewer system, treatment with Municipal Waste Water	%	9.1	12.3	14.2	17.1	18.0	18.8	19.3	19.5
Unknown	%	49.0	45.4	47.4	46.7	41.6	41.4	40.6	40.4
Total	**%**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

7.6.2.2.3.2 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 CH4/kg COD, the default value in the Good Practice Guidance from IPCC (2000).

7.6.2.2.3.3 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, w ell managed	0	IPCC (2006). Table 6.8 Aerobic Treatment Plant. Well managed
Secondary treatment: Aerobic, not w ell managed	30	IPCC (2006). Table 6.8 Aerobic Treatment Plant. Not w ell managed
Secondary treatment: Anaerobic, no CH4 recovery	80	IPCC (2006). Table 6.8 Anaerobic digester/reactor. CH4 capture not considered
Septic Tank	50	IPCC (2006). Table 6.3 Septic system
Treatment w ith Municipal Waste Water	16-18	Weighted average for the domestic w astew ater system w hen there is any form of treatment.
Unknow n	10-14	Weighted average based on MCF values for industrial treatment situations and respective organic load

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 of the urban sector that was explained in previous chapters, have decreased from 18% in 1990 to 16% in 2015. For the unknown situations an average weighted MCF was calculated based on all known industrial treatment situations.. Values also change over time, from 12% in 1990, 14% in 1995, and 10% in 2015

7.6.2.2.4 Comparison of the Country Specific Methodology and the IPCC defaults

In order to evaluate if Portugal was over-estimating or under-estimating emissions in the base year, the CS Pollutant Coefficients (PC) used in submission 2006 were compared with the Pollutant Coefficients proposed by the IPCC GP (table 5.4 of the Good Practice). For the industrial sectors identified in Portugal, and whenever possible[133], the comparison of the PC of Cartaxo el at (1985) (named CS) were compared with the equivalent IPCC in the next table[134]:

[133] The level of detail of the IPCC Pollutant Coefficients is not so detailed as the CS data set.

[134] 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 el 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, sw ine	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 w ater 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	-
Chorine and alkalis	ton ClNa	39.0	NA	-
Inorganic acids	ton	50.0	NA	-
Cyclic Hydrocarbons	ton	570.0	201.0	0.35
Aliphatic Hydrocarbons	ton	570.0	201.0	0.35
Synthetic fertilizers	ton	37.5	NA	-
Pesticides	ton	30.0	NA	-
Polymers	ton	45.0	2.2	0.05
Synthetic rubber	ton	45.0	2.2	0.05
Artificial fibres production	ton	450.0	2.2	0.00
Polyester fibres production	ton	16.3	2.2	0.14
Acrylic fibres production	ton	121.1	2.2	0.02
Paints, varnishes and lacquers	ton	9.2	30.3	3.29
Pharmaceutical products	employe	13.5	NA	-
Soaps	ton	12.0	2.6	0.21
detergents	ton	1.7	2.6	1.50
Petroleum refining	ton	1.5	0.6	0.40

Departing from the revised COD estimates, new estimates of COD were made using the Pollution Coefficients that are IPCC default (whenever available) and emission estimates rebuilt. The results are presented in the next two figures.

Figure 7-19 - Comparison between COD estimates using CS PC and IPCC defaults.

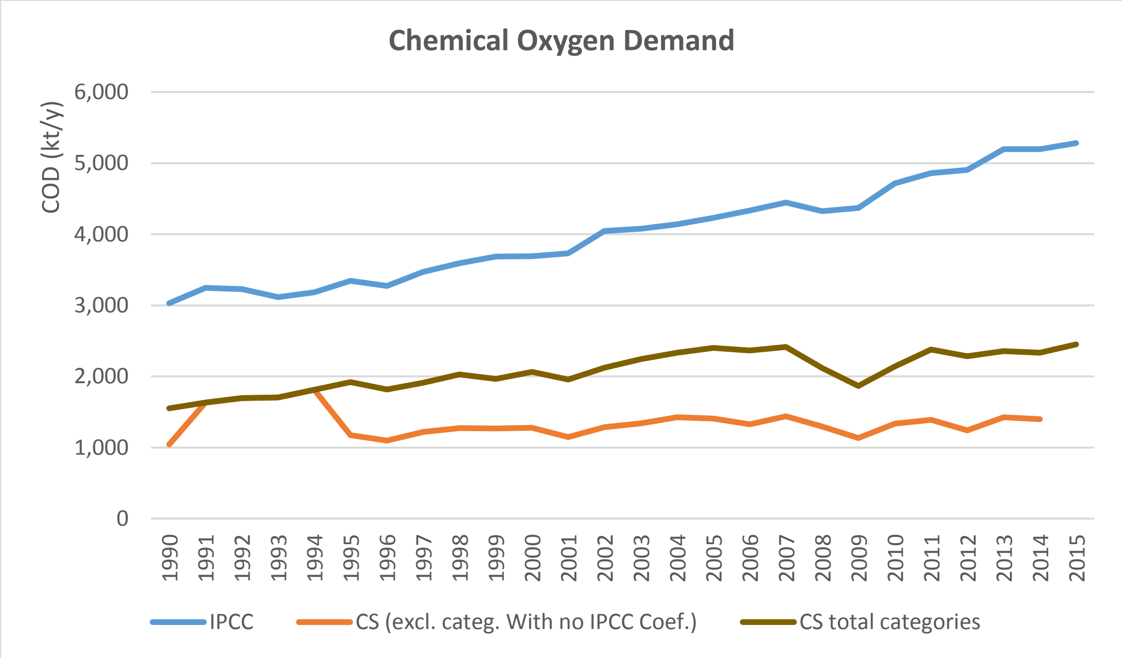
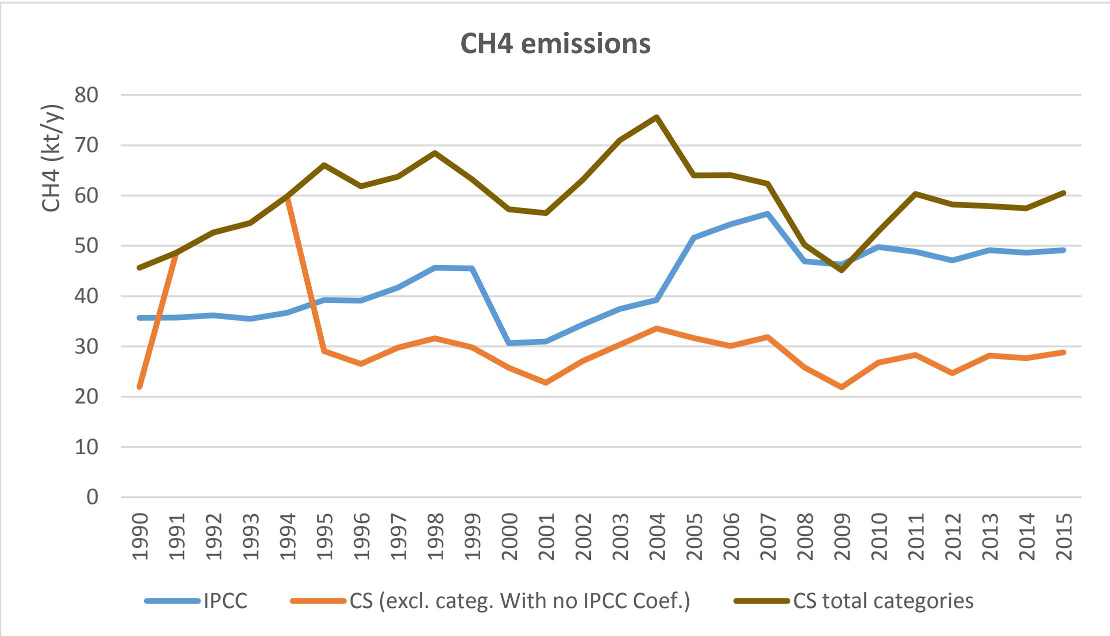


Figure 7-20 - Comparison between CH4 emission estimates using CS PC and IPCC defaults.



When considering the same categories, i.e. categories where both IPCC and CS pollution coefficient are available, the comparison of country specific coeficients to IPCC defaults indicates that estimates made by INERPA are probably under-estimating AD and emissions in the base year. For the most recent years, the comparison of the same categories shows a potentially under-estimating of national emissions. However, regarding that national coeficients refer to an old study and probably to less efficient production processes, and also the fact that national estimates consider a broader universe of industries, we can assume that the national inventory does not under evaluate the emissions of this sector.

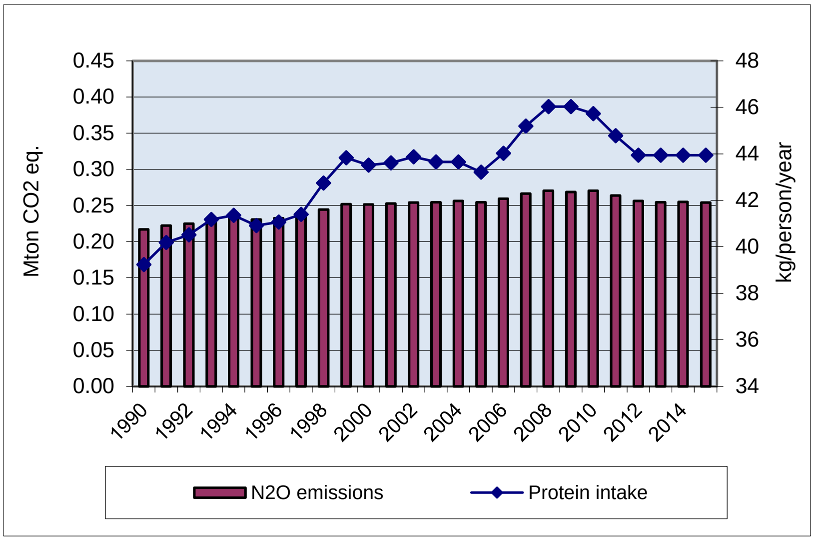
7.6.2.3 N2O emissions from wastewater

Sewage can be disposed on land or discharged into aquatic environments (e.g. rivers and estuaries), either directly without treatment or after treatment in septic systems or wastewater treatment facilities. N2O can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into aquatic environments. N2O can be generated during all these stages through nitrification/denitrification of the nitrogen in faeces, urine and other liquid wastes, which are typically in the form of urea and proteins. In general, temperature, pH, BOD, and nitrogen concentration influence N_2O 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 N2O 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 7-21 – N2O emissions from human sewage disposed into waterways and per capita protein intake.



Source: Protein intake: INE data; 2013-2015: data refer to 2012.

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7.6.2.3.1 Methodology

Emissions of N2O from 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), the non-consumedprotein and the industrial and commercial sources discharged into the sewer system.

N2O emissions from domestic wastewater were estimated as follows:

$$N2O_{(S)} = (P * Protein * Frac_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SEW} * EF \times 44/28$$

where:

$N2O_{(s)}$ - N_2O emissions from human sewage (kg N_2O-N/yr);

P - number of inhabitants in country;

Protein - annual per capita protein intake (kg/person/yr);

F_{NPR} - fraction of nitrogen in protein (kg N/kg protein);

$F_{NON-CON}$ - factor for non-consumed protein added to the wastewater (1.2);

$F_{IND-COM}$ - factor for industrial and commercial co-discharged protein into the sewer system (1.25);

N_{SEW} - nitrogen in sewage sludge applied to agriculture soils (please see CRF 4.D chapter);

EF - emission factor for N2O emissions from discharged wastewater (kg N_2O-N/kg sewage-N produced);

44/28 is the molecular weight ratio of N_2O to N_2.

7.6.2.3.2 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 and 2014 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, representing an intermediate value between the IPCC proposed value for developed countries using garbage disposals (1.4) and developing countries (1.1).

Table 7.26 - Data and parameters used calculation of N2O 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*
	2014	*43.9*
	2015	*43.9*
Fraction of nitrogen in protein	16%	2006 IPCC default
Fraction of non-consumed	20%	Expert judgement
Emission factor	0.005 kg N2O-N/kg N	2006 IPCC default

Note:

2013-2015: data refer to 2012.

7.6.3 Uncertainty and time-series consistency

7.6.3.1 Wastewater Handling

For urban waste water treatment the activity data, expressed in organic load to wastewater systems, was estimated from population, BOD per capita production, and the degree of utilisation of each type of treatment. The error associated with these variables needs to be incorporated in the determination of the final uncertainty value. Assuming the default uncertainties proposed in 2006 IPCC, 5% for human population and 30% for BOD per capita, and 50% for the degree of utilisation of each type of treatment, a final 59% error was set for this activity.

Concerning the methane emission factor, the uncertainty of this parameter includes an error for the Maximum Methane Producing Capacity (Bo), for which the GPG default of 30% was used, and the error determination in the fraction of water treated anaerobically (MCF). For urban water the uncertainty in this last fraction was estimated to vary from 47% in 1990 to as 25% in 2015, considering the percentage of individual septic tanks and the lack of knowledge of in which conditions they operate.

As regards domestic wastewater handling N2O emissions, the activity data (N load in effluent) was estimated from the population, the protein consumption per capita, the fraction of N in protein, the factor to adjust for non-consumed protein and the quantity of N in sludge subtracted to the effluent. The error associated with these variables were set from the default range values or uncertainties proposed in 2006 IPCC: 5% for human population, 10% for the protein intake, 6.3%

for the fraction of N in protein, 9% for the factor to adjust for non-consumed protein, and 20% for the factor related to industrial and commercial co-discharged protein into the sewer system. The quantity of N in sludge subtracted to the effluent is considered to be very uncertain due to scarce data on sludge amounts produced and the respective content in N, and a value of 100% was considered. The equation 3.2 was applied to estimate the overall error for the activity data which is estimated as 25% in 2015. The uncertainty considered for the emission factor (kg N2O-N/kg-N) was set from the default range values proposed in 2006 IPCC and is approx. 2500%.

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 34 and 46%, according to years.

For industrial wastewater treatment, also the uncertainty in the methane emission factor also changes with time and considers:

- the uncertainty in Bo, the maximum methane generation potential, is 30% according to the GP;
- the error of the allocation of each specific treatment system, established from the % 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 for the methane emission factor varies in time from 22% to 37%.

7.6.4 Source-specific QA/QC and verification

7.6.4.1 Wastewater Handling

7.6.4.1.1 General QC 1

General QC 1 procedures were applied following the guidance from the IPCC GPG (IPCC 2000, Table 8.1) in particular:

- Checks on data units, calculation procedures, and data field relationships;
- Check for consistency in data between source categories;

- Verification of uncertainties estimates;
- Undertake completeness checks;
- Comparison of estimates to previous estimates.

7.6.4.1.2 QC2 procedures

Country-specific emission factors, in particular for industrial wastewater sector, were compared with IPCC default values. Domestic wastewater emissions were also estimated using the IPCC default method.

National emission rates and implied emissions factors (IEF) were compared with 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.

7.6.5 Source-specific recalculations

The recalculations made refer to:

- Wastewater treatment and discharge (CRF 5D):
  - N2O emissions from wastewater (CRF 5D1 and CRF 5D2)
    1. Emissions from industrial sources previously estimated on the basis of an emission factor (0.02 kg N2O/kg inhab-eq) from EMEP/CORINAIR (EEA, 2002) are now calculated together with domestic wastewater using the default factor (1.25) for industrial and commercial co-discharged protein into the sewer system (FIND-COM) proposed by 2006 IPCC;
    2. Correction of a calculation error in the previous estimates: instead of subtracting N from wastewater effluent (equation 6.8) we were subtracting the N2O emissions from sludge removal in equation 6.7 and consequentely the emissions were underestimated.
  - CH4 emissions from industrial wastewater (CRF 5D2)

    Several revisions have been made for this category:
    1. Industrial treatment in septic tanks was excluded from 2005 onwards based on the knowledge that this type of treatment does not exist nowadays; treatment of IWW in textile and wood industry was not considered for the whole time series;
    2. MCF revision for situations where industrial treatment type is unknown: previous values, which referred to the MCF weighted averages for all domestic wastewater treatment types (values varying from 24% to 17%), were replaced by new figures referring to MCF weighted averages for industrial wastewater treatment types (values ranging from 10% to 14%);
    3. Compilation error related to anaerobic treatment.

7.6.6 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).

7.7 Biogas burning without energy recovery (CRF 5.E.)

7.7.1 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_2 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_4 and N_2O 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 2015, 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.

CH4 recovered in flares and valorised for energy purposes is estimated on the basis of average biogas flows (continuous measurement) and the number of hours of burning. The concentration of CH4 in biogas used in the estimates of the CH4 quantities refer to monitoring plans (quaterly measurements) measuring the biogas quality (generally CH4, CO2, O2, N2, H2S) at the entrance of the flares or the biogas energy recovery system.

7.7.2 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.

Quantities of landfill gas and biogas combusted			**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	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	2,335,114	2,575,738	2,354,043
	Flaring b)	GJ	-	-	-	-	-	266,085	440,544	420,404	416,178	356,085	287,131	60,069	ot available	ot available	ot available	30,104
Emission factors																		
	CO2	kg/GJ	54.6															
	CH4	g/GJ	1															
	N2O	g/GJ	0.1															
	NOx	g/GJ	74															
	NMVOC	g/GJ	23															
	CO	g/GJ	29															
	SOx	g/GJ	0.67															
Emissions with energy recovery (CRF 1A1a)			**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	CO2 c)	kton	2.1	1.5	1.6	1.3	8.0	18.7	17.3	29.3	43.0	52.9	68.9	91.1	112.0	127.5	140.6	128.5
	CH4	ton	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.6	0.8	0.9	1.1	1.7	2.2	2.6	2.9	3.0
	N2O	ton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3
Emissions without energy recovery (CRF 5E)			**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	CO2 d)	kton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CH4	ton	-	-	-	-	-	0.266	0.441	0.420	0.416	0.356	0.287	0.060	0.000	0.000	0.000	0.030
	N2O	ton	-	-	-	-	-	0.027	0.044	0.042	0.042	0.036	0.029	0.006	0.000	0.000	0.000	0.003

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, CO2 emissions from source categories “Solid waste disposal on land and Waste incineration” should only be included if they derive from non-biological or inorganic waste sources.

7.7.3 Uncertainty and time-series consistency

7.7.3.1 Landfill gas and other biogas burning

CH4 and N2O 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 5 %, which is in accordance to the values considered for LPS data in category 1A1a (biogas burning with energy recovery).

The uncertainty associated with CH4 and N2O emission factors was set to 150 % and 1000 %, respectively.

7.7.4 Source-specific QA/QC and verification

General CQ1 procedures were applied.

7.7.5 Source-specific recalculations

Update of EF for biogas combustion based on the 2006 IPCC and 2016 Guidebook. Being a minor source this update resulted in insignificant revision.

7.7.6 Source-specific planned improvements

Not foreseen.

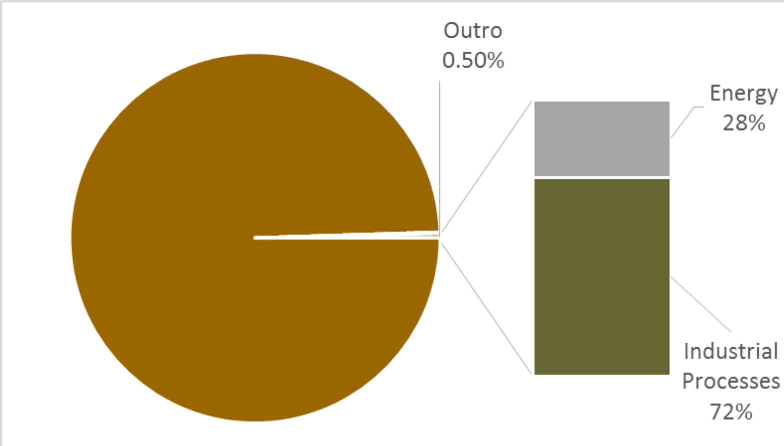
8 OTHER (CRF 6)

Portugal does not report any emissions under the Other sector.

9 INDIRECT CO2 AND NITROUS OXIDE EMISSIONS

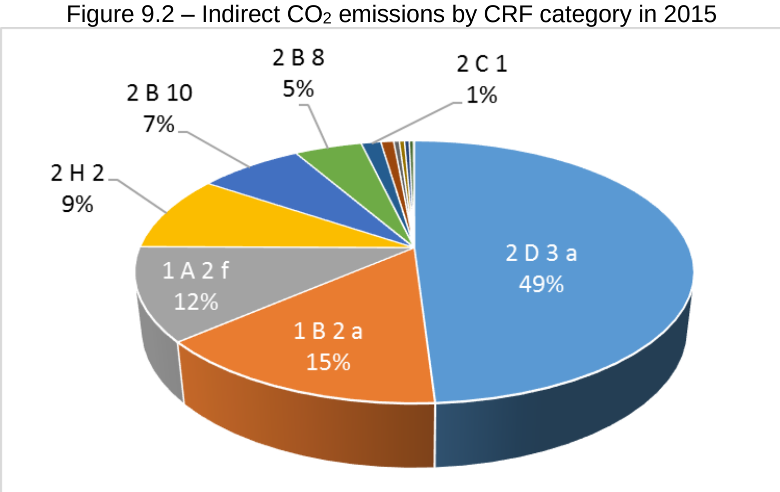
Indirect CO_2 emissions represent 342 kt in 2015 (considering also solvent use and road paving emissions) and 0.50% of total emissions, decreasing 9% from year 1990. The two most relevant sectors are Industrial Processes (CRF 2) and Energy (CRF 1), with respectively, 72% and 28% of indirect CO_2 emissions.

Figure 9.1 – Indirect CO_2 emissions in 2015



In 2015, the most relevant category to indirect CO_2 emissions is 2D3a, representing 49% of the total (entirely NMVOC emissions), followed by 1B2a (15% of indirect CO_2 emissions, from which 81% NMVOC, 17% CH_4 and 2% CO), 1A2f (12% of indirect CO_2 emissions, from which 56% NMVOC; 37% CO; 7% CH_4) and 2H2 (9% of indirect CO_2 emissions, entirely associated to NMVOC emissions).

Figure 9.2 – Indirect CO_2 emissions by CRF category in 2015



In order to ensure consistency with Portugal reporting under the first commitment period of the Kyoto Protocol, the indirect CO_2 emissions from solvent use and road paving with asphalt are reported in category 2D3a and 2D3b of the CRF tables. For other sources of indirect CO_2, the emissions are reported in CRF Table 6.

In the calculation of indirect CO_2 emissions, only fossil carbon has been considered.

Indirect CO_2 emissions due to atmospheric oxidation of NMVOC, CH_4 and CO emissions are calculated using the equation below:

$$Emissions_{CO_2} = \left[Emissions_{NMVOC} \times 0.60 \times \frac{44}{12}\right] + \left[Emissions_{CH_4} \times \frac{44}{16}\right] + \left[Emissions_{CO} \times \frac{44}{28}\right]$$

According to the information provided by box 7.2 of Volume 1: General Guidance and Reporting of 2006 IPCC Guidelines, the carbon fraction of NMVOC is assumed to be 60% by mass.

CH_4 estimates, methodologies and emission factors are presented in this document.

NMVOC and CO emissions are reported under the United Nations Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution and the European Union National Emissions Ceilings Directive. Methodologies and emission factors used in the estimates are presented in the Portuguese Informative Inventory Report.

In next table it is possible to check which CRF categories contribute to CO_2 indirect emissions and where these emissions are reported (Table 6 or in the sectorial tables).

Table 9.1 – CRF categories and description of CO_2 Indirect emissions.

CRF category	Description	Indirect CO_2	NMVOC	CH_4	CO	Reported in:
1.A.1.b	Petroleum Refining	√	√	√	√	Table 6
1.A.1.c.i	Manufacture of Solid Fuels	√	√	√	√	Table 6
1.A.2.a	Iron and Steel	√	√	√	√	Table 6
1.A.2.f	Non-metallic Minerals	√	√	√	√	Table 6
1.B.1.a.1.i	Underground Mines – Mining Activities	√	√	√		Table 6
1.B.1.a.1.ii	Underground Mines – Post-Mining Activities	√		√		Table 6
1.B.1.a.1.iii	Abandoned Underground Mines	√		√		Table 6
1.B.2.a.3	Fugitive Emissions – Oil – Transport	√	√	√		Table 6
1.B.2.a.4	Fugitive Emissions – Oil – Refining/Storage	√	√	√	√	Table 6
1.B.2.a.5	Fugitive Emissions – Oil – Distribution of Oil Products	√	√			Table 6
1.B.2.c.2.i	Flaring - Oil	√	√	√	√	Table 6
2.B.1	Ammonia	√	√			Table 6
2.B.8.b	Ethylene	√	√	√		Table 6
2.B.8.c	Vinylchloride Monomer	√	√			Table 6
2.B.8.g.i	Low-Density Polyethylene	√	√			Table 6
2.B.8.g.ii	High-Density Polyethylene	√	√			Table 6

CRF category	Description	Indirect CO_2	NMVOC	CH_4	CO	Reported in:
2.B.8.g.iii	Polypropylene	√	√			Table 6
2.B.8.g.iv	Polystyrene	√	√			Table 6
2.B.8.g.v	Formaldehyde	√	√			Table 6
2.B.8.g.vi	Phthalic Anhydride	√	√		√	Table 6
2.B.8.g.vii	Polyamide Fiber	√	√			Table 6
2.B.8.g.viii	Polyester Fiber	√	√			Table 6
2.B.8.g.ix	Polystyrene Fiber	√	√			Table 6
2.B.8.g.x	Polypropylene Fiber	√	√			Table 6
2.B.8.g.xi	Polyvinylchloride Fiber	√	√			Table 6
2.B.8.g.xii	Acrylic Fiber	√	√			Table 6
2.B.8.g.xiii	Acrylonitrile Fiber	√	√			Table 6
2.B.8.g.xiv	Polyvinylchloride	√	√			Table 6
2.B.10.b	Ammonium Sulphate	√	√			Table 6
2.C.1.a	Steel	√	√	√	√	Table 6
2.C.1.b	Pig Iron	√			√	Table 6
2.C.1.d	Sinter	√	√	√	√	Table 6
2.D.3.a	**Solvent Use**	**√**	**√**			**CRF 2.D.3.a**
2.D.3.b	**Road Paving with Asphalt**	**√**	**√**			**CRF 2.D.3.b**
2.H.2	Food and Beverages	√	√			Table 6
2.H.3.a	Chipboard Production	√	√			Table 6

10 RECALCULATIONS AND IMPROVEMENTS

This section presents an overview of responses to the UNFCCC and information on recalculations made in the 2017 submission. The recalculations made result mostly from recommendations issued from last UNFCCC and EU reviews and updates of activity data.

10.1 Overview of the Review Processes

Next table presents the status of implementation of adjustment and recommendations issued from the 2016 country UNFCCC and EU review processes. Despite the fact that no UNFCCC review report is available, the table includes already implemented issues from the provisional findings list.

Table 10.1 – Reporting on implementation of UNFCCC and EU recommendations and adjustments.

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
1A - Energy, Fuel Combustion	The ERT identified that the CO_2 EF used for city gas (57.1 t/TJ) was higher than the default value from the 2006 IPCC GL (44.4 t/TJ – gas works gas).	UNFCCC review - Saturday Paper/Attachment C - Energy	The EF used for "City Gas" Combustion was changed to "Gas Works Gas" (instead the "Refinery Gas", which was used before). The revised estimate were included in the official Portuguese 2016 submission to UNFCCC (submited in december 22nd).	3.3.2.3 Emission Factors 3.3.4.2.4 Emission Factors 3.3.4.3.4 Emission Factors
1A3a - Energy, Fuel Combustion, Domestic Aviation	The ERT noted the jet kerosene consumption in civil aviation is significantly higher in 1990 than in the following years. Also, this is reflected in the domestic share of aviation, which for 1990 is 13.5 %, while the average for the five years following is 11.1 %.	UNFCCC review - Saturday Paper/Attachment C - Energy	The values of jet kerosene consumption were corrected, as well as energy and emissions values in civil aviation. The revised estimate were included in the official Portuguese 2016 submission to UNFCCC (submited in december 22nd).	3.2.1 International aviation bunkers 3.3.3.1 Civil Aviation
1A - Energy, Fuel Combustion	The ERT identified that Portugal calculates CO2 emissions from fuel combustion using the default oxidation factors from the 1996 IPCC guidelines, instead of the one in the 2006 IPCC GL. The ERT could not determine based on the information provided in the NIR whether Portugal had included correctly the indirect CO2 emissions in the CRF (Table 6) associated with energy combustion.	UNFCCC review - Saturday Paper/Attachment C - Energy	CO2 estimates were revised using the oxidation factor of 1 in all cases where the default CO2 EFs from the 2006 IPCC GL where used. The revised estimate were included in the official Portuguese 2016 submission to UNFCCC (submited in december 22nd).	3. Energy
2.B.1 - Industrial Processes and Product Use, Chemical Industry, Ammonia production	The ERT noted that Portugal has decided to not deduct the CO2 used in the production of urea in the estimation of the CO_2 emission from ammonia production. In addition, the ERT noted that Portugal has estimated and reported CO_2 emissions from the use of urea in the agriculture sector (3H).	UNFCCC review - Saturday Paper/Attachment C - IPPU	Portugal deducted the CO2 used in the production of urea in the estimation of the CO2 emission from ammonia production.	4.4.1 Ammonia Production
2.B.8.b - Industrial Processes and Product Use, Chemical Industry, Ethylene	Portugal reported CO2 emissions from ethylene production as not occurring, however, the ERT notes that a default EF for this gas is available in the 2006 IPCC GL.	UNFCCC review - Saturday Paper/Attachment C - IPPU	Portugal revised the estimates for CO2 emissions from category 2.B.8.b – Ethylene using 2006 IPCC GL methodology (tier 1) and default factors.	4.4.9 Ethylene Production 4.4.9.2 Methodology 4.4.9.6 Recalculation
2.B.8.c - Industrial Processes and Product Use, Chemical Production, Petrochemical and Carbon Black Production, Ethylene dichloride and vinyl chloride monomer	Portugal reports CO2 and CH4 emissions from 2.B.8.c Ethylene dichloride and vinyl chloride monomer as not occurring, however, ERT noted that 2006 IPPC GL provides methodology and emission factors for these gases.	UNFCCC review - Saturday Paper/Attachment C - IPPU	Portugal started estimating CO2 and CH4 emissions from 2.B.8.c Ethylene dichloride and vinyl chloride monomer.	4.4.10 Ethylene Dichloride and Vinyl Chloride Monomer (VCM) Production
2.A.3 – Industrial Processes and Product Use, Mineral Industry,Glass Production	The ERT noted that Portugal has estimated CO2 emissions from glass production using a tier 3 methodology for the period 2005 – 2014. For the period 1990-2004, Portugal informed the ERT during the review week that emissions have been estimated using the glass production and data on the consumption of the raw material (2005 data). The ERT noted that the IEF reported by Portugal for 1990 amounts to 0.46 t CO2 / ton glass produced, which is more than two times higher than IEFs reported for all the EU countries in 1990, whose reported IEFs range between 0.05 and 0.21 t CO2 / ton glass.	UNFCCC review - Saturday Paper/Attachment C - IPPU	The information provided by Portugal during the review was not correct and corresponds to CO2 emissions related to combustion (1A2f) and not to CO2 emissions related to the process (2A3). Portugal presented the correct estimates for 2.A.3 – Glass Production from the industrial processes and IEF as reported in the PT 2016 submission. The data provided in the CRF is correct.	4.3.4 Glass Production

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
2.F - Industrial Processes and Product Use, Product Uses as Substitutes for ODS	During the review week, Portugal informed the ERT that an internal thorough review of the category 2.F - Product Uses as Substitutes for ODS" was taking place in the country and that the methodologies recommended by the 2006 IPCC guidelines would be used in the next submissions. This could indicate potential overestimation of emissions for the base year (1995) and potential underestimation for the years 2013 and 2014, depending on the direction of recalculations.	UNFCCC review - Saturday Paper/Attachment C - IPPU	Emissions estimations for 2.F category were presented and all issues were clarified.	4.7 Product Uses as substitutes for ODS
3.B(b) - Agriculture, Manure management	The ERT recommends that Portugal provide revised estimates for CH_4 emissions from manure management for swine by using the MCF values provided for in the 2006 IPCC GL for MMS liquid/slurry as agreed during the European Union review or using MCF values agreed with the Agriculture Ministry if the national process is completed in time and is consistent with the 2006 IPCC GL.	UNFCCC review - Saturday Paper/Attachment C - Agriculture	Portugal provided a revised estimate of CH_4 emissions from manure management, changing the MCF values (%) of the manure reported under anaerobic lagoon from 73/76 to 25/32 (cool /temperate) for the livestock categories (dairy cattle and swine). No other changes were done. The revised estimate were included in the official Portuguese 2016 submission to UNFCCC (submited in december 22nd).	5.4 CH4 Emissions from Manure Management
5B - CH4 and N2O emissions from Biological treatment of solid waste	The ERT notes that CH4 and N2O emission factors for composting and anaerobic digestion at biogas facilities are not in line with the corrigenda 2015 of the IPCC 2006 GL.	UNFCCC review - Saturday Paper (issue not leading to an adjustment)	Revised estimates of composting and AD emissions were provided in the 2016 resubmission under the UNFCCC review, applying the EFs from IPCC TFI, 31 July 2015 corrigendum.	7.4.2 Biological treatment of solid waste (CRF 5.B.)/ Methodological issues (EF updates)
General	The ERT notes that Portugal's calculation may have failed to identify some non-LULUCF key categories. A key category analysis should be developed with and without the LULUCF sector.	UNFCCC review - Provisional Main Findings	This recommendation has been implemented in the 2017 submission.	1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals; ANNEX L: Uncertainty Assessment
General	The ERT recommends that Portugal improve the description of its National System (Institutional Arrangements) by providing a more detailed description of the institutions participating and their functions and its methodological development plan.	UNFCCC review - Provisional Main Findings	This recommendation has been implemented in the 2017 submission.	1.2 Institutional arrangements for inventory preparation
General	The ERT recommends that Portugal improve the reporting of the results of the uncertainty analysis by providing in the NIR the level of uncertainty for the last reported year and showing the results of the analysis.	UNFCCC review - Provisional Main Findings	This recommendation has been implemented for the majority of sectors in the 2017 submission.	1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals; ANNEX L: Uncertainty Assessment
General	The ERT recommends that Portugal perform its key category analysis with the level of disaggregation recommended by the 2006 IPCC Guidelines, regardless of the level of disaggregation used at the uncertainty analysis.	UNFCCC review - Provisional Main Findings	This recommendation has been implemented for the 2017 submission.	1.5 Brief description of key source categories; ANNEX K: Key Category Analysis
General	Portugal did not include the emissions of F gases in its uncertainty analysis. Furthermore, the ERT, together with Portugal, has identified calculation errors in the uncertainty analysis.	UNFCCC review - Provisional Main Findings	Uncertainty for Fgases has been estimated for the 2017 submission, and QC procedures applied to avoid errors.	4.7.5 Product Uses as substitutes for ODS (CRF 2.F); 4.8 Other Product Manufacture and Use (CRF 2.G); ANNEX L: Uncertainty Assessment

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
1.A - Fuel Combustion - Sectoral Approach	The ERT noted that the Portuguese NIR in many places refer to the 1996 IPCC guidelines or the IPCC GPG rather than the 2006 IPCC GL.	UNFCCC review - Provisional Main Findings	Revisions to be included in the complete NIR 2017.	3. Energy
1.A.1.C - Manufacture of Solid Fuels and Other Energy Industries	Although emissions are reported for both manufacture of solid fuels and from other energy industries in 1990, there is no information in the NIR.	UNFCCC review - Provisional Main Findings	Portugal explained that these emissions are related to coke production in iron and steel production in the period 1990-2001. Based on the calculation sheet provided by the Party, the ERT could conclude that both combustion and process emissions were reported in this category.	4.5.1 Iron and Steel Production 4.5.1.2 Methodology
1.B.2.B - Natural Gas	The ERT noted that no information is provided on the basis for the losses reported in the energy balance of fugitive CH4 emission , all gas is imported through one plant in Sines, the current methodology used seems to significantly overestimate the fugitive CO2 emission from natural gas.	UNFCCC review - Provisional Main Findings	The methodology for estimating the fugitive emissions from the transportation and distribution of Natural Gas was revised The methodology is based on default values provided by the national regulatory entity of natural gas.	3.3.6.3 Fugitive Emissions from Natural Gas
2.A.4 - Other Process Uses of Carbonates, CO2	The ERT recommends that Portugal complete the AD on limestone and dolomite use to improve time-series consistency.	UNFCCC review - Provisional Main Findings	Implemented. This issue refers to the 2014 submission and respective review report (FCCC/ARR/2014/PRT) and is not valid anymore. IEF for this category do not present significant variations (0.42 – 0.45). The IEF related to uses of carbonates in fertilizers lies between 0.45-0.46 t CO2/t CaCO3 and the IEF related to soda ash consumption is 0.415 t CO2/t CaCO3. In recent years the IEF rises due to an increase in the use of carbonates in fertilizers production (highest IEF) and a decrease in soda ash consumption (lowest IEF).	-
2.B - Chemical Industry, CO2, CH4	The ERT recommends that Portugal explain the changes in the estimation methodology of CH4 emissions from ethylene production for the period 1998–2012, including the data sources, and the changes in the emission estimates.	UNFCCC review - Provisional Main Findings	In the subchapter "4.4.9.4 - Activity Data" of the Portuguese NIR, it was introduced the text "For "Repsol Polímeros" Petrochemical Plant in Sines - produced quantities were provided directly from the facility from 1990 onwards". There was only this change in the activity data. The EF is exactly the same as in the previous submission. We think this description reflects the change occurred in the activity data.	4.4.9 Ethylene Production 4.4.9.2 Methodology 4.4.9.4 Activity Data
2.A.3 - Glass Production, CO2	ERT recommend Portugal to improve QA/QC activity related to description in the NIR in order to assure report transparency.	UNFCCC review - Provisional Main Findings	Portugal presented in the NIR that estimated CO2 emissions from glass production for the period 1990-2004 "assuming the same ratio between CO2 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". Portugal informed the ERT during the review process that description presented in the NIR will be changed and provided equations for emissions estimations. The description in the NIR has been revised and could be checked in the next complete NIR 2017.	4.3.4 Glass Production 4.3.4.2 Methodology 4.3.4.3 Emission Factors 4.3.4.4 Activity Data
2.B.1 - Ammonia Production, CO2	The ERT recommends to the Party to review the methodology used for estimate CO2 emissions in this category and alocate emissions in line with 2006 IPCC GLs.	UNFCCC review - Provisional Main Findings	Implemented.	4.4.1 Ammonia Production 4.4.1.2 Methodology
2.B.1 - Ammonia Production, CO2	The ERT recommends Portugal to provide a recalculation of the CO2 emissions from ammonia production including the deduction of CO2 used in urea production.	UNFCCC review - Provisional Main Findings	Implemented.	4.4.1 Ammonia Production 4.4.1.2 Methodology 4.4.1.6 Recalculations

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
2.B.8 - Petrochemical and Carbon Black Production, CO2	ERT recommeds the Party to correct the reported value for CO2 emissions from Balck Carbon in its next submission and improve the transparency of the description in the NIR.	UNFCCC review - Provisional Main Findings	The Carbon Black sector was revised, being considered a new time series of activity data as well as new emission factors. Explanations will be provided in the full version of the NIR.	4.4.13 Carbon Black Production
2.B.8 - Petrochemical and Carbon Black Production, CO2	The ERT recommends that, in the absence of country-specific estimates for this category, the Party submits revised CRF tables containing the emissions estimates for CO2 emissions using IPCC 2006 default factors provided in the table 3.14.	UNFCCC review - Provisional Main Findings	Portugal confirmed that CO2 emissions occurs and are not yet estimated. Portugal also indicated that CO2 emissions will be included in the next submission.	4.4.13.3 Emission Factors
2.C.1 - Iron and Steel Production, CO2	The ERT recommends Portugal to improve description of the CO2 emissions estimation from iron and steel production in the NIR in order to assure transparency.	UNFCCC review - Provisional Main Findings	Under development.	4.5.1.2 Methodology
2.F.1 – Product Uses as Substitutes for ODS, HFC, PFC, SF6	The ERT recommends Portugal to implement 2006 IPCC methodology and calculate the emissions estimation from 2.F.1 - Refrigeration and Air Conditioning, 2.F.2 - Foam Blowing, 2.F.3- Fire Protection and 2.F.4.a- Aerosols-Metered Dose Inhalers categories.	UNFCCC review - Provisional Main Findings	Implemented.	4.7 Product Uses as substitutes for ODS
2 - Industrial Processes and Product Use, indirect CO2	The ERT recommends Portugal to report correct values from indirect CO2 emissions from IPPU sector in its next submission and improve QA\QC procedures.	UNFCCC review - Provisional Main Findings	Implemented.	9 Indirect CO2 and Nitrous Oxide Emissions
3.A Enteric fermentation – CH4	The ERT recommends that the use of the equation referred to in table 10.10 of the NIR is further clarified or reconsidered since it is used in the reference to estimate parameters for different species with similar digestive systems meanwhile it was used in the inventory to correct parameters for one species in a time series where emission factor calculations are already weighed by the weight of the animals.	UNFCCC review - Provisional Main Findings	Implemented. The correlation factor used (centered in 1998) to correct parameters in the time serie was withdrawn in 2017 submission.	5.3 CH4 Emissions from Enteric Fermentation
3.D.a.2 Organic N fertilizers – N2O	The ERT recommends that the Party accounts for the use of compost as fertilizer and associated emissions in the next submission given the implementation of the regulatory framework that allows for its use.	UNFCCC review - Provisional Main Findings	Implemented. N2O emission estimates from this source category will be reported from 2015 in the submission 2017.	5.7 N2O Emissions from Managed Soils
3.D.b.2 Nitrogen leaching and run-off – N2O	The ERT encourages the Party to further work on determining the percentage of the territory (soils) that has its water-holding capacity exceeded during the rainy season.	UNFCCC review - Provisional Main Findings	The estimate of leaching /run off losses was kept for all territory . Clarification/explanation will be included in the text of the NIR 2017	5.7 N2O Emissions from Managed Soils
3.B Manure management – CH4	The ERT notes that no description of the climatic zones was provided to the islands that integrate the territory of Portugal. The ERT recommends that this information is added to the NIR.	UNFCCC review - Provisional Main Findings	Implemented. Clarification will be included in the text of NIR 2017	5.4 CH4 Emissions from Manure Management
4.A.2 - Land Converted To Forest Land	The ERT recommends the next review team verifies the consistency of the information provided for this category.	UNFCCC review - Provisional Main Findings	The criterion for allocation of industrial wood harvesting to lands-converted to eucalyptus was modified.	6.2.2.2.2 Losses in Living Biomass
4(KP) B1 Forest management	The ERT recommends the country to maintain the format of fig.6.9 as it is in NIR 2014 (fig. 7.9) and improve the QA/QC process in its reporting.	UNFCCC review - Provisional Main Findings	Figure 6.9 was updated as suggested by the ERT	6.1.2.8 Allocation Land-use and Land-use Change to KP Accounting Categories

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
4(KP) KP LULUCF	The ERT recommends that Portugal specifies and provides information on which types of natural disturbances have been included in the BL estimate during 2017 review process.	UNFCCC review - Provisional Main Findings	Text clarified this	11.1.7 Application of the Natural Disturbances Provision
4(KP) KP LULUCF	The ERT recommends the next review team to check and add the information expected in table 11.2.	UNFCCC review - Provisional Main Findings	Table 11.2 has been filled in	11.4.2 Information on GHG Emissions from Base Year and Commitment Period on Article 3.4 CM and GM
1AB Reference approach, CO_2, 2005	For the reference approach – jet kerosene for the year 2005 the TERT noted that fuel consumption of international bunkers (17.2 PJ) is much lower (<50%) than in the years 2008-2015 (36.6 – 41.3 PJ) and that it is not consistent with jet kerosene consumption reported under 1D International aviation (31.8 PJ) for 2005.	EU review - PT-1AB-2016-0003/ Table 4	The data of jet kerosene consumption of International bunkers for the period 1990-2006 was revised using the database of Eurostat. Although the jet kerosene consumption in table 1.A(b) is not the same as table 1.D the consistency between the two tables has increased since last submission.	3.2.1 International aviation bunkers 3.6 Reference Approach
2A4 Other process uses of carbonates, CO2, 2005, 2008-2013	For category 2A4 Other process uses of carbonates and gas CO_2 for the years 1990-2014 the TERT noted that Portugal uses one EF for clay in 1990-2013 (0.07 t CO2/t clay) and a different EF for clay in 2014 (0.03 t CO2/t clay). As clay has the largest share of carbonates used in ceramics production, this causes much higher emissions in 1990-2013 compared to 2014.	EU review - PT-2A4-2016-0002/ Table 4	Portugal explained that in 2013, a large number of facilities (ETS EFs are used in the GHG inventory) used a default EF. In 2014, part of these facilities implemented an analysis to estimate the carbon content of clay and the average value decreased considerably. The 2013 EF value for clay was used for the time series 1990-2012. Portugal further explained that since there are no changes on the raw-materials carbon contents from 2013 to 2014, they assume that the 2014 values are closer to the national reality and provided revised estimates using these raw-materials average carbon contents for the entire period (1990-2014). The TERT also noted that there is a sharp decrease in biomass consumption in energy balance from 2011 and this results in much lower emission estimates for years 2011-2014. Portugal explained that the sharp decrease in biomass consumption was due to a change in the type of inquiry made by national statistics authorities. Assuming the information of the 2011 onwards revised inquiry is of better quality than the previous one, Portugal admited that it is a more realistic approach to backcast the biomass consumption in the period 1990-2010 based on 2011 biomass consumption value. Portugal provided revised estimates for years 2005, 2008-2010 and 2013. The TERT agreed with the revised estimate provided by Portugal. The TERT recommends that Portugal include the revised estimate in its next submission.	4.3.6 Uses of Carbonates in Ceramics
2B1 Ammonia production, CO_2, 2005, 2008	For category 2B1 Ammonia production and gas CO_2 for years 2005 and 2008 the TERT noted that Portugal reports in its NIR that although CO_2 emissions are partly recovered from ammonia production and used in urea production Portugal does not deduct CO_2 recovered for urea production from ammonia production emissions. In accordance with UNFCCC reporting Guidelines and 2006 IPCC Guidelines, CO_2 recovered for urea production should be deducted from the emissions from ammonia production.	EU review - PT-2B1-2016-0003/ Table 4	Portugal confirmed that they did not deduct the CO_2 recovered to produce urea and agreed that there is a double-counting issue that Portugal wants to correct in the next inventory submission. The TERT noted that the issue is below the threshold of significance for technical correction. The TERT recommends that Portugal deduct CO_2 recovered for urea production from ammonia production emissions and ensure that emissions of CO_2 from urea use are accounted for in the corresponding sectors in its next submission.	4.4.1 Ammonia Production

CRF category / issue	Review recommendation	Review report / paragraph	MS response / status of implementation	Chapter/section in the NIR
5C Incineration and open burning of waste, CO_2, 2005-2014	For category 5C Incineration and open burning of waste and the gas CO_2 the TERT noted that, concerning textiles, the dry matter fraction (dm=0.8) was applied twice (to CF and to FCF) although it should be only applied once for the two parameters (see eq 5.2 or 5.1 of the 2006 IPCC Guidelines). Moreover, concerning clinical waste, the fraction of dry matter (the default value proposed in Table 2.6 of the 2006 IPCC Guidelines, Vol 5, Chapter 2) is 65%. The TERT recommended Portugal to apply the conversion factor for dry matter for clinical waste and only once and also recommends to use the dry matter factor for textiles as provided by the 2006 IPCC Guidelines.	EU review - PT-5C-2016-0001/ Table 4	Despite the fact that the issue is below the threshold of significance for technical correction, this recommendation was implemented for all years for the 2016 resubmission under the 2016 UNFCCC review.	7.5.2.1.1 Waste Incineration (CRF 5.C.)/ Methodological issues/CO2 emissions/Municipal Solid Waste (MSW C content revision)
5D Wastewater treatment and discharge, CH_4, 2005-2014	For CH_4 emissions from categories 5D1 and 5D2 Industrial and Domestic wastewater treatment and discharge for the years 2005-2014 the TERT noted very high emissions. These high CH_4 emissions were due to a high share of 6-7% septic tanks among industrial wastewater treatment systems (which is unlikely) and an unclear category of wastewater treatment systems, representing 30-40% of total industrial degradable organic carbon. After the revision of the estimates provided by Portugal, the TERT considered that CH4 emissions from Domestic and Industrial wastewater remain high compared to other countries and recommended Portugal to improve the MCF (methane correction factors) values used which are currently based on conservative expert judgement.	EU review - PT-5A-2016-0003/ Table 4	The revised estimates provided under this review to correct the data related to the use of septic tanks for industrial wastewater were accepted by the TERT. The revised estimates were inluded in the 2017 submission (UNFCCC review did not consider this issue). Portugal will continue to endeavour to improve the estimates of this sector.	7.6.2.2 Industrial Wastewater Handling CH4 Emissions
5D Wastewater treatment and discharge, N_2O, 2005-2014	For category 5D Wastewater treatment and discharge and gas N_2O for years 2005-2014 the TERT noted that the N_2O emissions per capita for category 5D Wastewater treatment and discharge are high compared to other Member States because the EF used for industrial wastewater is from an outdated document (EMEP 2000).	EU review - PT-5D-2016-0002/ Table 4	Portugal provided revised estimates for the complete time series based on the guidance from the IPCCC 2006 which were agreed by the TERT. The revised estimates were inluded in the 2017 submission (UNFCCC review did not consider this issue).	7.6.2.3.1 N2O emissions from wastewater/ Methodology

10.2 Overview recalculations

Next table presents in a tabular form a synthesis of the main recalculations made in this 2016 submission and the implications in 1990 and 2014 emission levels.

Table 10.2 – Synthesis of the recalculations made for the 2016 inventory submission by CRF category and their implications to the emissions level in 1990 and 2014

CRF Category		Implication To the CRF category (Gg CO2eq.)		Implication to the Total Emissions without LULUCF & Indirect CO_2 emissions (%)	
		in 1990	in 2014	in 1990	in 2014
Total		**-1 549.66**	**-893.86**	**-2.41**	**-1.39**
1. Energy		**-295.02**	**-427.26**	**0.46**	**-0.67**
.A.	Fuel Combustion Activities	-172.37	0.03	-0.27	0.00
.1.	Energy Industries	2.90	53.21	0.00	0.08
.2.	Manufacturing Industries and Construction	-148.04	-176.54	-0.23	-0.28
3.	Transport	-36.58	-23.22	-0.06	-0.04
4.	Other Sectors	45.37	24.41	0.00	0.00
5.	Other	-0.47	0.00	0.00	0.00
.B.	Fugitive Emissions from Fuels	-122.65	-427.29	-0.19	-0.67
.1.	Solid fuel	0.00	0.00	0.00	0.00
2.	Oil and Natural Gas	-122.65	-427.29	-0.19	-0.67
2. Industrial Processes and Product Use		**-355.06**	**-9.11**	**-0.55**	**-0.01**
A.	Mineral Industry	-341.27	-14.99	-0.53	-0.02
B.	Chemical Industry	-11.88	3.31	-0.02	0.01
C.	Metal Industry	0.00	0.00	0.00	0.00
D.	Non-energy Products from Fuels and Solvent Use	-1.90	3.41	0.00	0.01
F	F-Gases	0.00	0.00	0.00	0.00
G.	Other Product Manufacture and Use	0.00	-0.84	0.00	0.00
3. Agriculture		**174.71**	**-50.73**	**0.27**	**-0.08**
A.	Enteric Fermentation	177.96	18.78	0.28	0.03
B.	Manure Management	8.89	3.49	0.01	0.01
C.	Rice Cultivation	0.00	0.00	0.00	0.00
D.	Agricultural Soils	-12.15	-63.02	-0.02	-0.10
F.	Field Burning of Agricultural Residues	0.00	0.00	0.00	0.00
G	Liming	0.00	0.00	0.00	0.00
H.	Urea application	0.00	0.00	0.00	0.00
4. Land Use, Land-use Change and Forestry		-404.63	326.81	0.00	0.00
A	Forestland	-183.97	442.58	0.00	0.00
B	Cropland	-266.52	-27.17	0.00	0.00
C	Grassland	-107.25	-26.52	0.00	0.00
D	Wetlands	0.00	-2.09	0.00	0.00
E	Settlements	-0.03	-16.01	0.00	0.00
F	Other land	60.65	110.25	0.00	0.00
G	Harvest wood products	70.14	-162.85	0.00	0.00
5. Waste		**-669.67**	**-733.57**	**-1.04**	**-1.14**
A.	Solid Waste Disposal	0.00	30.09	0.00	0.05
B.	Biological Treatment of Solid Waste	0.00	0.00	0.00	0.00
C.	Incineration and Open Burning of Waste	0.00	-0.05	0.00	0.02
D.	Waste Water Treatment and Discharge	-669.67	-763.61	-1.04	-1.19
E	Other	0.00	0.00	0.00	0.00

The explanations and justifications for recalculations presented in **Table 10.2** are described in the below sections by CRF category.

More information can be found from Category-Specific Recalculation Sections (Chapters 3 to 7).

10.2.1 Recalculations Energy sector (CRF 1)

Energy Industries (CRF 1.A.1)

Update of gas and biomass fuel consumption activity data for 2012, 2013 and 2014.

Manufacturing industries and construction (CRF 1.A.2)

Review of the time series of activity data and emission factors for the two main installations in the Chemical sector.

Transport (CRF 1.A.3)

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

The major changes between submissions (2016 and 2017) result from the following actions:

- Revision of 2012, 2013 and 2014 vkm values for Heavy duty trucks by INE;
- Revision of the incorporation rate of biodiesel from 2006 until 2015;
- Correction of CO2 emissions calculation since CO2 emissions from the use of urea-based additives in catalytic converters are now reported under 2.D.3.c as recommended by the ESD and UNFCCC reviews 2016;
- Revision of the 2013 Energy Balances data by DGEG;
- Report of CO2, CH4 and N2O emissions for lubricants used in 2-stroke engines under 1.A.3.b.iv as recommended by the ESD review 2016.

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

Recalculations for this source category comprise an update and correction of the 2014 data due to a compilation error detected during the QA/QC procedure.

Other Sectors (CRF 1.A.4.)

Agriculture / Forestry / Fishing (CRF1.A.4.c)

Recalculations for this source category comprise the correction of a compilation error in residual fueloil consumption between 2004 and 2013.

Oil and natural gas and other emissions from energy production (CRF1.B.2)

Correction of CO2 emissions compilation error in Refineries (1.B.2.a.4)

The methodology for estimating the fugitive emissions from the transportation and distribution of Natural Gas was revised (1.B.2.b)

10.2.2 Recalculations: Industrial Processes sector (CRF 2)

The major changes between submissions (2015 and 2016) result from the following actions:

- Revision of ceramics production (2.A.4.a) emission factors based on ETS data;
- Revision of other process uses of carbonates (2.A.4.d) activity data;
- In ammonia production subsector (2B1), We implemented the deduction of the CO2 used for the urea production. This led to a decrease of 29.7 kt of CO2 in 1990 and 20.7 kt of CO2 in 2008 (last year with ammonia production);
- Revision of the Ethylene CH4 emission factor (2.B.8.b);
- Revision of the vinyl chloride monomer (2.B.8.c) activity data for all the period 1990-2014;
- Revision of Carbon Black emissions estimates, activity data and emission factors (2.B.8.f);
- Correction of the emissions from lubricant use in non-energy products from fuels and solvent use (2.D.1) since the CO2, CH4 and N2O emissions for lubricants used in 2-stroke engines are now reported under 1.A.3.b.iv as recommended by the ESD review 2016;
- Report of CO2 emissions from the use of urea-based additives in catalytic converters under 2.D.3.c as recommended by the ESD and UNFCCC reviews 2016;
- Revision of N2O consumption for medical applications (2G3a) from 1994 onwards.

10.2.3 Recalculations: Agriculture sector (CRF 3)

Enteric Fermentation (CRF 3A) - CH_4 emissions

Following recommendation of 2016 UNFCCC review it was withdrawn the correlation factor used (centered in 1998) to correct non dairy cattle, sheep and goats parameters in the time serie. In previous submission the estimated values of parameters, centered in 1998, were corrected by an exponencial function (equation of table 10.10) of the carcass weight variation (yearly average)..

Manure Management (CRF 3Ba) - CH_4 emissions

Only minor corrections were done in result of QA/QC verifications with no significant impact in the total CH_4 emissions from this source category .

Manure Management (CRF 3Bb) – N_2O emissions (direct and indirect)

Only minor corrections were done in result of QA/QC verifications with no significant impact in the total N_2O emission estimates of this source category.

Agricultural soils (CRF 3D) – N_2O emissions (direct and indirect)

Changes result mainly from the following reasons:

- Downward revision of 2013 and 2014 values for apparent consumption of N synthetic fertilizers, updated by INE;
- Downward revision of 2013 and 2014 values of sewage sludge applied to agricultural soils, updated by the waste sector;
- implementation of the tier 2 methodology of EMEP/EEA Guidebook 2016 to estimate NH3 emissions from N synthetic fertilizers application, which includes new default emission factors (lower than the previous one). Less N volatilized in form of NH3 less N2O indirect emissions from atmospheric deposition.

Urea application (CRF 3 H) – CO_2 emissions

Changes between last year submission and this year submission result from the INE update of N synthetic fertilizers values for 2013 and 2014, including the amounts of urea.

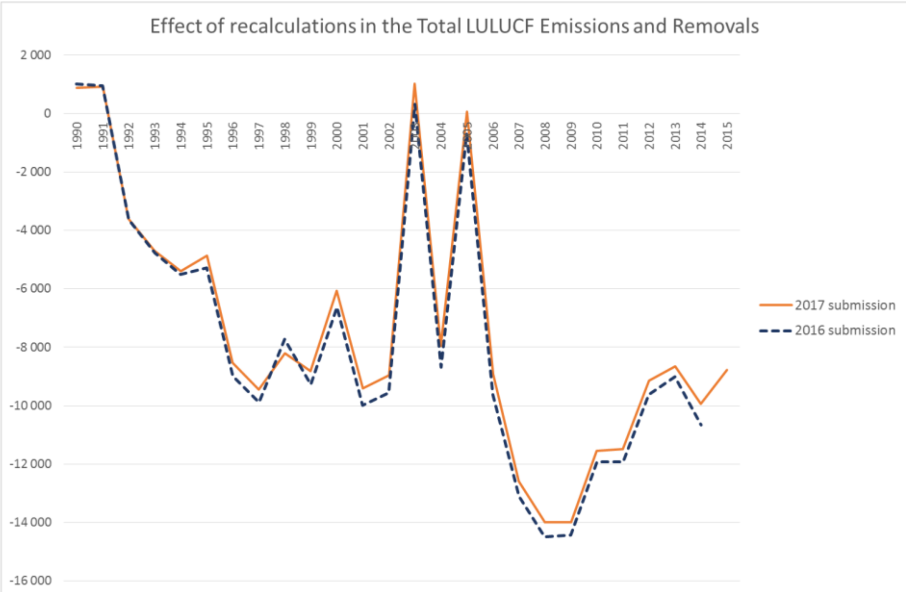
10.2.4 Recalculations: LULUCF (CRF 4)

The following recalculations were made since the last submission:

- Data for HWP was made consistent with the most recent UNECE database
- Category 4(IV) is now estimated
- Mistake in C Stock levels for biomass and litter from shrubland detected and corrected
- Change in harvest allocation between LF / FF and 3.3AR / 3.4FM introduced
- Minor mistake in HWP estimates detected and corrected

However it should be noted that the impact of these recalculations in the final totals was small (Figure 10-1).

Figure 10-1: Effect of recalculations in the Total LULUCF Emissions and Removals.



10.2.5 Recalculations: Waste sector (CRF 5)

The major changes between submissions (2016 and 2017) refer to:

<u>Wastewater treatment and discharge (CRF 5D)</u>

- N2O emissions from wastewater (CRF 5D1 and CRF 5D2):

  a) Emissions from industrial sources previously estimated on the basis of an emission factor (0.02 kg N2O/kg inhab-eq) from EMEP/CORINAIR (EEA, 2002) are now calculated together with domestic wastewater using the default factor (1.25) for industrial and commercial co-discharged protein into the sewer system (FIND-COM) proposed by 2006 IPCC;
  b) Correction of a calculation error in the previous estimates: instead of subtracting N from wastewater efluent (equation 6.8) we were subtracting the N2O emissions from sludge removal in equation 6.7 and consequentely the emissions were underestimated.

- CH4 emissions from industrial wastewater (CRF 5D2)

Several revisions have been made for this category:

a) Industrial treatment in septic tanks was excluded from 2005 onwards based on the knowledge that this type of treatment does not exist nowadays; treatment of IWW in textile and wood industry was not considered for the whole time series;
b) MCF revision for situations where industrial treatment type is unknown: previous values, which referred to the MCF weighted averages for all domestic wastewater treatment types (values varying from 24% to 17%), were replaced by new figures referring to MCF weighted averages for industrial wastewater treatment types (values ranging from 10% to 14%);
c) Compilation error related to anaerobic treatment.

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

11 KP LULUCF

11.1 General Information

11.1.1 Information on how inventory methodologies have been applied

Methodologies for estimating emissions and removals have been applied following the guidance established under the IPCC 2006 Guidelines for National Greenhouse Gas Inventories and the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.

11.1.1.1 Article 3.3 – Afforestation and Reforestation

The areas estimates for this activity are described in section 6.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.3 - Afforestation and reforestation were the same as those described for:

- land converted to forest land in section 6.2.2 (only for land converted to forest land after 1990);
- N2O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter in section 6.11;
- GHG emissions from biomass burning in section 6.13.

11.1.1.2 Article 3.3 – Deforestation

The areas estimates for this activity are described in section 6.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.3 - Deforestation were, depending on land use prior to deforestation, the same as those described for:

- forest land converted to cropland in section 6.3.2 (only for forest land converted to cropland after 1990);
- forest land converted to grassland in section 6.4.2 (only for forest land converted to grassland after 1990);
- forest land converted to wetlands in section 6.5.2 (only for forest land converted to wetlands after 1990);
- forest land converted to settlements in section 6.6.2 (only for forest land converted to settlements after 1990); and
- forest land converted to other land in section 6.7.2 (only for forest land converted to other land after 1990);
- N_2O emissions from disturbances associated with land-use conversion to cropland in Section 6.11 (only for forest land converted to cropland after 1990);
- N2O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter in section 6.11;
- GHG emissions from biomass burning in section 6.13.

11.1.1.3 Article 3.4 – Forest Management

The areas estimates for this activity are described in section 6.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.4 – Forest Management were the same as those described for:

- forest land remaining forest land in section 6.2.1;
- land converted to forests in section 6.2.2 (only for land converted to forest land before 1990);
- N2O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter in section 6.11;
- GHG emissions from biomass burning in section 6.13

11.1.1.4 Article 3.4 – Cropland Management

The areas estimates for this activity are described in section 6.1.2.8.

The methods used for estimating emissions and removals in lands under article 3.4 – cropland management were, depending on land use on the previous reporting year, the same as those described for:

- cropland remaining cropland in section 6.3.1;
- land converted to cropland in section 6.3.2 (for land converted to cropland after 1990; excluding forest land converted to cropland since 1990, which is reported as 3.3 D);
- cropland converted to wetlands in section 6.5.2. (only for cropland converted to wetlands after 2008);
- cropland converted to settlements in section 6.6.2 (only for cropland converted to settlements after 2008);
- cropland converted to other land in section 6.7.2 (only for cropland converted to other land after 2008);
- areas under no-till in section 6.3.1.5;
- N2O emissions from disturbances associated with land-use conversion to cropland in section 6.11 (except for forest land converted to cropland after 1990, which is reported under 3.3 D);
- carbon emissions from lime application in section 6.12;
- N2O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter in section 6.11;
- GHG emissions from biomass burning in section 6.13.

11.1.1.5 Article 3.4 – Grassland Management

The areas estimates for this activity are described in section 6.1.2.8.

The methods used for estimating emissions and removals in lands under Article 3.4 – Grassland Management were, depending on land use on the previous reporting year, the same as those described for:

- grassland remaining grassland in section 6.4.1;
- land converted to grassland in section 6.4.2 (for land converted to grassland after 1990; excluding forest land converted to grassland, which is reported as 3.3 D);
- cropland converted to wetlands in section 6.5.2. (only for cropland converted to wetlands after 2008);
- cropland converted to settlements in section 6.6.2 (only for cropland converted to settlements after 2008);
- cropland converted to other land in section 6.7.2 (only for cropland converted to other land after 2008);
- areas under biodiverse pastures in section 6.4.1.4.1;
- N2O emissions from N Mineralization/Immobilization associated with Loss/Gain of Soil Organic Matter in section 6.11;
- GHG emissions from biomass burning in section 6.13.

11.1.2 Geographical locations of the boundaries of the area that encompasses and Spatial Assessment Unit

The entirety of the territory of Portugal is considered managed and is therefore included in both UNFCCC Reporting and, consistently, in KP Reporting and KP Accounting.

The definitions for each of these activities were applied consistently over the full time series 1970-2015 and therefore they were also applied consistently for the estimates of emissions and removals in the base year (1990) and the commitment period (2013-2020). This was ensured by defining strict terms of reference for Land-use cartography – COS (for the years 1995, 2007, 2010)[135] that captured the reporting requirements for the Kyoto Protocol.

This instrument developed data for the respective three reference years using the same information protocol and the same teams. Their results are therefore considered fully consistent over time.

The spatial assessment unit for all land-uses and activities was 1ha, consistent with the methodology of COS and the forest definition of Portugal. The methodology to identify geographical locations and the information sources that were used are described in section 6.1.2.

The methodology used to develop the land transition matrix is described in section 6.1.2.

The hierarchy for activities used is the following: 3.3 Deforestation > 3.3 Afforestation and Reforestation > 3.4 Forest Management > 3.4 Cropland Management > 3.4 Grazing Land Management > Not Accounted. The application of this hierarchy is described in Table 11.1.

[135] The project to develop land use cartography is still ongoing and wasn't used in this submission. However its development was informed by the data needs for UNFCCC and KP reporting purposes.

Table 11.1 - Application of the Activity Hierarchy in Portugal.

Land-Use Transition	Accounted as	Notes
FL -> CL FL -> GL FL -> WL FL -> SL FL -> OL	3.3 D	All transitions since 1990
CL -> FL	3.3 AR	All transitions since year of conversion
	3.4 CM	Until year of conversion-1
GL -> FL	3.3 AR	All transitions since year of conversion
	3.4 GM	Until year of conversion-1
WL -> FL ST -> FL OL-> FL	3.3 AR	All transitions since year of conversion
CL -> GL	3.4 GM	Since year of conversion
	3.4 CM	Until year of conversion-1
CL -> WL CL -> SL CL -> OL	Not accounted	All transitions until 2007
	3.4 CM	All transitions since 2008
GL -> CL	3.4 CM	Since year of conversion
	3.4 GM	Until year of conversion-1
GL -> WL GL -> SL GL -> OL	Not accounted	All transitions until 2007
	3.4 GM	All transitions since 2008
All other FL	3.4 FM	
All other CL	3.4 CM	
All other GL	3.4 GM	
All other land-uses and land-use transitions	Not accounted	

11.1.3 Definition of forest

In its Initial Report, Portugal adopted a forest definition with the following parameters:

- Minimum tree cover: 10%
- Minimum land area: 1 ha
- Minimum tree height: 5 m
- Minimum width: 20 m

Consistent with national definitions and values reported to FAO, agri-forest systems of cork-oak and holm-oak were included as forests whenever the tree cover exceeded 10%.

Consistent with national definitions and values reported to FAO, some woody perennial crops like olive groves, vineyards and fruit production orchards were included as cropland, even if they would reach the forest thresholds mentioned above. However, as Portugal accounts also for Cropland management, any losses of area and biomass from perennial crops are also accounted for under the KP.

These parameters were chosen in the Initial Report to the 1st Commitment Period of the Kyoto Protocol and are within the agreed values in decision 16/CMP.1 and 2/CMP.7. Portugal will continue to use this definition in the Second Commitement Period.

11.1.4 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

Portugal accounts for all mandatory Article 3.3 and 3.4 activities – Afforestation (A), Reforestation (R) and Deforestation (D) and Forest Management (FM), and has elected in the previous Commitment Period the following voluntary Article 3.4 activities Cropland Management (CM) and Grassland Management (GM).

Portugal will continue to report and account those activities and has not elected any further activities for the Second Commitment Period under the Kyoto Protocol.

11.1.5 Information on Anthropogenic GHG Emissions from Articles 3.3 and 3.4

The methodologies for estimating GHG Emissions from activities under Article 3.3. and 3.4 have been summarised for each activity in section 11.1.1.

11.1.6 Information on Pools and Gases

As referred before the area of organic soils in Portugal is negligible and therefore the pool is not considered. Otherwise, all pools and gases were considered.

11.1.7 Application of the Natural Disturbances Provision

Portugal has indicated in its Initial Report to the Second Commitment Period its intention to use this provision, if and when the emissions established in the Background Level + Margin have been exceeded. To that effect 2 values for background level and margin have been provided for application in forests under Article 3.3 AR and Article 3.4 FM.

Background Level for Portuga includes only information relative to Forest Fires and other types of disturbances were not considered.

This provision has not yet been applied by Portugal.

11.1.8 Information on Harvested Wood Products

11.1.8.1 Activity Data and HWP Product Categories

Activity data for HWP is withdrawn from the UNECE database and includes data on production, imports and exports for different Product Categories.

As outlined in section 6.8, the product categories considered are: paper products, sawnwood and wood panels.

11.1.8.2 Information on Half-Lives Used

The IPCC default half-lives for the product categories identified above have been used for the purpose of KP Reporting and Accounting.

11.1.8.3 Information on Inclusion of HWP in the Projected Forest Management Reference Level

The full time series of HWP production since 1900, and the respective carbon stock changes, have been included in the estimation of the FMRL for Portugal.

11.1.8.4 Information on how HWP from the 1st Commitment Period were Considered

All products produced since 1990 have been included in the estimated for HWP for use under the KP. This will have a neutral impact on accounting, since Portugal is using a projected FMRL.

11.1.8.5 Information on HWP from Deforestation

All harvesting for industrial purposes is assumed to come from 3.4 Forest Management. All wood harvested as a consequence od deforestation leads to additional emmissions and is reported as instantly oxidised in the year of harvesting.

11.1.8.6 Information on HWP deposited on Solid Waste Disposal Sites

The use of the default IPCC methodology (with half-lives) considers the emissions over time using a decay curve, and does not consider eventual sink effects of solid waste disposal sites. Hence, no separate estimates of the HWP pool in SWDS was carried out.

11.1.8.7 Information on Exclusion of Wood Imports from the HWP accounted Pool

The use of the default IPCC methodology ensures the exclusion of imported wood and HWP from accounting.

11.2 Information on Factoring Out

Portugal did not factor out indirect effects of climate change in expected emissions and removals from forest management. This was mostly due to technical difficulties associated with that calculation. However, and in qualitative terms, science on the impacts of climate change impacts in Portugal suggests that the net-effect will most likely result in a reduction of forest productivity.

"*The present capacity of Portuguese forests to store carbon is high. In the future, however, it may not be as high as it could be under present climatic condition due to: (1) decreases or only modest increases in NPP, (2) lower standing biomass due to changes in vegetation and increase in fire frequency and (3) enhanced soil respiration due to warmer winters, thus decreasing the importance of the below ground carbon store*"[136]

[136] http://www.siam.fc.ul.pt/SIAMExecutiveSummary.pdf

11.3 Specific Information on Article 3.3

11.3.1 Demonstration that Activities Started after 1990 and are Human Induced

As explained in section 6.1.2 "Representation of Land-Areas and Land-Use Changes" Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

Only lands afforested since 1990 (i.e. converted from non-forest land to forest land) and deforested since 1990 (i.e. converted from forest to non-forest land) are considered for the purposes of accounting for activities under Article 3.3.

Deforestation is considered as human-induced by definition. Afforestation is a common activity by farmers and forest owners (97% of forest land in Portugal is privately owned) and is carried out with and without public support.

Public support through programmes for afforestation in agriculture lands, i.e. carried out in areas classified for UNFCCC LULUCF reporting as cropland and grassland, and for afforestation in other lands, i.e. carried out in areas classified for UNFCCC LULUCF reporting as other land (mostly shrublands). These programmes are funded by National and EU funds and have been present (although under different names and support levels) since Portugal joined the EU in 1986. Fast-growing species are not eligible for public support and, hence, all afforestation with these species results from direct investment by forest owners.

11.3.2 Information on Difference between Deforestation and Harvest or Disturbance

As explained in section 6.1.2 "Representation of Land-Areas and Land-Use Changes" Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

The main sources of forest disturbance in Portugal are harvesting and forest fires. The usual practice is to reforest those areas after the disturbance event. In the case of forest fires, public support for reforestation and re-establishement of forest cover is provided for. These programmes are funded by National and EU funds and have been present (although under different names and support levels) since Portugal joined the EU in 1986.

Some losses of forest cover are obvious deforestation events and are classified as deforestation as soon as they are detected (e.g. convertions to settlements, flooding by a recently constructed water reservoir, convertion to irrigated farmland). In other situations the land use following forest cover loss is less obvious. In those situations, and consistent with the KP forest definition, land is considered as "temporarily unstocked" for a period of up to 5 years. After such period the land should be confirmed as forest land (i.e., no deforestation has occurred) or non-forest land. In the later case the land is considered deforested and the time series for area of FM is recalculated since the year when the event was first detected.

11.4 Specific Information on Article 3.4

11.4.1 Demonstration that Activities Started after 1990 and are Human Induced

As explained in section 6.1.2 “Representation of Land-Areas and Land-Use Changes” Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

All forests are considered managed and agriculture and grazing are, by definition, human induced activities.

11.4.2 Information on GHG Emissions from Base Year and Commitment Period on Article 3.4 CM and GM

The calculation of emissions and removals is explained in sections 6.3 Cropland (CRF 4.B) and 6.4 Grassland (CRF 4.C). and include estimations for the year 1990 (base year for Portugal) and all years in the period 2013-2020.

A summary of the reported values is presented in Table 11.2.

Table 11.2 - Summary of reported emissions and removals under the KP for the Article 3.4 Activities Cropland Management and Grassland Mangement.

KP Activity	1990	2013	2014	2015	2016	2017	2018	2019	2020
3.4 Cropland Management	3054	326	338	336	NA	NA	NA	NA	NA
3.4 Grassland Management	1444	27	7	-55	NA	NA	NA	NA	NA

11.4.3 Demonstration of No Double Counting Between 3.4 FM and 3.3 ARD

As explained in section 6.1.2 “Representation of Land-Areas and Land-Use Changes” Portugal detects land-use and land-use changes based on wall-to-wall maps for the years 1995, 2007 and 2010. As outlined in that section, a full time series for the period 1990-2012 is then derived from those maps and other auxiliary information.

This time series is used to derive time series for activity data of all activities under the KP. Land is allocated to each activity following the hierarchy of activities described in Table 11.1. Once allocated to one activity in a particular year, land can not be allocated to another activity in the same year. As part of Portugal’s QA/QC procedures, some comparisons between KP and UNFCCC reported areas are made to ensure that no double counting is taking place.

11.4.4 Information on Conversion of Natural Forests

Not Occurring in Portugal.

11.4.5 Demonstration of Methodological Consistency between the FMRL and Accounting for 3.4 FM and Technical Corrections on the FMRL

All spreadsheets for estimating emissions and removals from KP LULUCF have been adapted so that they recalculate automatically the FMRL if and when the base information changes. Folowing the specifications of Decision 2/CMP.7, the assumptions used in FMRL construction are kept constant.

All changes to the FMRL value are therefore due to changes in the base information (historical time series) or changes in methodologies in use, which then apply both to the historic time series and to reporting in the commitment period.

Since the communication of the FMRL by Portugal in 2011, several changes have been introduced in the reporting by Portugal. Table 11.3 summarises the main differences between the original FMRL submission and the current estimates, following the methodological and time series changes introduced since 2011.

The impact of these changes is presented in Table 11.4, and results in a technical correction factor of 3302GgCO2e.

Table 11.3 - Main differences in the original and recalculated values of the drivers of the FMRL

Forest Management Reference Level Changes in Main Drivers of Emissions and Removals (1)	Original Value (2)	Recalculated Value	unit
FM Forest Area	**3 700**	**3 725**	**1.000 ha**
Pinus pinaster	920	945	1.000 ha
Quercus suber	837	830	1.000 ha
Eucalyptus spp.	981	737	1.000 ha
Quercus rotundifolia	410	561	1.000 ha
Quercus spp.	202	189	1.000 ha
Other broadleaves	98	270	1.000 ha
Pinus pinea	227	142	1.000 ha
Other coniferous	26	12	1.000 ha
FM Forest Harvesting	**11 168**	**11 909**	**1.000 m^3 ub**
Pinus pinaster	3 435	3 462	1.000 m^3 ub
Quercus suber	65	147	1.000 m^3 ub
Eucalyptus spp.	7 034	7 157	1.000 m^3 ub
Quercus rotundifolia	48	92	1.000 m^3 ub
Quercus spp.	148	253	1.000 m^3 ub
Other broadleaves	77	297	1.000 m^3 ub
Pinus pinea	325	448	1.000 m^3 ub
Other coniferous	36	53	1.000 m^3 ub
FM Annual Burnt Area	**46 836**	**35 533**	**ha**
Pinus pinaster	14 899	16 676	ha
Quercus suber	3 222	2 906	ha
Eucalyptus spp.	18 923	9 511	ha
Quercus rotundifolia	1 204	992	ha
Quercus spp.	5 388	1 527	ha
Other broadleaves	1 811	2 395	ha
Pinus pinea	854	403	ha
Other coniferous	535	1 122	ha
FM HWP Production from Domestic Wood			
Industrial Roundwood	NA	9 227	1.000 m^3
Wood Pulp	2 038	1 738	1.000 ton
Wood Panels	1 329	1 123	1.000 m^3
Sawnwood	1 010	862	1.000 m^3
Paper and Paper Board	NA	1 274	1.000 ton
GWP	**AR2**	**AR4**	
CO_2	1	1	Gg CO_2 eq. / Gg CO_2
CH_4	21	25	Gg CO_2 eq. / Gg CH_4
N_2O	310	298	Gg CO_2 eq. / Gg N_2O

(1) Numerical values reported in this table represent the annual average for the period 2013-2020

(2) As cointained in the "Submission of Information on Forest Management Reference Level by Portugal" dated 24 th February 2011

Table 11.4 - Impact of recalculations, methodology changes and time series changes on the FMRL of Portugal

Forest Management Reference Level Changes in Reported Emissions and Removals [1]	Original Value [2]	Recalculated Value	Technical Correction	unit
Forest Management Reference Level	**-6 830,0**	**-3 527,5**	**3 302,5**	**Gg CO_2 eq.**
4(KP-I) Gains Above Ground Biomass	-6 529,6	-6 053,8		GgC
4(KP-I) Gains Below Ground Biomass	-1 315,5	-1 217,4		GgC
4(KP-I) Losses Above Ground Biomass	3 747,3	4 976,0		GgC
4(KP-I) Losses Below Ground Biomass	757,9	949,4		GgC
4(KP-I) Net-changes in Litter	34,9	10,0		GgC
4(KP-I) Net-changes in Dead Wood	IE	IE		GgC
4(KP-I) Net-changes in Soils	1 168,0	19,3		GgC
4(KP-I) Net-changes in HWP	-94,9	54,0		GgC
4(KP-II 3) N2O emissions from loss of SOM	NE	20,6		Gg CO_2 eq.
4(KP-II 4) Forest Fire Emissions (Natural Disturbances Background Level)	1 356,8	1 080,9		Gg CO2 eq.

(1) Numerical values reported in this table represent the annual average for the period 2013-2020

(2) As contained in the "Submission of Information on Forest Management Reference Level by Portugal" dated 24 th February 2011

11.4.6 Information on the Application of the Equivalent Forests Provision

Portugal is not applying this provision.

12 INFORMATION ON ACCOUNTING KYOTO UNITS

12.1 Background information

This section includes supplementary information required under Article 7, paragraph 1, following the reporting requirements of the Annex of Decision 15/CMP.1.

12.2 Summary of information reported in the SEF tables

Information on Kyoto Protocol units as reported in the SEF tables for year 2016 is summarized below.

At the beginning of 2016 there were a total of 1,057,277 CERs in entity holdings accounts. No AAUs, no ERUs, no RMUs, no tCERs, no lCERs were held in any account. At the end of 2016, a total of 167 CERs in entity holdings accounts and no AAUs, no ERUs, no RMUs, no tCERs, no lCERs were held in any account.

In 2016 the Portuguese registry received 2,346,513 CERs from other registries and transferred 3,403,623 CERs to other national registries. No external transactions involved other unit types.

In 2016 there were no other transactions and no expiry, cancellation or replacements of units. Furthermore, no corrective transactions relating to additions and subtractions, replacement or retirement occurred.

The standard electronic format (SEF) tables are presented in ANNEX C: Standard Electronic Format (SEF) tables 2016.

12.3 Discrepancies and notifications

No discrepant transactions, no CDM notifications and no non-replacements occurred in 2016 and no invalid units were registered at the end of 2016. Therefore the relevant reports (R2, R3, R4, R5) are empty and are not submitted.

12.4 Publicly Accessible Information

The front page of the Registry website displays the link (http://www.apambiente.pt/index.php?ref=77&subref=873) where the public information is available. This information is updated on a regular basis.

12.5 Calculation of the Commitment Period Reserve (CPR)

The CPR for the second commitment period is described the 2016 Portuguese Initial Report and is equal to 386,623,772.11 t CO2 equivalent.

12.6 KP-LULUCF accounting

Portugal selected accounting of the KP-LULUCF activities at the end of the commitment period.

The CRF table "accounting", includes information on accounting for activities under art. 3.3 and 3.4 of the Kyoto Protocol, based on the reporting for 2013, 2014 and 2015.

13 CHANGES IN NATIONAL SYSTEM

No major changes occurred in the national inventory system and the institutional arrangements since the 2016 submission.

14 INFORMATION ON CHANGES IN NATIONAL REGISTRY

The following changes to the national registry of Portugal have occurred in 2016:

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.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	New tables were added to the CSEUR database for the implementation of the CP2 SEF functionality. Versions of the CSEUR released after 6.7.3 (the production version at the time of the last Chapter 14 submission) introduced other minor changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model, including the new tables, is provided in Annex A. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced since version 6.7.3 of the national registry are listed in Annex B. Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was completed in January 2017 and the test report is attached No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	The mandatory use of hard tokens for authentication and signature was introduced for registry administrators.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period. The url with the list of publicly available information is https://ets-registry.webgate.ec.europa.eu/euregistry/PT/public/reports/publicReports.xhtml
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.

Reporting Item	Description
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	Changes introduced since version 6.7.3 of the national registry are listed in Annex B. 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. Annex H testing was carried out in January 2017 and the test report is attached.
The previous Annual Review recommendations	There previous annual review recommendations are not available in the UNFCCC site.

15 INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

This chapter provides information on how Portugal is implementing its commitment under Article 3, paragraph 14 of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing countries.

Portugal's contribution to the minimization of the adverse effects of climate change in other Parties, particularly developing countries, is carried out first of all through a strong commitment to implementing the Convention and the Kyoto Protocol.

By working on the implementation of the Protocol, Portugal is struggling to minimize not only the adverse effects of climate change in specific sectors, industries or other Parties, but also any adverse effects due to the reduction of greenhouse gases. This is due to the development of different actions and implementation of different instruments conceived to promote sustainable development and the commitment to support developing countries.

The policies and measures implemented, adopted or foreseen in the National Plan for Climate Change (PNAC), targeting the six GHG of the Kyoto Protocol through its broad portfolio of instruments and wide-ranging coverage of all sectors of the economy, make up a significant effort by the Portuguese Government to address climate change, including the minimization of adverse effects of such policies.

The transition to a lower carbon Portuguese economy relies on the contribution of all sectors. Particularly, the Portuguese Energy Strategy relies to a great extent in the diversification of energy sources (including those referring to fossil fuels) and to the increase of endogenous resources (renewable). In some cases, the measures pertaining to the diversification of primary energy sources (namely shifting to natural gas), can simultaneously have positive effects on Portugal's emissions reduction and in the economy of some fossil fuel exporting countries.

As a member of the EU, Portugal also pursues the minimization of adverse effects of the policies and measures in this context through the implementation of activities such as the:

EU Emissions Trading System (EU ETS): the EU's main policy mechanism for reducing CO2 emissions from energy intensive sectors;

Inclusion of aviation in the EU emission trading scheme which addresses the challenge of reducing emissions from this sector, and enables the creation of additional financial resources for climate change mitigation and adaptation in developing countries through the auction of emission allowances by member states;

EU Renewables Directive (Directive 2009/28/EC): sets ambitious targets for each member state for the share of renewable energy generation by 2020 and the proportion of renewable energy in the transport sector (includes biofuels, biogas, hydrogen and electricity from renewables);

Effort Sharing Decision (Decision 406/2009/EC) 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 developed an integrated framework of policy instruments in the 2020/2030 timeframe: the Strategic Framework for Climate Policy (QEPiC). It includes the main national policy instruments in the areas of climate change mitigation and adaptation: the National Programme for Climate Change 2020/2030 (PNAC) and the National Strategy for Adaptation to Climate Change 2020 (ENAAC).

PNAC provides the national response to the commitments made for 2020 and put forward for 2030, at national level, as regards climate change.

It establishes a National System for Policies and Measures (SPeM) and a governance, monitoring and reporting structure for the ENAAC and integrates the National System for the Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants (SNIERPA). The integration of these support mechanisms represents and articulated framework for the implementation and follow-up of the national climate policy, constituting the national reference for Monitoring, Reporting and Verification (MRV).

PNAC 2020/2030 is focused on climate change mitigation and covers all sectors of the national economy. It identifies the climate policy objectives, in line with the cost-effective emissions' reduction potential, to maintain a low carbon trajectory, consolidating the progress achieved in the past years. The PNAC sets guidelines, defines sectoral emissions reduction targets and identifies a set of policies and measures to be developed together with the relevant policy sectors in areas such as transports, energy, agriculture and forestry. The PNAC therefore features a compilation of other policy instruments (being a "plan of plans") and becomes a dynamic reference framework for the identification and definition of sectoral policies and measures, based on their ex-ante and ex-post evaluation as regards the low carbon dimension.

PNAC 2020/2030 sets the following objectives:

a) Promote the low carbon transition, generating more wealth and employment and contributing to green growth;

b) Ensure a sustainable national GHG emissions reduction trajectory to achieve the target of -18 % to -23 % in 2020 and -30 % to -40 % in 2030 compared to 2005, thus fulfilling the national mitigation commitments and keeping Portugal in line with the European objectives;

c) Mainstream mitigation objectives into sectoral policies.

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 green climate fund.

At a bilateral level, Portugal supports projects in Angola, Cabo Verde, Guiné-Bissau, Moçambique and São Tomé e Príncipe; and promotes the sectoral integration of 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.

16 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
ANAC	Portuguese Civil Aviation Authority	Autoridade Nacional da Aviação Civil
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 Betuminous Mixes Producers	Associação Portuguesa de Fabricantes de Misturas Betuminosas
AS	Ammonium Sulphate	Sulfato de Amónia
ASN	Ammonium Sulphate Nitrate	Sulfonitrato de Amónia
BAT	Best Available Technologies	-
BOD	Biochemical Oxygen Demand	Carência Bioquímica de Oxigénio
BOF	Basic Oxygen Furnace	-
CAFE	Clean Air For Europe	-
CAN	Calcium Ammonium Nitrate	Nitrato de Cálcio-amónio
CCDR-LVT	Lisbon and Tagus Valley Coordination and Regional Development Comission	Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
CELPA	Portuguese Paper Industry Association	Associação da Indústria Papeleira
CFC	Clorofluorcarbons	Clorofluorcarbonetos
CH4	Methane	Metano
CITEPA	Interprofessional Technical Center of Studies of Atmospheric Pollution	Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique
CKD	Cement Kiln Dust	-
CMN	Calcium Magnesium Nitrate	-
CN	Calcium Nitrate	Nitrato de Cálcio
CO	Carbon Monoxide	Monóxido de Carbono
CO2	Carbon Dioxide	Dióxido de Carbono ou anidrido carbónico
CO2e	Carbon dioxide equivalente	Dióxido de carbono equivalente
COD	Chemical Oxygen Demand	Carência Química de Oxigénio

CONCAWE	European Oil Company Organisation for Environment, Health and Safety	Organização para o Meio Ambiente, Saúde e Segurança das Empresas Europeias de Petróleo
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	Direção Geral de Agricultura e do Desenvolvimento Rural
DGAE (ex DGE)	General Directorate for Economic Activities	Direcção Geral das Actividades Económicas
DGAV	General Directorate for Food and Veterenary	Direção geral de Alimentação e Veterinária
DGEG (ex DGEG)	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 NH3	-
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	Agricultre and Food Planning and Policies Office (changed to GPP)	Gabinete de Planeamento e Política Agro-Alimentar
GWP	Global Warming Potential	-
H2S	Hydrogen Sulfide	Sulfureto de Hidrogénio
HCFC	Hydroclorofluorcarbons	-
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
IMT (ex. IMTT, DGV)	Institute for Mobility and Transportation	Instituto da Mobilidade e dos Transportes
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 Sea and Atmosphere 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
MA	Ministry of Environment	Ministério do Ambiente
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

Na2S	Sodium Sulphide	Sulfureto de Sódio
NaOH	Sodium Hydroxide	Hidróxido de Sódio
NAPFUE	Corinair Fuel Nomenclature	
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	-
NH3	Ammoniac	Amoníaco
NMVOC	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NOx	Nitrogen Oxides (NO + NO2)	Óxidos de Azoto (NO+NO2)
NPK	Nitrogen, Phosphorus and Potassium	Nitrogénio, Fósforo e Potássio
NSS	Normal Super Phosphates	Superfosfatos simples
NUTS (0..III)	Nomenclature of Territorial Units for Statistics	Nomenclatura de Unidades Territoriais para fins estatísticos
OD	Origin - Destiny	Origem - Destino
ODS	Ozone Depleting Substances	-
OECD	Organization for Economic Co-operation and Development	Organização para a Cooperação e Desenvolvimento Económico (OCDE)
OX	Oxidation Factor	Factor de Oxidação
PAF	Florestal Action Program	Programa de Acção Florestal
PAH	Polycyclic Aromatic Hydrocarbons	Hidrocarbonetos Aromáticos Policíclicos
PCI	Low Heating Value (LHV)	Poder Calorífico Inferior
PDM	Methodological Development Plan	Plano de Desenvolvimento Metodológico
PEN	National Energetic Program	Plano Energético Nacional
PER	Perchloro-ethylene	Percloroetileno
PERSU	Strategic Plan on Municipal Solid Wastes	Plano Estratégico dos Resíduos Sólidos Urbanos
PETROGAL	Portuguese Petroleum Company	Empresa de Petróleos de Portugal
PFC	Perfluorinated Hidrocarbons	-
PM1	Particles with Aerodynamic Diameter smaller than 1 micrometer	Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro
PM10	Particles with Aerodynamic Diameter smaller than 10 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros
PM2.5	Particles with Aerodynamic Diameter smaller than 2.5 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 2.5 micrómetros
PNAC	National Climate Change Program	Programa Nacional para as Alterações Climáticas
PNPA	National Plan for Environmental Policy	Plano Nacional da Política de Ambiente
PP	Poly Propylene	Polipropileno
PS	Poly Styrene	Poliestireno

PTEN	National Emission Ceilings Program	Programa para os Tectos de Emissão Nacional
PVC	Poly Vinyl Chloride	Cloreto de Polivinil
RA	Agricultural Region	Região Agrária
RCM	Council Minister´s Resolution	Resolução do Conselho de Ministros
REN	National Electric System	Rede Eléctrica Nacional
RVP	Reid Vapour Pressure	Pressão de Vapor de Reid
SF6	Sulphur Hexafluoride	Hexafluoreto de Enxofre
SNIERPA	National System of Inventories of Emissions and Remotions of Atmospheric Pollutants	Sistema Nacional de Inventários de Emissões e Remoções de Poluentes Atmosféricos
SOx	Sulphur Oxides	Óxidos de Enxofre
SW	Solid Wastes	Resíduos Sólidos
SWDS	Solid Waste Disposal Sites	Locais para Deposição de Resíduos Sólidos
TANKS	Software designed to estimate air emissions from organic liquids in storage tanks (USEPA, September 27, 2001)	Software criado para a estimativa de emissões atmosféricas a partir de líquidos orgânicos em tanques de armazenamento (USEPA, 27 de Setembro de 2001)
TNT	Trinitrotoluene	Trinitrotolueno
TOE	Tons of oil equivalent	Toneladas Equivalentes de Petróleo (TEP)
TOW	Total Organic Waste	Resíduo Orgânico Total
TRANSGÁS	Portuguese Company of Natural Gas	Sociedade Portuguesa de Gás Natural (Empresa)
TSP	Total Suspended Particles	Partículas Totais em Suspensão
TSS	Triple Super Phosphates	Superfosfatos Triplos
UNECE	United Nations Economic Commission for Europe	-
UNFCCC	United Nations Framework Convention on Climate Change	Convenção Quadro das Nações Unidas para as Alterações Climáticas
USEPA	United States Environmental Protection Agency	Agência de Protecção Ambiental dos Estados Unidos da América
VCM	Vinyl Chloride Monomer	Monómero de Cloreto de Vinilo
VOC	Volatile Organic Compounds	Compostos Orgânicos Voláteis
VRF	Vacuum Residual Fuel Oil	Resíduo de Alto Vácuo
WWH	Wastewater Handling	Tratamento de Águas Residuais
ZA	Agricultural Zone	Zona Agrária

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ANNEX A: Database Structure of the Consolidated European Registries (CSEUR)

File attached (Annex A - CSEUR.PDF).

ANNEX B: Changes Regarding Test Results (CSEUR)

File attached (Annex B - Changes from EUCR v7.0.1-v8.0.7.pdf).

ANNEX C: Standard Electronic Format (SEF) tables 2016

Party	Portugal
Submission Year	2017
Reported Year	2016
Commitment Period	2

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	1,057,277	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	NO	NO	NO	1,057,277	NO	NO

Party	Portugal
Submission Year	2017
Reported Year	2016
Commitment Period	2

Table 2a. Annual internal transactions

Transaction type	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Art6 issuance and conversion												
Party verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Art3.3 and 3.4 issuance or cancellation												
3.3 Afforestation reforestation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland management			NO				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
3.4 Wetland drainage and rewetting			NO				NO	NO	NO	NO		
Art 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Cancellation for reversal of storage												NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Cancellation for non submission of certification report												NO
Other cancelation												
Voluntary cancellation							NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation							NO					
Subtotal		NO	NO				NO	NO	NO	NO	NO	NO

Transaction type	Retirement					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO
Retirement from PPSR	NO					
Total	NO	NO	NO	NO	NO	NO

Table 2b. Annual external transactions

	Additions						Subtractions					
Total transfers and acquisitions	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
EU	NO	NO	NO	510	NO	NO	NO	NO	NO	3,403,623	NO	NO
CDM	NO	NO	NO	2,346,003	NO	NO	NO	NO	NO	NO	NO	NO
Subtotal	NO	NO	NO	2,346,513	NO	NO	NO	NO	NO	3,403,623	NO	NO

Table 2c. Annual transactions between PPSR accounts

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO						NO					

Table 2d. Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation Fund

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
First international transfers of AAUs	NO						NO					
Issuance of ERU from Party-verified projects		NO						NO				
Issuance of independently verified ERUs		NO						NO				

Table 2e. Total annual transactions

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of sub-totals in table 2a and table 2b)	NO	NO	NO	2,346,513	NO	NO	NO	NO	NO	3,403,623	NO	NO

Party	Portugal
Submission Year	2017
Reported Year	2016
Commitment Period	2

Table 3. Expiry, cancellation and replacement

Transaction or event type	Requirement to replace or cancel			Replacement						Cancellation					
Transaction or event type	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Temporary CERs															
Expired in retirement and replacement accounts	NO			NO	NO	NO	NO	NO							
Expired in holding accounts	NO													NO	
Long-term CERs															
Expired in retirement and replacement accounts		NO		NO	NO	NO	NO								
Expired in holding accounts		NO													NO
Subject to reversal of Storage		NO		NO	NO	NO	NO		NO						NO
Subject to non submission of certification Report		NO		NO	NO	NO	NO		NO						NO
Carbon Capture and Storage CERs															
Subject to net reversal of storage			NO							NO	NO	NO	NO		
Subject to non submission of certification report			NO							NO	NO	NO	NO		
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	Portugal
Submission Year	2017
Reported Year	2016
Commitment Period	2

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	167	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	NO	NO	NO	167	NO	NO

Party	Portugal
Submission Year	2017
Reported Year	2016
Commitment Period	2

Table 5a. Summary information on additions and subtractions

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Assigned amount units issued	NO											
Article 3 Paragraph 7 ter cancellations							NO					
Cancellation following increase in ambition							NO					
Cancellation of remaining units after carry over							NO	NO	NO	NO	NO	NO
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over		NO		NO				NO		NO		
Carry-over to PPSR	NO						NO					
Total	NO	NO		NO			NO	NO	NO	NO	NO	NO

Table 5b. Summary information on annual transactions

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	935,003	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	1,057,274	NO	NO	NO	NO	NO	935,000	NO	NO
Year 4 (2016)	NO	NO	NO	2,346,513	NO	NO	NO	NO	NO	3,403,623	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	4,338,790	NO	NO	NO	NO	NO	4,338,623	NO	NO

Table 5c. Summary information on annual transactions between PPSR accounts

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO						NO					
Year 2 (2014)	NO						NO					
Year 3 (2015)	NO						NO					
Year 4 (2016)	NO						NO					
Year 5 (2017)	NO						NO					
Year 6 (2018)	NO						NO					
Year 7 (2019)	NO						NO					
Year 8 (2020)	NO						NO					
Year 2021	NO						NO					
Year 2022	NO						NO					
Year 2023	NO						NO					
Total	NO						NO					

Table 5d. Summary information on expiry, cancellation and replacement

	Requirement to replace or cancel			Replacement						Cancellation					
	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 5e. Summary information on retirement

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO

Party	Portugal
Submission Year	2017
Reported Year	2016
Commitment Period	2

Table 6a. Memo item: corrective transactions relating to additions and subtractions

Additions						Subtractions					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6b. Memo item: corrective transactions relating to replacement

Expiry, cancellation and requirement to replace		Replacement					
tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6c. Memo item: corrective transactions relating to retirement

Retirement					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

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	2002
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	2,334
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	715,095
Fuel Sales		**NAPFUE**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Aviation Gasoline	L	209	1,985	1,847	2,192	2,179	2,086	2,280	2,280	2,869	2,258	1,268	1,168	1,333	1,257
Jet Fuel	L	207	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	1,086,001	1,139,566

Annex D Table 2– Aircraft type and representative aircraft for LTO and cruise emission factors.

Code	Aircraft Name	Fuel Type	Description	Representative	
				LTO	Cruise
100	Fokker 100	L JeK	L2J	100	100
146	BAe 146 all pax models	L JeK	L4J	146	146
310	Airbus A310 all pax models	L JeK	L2J	310	310
321	Airbus A321-100/200	L JeK	L2J	321	320
330	Airbus A330 all models	L JeK	L2J	330	330
340	Airbus A340 all models	L JeK	L4J	342	340
707	Boeing 707/720 all pax models	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
727	Boeing 727 all pax models	L JeK	L3J	727	727
737	Boeing 737 all pax models	L JeK	L2J	731	731
747	Boeing 747 all pax models	L JeK	L4J	747	741
757	Boeing 757 all pax models	L JeK	L2J	752	757
767	Boeing 767 all pax models	L JeK	L2J	767	767
777	Boeing 777 all pax models	L JeK	L2J	772	777
14F	BAe 146 Freighter (-100/200/300QT & QC)	L JeK	L4J	146	146
31F	Airbus A310 Freighter	L JeK	L2J	310	310
32S	Airbus A318/319/320/321	L JeK	L2J	320	320
70F	Boeing 707 Freighter	L JeK	L4J	70F	340
70M	Boeing 707 Combi	L JeK	L4J	707	340
72F	Boeing 727 Freighter (-100/200)	L JeK	L3J	72F	727
72M	Boeing 727 Combi	L JeK	L3J	727	727
73F	Boeing 737 all Freighter models	L JeK	L2J	731	731
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
74F	Boeing 747 all Freighter models	L JeK	L4J	74F	741
74M	Boeing 747 all Combi models	L JeK	L4J	747	741
75F	Boeing 757 Freighter	L JeK	L2J	75F	757
76F	Boeing 767 all Freighter models	L JeK	L2J	767	767
A109	Agusta A-109	L JeK	H2T	S61	NA
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
AB4	Airbus Industrie A300B2/B4/C4 pax	L JeK	L2J	AB4	310
31X	Airbus A310-200 Freighter	L JeK	L2J	312	310
319	Airbus A319	L JeK	L2J	319	320
A32	Antonov AN-32	L JeK	L2T	A32	NA
320	Airbus A320-100/200	L JeK	L2J	321	320
321	Airbus A321-100/200	L JeK	L2J	321	320
332	Airbus A330-200	L JeK	L2J	330	330
333	Airbus A330-300	L JeK	L2J	330	330
342	Airbus A340-200	L JeK	L4J	342	340
343	Airbus A340-300	L JeK	L4J	343	340
346	Airbus A340-600	L JeK	L4J	346	340
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
A660	Ayres Turbo Thrush (S-2R-T660)	L JeK	L1T	C208	C208
AA5	Gulfstream American AA-5 Traveler	L AvG	L1P	AA5	DHO
AB3	Airbus Industrie A300 pax	L JeK	L2J	AB3	310
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
ABB	Airbus Industrie A300-600ST Beluga Freighter	L JeK	L2J	AB6	310
ABF	Airbus Industrie A300 Freighter	L JeK	L2J	AB3	310
AC11	Rockwell Commander	L AvG	L1P	C150	DHO
ACT	Gulfstream/Rockwell (Aero) Turbo Commander	L JeK	L2T	ACT	NA
ACD	Gulfstream/Rockwell (Aero) Commander/Turbo Commander	L JeK	L2T	ACD	NA
AEST	Aerostar 600	L AvG	L2P	AEST	DHO
AJET	Dassault Alpha Jet	L JeK	L2J	FA10	S20
ALO3	Aerospatiale Alouette 3	L JeK	H1T	ALO3	NA
ANF	Antonov AN-12	L JeK	L4T	ANF	NA

A26	Antonov AN-26	L JeK	L2T	A26	AN6
AN4	Antonov AN-24	L JeK	L2T	AN4	NA
AN6	Antonov AN-26 / AN-30 /AN-32	L JeK	L2T	A26	AN6
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
APH	Eurocopter (Aerospatiale) SA330 Puma / AS332 Super Puma	L JeK	H2T	S61	NA
ARJ	Avro RJ70 / RJ85 / RJ100 Avroliner	L JeK	L4J	ARJ	146
AS32	Aerospatiale Super Puma	L JeK	H2T	S61	NA
AS50	Aerospatiale Fennec (AS-550)	L JeK	H1T	S61	NA
AS65	Aerospatiale Dolphin (AS-366)	L JeK	H2T	AS65	NA
ASTR	IAI Gulfstream G100	L JeK	L2J	WWP	S20
AT3	AIDC AT-3 Tzu-Chung	L JeK	L2J	AT3	NA
AT43	Aerospatiale/Alenia ATR 42-300 / 320	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5T	Air Tractor AT-502	L JeK	L1T	C208	C208
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT8T	Air Tractor AT-802 Fire Boss	L JeK	L1T	C208	NA
ATP	British Aerospace ATP	L JeK	L2T	ATR	AT42
ATR	Aerospatiale/Alenia ATR 42/ ATR 72	L JeK	L2T	ATR	AT42
B06	Agusta AB-206 LongRanger	L JeK	H1T	S61	NA
MBH	Eurocopter (MBB) Bo.105	L JeK	H2T	S61	NA
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
B12	British Aerospace (BAC) One Eleven 200	L JeK	L2J	B12	B11
BES	Beechcfrat 1900/1900C	L JeK	L2T	BE1	BE1
B200	Beech 200 Super King Air	L JeK	L2T	BE20	BE20
B350	Beech Super King Air 350	L JeK	L2T	BE30	B350
B412	Bell 412	LJeK	H1T	BH2	NA
B36T	Allison 36 Turbine Bonanza	L JeK	L1T	C208	C208
70M	Boeing 707 Combi	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
B72	Boeing 720B pax	L JeK	L4J	B72	NA
72X	Boeing 727-100 Freighter	L JeK	L3J	721	727
72S	Boeing 727-200 Advanced pax	L JeK	L3J	722	727
731	Boeing 737-100 pax	L JeK	L2J	731	731
73M	Boeing 737-200 Combi	L JeK	L2J	732	731
73Y	Boeing 737-300 Freighter	L JeK	L2J	733	731
735	Boeing 737-500 pax	L JeK	L2J	735	734
B735	Boeing 737-500	L JeK	L2J	735	734
736	Boeing 737-600 pax	L JeK	L2J	736	734
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
73H	Boeing 737-800 (winglets) pax	L JeK	L2J	73H	734
739	Boeing 737-900 pax	L JeK	L2J	739	734
741	Boeing 747-100 pax	L JeK	L4J	741	741
74C	Boeing 747-200 Combi	L JeK	L4J	742	741
74U	Boeing 747-300 / 747-200 SUD Freighter	L JeK	L4J	743	741
74J	Boeing 747-400 (Domestic) pax	L JeK	L4J	744	74J
B74S	Boeing 747SP	L JeK	L4J	B74S	741
B74R	Boeing 747SR	LJeK	L4J	74V	741
75M	Boeing 757 Mixed Configuration	L JeK	L2J	752	757
753	Boeing 757-300 pax	L JeK	L2J	752	757
76X	Boeing 767-200 Freighter	L JeK	L2J	762	767
76Y	Boeing 767-300 Freighter	L JeK	L2J	763	767
764	Boeing 767-400 pax	L JeK	L2J	764	767
772	Boeing 777-200 pax	L JeK	L2J	772	777
773	Boeing 777-300 pax	L JeK	L2J	773	777

B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
BE1	Beechcraft 1900/1900C/1900D	L JeK	L2T	BE1	BE1
BE10	Beech King Air 100	L JeK	L2T	BE10	B350
BE18	Beech 18	L AvG	L2P	BE18	DHO
BE19	Beech 19 Sport	L AvG	L1P	BE19	DHO
BE2	Beechcraft twin piston engines	L AvG	L2P	BE55	DHO
BE20	Beech Huron	L JeK	L2T	BE20	BE20
BE30	Beech Super King Air 300	L JeK	L2T	BE30	B350
BE33	Beech Bonanza 33	L AvG	L1P	BE33	DHO
BE35	Beech Bonanza 35	L AvG	L1P	BE33	DHO
BE36	Beech Bonanza 36	L AvG	L1P	BE33	DHO
BE4	Beech Beechjet	L JeK	L2J	BE40	LOH
BE40	Beech Beechjet	L JeK	L2J	BE40	LOH
BE55	Beech Baron	L AvG	L2P	BE55	DHO
BE58	Beech Baron 58	L AvG	L2P	BE55	DHO
BE76	Beech Duchess	L AvG	L2P	BE55	DHO
BE95	Beech 95 Travel Air	LJeK	L2T	BE10	B350
BE9L	Beech King Air 90	L JeK	L2T	BE10	B350
BEC	Beechcraft light aircraft	L AvG	L1P	BE19	DHO
BEH	Beechcraft 1900D	L JeK	L2T	BE1	BE1
BEP	Beechcraft light aircraft - single engine	L AvG	L1P	BE19	DHO
BET	Beechcraft light aircraft - twin turboprop engine	L JeK	L2T	BE20	BE1
BH2	Bell Helicopters	L JeK	H1T	BH2	NA
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
C130	Lockheed Hercules	L JeK	L4T	C130	LOH
C150	Cessna 150	L AvG	L1P	C150	DHO
C160	Transall C-160	L JeK	L2T	C160	NA
C17	Boeing Globemaster 3	L JeK	L4J	C17	NA
C172	Cessna 172 Mescalero	L AvG	L1P	C150	DHO
C177	Cessna 177 Cardinal	L AvG	L1P	C150	DHO
C182	Cessna 182 Skylane	L AvG	L1P	C150	DHO
C185	Cessna 185 Skywagon	L AvG	L1P	C150	DHO
C206	Cessna 206 Stationair	L AvG	L1P	C150	DHO
C208	Cessna 208 Caravan	L JeK	L1T	C208	C208
C210	Cessna 210 Centurion	L AvG	L1P	C150	DHO
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
C303	Cessna T303 Crusader	L AvG	L2P	C404	DHO
C310	Cessna 310	L AvG	L2P	C337	DHO
C337	Cessna 337 Super Skymaster	L AvG	L2P	C337	DHO
C402	Cessna 402 Businessliner	L AvG	L2P	C404	DHO
C404	Cessna 402 Titan	L AvG	L2P	C404	DHO
C414	Cessna 414 Chancellor	L AvG	L2P	C404	DHO
C421	Cessna 421 Executive Commuter	L AvG	L2P	C404	DHO
C425	Cessna 425 Conquest	L JeK	L2T	C425	NA
C441	Cessna 441 Conquest	L JeK	L2T	C441	NA
C500	Cessna 500 Citation	L JeK	L2J	C500	DHO
C501	Cessna 501 Citation 1SP	L JeK	L2J	C500	DHO
C510	Cessna Citation Muatang	LJeK	L2J	C500	DHO
C525	Cessna 525 Citation	L JeK	L2J	C500	DHO
C550	Cessna 550 Citation 2	L JeK	L2J	C550	DHO
C551	Cessna 551 Citation 2SP	L JeK	L2J	C551	DHO
C560	Cessna 560 Citation 5	L JeK	L2J	C560	S20
C56X	Cessna 560XL Citation Excel	L JeK	L2J	C560	S20
C650	Cessna 650 Citation 3	L JeK	L2J	C680	SH6
C680	Cessna 680 Citation Sovereign	L JeK	L2J	C680	SH6
C750	Cessna 750 Citation 10	L JeK	L2J	C750	F50
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ

CL4	Canadair CL-44	L JeK	L4T	CL4	F28
CL30	BD-100 Challenge	LJeK	L2J	CL30	NA
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CN2	Cessna light aircraft - twin piston engines	L AvG	L2P	C404	DHO
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CNA	Cessna light aircraft	0	0	C150	DHO
CNJ	Cessna Citation	L JeK	L2J	C500	DHO
CNT	Cessna light aircraft - twin turboprop engines	L JeK	L2T	CNT	NA
CRJ	Canadair Regional Jet	L JeK	L2J	CR1	FRJ
CRV	Aerospatiale (Sud Aviation) Se.210 Caravelle	L JeK	L2J	CRV	D94
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CVF	Convair CV-240 / 440 / 580 / 600 / 640 Freighter	L JeK	L2T	CVF	NA
CVY	Convair CV-580 / 600 / 640 Freighter	L JeK	L2T	CVY	BE1
CVR	Convair CV-240 / 440 / 580 / 600 / 640 pax	L JeK	L2T	CVR	NA
D10	Douglas DC-10 pax	L JeK	L3J	D10	D10
D1F	Douglas DC-10 all Freighters	L JeK	L3J	D10	D10
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D8F	Douglas DC-8 all Freighters	L JeK	L4J	D8T	340
D8M	Douglas DC-8 all Combi models	L JeK	L4J	DC8	340
D9F	Douglas DC-9 all Freighters	L JeK	L2J	D9F	D91
D1X	Douglas DC-10-10 Freighter	L JeK	L3J	D11	D10
DC3T	Douglas DC-3	L JeK	L2T	DC3T	NA
DC8	Douglas DC-8 all pax models	L JeK	L4J	DC8	340
D8T	Douglas DC-8-50 Freighter	L JeK	L4J	D8T	340
D8L	Douglas DC-8-62 pax	L JeK	L4J	D8X	340
D8Y	Douglas DC-8-71 / 72 / 73 Freighters	L JeK	L4J	D8Y	340
DC9	Douglas DC-9 all pax models	L JeK	L2J	DC9	D91
DF3	Dassault (Breguet Mystere) Falcon 50 / 900	L JeK	L3J	FA50	F50
DFL	Dassault (Breguet Mystere) Falcon	0	0	FA10	S20
DHR	De Havilland Canada DHC-2 Turbo-Beaver	L AvG	L1P	DHB	DHO
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DH8	De Havilland Canada DHC-8 Dash 8 all models	L JeK	L2T	DH8	DH8
DH1	De Havilland Canada DHC-8-100 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH3	De Havilland Canada DHC-8-300 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH4	De Havilland Canada DHC-8-400 Dash 8Q	L JeK	L2T	DH8	DH8
DHB	De Havilland Canada DHC-2 Beaver / Turbo Beaver	L AvG	L1P	DHB	DHO
DHP	De Havilland Canada DHC-2 Beaver	L AvG	L1P	DHB	DHO
DHS	De Havilland Canada DHC-3 Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DHO	De Havilland Canada DHC-3 Otter / Turbo Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DR40	Robin DN-400	L AvG	L1P	C150	DHO
EMB	Embraer EMB.110 Bandeirnate	L JeK	L2T	EMB	EMB
EM2	Embraer EMB.120 Brasilia	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 Brasilia	L JeK	L2T	EM2	NA
EMB	Embraer EMB.110 Bandeirnate	L JeK	L2T	EMB	EMB
EMJ	Embraer 170/190	L JeK	L2J	EMJ	FRJ
ERJ	Embraer RJ135 / RJ140 / RJ145	L JeK	L2J	ERJ	ERJ
100	Fokker 100	L JeK	L2J	100	100

F16	Lockheed F-16 Fighting Falcon	L JeK	L1J	F16	NA
F27	Fairchild FH.227	L JeK	L2T	FK7	NA
F28	Fokker F.28 Fellowship 3000	L JeK	L2J	F24	F28
F2TH	Dassault Falcon 2000	L JeK	L2J	F2TH	NA
F406	Cessna F406 Caravan 2	L JeK	L2T	F406	F406
F50	Fokker 50	L JeK	L2T	F50	F50
F70	Fokker 70	L JeK	L2J	F70	NA
F900	Dassault Falcon 900	L JeK	L3J	F900	F50
FA10	Dassault Falcon 10	L JeK	L2J	FA10	S20
FA20	Dassault Falcon 20	L JeK	L2J	FA20	S20
FA50	Dassault Falcon 50	L JeK	L3J	FA50	F50
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
GALX	IAI Galaxi	L JeK	L2J	WWP	S20
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ
GLF2	Grumman Gulfstream 2	L JeK	L2J	GLF3	NA
GLF3	Grumman Gulfstream 3	L JeK	L2J	GLF3	NA
GLF4	Grumman Gulfstream 4	L JeK	L2J	GLF4	NA
GLF5	Grumman Gulfstream 5	L JeK	L2J	GLF5	NA
GRG	Grumman G.21 Goose	L AvG	A2P	GRG	B350
GRJ	Gulfstream Aerospace G-1159 Gulfstream II / III / IV / V	L JeK	L2J	GLF3	NA
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25B	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H60	Sikorsky Black Hawk	L JeK	H2T	S61	NA
HS7	Hawker Siddeley HS.748	L JeK	L2T	HS7	FRJ
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL8	Ilyushin IL18	L JeK	L4T	IL8	NA
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
ILW	Ilyushin IL86	L JeK	L4J	ILW	340
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
J41	British Aerospace Jetstream 41	L JeK	L2T	J41	J41
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
L10	Lockheed L-1011 Tristar pax	L JeK	L3J	L10	D10
L11	Lockheed L-1011 1 / 50 / 100 / 150 / 200 / 250 Tristar pax	L JeK	L3J	L10	D10
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
L1F	Lockheed L-1011 Tristar Freighter	L JeK	L3J	L10	D10
L29	Aero (2) L-29 Delfin	L JeK	L1J	F16	NA
L4T	LET 410	L JeK	L2T	L4T	NA
LJ31	Learjet 31	L JeK	L2J	LJ31	S20
LJ35	Learjet 35	L JeK	L2J	LJ35	S20
LJ40	Learjet 40	LJeK	L2J	LJ35	S20
LJ45	Learjet 45	L JeK	L2J	LJ35	S20
LJ60	Learjet 60	L JeK	L2J	LJ35	S20
LOE	Lockheed L-188 Electra pax	L JeK	L4T	LOE	NA
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
LOH	Lockheed L-182 / 282 / 382 (L-100) Hercules	L JeK	L4T	C130	LOH
LOM	Lockheed L-188 Electra Mixed Configuration	L JeK	L4T	LOM	NA
LRJ	Gates Learjet	L JeK	L2J	LJ23	S20
LYNX	Westland Lynx	L JeK	H2T	S61	NA
M11	McDonnell Douglas MD11 pax	L JeK	L3J	M11	D10
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10

M1M	McDonnell Douglas MD11 Mixed Configuration	L JeK	L3J	M11	D10
M20P	Mooney M-20	L AvG	L1P	M20P	DHO
M20T	Mooney TLS	L AvG	L1P	M20P	DHO
M80	McDonnell Douglas MD80	L JeK	L2J	M81	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M82	McDonnell Douglas MD82	L JeK	L2J	M82	M82
M83	McDonnell Douglas MD83	L JeK	L2J	M83	M82
M88	McDonnell Douglas MD88	L JeK	L2J	M88	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MU2	Mitsubishi Mu-2	L JeK	L2T	MU2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
NDC	Aerospatiale SN.601 Corvette	L JeK	L2J	NDC	DHO
P180	Piaggio P-180 Avanti	L JeK	L2T	P180	B350
P28A	Piper Archer 2	L AvG	L1P	P28A	DHO
PN6	Partenavia P.68	L AvG	L2P	PN6	DHO
PA18	Piper Super Club	L AvG	L1P	PA18	DHO
PA2	Piper light aircraft - twin piston engines	L AvG	L2P	PA31	DHO
PA24	Piper Comanche	L AvG	L1P	PA24	DHO
PA27	Piper Aztec	L AvG	L1P	PA27	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA31	Piper Navajo	L AvG	L2P	PA31	DHO
PA32	Piper Saratoga	L AvG	L1P	PA32	DHO
PA34	Piper Seneca	L AvG	L2P	PA44	DHO
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
PUM A	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
TOB A	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
WG3 0	Westland WG-30	L JeK	H2T	S61	NA
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK5	Yakovlev Yak 50	L AvG	L1P	C150	DHO
100	Fokker 100	L JeK	L2J	100	100
146	BAe 146 all pax models	L JeK	L4J	146	146
310	Airbus A310 all pax models	L JeK	L2J	310	310
321	Airbus A321-100/200	L JeK	L2J	321	320
330	Airbus A330 all models	L JeK	L2J	330	330
340	Airbus A340 all models	L JeK	L4J	342	340
707	Boeing 707/720 all pax models	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
727	Boeing 727 all pax models	L JeK	L3J	727	727
737	Boeing 737 all pax models	L JeK	L2J	731	731
747	Boeing 747 all pax models	L JeK	L4J	747	741
757	Boeing 757 all pax models	L JeK	L2J	752	757
767	Boeing 767 all pax models	L JeK	L2J	767	767
777	Boeing 777 all pax models	L JeK	L2J	772	777
14F	BAe 146 Freighter (-100/200/300QT & QC)	L JeK	L4J	146	146
31F	Airbus A310 Freighter	L JeK	L2J	310	310
32S	Airbus A318/319/320/321	L JeK	L2J	320	320
70F	Boeing 707 Freighter	L JeK	L4J	70F	340
70M	Boeing 707 Combi	L JeK	L4J	707	340
72F	Boeing 727 Freighter (-100/200)	L JeK	L3J	72F	727
72M	Boeing 727 Combi	L JeK	L3J	727	727
73F	Boeing 737 all Freighter models	L JeK	L2J	731	731
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
74F	Boeing 747 all Freighter models	L JeK	L4J	74F	741
74M	Boeing 747 all Combi models	L JeK	L4J	747	741
75F	Boeing 757 Freighter	L JeK	L2J	75F	757
76F	Boeing 767 all Freighter models	L JeK	L2J	767	767
A109	Agusta A-109	L JeK	H2T	S61	NA
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
AB4	Airbus Industrie A300B2/B4/C4 pax	L JeK	L2J	AB4	310
31X	Airbus A310-200 Freighter	L JeK	L2J	312	310
319	Airbus A319	L JeK	L2J	319	320
A32	Antonov AN-32	L JeK	L2T	A32	NA

320	Airbus A320-100/200	L JeK	L2J	321	320
321	Airbus A321-100/200	L JeK	L2J	321	320
332	Airbus A330-200	L JeK	L2J	330	330
333	Airbus A330-300	L JeK	L2J	330	330
342	Airbus A340-200	L JeK	L4J	342	340
343	Airbus A340-300	L JeK	L4J	343	340
346	Airbus A340-600	L JeK	L4J	346	340
A4F	Antonov AN-124 Ruslan	L JeK	L4J	A4F	340
A660	Ayres Turbo Thrush (S-2R-T660)	L JeK	L1T	C208	C208
AA5	Gulfstream American AA-5 Traveler	L AvG	L1P	AA5	DHO
AB3	Airbus Industrie A300 pax	L JeK	L2J	AB3	310
AB6	Airbus Industrie A300-600 pax	L JeK	L2J	AB6	310
ABB	Airbus Industrie A300-600ST Beluga Freighter	L JeK	L2J	AB6	310
ABF	Airbus Industrie A300 Freighter	L JeK	L2J	AB3	310
AC11	Rockwell Commander	L AvG	L1P	C150	DHO
ACT	Gulfstream/Rockwell (Aero) Turbo Commander	L JeK	L2T	ACT	NA
ACD	Gulfstream/Rockwell (Aero) Commander/Turbo Commander	L JeK	L2T	ACD	NA
AEST	Aerostar 600	L AvG	L2P	AEST	DHO
AJET	Dassault Alpha Jet	L JeK	L2J	FA10	S20
ALO3	Aerospatiale Alouette 3	L JeK	H1T	ALO3	NA
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
A26	Antonov AN-26	L JeK	L2T	A26	AN6
AN4	Antonov AN-24	L JeK	L2T	AN4	NA
AN6	Antonov AN-26 / AN-30 /AN-32	L JeK	L2T	A26	AN6
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
AN7	Antonov AN-72 / AN-74	L JeK	L2J	AN7	F27
ANF	Antonov AN-12	L JeK	L4T	ANF	NA
APH	Eurocopter (Aerospatiale) SA330 Puma / AS332 Super Puma	L JeK	H2T	S61	NA
ARJ	Avro RJ70 / RJ85 / RJ100 Avroliner	L JeK	L4J	ARJ	146
AS32	Aerospatiale Super Puma	L JeK	H2T	S61	NA
AS50	Aerospatiale Fennec (AS-550)	L JeK	H1T	S61	NA
AS65	Aerospatiale Dolphin (AS-366)	L JeK	H2T	AS65	NA
ASTR	IAI Gulfstream G100	L JeK	L2J	WWP	S20
AT3	AIDC AT-3 Tzu-Chung	L JeK	L2J	AT3	NA
AT43	Aerospatiale/Alenia ATR 42-300 / 320	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5	Aerospatiale/Alenia ATR 42-500	L JeK	L2T	ATR	AT42
AT5T	Air Tractor AT-502	L JeK	L1T	C208	C208
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT7	Aerospatiale/Alenia ATR 72	L JeK	L2T	ATR	AT7
AT8T	Air Tractor AT-802 Fire Boss	L JeK	L1T	C208	NA
ATP	British Aerospace ATP	L JeK	L2T	ATR	AT42
ATR	Aerospatiale/Alenia ATR 42/ ATR 72	L JeK	L2T	ATR	AT42
B06	Agusta AB-206 LongRanger	L JeK	H1T	S61	NA
MBH	Eurocopter (MBB) Bo.105	L JeK	H2T	S61	NA
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
B12	British Aerospace (BAC) One Eleven 200	L JeK	L2J	B12	B11
BES	Beechcfrat 1900/1900C	L JeK	L2T	BE1	BE1
B200	Beech 200 Super King Air	L JeK	L2T	BE20	BE20
B350	Beech Super King Air 350	L JeK	L2T	BE30	B350
B412	Bell 412	LJeK	H1T	BH2	NA
B36T	Allison 36 Turbine Bonanza	L JeK	L1T	C208	C208
70M	Boeing 707 Combi	L JeK	L4J	707	340
717	Boeing 717	L JeK	L2J	717	NA
B72	Boeing 720B pax	L JeK	L4J	B72	NA
72X	Boeing 727-100 Freighter	L JeK	L3J	721	727
72S	Boeing 727-200 Advanced pax	L JeK	L3J	722	727

731	Boeing 737-100 pax	L JeK	L2J	731	731
73M	Boeing 737-200 Combi	L JeK	L2J	732	731
73Y	Boeing 737-300 Freighter	L JeK	L2J	733	731
735	Boeing 737-500 pax	L JeK	L2J	735	734
B735	Boeing 737-500	L JeK	L2J	735	734
736	Boeing 737-600 pax	L JeK	L2J	736	734
73W	Boeing 737-700 (winglets) pax	L JeK	L2J	73W	734
73H	Boeing 737-800 (winglets) pax	L JeK	L2J	73H	734
739	Boeing 737-900 pax	L JeK	L2J	739	734
741	Boeing 747-100 pax	L JeK	L4J	741	741
74C	Boeing 747-200 Combi	L JeK	L4J	742	741
74U	Boeing 747-300 / 747-200 SUD Freighter	L JeK	L4J	743	741
74J	Boeing 747-400 (Domestic) pax	L JeK	L4J	744	74J
B74S	Boeing 747SP	L JeK	L4J	B74S	741
B74R	Boeing 747SR	LJeK	L4J	74V	741
75M	Boeing 757 Mixed Configuration	L JeK	L2J	752	757
753	Boeing 757-300 pax	L JeK	L2J	752	757
76X	Boeing 767-200 Freighter	L JeK	L2J	762	767
76Y	Boeing 767-300 Freighter	L JeK	L2J	763	767
764	Boeing 767-400 pax	L JeK	L2J	764	767
772	Boeing 777-200 pax	L JeK	L2J	772	777
773	Boeing 777-300 pax	L JeK	L2J	773	777
B11	British Aerospace (BAC) One Eleven / RomBAC One Eleven	L JeK	L2J	B11	B11
BE1	Beechcraft 1900/1900C/1900D	L JeK	L2T	BE1	BE1
BE10	Beech King Air 100	L JeK	L2T	BE10	B350
BE18	Beech 18	L AvG	L2P	BE18	DHO
BE19	Beech 19 Sport	L AvG	L1P	BE19	DHO
BE2	Beechcraft twin piston engines	L AvG	L2P	BE55	DHO
BE20	Beech Huron	L JeK	L2T	BE20	BE20
BE30	Beech Super King Air 300	L JeK	L2T	BE30	B350
BE33	Beech Bonanza 33	L AvG	L1P	BE33	DHO
BE35	Beech Bonanza 35	L AvG	L1P	BE33	DHO
BE36	Beech Bonanza 36	L AvG	L1P	BE33	DHO
BE4	Beech Beechjet	L JeK	L2J	BE40	LOH
BE40	Beech Beechjet	L JeK	L2J	BE40	LOH
BE55	Beech Baron	L AvG	L2P	BE55	DHO
BE58	Beech Baron 58	L AvG	L2P	BE55	DHO
BE76	Beech Duchess	L AvG	L2P	BE55	DHO
BE95	Beech 95 Travel Air	LJeK	L2T	BE10	B350
BE9L	Beech King Air 90	L JeK	L2T	BE10	B350
BEC	Beechcraft light aircraft	L AvG	L1P	BE19	DHO
BEH	Beechcraft 1900D	L JeK	L2T	BE1	BE1
BEP	Beechcraft light aircraft - single engine	L AvG	L1P	BE19	DHO
BET	Beechcraft light aircraft - twin turboprop engine	L JeK	L2T	BE20	BE1
BH2	Bell Helicopters	L JeK	H1T	BH2	NA
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
BNI	Pilatus Britten-Norman BN-2A/B Islander	L AvG	L2P	BNI	DHO
C130	Lockheed Hercules	L JeK	L4T	C130	LOH
C150	Cessna 150	L AvG	L1P	C150	DHO
C160	Transall C-160	L JeK	L2T	C160	NA
C17	Boeing Globemaster 3	L JeK	L4J	C17	NA
C172	Cessna 172 Mescalero	L AvG	L1P	C150	DHO
C177	Cessna 177 Cardinal	L AvG	L1P	C150	DHO
C182	Cessna 182 Skylane	L AvG	L1P	C150	DHO
C185	Cessna 185 Skywagon	L AvG	L1P	C150	DHO
C206	Cessna 206 Stationair	L AvG	L1P	C150	DHO
C208	Cessna 208 Caravan	L JeK	L1T	C208	C208
C210	Cessna 210 Centurion	L AvG	L1P	C150	DHO
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA

C303	Cessna T303 Crusader	L AvG	L2P	C404	DHO
C310	Cessna 310	L AvG	L2P	C337	DHO
C337	Cessna 337 Super Skymaster	L AvG	L2P	C337	DHO
C402	Cessna 402 Businessliner	L AvG	L2P	C404	DHO
C404	Cessna 402 Titan	L AvG	L2P	C404	DHO
C414	Cessna 414 Chancellor	L AvG	L2P	C404	DHO
C421	Cessna 421 Executive Commuter	L AvG	L2P	C404	DHO
C425	Cessna 425 Conquest	L JeK	L2T	C425	NA
C441	Cessna 441 Conquest	L JeK	L2T	C441	NA
C500	Cessna 500 Citation	L JeK	L2J	C500	DHO
C501	Cessna 501 Citation 1SP	L JeK	L2J	C500	DHO
C510	Cessna Citation Muatang	LJeK	L2J	C500	DHO
C525	Cessna 525 Citation	L JeK	L2J	C500	DHO
C550	Cessna 550 Citation 2	L JeK	L2J	C550	DHO
C551	Cessna 551 Citation 2SP	L JeK	L2J	C551	DHO
C560	Cessna 560 Citation 5	L JeK	L2J	C560	S20
C56X	Cessna 560XL Citation Excel	L JeK	L2J	C560	S20
C650	Cessna 650 Citation 3	L JeK	L2J	C680	SH6
C680	Cessna 680 Citation Sovereign	L JeK	L2J	C680	SH6
C750	Cessna 750 Citation 10	L JeK	L2J	C750	F50
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ
CL4	Canadair CL-44	L JeK	L4T	CL4	F28
CL30	BD-100 Challenge	LJeK	L2J	CL30	NA
CCJ	Canadair Challenger	L JeK	L2J	CCJ	AN6
CN2	Cessna light aircraft - twin piston engines	L AvG	L2P	C404	DHO
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CNA	Cessna light aircraft	0	0	C150	DHO
CNJ	Cessna Citation	L JeK	L2J	C500	DHO
CNT	Cessna light aircraft - twin turboprop engines	L JeK	L2T	CNT	NA
CRJ	Canadair Regional Jet	L JeK	L2J	CR1	FRJ
CRV	Aerospatiale (Sud Aviation) Se.210 Caravelle	L JeK	L2J	CRV	D94
CS2	CASA / IPTN 212 Aviocar	L JeK	L2T	CS2	NA
CS5	CASA / IPTN CN-235	L JeK	L2T	CS5	NA
CVF	Convair CV-240 / 440 / 580 / 600 / 640 Freighter	L JeK	L2T	CVF	NA
CVY	Convair CV-580 / 600 / 640 Freighter	L JeK	L2T	CVY	BE1
CVR	Convair CV-240 / 440 / 580 / 600 / 640 pax	L JeK	L2T	CVR	NA
D10	Douglas DC-10 pax	L JeK	L3J	D10	D10
D1F	Douglas DC-10 all Freighters	L JeK	L3J	D10	D10
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D28	Fairchild Dornier Do.228	L JeK	L2T	D28	BE20
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D38	Fairchild Dornier Do.328	L JeK	L2T	FRJ	FRJ
D8F	Douglas DC-8 all Freighters	L JeK	L4J	D8T	340
D8M	Douglas DC-8 all Combi models	L JeK	L4J	DC8	340
D9F	Douglas DC-9 all Freighters	L JeK	L2J	D9F	D91
D1X	Douglas DC-10-10 Freighter	L JeK	L3J	D11	D10
DC3T	Douglas DC-3	L JeK	L2T	DC3T	NA
DC8	Douglas DC-8 all pax models	L JeK	L4J	DC8	340
D8T	Douglas DC-8-50 Freighter	L JeK	L4J	D8T	340
D8L	Douglas DC-8-62 pax	L JeK	L4J	D8X	340
D8Y	Douglas DC-8-71 / 72 / 73 Freighters	L JeK	L4J	D8Y	340
DC9	Douglas DC-9 all pax models	L JeK	L2J	DC9	D91
DF3	Dassault (Breguet Mystere) Falcon 50 / 900	L JeK	L3J	FA50	F50
DFL	Dassault (Breguet Mystere) Falcon	0	0	FA10	S20
DHR	De Havilland Canada DHC-2 Turbo-Beaver	L AvG	L1P	DHB	DHO
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DH8	De Havilland Canada DHC-8 Dash 8 all models	L JeK	L2T	DH8	DH8
DH1	De Havilland Canada DHC-8-100 Dash 8 / 8Q	L JeK	L2T	DH8	DH8
DH3	De Havilland Canada DHC-8-300 Dash 8 / 8Q	L JeK	L2T	DH8	DH8

DH4	De Havilland Canada DHC-8-400 Dash 8Q	L JeK	L2T	DH8	DH8
DHB	De Havilland Canada DHC-2 Beaver / Turbo Beaver	L AvG	L1P	DHB	DHO
DHP	De Havilland Canada DHC-2 Beaver	L AvG	L1P	DHB	DHO
DHS	De Havilland Canada DHC-3 Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DH7	De Havilland Canada DHC-7 Dash 7	L JeK	L4T	DH7	DH7
DHO	De Havilland Canada DHC-3 Otter / Turbo Otter	L AvG	L1P	DHB	DHO
DHT	De Havilland Canada DHC-6 Twin Otter	L JeK	L2T	DHT	B350
DR40	Robin DN-400	L AvG	L1P	C150	DHO
EMB	Embraer EMB.110 Bandeirnate	L JeK	L2T	EMB	EMB
EM2	Embraer EMB.120 Brasilia	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 Brasilia	L JeK	L2T	EM2	NA
EMB	Embraer EMB.110 Bandeirnate	L JeK	L2T	EMB	EMB
EMJ	Embraer 170/190	L JeK	L2J	EMJ	FRJ
ERJ	Embraer RJ135 / RJ140 / RJ145	L JeK	L2J	ERJ	ERJ
100	Fokker 100	L JeK	L2J	100	100
F16	Lockheed F-16 Fighting Falcon	L JeK	L1J	F16	NA
F27	Fairchild FH.227	L JeK	L2T	FK7	NA
F28	Fokker F.28 Fellowship 3000	L JeK	L2J	F24	F28
F2TH	Dassault Falcon 2000	L JeK	L2J	F2TH	NA
F406	Cessna F406 Caravan 2	L JeK	L2T	F406	F406
F50	Fokker 50	L JeK	L2T	F50	F50
F70	Fokker 70	L JeK	L2J	F70	NA
F900	Dassault Falcon 900	L JeK	L3J	F900	F50
FA10	Dassault Falcon 10	L JeK	L2J	FA10	S20
FA20	Dassault Falcon 20	L JeK	L2J	FA20	S20
FA50	Dassault Falcon 50	L JeK	L3J	FA50	F50
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
GALX	IAI Galaxi	L JeK	L2J	WWP	S20
CCX	Canadair Global Express	L JeK	L2J	CR7	FRJ
GLF2	Grumman Gulfstream 2	L JeK	L2J	GLF3	NA
GLF3	Grumman Gulfstream 3	L JeK	L2J	GLF3	NA
GLF4	Grumman Gulfstream 4	L JeK	L2J	GLF4	NA
GLF5	Grumman Gulfstream 5	L JeK	L2J	GLF5	NA
GRG	Grumman G.21 Goose	L AvG	A2P	GRG	B350
GRJ	Gulfstream Aerospace G-1159 Gulfstream II / III / IV / V	L JeK	L2J	GLF3	NA
GRS	Gulfstream Aerospace G-159 Gulfstream I	L JeK	L2T	GRS	NA
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H25B	British Aerospace (Hawker Siddeley) HS-125	L JeK	L2J	H25	S20
H60	Sikorsky Black Hawk	L JeK	H2T	S61	NA
HS7	Hawker Siddeley HS.748	L JeK	L2T	HS7	FRJ
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL6	Ilyushin IL62	L JeK	L4J	IL6	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL7	Ilyushin IL76	L JeK	L4J	IL7	340
IL8	Ilyushin IL18	L JeK	L4T	IL8	NA
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
IL9	Ilyushin IL96 pax	L JeK	L4J	IL9	340
ILW	Ilyushin IL86	L JeK	L4J	ILW	340
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
FRJ	Fairchild Dornier 328JET	L JeK	L2J	FRJ	FRJ

J41	British Aerospace Jetstream 41	L JeK	L2T	J41	J41
J31	British Aerospace Jetstream 31	L JeK	L2T	J31	J31
L10	Lockheed L-1011 Tristar pax	L JeK	L3J	L10	D10
L11	Lockheed L-1011 1 / 50 / 100 / 150 / 200 / 250 Tristar pax	L JeK	L3J	L10	D10
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
L1F	Lockheed L-1011 Tristar Freighter	L JeK	L3J	L10	D10
L29	Aero (2) L-29 Delfin	L JeK	L1J	F16	NA
L4T	LET 410	L JeK	L2T	L4T	NA
LJ31	Learjet 31	L JeK	L2J	LJ31	S20
LJ35	Learjet 35	L JeK	L2J	LJ35	S20
LJ40	Learjet 40	LJeK	L2J	LJ35	S20
LJ45	Learjet 45	L JeK	L2J	LJ35	S20
LJ60	Learjet 60	L JeK	L2J	LJ35	S20
LOE	Lockheed L-188 Electra pax	L JeK	L4T	LOE	NA
LOF	Lockheed L-188 Electra Freighter	L JeK	L4T	LOF	NA
LOH	Lockheed L-182 / 282 / 382 (L-100) Hercules	L JeK	L4T	C130	LOH
LOM	Lockheed L-188 Electra Mixed Configuration	L JeK	L4T	LOM	NA
LRJ	Gates Learjet	L JeK	L2J	LJ23	S20
LYNX	Westland Lynx	L JeK	H2T	S61	NA
M11	McDonnell Douglas MD11 pax	L JeK	L3J	M11	D10
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M1M	McDonnell Douglas MD11 Mixed Configuration	L JeK	L3J	M11	D10
M20P	Mooney M-20	L AvG	L1P	M20P	DHO
M20T	Mooney TLS	L AvG	L1P	M20P	DHO
M80	McDonnell Douglas MD80	L JeK	L2J	M81	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
M1F	McDonnell Douglas MD11 Freighter	L JeK	L3J	M11	D10
M82	McDonnell Douglas MD82	L JeK	L2J	M82	M82
M83	McDonnell Douglas MD83	L JeK	L2J	M83	M82
M88	McDonnell Douglas MD88	L JeK	L2J	M88	M82
M90	McDonnell Douglas MD90	L JeK	L2J	M90	M82
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MIH	MIL Mi-8 / Mi-17 / Mi-171 / Mil-172	L JeK	H2T	S61	NA
MU2	Mitsubishi Mu-2	L JeK	L2T	MU2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
ND2	Aerospatiale (Nord) 262	L JeK	L2T	ND2	NA
NDC	Aerospatiale SN.601 Corvette	L JeK	L2J	NDC	DHO
P180	Piaggio P-180 Avanti	L JeK	L2T	P180	B350
P28A	Piper Archer 2	L AvG	L1P	P28A	DHO
PN6	Partenavia P.68	L AvG	L2P	PN6	DHO
PA18	Piper Super Club	L AvG	L1P	PA18	DHO
PA2	Piper light aircraft - twin piston engines	L AvG	L2P	PA31	DHO
PA24	Piper Comanche	L AvG	L1P	PA24	DHO
PA27	Piper Aztec	L AvG	L1P	PA27	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA3	Piper Twin Comanche	L AvG	L2P	PA31	DHO
PA31	Piper Navajo	L AvG	L2P	PA31	DHO
PA32	Piper Saratoga	L AvG	L1P	PA32	DHO
PA34	Piper Seneca	L AvG	L2P	PA44	DHO
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

PUM A	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
TOB A	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
WG3 0	Westland WG-30	L JeK	H2T	S61	NA
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
WWP	Israel Aircraft Industries 1124 Westwind	L JeK	L2J	WWP	S20
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK4	Yakovlev Yak 40	L JeK	L3J	YK4	NA
YK2	Yakovlev Yak 42	L JeK	L3J	YK2	NA
YK5	Yakovlev Yak 50	L AvG	L1P	C150	DHO

Annex D Table 3 – 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	2002
Gasoline	L	208	1,376,217	1,513,827	1,690,627	1,781,289	1,828,767	1,885,861	1,935,188	1,923,621	1,990,008	2,013,486	2,052,007	1,932,893	2,029,090
Diesel	L	205	1,603,658	1,665,579	1,769,092	1,822,672	1,965,847	2,110,210	2,269,116	2,513,347	2,998,556	3,240,566	3,759,009	3,976,418	4,029,320
LPG	L	303	21	56	98	109	117	289	1,799	17,321	19,794	23,862	22,329	21,653	21,213
CNG	G	302	0	0	0	0	0	0	0	0	0	0	648	4,287	6,616
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel		NAPFUE	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gasoline	L	208	1,967,402	1,889,720	1,791,425	1,669,150	1,562,258	1,483,025	1,454,631	1,379,957	1,243,253	1,132,122	1,091,901	1,091,475	1,079,326
Diesel	L	205	4,065,129	4,121,935	4,147,187	4,290,841	4,272,991	4,270,954	4,281,060	4,287,166	4,022,401	3,691,647	3,622,111	3,721,710	3,779,888
LPG	L	303	20,484	18,869	20,935	22,356	23,218	25,865	30,309	28,950	30,127	31,856	33,421	33,519	35,804
CNG	G	302	8,643	8,517	9,572	9,508	10,527	11,004	10,934	11,459	11,493	10,946	11,315	11,058	11,923
Biodiesel	B	223	0	0	0	65,776	128,777	127,573	218,216	321,397	313,020	286,604	275,214	276,123	321,320

Annex D Table 4 – 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	2002
Coal	S	102	845	456	583	482	502	185	255	0	0	0	0	0	77
Coke	S	108	252	168	168	84	84	28	56	0	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	1,522,420
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Coal	S	102	0	0	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	0
Diesel-oil	L	204	1,316,850	1,192,991	1,110,181	1,020,949	1,029,964	1,088,146	746,675	634,969	553,578	451,450	407,744	428,733	407,020
Biodiesel	B	223	0	0	0	13,593	26,433	27,117	32,394	40,730	36,878	29,941	26,464	27,078	29,700

Other Sectors (CRF 1.A.4)

Annex D Table 5 – Activity data for CRF 1.A.4.a: Fuel consumption in the commercial, services and institutional sector (GJ).

Fuel		NAPFUE	1990	1991	1992	1995	1996	1997	1998	1999	2000	2001	2002
Residual Oil	L	203	2,377,775	2,082,473	1,987,019	4,274,308	3,304,671	1,388,428	2,838,261	3,440,598	3,314,158	3,449,183	3,534,234
Diesel/Gas Oil	L	204	5,639,815	6,917,498	8,280,078	7,888,815	8,726,269	13,105,635	16,719,028	18,351,231	18,391,384	21,956,952	24,194,942
Kerosene	L	206	74,919	33,396	64,201	13,467	12,685	25,068	27,142	17,200	6,137	7,572	9,494
Gasoline	L	208	579,621	638,690	617,687	1,174,935	1,419,347	2,593,860	3,262,569	3,219,051	2,217,473	2,854,812	2,486,947
LPG	L	303	1,198,048	1,373,765	1,580,371	1,268,113	2,562,028	3,836,555	4,010,705	4,233,884	4,414,101	5,206,806	5,113,787
City Gas	L	308	504,399	556,773	528,075	732,803	785,507	777,866	908,944	1,044,085	732,238	69,195	0
Natural Gas	G	301	0	0	0	0	0	15,786	563,881	1,593,080	2,579,983	4,042,999	5,152,623
Wood	B	111	0	0	0	0	0	0	0	0	0	0	0
Biogas	B	309	0	0	0	0	0	0	0	37,572	76,912	41,033	45,650
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2003	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015
Residual Oil	L	203	2,907,217	3,152,344	3,182,777	2,220,557	1,905,882	2,672,347	1,385,221	1,030,689	850,701	768,683	1,218,547
Diesel/Gas Oil	L	204	29,771,236	33,061,615	28,690,066	12,587,334	12,101,443	4,807,532	3,312,792	2,680,918	2,454,310	2,659,231	1,720,719
Kerosene	L	206	7,344	7,216	6,334	1,298	5,191	879	2,219	2,177	4,103	84	2,386
Gasoline	L	208	2,364,277	2,426,561	1,637,165	28,471	27,801	37,473	2,177	0	0	0	0
LPG	L	303	5,287,262	5,413,453	4,806,060	5,143,317	4,804,021	2,146,848	1,927,378	1,919,549	1,958,653	3,135,595	3,383,577
City Gas	L	308	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	G	301	6,020,765	6,592,309	6,494,120	8,545,510	10,053,470	10,731,187	11,091,210	12,311,704	12,384,387	12,315,682	12,423,534
Wood	B	111	0	0	0	0	0	0	2,532,762	1,463,891	1,462,176	1,679,456	1,302,845
Biogas	B	309	36,551	76,039	102,253	130,750	135,839	157,677	166,930	146,480	170,539	104,655	91,330
Biodiesel	B	223	0	0	0	128,950	190,896	51,132	52,967	39,371	51,243	72,825	26,866

Annex D Table 6 – Activity data for CRF 1.A.4.b: Fuel consumption in the residential sector (GJ).

Fuel		NAPFUE	1990	1991	1992	1995	1996	1997	1998	1999	2000	2001	2002
Residual Oil	L	203	63,570	62,136	55,570	42,592	43,339	40,296	10,922	3,883	2,596	0	0
Diesel/Gas Oil	L	204	158,313	210,952	285,685	201,062	132,690	91,954	106,045	144,312	90,483	82,460	120,375
Kerosene	L	206	793,847	753,503	626,435	356,029	416,128	728,737	761,963	705,693	365,545	194,522	147,927
Gasoline	L	208	6,189	7,791	5,904	9,584	13,758	14,908	14,701	6,081	773	93	24,864
LPG	L	303	23,458,865	24,712,407	26,379,429	28,700,786	30,988,266	30,036,100	31,626,170	33,487,398	34,345,777	31,576,352	31,565,739
City Gas	L	308	1,923,876	1,950,110	1,984,435	1,929,958	1,977,160	1,991,632	2,106,088	2,039,388	1,212,913	156,763	0
Natural Gas	G	301	0	0	0	0	0	35,408	400,760	1,506,342	3,192,297	4,927,459	6,165,244
Wood	B	111	53,770,921	51,344,184	49,611,501	48,033,473	48,172,943	46,841,627	45,510,311	44,178,995	42,847,679	41,516,363	40,185,047
Charcoal	B	112	749,950	738,791	727,632	694,155	682,996	671,837	660,678	626,132	591,586	557,041	522,495
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2003	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015
Residual Oil	L	203	0	0	0	0	0	0	0	0	0	0	0
Diesel/Gas Oil	L	204	380,360	667,243	600,226	332,928	395,815	5,191,318	3,670,468	2,726,117	2,516,862	2,407,177	2,269,440
Kerosene	L	206	89,834	88,654	50,117	28,678	22,398	27,213	26,711	18,463	19,803	11,178	7,871
Gasoline	L	208	36,183	37,371	57	0	0	0	0	0	0	0	0
LPG	L	303	30,542,812	30,029,737	29,312,438	22,777,808	21,795,551	23,214,739	20,873,374	19,522,514	18,948,048	17,170,849	15,889,364
City Gas	L	308	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	G	301	6,647,494	7,618,313	8,394,267	11,924,258	11,103,017	12,571,537	10,851,181	10,839,207	10,415,042	10,852,311	11,049,300
Wood	B	111	38,853,731	37,522,415	36,191,099	32,197,151	30,865,835	29,534,519	31,507,615	31,522,887	32,256,276	32,080,962	31,922,552
Charcoal	B	112	487,949	453,404	418,858	315,221	280,675	246,130	246,130	246,130	246,130	246,130	246,130
Biodiesel	B	223	0	0	0	1	41	26,859	710	2,921	76	69	2,616

Annex D Table 7 – 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	1995	1996	1997	1998	1999	2000	2001	2002
Residual Oil	L	203	524,617	376,193	286,335	426,845	511,483	547,071	474,723	677,941	889,643	799,840	1,207,470
Kerosene	L	206	350,338	311,043	272,158	191,157	183,421	427,000	494,010	24,166	44,397	47,082	50,284
Gasoline	L	208	33,650	35,681	47,407	129,648	162,646	197,586	174,417	159,737	42,723	119,538	106,820
LPG	L	303	329,856	405,427	478,962	572,444	826,953	560,179	713,861	674,638	496,882	673,259	639,651
Natural Gas	G	301	0	0	0	0	0	0	36	174	4,897	213,356	284,851
Biogas	B	309	0	0	0	0	0	0	0	0	9,294	7,773	5,939

Fuel		NAPFUE	2003	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015
Residual Oil	L	203	1,083,548	405,069	858,912	199,621	99,477	153,402	172,535	46,849	33,703	36,048	53,674
Kerosene	L	206	47,237	48,915	54,581	38,935	45,173	39,019	30,395	33,493	29,516	24,785	25,538
Gasoline	L	208	116,977	117,435	208,555	36,091	32,407	24,033	13,147	16,203	24,619	14,780	27,717
LPG	L	303	532,506	523,451	541,228	362,700	296,549	308,858	271,637	267,660	214,446	194,350	222,317
Natural Gas	G	301	292,066	295,599	325,872	305,260	370,699	423,872	486,213	516,693	570,870	305,385	327,408
Biogas	B	309	6,344	11,122	29,039	13,766	19,833	23,013	24,686	18,787	16,527	15,774	12,929

Annex D Table 8 – 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	2002
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	11,433,231
Biodiesel	B	223	0	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Diesel/Gas Oil	L	204	9,133,707	8,703,013	12,775,956	12,053,442	11,905,304	11,241,230	10,005,353	9,649,630	9,487,624	9,624,560	9,945,778	10,013,090	10,040,638
Biodiesel	B	223	0	0	0	159,969	307,367	280,546	433,071	618,948	631,782	637,571	644,970	632,545	732,572

Annex D Table 9 – Activity data for CRF 1.A.4.c.iii: Fuels consumption in fisheries (excluding consumption in fishing vessels) (GJ).

Fuel		NAPFUE	1990	1991	1992	1995	1996	1997	1998	1999	2000	2001	2002
Residual Oil	L	203	4,004	5,415	7,458	12,145	5,132	8,888	6,383	49,680	6,483	18,055	28,129
Diesel/Gas Oil	L	204	99,086	95,355	84,795	84,915	64,556	209,384	597,882	0	1,081,354	2,179,005	1,097,824
Kerosene	L	206	7	0	7	0	0	0	2,652	74,960	10,079	94	47
Gasoline	L	208	1,406	0	214	707	985	728	4,040	61,587	279,165	286,314	280,882
LPG	L	303	2,847	5,792	4,077	0	110	3,902	2,531	8,434	20,809	32,648	21,140
Natural Gas	G	301	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

Fuel		NAPFUE	2003	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015
Residual Oil	L	203	25,341	0	0	48,147	0	91,830	47,735	84,842	44,785	95,603	35,958
Diesel/Gas Oil	L	204	596,445	568,387	587,681	519,123	0	649,478	913,983	932,934	1,059,745	1,116,035	1,539,689
Kerosene	L	206	47	320	15	0	0	0	0	0	0	0	0
Gasoline	L	208	278,706	260,910	29,919	5,569	30,062	21,060	18,255	4,145	11,305	5,317	4,899
LPG	L	303	20,708	91,294	5,903	5,778	3,014	1,675	461	209	0	0	293
Natural Gas	G	301	0	0	0	2,010	3,098	4,396	4,145	2,219	16,789	23,739	22,441
Biodiesel	B	223	0	0	0	70,531	112,475	195,569	218,127	221,762	228,854	195,612	242,260

Annex D Table 10 – 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	2002
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	0
Thick Fuel-oil	L	204	0	0	0	0	413,200	96,000	24,000	22,400	42,240	21,120	0	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	6,446,147
NATO's Nafta	L	208	0	0	0	0	0	0	0	0	0	0	0	0	0

Fuel		NAPFUE	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Thin Fuel-oil	L	203	0	0	0	0	0	0	0	0	22,014	18,018	52,026	66,026	149,898
Thick Fuel-oil	L	204	0	0	0	0	0	0	714,669	765,555	717,098	9,158	0	0	0
Diesel/Gas Oil	L	206	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	4,236,519	3,785,012
NATO's Nafta	L	208	0	0	0	0	0	0	0	0	0	0	0	0	0

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

Annex D Table 11 – 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	2002
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	939
Fuel		**NAPFUE**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Jet Fuel	L	207	749	570	1,025	1,064	1,026	1,200	1,205	1,208	1,086	683	822	961	1,065

ANNEX E: Energy Balance Sheet for 2015

BALANÇO ENERGÉTICO tep		Hulha e Antracite	Coque de Carvão	**Total de Carvão**	Petróleo Bruto	Refugos e Produtos Intermédios	GPL	Gasolinas	Petróleos	Jets	Gasóleo	Fuelóleo	Nafta	Coque de Petróleo	**Total de Petróleo Energético**	Lubrificantes	Asfaltos	Parafinas	Solventes	Outros	**Total de Petróleo Não Energético**	**Total de Petróleo**	**Gás Natural**
2015 (provisório)		1	2	3 = 1+ 2	4	5	6	7	8	9	10	11	12	13	14 = 4 a 13	15	16	17	18	19	20 = 15 a 19	21= 14 + 20	22
IMPORTAÇÕES	1.	3 313 150	5 586	**3 318 736**	14 360 476	1 258 229	814 275	143 752	948	10 796	795 950	260 748	64 141	296 791	**18 006 106**	42 800	115 859	4 394	128		**163 181**	**18 169 287**	**4 081 859**
PRODUÇÃO DOMÉSTICA	2.																						
VARIAÇÃO DE "STOCKS"	3.	- 49 958	- 29	**- 49 987**	125 016	106 950	- 1 099	1 051			71 225	- 70 700		- 53 032	**179 411**	- 19 061	4 482	- 913	990	- 18 479	**- 32 981**	**146 430**	**- 15 428**
SAÍDAS	4.	110 032	41	**110 073**		151 843	79 347	1 876 984		1 048 263	2 434 858	2 136 441	430 521		**8 158 257**	122 780	89 628	6 137	16 462	182 476	**417 483**	**8 575 740**	
Exportações	*4.1*	*110 032*	*41*	*110 073*		*151 843*	*79 347*	*1 876 984*		*1 867*	*2 323 761*	*1 608 181*	*430 521*		*6 472 504*	*122 182*	*89 628*	*6 137*	*16 462*	*182 476*	*416 885*	*6 889 389*	
Transportes Marítimos Internacionais	*4.2*										*111 097*	*528 260*			*639 357*	*598*					*598*	*639 955*	
Aviação Internacional	*4.3*									*1 046 396*					*1 046 396*							*1 046 396*	
CONSUMO DE ENERGIA PRIMÁRIA	5.	3 253 076	5 574	**3 258 650**	14 235 460	999 436	736 027	-1 734 283	948	-1 037 467	-1 710 133	-1 804 993	- 366 380	349 823	**9 668 438**	- 60 919	21 749	- 830	- 17 324	- 163 997	**- 221 321**	**9 447 117**	**4 097 287**
PARA NOVAS FORMAS DE ENERGIA	6.	3 245 793		**3 245 793**	14 229 583	328 487	- 191 901	-2 860 762	- 357	-1 191 797	-6 538 354	-2 112 740	-1 057 454		**604 705**	- 111 775	- 155 993	- 12 478	- 26 656	- 203 047	**- 509 949**	**94 757**	**2 375 600**
Briquetes	*6.1*																						
Coque	*6.2*																						
Produtos de Petróleo	*6.3*				*14 229 583*	*470 191*	*- 191 901*	*-2 860 762*	*- 357*	*-1 191 797*	*-6 562 879*	*-2 385 838*	*-1 303 056*		*203 184*	*- 111 775*	*- 155 993*	*- 12 478*	*- 26 656*	*- 203 047*	*- 509 948*	*- 306 764*	
Hidrogénio	*6.4*																						*244 500*
Petroquímica	*6.5*					*- 173 530*							*245 602*		*72 072*							*72 072*	
Eletricidade	*6.6*	*3 245 793*		*3 245 793*							*24 446*	*152 965*			*177 411*							*177 411*	*900 039*
Cogeração	*6.7*					*31 826*					*79*	*120 133*			*152 038*							*152 038*	*1 231 061*
Produção de Eletricidade	*6.7.1*										*53*	*45 986*			*46 039*							*46 039*	
Refinação de Petróleo	*6.7.2*					*31826*									*31826*							*31826*	*406 532*
Gás de Cidade	*6.7.3*																						
Agricultura	*6.7.4*																						*4 020*
Alimentação, bebidas e tabaco	*6.7.5*											*9 735*			*9 735*							*9 735*	*84 193*
Têxteis	*6.7.6*										*5*				*5*							*5*	*117 749*
Papel e Artigos de Papel	*6.7.7*										*3*	*28 551*			*28 554*							*28 554*	*396 306*
Químicas e Plásticos	*6.7.8*											*23 136*			*23 136*							*23 136*	*63 735*
Cerâmicas	*6.7.9*																						*30 963*
Vidro e Artigos de Vidro	*6.7.10*																						
Cimento e Cal	*6.7.11*																						*3 244*
Metalúrgicas	*6.7.12*																						
Siderurgia	*6.7.13*																						
Vestuário, Calçado e Curtumes	*6.7.14*																						*7 941*
Madeira e Artigos de Madeira	*6.7.15*										*18*	*12 725*			*12 743*							*12 743*	
Borracha	*6.7.16*																						*15 518*
Metalo-eletro-mecânicas	*6.7.17*																						*2 516*
Outras Indústrias Transformadoras	*6.7.18*																						*1 844*
Indústrias Extrativas	*6.7.19*																						*23 868*
Serviços	*6.7.20*																						*72 632*

BALANÇO ENERGÉTICO tep 2015 (provisório)		Hulha e Antracite 1	Coque de Carvão 2	**Total de Carvão** 3 = 1+ 2	Petróleo Bruto 4	Refugos e Produtos Intermédios 5	GPL 6	Gasolinas 7	Petróleos 8	Jets 9	Gasóleo 10	Fuelóleo 11	Nafta 12	Coque de Petróleo 13	**Total de Petróleo Energético** 14 = 4 a 13	Lubrificantes 15	Asfaltos 16	Parafinas 17	Solventes 18	Outros 19	**Total de Petróleo Não Energético** 20 = 15 a 19	**Total de Petróleo** 21= 14 + 20	**Gás Natural** 22
CONSUMO DO SECTOR ENERGÉTICO	7.				5 877	670 949	1 527		215		56	120 195	353		**799 172**	1 887	- 386	67	50	21	**1 639**	**800 811**	**133 589**
Consumo Próprio da Refinação	*7.1*					*658 300*	*1 264*				*40*	*120 195*			*779 799*	*26*					*26*	*779 825*	*125 430*
Perdas da Refinação	*7.2*				*5 877*	*12 649*	*258*		*215*				*353*		*19 352*	*242*	*- 386*	*67*	*50*		*- 27*	*19 325*	
Coquerie e outras não especificadas	*7.3*																						
Centrais Elétricas	*7.4*															*1 617*					*1 617*	*1 617*	
Bombagem Hidroelétrica	*7.5*																						
Extração de Carvão, Petróleo e Gás Natural	*7.6*															*2*					*2*	*2*	*6*
Perdas de Transporte e Distribuição	*7.7*						*5*				*16*				*21*					*21*	*21*	*42*	*8 153*
CONSUMO COMO MATÉRIA PRIMA	8.						*354 928*						*690 721*		*1 045 649*							*1 045 649*	
DISPONÍVEL PARA CONSUMO FINAL	9.	7 283	5 574	**12 857**			571 473	1 126 479	1 090	154 330	4 828 165	187 552		349 823	**7 218 912**	48 969	178 128	11 581	9 282	39 029	**286 989**	**7 505 900**	**1 588 098**
ACERTOS		- 352	- 358	- 710			851	- 9 956	197	4 948	- 31 150	25 635		1 350	- 8 125	2 257	553	135	391	3 103	6 439	- 1 687	- 29 750
CONSUMO FINAL	10.	7 635	5 932	**13 567**			570 622	1 136 435	893	149 382	4 859 315	161 917		348 473	**7 227 037**	46 712	177 575	11 446	8 891	35 926	**280 550**	**7 507 587**	**1 617 848**
AGRICULTURA E PESCAS	10.1						5 317	779	610		345 078	3 931			**355 715**	242					**242**	**355 957**	4 336
Agricultura	*10.1.1*						*5 310*	*662*	*610*		*257 316*	*1 282*			*265 180*	*93*					*93*	*265 273*	*3 800*
Pescas	*10.1.2*						*7*	*117*			*87 762*	*2 649*			*90 535*	*149*					*149*	*90 684*	*536*
INDÚSTRIAS EXTRATIVAS	10.2	41		**41**			1 308				33 429	525			**35 262**	1 066					**1 066**	**36 328**	**4 057**
INDÚSTRIAS TRANSFORMADORAS	10.3	7 594	5 932	**13 526**			56 121	27	35		113 265	65 993		348 473	**583 914**	10 071	3 748	11 399	8 837	35 926	**69 981**	**653 895**	**1 093 825**
Alimentação, bebidas e tabaco	*10.3.1*						*17 747*		*6*		*31 756*	*27 837*			*77 346*	*362*					*362*	*77 708*	*145 649*
Têxteis	*10.3.2*						*2 751*				*1 761*	*2 124*			*6 636*	*849*					*849*	*7 485*	*115 997*
Papel e Artigos de Papel	*10.3.3*						*2 008*		*7*		*4 790*	*27 851*			*34 656*	*310*				*11 646*	*11 956*	*46 612*	*101 904*
Químicas e Plásticos	*10.3.4*						*2 424*		*2*		*2 338*	*3 802*			*8 566*	*1 559*	*3 748*	*7 398*	*8 588*	*24 280*	*45 573*	*54 139*	*137 143*
Cerâmicas	*10.3.5*						*3 563*		*2*		*3 852*			*10 680*	*18 097*	*102*					*102*	*18 199*	*194 943*
Vidro e Artigos de Vidro	*10.3.6*						*117*				*1 109*	*47*			*1 273*	*176*					*176*	*1 449*	*208 503*
Cimento e Cal	*10.3.7*						*624*		*2*		*20 086*	*117*		*337 793*	*358 622*	*223*					*223*	*358 845*	*33 275*
Metalúrgicas	*10.3.8*		*4 414*	*4 414*			*2 413*				*1 041*				*3 454*	*388*			*1*		*389*	*3 843*	*20 098*
Siderurgia	*10.3.9*	*7 425*	*1 371*	*8 796*			*76*				*1 644*				*1 720*	*352*			*1*		*353*	*2 073*	*51 348*
Vestuário, Calçado e Curtumes	*10.3.10*						*2 998*		*1*		*3 427*	*2 050*			*8 476*	*41*			*2*		*43*	*8 519*	*13 197*
Madeira e Artigos de Madeira	*10.3.11*						*1 677*				*7 076*	*444*			*9 197*	*372*		*3 473*			*3 845*	*13 042*	*7 834*
Borracha	*10.3.12*						*146*				*107*				*253*	*2 024*		*456*	*1*		*2 481*	*2 734*	*3 796*
Metalo-eletro-mecânicas	*10.3.13*	*26*	*106*	*132*			*17 083*	*27*	*13*		*8 050*	*370*			*25 543*	*2 856*		*46*	*80*		*2 982*	*28 525*	*54 379*
Outras Indústrias Transformadoras	*10.3.14*	*143*	*41*	*184*			*2 494*		*2*		*26 228*	*1 351*			*30 075*	*457*		*26*	*164*		*647*	*30 722*	*5 759*
CONSTRUÇÃO E OBRAS PÚBLICAS	10.4						8 208		3		84 534	14 235			**106 980**	1 542	173 827		44		**175 413**	**282 393**	**14 533**
TRANSPORTES	10.5						39 338	1 135 629		123 938	4 187 000	48 128			**5 534 033**	31 763					**31 763**	**5 565 796**	**13 090**
Aviação Nacional	*10.5.1*							*1 321*		*123 938*					*125 259*	*2*					*2*	*125 261*	
Transportes Marítimos Nacionais	*10.5.2*							*44*			*49 904*	*48 128*			*98 076*	*292*					*292*	*98 368*	
Caminho de Ferro	*10.5.3*										*10 431*				*10 431*							*10 431*	
Rodoviários	*10.5.4*						*39 338*	*1 134 264*			*4 126 665*				*5 300 267*	*31 469*					*31 469*	*5 331 736*	*13 090*
SETOR DOMÉSTICO	10.6						379 514		188		54 268				**433 970**							**433 970**	**263 908**
SERVIÇOS	10.7						80 816		57	25 444	41 741	29 105			**177 163**	2 028		47	10		**2 085**	**179 248**	**224 099**

BALANÇO ENERGÉTICO tep 2015 (provisório)		Gases Incond. de Petroquímica 23	Hidrogénio 24	**Outros Gases Derivados** 25 = 23 + 24	Hidro-eletricidade 26	Eólica 27	Foto-voltaica 28	Geo-térmica 29	Termo-eletricidade 30	**Total de Eletricidade** 31	**Calor** 32	Resíduos Não Renováveis 33	Solar Térmico 34	Lenhas e Resíduos Vegetais 35	Resíduos Sólidos Urbanos 36	Licores Sulfitivos 37	Outros Renováveis 38	Biogás 39	Biocombus-tíveis 40	**Renováveis Sem Eletricidade** 41= 34 a 40	**TOTAL GERAL** 42=3+21+22+25+31+32+33+41
IMPORTAÇÕES	1.									**694 664**		33 609		58 349			18 036		67 675	**144 060**	26 442 215
PRODUÇÃO DOMÉSTICA	2.				842 760	998 257	68 469	17 507		**1 926 993**		132 917	80 267	1 595 773	97 388	983 554	22 563	82 580	320 678	**3 182 803**	**5 242 713**
VARIAÇÃO DE "STOCKS"	3.																		6 955	**6 955**	**87 970**
SAÍDAS	4.									**499 781**				317 265					34 529	**351 794**	**9 537 388**
Exportações	*4.1*									*499 781*				*317 265*					*34 529*	*351 794*	*7 851 037*
Transportes Marítimos Internacionais	*4.2*																				*639 955*
Aviação Internacional	*4.3*																				*1 046 396*
CONSUMO DE ENERGIA PRIMÁRIA	5.				*842 760*	*998 257*	*68 469*	*17 507*		**2 121 876**		166 526	80 267	1 336 857	97 388	983 554	40 599	82 580	346 869	**2 968 114**	**22 059 570**
PARA NOVAS FORMAS DE ENERGIA	6.				*842 760*	*998 257*	*68 469*	*17 507*	-2 581 188	**-2 581 188**	**-1 397 727**	111 462		437 270	97 388	983 554		74 556	342 954	**1 935 722**	**3 784 419**
Briquetes	*6.1*																				
Coque	*6.2*																				
Produtos de Petróleo	*6.3*		*201 918*	*201 918*															*342 954*	*342 954*	*238 108*
Hidrogénio	*6.4*		*- 201 918*	*- 201 918*																	*42 582*
Petroquímica	*6.5*	*- 72 072*		*- 72 072*																	
Eletricidade	*6.6*				*842 760*	*998 257*	*68 469*	*17 507*	*-1 963 936*	*-1 963 936*		*97 388*		*298 276*	*97 388*			*70 565*		*466 229*	*2 922 924*
Cogeração	*6.7*	*72 072*		*72 072*					*- 617 252*	*- 617 252*	*-1 397 727*	*14 074*		*138 994*		*983 554*		*3 991*		*1 126 539*	*580 805*
Produção de Eletricidade	*6.7.1*								*- 16 591*	*- 16 591*	*- 836*										*28 612*
Refinação de Petróleo	*6.7.2*								*- 129 293*	*- 129 293*	*- 211 409*										*97 656*
Gás de Cidade	*6.7.3*																				
Agricultura	*6.7.4*								*- 1 772*	*- 1 772*	*- 1 599*							*309*		*309*	*958*
Alimentação, bebidas e tabaco	*6.7.5*								*- 26 383*	*- 26 383*	*- 47 493*										*20 052*
Têxteis	*6.7.6*								*- 47 309*	*- 47 309*	*- 39 927*										*30 518*
Papel e Artigos de Papel	*6.7.7*								*- 304 423*	*- 304 423*	*- 935 962*			*114 309*		*983 554*				*1 097 863*	*282 338*
Químicas e Plásticos	*6.7.8*	*72 072*		*72 072*					*- 28 373*	*- 28 373*	*- 77 534*	*11 724*									*64 760*
Cerâmicas	*6.7.9*								*- 10 116*	*- 10 116*	*- 15 675*										*5 172*
Vidro e Artigos de Vidro	*6.7.10*																				
Cimento e Cal	*6.7.11*								*- 1 360*	*- 1 360*	*- 1 016*										*868*
Metalúrgicas	*6.7.12*																				
Siderurgia	*6.7.13*																				
Vestuário, Calçado e Curtumes	*6.7.14*								*- 2 926*	*- 2 926*	*- 2 429*										*2 586*
Madeira e Artigos de Madeira	*6.7.15*								*- 6 882*	*- 6 882*	*- 12 340*			*24 685*						*24 685*	*18 206*
Borracha	*6.7.16*								*- 3 935*	*- 3 935*	*- 10 521*	*2 350*									*3 412*
Metalo-eletro-mecânicas	*6.7.17*								*- 1 073*	*- 1 073*	*- 666*										*777*
Outras Indústrias Transformadoras	*6.7.18*								*- 1 617*	*- 1 617*	*- 865*							*2 695*		*2 695*	*2 057*
Indústrias Extrativas	*6.7.19*								*- 8 022*	*- 8 022*	*- 11 738*										*4 108*
Serviços	*6.7.20*								*- 27 177*	*- 27 177*	*- 27 717*							*987*		*987*	*18 725*

BALANÇO ENERGÉTICO tep 2015 (provisório)		Gases Incond. de Petroquímica 23	Hidrogénio 24	**Outros Gases Derivados** 25 = 23 + 24	Hidro-eletricidade 26	Eólica 27	Foto-voltaica 28	Geo-térmica 29	Termo-eletricidade 30	**Total de Eletricidade** 31	**Calor** 32	Resíduos Não Renováveis 33	Solar Térmico 34	Lenhas e Resíduos Vegetais 35	Resíduos Sólidos Urbanos 36	Licores Sulfitivos 37	Outros Renováveis 38	Biogás 39	Biocombus-tíveis 40	**Renováveis Sem Eletricidade** 41= 34 a 40	**TOTAL GERAL** 42=3+21+22+25+31+32+33+41
CONSUMO DO SECTOR ENERGÉTICO	7.									**763 057**	**211 409**										**1 908 866**
Consumo Próprio da Refinação	*7.1*									*75 026*	*211 409*										*1 191 690*
Perdas da Refinação	*7.2*																				*19 325*
Coquerie e outras não especificadas	*7.3*									*4*											*4*
Centrais Elétricas	*7.4*									*139 947*											*141 564*
Bombagem Hidroelétrica	*7.5*									*126 316*											*126 316*
Extração de Carvão, Petróleo e Gás Natural	*7.6*									*610*											*618*
Perdas de Transporte e Distribuição	*7.7*									*421 154*											*429 349*
CONSUMO COMO MATÉRIA PRIMA	8.																				*1 045 649*
DISPONÍVEL PARA CONSUMO FINAL	9.									**3 940 007**	**1 186 318**	55 064	80 267	899 587			40 599	8 024	3 915	**1 032 392**	**15 320 636**
ACERTOS										20									303	303	- 31 824
CONSUMO FINAL	10.									**3 939 987**	**1 186 318**	55 064	80 267	899 587			40 599	8 024	3 612	**1 032 089**	**15 352 460**
AGRICULTURA E PESCAS	10.1									**73 597**	**1 599**			2 667					**3**	**2 670**	**438 159**
Agricultura	*10.1.1*									*69 749*	*1 599*			*2 667*					*1*	*2 668*	*343 089*
Pescas	*10.1.2*									*3 848*									*2*	*2*	*95 070*
INDÚSTRIAS EXTRATIVAS	10.2									**54 297**	**11 738**										**106 461**
INDÚSTRIAS TRANSFORMADORAS	10.3									**1 262 978**	**1 145 264**	**55 064**		**102 679**			**39 082**	8 024	**278**	**150 063**	**4 374 615**
Alimentação, bebidas e tabaco	*10.3.1*									*159 404*	*47 493*			*27 572*				*1 258*		*28 830*	*459 084*
Têxteis	*10.3.2*									*90 921*	*39 927*			*2 099*						*2 099*	*256 429*
Papel e Artigos de Papel	*10.3.3*									*261 989*	*935 962*			*19 930*			*455*	*6 766*		*27 151*	*1 373 618*
Químicas e Plásticos	*10.3.4*									*182 214*	*77 534*	*54*		*1 075*					*278*	*1 353*	*452 437*
Cerâmicas	*10.3.5*									*33 414*	*15 675*			*17 887*						*17 887*	*280 118*
Vidro e Artigos de Vidro	*10.3.6*									*44 326*											*254 278*
Cimento e Cal	*10.3.7*									*72 841*	*1 016*	*55 010*		*7 395*			*38 627*			*46 022*	*567 009*
Metalúrgicas	*10.3.8*									*20 583*				*2*						*2*	*48 940*
Siderurgia	*10.3.9*									*108 652*											*170 869*
Vestuário, Calçado e Curtumes	*10.3.10*									*23 578*	*2 429*			*1 870*						*1 870*	*49 593*
Madeira e Artigos de Madeira	*10.3.11*									*44 920*	*12 340*			*23 662*						*23 662*	*101 798*
Borracha	*10.3.12*									*18 639*	*10 521*			*467*						*467*	*36 157*
Metalo-eletro-mecânicas	*10.3.13*									*169 382*	*666*			*548*						*548*	*253 632*
Outras Indústrias Transformadoras	*10.3.14*									*32 115*	*1 701*			*172*						*172*	*70 653*
CONSTRUÇÃO E OBRAS PÚBLICAS	10.4									26 384				154						**154**	**323 464**
TRANSPORTES	10.5									25 884									3 331	**3 331**	**5 608 101**
Aviação Nacional	*10.5.1*																				*125 261*
Transportes Marítimos Nacionais	*10.5.2*																				*98 368*
Caminho de Ferro	*10.5.3*									*25 828*											*36 259*
Rodoviários	*10.5.4*									*56*									*3 331*	*3 331*	*5 348 213*
SETOR DOMÉSTICO	10.6									1 029 809			37 571	*762 949*						**800 520**	**2 528 207**
SERVIÇOS	10.7									**1 467 038**	**27 717**		42 696	31 138			1 517			**75 351**	**1 973 453**

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	2002
Dairy-Cattle	Dairy cows	394	388	381	383	382	383	380	379	375	369	353	331	311
Non-dairy cattle	Beef calfs (<1 yr)	46	52	53	53	58	60	64	64	65	66	67	72	75
	Calfs M.Rep. (<1 yr)	186	185	182	176	167	162	155	151	149	149	144	140	137
	Calfs F Rep. (<1 yr)	177	178	178	174	164	158	152	152	155	165	174	180	186
	Males 1-2 yrs	112	114	114	108	103	103	105	101	95	86	82	81	80
	Beef Fem. 1-2 yrs	18	19	20	22	22	22	24	24	24	20	17	14	14
	Females rep. 1-2 yrs	111	115	112	109	106	109	112	109	108	116	127	135	136
	Steers (>2 yrs)	38	38	36	37	35	33	33	31	31	29	26	24	23
	Heifers Beef (>2 yrs)	4	5	7	9	10	10	9	9	9	7	6	6	8
	Heifers rep. (>2 yrs)	45	46	45	48	50	52	51	50	52	60	67	77	80
	non-dairy cows	242	245	238	241	252	273	296	316	332	338	345	352	362
Swine	Piglets (<20 kg)	727	756	756	750	735	726	703	701	695	691	663	626	591
	Fatt. Pigs (20-50 kg)	662	675	660	671	668	660	633	631	633	623	585	535	493
	Fatt. Pigs (50-80 kg)	525	545	544	539	532	525	505	496	492	498	483	446	402
	Fatt. Pigs (80-110 kg)	218	227	226	225	210	198	179	177	174	176	174	184	197
	Fatt. Pigs (> 110 kg)	44	46	46	47	45	44	40	39	38	38	38	43	42
	Boars (>50 kg)	26	28	27	28	28	26	24	23	23	22	20	19	17
	Sows, pregnant	210	219	218	220	216	211	204	204	202	201	195	197	196
	Sows, non-pregnant	124	131	135	136	134	132	127	128	127	127	124	111	91
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	2 328
	Other Ovine	663	725	789	794	811	817	813	802	834	840	733	506	299
	Lambs	307	326	320	300	279	278	292	297	301	307	319	320	330
Goats	Does	614	588	556	538	528	517	509	498	485	472	460	440	417
	Other Caprine	149	156	166	160	153	151	147	151	154	151	129	91	62
	kids	47	49	47	44	45	41	41	36	37	36	33	30	29
Equidae	Horses	33	38	40	42	44	48	52	54	56	57	58	59	59
	Asses and Mules.	118	116	114	114	109	103	96	90	82	75	69	63	57
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	3 019
	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	8 739
	Broilers	18 524	18 812	19 243	19 674	19 530	18 813	18 355	18 733	20 538	22 936	24 374	24 259	22 590
	Turkeys	1 149	1 122	1 082	1 041	996	945	936	972	1 061	1 158	1 208	1 201	1 139
	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	1 613
Other	Rabbits *	475	464	447	430	415	401	384	363	346	338	336	332	325

*Reproductive females

Annex F Table 1 - continuation

Animal	Sub-class	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Dairy-Cattle	Dairy cows	297	294	290	284	275	269	263	255	247	241	236	233	235
Non-dairy cattle	Beef calfs (<1 yr)	82	91	104	108	108	108	109	114	120	125	119	113	112
	Calfs M.Rep. (<1 yr)	141	140	136	131	129	127	123	123	128	136	136	142	152
	Calfs F Rep. (<1 yr)	186	187	183	180	178	174	169	171	179	190	191	198	209
	Males 1-2 yrs	80	79	81	77	75	73	72	66	60	55	54	53	58
	Beef Fem. 1-2 yrs	15	16	17	17	16	17	18	20	19	20	19	17	15
	Females rep. 1-2 yrs	133	135	135	139	139	141	142	137	132	131	135	139	148
	Steers (>2 yrs)	23	23	25	28	31	33	34	38	41	44	42	39	37
	Heifers Beef (>2 yrs)	8	8	9	9	9	9	10	12	13	14	14	15	15
	Heifers rep. (>2 yrs)	86	90	94	96	96	97	102	110	111	110	105	103	96
	non-dairy cows	371	382	397	411	425	432	436	438	440	442	443	450	461
Swine	Piglets (<20 kg)	571	570	574	583	590	592	602	597	614	634	658	681	713
	Fatt. Pigs (20-50 kg)	471	467	467	466	468	464	460	448	446	455	464	472	485
	Fatt. Pigs (50-80 kg)	374	373	368	362	356	357	362	360	362	366	366	369	380
	Fatt. Pigs (80-110 kg)	208	213	214	221	222	227	237	244	251	255	263	273	285
	Fatt. Pigs (> 110 kg)	43	40	41	43	44	44	40	36	30	27	25	28	30
	Boars (>50 kg)	16	14	12	12	11	10	8	7	6	5	5	5	6
	Sows, pregnant	198	194	191	189	185	183	181	179	172	166	159	159	162
	Sows, non-pregnant	73	67	68	70	71	70	69	66	66	66	68	69	71
Sheep	Ewes	2 282	2 273	2 293	2 275	2 225	2 137	2 030	1 915	1 811	1 735	1 683	1 638	1,620
	Other Ovine	204	216	234	267	250	225	206	191	179	160	167	162	155
	Lambs	324	329	322	328	340	337	307	277	264	267	263	267	275
Goats	Does	392	382	380	380	373	365	358	356	353	349	342	333	324
	Other Caprine	48	52	57	65	59	52	44	40	38	35	36	35	37
	kids	28	28	26	25	28	30	31	29	29	28	27	25	23
Equidae	Horses	58	56	52	49	47	46	42	38	33	30	27	26	26
	Asses and Mules.	51	45	40	36	33	29	26	22	20	18	15	14	13
Poultry	Hens, reproductive	3 206	3 253	3 056	2 800	2 717	2 877	3 218	3 453	3 542	3 396	3 179	3 060	2,960
	Hens eggs	8 440	7 942	7 349	6 830	6 490	6 758	7 341	7 867	7 883	7 475	7 138	6 887	6,803
	Broilers	20 921	19 620	18 686	17 885	16 848	16 780	17 915	19 207	19 452	18 650	17 847	17 313	17,045
	Turkeys	1 077	963	798	799	1 017	1 318	1 485	1 445	1 331	1 144	956	831	769
	Other poultry	1 531	1 445	1 353	1 314	1 332	1 414	1 504	1 522	1 460	1 319	1 178	1 084	1,038
Other	Rabbits*	318	306	289	270	254	251	255	255	243	218	193	177	169

*Reproductive females

Annex F Table 2 – Share (in %) of livestock population (by sub class) living in cool regions – complete time series.

Animal	Sub-class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Dairy-Cattle	Dairy cows	64.38	63.33	62.92	63.46	64.26	64.72	64.44	63.76	62.82	61.02	59.66	58.11	57.36
Non-dairy cattle	Beef calfs (<1 yr)	80.12	74.76	66.13	55.54	52.34	53.55	56.50	58.77	61.34	66.31	68.07	69.47	67.79
	Calfs M.Rep. (<1 yr)	55.75	53.88	54.31	53.16	51.95	50.28	49.54	49.68	49.21	46.14	41.41	35.30	32.83
	Calfs F Rep. (<1 yr)	55.75	54.47	55.44	54.01	53.52	52.47	52.49	51.25	49.22	45.86	43.64	42.07	40.56
	Males 1-2 yrs	54.70	53.00	51.42	50.09	53.06	53.94	54.53	53.53	53.02	51.14	49.62	45.58	41.97
	Beef Fem. 1-2 yrs	50.68	43.86	44.89	44.38	48.81	46.19	44.86	44.53	43.87	40.87	35.13	29.02	28.59
	Females rep. 1-2 yrs	51.30	47.11	46.40	45.64	48.35	46.38	45.76	44.52	42.79	41.60	40.89	40.68	39.73
	Steers (>2 yrs)	66.59	64.59	60.91	54.81	49.45	47.26	47.01	44.92	42.76	37.05	32.89	27.62	26.32
	Heifers Beef (>2 yrs)	43.44	46.67	50.28	51.69	57.12	59.66	65.36	61.71	58.67	54.75	49.31	36.64	41.06
	Heifers rep. (>2 yrs)	42.16	42.68	45.22	46.78	45.52	43.30	43.91	42.91	41.68	41.03	41.93	42.72	40.70
	non-dairy cows	43.19	41.36	38.96	36.28	34.05	33.09	32.38	32.04	31.15	29.42	28.20	26.92	26.15
Swine	Piglets (<20 kg)	47.97	48.47	48.52	47.40	46.50	46.01	45.99	46.04	45.92	45.46	44.83	44.44	44.01
	Fatt. Pigs (20-50 kg)	45.06	44.00	44.77	45.11	45.69	45.04	45.05	44.94	44.51	43.74	42.62	41.41	40.13
	Fatt. Pigs (50-80 kg)	48.49	46.83	47.58	46.38	45.85	45.19	44.90	45.29	45.48	45.48	44.45	42.67	40.45
	Fatt. Pigs (80-110 kg)	47.73	45.78	46.43	44.88	44.32	43.53	43.32	43.75	44.21	44.27	42.97	40.49	38.48
	Fatt. Pigs (> 110 kg)	48.80	46.15	46.64	44.25	44.04	43.81	44.66	44.92	45.12	44.80	42.37	36.85	34.06
	Boars (>50 kg)	47.15	48.31	48.04	49.46	49.41	48.66	48.19	46.58	45.47	45.33	47.91	50.09	50.52
	Sows, pregnant	43.45	44.26	45.74	46.54	46.60	45.88	46.13	45.84	45.81	45.56	44.65	42.55	40.22
	Sows, non-pregnant	47.54	49.58	50.09	48.68	46.65	45.92	46.54	46.30	46.33	45.95	44.90	43.63	43.48
Sheep	Ewes	31.33	31.25	31.54	32.17	32.53	32.87	33.03	33.45	33.77	33.88	33.72	33.31	33.03
	Other Ovine	28.94	29.69	30.30	30.73	30.34	30.04	29.38	28.63	27.61	25.87	24.47	23.51	23.26
	Lambs	31.33	31.26	31.52	32.10	32.51	32.87	33.03	33.46	33.78	33.88	33.71	33.31	33.02
Goats	Does	56.28	56.02	55.40	55.26	55.81	56.60	57.45	57.67	57.13	56.88	55.82	55.14	53.98
	Other Caprine	60.90	61.70	62.44	62.06	61.12	59.92	58.62	58.62	56.71	55.33	53.69	55.18	57.83
	kids	56.28	55.96	55.38	55.26	55.92	56.61	57.37	57.66	57.13	56.89	55.90	55.25	53.96
Equidae	Horses	41.74	41.74	41.74	41.74	41.74	41.60	42.28	43.19	43.86	43.67	43.03	42.32	43.20
	Asses and Mules.	67.97	67.97	67.97	67.97	67.97	68.42	69.16	70.29	71.07	71.77	72.20	72.72	73.33
Poultry	Hens, reproductive	70.82	71.07	71.47	71.89	71.88	71.41	71.20	71.46	71.35	70.11	68.60	68.20	68.65
	Hens eggs	70.82	71.10	71.50	71.90	71.90	71.52	71.24	71.58	71.24	69.86	68.57	68.16	68.62
	Broilers	69.22	68.83	68.27	67.73	66.79	65.37	63.91	63.05	63.01	63.10	63.62	64.45	65.77
	Turkeys	21.56	21.25	20.77	20.25	19.94	19.87	19.94	19.89	19.55	19.10	18.66	18.34	18.09
	Other poultry	33.91	34.28	34.84	35.41	35.07	33.84	32.74	32.60	32.93	32.73	31.91	30.95	29.73
Other	Rabbits*	75.28	74.74	73.88	72.95	73.37	75.31	77.73	79.14	79.38	79.60	80.02	80.66	81.56

*Reproductive females

Annex F Table 2 – continuation

Animal	Sub-class	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Dairy-Cattle	Dairy cows	56.34	55.72	54.50	53.35	52.15	51.71	50.71	49.52	48.39	47.58	47.13	46.84	47.06
Non-dairy cattle	Beef calfs (<1 yr)	59.03	52.77	47.70	49.34	48.92	48.43	47.45	46.50	45.18	45.01	44.97	45.23	43.57
	Calfs M.Rep. (<1 yr)	32.24	32.22	29.46	26.68	24.20	24.08	24.41	25.49	25.74	25.50	25.04	24.79	24.44
	Calfs F Rep. (<1 yr)	38.94	36.23	34.52	32.60	31.88	31.51	32.19	33.37	33.79	33.50	33.05	32.62	32.46
	Males 1-2 yrs	40.26	39.88	39.94	39.40	39.09	40.43	41.31	42.80	43.68	44.32	45.30	45.67	44.12
	Beef Fem. 1-2 yrs	26.06	23.28	27.84	33.79	39.17	39.94	42.15	40.83	37.90	34.13	33.59	33.63	35.71
	Females rep. 1-2 yrs	39.16	38.70	36.75	35.55	34.52	34.59	35.43	37.19	38.85	39.03	38.51	38.04	36.63
	Steers (>2 yrs)	25.00	25.84	25.55	25.87	25.70	26.82	27.73	27.79	27.88	27.86	26.74	25.49	23.99
	Heifers Beef (>2 yrs)	41.29	45.56	48.59	54.58	58.10	53.93	50.23	41.96	36.45	31.85	31.09	31.95	34.67
	Heifers rep. (>2 yrs)	39.12	36.17	35.67	35.20	35.60	34.35	32.06	31.87	32.41	34.07	33.90	33.80	31.52
	non-dairy cows	24.62	22.71	21.28	20.01	19.19	18.63	18.63	18.82	18.82	18.67	18.66	18.57	18.49
Swine	Piglets (<20 kg)	43.27	42.12	41.84	41.65	40.90	39.55	38.14	37.49	36.06	34.91	33.43	33.17	33.63
	Fatt. Pigs (20-50 kg)	39.27	38.05	37.70	37.99	38.43	38.15	37.23	36.65	35.56	34.66	33.16	32.67	32.05
	Fatt. Pigs (50-80 kg)	38.79	38.15	37.97	37.86	37.53	36.88	36.54	36.43	35.82	34.81	33.63	33.29	33.05
	Fatt. Pigs (80-110 kg)	37.66	37.74	38.23	38.16	37.34	35.79	34.48	33.46	32.97	32.40	32.08	31.88	32.18
	Fatt. Pigs (> 110 kg)	32.14	32.57	33.11	34.90	34.65	32.27	29.25	28.09	27.28	25.61	26.12	28.30	29.22
	Boars (>50 kg)	50.75	51.81	52.73	51.89	49.57	50.55	49.83	48.74	44.57	38.94	42.75	39.18	41.96
	Sows, pregnant	39.07	38.79	39.20	39.44	39.54	39.56	39.32	38.79	38.19	37.79	37.62	37.64	37.99
	Sows, non-pregnant	45.13	46.45	45.75	45.16	44.67	44.54	44.29	44.01	42.37	40.57	38.88	38.56	38.19
Sheep	Ewes	32.86	33.04	33.51	33.94	34.25	34.42	34.83	35.32	35.67	35.79	35.80	35.38	34.54
	Other Ovine	24.95	24.38	24.39	25.42	26.30	26.68	26.85	28.39	28.50	28.29	25.20	24.79	23.80
	Lambs	32.86	33.03	33.50	33.95	34.26	34.42	34.78	35.31	35.67	35.79	35.80	35.34	34.49
Goats	Does	53.93	54.17	54.85	55.13	55.21	54.94	54.64	53.73	52.80	52.36	52.63	52.85	52.47
	Other Caprine	62.02	62.16	62.38	60.99	60.44	59.49	59.66	58.81	55.39	51.91	48.03	46.55	45.40
	kids	53.92	54.15	54.82	55.11	55.16	54.93	54.65	53.71	52.83	52.37	52.63	52.85	52.48
Equidae	Horses	44.60	47.28	48.58	49.47	49.65	49.61	49.27	48.26	49.17	51.79	56.38	58.59	59.70
	Asses and Mules.	74.00	74.89	75.01	75.91	76.29	77.21	77.91	80.06	80.80	79.73	75.39	73.05	70.98
Poultry	Hens, reproductive	69.10	69.70	70.49	70.96	70.75	69.75	68.82	68.08	67.54	67.02	66.45	66.02	65.80
	Hens eggs	69.07	69.67	70.51	70.98	70.80	69.76	68.80	68.10	67.54	67.02	66.44	66.02	65.80
	Broilers	67.28	68.54	69.41	69.98	70.76	71.46	71.76	71.89	72.19	72.72	73.29	73.70	73.92
	Turkeys	17.85	18.07	19.03	19.96	19.77	18.31	16.55	15.18	14.77	15.60	16.75	17.81	18.47
	Other poultry	28.43	27.55	27.11	26.96	26.64	26.59	26.98	27.61	28.21	28.89	29.72	30.40	30.79
Other	Rabbits*	82.48	83.20	83.72	83.84	83.74	84.22	85.45	86.76	87.53	87.80	88.14	88.42	88.58

*Reproductive females

Annex F Table 3 – 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	2002
Dairy-Cattle	Dairy cows	4.79	4.85	4.88	4.78	4.90	5.05	5.19	5.29	5.45	5.93	6.29	6.52	6.92
Non-dairy cattle	Beef calfs (<1 yr)	0.45	0.46	0.48	0.50	0.51	0.51	0.50	0.50	0.49	0.48	0.48	0.47	0.48
	Calfs M.Rep. (<1 yr)	1.09	1.10	1.10	1.11	1.11	1.12	1.12	1.12	1.12	1.14	1.16	1.19	1.20
	Calfs F Rep. (<1 yr)	0.93	0.94	0.93	0.94	0.94	0.95	0.95	0.95	0.96	0.97	0.98	0.99	0.99
	Males 1-2 yrs	4.15	4.15	4.15	4.14	4.02	3.95	3.89	3.88	3.84	3.84	3.83	3.88	3.91
	Beef Fem. 1-2 yrs	2.96	3.05	3.00	2.97	2.86	2.88	2.87	2.84	2.82	2.83	2.89	2.95	2.92
	Females rep. 1-2 yrs	2.99	3.04	3.02	3.00	2.92	2.92	2.90	2.89	2.88	2.87	2.85	2.81	2.79
	Steers (>2 yrs)	4.30	4.31	4.38	4.50	4.61	4.62	4.57	4.58	4.58	4.68	4.73	4.80	4.77
	Heifers Beef (>2 yrs)	3.37	3.27	3.16	3.10	2.96	2.88	2.75	2.78	2.81	2.84	2.90	3.09	2.97
	Heifers rep. (>2 yrs)	3.39	3.35	3.26	3.20	3.18	3.19	3.14	3.12	3.11	3.08	3.03	2.98	2.98
	non-dairy cows	2.52	2.54	2.56	2.59	2.61	2.62	2.63	2.63	2.64	2.66	2.67	2.68	2.69
Swine	Piglets (<20 kg)	1.12	1.12	1.12	1.13	1.13	1.14	1.14	1.14	1.14	1.15	1.15	1.16	1.16
	Fatt. Pigs (20-50 kg)	6.28	6.31	6.32	6.33	6.34	6.36	6.38	6.40	6.42	6.45	6.48	6.52	6.55
	Fatt. Pigs (50-80 kg)	9.18	9.24	9.24	9.30	9.33	9.37	9.40	9.42	9.44	9.46	9.51	9.57	9.65
	Fatt. Pigs (80-110 kg)	11.00	11.08	11.10	11.17	11.21	11.26	11.30	11.31	11.33	11.36	11.42	11.52	11.60
	Fatt. Pigs (> 110 kg)	12.09	12.20	12.21	12.32	12.35	12.39	12.40	12.42	12.45	12.49	12.60	12.80	12.91
	Boars (>50 kg)	12.11	12.11	12.15	12.14	12.17	12.23	12.27	12.35	12.42	12.45	12.41	12.37	12.39
	Sows, pregnant	11.83	11.83	11.82	11.83	11.86	11.91	11.93	11.97	12.00	12.03	12.09	12.18	12.28
	Sows, non-pregnant	24.21	24.15	24.18	24.32	24.50	24.60	24.63	24.70	24.76	24.85	24.97	25.11	25.18
Sheep	Sheep	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Goats	Goats	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.54	0.54	0.54	0.54
Equides	Horses	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Asses and Mules.	0.35	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36
Poultry	Hens, reproductive	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.23
	Hens eggs	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.11	0.11	0.11	0.11	0.11
	Broilers	3.77	3.77	3.77	3.77	3.77	3.78	3.76	3.74	3.73	3.73	3.75	3.76	3.74
	Turkeys	1.55	1.55	1.55	1.55	1.55	1.55	1.54	1.53	1.52	1.51	1.51	1.50	1.50
	Other poultry	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Other	Rabbits*	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

*Per female cage

Annex F Table 3 – Continuation.

Animal	Sub-class	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Dairy-Cattle	Dairy cows	6.87	6.97	7.33	7.46	7.58	7.82	8.04	8.19	8.27	8.46	8.40	8.73	8.52
Non-dairy cattle	Beef calfs (<1 yr)	0.50	0.51	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.53
	Calfs M.Rep. (<1 yr)	1.20	1.20	1.21	1.22	1.24	1.24	1.23	1.23	1.23	1.23	1.23	1.23	1.23
	Calfs F Rep. (<1 yr)	1.00	1.01	1.01	1.02	1.02	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02
	Males 1-2 yrs	3.90	3.86	3.81	3.77	3.73	3.65	3.58	3.51	3.49	3.48	3.46	3.45	3.48
	Beef Fem. 1-2 yrs	2.92	2.92	2.82	2.70	2.58	2.54	2.48	2.46	2.50	2.55	2.56	2.55	2.53
	Females rep. 1-2 yrs	2.77	2.74	2.73	2.72	2.69	2.66	2.61	2.55	2.53	2.53	2.53	2.54	2.56
	Steers (>2 yrs)	4.74	4.66	4.61	4.54	4.48	4.39	4.31	4.25	4.25	4.25	4.27	4.30	4.33
	Heifers Beef (>2 yrs)	2.93	2.83	2.74	2.62	2.53	2.56	2.58	2.66	2.74	2.81	2.82	2.81	2.77
	Heifers rep. (>2 yrs)	2.97	2.98	2.95	2.92	2.87	2.85	2.85	2.81	2.80	2.78	2.78	2.78	2.82
	non-dairy cows	2.71	2.72	2.74	2.75	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.77
Swine	Piglets (<20 kg)	1.17	1.17	1.18	1.18	1.18	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.21
	Fatt. Pigs (20-50 kg)	6.58	6.62	6.64	6.65	6.66	6.69	6.72	6.74	6.76	6.77	6.80	6.81	6.82
	Fatt. Pigs (50-80 kg)	9.71	9.75	9.78	9.81	9.84	9.88	9.91	9.94	9.95	9.98	10.01	10.01	10.02
	Fatt. Pigs (80-110 kg)	11.66	11.68	11.70	11.73	11.78	11.86	11.92	11.98	12.00	12.01	12.02	12.03	12.02
	Fatt. Pigs (> 110 kg)	13.00	13.02	13.04	13.02	13.06	13.17	13.29	13.36	13.39	13.44	13.42	13.36	13.33
	Boars (>50 kg)	12.42	12.42	12.42	12.48	12.58	12.58	12.63	12.70	12.83	13.00	12.89	13.00	12.91
	Sows, pregnant	12.34	12.38	12.40	12.42	12.45	12.48	12.52	12.56	12.58	12.59	12.60	12.60	12.59
	Sows, non-pregnant	25.14	25.12	25.23	25.32	25.41	25.48	25.56	25.64	25.74	25.85	25.95	25.97	26.00
Sheep	Sheep	0.41	0.41	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Goats	Goats	0.54	0.54	0.54	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.54	0.54	0.54
Equidae	Horses	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Asses and Mules.	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.37
Poultry	Hens, reproductive	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.25	0.25	0.25
	Hens eggs	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Broilers	3.71	3.65	3.63	3.61	3.60	3.60	3.61	3.63	3.61	3.56	3.45	3.41	3.38
	Turkeys	1.49	1.48	1.48	1.47	1.47	1.46	1.45	1.43	1.42	1.43	1.48	1.50	1.52
	Other poultry	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Other	Rabbits*	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11

*Per female cage

Annex F Table 4 – 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
Rabbits*	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

*Per female cage

Animal Type	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Dairy	33 363	33 086	33 467	32 919	31 822	31 289	30 783	29 845	28 894	28 329	27 683	27 664	27 760
Non-Dairy	55 201	56 592	58 318	59 523	60 536	61 211	61 741	62 388	62 835	63 410	63 203	63 778	65 181
Sheep	22 270	22 274	22 565	22 621	22 054	21 087	19 975	18 824	17 793	16 970	16 529	16 090	15 878
Goats	3 060	3 016	3 041	3 094	3 004	2 898	2 793	2 758	2 717	2 670	2 631	2 570	2 513
Horses	2 567	2 449	2 273	2 141	2 083	2 009	1 833	1 672	1 467	1 320	1 173	1 144	1 144
Mules and Asses	1 115	983	880	785	726	645	565	491	433	396	337	308	286
Swine	19 650	19 285	19 190	19 248	19 183	19 131	19 114	18 836	18 696	18 703	18 820	19 133	19 739
Poultry	19 454	18 288	17 053	16 174	15 721	16 417	17 785	18 818	18 784	17 721	16 691	15 993	15 662
Rabbits*	2 862	2 754	2 599	2 429	2 290	2 256	2 294	2 295	2 184	1 962	1 741	1 593	1 519
Total	159 541	158 726	159 387	158 934	157 419	156 944	156 882	155 927	153 802	151 482	148 815	148 273	149 682

*Per female cage

Annex F Table 5 – Total amounts of Nitrogen (t N/yr) added to managed soils: activity data for direct N2O 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)	59,921	60,450	59,843	59,292	58,822	58,384	57,301	56,814	57,064	58,762	58,699	56,630	54,144
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	44 711	44 406	43 910	43 325	42 083
Organic Fertilizer (other)	319	319	319	319	319	319	386	467	301	440	263	377	1 419
Total	341,559	337,996	331,899	330,081	332,341	324,890	347,171	345,132	331,291	334,385	355,419	339,448	342,416

Sources	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Synthetic Fertilizer	110 132	125 844	102 663	87 391	113 005	105 131	97 293	100 249	95 088	106 864	110,643	122,842	121,028
Organic Fertilizer (manure)	51,180	49,842	48,989	47,936	46,667	46,318	46,405	45,922	45,019	43,827	42,735	42,335	42,547
Pasture	80 397	81 686	83 729	84 961	85 352	85 152	84 605	84 097	83 346	83 035	82,253	82,468	83,692
Crop Residues	42 410	40 791	40 151	38 626	38 822	38 354	37 422	36 2371	41 392	42 558	50,002	47,837	43,602
Organic Fertilizer (other)	1 072	567	366	429	693	1 191	2 035	491	682	1 087	1,246	489	1,648
Total	285,191	298,730	275,897	259,342	284,540	276,146	267,760	267,130	265,527	277,371	286,879	295,971	292,516

Annex F Table 6 – Nitrogen amount consumption (kt N/yr) by type of N-fertilizer - time series activity data.

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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
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
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
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
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
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
Total	158.50	158.50	158.50	158.50	158.50	145.82	168.23	164.29	149.30	148.94	170.01	157.51	163.90

Sources	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ammonium nitrate (AN)	-	-	-	-	-	-	-	4.01	4.18	3.70	7.70	4.63	4.67
Ammonium phosphate (MAP&DAP)	9.10	8.55	-	-	-	-	1.01	0.54	0.21	1.37	2.04	1.11	0.56
Ammonium sulphate (AS)	10.31	10.27	10.30	4.22	5.86	2.54	1.95	3.06	0.00	0.00	0.00	0.00	0.00
Calcium ammonia nitrate (CAN)	35.89	43.31	29.68	19.21	34.63	26.75	27.18	34.99	23.49	17.62	25.38	18.55	19.12
Urea	9.23	8.20	11.85	20.45	21.98	26.01	24.06	13.85	22.19	20.88	15.57	24.01	32.19
Other NK & NPK	30.64	37.00	39.94	33.76	41.10	28.97	16.09	24.90	23.13	17.19	24.57	30.27	27.21
Other N	14.96	18.51	10.90	9.76	9.43	20.86	22.71	18.90	21.89	46.10	35.39	44.26	37.27
Total	110.13	125.84	102.66	87.39	113.01	105.13	97.29	100.25	95.09	106.86	110.64	122.84	121.03

ANNEX G: Waste Background Data Tables

Annex G 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	1,779.3	739.2	50.3	0.0
1991	9,867,147	272.7	89	2,690.9	1,734.5	906.1	50.3	0.0
1992	9,916,044	285.5	91	2,831.4	1,824.4	956.7	50.3	0.0
1993	9,964,941	298.9	92	2,978.4	1,918.6	1,009.6	50.3	0.0
1994	10,013,838	312.8	93	3,132.3	1,865.1	1,179.4	87.8	0.0
1995	10,062,735	332.0	95	3,341.2	1,982.4	1,248.5	110.4	0.0
1996	10,111,632	350.4	96	3,542.8	2,058.3	1,373.6	110.8	0.0
1997	10,160,529	368.9	97	3,748.6	2,038.6	1,596.1	113.8	0.0
1998	10,209,426	387.8	98	3,958.7	1,539.9	2,302.1	116.8	0.0
1999	10,258,323	425.3	99	4,173.3	975.1	2,736.9	114.9	346.4
2000	10,307,220	439.5	100	4,247.9	588.8	2,610.5	137.4	911.1
2001	10,356,117	446.0	100	4,403.1	460.1	2,912.1	139.2	891.7
2002	10,444,592	457.0	100	4,537.8	27.8	3,490.6	75.5	943.9
2003	10,473,050	464.6	100	4,629.2	25.9	3,367.4	232.5	1,003.4
2004	10,494,672	435.9	100	4,351.6	22.3	3,206.1	129.0	994.2
2005	10,511,988	436.3	100	4,316.2	0.0	3,128.4	130.7	1,057.0
2006	10,532,588	447.1	100	4,382.1	0.0	3,264.5	133.3	984.4
2007	10,553,339	455.4	100	4,331.3	0.0	3,233.3	143.5	954.5
2008	10,563,014	496.3	100	4,708.5	0.0	3,530.2	185.3	993.0
2009	10,573,479	497.2	100	4,649.9	0.0	3,351.1	216.2	1,082.6
2010	10,572,721	524.0	100	5,006.9	0.0	3,682.6	232.1	1,092.2
2011	10,542,398	497.0	100	4,770.8	0.0	3,395.3	244.1	1,131.5
2012	10,487,289	452.1	100	4,287.9	0.0	2,920.9	332.7	1,034.3
2013	10,572,721	427.7	100	4,073.2	0.0	2,601.9	353.4	1,117.8
2014	10,542,398	437.5	100	4,077.9	0.0	2,532.1	493.9	1,051.9
2015	10,487,289	445.4	100	3,949.2	0.0	2,429.0	390.7	1,129.5

Sources:INE; APA; Quercus Study

Annex G 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	**1980**	800	304	**2000**	236	1,044
1961	832	0	**1981**	807	313	**2001**	140	888
1962	844	0	**1982**	817	320	**2002**	6	771
1963	857	0	**1983**	828	326	**2003**	6	721
1964	870	0	**1984**	839	332	**2004**	5	749
1965	883	0	**1985**	850	339	**2005**	0	782
1966	896	0	**1986**	861	345	**2006**	0	810
1967	909	0	**1987**	873	352	**2007**	0	838
1968	923	0	**1988**	885	359	**2008**	0	865
1969	937	0	**1989**	897	365	**2009**	0	567
1970	951	0	**1990**	905	376	**2010**	0	491
1971	965	0	**1991**	858	448	**2011**	0	597
1972	980	0	**1992**	874	458	**2012**	0	275
1973	994	0	**1993**	891	469	**2013**	0	281
1974	1,009	0	**1994**	849	537	**2014**	0	310
1975	1,024	0	**1995**	868	546	**2015**	0	301
1976	1,040	0	**1996**	865	577	**2016**	-	-
1977	1,055	0	**1997**	825	646	**2017**	-	-
1978	1,055	0	**1998**	601	899	**2018**	-	-
1979	1,087	0	**1999**	402	1,129	**2019**	-	-

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 G Table 3 – Quantities of CH4 recovered and combusted (SWDS).

	Biogas burned	Biogas burned	Biogas burned as % of CH4 generated in SWDS
	kton CH4	kton CO2 eq.	%
1990	-	-	-
1991	-	-	-
1992	-	-	-
1993	-	-	-
1994	-	-	-
1995	-	-	-
1996	-	-	-
1997	-	-	-
1998	-	-	-
1999	-	-	-
2000	-	-	-
2001	-	-	-
2002	-	-	-
2003	-	-	-
2004	2	54	1.0
2005	11	273	5.1
2006	15	368	6.8
2007	19	470	8.6
2008	24	595	10.8
2009	26	651	11.8
2010	32	794	14.4
2011	33	834	15.1
2012	40	1,000	18.1
2013	45	1,130	20.9
2014	50	1,248	23.6
2015	46	1,146	22.2

Source: APA´s questionnaires ; 2013 : DGEG data.

Annex G 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
2014	10,375	227	116	19	55	18	20
2015	10,341	226	115	19	54	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 G Table 5 – Quantities of CH4 combusted from municipal and industrial wastewater handling systems.

Year	Municipal treatment systems		Industrial treatment systems	
	kton CH4/year	% emissions of total emissions generated	kton CH4/year	% emissions of total emissions generated
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	0.7	1.60	0.04	0.06
2001	0.3	0.85	0.14	0.24
2002	0.4	0.94	0.18	0.29
2003	0.2	0.59	0.19	0.27
2004	0.6	1.55	0.24	0.31
2005	0.9	2.08	0.25	0.39
2006	0.8	1.94	0.31	0.48
2007	0.7	1.75	0.34	0.55
2008	0.6	1.72	0.45	0.89
2009	1.2	3.20	0.40	0.90
2010	1.3	3.47	0.19	0.36
2011	1.4	3.89	0.21	0.34
2012	1.4	3.77	0.20	0.35
2013	2.2	5.99	0.01	0.03
2014	2.2	6.01	0.09	0.15
2015	2.1	5.76	0.36	0.59

Source: DGEG data

Annex G 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*	*4*
2001	3	1	*35*	*3*
2002	3	1	38	2
2003	2	1	47	7
2004	*2*	*1*	54	11
2005	*1*	*0*	61	11
2006	1	0	68	12
2007	3	1	75	13
2008	3	1	82	6
2009	3	1	70	12
2010	3	1	20	15
2011	2	1	28	15
2012	1	1	40	15
2013	1	0.4	23	19
2014	1	0.5	23	26
2015	*1*	*0.4*	*23*	23

Note: Estimates in italics

Sources: APA (include estimates); DGS

Annex G 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	213	134	175	110
2000	560	352	460	289
2001	548	344	450	283
2002	580	364	476	299
2003	616	387	506	318
2004	610	384	502	315
2005	649	408	533	335
2006	604	380	497	312
2007	586	368	482	303
2008	610	383	501	315
2009	665	418	546	343
2010	671	422	551	346
2011	687	444	585	378
2012	628	406	535	345
2013	668	450	558	377
2014	582	470	496	401
2015	646	483	564	422

ANNEX H: TEST RESULTS EU

Files uploaded in the CDR Eionet or File attached (Test Report - ITL Annex H tests for EUCR software.pdf)

ANNEX I: Methodological Note concerning the calculation of carbon sequestration in areas with sown biodiverse pastures

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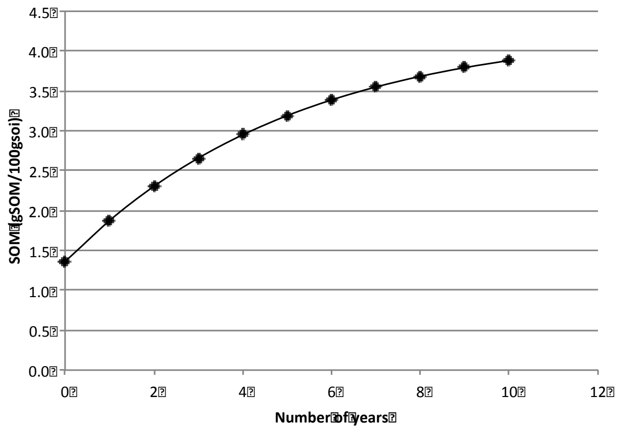
Summary

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 $tCO_2.ha^{-1}.yr^{-1}$** 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_2 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^{-3} 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.

$$BD = \frac{100}{\frac{SOM}{0.244 g.cm^{-3}} + \frac{100 - SOM}{MBD}}$$

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 $tCO_2.ha^{-1}.yr^{-1}$**.

Table 1 – Carbon sequestration factor, by year after sown biodiverse pastures sowing.

($tCO_2.ha^{-1}.yr^{-1}$)	Year after sowing									
	1	2	3	4	5	6	7	8	9	10
Carbon sequestration factor	14.70	11.54	9.15	7.30	5.86	4.72	3.82	3.10	2.53	2.06

References

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Teixeira, R., Domingos, T., Costa, A., Oliveira, R., Farropas, L., Calouro, F., Barradas, A.M., Carneiro, J.P., 2011. Soil Organic Matter Dynamics in Portuguese Natural and Sown Rainfed Grassland. Ecological Modelling 222: 993-1001.

ANNEX J: 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

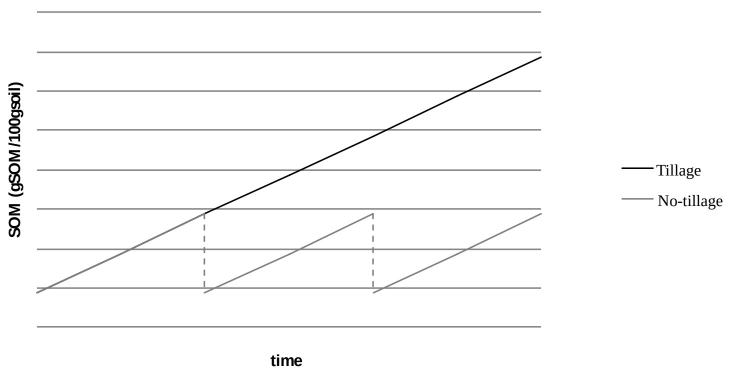
Harrowing is a common practice for shrub encroachment control in natural grasslands under canopy in Portugal. However, such operation is disruptive for the soil and leads to soil organic matter (SOM) loss and, consequently, carbon emissions. Less disruptive methods (eg. forestry mowers) lead to an increase 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 $tCO_2.ha^{-1}.yr^{-1}$**.

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 β_1 coefficient (in units of gSOM/100gsoil.yr^{-1}). The 95% CI for the modelled β_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
Independent variables	Aspect, forest type, herbaceous cover, potassium, topography	Herbaceous cover, aspect, potassium
R-squared	40 – 42% (p-value = 0)	53 – 55% (p-value = 0)
Predicted versus observed data	observed ≈ 0.45 predicted	
Homoscedasticity of the residuals	No pattern in the representation of residuals versus fitted values	
Omitted-variable test	Results vary	There are omitted variables
Multicollinearity of independent variables	No multicollinearity problems	
Normality of residuals	Although a graphical assessment shows a roughly normal distribution, the Shapiro-Wilk test indicates non-normality of residues	

Table 2: Higher and lower ΔSOM obtained from the linear regression approach (95% CI), considering the average of the sampling years.

Years from last intervention	ΔSOM ((g_{SOM}/100g_{soil}).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 β_1, 0.059 (gSOM/100gsoil).yr^{-1} was chosen for being the most conservative. This value was then converted into soil carbon by a factor of 0.58 (gSOC/gSOM). The carbon content per area was estimated using the conservative HWSDB-based bulk density 1.35 $gsoilcm^{-3}$ (Fisher et al., 2008; Teixeira et al., 2011) and a sampling depth of 20 cm. The conversion to carbon dioxide with a factor $^{44}/_{12}$ gives a carbon sequestration factor of **3.41 $tCO_2.ha^{-1}.yr^{-1}$** for a period of 10 years.

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ANNEX K: Key Category Analysis

K.1 Introduction

This chapter provides an analysis of key categories following recommendations of the 2006 IPCC Guidelines. A key category (source or sink) "is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both." The aim of defining key categories is the improvement of the inventory´s accuracy. As key categories are the most important sources or removals in terms of their contribution to the absolute level of national emissions, the identification of these categories enables the prioritisation of national efforts and a more efficient use of available resources in order to reach an improvement of national estimates. Information on key categories is also important for the development of policies and measures for emissions reduction.

The methods purposed by the 2006 IPCC Guidelines for performing key category analysis, include:

- Tier 1 approach (level and trend assessments);
- Tier 2 approach (level and trend assessments with uncertainty analysis);
- Qualitative approach.

K.2 Methodology for key category identification: Portuguese inventory

Having as a basis the 2017 Portuguese inventory estimates (1990-2015), the determination of key categories was conducted using Approach 1 and Approach 2 with and without the LULUCF sector.

In accordance with the recommendations from the last UNFCCC review, the disaggregation level of the key category analysis has been revised in order to follow the guidance from 2006 IPCC.

Level assessment was undertaken for the base year and the latest reported inventory year; the trend assessment was performed for the 1990-2015 period. The analysis performed without LULUCF resulted in the identification of 33 key categories. Including the LULUCF sector in the analysis, 42 categories were identified.

A.3 Presentation of results

Key category analysis can be very influenced by the definitions of source categories (extent of the split). If a large category is broken into many subcategories, then these subcategories may not have a significant contribution to the total inventory to be considered as a key source. On the opposite, several non-key sources categories may become key source categories if aggregated into a unique source category.

In a general way, the source and removal categories have been split according to the disaggregation level proposed by the 2016 IPCC.

For this submission the analysis was based on the application of Approach 1 and Approach 2 with and without the LULUCF sector as mentioned before.

Without LULUCF, the analysis resulted in the identification of 33 key categories. Including the LULUCF sector 42 categories were identified.

Table K-1 presents a summary of identified key categories for 1990-2015 without LULUCF using both approaches, and the criteria used (level, trend) in the identification. Table K-2 presents a summary of identified key categories for 1990-2015 with LULUCF.

Table K. 1 – Overview of key categories (without LULUCF) using Approach 1 and 2 for the base and latest inventory year.

IPCC CATEGORIES	GHG	Key source Category Flag	Criteria for Identification	Current year emissions (kton CO2 eq.)
1.A.3.b Road Transportation	CO2	√	Level 1 and 2, Trend 1 and 2	15358.3
1.A.1 Energy industries - Solid fuels	CO2	√	Level 1, Trend 1	12228.8
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	√	Level 1, Trend 1 and 2	3931.6
5.A Solid waste disposal	CH4	√	Level 1 and 2, Trend 1 and 2	3709.0
1.A.1 Energy industries - Gaseous fuels	CO2	√	Level 1, Trend 1 and 2	3568.5
3.A Enteric fermentation	CH4	√	Level 1, Trend 1	3479.4
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	3441.0
2.A.1 Mineral Industry - Cement production	CO2	√	Level 1 and 2, Trend 1 and 2	2921.2
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	2636.1
2.F.1 Refrigeration and Air Conditioning	Fgases	√	Level 1 and 2	2613.0
5.D Wastewater treatment and discharge	CH4	√	Level 1 and 2, Trend 1 and 2	2357.7
1.A.1 Energy industries - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	2024.5
3.D.1 Direct N2O Emissions From Managed Soils	N2O	√	Level 1 and 2, Trend 1 and 2	1690.2
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	√	Level 1, Trend 1 and 2	1336.5
1.B.2.a Fugitive emissions - Oil	CO2	√	Level 1 and 2, Trend 1 and 2	1001.2
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	√	Level 1	650.2
3.B Manure Management	CH4	√	Level 1, Trend 1	591.2
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	√	Level 1	423.5
1.A.1 Energy industries - Other fossil fuels	CO2	√	Level 1 and 2, Trend 1 and 2	411.8
1.A.3.a Civil (domestic) aviation	CO2	√	Level 1 and 2, Trend 2	366.0
2.A.4 Mineral Industry - Other Process Uses of Carbonates	CO2	√	Level 1	354.9
2.A.2 Mineral Industry - Lime production	CO2	√	Level 2, Trend 2	351.3
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	√	Trend 1 and 2	300.2
1.A.3.d Domestic navigation - Residual fuel oil	CO2	√	Level 1 and 2	266.4
5.D Wastewater treatment and discharge	N2O	√	Level 2	254.2
1.A.4 Combustion Other Sectors - Biomass	CH4	√	Level 1 and 2, Trend 1 and 2	241.2
2.D Non-energy products from fuels and solvent use	CO2	√	Level 2, Trend 2	191.7
3.C Rice cultivation	CH4	√	Level 2	142.0
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	√	Level 2, Trend 2	88.4
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	56.2
1.A.2 Manufacturing industries and construction - Biomass	N2O	√	Trend 2	46.1
2.B.2 Chemical Industry - Nitric acid production	N2O	√	Level 1, Trend 1 and 2	38.0
1.B.1.Fugitive emissions – Solid Fuels (Mining activities)	CH4	√	Trend 2	8.6

Table K. 2 – Overview of key categories (with LULUCF) using Approach 1 and 2 for the base and latest inventory year.

IPCC CATEGORIES	GHG	Key source Category Flag	Criteria for Identification	Current year emissions (kton CO2 eq.)
1.A.3.b Road Transportation	CO2	√	Level 1 and 2, Trend 1 and 2	15358.3
1.A.1 Energy industries - Solid fuels	CO2	√	Level 1, Trend 1	12228.8
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	√	Level 1, Trend 1	3931.6
5.A Solid waste disposal	CH4	√	Level 1 and 2, Trend 1 and 2	3709.0
1.A.1 Energy industries - Gaseous fuels	CO2	√	Level 1, Trend 1	3568.5
3.A Enteric fermentation	CH4	√	Level 1	3479.4
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	3441.0
2.A.1 Mineral Industry - Cement production	CO2	√	Level 1 and 2	2921.2
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	√	Level 1, Trend 1	2636.1
2.F.1 Refrigeration and Air Conditioning	Fgases	√	Level 1 and 2	2613.0
4.E.2 Land converted to Settlements	CO2	√	Level 1 and 2, Trend 1 and 2	2445.9
5.D Wastewater treatment and discharge	CH4	√	Level 1 and 2	2357.7
1.A.1 Energy industries - Liquid fuels	CO2	√	Level 1 and 2, Trend 1 and 2	2024.5
3.D.1 Direct N2O Emissions From Managed Soils	N2O	√	Level 1 and 2, Trend 2	1690.2
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	√	Level 1, Trend 1	1336.5
1.B.2.a Fugitive emissions - Oil	CO2	√	Level 1 and 2, Trend 1 and 2	1001.2
4.B.2 Land converted to Cropland	CO2	√	Level 1 and 2, Trend 1 and 2	759.2
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	√	Level 1	650.2
3.B Manure Management	CH4	√	Level 1	591.2
4.C.2 Land converted to Grassland	CO2	√	Level 1 and 2, Trend 1 and 2	456.3
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	√	Level 1	423.5
1.A.1 Energy industries - Other fossil fuels	CO2	√	Level 2, Trend 1 and 2	411.8
4.D.2 Land converted to Wetlands	CO2	√	Level 2, Trend 1 and 2	394.4
1.A.3.a Civil (domestic) aviation	CO2	√	Level 2	366.0
2.A.2 Mineral Industry - Lime production	CO2	√	Level 2	351.3
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	√	Trend 1	300.2
1.A.3.d Domestic navigation - Residual fuel oil	CO2	√	Level 2	266.4
5.D Wastewater treatment and discharge	N2O	√	Level 2, Trend 2	254.2
1.A.4 Combustion Other Sectors - Biomass	CH4	√	Level 2, Trend 2	241.2
2.D Non-energy products from fuels and solvent use	CO2	√	Level 2, Trend 2	191.7
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	√	Level 2, Trend 2	88.4
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	√	Level 1, Trend 1 and 2	56.2
4.B.2 Land converted to Cropland	N2O	√	Level 2, Trend 1 and 2	49.8
2.B.2 Chemical Industry - Nitric acid production	N2O	√	Level 1, Trend 1	38.0
4.C.2 Land converted to Grassland	N2O	√	Trend 2	28.9
1.B.1.Fugitive emissions – Solid Fuels (Mining activities)	CH4	√	Trend 2	8.6
4.B.1. Cropland remaining Cropland	CO2	√	Trend 1	-204.4
4.C.1. Grassland remaining Grassland	CO2	√	Trend 1	-369.0
4.G. Other (Harvested Wood Products)	CO2	√	Level 1, Trend 1	-424.2
4.F.2 Land converted to Other Land	CO2	√	Level 1 and 2, Trend 1 and 2	-813.0
4.A.2 Land converted to Forest land	CO2	√	Level 1 and 2, Trend 1 and 2	-3043.5
4.A.1. Forest land remaining Forest land	CO2	√	Level 1 and 2, Trend 1 and 2	-8409.3

The following tables Tables K.3 to K.8, present the two approaches with and without LULUCF categories for the base year and the latest reported inventory year for level assessment and trend assessment for 1990-2015.

Tables K.9 to K.14, present the two approaches with LULUCF categories for the base year and the latest reported inventory year for level assessment and trend assessment for 1990-2015.

Table K. 3 – Level assessment (Approach 1) without LULUCF: 1990.

Tier 1 Level Assessment (1990)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1990	Level Assess.	Cumulative Total
1.A.3.b Road Transportation	CO2	9266	9266	0.16	0.16
1.A.1 Energy industries - Liquid fuels	CO2	8345	8345	0.14	0.30
1.A.1 Energy industries - Solid fuels	CO2	7983	7983	0.13	0.43
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	6502	0.11	0.54
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	4063	0.07	0.61
3.A Enteric fermentation	CH4	3521	3521	0.06	0.67
2.A.1 Mineral Industry - Cement production	CO2	3176	3176	0.05	0.72
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	3088	0.05	0.77
5.A Solid waste disposal	CH4	2728	2728	0.05	0.82
5.D Wastewater treatment and discharge	CH4	2399	2399	0.04	0.86
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1807	0.03	0.89
3.B Manure Management	CH4	674	674	0.01	0.90
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	662	662	0.01	0.91
2.B.1 Chemical Industry - Ammonia production	CO2	540	540	0.01	0.92
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	499	499	0.01	0.93
2.B.2 Chemical Industry - Nitric acid production	N2O	498	498	0.01	0.94
1.A.4 Combustion Other Sectors - Biomass	CH4	407	407	0.01	0.95
1.A.3.d Domestic navigation - Residual fuel oil	CO2	263	263	0.00	0.95

Table K. 4 – Level assessment (Approach 1) without LULUCF: 2015.

Tier 1 Level Assessment (2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Level Assess.	Cumulative Total
1.A.3.b Road Transportation	CO2	9266	15358	0.22	0.22
1.A.1 Energy industries - Solid fuels	CO2	7983	12229	0.18	0.40
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	0	3932	0.06	0.46
5.A Solid waste disposal	CH4	2728	3709	0.05	0.51
1.A.1 Energy industries - Gaseous fuels	CO2	0	3568	0.05	0.56
3.A Enteric fermentation	CH4	3521	3479	0.05	0.62
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.05	0.67
2.A.1 Mineral Industry - Cement production	CO2	3176	2921	0.04	0.71
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	2636	0.04	0.75
2.F.1 Refrigeration and Air Conditioning	Fgases	NA	2613	0.04	0.78
5.D Wastewater treatment and discharge	CH4	2399	2358	0.03	0.82
1.A.1 Energy industries - Liquid fuels	CO2	8345	2025	0.03	0.85
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1690	0.02	0.87
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	0	1336	0.02	0.89
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	0.91
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	662	650	0.01	0.92
3.B Manure Management	CH4	674	591	0.01	0.92
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	499	424	0.01	0.93
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.01	0.94
1.A.3.a Civil (domestic) aviation	CO2	178	366	0.01	0.94
2.A.4 Mineral Industry - Other Process Uses of Carbonates	CO2	205	355	0.01	0.95

Table K. 5 – Trend assessment (Approach 1) without LULUCF: 1990-2015.

Tier 1 Trend Assessment (1990-2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Trend Assess.	Contribution to Trend	Cumulative Total
1.A.1 Energy industries - Liquid fuels	CO2	8345	2025	0.10	0.18	0.18
1.A.3.b Road Transportation	CO2	9266	15358	0.06	0.11	0.29
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.05	0.10	0.39
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	0	3932	0.05	0.09	0.48
1.A.1 Energy industries - Gaseous fuels	CO2	0	3568	0.05	0.09	0.57
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	56	0.05	0.08	0.65
1.A.1 Energy industries - Solid fuels	CO2	7983	12229	0.04	0.07	0.73
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	2636	0.03	0.05	0.77
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	0	1336	0.02	0.03	0.81
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	0.02	0.83
2.A.1 Mineral Industry - Cement production	CO2	3176	2921	0.01	0.02	0.85
2.B.1 Chemical Industry - Ammonia production	CO2	540	0	0.01	0.01	0.86
3.A Enteric fermentation	CH4	3521	3479	0.01	0.01	0.88
5.A Solid waste disposal	CH4	2728	3709	0.01	0.01	0.89
2.B.2 Chemical Industry - Nitric acid production	N2O	498	38	0.01	0.01	0.90
5.D Wastewater treatment and discharge	CH4	2399	2358	0.01	0.01	0.91
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.01	0.01	0.92
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1690	0.01	0.01	0.93
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	15	300	0.00	0.01	0.94
1.A.4 Combustion Other Sectors - Biomass	CH4	407	241	0.00	0.01	0.95
3.B Manure Management	CH4	674	591	0.00	0.00	0.95

Table K. 6 – Level assessment (Approach 2) without LULUCF: 1990.

Tier 2 Level Assessment (1990)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate kton CO2 eq.) 1990	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
5.A Solid waste disposal	CH4	2728	2728	0.05	144.43	6.63	0.36	0.36
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1807	0.03	75.95	2.31	0.12	0.48
5.D Wastewater treatment and discharge	CH4	2399	2399	0.04	46.11	1.86	0.10	0.58
5.D Wastewater treatment and discharge	N2O	217	217	0.00	500.64	1.83	0.10	0.68
2.A.1 Mineral Industry - Cement production	CO2	3176	3176	0.05	14.37	0.77	0.04	0.72
1.A.3.b Road Transportation	CO2	9266	9266	0.16	3.75	0.59	0.03	0.75
2.D Non-energy products from fuels and solvent use	CO2	248	248	0.00	140.20	0.59	0.03	0.78
1.A.4 Combustion Other Sectors - Biomass	CH4	407	407	0.01	83.77	0.57	0.03	0.81
1.A.1 Energy industries - Liquid fuels	CO2	8345	8345	0.14	2.75	0.39	0.02	0.83
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141	141	0.00	144.34	0.34	0.02	0.85
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	6502	0.11	2.69	0.29	0.02	0.87
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	3088	0.05	4.95	0.26	0.01	0.88
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	4063	0.07	3.54	0.24	0.01	0.90

Table K. 7 – Level assessment (Approach 2) without LULUCF: 2015.

Tier 2 Level Assessment (2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
3.D.1Direct N2OEmissionsFrom Managed Soils	N2O	1807	1690	0.02	78.27	1.92	0.13	0.13
5.D Wastewater treatment and discharge	N2O	217	254	0.00	500.64	1.85	0.13	0.26
5.A Solid waste disposal	CH4	2728	3709	0.05	26.56	1.43	0.10	0.36
5.D Wastewater treatment and discharge	CH4	2399	2358	0.03	39.80	1.37	0.09	0.45
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	93.58	1.36	0.09	0.54
2.F.1 Refrigeration and Air Conditioning	Fgase	NA	2613	0.04	31.42	1.19	0.08	0.63
1.A.3.b Road Transportation	CO2	9266	15358	0.22	3.69	0.82	0.06	0.68
2.A.1 Mineral Industry - Cement production	CO2	3176	2921	0.04	14.66	0.62	0.04	0.73
1.A.4 Combustion Other Sectors - Biomass	CH4	407	241	0.00	143.87	0.50	0.03	0.76
2.D Non-energy products from fuels and solvent use	CO2	248	192	0.00	164.65	0.46	0.03	0.79
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.05	7.90	0.40	0.03	0.82
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.01	40.85	0.24	0.02	0.84
1.A.3.a Civil (domestic) aviation	CO2	178	366	0.01	35.89	0.19	0.01	0.85
2.A.2 Mineral Industry - Lime production	CO2	203	351	0.01	35.60	0.18	0.01	0.86
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141	88	0.00	135.81	0.17	0.01	0.87
1.A.3.d Domestic navigation - Residual fuel oil	CO2	263	266	0.00	38.46	0.15	0.01	0.88
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	2636	0.04	3.60	0.14	0.01	0.89
3.C Rice cultivation	CH4	134	142	0.00	64.34	0.13	0.01	0.90

Table K. 8 – Trend assessment (Approach 2) without LULUCF: 1990-2015.

Tier 2 Trend Assessment (1990-2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Trend Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	93.58	1.24	0.22	0.22
1.A.4 Combustion Other Sectors - Biomass	CH4	407	241	0.00	143.87	0.44	0.08	0.30
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.05	7.90	0.43	0.08	0.37
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1690	0.01	78.27	0.42	0.07	0.44
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	56	0.05	6.22	0.29	0.05	0.49
1.A.3.b Road Transportation	CO2	9266	15358	0.06	3.69	0.23	0.04	0.53
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.01	40.85	0.22	0.04	0.57
5.D Wastewater treatment and discharge	CH4	2399	2358	0.01	39.80	0.22	0.04	0.61
2.D Non-energy products from fuels and solvent use	CO2	248	192	0.00	164.65	0.21	0.04	0.65
1.B.1.Fugitive emissions – Solid Fuels (Mining activities)	CH4	89	9	0.00	166.97	0.21	0.04	0.69
5.A Solid waste disposal	CH4	2728	3709	0.01	26.56	0.19	0.03	0.72
2.A.1 Mineral Industry - Cement production	CO2	3176	2921	0.01	14.66	0.15	0.03	0.75
1.A.1 Energy industries - Liquid fuels	CO2	8345	2025	0.10	1.34	0.14	0.02	0.77
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141	88	0.00	135.81	0.14	0.02	0.79
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	2636	0.03	3.60	0.10	0.02	0.81
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	15	300	0.00	20.84	0.08	0.01	0.82
1.A.3.a Civil (domestic) aviation	CO2	178	366	0.00	35.89	0.08	0.01	0.84
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	0	3932	0.05	1.44	0.07	0.01	0.85
2.B.2 Chemical Industry - Nitric acid production	N2O	498	38	0.01	10.20	0.07	0.01	0.86
1.A.1 Energy industries - Gaseous fuels	CO2	0	3568	0.05	1.19	0.06	0.01	0.87
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	0	1336	0.02	3.18	0.06	0.01	0.88
2.A.2 Mineral Industry - Lime production	CO2	203	351	0.00	35.60	0.05	0.01	0.89
1.A.2 Manufacturing industries and construction - Biomass	N2O	69	46	0.00	107.82	0.05	0.01	0.90

Table K. 9 – Level assessment (Approach 1) with LULUCF: 1990.

Tier 1 Level Assessment (1990)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1990	Level Assess.	Cumulative Total
1.A.3.b Road Transportation	CO2	9266	9266	0.12	0.12
1.A.1 Energy industries - Liquid fuels	CO2	8345	8345	0.11	0.23
1.A.1 Energy industries - Solid fuels	CO2	7983	7983	0.11	0.34
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	6502	0.09	0.43
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	4063	0.05	0.48
4.B.2 Land converted to Cropland	CO2	4048	4048	0.05	0.53
4.A.1 Forest land remaining Forest land	CO2	-3880	-3880	0.05	0.59
3.A Enteric fermentation	CH4	3521	3521	0.05	0.63
4.C.2 Land converted to Grassland	CO2	3228	3228	0.04	0.67
2.A.1 Mineral Industry - Cement production	CO2	3176	3176	0.04	0.72
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	3088	0.04	0.76
5.A Solid waste disposal	CH4	2728	2728	0.04	0.79
5.D Wastewater treatment and discharge	CH4	2399	2399	0.03	0.83
4.A.2 Land converted to Forest land	CO2	-2125	-2125	0.03	0.85
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1807	0.02	0.88
4.G. Other (Harvested Wood Products)	CO2	-1674	-1674	0.02	0.90
4.F.2 Land converted to Other Land	CO2	926	926	0.01	0.91
3.B Manure Management	CH4	674	674	0.01	0.92
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	662	662	0.01	0.93
2.B.1 Chemical Industry - Ammonia production	CO2	540	540	0.01	0.94
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	499	499	0.01	0.94
2.B.2 Chemical Industry - Nitric acid production	N2O	498	498	0.01	0.95

Table K. 10 – Level assessment (Approach 1) with LULUCF: 2015.

Tier 1 Level Assessment (2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Level Assess.	Cumulative Total
1.A.3.b Road Transportation	CO2	9266	15358	0.18	0.18
1.A.1 Energy industries - Solid fuels	CO2	7983	12229	0.15	0.33
4.A.1 Forest land remaining Forest land	CO2	-3880	-8409	0.10	0.43
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	0	3932	0.05	0.48
5.A Solid waste disposal	CH4	2728	3709	0.04	0.52
1.A.1 Energy industries - Gaseous fuels	CO2	0	3568	0.04	0.57
3.A Enteric fermentation	CH4	3521	3479	0.04	0.61
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.04	0.65
4.A.2 Land converted to Forest land	CO2	-2125	-3044	0.04	0.69
2.A.1 Mineral Industry - Cement production	CO2	3176	2921	0.04	0.72
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	2636	0.03	0.75
2.F.1 Refrigeration and Air Conditioning	Fgases	NA	2613	0.03	0.79
4.E.2 Land converted to Settlements	CO2	30	2446	0.03	0.82
5.D Wastewater treatment and discharge	CH4	2399	2358	0.03	0.84
1.A.1 Energy industries - Liquid fuels	CO2	8345	2025	0.02	0.87
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1690	0.02	0.89
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	0	1336	0.02	0.90
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	0.92
4.F.2 Land converted to Other Land	CO2	926	-813	0.01	0.93
4.B.2 Land converted to Cropland	CO2	4048	759	0.01	0.94
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	662	650	0.01	0.94
3.B Manure Management	CH4	674	591	0.01	0.95

Table K. 11 – Trend assessment (Approach 1) with LULUCF: 1990-2015.

Tier 1 Trend Assessment (1990-2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Trend Assess.	Contribution to Trend	Cumulative Total
1.A.1 Energy industries - Liquid fuels	CO2	8345	2025	0.08	0.11	0.11
1.A.3.b Road Transportation	CO2	9266	15358	0.08	0.11	0.22
4.A.1 Forest land remaining Forest land	CO2	-3880	-8409	0.06	0.08	0.29
1.A.1 Energy industries - Solid fuels	CO2	7983	12229	0.06	0.08	0.37
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	0	3932	0.05	0.07	0.44
1.A.1 Energy industries - Gaseous fuels	CO2	0	3568	0.05	0.06	0.50
4.B.2 Land converted to Cropland	CO2	4048	759	0.04	0.06	0.56
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	56	0.04	0.05	0.61
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.04	0.05	0.66
4.C.2 Land converted to Grassland	CO2	3228	456	0.04	0.05	0.71
4.E.2 Land converted to Settlements	CO2	30	2446	0.03	0.04	0.75
4.F.2 Land converted to Other Land	CO2	926	-813	0.02	0.03	0.78
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063	2636	0.02	0.02	0.80
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	0	1336	0.02	0.02	0.83
4.G. Other (Harvested Wood Products)	CO2	-1674	-424	0.02	0.02	0.85
5.A Solid waste disposal	CH4	2728	3709	0.01	0.02	0.87
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	0.02	0.88
4.A.2 Land converted to Forest land	CO2	-2125	-3044	0.01	0.02	0.90
2.B.1 Chemical Industry - Ammonia production	CO2	540	0	0.01	0.01	0.91
2.B.2 Chemical Industry - Nitric acid production	N2O	498	38	0.01	0.01	0.92
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.01	0.01	0.92
4.D.2 Land converted to Wetlands	CO2	0	394	0.01	0.01	0.93
4.C.1 Grassland remaining Grassland	CO2	0	-369	0.00	0.01	0.94
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	15	300	0.00	0.00	0.94
4.B.2 Land converted to Cropland	N2O	321	50	0.00	0.00	0.95
4.B.1 Cropland remaining Cropland	CO2	21	-204	0.00	0.00	0.95

Table K. 12 – Level assessment (Approach 2) with LULUCF: 1990.

Tier 2 Level Assessment (1990)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate kton CO2 eq.) 1990	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
5.A Solid waste disposal	CH4	2728	2728	0.04	144.43	5.23	0.22	0.22
4.B.2 Land converted to Cropland	CO2	4048	4048	0.05	64.61	3.47	0.14	0.36
4.C.2 Land converted to Grassland	CO2	3228	3228	0.04	55.20	2.36	0.10	0.46
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1807	0.02	75.95	1.82	0.08	0.53
5.D Wastewater treatment and discharge	CH4	2399	2399	0.03	46.11	1.47	0.06	0.60
5.D Wastewater treatment and discharge	N2O	217	217	0.00	500.64	1.44	0.06	0.66
4.A.1. Forest land remaining Forest land	CO2	-3880	-3880	0.05	26.63	1.37	0.06	0.71
4.F.2 Land converted to Other Land	CO2	926	926	0.01	76.89	0.94	0.04	0.75
4.A.2 Land converted to Forest land	CO2	-2125	-2125	0.03	22.72	0.64	0.03	0.78
2.A.1 Mineral Industry - Cement production	CO2	3176	3176	0.04	14.37	0.61	0.03	0.80
1.A.3.b Road Transportation	CO2	9266	9266	0.12	3.75	0.46	0.02	0.82
2.D Non-energy products from fuels and solvent use	CO2	248	248	0.00	140.20	0.46	0.02	0.84
1.A.4 Combustion Other Sectors - Biomass	CH4	407	407	0.01	83.77	0.45	0.02	0.86
1.A.1 Energy industries - Liquid fuels	CO2	8345	8345	0.11	2.75	0.30	0.01	0.87
4.B.2 Land converted to Cropland	N2O	321	321	0.00	69.15	0.29	0.01	0.89
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141	141	0.00	144.34	0.27	0.01	0.90

Table K. 13 – Level assessment (Approach 2) with LULUCF: 2015.

Tier 2 Level Assessment (2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate kton CO2 eq.) 2015	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4.A.1. Forest land remaining Forest land	CO2	-3880	-8409	0.10	18.50	1.87	0.11	0.11
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1690	0.02	78.27	1.59	0.10	0.21
5.D Wastewater treatment and discharge	N2O	217	254	0.00	500.64	1.53	0.09	0.30
5.A Solid waste disposal	CH4	2728	3709	0.04	26.56	1.18	0.07	0.37
5.D Wastewater treatment and discharge	CH4	2399	2358	0.03	39.80	1.13	0.07	0.44
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	93.58	1.13	0.07	0.50
2.F.1 Refrigeration and Air Conditioning	Fgase	NA	2613	0.03	31.42	0.99	0.06	0.56
1.A.3.b Road Transportation	CO2	9266	15358	0.18	3.69	0.68	0.04	0.60
4.F.2 Land converted to Other Land	CO2	926	-813	0.01	63.42	0.62	0.04	0.64
4.E.2 Land converted to Settlements	CO2	30	2446	0.03	18.82	0.55	0.03	0.67
2.A.1 Mineral Industry - Cement production	CO2	3176	2921	0.04	14.66	0.51	0.03	0.70
4.C.2 Land converted to Grassland	CO2	3228	456	0.01	87.53	0.48	0.03	0.73
4.A.2 Land converted to Forest land	CO2	-2125	-3044	0.04	13.09	0.48	0.03	0.76
1.A.4 Combustion Other Sectors - Biomass	CH4	407	241	0.00	143.87	0.42	0.02	0.79
2.D Non-energy products from fuels and solvent use	CO2	248	192	0.00	164.65	0.38	0.02	0.81
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.04	7.90	0.33	0.02	0.83
4.B.2 Land converted to Cropland	CO2	4048	759	0.01	34.07	0.31	0.02	0.85
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.00	40.85	0.20	0.01	0.86
1.A.3.a Civil (domestic) aviation	CO2	178	366	0.00	35.89	0.16	0.01	0.87
2.A.2 Mineral Industry - Lime production	CO2	203	351	0.00	35.60	0.15	0.01	0.88
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141	88	0.00	135.81	0.14	0.01	0.89
1.A.3.d Domestic navigation - Residual fuel oil	CO2	263	266	0.00	38.46	0.12	0.01	0.89
4.D.2 Land converted to Wetlands	CO2	0	394	0.00	24.99	0.12	0.01	0.90

Table K. 14 – Trend assessment (Approach 2) with LULUCF: 1990-2015.

Tier 2 Trend Assessment (1990-2015)

IPCC SOURCE CATEGORIES	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2015	Trend Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4.C.2 Land converted to Grassland	CO2	3228	456	0.04	87.53	3.17	0.23	0.23
4.B.2 Land converted to Cropland	CO2	4048	759	0.04	34.07	1.46	0.11	0.34
4.F.2 Land converted to Other Land	CO2	926	-813	0.02	63.42	1.45	0.11	0.45
1.B.2.a Fugitive emissions - Oil	CO2	0	1001	0.01	93.58	1.24	0.09	0.54
4.A.1 Forest land remaining Forest land	CO2	-3880	-8409	0.06	18.50	1.10	0.08	0.62
4.E.2 Land converted to Settlements	CO2	30	2446	0.03	18.82	0.60	0.04	0.67
5.A Solid waste disposal	CH4	2728	3709	0.01	26.56	0.36	0.03	0.69
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502	3441	0.04	7.90	0.31	0.02	0.72
1.A.4 Combustion Other Sectors - Biomass	CH4	407	241	0.00	143.87	0.31	0.02	0.74
1.A.3.b Road Transportation	CO2	9266	15358	0.08	3.69	0.30	0.02	0.76
5.D Wastewater treatment and discharge	N2O	217	254	0.00	500.64	0.27	0.02	0.78
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088	56	0.04	6.22	0.25	0.02	0.80
1.A.1 Energy industries - Other fossil fuels	CO2	0	412	0.01	40.85	0.22	0.02	0.82
1.B.1 Fugitive emissions – Solid Fuels (Mining activities)	CH4	89	9	0.00	166.97	0.17	0.01	0.83
4.A.2 Land converted to Forest land	CO2	-2125	-3044	0.01	13.09	0.15	0.01	0.84
4.B.2 Land converted to Cropland	N2O	321	50	0.00	42.52	0.15	0.01	0.85
4.D.2 Land converted to Wetlands	CO2	0	394	0.01	24.99	0.13	0.01	0.86
4.C.2 Land converted to Grassland	N2O	162	29	0.00	71.46	0.12	0.01	0.87
2.D Non-energy products from fuels and solvent use	CO2	248	192	0.00	164.65	0.12	0.01	0.88
1.A.1 Energy industries - Liquid fuels	CO2	8345	2025	0.08	1.34	0.11	0.01	0.89
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807	1690	0.00	78.27	0.10	0.01	0.89
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141	88	0.00	135.81	0.09	0.01	0.90

ANNEX L: Uncertainty Assessment

Uncertainty in the inventory of emissions and removals of GHG result from the natural variability of emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameter due to errors in original monitoring data, reference studies and expert judgment.

Uncertainty values were defined as the range of 95% confidence interval (IPCC,1997; IPCC, 2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

The uncertainty analysis was performed only for the direct GHG: CO_2, CH_4, N_2O considering all emissions in CO_2e. The uncertainty of all source activities was considered to overall uncertainty including the uncertainty of LULUCF category.

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

The uncertainty is estimated for individual years, from emission estimates in specific years and uncertainty values for both activity data and implied emission factors, but also for the trend of emissions for each individual category.

Table L. 1 – Approach 1 Uncertainty Estimates: 2015.

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
1.A.1 Energy industries - Liquid fuels	CO2	8345.45	2024.51	1.2	0.5	1.3401	0.0020		0.0333	0.0000	0.0581	0.0034
1.A.1 Energy industries - Solid fuels	CO2	7982.90	12228.81	0.0	0.0	0.0002	0.0000		0.2014	0.0000	0.0000	0.0000
1.A.1 Energy industries - Gaseous fuels	CO2	0.00	3568.49	0.9	0.7	1.1949	0.0051		0.0588	0.0000	0.0774	0.0060
1.A.1 Energy industries - Other fossil fuels	CO2	0.00	411.80	5.0	40.5	40.8542	0.0787		0.0068	0.0000	0.0480	0.0023
1.A.2 Manufacturing industries and construction - Liquid fuels	CO2	6502.09	3441.02	2.9	7.4	7.9049	0.2058		0.0567	0.0000	0.2303	0.0530
1.A.2 Manufacturing industries and construction - Solid fuels	CO2	3088.35	56.25	3.4	5.2	6.2220	0.0000		0.0009	0.0000	0.0044	0.0000
1.A.2 Manufacturing industries and construction - Gaseous fuels	CO2	0.00	3931.64	0.8	1.2	1.4368	0.0089		0.0647	0.0000	0.0735	0.0054
1.A.2 Manufacturing industries and construction - Other fossil fuels	CO2	15.14	300.24	6.1	19.9	20.8421	0.0109		0.0049	0.0000	0.0426	0.0018
1.A.3.a Civil (domestic) aviation	CO2	177.82	365.96	35.5	5.0	35.8922	0.0480		0.0060	0.0000	0.3029	0.0918
1.A.3.b Road Transportation	CO2	9265.86	15358.34	2.5	2.7	3.6857	0.8914		0.2529	0.0000	0.8779	0.7708
1.A.3.c Railways - Liquid fuels	CO2	177.19	30.16	2.9	1.7	3.3431	0.0000		0.0005	0.0000	0.0020	0.0000
1.A.3.d Domestic navigation - Residual fuel oil	CO2	262.52	266.37	38.0	5.8	38.4636	0.0292		0.0044	0.0000	0.2359	0.0556
1.A.4 Combustion Other Sectors - Liquid fuels	CO2	4063.02	2636.07	3.6	0.2	3.6003	0.0251		0.0434	0.0000	0.2208	0.0488
1.A.4 Combustion Other Sectors - Gaseous fuels	CO2	0.00	1336.45	2.0	2.5	3.1764	0.0050		0.0220	0.0000	0.0614	0.0038
1.A.5 Combustion Non-SpecifiedOther - Liquid fuels	CO2	96.11	76.17	5.0	5.0	7.0711	0.0001		0.0013	0.0000	0.0089	0.0001
1.A.5 Combustion Non-SpecifiedOther - Solid fuels	CO2	8.40	0.00	0.0	0.0	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\|\frac{D}{\sum C}\right\|$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
1.B.2.a Fugitive emissions - Oil	CO2	0.48	1001.24	19.4	91.5	93.5831	2.4426		0.0165	0.0000	0.4524	0.2047
1.B.2.b Fugitive emissions - Natural Gas	CO2	0.00	0.02	0.0	0.0	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
1.B.2.c Venting and Flaring	CO2	117.94	135.01	25.2	0.0	25.1659	0.0032		0.0022	0.0000	0.0791	0.0063
1.B.2.d Geothermal	CO2	0.80	36.23	3.6	35.6	35.7288	0.0005		0.0006	0.0000	0.0030	0.0000
2.A.1 Mineral Industry - Cement production	CO2	3176.37	2921.24	14.6	1.3	14.6607	0.5103		0.0481	0.0000	0.9935	0.9871
2.A.2 Mineral Industry - Lime production	CO2	203.40	351.26	35.0	6.3	35.5985	0.0435		0.0058	0.0000	0.2866	0.0821
2.A.3 Mineral Industry - Glass production	CO2	83.88	167.42	5.4	2.2	5.8310	0.0003		0.0028	0.0000	0.0210	0.0004
2.A.4 Mineral Industry - Other Process Uses of Carbonates	CO2	205.09	354.90	2.4	2.5	3.4819	0.0004		0.0058	0.0000	0.0200	0.0004
2.B.1 Chemical Industry - Ammonia production	CO2	539.52	0.00	0.0	0.0	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CO2	661.74	650.22	2.9	12.7	13.0070	0.0199		0.0107	0.0000	0.0442	0.0020
2.C.1 Metal Industry - Iron and Steel production	CO2	108.55	94.96	10.0	10.0	14.1421	0.0005		0.0016	0.0000	0.0221	0.0005
2.D Non-energy products from fuels and solvent use	CO2	247.97	191.69	8.3	164.4	164.6495	0.2772		0.0032	0.0000	0.0371	0.0014
3.G Liming	CO2	12.59	7.33	0.0	0.0	0.0000	0.0000		0.0001	0.0000	0.0000	0.0000
3.H Urea application	CO2	21.28	51.31	0.0	0.0	0.0000	0.0000		0.0008	0.0000	0.0000	0.0000
4.A.1. Forest land remaining Forest land	CO2	-3879.76	-8409.29	2.2	18.4	18.4978	6.7319		0.1385	0.0000	0.4329	0.1874
4.A.2 Land converted to Forest land	CO2	-2124.51	-3043.54	4.8	12.2	13.0878	0.4414		0.0501	0.0000	0.3379	0.1142
4.B.1. Cropland remaining Cropland	CO2	21.11	-204.38	3.3	23.2	23.4011	0.0064		0.0034	0.0000	0.0156	0.0002

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
4.B.2 Land converted to Cropland	CO2	4047.89	759.19	5.9	33.6	34.0739	0.1862		0.0125	0.0000	0.1035	0.0107
4.C.1. Grassland remaining Grassland	CO2	0.00	-369.05	10.0	14.7	17.7482	0.0119		0.0061	0.0000	0.0859	0.0074
4.C.2 Land converted to Grassland	CO2	3228.47	456.28	7.3	87.2	87.5256	0.4437		0.0075	0.0000	0.0771	0.0059
4.D.2 Land converted to Wetlands	CO2	0.00	394.38	18.1	17.3	24.9922	0.0270		0.0065	0.0000	0.1658	0.0275
4.E.2 Land converted to Settlements	CO2	30.46	2445.88	8.8	16.6	18.8221	0.5896		0.0403	0.0000	0.5034	0.2534
4.F.2 Land converted to Other Land	CO2	925.89	-812.97	10.5	62.5	63.4241	0.7397		0.0134	0.0000	0.1993	0.0397
4.G. Other (Harvested Wood Products)	CO2	-1673.53	-424.23	0.0	0.0	0.0000	0.0000		0.0070	0.0000	0.0000	0.0000
5.C Incineration and open burning of waste	CO2	6.86	22.40	16.9	250.1	250.6242	0.0088		0.0004	0.0000	0.0088	0.0001
1.A.1 Energy industries - Liquid fuels	CH4	3.34	1.29	1.2	101.9	101.9089	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.1 Energy industries - Solid fuels	CH4	2.70	3.30	1.5	103.0	103.0262	0.0000		0.0001	0.0000	0.0001	0.0000
1.A.1 Energy industries - Gaseous fuels	CH4	0.00	1.59	0.9	72.2	72.2082	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.1 Energy industries - Other fossil fuels	CH4	0.00	2.84	5.0	100.5	100.6231	0.0000		0.0000	0.0000	0.0003	0.0000
1.A.1 Energy industries - Biomass	CH4	0.00	5.88	12.0	69.0	70.0127	0.0000		0.0001	0.0000	0.0016	0.0000
1.A.2 Manufacturing industries and construction - Liquid fuels	CH4	14.78	9.09	2.2	46.7	46.7706	0.0001		0.0001	0.0000	0.0005	0.0000
1.A.2 Manufacturing industries and construction - Solid fuels	CH4	2.03	0.07	2.6	84.5	84.5123	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.2 Manufacturing industries and construction - Gaseous fuels	CH4	0.00	22.40	0.8	86.0	86.0211	0.0010		0.0004	0.0000	0.0004	0.0000

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
1.A.2 Manufacturing industries and construction - Other fossil fuels	CH4	0.04	0.11	3.1	98.0	98.0390	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.2 Manufacturing industries and construction - Biomass	CH4	15.43	17.27	7.0	58.3	58.7486	0.0003		0.0003	0.0000	0.0028	0.0000
1.A.3.a Civil (domestic) aviation	CH4	0.98	0.35	35.5	94.8	101.2228	0.0000		0.0000	0.0000	0.0003	0.0000
1.A.3.b Road Transportation	CH4	101.74	26.81	2.5	20.7	20.8251	0.0001		0.0004	0.0000	0.0015	0.0000
1.A.3.c Railways - Liquid fuels	CH4	0.25	0.05	2.9	140.2	140.2002	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.3.d Domestic navigation - Residual fuel oil	CH4	0.60	0.61	38.0	76.9	85.7566	0.0000		0.0000	0.0000	0.0005	0.0000
1.A.4 Combustion Other Sectors - Liquid fuels	CH4	6.83	4.36	3.6	72.9	72.9456	0.0000		0.0001	0.0000	0.0004	0.0000
1.A.4 Combustion Other Sectors - Gaseous fuels	CH4	0.00	0.63	2.0	93.5	93.4919	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.4 Combustion Other Sectors - Biomass	CH4	407.03	241.16	47.1	135.9	143.8701	0.3349		0.0040	0.0000	0.2646	0.0700
1.A.5 Combustion Non-SpecifiedOther - Liquid fuels	CH4	0.02	0.01	5.0	40.0	40.3113	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.5 Combustion Non-SpecifiedOther - Solid fuels	CH4	0.02	0.00	0.0	0.0	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
1.B.1.Fugitive emissions – Solid Fuels (Mining activities)	CH4	88.53	8.65	10.0	166.7	166.9664	0.0006		0.0001	0.0000	0.0020	0.0000
1.B.2.a Fugitive emissions - Oil	CH4	26.18	34.73	0.0	81.1	81.1074	0.0022		0.0006	0.0000	0.0000	0.0000
1.B.2.b Fugitive emissions - Natural Gas	CH4	0.00	53.81	4.9	0.0	4.9231	0.0000		0.0009	0.0000	0.0062	0.0000
1.B.2.c Venting and Flaring	CH4	0.54	1.64	22.0	66.5	70.0102	0.0000		0.0000	0.0000	0.0008	0.0000
2.B.8 Chemical Industry - Petrochemical and Carbon Black production	CH4	25.53	26.61	9.1	10.8	14.1359	0.0000		0.0004	0.0000	0.0056	0.0000

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
2.C.1 Metal Industry - Iron and Steel production	CH4	5.55	16.28	10.0	5.0	11.1803	0.0000		0.0003	0.0000	0.0038	0.0000
2.D Non-energy products from fuels and solvent use	CH4	0.90	0.87	99.7	100.3	141.4214	0.0000		0.0000	0.0000	0.0020	0.0000
3.A Enteric fermentation	CH4	3520.64	3479.39	0.8	13.5	13.4943	0.6133		0.0573	0.0000	0.0682	0.0047
3.B Manure Management	CH4	673.65	591.23	8.3	49.8	50.5160	0.2482		0.0097	0.0000	0.1144	0.0131
3.C Rice cultivation	CH4	133.92	141.99	10.2	63.5	64.3410	0.0232		0.0023	0.0000	0.0337	0.0011
3.F Field burning of agricultural residues	CH4	37.24	29.33	35.4	23.5	42.4253	0.0004		0.0005	0.0000	0.0241	0.0006
4.A.1. Forest land remaining Forest land	CH4	155.70	59.20	10.1	34.7	36.1493	0.0013		0.0010	0.0000	0.0139	0.0002
4.A.2 Land converted to Forest land	CH4	22.45	6.93	10.1	19.3	21.7560	0.0000		0.0001	0.0000	0.0016	0.0000
4.B.1. Cropland remaining Cropland	CH4	7.03	1.55	14.4	22.5	26.6638	0.0000		0.0000	0.0000	0.0005	0.0000
4.B.2 Land converted to Cropland	CH4	9.08	1.70	12.5	22.5	25.7259	0.0000		0.0000	0.0000	0.0005	0.0000
4.C.1. Grassland remaining Grassland	CH4	1.57	1.40	25.0	72.3	76.4853	0.0000		0.0000	0.0000	0.0008	0.0000
4.C.2 Land converted to Grassland	CH4	4.54	2.05	13.5	39.0	41.3277	0.0000		0.0000	0.0000	0.0006	0.0000
4.F.2 Land converted to Other Land	CH4	4.08	2.17	7.4	28.8	29.7675	0.0000		0.0000	0.0000	0.0004	0.0000
5.A Solid waste disposal	CH4	2728.45	3709.04	12.7	23.3	26.5642	2.7008		0.0611	0.0000	1.0997	1.2094
5.B Biological treatment of solid waste	CH4	5.03	23.07	14.1	119.6	120.3984	0.0021		0.0004	0.0000	0.0076	0.0001
5.C Incineration and open burning of waste	CH4	0.27	0.15	16.9	92.7	94.2650	0.0000		0.0000	0.0000	0.0001	0.0000
5.D Wastewater treatment and discharge	CH4	2398.94	2357.72	39.8	0.0	39.8049	2.4504		0.0388	0.0000	2.1856	4.7771

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G\bullet D)^2}{(\sum D)^2}$	Note B	$\left\|\frac{D}{\sum C}\right\|$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
5.E Other (Biogas burning)	CH4	0.00	0.00	5.0	150.0	150.0833	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.1 Energy industries - Liquid fuels	N2O	10.71	2.37	1.2	75.3	75.2834	0.0000		0.0000	0.0000	0.0001	0.0000
1.A.1 Energy industries - Solid fuels	N2O	37.81	58.98	1.5	49.8	49.8139	0.0024		0.0010	0.0000	0.0021	0.0000
1.A.1 Energy industries - Gaseous fuels	N2O	0.00	38.98	0.9	73.0	73.0519	0.0023		0.0006	0.0000	0.0008	0.0000
1.A.1 Energy industries - Other fossil fuels	N2O	0.00	7.20	5.0	100.0	100.1249	0.0001		0.0001	0.0000	0.0008	0.0000
1.A.1 Energy industries - Biomass	N2O	0.00	25.04	12.0	46.1	47.6465	0.0004		0.0004	0.0000	0.0070	0.0000
1.A.2 Manufacturing industries and construction - Liquid fuels	N2O	25.83	12.54	2.9	59.4	59.4944	0.0002		0.0002	0.0000	0.0008	0.0000
1.A.2 Manufacturing industries and construction - Solid fuels	N2O	6.03	0.17	2.6	71.8	71.8327	0.0000		0.0000	0.0000	0.0000	0.0000
1.A.2 Manufacturing industries and construction - Gaseous fuels	N2O	0.00	21.13	0.8	35.7	35.7468	0.0002		0.0003	0.0000	0.0004	0.0000
1.A.2 Manufacturing industries and construction - Other fossil fuels	N2O	0.14	12.66	6.1	166.4	166.5439	0.0012		0.0002	0.0000	0.0018	0.0000
1.A.2 Manufacturing industries and construction - Biomass	N2O	69.07	46.08	7.0	107.6	107.8222	0.0069		0.0008	0.0000	0.0075	0.0001
1.A.3.a Civil (domestic) aviation	N2O	1.48	3.05	35.5	498.3	499.6005	0.0006		0.0001	0.0000	0.0025	0.0000
1.A.3.b Road Transportation	N2O	64.46	135.76	2.5	3.3	4.0784	0.0001		0.0022	0.0000	0.0078	0.0001
1.A.3.c Railways - Liquid fuels	N2O	20.37	3.72	2.9	140.2	140.2002	0.0001		0.0001	0.0000	0.0002	0.0000
1.A.3.d Domestic navigation - Residual fuel oil	N2O	2.05	2.08	38.0	384.3	386.2107	0.0002		0.0000	0.0000	0.0018	0.0000
1.A.4 Combustion Other Sectors - Liquid fuels	N2O	141.38	88.35	3.6	135.8	135.8059	0.0401		0.0015	0.0000	0.0074	0.0001
1.A.4 Combustion Other Sectors - Gaseous fuels	N2O	0.00	7.08	2.0	105.5	105.5581	0.0002		0.0001	0.0000	0.0003	0.0000

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G\bullet D)^2}{(\sum D)^2}$	Note B	$\left\|\frac{D}{\sum C}\right\|$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
1.A.4 Combustion Other Sectors - Biomass	N2O	64.32	47.14	47.1	107.1	117.0414	0.0085		0.0008	0.0000	0.0517	0.0027
1.A.5 Combustion Non-SpecifiedOther - Liquid fuels	N2O	0.80	0.63	5.0	50.0	50.2494	0.0000		0.0000	0.0000	0.0001	0.0000
1.A.5 Combustion Non-SpecifiedOther - Solid fuels	N2O	0.04	0.00	0.0	0.0	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
1.B.2.c Venting and Flaring	N2O	2.38	3.13	22.0	368.0	368.6819	0.0004		0.0001	0.0000	0.0016	0.0000
2.B.2 Chemical Industry - Nitric acid production	N2O	497.84	38.00	2.0	10.0	10.1980	0.0000		0.0006	0.0000	0.0018	0.0000
2.G Other product manufacture and use	N2O	82.90	46.12	5.0	0.0	5.0000	0.0000		0.0008	0.0000	0.0054	0.0000
3.B Manure Management	N2O	254.22	192.64	36.4	55.8	66.6510	0.0459		0.0032	0.0000	0.1633	0.0267
3.D.1 Direct N2O Emissions From Managed Soils	N2O	1807.42	1690.16	18.3	76.1	78.2717	4.8690		0.0278	0.0000	0.7201	0.5185
3.D.2 Indirect N2O Emissions From Managed Soils	N2O	498.85	423.53	96.9	120.2	154.3453	1.1888		0.0070	0.0000	0.9553	0.9126
3.F Field burning of agricultural residues	N2O	21.35	16.62	35.4	16.8	39.1524	0.0001		0.0003	0.0000	0.0137	0.0002
4.A.1. Forest land remaining Forest land	N2O	37.66	21.57	10.1	60.7	61.5365	0.0005		0.0004	0.0000	0.0051	0.0000
4.A.2 Land converted to Forest land	N2O	15.85	13.00	10.1	49.4	50.3848	0.0001		0.0002	0.0000	0.0031	0.0000
4.B.1. Cropland remaining Cropland	N2O	1.15	0.25	14.4	56.6	58.3512	0.0000		0.0000	0.0000	0.0001	0.0000
4.B.2 Land converted to Cropland	N2O	320.98	49.81	12.5	40.7	42.5245	0.0012		0.0008	0.0000	0.0145	0.0002
4.C.1. Grassland remaining Grassland	N2O	0.26	0.23	25.0	129.7	132.0984	0.0000		0.0000	0.0000	0.0001	0.0000
4.C.2 Land converted to Grassland	N2O	161.77	28.85	13.5	70.2	71.4636	0.0012		0.0005	0.0000	0.0091	0.0001
4.D.2 Land converted to Wetlands	N2O	0.00	31.57	0.0	0.0	0.0000	0.0000		0.0005	0.0000	0.0000	0.0000

IPCC category/Group	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty (1)	Emission factor / estimation parameter uncertainty (1)	Combined uncertainty	Contribution to variance by category in year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty (2)	Uncertainty in trend in national emissions introduced by activity data uncertainty (3)	Uncertainty introduced into the trend in total national emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%		%	%	%	%	%
		input data	input data	input data Note A	input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	I*F Note C	J*E*sqrt(2) Note D	K^2 + L^2
4.E.2 Land converted to Settlements	N2O	2.31	181.96	0.0	0.0	0.0000	0.0000		0.0030	0.0000	0.0000	0.0000
4.F.2 Land converted to Other Land	N2O	0.74	17.58	7.4	54.8	55.2755	0.0003		0.0003	0.0000	0.0030	0.0000
5.B Biological treatment of solid waste	N2O	3.59	13.64	14.1	112.5	113.3854	0.0007		0.0002	0.0000	0.0045	0.0000
5.C Incineration and open burning of waste	N2O	0.90	0.71	16.9	97.7	99.1543	0.0000		0.0000	0.0000	0.0003	0.0000
5.D Wastewater treatment and discharge	N2O	216.74	254.15	2.1	500.6	500.6403	4.5042		0.0042	0.0000	0.0127	0.0002
5.E Other (Biogas burning)	N2O	0.00	0.00	5.0	1000.0	1000.0125	0.0000		0.0000	0.0000	0.0000	0.0000
2.F.1 Refrigeration and Air Conditioning	Fgases	0.00	2613.00	22.2	22.2	31.4245	1.8758		0.0430	0.0000	1.3508	1.8245
2.F.2 Foam blowing agents	Fgases	0.00	41.57	45.0	31.6	54.9266	0.0015		0.0007	0.0000	0.0435	0.0019
2.F.3 Fire protection	Fgases	0.00	31.64	42.4	21.2	47.4217	0.0006		0.0005	0.0000	0.0313	0.0010
2.F.4 Aerosols	Fgases	0.00	6.93	30.0	50.0	58.3095	0.0000		0.0001	0.0000	0.0048	0.0000
2.G.1 Electrical equipment	Fgases	0.00	26.19	10.0	58.3	59.1608	0.0007		0.0004	0.0000	0.0061	0.0000
Total[1]		60724.32	59952.92				32.7288					12.3394
Total Uncertainties						Uncertainty in total inventory %:	5.72				Trend uncertainty %:	3.51

[1] Totals exclude indirect N_2O from managed soils (CRF Table 4(IV)) and indirect CO_2.