



Instituto do Ambiente
MINISTÉRIO DO AMBIENTE, DO ORDENAMENTO DO TERRITÓRIO
E DO DESENVOLVIMENTO REGIONAL



**PORTUGUESE NATIONAL INVENTORY REPORT
ON GREENHOUSE GASES, 1990 - 2004**

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

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PREFACE

The Institute for the Environment (Instituto do Ambiente)/ Ministry for the Environment, Spatial Planning and Regional Development (Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional), in accordance to its attributions as national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions, has prepared the National Inventory of Greenhouse Gas (GHGs) Emissions and Sinks to comply with international commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the European Commission.

The Conference of Parties to the UNFCCC and the Council Decision 280/2004/EC, concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, define that each Party should provide each year an update of its inventory of emissions and removals of Greenhouse Gases (GHG) not controlled by the Montreal Protocol, taking into account the UNFCCC Reporting Guidelines on Annual Inventories. This includes a report on annual emissions estimates (CRF tables), accompanied by a National Inventory Report (NIR), describing the input data, methodologies, background information and explanation on the whole process of inventory preparation.

This 2006 NIR report refers to the 2006 Portuguese Submission on GHG data (CRF tables).

This report goes beyond the UNFCCC scope, however, including also emissions estimates for pollutants covered by the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP), to temporarily fulfil the requirements of CLRTAP reporting obligations, that require that Parties should also submit an informative inventory report. In the future a specific and independent report shall be produced to CLRTAP, however this goal was still not possible to achieve this year.

Ministry for Environment, Spatial Planning and Regional Development

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EXECUTIVE SUMMARY

ES.1 Background information on greenhouse gas inventories and climate change

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC), Portugal is requested to provide each year an update of its inventory of emissions and removals of greenhouse gas not controlled by the Montreal Protocol, taking into account the adopted Reporting Guidelines on Annual Inventories (FCCC/SBSTA/2004/8).

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

This report was prepared in order to comply with the international commitments under the UNFCCC and the European Commission (EC). It presents a description of the methods, assumptions and background data used in the preparation of the 2006 national inventory submission of GHG. The Revised (1996) IPCC Guidelines for National Greenhouse Gas Inventories (IPCC,1997) and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC,2000) have been applied as far as possible.

The report presents estimates for the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF₆), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x). The period covered is 1990-2004.

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

Furthermore, the report includes information on pollutants covered by the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP), which will serve in the future the reporting requirements under LRTAP Convention. The pollutants covered are: ammonia (NH₃), Particulate Matter (PM, PM₁₀, PM_{2.5} and PM_{1.0}) and heavy metals. The NIR covers also biogenic NMVOC emissions resulting from vegetation foliage, which emissions are also not included in UNFCCC emission reporting.

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

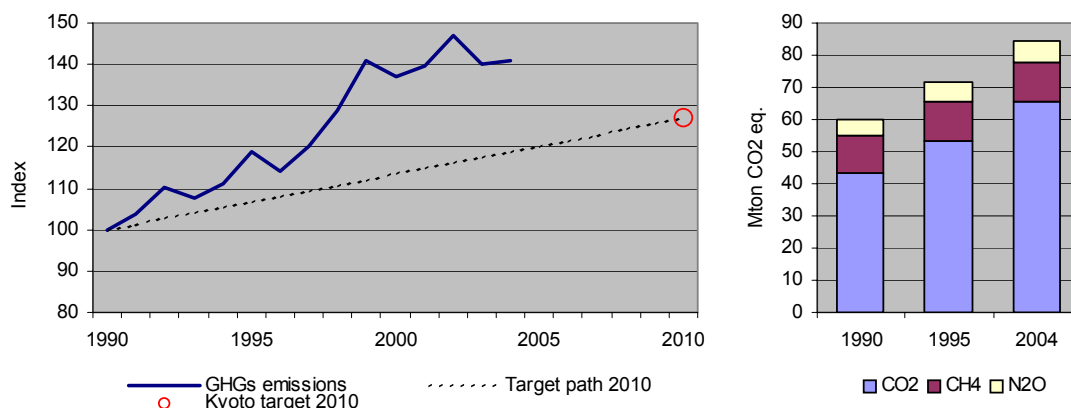
Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for all years in the period from 1990 to 2004, i.e., the inventory is internally consistent.

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

ES.2 Summary of national emissions and removal related trends

In 2004, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated about 84.4 Mton CO₂eq., representing an increase of 41% compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions to +27 per cent compared to the 1990 level. Comparing the 1990-2004 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2004, 21.8 per cent above this target path (Figure ES. 1).

Figure ES. 1 – GHG emissions (without LUCF)



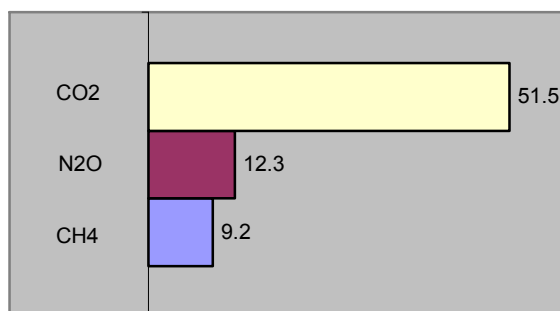
Despite the positive effect in emissions levels of some measures, such as the introduction of natural gas (1997), the new combined cycle thermoelectric unit of natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial processes, and the improvement of fuels quality, the overall trend of Portuguese emissions is still growing, even if in recent years, at a more moderate rate.

The principal source of GHGs in Portugal is associated with the energy sector and is primarily related to fossil fuel combustion. The largest gas emitted is CO₂ which represented in 2004 77.9 per cent of total GHGs emissions in global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for approximately 90 per cent of total CO₂ emissions in the same year.

Energy-related CO₂ emissions are dependent on the type of fuel and its carbon intensity. In average, during the period in consideration, 84 per cent of the primary enegy consumed was produced from fossil fuel combustion (coal, oil and natural gas); the percentage of renewable energy represents the remaining part, i.e. 16 per cent in average.

Figure ES. 2 illustrates the growth of GHG in the period 1990-2004. CO₂ is the gas having registered the biggest increase (51.5%). Portugal has chosen 1995 as the base year for fluorinated gases. However, F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2004: 0.4%).

Figure ES. 2– Increase of emissions by gas over the 1990-2004 period



The overall trend for direct GHG emissions in the 1990-2004 period are presented in Table ES. 1.

Table ES. 1 – GHG emissions and removals in Portugal by gas: 1990-2004

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO ₂ equivalent (Gg)															
Net CO ₂ emissions/removals	47 015	47 668	49 727	47 760	47 849	51 330	47 093	50 174	54 217	61 420	59 820	61 311	64 974	72 200	63 141
CO ₂ emissions (without LUCF)	43 366	45 181	49 326	47 925	49 138	53 131	50 258	53 543	58 234	64 894	63 762	65 018	69 250	64 600	65 717
CH ₄	11 379	11 733	11 557	11 579	12 087	12 520	12 530	12 716	13 292	13 507	12 457	12 330	12 663	13 105	12 365
N ₂ O	5 377	5 412	5 374	5 282	5 554	5 706	6 003	6 003	5 755	6 174	6 154	6 169	6 291	5 784	6 033
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	1	2	10	19	33	53	92	139	172	214.30	30125	357.73
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
SF ₆	2	2	2	3	3	3	3	3	3	4	5	5	4.57	4.57	3.44
Total (with net CO ₂ emis./removals)	63 772	64 815	66 661	64 624	65 495	69 569	65 647	68 930	73 321	81 198	78 575	79 986	84 147	91 395	81 900
Total (without CO ₂ from LULUCF)	60 123	62 328	66 260	64 790	66 784	71 370	68 812	72 299	77 337	84 671	82 517	83 693	88 423	83 795	84 476
Total (without LULUCF)	59 953	62 061	66 175	64 739	66 755	71 184	68 747	72 275	77 215	84 605	82 371	83 596	88 285	83 187	84 355

NE - not Estimated; NO - not occurring

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

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into six large sectors: Energy, Industrial Processes, Solvent use, Agriculture, Land-Use Change and Forestry, and Waste. Figure ES. 3 and

Figure ES. 4 present direct GHG emissions by sector for 1990 and 2004, respectively. Emissions have risen for all sectors.

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

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

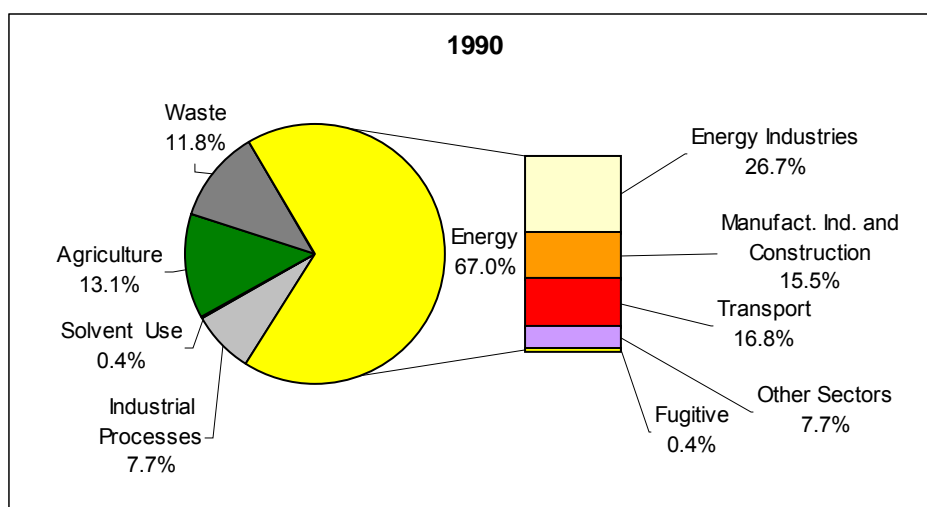
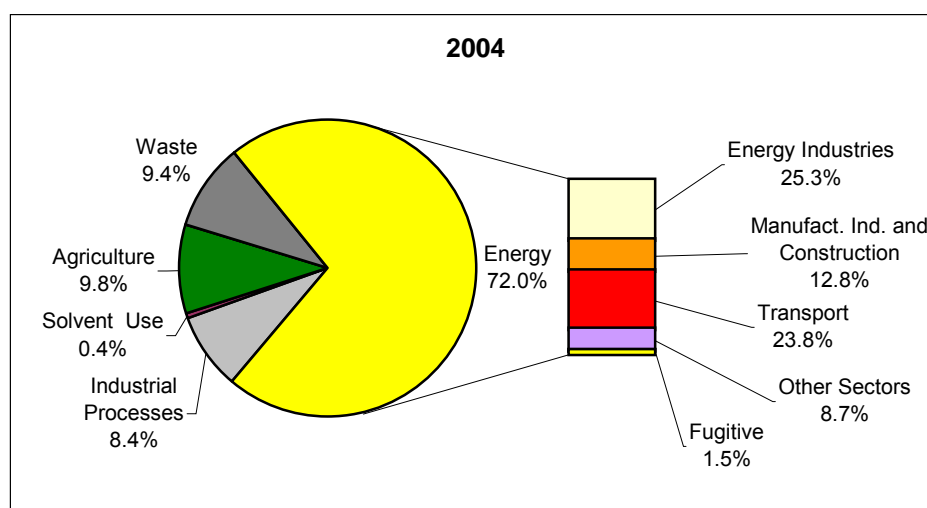


Figure ES. 4 – GHG emissions in Portugal by sector: 2004



Using this aggregated division, Energy was by far the most important sector, accounting for 72.0% of total emissions in 2004, and showing an increase of 51.2% over the 1990-2004 period. Energy industries and transport are the two most important sources representing respectively 25.3% and 23.8% of total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation (which continues to grow following the continued increase of electricity demand) and transport sources. Transportation sources, which are largely dominated by road traffic, are one of the sectors that are rising faster. In the period 1990-2004 these emissions increased 99.4%, due to the steady growth of vehicle fleets and road travel, in association with the increase in family income and the strong investment in road infrastructure of the country, that was done in the 90s decade. Indirectly the increase in road traffic activity also augmented the emissions from fossil fuel storage, handling and distribution.

Agriculture was the second most significant source of GHGs emissions (9.8% of total emissions). Waste and Industrial processes represented, respectively, 9.4% and 8.4% of Portuguese emissions in 2004, recording an increase of approximately 53.5% (industrial

processes) and 12.5% (waste). Solvent use represents less than 1% of total emissions, and is mainly related to NMVOC emissions¹.

Estimates of emissions and sinks from land use change and forestry category, show that this category was a net emitter in 1990 (3.8 Mt CO₂ eq.) and a carbon sink in 2004 (-2.5 Mt CO₂ eq.): The situation was temporarily inverted in 2003, when this source appeared as a net emitter (8.2 Mt CO₂ eq.), and which was due to the exceptional occurrences and extension, in that year, of forest fires.

Table ES. 2 presents the overall sectoral trend for direct GHG emissions in the 1990-2004 period.

Table ES. 2 – GHG emissions and removals in Portugal by sector: 1990-2004

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	CO ₂ equivalent (Gg)														
1. Energy	40 169	41968	46 328	44 944	45 548	48 913	46 348	49 010	53 357	60 647	59 189	60 440	64 441	60 011	60 752
2. Industrial Processes	4 626	4 600	4 370	4 224	5 031	5 782	5 536	6 220	6 465	6 170	6 042	6 551	6 957	6 901	7 100
3. Solvent and Other Product Use	220	234	243	236	253	256	275	285	290	285	290	304	312	318	320
4. Agriculture	7 878	7 993	7 855	7 745	7 985	8 059	8 360	8 238	8 219	8 324	8 577	8 414	8 473	7 866	8 240
5. Land-Use Change and Forestry ⁽¹⁾	3 818	2 753	486	-115	-1260	-1615	-3 100	-3 345	-3 894	-3 407	-3 796	-3 610	-4 138	8 209	-2 455
6. Waste	7 061	7 266	7 379	7 592	7 938	8 174	8 228	8 522	8 884	9 179	8 274	7 888	8 102	8 091	7 944
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ES.4 Information on indirect GHG and SO_x emissions

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

Table ES. 3– Indirect GHG and SO_x emissions: 1990-2004

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	(Gg)														
CO	952	1009	982	939	898	942	881	835	861	814	831	763	766	927	733
NO _x	245	260	277	266	265	276	268	266	277	287	285	286	294	276	271
NM _V OC	279	286	293	285	292	297	298	300	303	294	292	294	297	309	297
SO ₂	317	308	370	316	296	332	271	292	341	342	306	294	294	201	204

In 2004, SO_x and CO emissions have decreased from 1990 levels: -35.7% and -23%, respectively. The other gases, NMVOC and NO_x emissions have increased, respectively, 6.4% and 10.5% (Table ES. 3).

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

Within energy, transportation is responsible for the greatest share of CO, NO_x, and NMVOC emissions, respectively 45.5%, 40.1% and 18.3% of 2004 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. NO_x emissions from transport presented a 11.7% increase over the 1990-2004 period; CO and NMVOC recorded significant reductions, respectively, -34.6% and -27.3%.

¹ These are converted into ultimate carbon dioxide after being emitted to atmosphere.

SO_x emissions are mainly generated in the energy industry sector (60.5% of total emissions in 2004) and combustion in manufacturing industries (21.4% of total emissions in 2004), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. However the emissions variation in the period 1990-2004 shows a decrease in SO_x emissions in both sub-categories: energy industries –38.6% and manufacturing industries –46.1%. These tendencies reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 of 10th November). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO_x emissions.

CHAPTER: 1 - INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

Global Warming and Climate Change

Although key greenhouse gases - CO₂, CH₄, N₂O, Ozone – occur naturally in the atmosphere, human activities have increased the atmospheric concentrations of greenhouse gases since the pre-industrial era. Other substances which are exclusively produced by industrial activities are also greenhouse gases: stratospheric ozone depleting substances (CFCs, HCFCs and halons which are covered by the Montreal Protocol), and some other fluorine-containing halogenated substances – HFCs, PFCs and SF₆. There are also several gases that do not have a direct effect in global warming but affect the formation or destruction of other GHG. CO, NO_x, and NMVOCs are precursor substances for ozone which is a GHG. SO_x produce aerosols, which are extremely small particles or liquid droplets that can also affect the absorptive characteristics of the atmosphere.

Land-use and Land-use change, particularly deforestation, is another factor that contributes to the phenomenon of global warming and climate change as it changes carbon stocks and carbon sequestration and consequently the CO₂ fluxes from and to the atmosphere.

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

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

Climate Change in Portugal

The mean temperature has risen in all regions of Portugal since the 1970s, at a rate of approximately 0.45 °C/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 5 of the 10 warmest years occurred in the 1990s (1997, 1995, 1996, 1990 and 1998).

An analysis of temperature indices indicates that the increase of the mean temperature was accompanied by a change in the frequency of very hot days and a decrease in the frequency of very cold ones.

The heat wave duration index has also been rising. Heat waves are defined when, in a period of at least 6 consecutive days, the daily maximum temperature is 5 °C higher than the daily mean value of the reference period (1961-1990). Although they can occur at any time of the year, heat waves have a more significant impact in the summer months. Heat waves were more frequent in the 1990s. The heat waves of 1981, 1991, 2003 and, more recently, the two registered in June 2005 were of particular significance due to their duration and spatial extension.

The last 2 decades of the 20th century were particularly dry in mainland Portugal as opposed to the average values registered between 1961 and 1990. In fact, only in 6 of the last 20 years of the past century was the annual precipitation higher than the average. In 2001 and 2002, however, the annual precipitation values were higher than the average observed in the

reference period. The driest of the past 75 years was 2005, and 2004 was the second driest on record.

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

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

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

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

The Convention, the Kyoto Protocol and national commitments

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

Portugal has ratified the United Nations Framework Convention on Climate Change (UNFCCC) on May 31, 1994. The ultimate objective of the Convention is the “stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.”

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

Portugal signed and ratified the Kyoto Protocol on April 29, 1998, and 31 May, 2002, respectively. The EU as a whole agreed to a -8% reduction. Under the EU burden-sharing agreement Portugal is committed to limiting its emissions to +27% compared to the 1990 level in the first commitment period.

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

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

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

History of national inventories

Air emission inventories in Portugal were only initiated in the late ninety-eighties/ early nineties when the first estimates of NO_x, SO_x and VOC emissions from combustion were made under the development of the National Energetic Plan (PEN - Plano Energético Nacional), and emissions from combustion and industrial processes were made under OECD inventory and under CORINAIR85 program. A major breakthrough occurred during the CORINAIR90 inventory realized during 1992 and 1993 by General-Directorate of Environment (DGA, renamed now IA). This inventory exercise, aiming also EMEP and OECD/IPCC, extended the range of the pollutants (SO_x, NO_x, NMVOC, CH₄, CO, CO₂, N₂O and NH₃) and emission sources covered, including not only combustion activities but also storage and distribution of fossil fuels, production processes, use of solvents, agriculture, urban and industrial wastes and nature (forest fires and NMVOC from forest). Information received under the Large Combustion Plant (LCP) directive was also much helpful to improve inventory quality and the individualization of Large Point Sources, as well as statistical information received from the National Statistical Institute (INE) allowing the full coverage of activity data for most emission sources. The CORINAIR90 Default Emission Factors Handbook (second edition), updating the first edition from CORINAIR85 was used extensively in the development of the current inventory and it was also a key point in the amelioration of the inventory.

The fulfilment of international compromises under conventions UNFCCC and CLRTAP, together with the publication of the IPCC Draft Guidelines for National Greenhouse Gas Inventories (IPCC, 1995) and latter of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), has result in substantial improvement of the methodologies that are used in the inventory, particularly for agriculture and wastes, and that were included at first time in the First National Communication in 1994. The inventory that resulted from CORINAIR90 (CEC,1992) and subsequent modifications from IPCC methodology still structures the present day methodology in what concerns activity data and methodology. Under the evaluation of the first communication the inventory was subjected to a review made by an international team. The second and third communications was also reviewed by international experts. These exercises had an important role in problem detection and contribute to overall improvement.

Since its first compilation, the Portuguese inventory has been continuously amended mainly from the use of more detailed methodologies, better access to underlying data allowing the development of the comprehensiveness of the inventory, and better database storage and calculation structure. Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for the different years considered (1990-2004), i.e., the inventory is internally consistent. Some major studies have contributed to the improvement of the inventory:

- Study of VOC emissions in Portugal, in 1995. This study made in collaboration with FCT (Faculdade de Ciências e Tecnologia) led to an important improvement in emission estimates from solvent sector, which is still used as basic information source for this sector;
- Study of Emission and Control of GHG in Portugal (Seixas et al, 2000). This project aimed the first development of projections toward 2010 and the identification of control measures to accomplish the Kyoto Protocol. This also led to improvements in the inventory: extension of the inventory including for the first time also carbon dioxide sinks (forest); a first attempt to estimate solid waste methane emissions from urban solid wastes using a Tier2 approach and, in general terms, a better insight into additional parameters used in the inventory methodologies, and that has resulted from interaction with several institutional agents: General Directorate of Energy, Ministry of Agriculture; and the inter-ministerial transport group;
- Study (Pereira et al,2002) for the quantification of carbon sinks in Portugal, made under the development of PNAC and PTEN national programmes;

- Revision of the Energy Balances with comparison of information collected at IA (LCP Directive) and Statistical Information received at DGGE: Energy Balances. The 1990s – DGE (2003);
- PNAC 2004 (National Plan for Climate Change) approved by Ministers Council and published recently in the National Official Journal (OJ nº 179, 31 July 2004, I Série B/ Resolução do Conselho de Ministros nº 119/2004);
- PNAC 2006 (National Plan for Climate Change) approved by Ministers Council and published in the National Official Journal (OJ nº 162, 23 August 2006, I Série B/ Resolução do Conselho de Ministros nº 104/2006)
- Sectorial Studies and Proposal for a PTEN (National Plan on Emission Ceilings);
- PNALE (National Plan for Allocation of Emissions) 2005-2007 or Portuguese PNALE I, adopted by Ministers Council (Resolução do Conselho de Ministros n.º 53/2005) and published in the National Official Journal (OJ nº 44, 3 March 2005, I Série B/);
- Bilateral meetings (IA/UE) for the determination of the Baseline Scenario under the CAFE program (IA,2004);
- Methodological Development Programme (PDM) under the implementation of the National Inventory System;
- UNFCCC reviews, in particular the in-depth review (September/October 2004), and the centralised review (October 2005).

Greenhouse gas emissions inventories

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

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

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

Furthermore the National Inventory includes, under the UNECE/CLRTAP Convention, emission estimates of ammonia (NH₃), Particulate Matter and Heavy Metals. Emissions are estimated for each civil year from 1990 to 2004.

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. The only exception to this rule, which results in an inconsistency, refers to data for the two Portuguese islands in what concerns Land Use Change and Forestry (IPCC category 5) which have not been compiled; therefore this category refers only to mainland Portugal. Emissions from air traffic and navigation realized between places in territorial Portugal, including movements between mainland and islands, are also include in national emission total.

The economic sectors covered are the following: energy production and transformation, combustion in industry, domestic, agriculture, fisheries, institutional and commerce sectors, transportation (road, rail, maritime and air), industrial production and industrial and non industrial use of solvents, waste production (urban, industrial and hospitals solid wastes, and domestic and industrial waste water treatment), agriculture, animal husbandry emissions, as well as emissions and removals from forestry and land use change.

Global warming potentials

A Global Warming Potential (GWP) is defined as the cumulative radiative forcing over a specified time horizon resulting from the emission of a unit mass of gas relative to some reference gas (IPCC, 1997). The reference gas used is CO₂. The mass emission of each gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide (CO₂ equivalents – CO₂ Eq.). The parties to the UNFCCC have agreed to use GWPs based on a 100-year time horizon (Table 1.1)

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

GHG	GWP
CO ₂	1
CH ₄	21
N ₂ O	310
HFC	
HFC-23	11 700
HFC-32	650
HFC-41	150
HFC-43-10mee	1 300
HFC-125	2 800
HFC-134	1 000
HFC-134 ^a	1 300
HFC-152 ^a	140
HFC-143	300
HFC-143 ^a	3 800
HFC-227ea	2 900
HFC-236fa	6 300
HFC-245ca	560
PFC	
CF ₄	6 500
C ₂ F ₆	9 200
SF ₆	23 900

1.2 Institutional arrangements for inventory preparation

Institutional arrangements in place

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

The principal objective of the system is to prepare in a timely fashion the inventory of air pollutants (INERPA), in accordance with the directives defined at international and EC levels, in order to make easier and more cost-effective the tasks of inventory planning, implementation and management.

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

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

Three bodies are established with differentiated responsibilities. These are:

- The Responsible Body appointed is the Institute for the Environment (IA), being responsible for: overall coordination and updating of the National Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants (INERPA); the inventory's approval, after consulting the Focal Points and the involved entities; and its submission to EC and international bodies to which Portugal is associated, in the several communication and information formats, thus ensuring compliance with the adopted requirements and directives;

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

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

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

Table 1.2 – Bodies that contribute information relevant to the preparation of the INIERPA

Sector of Activity	Focal Point	Involved Entities
National Statistics ³	National Statistics Institute	
Environment Statistics ⁴	Institute for the Environment	
Energy Statistics	Directorate-General for Geology and Energy	
Energy:		
Industry and civil construction.....	Directorate-General for the Enterprise	
Transport.....		
Road.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications and Directorate-General for Driver Licensing	Studies and Planning Office of the Institute of Portugal's Roads, Directorate-General of Land and Water Transport
Rail.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications	Studies and Planning Office, National Institute of Rail Transport, "Comboios de Portugal", National Railway Network
Aviation.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications	Studies and Planning Office, National Civil Aviation Institute
Sea.....	Environmental Auditor of the Ministry of Public Works, Transport and Communications	Studies and Planning Office, Port and Sea Transport Institute, Port Administration
Fugitive Emissions from Fossil Fuels.....	Directorate General for Geology and Energy	
Industrial Processes	Directorate-General for Enterprise	
Solvent Use and Other Products.....	Directorate-General for Enterprise	
Agriculture	Environmental Auditor of the Ministry for Agriculture, Fisheries and Forestry	Zootechnical Station Rebello da Silva Agro-Chemical Laboratory
Forestry and Land Use Change		
Forestry	Directorate-General of Forestry	
Land Use Change.....	Portuguese Geographical Institute	
Waste		
Disposal/incineration of waste	Institute for Waste Management	
Wastewater.....	Water Institute	Directorate-General for Health

1.3 Inventory Preparation Process

Responsability

The Institute for the Environment (Instituto do Ambiente - IA)/ Ministry for the Environment, Land-Use Planning and Regional Development (Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional), is the national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions. According to these attributions, the Institute makes an annual compilation of the Portuguese Inventory of air emissions which includes Greenhouse Gas (GHGs) and sinks, acidifying substances as well as other pollutants. The reporting obligations to the EU and the international instances are also under the responsibility of the IA.

The designated representative is:

Instituto do Ambiente (Institute for the Environment)

Direcção de Serviços para as Estratégias e Programas Ambientais (Department of Environmental Strategies & Programmes)

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

Telephone: +351 21 472 83 82

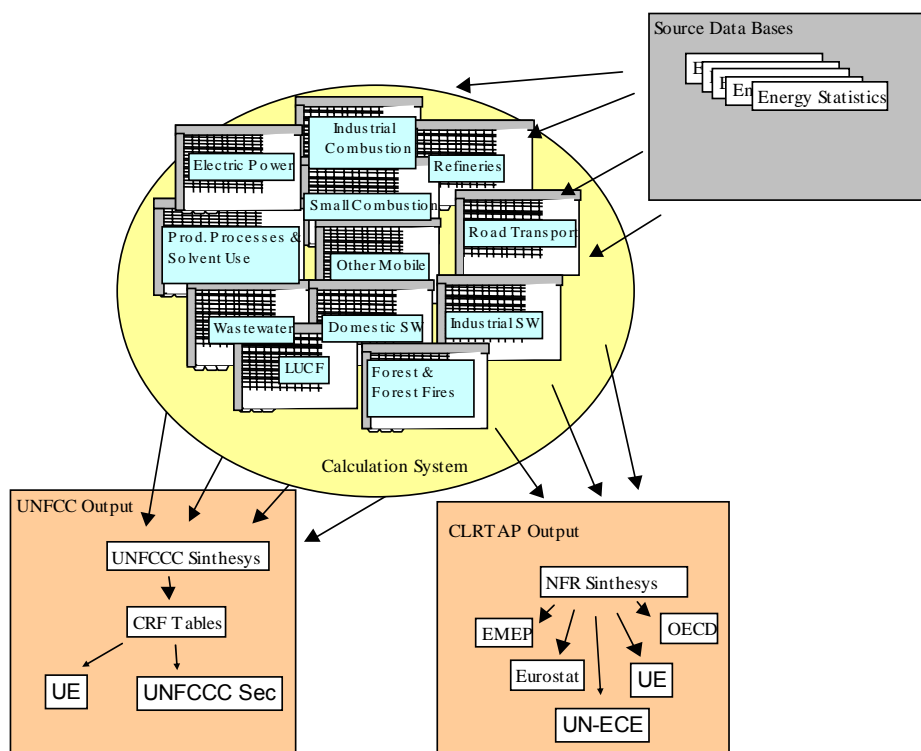
Fax: + 351 21 471 90 74

Filomena Boavida - filomena.boavida@iambiente.pt

Calculation, data archiving and documentation system

The emissions calculations have been performed by IA and INVENTAR², which also provides technical advice concerning all aspects of inventory development: methodologies, sources of information and emission factors, and participates in the annual definition of priorities concerning the Methodological Development Programme (PDM). However many other institutions and agencies contributed to the inventory process, providing activity data, sectoral expert judgement, technical support and comments. All calculation and reporting rely in a set of different Excel spreadsheet workbooks which had been developed in order that all information and calculations occur automatically. The structure of the information system is outlined below.

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



² InventAr, Estudos e Projectos Unip Lda

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

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

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

Annually reported data, e.g. CRF tables, are stored both in paper and magnetic format. IA plans to rebuild this informatics system, having found some limitations for its expansion, namely in what concerns the storage of large amounts of data. This problem will be aggravated in the future with the implementation of inventory improvements: spacialization of emission data, connection to plant-specific monitoring programs and uncertainty analysis. The restructuring of all the inventory system is under study and discussion.

1.4 General overview of methodologies and data sources used

The inventory has been compiled, to the extent as possible, in accordance with the recommendations from the UNFCCC Reporting Guidelines on Annual Inventories (SBSTA 1999 and SBSTA 2002). The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC,1997) and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC,2000) have been applied as far as appropriate and feasible. Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003) has been implemented, as far as possible, for the compilation of this 2006 submission.

Table 1.3 gives an overview of the methodologies and emission factors used in the inventory. Default methods and emission factors used and the choice between Tier 1 and Tier 2 approaches, were case by case dictated by the availability of proper background information and from national circumstances.

Table 1.3 – Summary of methods and emission factors (CRF summary 3 table)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂		CH ₄		N ₂ O		HFCs		PFCs		SF ₆	
	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF
1. Energy	CR,D,T1,T2	CR,D,OTH,P	CR,OTH,T1	CR,D,OTH	CR,T1,T2,T3	CR,D						
A. Fuel Combustion	CR,T1,T2	CR,D,OTH,PS	CR,T1,T2,T3	CR,D,OTH	CR,T1,T2,T3	CR,D						
1. Energy Industries	T2	CR,D,PS	T2	CR,D	T2	CR,D						
2. Manufacturing Ind. and Construction	T2	CR,D,PS	T2	CR,D,OTH	T2	CR,D						
3. Transport	CR,T1,T2	CR,D,OTH	CR,T1,T2,T3	CR,D,OTH	CR,T1,T2,T3	CR,D						
4. Other Sectors	T2	CR,D	T2	CR,D	T2	CR,D						
5. Other	NA	NA	NA	NA	NA	NA						
B. Fugitive Emissions from Fuels	D	D	CR,OTH	CR,OTH	NA	NA						
1. Solid Fuels	NA	NA	NA	NA	NA	NA						
2. Oil and Natural Gas	D	D	CR,OTH	CR,OTH	NA	NA						
2. Industrial Processes	CR,D,OTH,T	CR,CS,D,OT	D	CR,OTH	D	CR,OTH	RA,T2	CS,D	NA	NA	T3	CS
A. Mineral Products	CR,D,OTH,T2	CR,CS,D,OTH			NA	NA						
B. Chemical Industry	D,T2	CS,D,PS	D	CR,OTH	D	CR,OTH					NA	NA
C. Metal Production	D,T2	D,PS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D. Other Production	CR	CR										
E. Production of Halocarbons and SF ₆											NA	NA
F. Consumption of Halocarbons and SF ₆							RA,T2	CS,D			T3	CS
G. Other	NA	NA	NA	NA	NA	NA					NA	NA
3. Solvent and Other Product Use	D	CR,CS,OTH			NA	NA						
4. Agriculture			D,T2	CS,D	D,T1a	D						
A. Enteric Fermentation			T2	CS	D,T1a	D						
B. Manure Management			T2	CS	D	D						
C. Rice Cultivation			D	CS								
D. Agricultural Soils			NA	NA	T1a	D						
E. Prescribed Burning of Savannas			NA	NA	NA	NA						
F. Field Burning of Agricultural Residues			D	D	D	D						
G. Other			NA	NA	NA	NA						
5. Land Use, Land-Use Change and Forestry	CS,D,T2	CS,D	D	D	D	D						
A. Forest Land	CS,D,T2	CS,D	D	D	D	D						
B. Cropland	D,T2	CS,D	NA	NA	NA	NA						
C. Grassland	D,T2	CS,D	NA	NA	NA	NA						
D. Wetlands	D,T2	CS,D	NA	NA	NA	NA						
E. Settlements	D,T2	CS,D	NA	NA	NA	NA						
F. Other Land	D,T2	CS,D	NA	NA	NA	NA						
G. Other			NA	NA	NA	NA						
6. Waste	D	CS,D	D,T2	CR,CS,D,O	D	CR,D,OTH						
A. Solid Waste Disposal on Land	NA	NA	T2	CS,D								
B. Waste-water Handling			D	CS,D	D	D						
C. Waste Incineration	D	CS,D	D	CR,D	D	CR,D						
D. Other	D	CS,D	D	CR,OTH	D	CR,OTH						
7. Other (as specified in Summary 1.A)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

(1) Methods applied: D (IPCC default), RA (Reference Approach), T1 (IPCC Tier 1), T1a, T1b, T1c (IPCC Tier 1a, Tier 1b and Tier 1c, respectively), T2 (IPCC Tier 2), T3 (IPCC Tier 3), C (CORINAIR), CS (Country Specific), M (Model).

(2) Emission Factors: D (IPCC default), C (CORINAIR), CS (Country Specific), PS (Plant Specific), M (Model), MB-Mass Balance.

Table 1.4 gives an overview of the institutions and data sources providing data for the compilation of the Portuguese emission inventories.

Table 1.4 – Inventory Data Sources

IPCC category	IPCC sub-category	Sources of data
CRF 1 A – Energy. Fuel Combustion	CRF 1A1 – Energy Industry	<ul style="list-style-type: none"> • Large Point Source Surveys (LPS) • Large Combustion Plants (LCP) • EDP • General Directorate for Geology and Energy (DGGE): energy balances • Autonomous Gov. of Azores • National Statistical Institute (INE)
	CRF 1A2 - Manufacturing Industries and Construction	<ul style="list-style-type: none"> • LPS, LCP, EPER/PCIP • Regional Air Inventories • DGGE: energy balances
	CRF 1A3 – Transport	<ul style="list-style-type: none"> • DGGE: energy balances • ACAP • ANECRA • Road Institute (IEP) • INE • General Directorate of Terrestrial Transportation (DGT) • INAC
	CRF 1A4 – Other Sectors	<ul style="list-style-type: none"> • DGGE: energy balances
CRF 1 B – Fugitive Emissions from Fuels		<ul style="list-style-type: none"> • DGGE: energy balances and statistical yearbooks • GALP
CRF 2 – Industrial Processes	CRF 2A – Mineral Products	<ul style="list-style-type: none"> • LPS, LCP • CIMPOR, SECIL • DGGE: energy balances • Portuguese Association of Producers of Bitumen Materials (APORBET) • European Asphalt Pavement Association (EAPA) • Technology Centre for Ceramics and Glass (CTCV)
	CRF 2B – Chemical Industry	<ul style="list-style-type: none"> • DGGE: energy balances • LCP • INE • Regional Air Inventories
	CRF 2C – Metal Production	<ul style="list-style-type: none"> • DGGE: energy balances • LCP • SN • INE • Regional Air Inventories
	CRF 2D – Other Production	<ul style="list-style-type: none"> • LCP • DGGE: energy balances • CELPA
	CRF 2F – Consumption of Halocarbons and SF6	<ul style="list-style-type: none"> • INE • APIRAC • Data from Industry Importers • EDP, REN
CRF 3 – Solvent and Other Product Use		<ul style="list-style-type: none"> • DGGE: energy balances • Gen-Dir of Enterprise (DGE) • INE
CRF 4 – Agriculture		<ul style="list-style-type: none"> • Ministry of Agriculture • General-Directorate for Forest Resources (DGRF) • INE: agriculture survey
CRF 5 – Land Use Change and Forestry		<ul style="list-style-type: none"> • DGRF • IGP • ISA
CRF 6 – Waste	CRF 6A – Solid Waste Disposal on Land	<ul style="list-style-type: none"> • National Institute for Waste (INR) • INE • Quercus Survey
	CRF 6B – Wastewater Handling	<ul style="list-style-type: none"> • National Institute for Water (INAG) • INE
	CRF 6C – Waste Incineration	<ul style="list-style-type: none"> • INR • General Direction for Health/Ministry of Health • Data from Incineration Units

1.5 Brief description of key source categories

Key source analysis to the 2006 Portuguese inventory estimates (1990-2006) was conducted using both Tier 1 and Tier 2 approaches, using guidance from IPCC (2000). Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2004 period. Both approaches have been applied in two steps: without and with the LULUCF sector.

The Tier 2 analysis without LULUCF resulted in the identification of 46 key categories. The analysis with LULUCF resulted in the identification of 4 LULUCF categories, totalling 50 key categories that are listed in the Table 1.5.

Table 1.5 – Summary overview of Portuguese key source categories (1990-2004) based on Tier 1 and Tier 2 approaches

Key Categories of Emissions and removals by Gas	Activity	Gas	Tier 1				Tier 2				2004 emissions/removals (kton CO2 eq.)
			without LULUCF		with LULUCF		without LULUCF		with LULUCF		
			Level	Trend	Level	Trend	Level	Trend	Level	Trend	
1A 3 b Road Transportation	All Fuels	CO2	X	X	X	X	X	X	X	X	18708
1A 1a Public Electricity and Heat Production	Solid Fuels	CO2	X	X	X	X	X		X	X	1961
1A 2 f Other	Liquid Fuels	CO2	X	X	X	X	X		X		418
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO2	X	X	X	X	X	X	X	X	3776
2 A 1 Cement Production	Production Quantities	CO2	X	X	X	X	X	X	X		3538
4 D AGRICULTURAL SOILS	Input to Soils	N2O	X	X	X	X	X	X	X	X	3267
1A 4 a Commercial / Institutional	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	3162
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	3033
4 A ENTERIC FERMENTATION	Population size	CH4	X	X	X	X	X	X	X		3012
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	X	X	X	X	X	X	X	X	2942
1A 1 b Petroleum refining	Liquid Fuels	CO2	X	X	X						2475
1A 2 f Other	Gaseous Fuels	CO2	X	X	X	X		X		X	2035
1A 4 b Residential	Liquid Fuels	CO2	X	X	X	X	X		X		1892
6 A 3 Other	Industrial Waste Disposal on Land	CH4	X	X	X	X	X	X	X	X	1814
2 B 1 Ammonia Production	Production Quantities	CO2	X	X	X	X	X	X	X	X	1716
6 B 1 Industrial Wastewater	Wastewater	CH4	X	X	X	X	X	X	X	X	1656
1A 2 c Chemicals	Liquid Fuels	CO2	X	X	X	X					1343
4 B MANURE MANAGEMENT	Animal Excretion	CH4	X	X	X	X	X	X	X	X	1167
5 E2 Settlements	Emissions/Removals	CO2			X	X			X	X	1115
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	1054
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	X	X	X	X					695
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	X	X	X	X	X	X	X	X	693
2 B 2 Nitric Acid Production	Production Quantities	N2O	X	X	X						605
4 B MANURE MANAGEMENT	Animal Excretion	N2O	X	X	X	X	X	X	X	X	577
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	X	X	X	X					576
1A 3 b Road Transportation	All Fuels	N2O	X	X	X	X	X	X	X	X	563
1A 2 f Other	Solid Fuels	CO2	X	X	X	X		X	X	X	539
1B 2 a Oil	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	499
2 A 2 Lime Production	Production Quantities	CO2	X	X	X	X	X	X	X	X	437
1A 3 a ii Domestic	Liquid Fuels	CO2	X		X	X	X	X	X	X	401
1A 2 c Chemicals	Gaseous Fuels	CO2	X	X	X	X					388
1A 4 b Residential	Gaseous Fuels	CO2	X	X	X	X					384
1B 2 b Natural gas	Gaseous Fuels	CH4	X	X	X	X	X	X	X	X	373
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	X		X						362
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	X	X	X	X					334
1A 4 a Commercial / Institutional	Gaseous Fuels	CO2	X	X	X	X					332
6 C WASTE INCINERATION	Waste Incinerated	CO2	X	X	X	X	X	X	X	X	330
1A 4 b Residential	Biomass	CH4	X		X		X	X	X	X	309
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC		X		X	X	X	X	X	283
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2		X		X					248
1B 2 d Other (Geothermal)	Energy Production	CO2		X		X					244
6 B 1 Industrial Wastewater	Wastewater	N2O					X	X	X	X	228
1A 3 d ii National navigation	Liquid Fuels	CO2			X						211
4 C RICE CULTIVATION	Culture Surface	CH4			X		X	X	X	X	194
5 B Cropland	Emissions/Removals	CO2							X	X	191
2 A 7 Other	Production Quantities	CO2					X	X	X	X	171
3 C CHEMICAL PRODUCTS, MANUFACTURE AND CONSTRUCTION	Chemical manufacture and construction	CO2					X	X	X	X	141
5 LAND USE CHANGE AND FORESTRY	Emissions/Removals	CH4			X				X		110
3 A PAINT APPLICATION	Paint application	CO2					X	X	X	X	95
1A 3 c Railways	Liquid Fuels	CO2				X					86
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O					X	X	X	X	81
3 D OTHER	Other Use of Chemicals	CO2					X	X	X		80
1A 4 b Residential	Biomass	N2O					X	X	X	X	65
1A 1a Public Electricity and Heat Production	Solid Fuels	N2O					X		X	X	57
2 F 2 Foam Blowing	Consumption	HFC					X	X	X	X	56
1B 2 b Natural gas	Gaseous Fuels	CO2						X		X	48
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N2O					X	X	X	X	29
1A 2 f Other	Biomass	N2O					X		X		25
1A 2 d Pulp, Paper and Print	Biomass	N2O					X		X		17
1A 2 f Other	Gaseous Fuels	N2O						X		X	15
1A 4 b Residential	Liquid Fuels	N2O					X		X		13
2 A 6 Road Paving with Asphalt	Production Quantities	CO2					X	X	X	X	12
1A 1a Public Electricity and Heat Production	Liquid Fuels	N2O					X	X	X	X	8
1A 2 a Iron and Steel	Solid Fuels	CO2	X		X	X					0
5 A Forest Land	Emissions/Removals	CO2			X	X			X	X	-3994
Sub-total without LULUCF											83355
% of total without LULUCF											98.8
TOTAL EMISSIONS WITHOUT LULUCF											84355
Sub-total with LULUCF											80776
% of total with LULUCF											98.6
TOTAL EMISSIONS WITH LULUCF											81900

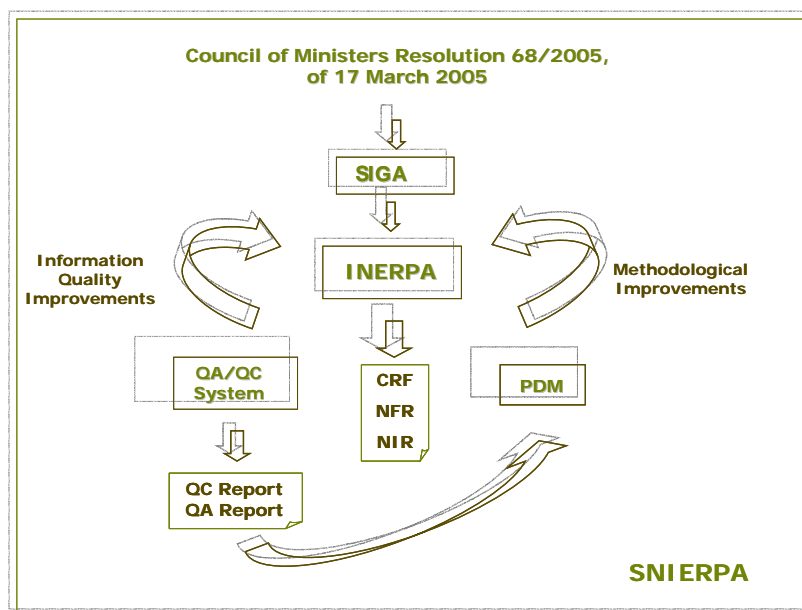
1.6 Information on QA/QC

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

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

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

Figure 1.2 – SNIERPA 's main elements relations



The SCGQ is composed of a Quality Control and Quality Assurance Programme and a Procedures Manual. The first schedules the application of the general (QC1) and specific (QC2) Quality Control as well as Quality Assurance (QA) procedures, described in detail in the Manual. The procedures were defined according to Good Practice and Uncertainty Management Guide (IPCC, 2000) and adapted to the specific National Inventory (INERPA) characteristics.

Quality Control tier 1 procedures defined in the QA/QC Manual include a series of checklists, which consider basic checks on the accuracy of data acquisition processes (including, e.g, transcription errors) and checks on calculation procedures, data and parameters. It includes also cross-checking among subcategories in terms of data consistency, verification of NIR and CRF tables. Documentation and archiving procedures include checks on information handling which should enable the recalculation of the inventory. QC tier 2 procedures, on the other hand, include technical verifications of emission factors, activity data, comparison of results among different approaches.

1.7 General uncertainty assessment

Emission estimates from the GHG inventory pretend to express the best estimate of emissions, which should not be over-estimated neither under-estimated. Nevertheless, natural variability of certain emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of

emission factors and parameter due to errors in original monitoring data, reference studies and expert judgement, all this factors lead to a certain error or level of uncertainty in emission estimates. However, the main purpose of the realization of the uncertainty assessment is not to contest the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of future inventories and guide future methodological developments. The uncertainty analysis have been done under an external consultancy with INVENTAR.

The uncertainty analysis was performed only for the direct GHG: CO₂, CH₄, N₂O, HFC and SF₆, considering all emissions in CO₂ equivalent (CO₂e). The uncertainty of all source activities was determined including, for the first time, the uncertainty of LULUCF category.

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

The uncertainty assessment was performed using inventory data for all years from 1990 to 2004. The results are presented in Table 1.6. The full range of emission possibilities, considering the confidence limit may be observable in

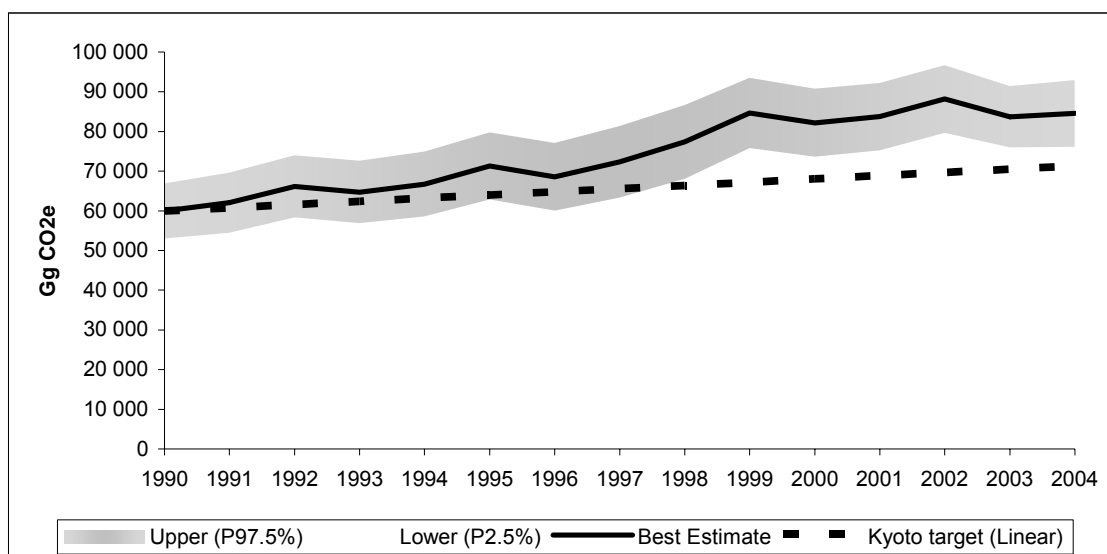
Figure 1.3. The uncertainty in trend from 1990 to 2004 is 13.3 per cent. Uncertainty values are defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

Albeit the inclusion for the first time of the uncertainty associated with sector 5 (LULUCF), since last year's submission the improvements made in the inventory have resulted in an increase in its quality, expressed in a decreased in the uncertainty, both in value and in trend. For example, total uncertainty in the base year was decreased from 14.4 per cent to 11.5 per cent and in 2003 from 14.7 per cent to 9.9 per cent. The uncertainty in trend has slightly increased from 13.3 per cent (1990-2003) to 13.5 per cent (1990-2004), in a certain sense reflecting the improvements made in the time series.

Table 1.6 – Uncertainty of the annual emission estimates, by gas and total uncertainty

Year	CO ₂	CH ₄	N ₂ O	LULUCF	F Gas	Total
	Per cent					
1990	7.7	21.0	110.9	33.1	-	11.5
1991	7.7	28.2	111.6	44.9	-	12.2
1992	7.1	28.6	111.5	304.6	-	11.8
1993	6.9	28.8	114.7	166.8	-	12.1
1994	7.0	28.2	110.1	64.3	-	12.2
1995	6.7	27.9	107.4	82.8	34.9	11.8
1996	6.8	27.9	104.4	52.0	37.2	12.4
1997	6.5	27.9	108.7	48.6	42.0	12.4
1998	6.4	27.5	111.5	52.7	44.5	12.0
1999	5.6	27.4	101.8	51.0	50.1	10.5
2000	4.0	27.5	106.1	54.9	57.2	10.4
2001	4.0	23.7	106.8	52.2	70.6	10.1
2002	3.9	24.4	104.4	53.1	79.4	9.6
2003	4.3	25.0	106.9	37.4	85.1	9.3
2004	4.4	24.5	106.6	60.9	85.3	9.9

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



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

1.8 Overview of the completeness

CRF Table 9 (Completeness) gives an overview of the level of completeness of the 2006 submitted inventories to the UNFCCC and EC. Additional information on this issue is given in the subchapters.

The inventory covers the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC),

perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO_x).

Furthermore the National Inventory includes, under the UNECE/CLRTAP Convention, emission estimates of ammonia (NH₃), Particulate Matter and Heavy Metals. Emissions are estimated for each civil year from 1990 to 2004.

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. The only exception to this rule, which results in an inconsistency, refers to data for the two Portuguese islands in what concerns Land Use Change and Forestry (IPCC category 5) which have not been compiled; therefore this category refers only to mainland Portugal. 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.

1.9 Future developments

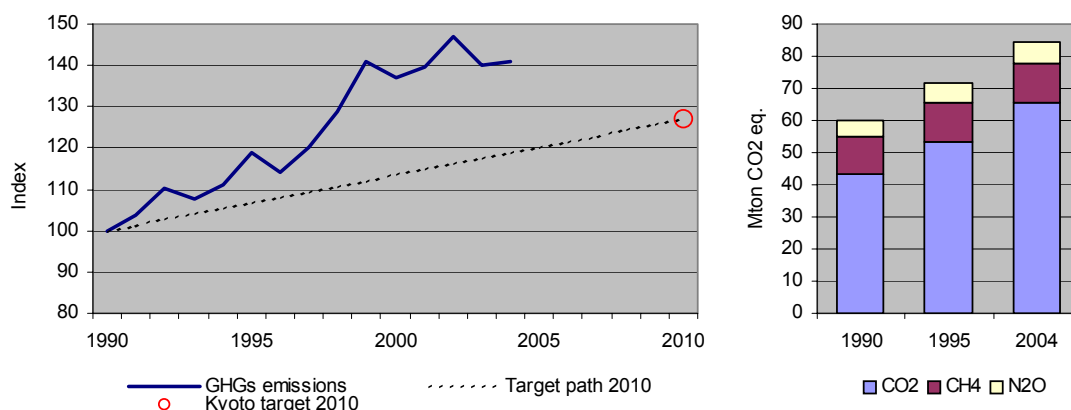
Future improvements are defined under the Methodological Development Plan (PDM) which is settled each year in the context of the National Inventory System (SNIERPA) and is developed under the responsibility of the IA under an external consultancy with Ecoprogresso and InventAr, in cooperation with the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

CHAPTER: 2 TRENDS IN PORTUGUESE GHG EMISSIONS

2.1 Trends of Total Emissions

In 2004, total Portuguese GHG emissions without land-use, land-use change and forestry (LULUCF) were estimated about 84.4 Mton CO₂eq., representing an increase of 41% compared to 1990 levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions to +27% compared to the 1990 level. Comparing the 1990-2004 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2004, 21.8 % above this target path.

Figure 2.1– GHG emissions (without LULUCF)



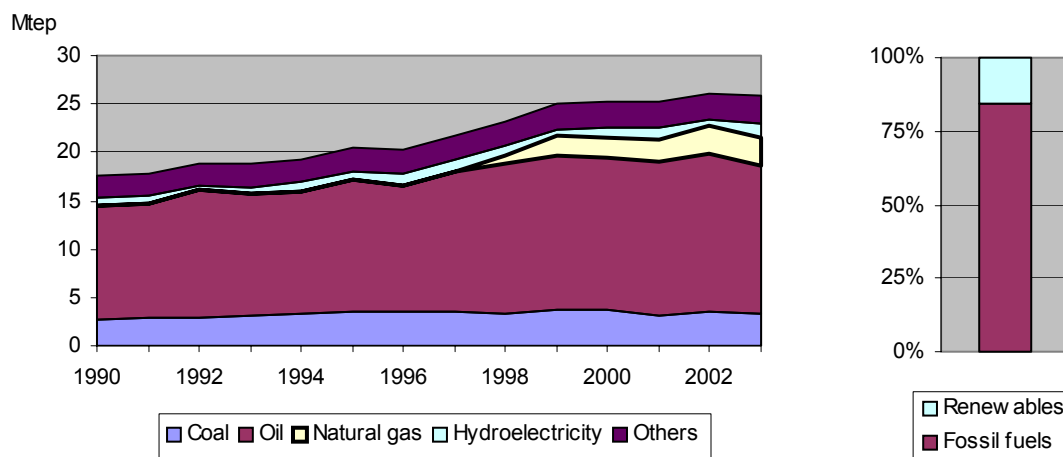
The principal source of GHGs in Portugal is associated with the energy sector and is primarily related to fossil fuel combustion. The largest gas emitted is CO₂ which represented in 2004 77.9% of total GHGs emissions in global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for approximately 90% of total CO₂ emissions in the same year.

Energy-related CO₂ emissions are dependent on the type of fuel and its carbon intensity. In average, during the period considered, 84% of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas); the percentage of renewable energy represents the remaining part, i.e. 16% in average, which refer to domestic sources. (Figure 2.2)

The average annual emissions growth rate for the overall period 1990-2004 is 2.9%. However, as illustrated in Figure 2.1, roughly three different periods can be identified in terms of the annual average rate evolution: from 1990 to 1995 3.8%; from 1995 to 1999 4.6%, and since 1999 a more moderate increase can be recognised.

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

Figure 2.2 – Primary energy consumption

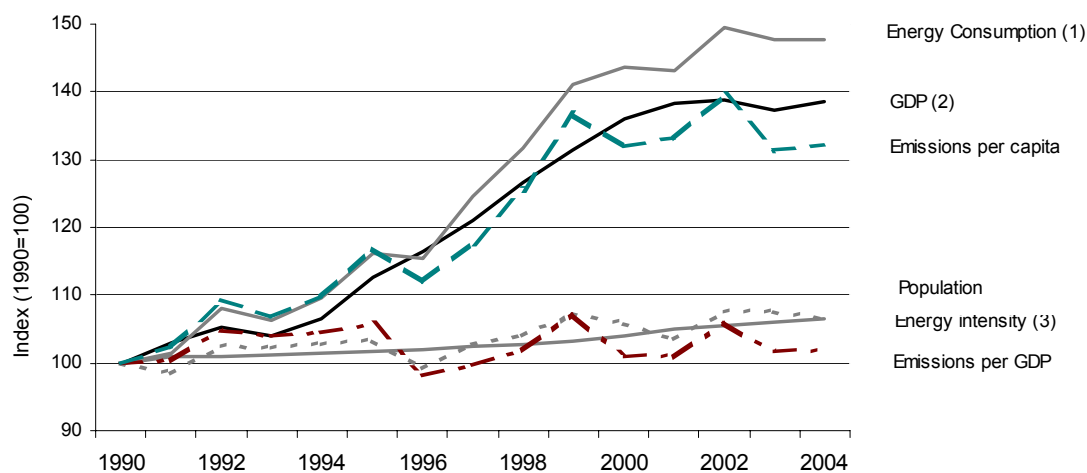


Notes: Hydroelectricity: domestic production. Others: includes fuelwood, wastes, and biogas. Fossil fuels: includes coal, oil and natural gas. Renewables: includes domestic hydroelectricity and others.

Source: DGGE.

During the 1990s, Portugal experienced a rapid economic growth with an increase in GDP of about 38.6% in the period 1990-2004, corresponding to an average annual increase of 2.8%. The most rapid growth occurred from the years 1993 to 2000, where the average annual growth rate reached the 4.4%. This increase was accompanied by the rise of primary energy consumption, which has registered an average annual growth of 5% during the 1993-2000 years. In 2004 the primary energy consumption in the country was almost one and half times the value of 1990.

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



Notes:

- (1) Primary Energy Consumption.
- (2) 1995 prices.
- (3) Energy Consumption per GDP.

Sources:

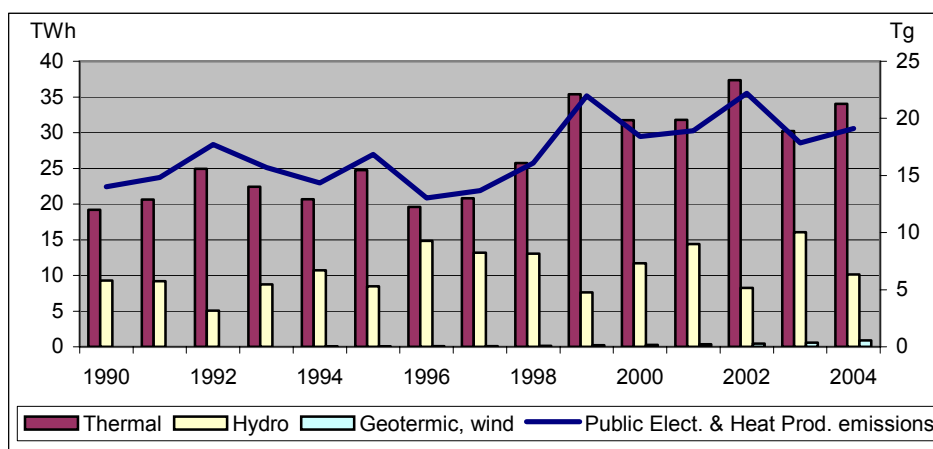
INE, DGGE.

During the period analysed, the country has not achieved a clear decoupling of emission trends from economic growth. However a slight decrease of carbon intensity (emissions per GDP unit) can be observed in the most recent years (see previous figure). This fact can be related to the implementation of some measures that had a positive effect in the emissions levels, such as the introduction of natural gas (1997), the new combined cycle thermoelectric unit of natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial processes, and the improvement of fuels quality.

The energy intensity continues however to rise (moderately), reflecting the continued growth of the transport and the residential/commercial sector, this latter registering a continued rise of electricity demand.

Since 2001, economic growth slowed considerably, contributing, at least partially, to the more moderate emissions growth registered in the most recent years. Emissions levels for the all period show however significant variations, which are related to the pronounced fluctuations of hydroelectric power generation, that is highly dependent on annual variations in precipitation. The year 2002 corresponded to a dry year (hydraulic index of 0.76), registering a reduction of the quantities of hydroelectric power generated and the consequent growth of emissions. On the opposite, 2003 was a year with higher precipitation (hydraulic index of 1.33, meaning that it rained 33% more than an average hydrologic year) which enabled a considerable increase of hydroelectric power and subsequent reduction in CO₂ emissions from electricity production in thermal plants. (see Figure 2.4) As compared to 2003, hydroelectric power production decreased in 2004, corresponding to an emissions increase.

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



Source:
DGGE.

2.2 Trends by Gas

Over the 1990-2004 period, all GHG emission levels grew (Figure 2.5). CO₂ is the gas having registered the biggest increase (51.5%). F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2004: 0.4%).

Figure 2.5 – Increase of GHG emissions by gas over the 1990-2004 period

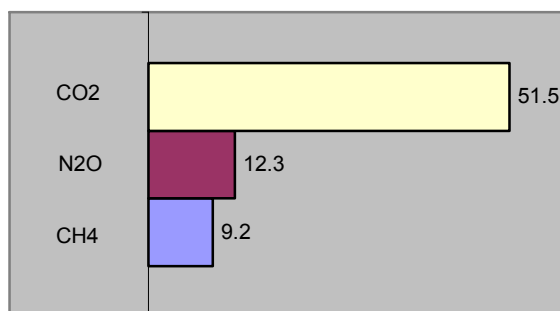


Figure 2.6 illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2004, being evident CO₂ as the primary GHG, accounting for about 77.9% of Portuguese emissions on a carbon equivalent basis in 2004 (LULUCF excluded). The second most important gas is CH₄, followed by N₂O, representing, respectively, 14.5% and 7.1% of total emissions in 2004. Portugal has chosen 1995 as the base year for fluorinated gases. In 2004 these gases represented about 0.4% of total GHG emissions.

Throughout the report, the reference to “total emissions” is meant to refer to “total emissions without CO₂ from LUCF on a carbon equivalent basis”.

Figure 2.6 – GHG emissions by gas: 1990 and 2004

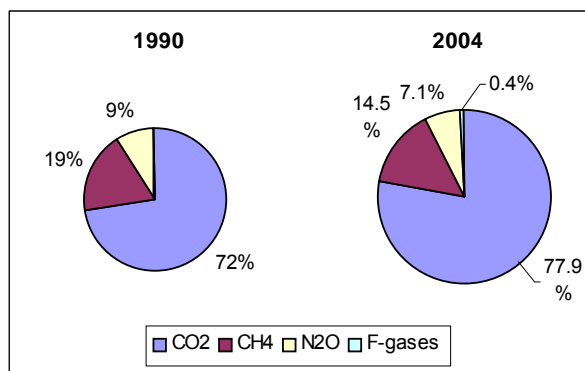
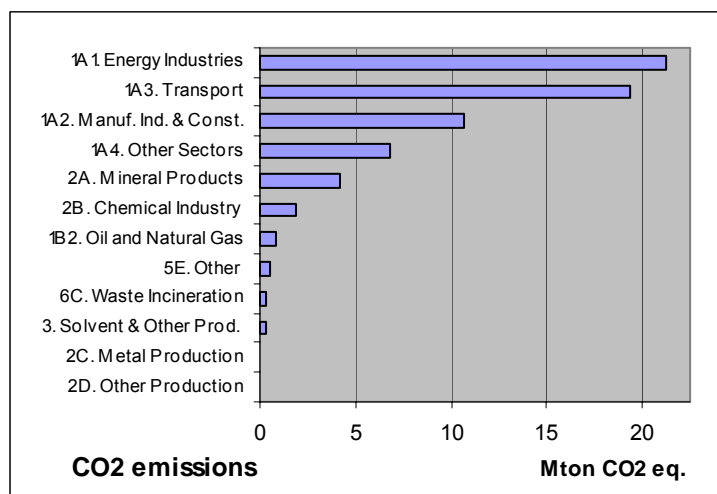


Table 2.1 – GHG emissions and removals in Portugal by gas: 1990-2004

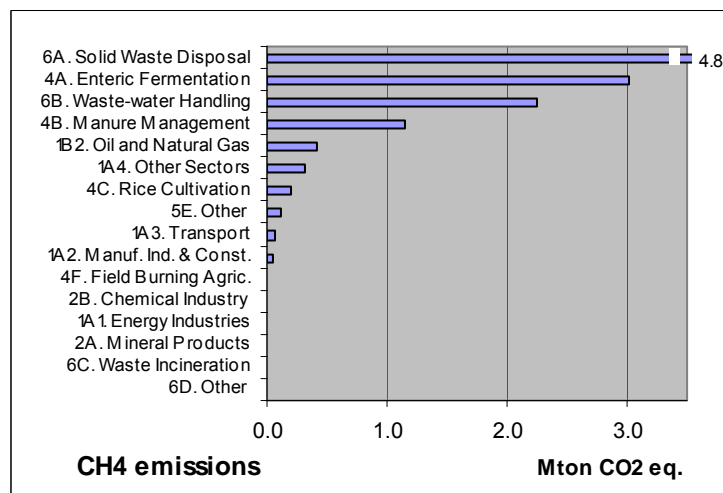
GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO ₂ equivalent (Gg)															
Net CO ₂ emissions/removals	47 015	47 668	49 727	47 760	47 849	51 330	47 093	50 174	54 217	61 420	59 820	61 311	64 974	72 200	63 141
CO ₂ emissions (without LUCF)	43 366	45 181	49 326	47 925	49 138	53 131	50 258	53 543	58 234	64 894	63 762	65 018	69 250	64 600	65 717
CH ₄	11 379	11 733	11 557	11 579	12 087	12 520	12 530	12 716	13 292	13 507	12 457	12 330	12 663	13 105	12 365
N ₂ O	5 377	5 412	5 374	5 282	5 554	5 706	6 003	6 003	5 755	6 174	6 154	6 169	6 291	5 784	6 033
HFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	1	2	10	19	33	53	92	139	172	214.30	30125	357.73
PFCs	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
SF ₆	2	2	2	3	3	3	3	3	3	4	5	5	4.57	4.57	3.44
Total (with net CO ₂ emis./removals)	63 772	64 815	66 661	64 624	65 495	69 569	65 647	68 930	73 321	81 198	78 575	79 986	84 147	91 395	81 900
Total (without CO ₂ from LULUCF)	60 123	62 328	66 260	64 790	66 784	71 370	68 812	72 299	77 337	84 671	82 517	83 693	88 423	83 795	84 476
Total (without LULUCF)	59 953	62 061	66 175	64 739	66 755	71 184	68 747	72 275	77 215	84 605	82 371	83 596	88 285	83 187	84 355

NE - not Estimated; NO - not occurring

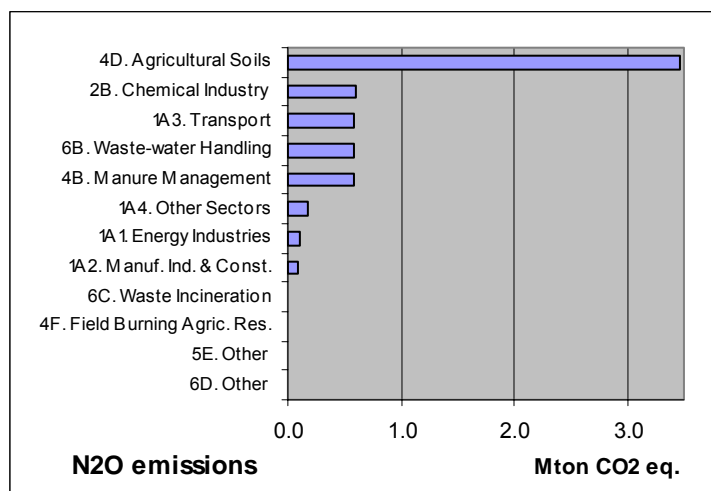
Next figures summarise the sources categories of emissions by gas (F-gases not presented).

Figure 2.7 – 2004 sources categories of CO₂

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

Figure 2.8 – 2004 sources categories of CH₄

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

Figure 2.9 – 2004 sources categories of N₂O

N₂O emissions are associated with direct and indirect emissions from agricultural soils, mainly related to the use of synthetic and manure fertilisers, manure deposition by livestock, nitrogen fixation by N-fixing crops (leguminous plants), and incorporation of crop residues into soils. Other significant sources are chemical industry (nitric acid production), wastewater treatment, fossil fuel combustion particularly in the transport sector, and biomass burning (wildfires, agricultural residues and residential combustion, and waste incineration).

2.3 Trends by Sector

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into six large IPCC categories: Energy, Industrial Processes, Solvent use, Agriculture, Land-Use Change and Forestry, and Waste. Emissions (Figure 2.10, Table 2.2) have risen for all these sectors. The interpretation of the LULUCF sector is somehow different, with positive figures representing that the sector is a net emitter, and negative values meaning that the source is estimated as a sink.

Figure 2.10 – GHG emissions and removals by sector: 1990-2004

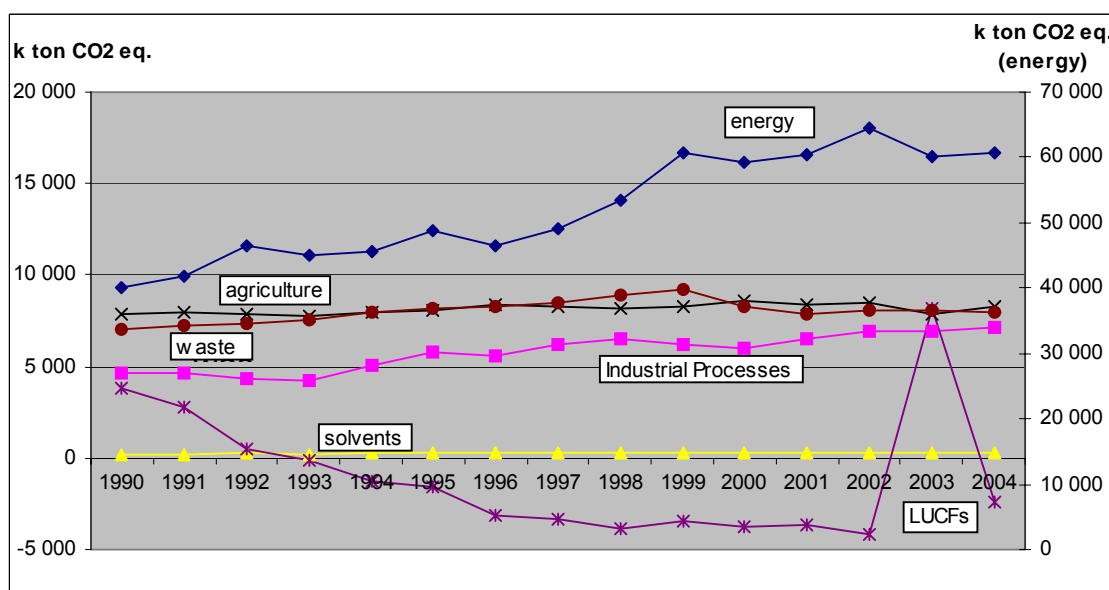


Figure 2.11 – GHGs emissions percentage change (1990-2004) by IPCC category (LULUCF excluded)

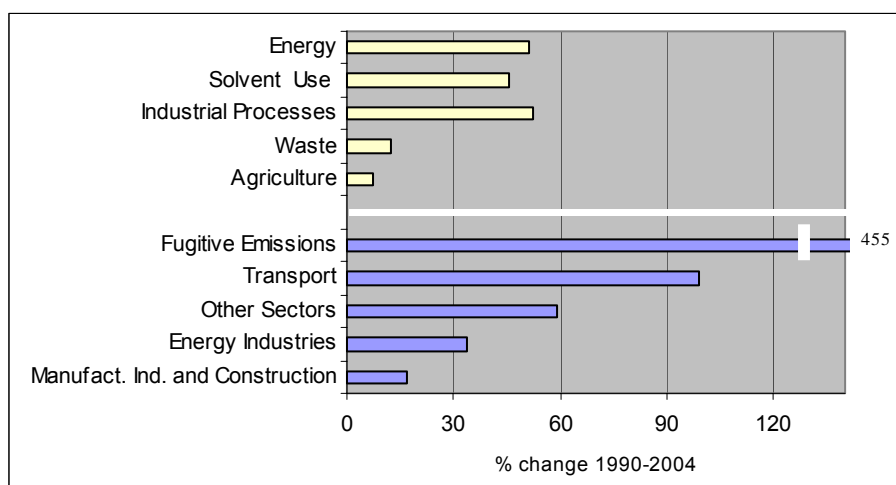


Table 2.2 – GHG emissions and removals by sector: 1990-2004

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO ₂ equivalent (Gg)															
1. Energy	40 169	41 968	46 328	44 944	45 548	48 913	46 348	49 010	53 357	60 647	59 189	60 440	64 441	60 011	60 752
2. Industrial Processes	4 626	4 600	4 370	4 224	5 031	5 782	5 536	6 220	6 465	6 170	6 042	6 551	6 957	6 901	7 100
3. Solvent and Other Product Use	220	234	243	236	253	256	275	285	290	285	290	304	312	318	320
4. Agriculture	7 878	7 993	7 855	7 745	7 985	8 059	8 360	8 238	8 219	8 324	8 577	8 414	8 473	7 866	8 240
5. Land-Use Change and Forestry ⁽⁷⁾	3 818	2 753	486	-115	-1260	-1615	-3 100	-3 345	-3 894	-3 407	-3 796	-3 610	-4 138	8 209	-2 455
6. Waste	7 061	7 266	7 379	7 592	7 938	8 174	8 228	8 522	8 884	9 179	8 274	7 888	8 102	8 091	7 944
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

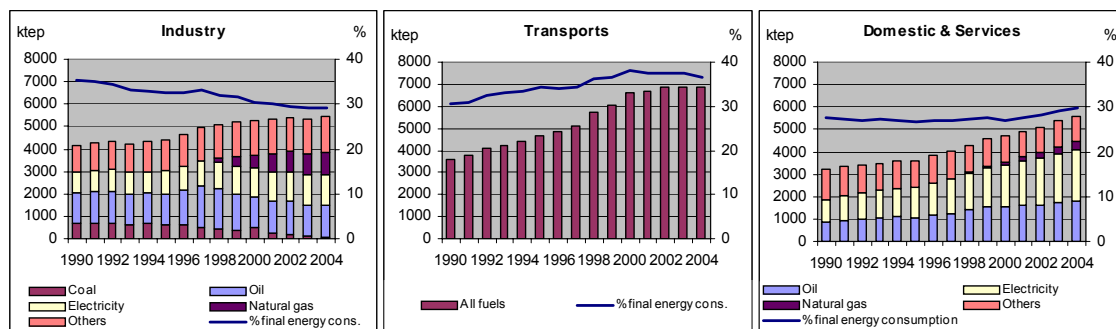
As previously mentioned, throughout the report, the reference to “total emissions” is meant to refer to “total emissions LULUCF on a carbon equivalent basis”.

Energy is by far the most important sector, accounting for 72% of total emissions in 2004, and presenting an increase of 51.2% over the 1990-2004 period. Energy industries and transport are the two most important sources representing respectively 25.3% and 23.8% of total emissions. Within the energy industries, public electricity and heat production represents alone 22.4% of the total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation and transportation, which continues to grow due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the grow of mobility.

The total final energy consumption raised 61% between 1990 and 2004, and is related to the fact that the country has one of the lowest energy per capita ratio in the EU (1.78 tep per capita in 2004).

The sectoral evolution of energy consumption presented in the next figure, shows that the sectoral structure of the energy demand has been changing. The share of the industrial sector, which represented in 1990, 35% of the final energy demand, decreased to 29% in 2004. On the other hand, as previously mentioned, transports have been increasing importance, having raised from 31% in 1990 to 37% of the final energy consumption in 2004. The increase of energy consumption of this sector was 92% from 1990 to 2004. Also, services is one of the sectors that are increasing the most, having registered a 215% rise of energy consumption from 1990 to 2004. In 2004, this sector together with the domestic sector, represented 30% of the share of the total energy consumed.

Figure 2.12 – Final energy consumption by main sectors and fuel



Mobile sources, which are largely dominated by road traffic, are one of the sectors that are rising faster. The overall energy consumed for transportation is supplied by petroleum-based products, with nearly one third being gasoline (29% in 2004). This fuel has been losing relatively importance since 1990, when the share was 40% of the sectoral energy consumption. In the period 1990-2004 the emissions of transportation sources increased 99.4%, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel, reflecting the increase in family income and the strong investment in the road infrastructure of the country in the 1990s decade. Indirectly the increase in road traffic activity also augments the emissions from fossil fuel storage, handling and distribution.

Still within the energy sector, other sectors, which include the residential and commercial activities, also registered a significant increase with almost 59% rise in the 1990-2004 period. As previously mentioned this relates to the significant growth of these sectors with reflects on the energy consumed and emissions generated.

Agriculture is the second most significant source of GHGs emissions (9.8% of total emissions) and is category showing the smallest emissions increase in the period analysed (4.6% growth from 1990 to 2004). This fact is related to the relatively decrease of importance of the sector in terms of the national economy, and is associated for instance with the reduction of the livestock production of certain categories of animals (e.g. swine), and the decrease of fertilizer consumption.

Waste and Industrial processes represent, respectively, 9.4% and 8.4% of Portuguese emissions in 2004, recording an increase of approximately 53.5% (industrial processes) and 12.5% (waste). The increase in the waste sector emissions, is primarily related to the rise of waste generation (associated with development of the family income and the urbanisation growth registred in the country during the last decade) and the deposition of waste in landfills. The growth of the industrial processes sector, whose emissions are generated as by-product of many non-energy-related activities, are mostly related to the increase of cement production, road paving, limestone and dolomite use, lime production, glass and ammonia production.

Solvent use represents less than 1% of total emissions, and is mainly related to NMVOC emissions³.

Estimates of emissions and sinks from land use change and forestry category, show this category as a net emitter in 1990 (3.8 Mt CO₂ eq.) and a carbon sink in 2004 (-2.5 Mt CO₂ eq.): The situation has been reinversed in 2004, where this source is appears as a net emitter (8.2 Mt CO₂ eq.), which was due to the exceptional occurrences in that year in what refers to the extention of the forest area burnt in wildfires.

³ These are converted into ultimate carbon dioxide after being emitted to atmosphere.

2.4 Indirect GHG and SO_x emissions

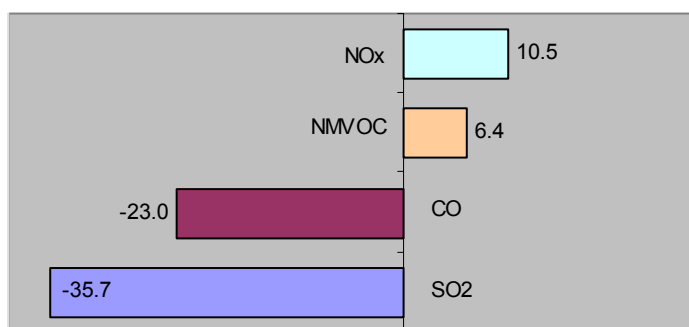
Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO_x, and NMVOC are precursor substances for ozone which is a GHG. SO_x produce aerosols, which are extremely small particles or liquid droplets, that can also affect the absorptive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

Table 2.3 – Indirect GHG and SO_x emissions: 1990-2004

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	(Gg)														
CO	952	1009	982	939	898	942	881	835	861	814	831	763	766	927	733
NO _x	245	260	277	266	265	276	268	266	277	287	285	286	294	276	271
NMVOC	279	286	293	285	292	297	298	300	303	294	292	294	297	309	297
SO ₂	317	308	370	316	296	332	271	292	341	342	306	294	294	201	204

In 2004, SO_x and CO emissions have decreased from 1990 levels: -35.7% and -23%, respectively. The other gases, NMVOC and NO_x emissions have increased, respectively, 6.4% and 10.5%.

Figure 2.13 – Variation of indirect GHG and SO_x emissions by gas: 1990-2004 period



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

Within energy, transportation is responsible for the greatest share of CO, NO_x, and NMVOC emissions, respectively 45.5%, 40.1% and 18.3% of 2004 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. NO_x emissions from transport presented a 11.7% increase over the 1990-2004 period; CO and NMVOC recorded significant reductions, respectively, -34.6% and -27.3%.

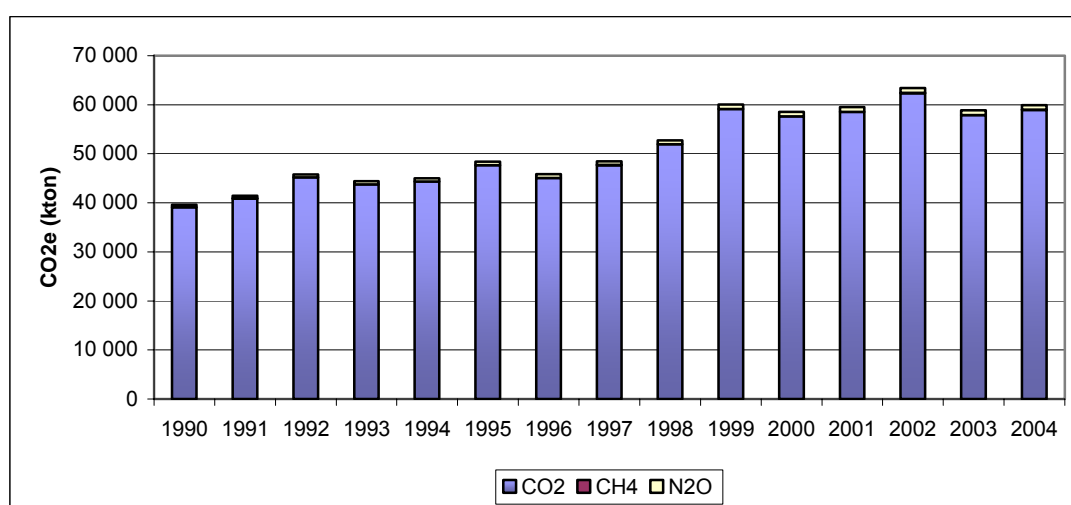
SO_x emissions are mainly generated in the energy industry sector (60.5% of total emissions in 2004) and combustion in manufacturing industries (21.4% of total emissions in 2004), which are major consumers of fossil fuels. Oil and coal represent the biggest share of the fuel mix used in thermal electrical production in the country, and they are in majority imported. However the emissions variation in the period 1990-2004 shows a decrease in SO_x emissions in both sub-categories: energy industries -38.6% and manufacturing industries -46.1%. These tendencies reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 of 10th November). The introduction of natural gas and its increasing use, since 1997, is also another positive factor that has contributed to control of SO_x emissions.

CHAPTER: 3 ENERGY (CRF 1)

3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting for 71.9 per cent of total emissions of CO₂e excluded of LULUCF in 2004. Total emissions from this sector have increased 51.2 per cent from base year to last year, although a slight decrease has occurred since 2002, as may be seen in Figure 3.1. The relative importance of total CO₂e emissions from the Energy sector has also been increasing, from 67.0 per cent in 1990 to 71.9 per cent in 2004. By far the most important gas emitted by this sector is CO₂, with 97.0 per cent of sector emissions expressed in CO₂ equivalent.

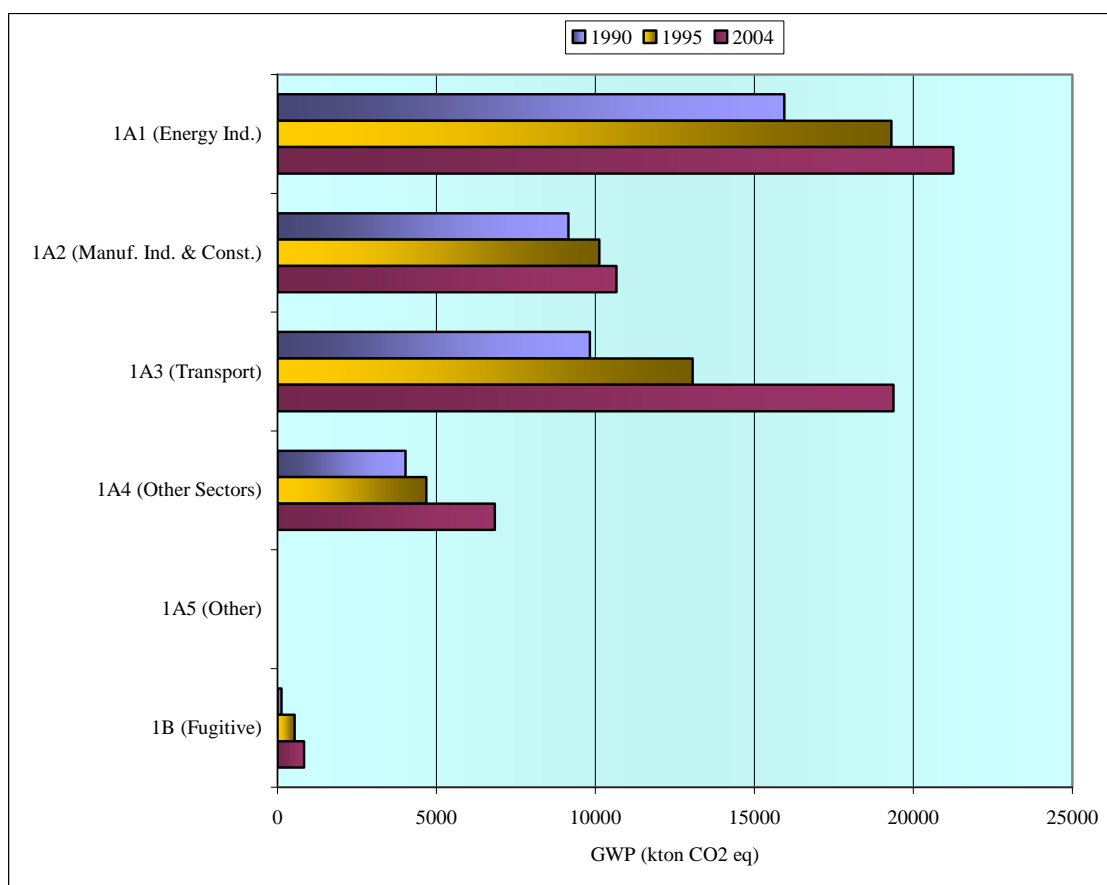
Figure 3.1 – Total CO₂ equivalent emissions from the Energy Sector (CRF Sector 1)⁴



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 also from Transportation activities (1A3). It is also noticeable the accentuated increase that emissions from this last sector have suffered during the period, 99 per cent from 1990 to 2004.

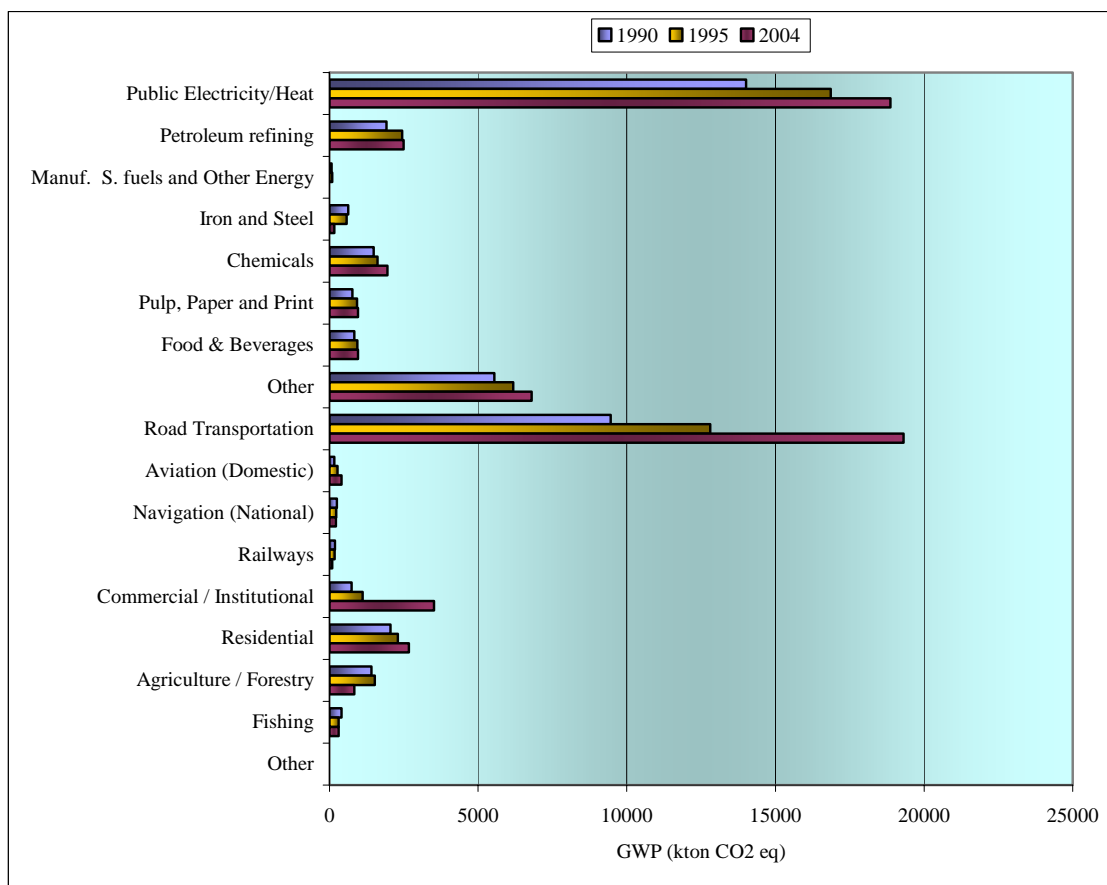
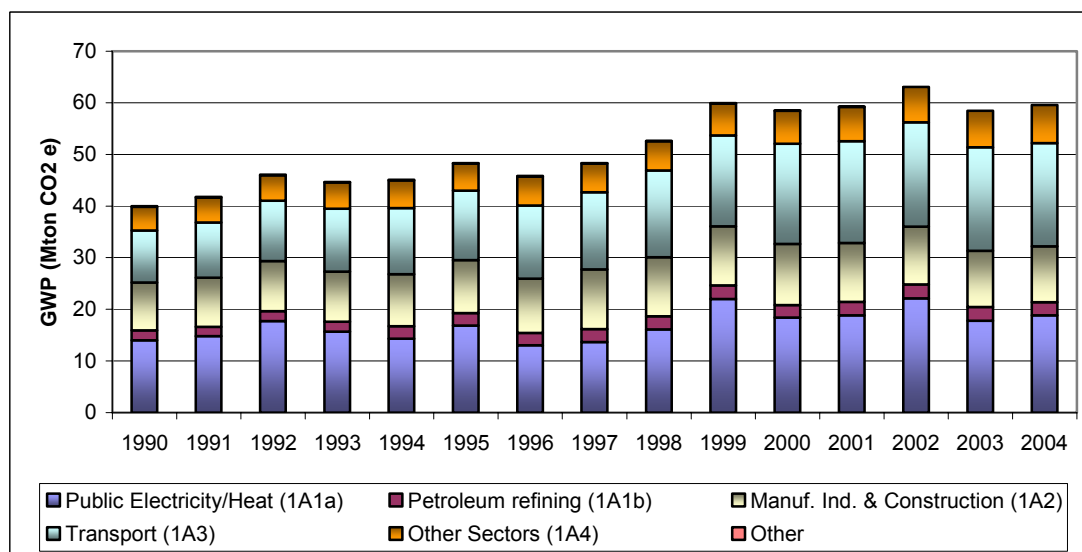
⁴ Emissions of CH₄ and N₂O are comparatively very small and are not well visible in graph.

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



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

Energy emissions are primarily related to fossil fuel combustion. In Portugal, due to the heavy dependence on fossil fuels electricity industries and transportation appear as the primary sources of Portuguese GHG emissions, representing, respectively, 25.3 per cent and 23.8 per cent of total GHG emissions in year 2004. It is noticeable that, since 2003, emissions from transportation have surpassed emissions from Public Electricity and Heat Production (22.4 per cent of total emissions) and are now the predominant source. Manufacturing industries and construction is the third larger source within Fuel Combustion Activities with 12.8 per cent of total emissions in 2004. GHG emissions from Refining of Petroleum Products is another relevant source with 3 per cent of total emissions for this sector. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 9.5 per cent of total sector emissions. Emissions for each sector in selected years are presented in Figure 3.3, and the full time trend in Figure 3.4.

Figure 3.3 – Total GHG emissions in source 1A, expressed as CO₂e, in 1990, 1995 and 2003Figure 3.4 – Trend of total GHG emissions in source 1A, expressed as CO₂e, by sub-sector (1990-2003)

GHG emissions from this activity sector are almost fully dominated by direct CO₂ emissions, which represents about 97.6 per cent of total GHG emissions in 2004. CH₄ and N₂O are minor

sources, respectively 0.8 per cent and 1.6 per cent of total GHG emissions from the 1A sector in 2004.

CO₂ emissions are dependent on the carbon content of the fuel used and, for this reason, estimates of CO₂ emissions are more accurate and methodology simpler to apply using fuel consumption data only. During the combustion process some carbon is released in smaller amounts in the form of other gases, including CH₄, CO, NMVOC and airborne particulate matter. It is presumed that all these other carbon containing non-CO₂ gases oxidise to CO₂ in the atmosphere and are include in carbon dioxide estimates (ultimate CO₂)⁵.

Emissions from fossil fuel combustion include also other atmospheric contaminants such as N₂O, NO_x, SO_x, NH₃, particulate matter, heavy metals and toxic organic compounds. Unlike CO₂, emissions estimates of these air contaminants require more detailed information, such as operating conditions, combustion and emission control technologies and fuel characteristics.

Fossil fuel combustion from international bunkers, i.e., international aviation and marine transportation, also generates air emissions in a similar way to other fuel combustion activity. In accordance with international guidelines, these emissions are not included in national totals, but are reported separately as a memo item. For the first time, Portuguese emissions for International maritime and aviation represent the real share between traffic inside and outside the country.

Biomass combustion also generates gas emissions. CO₂ emissions from this source are estimated in the inventory but not included in national emissions totals being considered that there are no net emissions of CO₂, as carbon released during biomass combustion had been in fact fixed from atmosphere by the photosynthetic process and when is burnt and returns to atmosphere does not increase the atmospheric/biosphere CO₂ pool. This activity is reported separately for information purposes only. Nevertheless non-CO₂ emissions from combustion of biofuels are however considered in inventory totals.

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

Apart from fuel combustion emissions, the Energy sector includes also emission estimates from production, transmission, storage and distribution of fossil fuels. Generated gases from these sources are CO₂, NMCOV, SO_x, CH₄, NO_x and CO, and emissions per sub-sector source are presented in Figure 3.5, where the major importance of emissions due to oil refining, transport and distribution may be seen for the beginning of the period, while the importance of emissions from storage and transportation of natural gas, because more relevant toward 2004.

GHG emissions realized as CO₂ also dominate in this source sector, with 67 per cent in 2004. Emissions by gas are represented in Figure 3.6.

⁵ Three CO₂ quantities may be referred in the inventory with different definitions: (1) End of pipe CO₂ - Carbon dioxide effectively emitted from the source: exhaust, chimney, etc; (2) Ultimate CO₂ - carbon dioxide increase contribution to atmosphere. Includes end of pipe CO₂ but also the conversion of other gases and particles that are emitted to atmosphere containing carbon and that are supposedly latter converted in CO₂; (3) Fossil ultimate CO₂ - CO₂ emissions resulting from carbon with fossil origin: fossil fuels, mineral rocks and all other non biomass carbon.

Figure 3.5 – Trend of total GHG emissions in source 1B, expressed as CO₂e, by sub-sector (1990-2004)

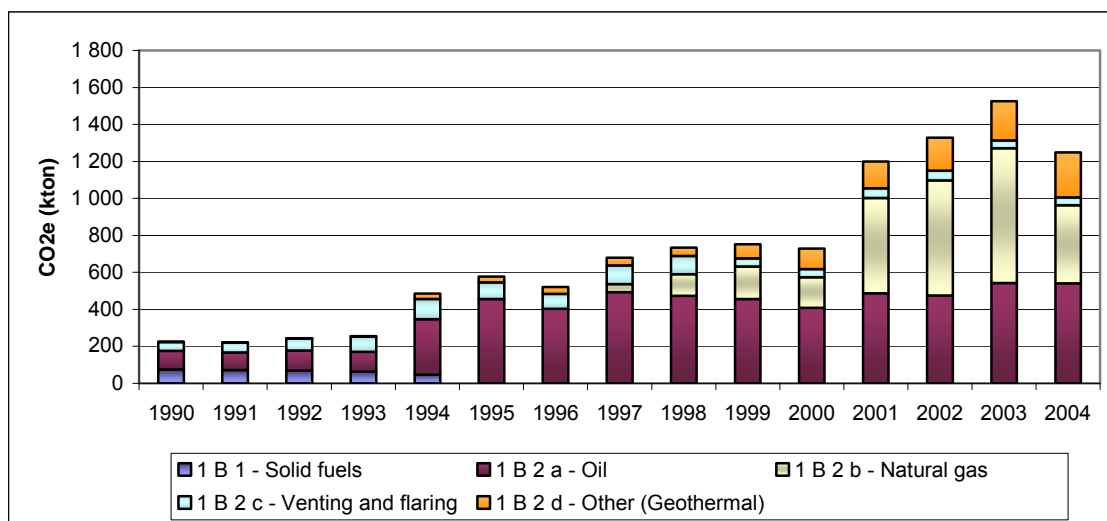
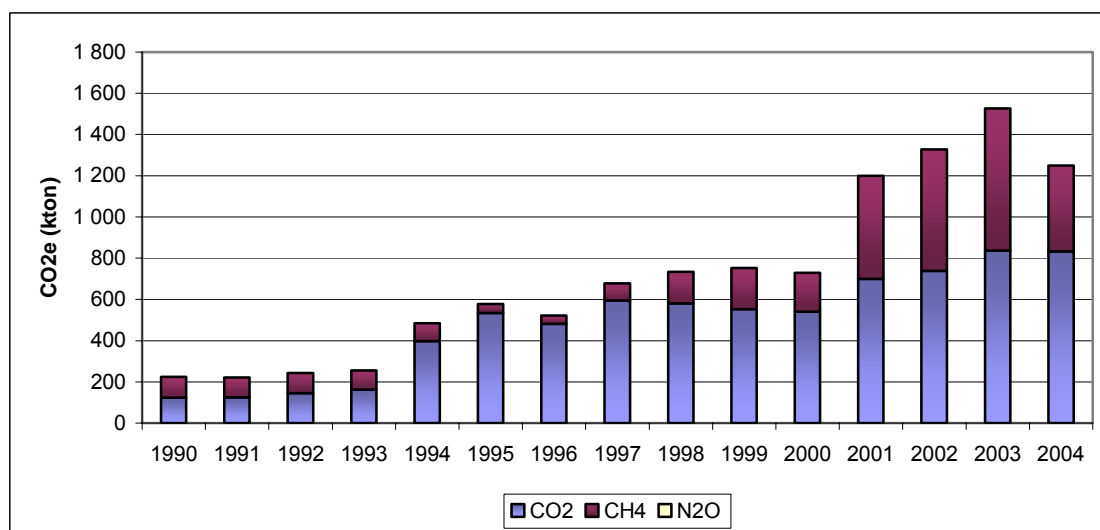


Figure 3.6 – Trend of total GHG emissions in source 1B, expressed as CO₂eq, by GHG (1990-2004)



3.2 Category sources

3.2.A Energy Industries (CRF 1A1)

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

OVERVIEW

Until 1950 electric energy production in Portugal was based in small power plant units using coal as energy source. In the nineteen-fifties increase in the demand for industry consumers cause the development of hydro-electric production units and the built of *Tapada do Outeiro* power plant using low energy coal (lignite) obtained from Portuguese mines. The next decade saw the entrance of petroleum products as the main energy sources, and three additional power

plants were built: *Carregado*, *Barreiro* and *Setúbal*. After the energy crisis of 1973/74 and 1979/81 there was a political shift towards the preference for imported coal (*Sines* and *Pêgo* power plants, started in 1985 and 1993 respectively) and, more recently, towards natural gas (*Turbogás* power plant already in operation and the new TER⁶ unit, build near the old unit in *Carregado* entered its final testing period at the end of 2003). In the islands of Azores and Madeira, the discontinuity in territory caused the prevalence of smaller units, basically one per island, working on fuel-oil or diesel-oil.

Apart from the dedicated electric power plants, auto-producers generate electric energy for own consumption and to sales to the public system. However not all combustion from these sources are included here because, according to the Revised 1996 IPCC Guidelines, emissions from auto-producers are to be reported under the industrial or commercial branch in which their main economic activity occurs. The present source sector includes only emissions resulting from main power producers⁷.

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

Large Point Source Energy Plants in Mainland Portugal

The number of Large Point Source Energy Plants (LPS-EP) in continental Portugal have increased from 6 units in 1990 to 11 units at present. Power plants and installed power are listed in Table 3.1 together with their main relevant characteristics.

⁶ TER – Termoelétrica do Carregado

⁷ Main Power Producers generate and sell electricity or heat as their main activity (primary activity) either public owned or private owned. In contrast there are other Auto-producer of electricity or heat, that also are agents producing or selling electricity or heat, but as a secondary activity and not as main business.

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

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

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

** This central is being de-activated. The smaller power value refers to situation after 2 of the 3 initial groups where closed. The intermediate value refers to the situation when 2 groups were operating.

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

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

There has also been a change in the production structure along the 1990-2004 period, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase of the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was Orimulsion, that was used as fuel in *Setúbal* power plant but only in 1994 and its use had no continuation.

- In 1990 three units (*Carregado*, *Setúbal* and *Barreiro*) were using fuel-oil, one unit (*Sines*) was consuming imported hard coal and another unit (*Tapada do Outeiro*) was using lignite coal and fuel-oil;
- A new build coal unit (*Pêgo*) using hard coal, started producing electricity in 1993 and doubled its production capacity in 1995;
- The old unit in northern Portugal (*Tapada do Outeiro*) that was burning low heating value lignite coal, partly mined in Portugal, stopped using this fuel in 1997 but was kept producing electricity with a small consumption of fuel-oil since;
- Between 1995 and 1997 *Carregado* power plant shifted part of its production groups from residual fuel-oil to natural gas. In the end of 2003 and beginning of 2004, *TER*, a new thermal power plant on Natural Gas has started operation in *Carregado*, near the old unit that is maintained in operation;

- A new unit (*Turbogás*) 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 2004, near the old unit of *Carregado*;
- *Mortágua* unit in central Portugal initiated production in 1999 using natural gas and wood wastes;
- Finally other new units (*Soporgene* and *Energin*) also in central Portugal have just started recently (*Soporgen* in 2001 and *Energin* in 2002) producing electricity from natural gas in close connection, respectively, with an industrial paper pulp plant and to a chemical industry plant.

Table 3.2 - Number of Electricity Power Plants using each type of fuel

Fuel	Number of units		
	1990	1995	2004
Lignite coal/Fuel-oil	1	1	0
Hard coal	1	2	2
Fuel oil	3	3	3
Diesel Oil	2	2	1
Natural gas	0	0	4
Natural gas/ Fuel-oil	0	0	1
Natural gas/ Wood Wastes	0	0	1

Energy Plants in Azores and Madeira Autonomous Regions

Electricity production in the autonomous regions of Madeira and Azores islands depends mostly on small and medium scale power plants using imported residual fuel oil and diesel oil, Table 3.3.

Table 3.3 - Electricity Power Plants in the Azores and Madeira

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

Non public co-generation Energy Producers

Apart from *Barreiro*, *Soporgen* and *Energin* power plant units, already discussed as Large Point Sources, production of electricity by co-generation process in smaller private owned units started and was promoted after 1993. Some of these units, although working actually in close association with other industrial activities, are independent companies, in legal terms, and which main activity was defined as electric and heat production. Consequently they must be included in this source sector and not in industry sector as emissions from other co-generation units are.

METHODOLOGY

Thermo-electricity Power Plants

A bottom-up sectoral Tier 2 approach was used to estimate emissions of CO₂ and other air pollutants from this activity. For carbon dioxide, a mass balance approach could be used in principle to estimate emissions from the carbon content of fuels. But because that information is not available from most power plants, the IPCC recommendation of using emission factors based on energy consumption was used: "Emission factors for CO₂ from fossil fuel combustion are expressed on a per unit energy basis because the carbon content of fuels is generally less variable when expressed on a per unit energy basis than when expressed on a per unit mass basis" (GPG).

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

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

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

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

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

EF_C – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

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

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

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

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

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

where

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

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

CO - carbon monoxide emissions (ton);

CH₄ - Methane emissions (ton);

TPM - Total Particulate Matter emissions (ton);

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

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

For emissions of sulphur oxides the following mass balance equation was used:

$$\text{SOx}_{(u,f,y)} = 2 * \text{Fuel}_{\text{Cons}(u,f,y)} * \text{CF}_{(f)} * \text{S}_{(u,f,y)} * 10^{-2} * (1 - \text{AshRet}_{(u,f)} * 10^{-2})$$

Where

SOx_(u,f,y) - Sulphur oxide emission estimated from consumption of fuel f in power plant u in year y (ton);

Fuel_{Cons(u,f,y)} - Consumption of fuel f in power plant u in year y (any unit in agreement with CF);

S_(u,f,y) - Sulphur content of fuel f, specific of each power plant and year (mass percentage);

CF_(f) - Factor to convert FuelCons from original units into metric tons. Equals 1 except to natural gas where it refers to density (ton/original unit);

AshRet_(u,f) - Sulphur retention in ash (mass percentage).

For the remaining pollutants, emission estimates were based on the application of emission factors, either to energy consumption (GJ/yr) or to fuel consumption expressed in mass (ton/yr).

In the first case, when activity data is expressed in energy units, the following equation is used:

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

where:

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

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

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

Presently for most pollutants, EF is independent of year and power plant. The only exception is NO_x where there are for some units some information concerning annual variations of the emission factors.

For emissions of Heavy Metals the following equation was used instead:

$$\text{HM}_{p(u,f,y)} = \text{Fuel}_{\text{Cons}(u,f,y)} * \text{EF}_{\text{HM}(u,f,y,p)} * 10^{-6} * (1 - \text{AshRet}_{(u,f,p)} * 10^{-2})$$

and,

$HM_{p(u,f,y)}$ - Heavy Metal p emission estimated from consumption of fuel f in power plant u in year y (ton);

$Fuel_{Cons(u,f,y)}$ - Consumption of fuel f in power plant u in year y (ton);

$EF_{HM(u,f,y,p)}$ - Emission Factor for heavy metal p from fuel f in power plant u and in year y (g/ton);

$AshRet_{(u,f,p)}$ - Retention of Heavy Metal p in ash from fuel f under burning conditions in power plant u (mass percentage).

EMISSION FACTORS

Large Point Source Energy Plants

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

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

Table 3.4 – Emission Factors for energy production sector. Greenhouse Gases

Fuel	$U_{CO_2}^{(i)}$	$Fa_{CO_2}^{(i)}$	Fossil _c	$CH_4^{(i)}$	$N_2O^{(i)}$
	kg/GJ	0..1		g/GJ	g/GJ
Lignite	101.2	0.980	100	1.0	1.4
Hard Coal	⁽ⁱⁱ⁾ 92.0	0.980	100	0.7	1.4
Fuel-oil	77.4	0.990	100	^(ii,iii) 0.7	0.6
Orimulsion	80.7	0.990	100	^(ii,iii) 0.7	0.6
Natural Gas	56.1	0.995	100	^(i,ii) 0.1 - 1.4	1.4
Biomass	109.6	1.000	0	15	⁽ⁱⁱ⁾ 4.3
Diesel (GT)	74.1	0.990	100	0.14	⁽ⁱⁱ⁾ 2.5

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

Emissions of Nitrogen Oxides (NO_x) and Particulate Material (TSP) are function of both fuel type and burning conditions (burning device and control equipment) and are therefore specific of each power plant and change over years. The range of emission factors for each fuel type is also presented in Figure 3.4 and Figure 3.5. For most units (*Sines*, *Pêgo*, *Carregado*, *Barreiro*, *Setúbal* and *Turbogas*) emission factors reflect actual monitoring data under *Autocontrolo* program.

Table 3.5 – Emission Factors for energy production sector. Indirect Precursors and other pollutants

Fuel	NOx g/GJ	NMVOC g/GJ	CO g/GJ	AshRet _(s) %
Lignite	310	1.5	16	5
Hard Coal	260 - 500	1.5	10	5
Fuel-oil	180 - 300	3.0	15	0
Orimulsion	300	3.0	15	0
Natural Gas	75 - 120	5.0	13 - 19	0
Biomass	70	150	500	0
Diesel (GT)	350	4.0	15	0

Table 3.6 – Emission Factors for energy production sector. Particulate Matter

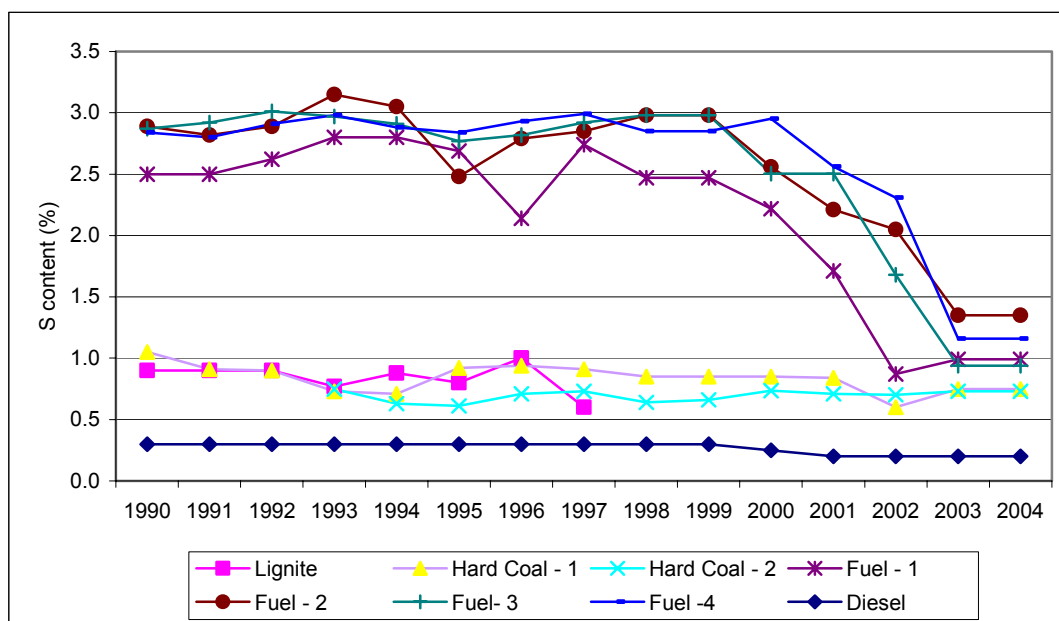
Fuel	PM g/GJ	PM10 %	PM2.5 %	PM1.0 %
Lignite	9.3	67	29	14
Hard Coal	6.8 – 40.1	67	29	14
Fuel-oil	0.26 – 69 (a)	63	41	28
Orimulsion	1.03	63	63	63
Natural Gas	0.82 – 2.54	100	100	100
Biomass	23.2	74	65	65
Diesel (GT)	30	100	100	100

(a) as function of sulphur content (USEPA) and control equipment

Table 3.7 – Emission Factors for energy production sector. Heavy Metals

Fuel	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
	g/t							
Lignite	4.00E-03	6.00E-02	4.00E-02	3.00E-02	2.00E-02	4.00E-02	0.00E+00	1.00E-01
Hard Coal	6.50E-03	1.25E-01	1.65E-01	1.20E-01	2.05E-01	2.15E-01	2.00E-02	6.65E-01
Fuel-oil	6.84E-01	5.07E-01	5.56E-01	1.70E+00	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Orimulsion	6.84E-01	5.07E-01	5.56E-01	1.70E+00	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Natural Gas	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Biomass	1.47E-02	1.00E-01	4.27E-02	5.00E-04	1.00E-01	6.03E-03	2.30E-02	2.00E+00

Average sulphur content for each fuel type has evolved along the 1990-2004 time series as shown in Figure 3.7 for the most important fuel types and power plants .

Figure 3.7 – Trends of sulphur content by fuel type⁸

Other Thermo-electricity Power Plants

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

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

The emission factors that were used in the inventory are shown from Table 3.8 to Table 3.11 for the public power plants belonging to the public system in Azores and Madeira, and from Table 3.12 to Table 3.15 for the non public co-generation self producers⁹.

⁸ Power plants are denominated by number and not by name due to confidentiality constraints

⁹ Power producers as main activity only.

Table 3.8 – Emission Factors for thermo-electricity production in Azores and Madeira. Greenhouse Gases

Region	Fuel	U _{CO2} ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1	Fossil _C %	CH ₄ g/GJ	N ₂ O ⁽ⁱ⁾ g/GJ
Azores	Fuel-oil	77.4	0.990	100	⁽ⁱⁱⁱ⁾ 2.9	0.6
Azores	Diesel oil	74.1	0.990	100	0.14	0.6
Madeira	Fuel-oil	77.4	0.990	100	⁽ⁱⁱⁱ⁾ 2.9	0.6

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

Table 3.9 – Emission Factors for thermo-electricity production in Azores and Madeira. Indirect Precursors and other pollutants.

Region	Fuel	NO _x g/GJ	NM VOC g/GJ	CO g/GJ
Azores	Fuel-oil	180	3	15
Azores	Diesel oil	1 300	2	15
Madeira	Fuel-oil	180	3	15

Table 3.10 - Emission Factors for thermo-electricity production in Azores and Madeira. Particulate Matter

Region	Fuel	PM g/GJ	PM ₁₀ %	PM _{2.5} %	PM _{1.0} %
Azores	Fuel-oil	30	82.2	77.3	77.1
Azores	Diesel oil	30	82.2	77.3	77.1
Madeira	Fuel-oil	30	82.2	77.3	77.1

Table 3.11 - Emission Factors for thermo-electricity production in Azores and Madeira. Heavy Metals

Fuel	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
	g/t							
Fuel-oil	6.84E-01	5.07E-01	5.56E-01	1.70E+00	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Diesel-oil	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01

Table 3.12 – Emission Factors for non public co-generation self producers. Greenhouse Gases

Fuel	U _{CO2} ⁽ⁱ⁾ kg/GJ	Fac _{ox} ⁽ⁱ⁾ 0..1	Fossil _C %	CH ₄ g/GJ	N ₂ O ⁽ⁱ⁾ g/GJ
LPG	63.1	0.995	100	⁽ⁱⁱⁱ⁾ 0.06	1.4
Fuel –oil	77.4	0.990	100	⁽ⁱⁱ⁾ 2.9	0.6
Diesel oil	74.1	0.990	100	⁽ⁱ⁾ 5	0.6
Natural Gas	56.1	0.995	100	⁽ⁱⁱ⁾ 1.4	1.4

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

Table 3.13 – Emission Factors for non public co-generation self producers. Precursor gases and other pollutants

Fuel	NO _x g/GJ	NM VOC g/GJ	CO g/GJ	S %
LPG	80	2.5	20	0.01
Fuel –oil	180	3	15	2.84-2.6
Diesel oil	580	50	15	0.3-0.2
Natural Gas	100	5	13	0.0007

Table 3.14 - Emission Factors for non public co-generation self producers. Particulate Matter

Fuel	PM g/GJ	PM ₁₀ %	PM _{2.5} %	PM _{1.0} %
LPG	6.9	100	100	100
Fuel –oil	37-88 ^(a)	71	52	39
Diesel oil	81.6	91.1	88.6	88.5
Natural Gas	0.8	100	100	100

(a) According to sulphur content

Table 3.15 - Emission Factors for non public co-generation self producers. Heavy Metals

Fuel	Cd g/t	Hg	As	Cr	Cu	Ni	Se	Zn
LPG	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Fuel -oil	6.84E-01	5.07E-01	5.56E-01	1.70E+00	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Diesel oil	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
Natural Gas	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04

ACTIVITY DATA

Activity data has different origins according to specific energy plants:

Large Point Source Energy Plants

Data on consumption of fuels by fuel type was available until 1998 from the Large Combustion Plants (LCP) directive - which relies in direct information reported from the individual plant producer to the Environment Ministry - for all power plants except the two gas turbines. From 1999 onwards consumption of fuels was also collected directly from energy plants but under the Self-control program (*Programa Autocontrolo*)¹⁰ or, when the unit is not obliged to this agreement, from plant activity reports (EDP, 2000; EDP, 2001; EDP, 2002; EDP, 2003; EDP, 2004; EDP, 2005). Activity data for both gas turbine units is from DGGE until 1997 and from industry reports (EDP, 2000; EDP, 2001; EDP, 2002; EDP, 2003; EDP, 2004; EDP, 2005) thereafter.

As a general rule power plant units report information about consumption in tons or cubic meters of gas together with the Low Heating Value ¹¹ for that specific year from where consumption of fuels in energy units are calculated from:

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

¹¹ Low Heating Value (LHV) or Net Calorific Values (NCV) measure the quantity of heat liberated by the complete combustion of a unit volume or mass of a fuel, assuming that the water resulting from combustion remains as a vapour

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

or

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

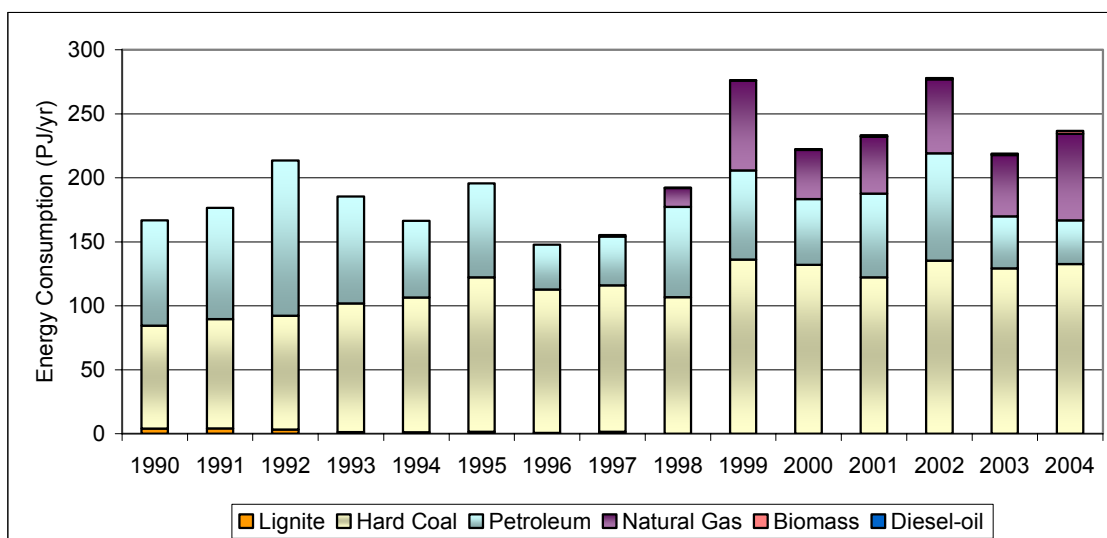
When LHV/NCV was not available it was estimated from interpolation or extrapolation from the remaining available time series. The average value and range of the reported LHV per fuel type is presented in next table.

Table 3.16 – Low Heating Value per fuel type

Fuel	LHV/NCV
Lignite	16.42 (15.57 - 17.02)MJ/kg
Hard Coal	25.98 (24.51 - 27.23)MJ/kg
Fuel-oil	40.08 (39.42 - 41.15)MJ/kg
Orimulsion	28.00MJ/kg
Diesel oil	43.30MJ/kg
Natural Gas	37.74 (36.02 - 38.96)MJ/N m3
Biomass	7.8MJ/kg

Total consumption per fuel type in comparable energy units (GJ) may be verified in Figure 3.8.

Figure 3.8 – Trends of fuel consumption per fuel type ¹²



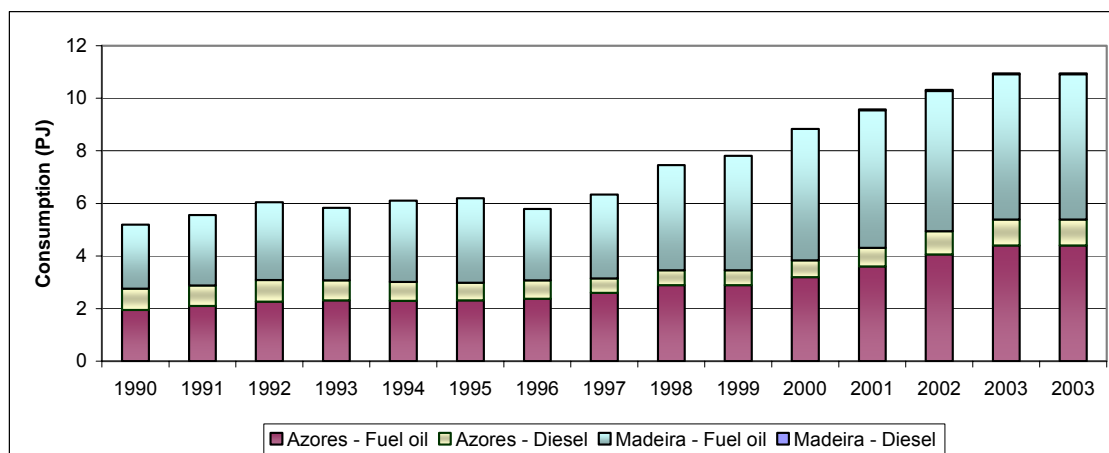
and the heat of the vapour is not recovered (GPG). In contrast, Gross Calorific Value (GCV) or Gross Heating Value (GHV) are estimated assuming that this water vapour is completely condensed and the heat is recovered (GPG). The default in IPCC Guidelines is to use the NCV.

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

Energy Plants in Azores and Madeira Autonomous Regions

The quantity of residual fuel-oil and diesel oil used in Madeira and Azores in electricity production is available from 1990 to 2000 from General-Directorate of Energy (DGE, 2003) and may be observed in the next figure. Figures for 2001, 2002 and 2003 are still provisional and result from a forecast based in 1990-2000 data using a linear interpolation.

Figure 3.9 – Trends of fuel consumption in Azores and Madeira Archipelagos



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

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

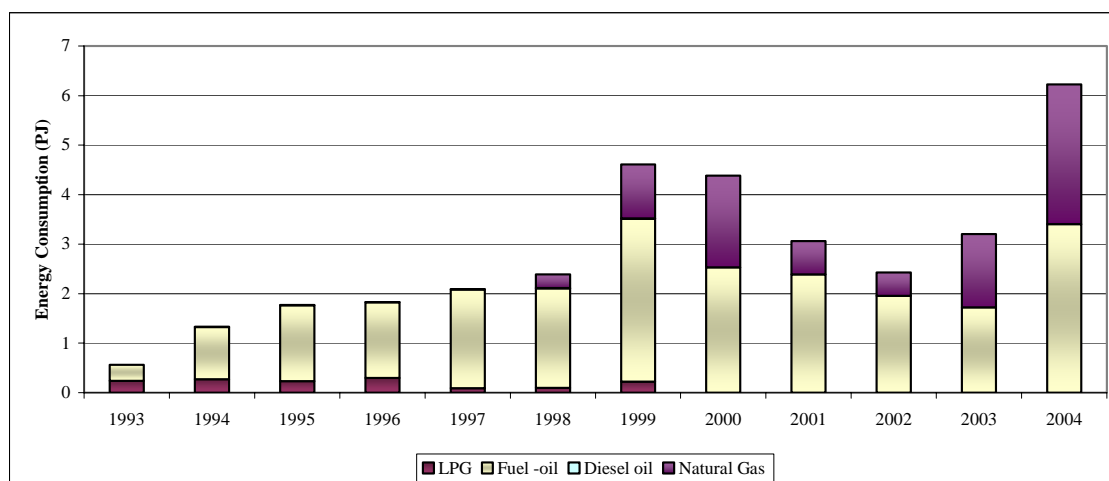
Table 3.17 - LHV per fuel type

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

Non-public co-generation Energy Producers

Consumption of fuels in co-generation units, except *Barreiro*, *Soporgen* and *Energim* power plants is available in toe units from the revised energy balances from DGGE and it is presented in Figure 3.10.

Figure 3.10 – Trends in consumption of fuels in non-public co-generation plants



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

Table 3.18 - LHV per fuel type used for non-public co-generation plants estimates

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

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. Therefore, different uncertainty values were considered in accordance with different provenience of data:

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

The uncertainty associated with the CO₂ emission factor is 5%, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 % for CH₄ and 1000% for N₂O.

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

RECALCULATIONS

The most relevant change was the use of plant specific data for the major power plants in the archipelagos of Madeira and Azores. No other changes occurred in methodology, the origin of the activity data and emission factors

FURTHER IMPROVEMENTS

The main aim in emission estimate development that is expected is the more widespread use of plant specific emission factors, covering more pollutants and more plant units. Further incorporation of time evolution of these emission factors is also necessary.

Efforts to increase the percentage of units treated as LPS is also considered a desirable objective. In the same sense on-going efforts should be maintained for the compatibilization of data acquisition by IA and DGGE in order for a better consistency of the data that is used for the Energy Balance and for the LPS data used in the inventory.

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

OVERVIEW

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

Oporto refinery, located in Matosinhos in northern Portugal, transforms, since 1966, crude oil and other intermediate materials received from Sines refinery by atmospheric and vacuum distillation, cracking, platforming and several treatments processes (dessulphurization). This refinery unit has also units for the production of oils, lubricants and aromatics (Benzene, Hexane, toluene, xylene, etc). Sines refinery, installed in 1978 in southern Portugal, has also extensive transformation of crude products after atmospheric and vacuum distillation, which are subjected to Fluid Catalytic Cracking (FCC), platforming, hydrocracking, alquilation and asphalts blowing. The now closed refinery at Lisbon performed mostly cracking. Refinery gas from this unit was used as combustible gas for domestic, service and industry use in Lisbon city.

Following the UNFCCC source categories classification, only emissions resulting from combustion in boilers and furnaces are included in this source sector. Process fugitive emissions, including combustion emissions realized in the FCC unit are included elsewhere.

SO_x and NMVOC emissions does also result from sulphur that is removed from intermediate or final products, mostly to respect environmental regulations, and conveyed in final flux gases. Elemental sulphur from the refining process is later recovered in both Sines and Oporto refineries but emissions from this source are considered under Emissions from Flaring and Venting in part 3.2.B.

METHODOLOGY

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

As explained in more detailed for sector "Public Electricity and Heat Production", emissions to atmosphere of total CO₂ and of ultimate CO₂ from fossil origin were estimated using the following equation set:

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

$$\text{Fossil}_{\text{CO}_2(y)} = U_{\text{CO}_2(y)} * C_{\text{Fossil}(f)} * 10^{-2}$$

where,

$U_{\text{CO}_2(y)}$ - Emissions to atmosphere of total carbon dioxide emissions (ton);

$\text{Fossil}_{\text{CO}_2(y)}$ - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

EF_C – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

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

$\text{Fac}_{\text{OX}(f)}$ – Oxidation factor for fuel f (ratio 0..1);

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

For all other pollutants other than sulphur oxides (SO_x) and Heavy Metals the following equation was applied to estimate air emissions:

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

Where

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

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

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

Sulphur oxides emissions from combustion are estimated from fuel consumption quantities and sulphur content from:

$$\text{SOx}_{(e,f,y)} = 2 * \text{Fuel}_{\text{Cons}(e,f,y)} * S_{(e,f,y)} * 10^{-2} * (1 - \text{AshRet}_{(e,f)} * 10^{-2})$$

Where

$\text{SOx}_{(e,f,y)}$ - Sulphur oxide emission estimated from consumption of fuel f in combustion equipment e in year y (ton/yr);

$\text{Fuel}_{\text{Cons}(e,f,y)}$ - Consumption of fuel f in combustion equipment e in year y (ton/yr);

$S_{(e,f,y)}$ - Sulphur content of fuel (mass percentage);

$\text{AshRet}_{(e,f)}$ - Sulphur retention in ash (mass percentage). It was assumed no ash retention for all fuels and combustion equipments in the refinery process.

For emissions of Heavy Metals the following equation was used:

$$HM_{p(u,f,y)} = Fuel_{Cons(u,f,y)} * CF_{(f)} * EF_{HM(u,f,y,p)} * 10^{-6} * (1 - AshRet_{(u,f,p)} * 10^{-2})$$

and,

$HM_{p(u,f,y)}$ - Heavy Metal p emission estimated from consumption of fuel f in refinery u in year y (ton);

$Fuel_{Cons(u,f,y)}$ - Consumption of fuel f in refinery u in year y (any unit in agreement with CF);

$EF_{HM(u,f,y,p)}$ - Emission Factor for heavy metal p from fuel f in refinery u and in year y (g/ton);

$CF_{(f)}$ - Factor to convert FuelCons from original units into metric tons. Equals 1 except to natural gas where it refers to density (ton/original unit);

$AshRet_{(u,f,p)}$ - Retention of Heavy Metal p in ash from fuel f under burning conditions in refinery u (mass percentage).

EMISSION FACTORS

The same set of emission factors was used for all three refineries and was set from international bibliography such as IPCC (1997), EMEP/CORINAIR (EEA,2002) and AP-42 (USEPA,1996b; USEPA, 1998b; USEPA,1991e; USEPA,1995c). The chosen Emission Factors are presented in Table 3.19 through Table 3.21 below.

Table 3.19 – Emission Factors for combustion sources in Refining of Petroleum Products. Greenhouse Gases.

Fuel	Equipment	$U_{CO_2}^{(i)}$ kg/GJ	$Fac_{ox}^{(i)}$ 0..1	Fossil _c %	$CH_4^{(ii)}$ g/GJ	$N_2O^{(i)}$ g/GJ
Fuel-oil	Boilers	77.4	0.990	100	2.9	0.6
	Furnaces	77.4	0.990	100	2.9	0.6
Fuel gas	Boilers	⁽ⁱⁱ⁾ 60.0	0.990	100	2.5	1.4
	Furnaces	⁽ⁱⁱ⁾ 60.0	0.990	100	2.5	1.4
LPG	Boilers	63.1	0.995	100	4	1.4
	Furnaces	63.1	0.995	100	4	1.4
Diesel oil	Engines	74.1	0.990	100	9.9	0.6

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

Table 3.20 – Emission Factors for combustion sources in Refining of Petroleum Products. Indirect Precursors, Particulate Matter and other pollutants

Fuel	Equipment	NO_x g/GJ	NMVOC g/GJ	CO g/GJ	PM g/GJ	PM_{10}	$PM_{2.5}$	$PM_{1.0}$
						%		
Fuel-oil	Boilers	180-190 ^(a)	3	15	66-135 ^(b)	86	56	36
	Furnaces	210	3	15	66-135 ^(b)			
Fuel gas	Boilers	140	2.5	17	3	100	100	100
	Furnaces	150	2.5	17	3			
LPG	Boilers	160	4	17	6.9	100	100	100
	Furnaces	160	4	17	6.9			
Diesel oil	Engines	1 100	100	12	6.6	50	12	8

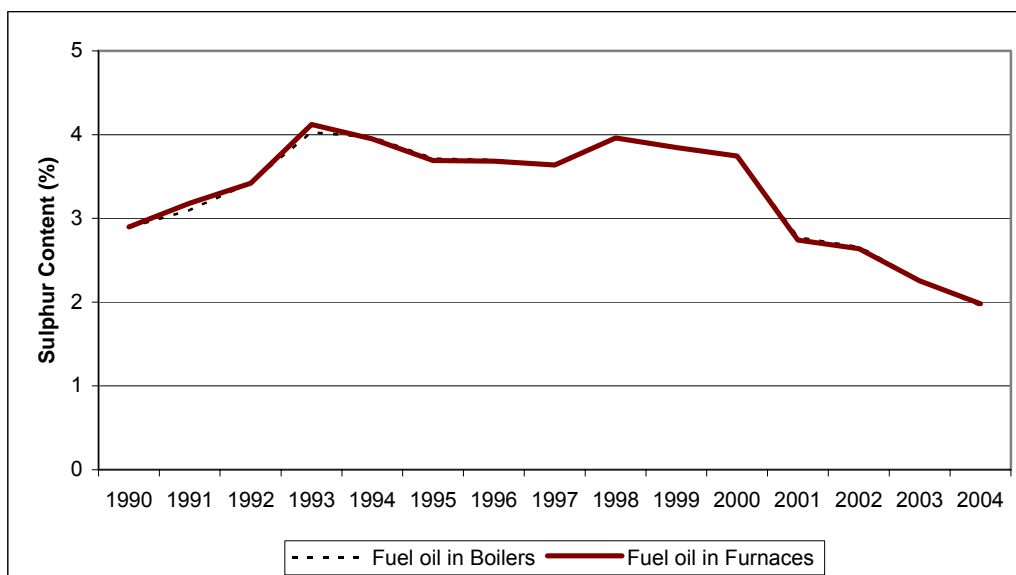
(a) variable according to equipment; (b) variable with sulphur content (AP-42)

Table 3.21 – Emission Factors for combustion sources in Refining of Petroleum Products. Heavy Metals

Fuel	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Type	g/t							
Fuel Oil	4.02E-04	5.07E-01	1.21E-03	4.02E-03	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Fuel Gas	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
LPG	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Diesel Oil	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01

Composition of fuels, in what concern sulphur, were reported for each year and for each pollutant directly from refineries under the LCP directive. Weighted average values from 1990 to 2004 are reported in Figure 3.11 for fuel-oil and show a continuous decrease since 1998. Fuel gas was reported to have no sulphur.

Figure 3.11 - Trends of sulphur content by fuel type



ACTIVITY DATA

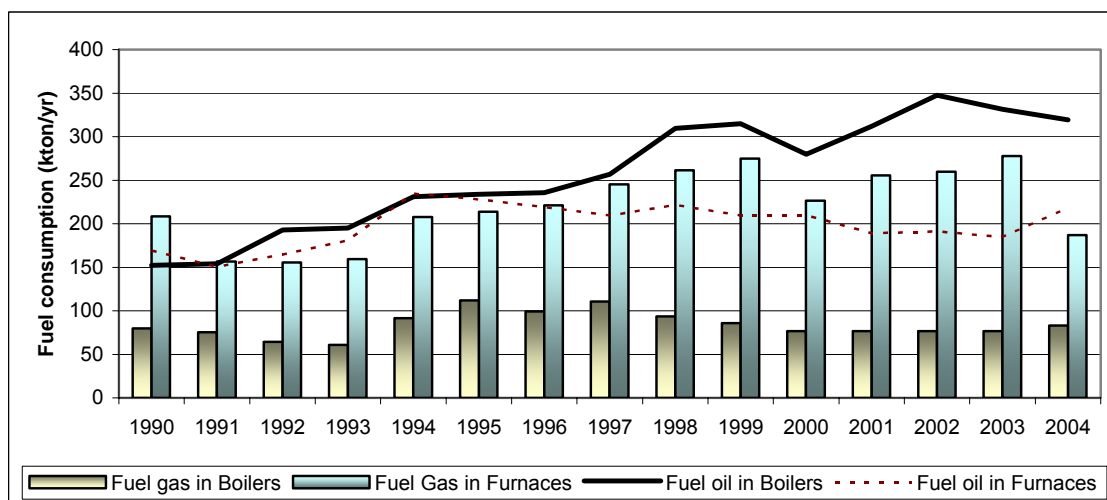
Emissions from this source sector include combustion air pollutants resulting from boilers and furnaces.

The three refinery units consume self produced residual fuel-oil¹³, fuel-gas, liquefied petroleum gases (LPG) and diesel oil.

Values of fuel consumption from 1990 to 2004 in boilers and furnaces were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in Figure 3.12 for fuel oil and fuel gas. Use of other fuels such as diesel oil and LPG although included in inventory estimates are not at all significant and do not need to be reported here.

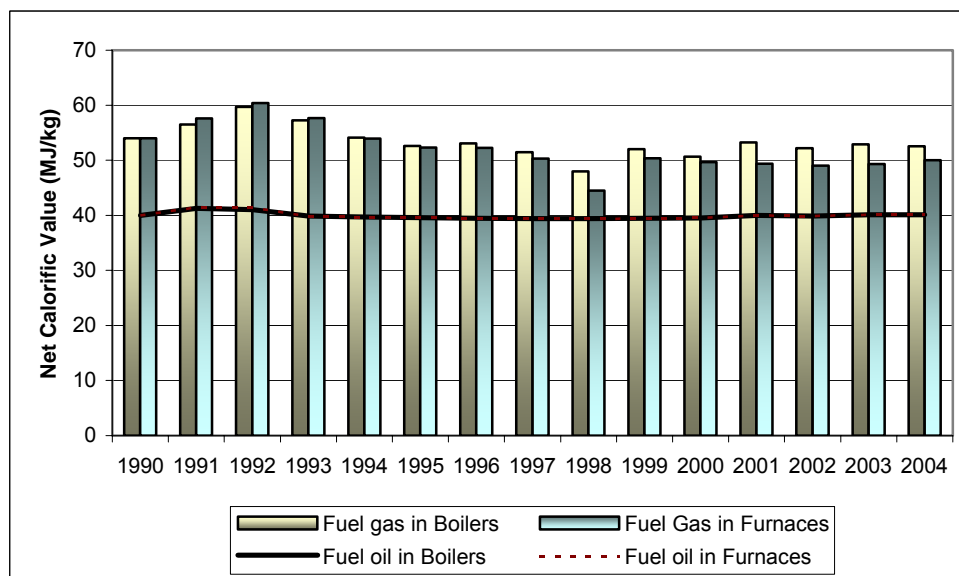
¹³ In strict terms this fuel is not traded and must not be named fuel-oil, to avoid confusion to traded fuel oil.

Figure 3.12 – Fuel consumption per year by type of equipment



Consumption expressed in energy was calculated with the following time series of Low Heating Values. This time series reflects actual information given by each refinery also under LCP directive and are weighted averages for all three plants.

Figure 3.13 – Net Calorific Value (NCV) or Low Heating Value (LHV) expressed in MJ/ kg by type of equipment



UNCERTAINTY ASSESSMENT

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

The uncertainty associated with the CO₂ emission factor is 5%, which is the value proposed for traded fuels (IPCC,2000). The uncertainty values in association with the other gases, methane and nitrous oxide, was also set in accordance with the GPG proposals, 150 % for CH₄ and 1000% for N₂O.

RECALCULATIONS

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

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

OVERVIEW

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

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

METHODOLOGY

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

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

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

where,

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

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

EF_C – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

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

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

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

For all pollutants other than sulphur oxides (SO_x) and Heavy Metals, the following equation was applied to estimate emissions:

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

where

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

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

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

Sulphur oxides emission from combustion are estimated from fuel consumption quantities and considering its sulphur content as:

$$SOx_{(y)} = 2 * Fuel_{Cons(y)} * S$$

where

$SOx_{(y)}$ - Sulphur oxide emission estimated from consumption of coke gas in year y (ton/yr);

$Fuel_{Cons(y)}$ - Consumption of coke gas in the coquerie in year y (M m³/yr) or fuel f in city gas production (ton/yr);

S - Sulphur content of coke gas used in the coquerie (g S/Nm³) or sulphur fraction of fuel f in city gas production (0..1).

For emissions of Heavy Metals the following equation was used, when data available:

$$HM_{p(u,f,y)} = Fuel_{Cons(f,y)} * CF_{(f)} * EF_{HM(f,y,p)} * 10^{-6} * (1 - AshRet_{(f,p)} * 10^{-2})$$

and,

$HM_{p(f,y)}$ - Heavy Metal p emission estimated from consumption of fuel f in year y (ton);

$Fuel_{Cons(f,y)}$ - Consumption of fuel f in year y (any unit in agreement with CF);

$EF_{HM(f,y,p)}$ - Emission Factor for heavy metal p from fuel f and in year y (g/ton);

$CF_{(f)}$ - Factor to convert $Fuel_{Cons}$ from original units into metric tons. Equals 1 except to natural gas where it refers to density (ton/original unit);

$AshRet_{(f,p)}$ - Retention of Heavy Metal p in ash from fuel f under burning conditions (mass percentage).

EMISSION FACTORS

Emissions factors for combustion of coke gas in the coquerie unit and in the city gas factory were set from IPCC96, EMEP/CORINAIR and AP-42. They are reported in Table 3.22.

Table 3.22 – Emission Factors used for the coquerie and city gas production

Source	Coquerie	City Gas Production			Unit
Fuel	Coke Gas	FO	Naphta	NG	
$U_{CO_2}^{(i)}$	$^{(iii)} 41$	77	77	56	kg/GJ
$Fac_{OX}^{(i)}$	0.995	0.990	0.990	0.995	ratio
Fossil _C	100	100	100	100	%
CH ₄	2.5	$^{(ii)} 2.9$	$^{(ii)} 2.9$	$^{(i)} 1.4$	g/GJ
N ₂ O ⁽ⁱ⁾	1.40	0.60	0.60	1.40	
SO _x	7.05				% S
	gS/Nm3	2.6-2.9	0.1	0.0007	
NO _x	120	160	160	100	
NM VOC	2.5	3.0	3.0	5.0	g/GJ
CO	17	15	15	13	
PST	3	85	6.5	0.8	
PM ₁₀	95.9	86.0	50.0	100	
PM _{2.5}	93.5	56.0	12.0	100	% PST
PM ₁	77.4	36.0	8.0	100	
Cd	NE	6.84E-01	2.55E-01	1.76E-05	
Hg	NE	5.07E-01	0.00E+00	4.18E-03	
Ar	NE	5.56E-01	0.00E+00	3.20E-06	
Cr	NE	1.70E+00	5.00E-02	2.24E-05	g/t
Cu	NE	7.41E-01	1.10E+00	1.36E-05	
Ni	NE	2.69E+01	2.85E-01	3.36E-05	
Se	NE	6.84E-02	3.00E-02	3.84E-07	

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

ACTIVITY DATA**Coke Production**

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

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

where

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

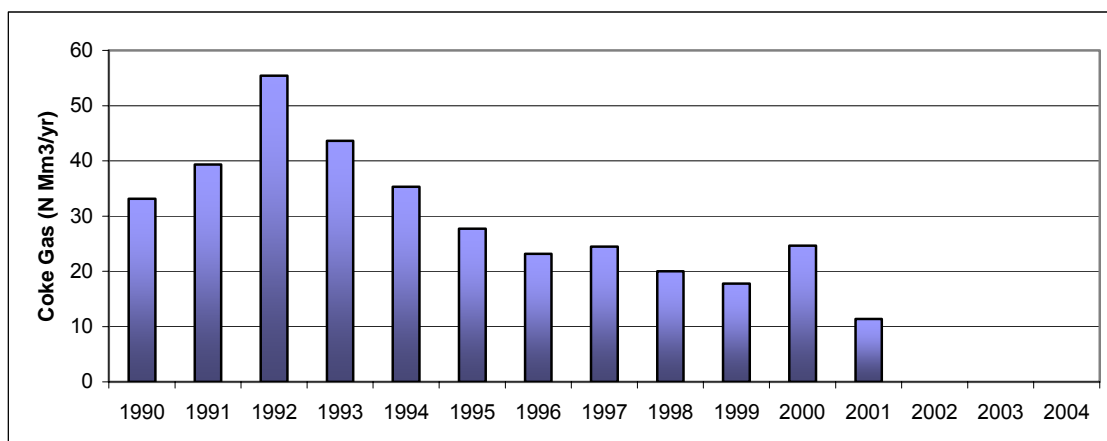
$Coquerie_{CONS(91-94)}$ - consumption of coke gas in the coquerie from 1990 till 1994;

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

$Total_{Plant_{CONS(y)}}$ - total consumption of coke gas in year y.

The coquerie has stopped operations in 2001. The full time series may be seen in Figure 3.14. Conversion in energy units was calculated using a LHV of 18.78 MJ/Nm³, the value that is reported under LCP directive.

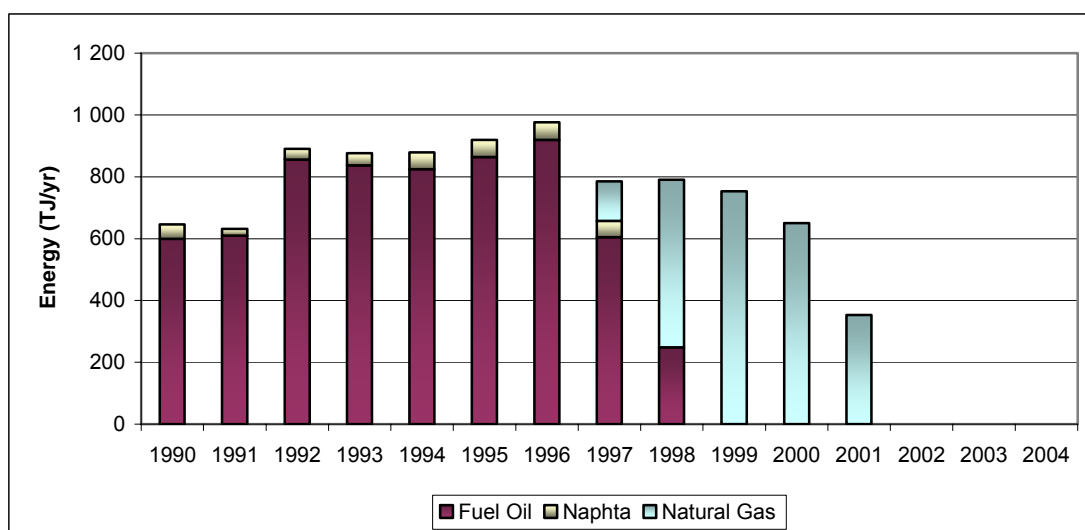
Figure 3.14 – Coke gas consumption in the coquerie: 1990-2004



City Gas Production

According to the energy balances from DGGE, this activity has used fuel oil, naphta and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001¹⁴. The available time series is presented in Figure 3.15.

Figure 3.15 – Consumption of fuels in co-generation in city gas production 1990-2004



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

¹⁴ This activity uses also fuel gas, LPG, fueloil, naphta and natural gas as feedstocks. These quantities, separated in the energy balance, are not included in the inventory at this point but in use of city gas as fuel

Table 3.23 – NCV/LHV per fuel type for city gas production

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

UNCERTAINTY ASSESSMENT

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

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

RECALCULATIONS

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

3.2.B Manufacturing Industries and Construction (CRF 1A2)

Emissions covered in this source category are those resulting from combustion activities in manufacturing industry and building and construction industry, excluding decarbonising emissions of CO₂ in cement and glass industry, which are covered under production processes (Chapter 4.2.A). The following sub-source categories are reported individually: Iron and Steel, Metallurgic industry, Chemicals, Pulp and Paper, Food Processing, Beverages and Tobacco, Textile, Ceramic, Glass and glass products, Cement, Clothing, shoes and leather industry, Wood, Rubber, Metal Equipment and Machines, Extractive industry, Construction and building and Other Transformation Industry.

Total emissions for this sub-sector are the sum of different industrial activities, using diverse fuels and combustion technologies. Emissions 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 units¹⁵.

3.2.B.1 METHODOLOGY

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

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

For Carbon Dioxide (CO₂), total emissions and ultimate fossil emissions are estimated using:

¹⁵ Only when the co-generation activity is reported to the energy balance as referring to the manufacturing industry. When economic activity is referred as Energy Production then emissions are included in source category CRF 1a1a (See chapter 3.2.A.1 for further explanations).

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

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

where,

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

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

EF_C – Carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

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

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

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

For the other pollutants when the energy consumption approach is used the equation simplifies to:

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

where:

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

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

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

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

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

where:

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

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

Production – Production activity rate (ton/yr).

Emissions of SO_x are directly related to the sulphur content of the fuel¹⁶. Estimates for SO_x were calculated assuming that there were no abatement technologies. The following equation applies:

$$Emi_{SOx} = 2 * \sum_f \sum_s \sum_t [S_{(f,s,t)} / 100 * Fuel_{Cons(f,s,t)} * (1 - AshRet_{(f,t)} * 10^{-2})]$$

where:

Em_{SOx} - Total emissions of SO_x (ton/yr);

$S_{(f,s,t)}$ - Sulphur content of fuel f in sector activity s and technology/ combustion equipment t(%);

$Fuel_{Consumption (f,s,t)}$ - Quantity of fuel that was consumed for each particular fuel f, for sector activity s and technology/ combustion equipment t (ton/yr);

$AshRet_{(u,f,p)}$ - Retention of Sulphur in ash from fuel f in equipment t (mass percentage).

For determination of emissions of Heavy Metals the following equation was used:

$$HM_{p(f,y)} = Fuel_{Cons(f,y)} * CF_{(f)} * EF_{HM (f,y,p)} * 10^{-6} * (1 - AshRet_{(f,p)} * 10^{-2})$$

and,

$HM_{p (f,y)}$ - Heavy Metal p emission estimated from consumption of fuel f in year y (ton);

$Fuel_{Cons(f,y)}$ - Consumption of fuel f in year y (any unit in agreement with CF);

$EF_{HM (f,y,p)}$ - Emission Factor for heavy metal p from fuel f in year y (g/ton);

$CF_{(f)}$ - Factor to convert FuelCons from original units into metric tons. Equals 1 except to natural gas where it refers to density (ton/original unit);

$AshRet_{(u,f,p)}$ - Retention of Heavy Metal p in ash from fuel f under burning conditions in refinery u (mass percentage).

The following procedural scheme was used:

- Emissions from the following industries were estimated based only on fuel consumption as activity data (energy approach): metallurgy; chemical and plastic industry; food, beverages and tobacco, textile industry; clothing, shoes and leather manufacturing, wood industry, rubber manufacturing, machines manufacturing Industry and other Metal Equipment Industry, extractive industry, building and construction and all other unspecified industry;

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

¹⁶ For some activities SO_x emissions may also be estimated using the production approach

- 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 in cement production and in equipments other than kilns, is converted into emission using the general purpose emission factors (energy approach). Carbon dioxide originated from decarbonising of limestone and dolomite is quantified in production processes and reported in CRF sector 2A;

- Emissions of SO_x, NO_x, NMVOC, CH₄ and particulate materials from combustion processes in furnaces in the ceramic industry are estimated using the production approach. Emissions estimates from combustion in other equipment, boilers and engines, and emission estimates for the other pollutants, also for furnaces, are based on the energy approach;

- Emissions from glass production. Also for this sector emissions estimates from use of fuels in furnaces of sulphur oxides, nitrogen oxides, methane, carbon monoxide and particulate matter are estimated using production as activity data. Emissions for the remaining pollutants, CO₂ and N₂O from furnaces and for all pollutants from other combustion equipments are estimated using energy consumption as activity data indicator. Carbon dioxide emissions from glass production comprehend both oxidation of carbon, that are estimated using the general emission factors based on energy consumption, and decarbonising of materials, which are included in production process and reported in CRF sector 2;

- air emissions from sintering (SO_x, NO_x, NMVOC, CO and PM) and production of lime (SO_x, NO_x, CO, CO₂ and PM) in integrated iron and steel production are estimated using production as activity data. The remaining pollutants resulting from the iron and steel industry, were estimated using the energy approach. For simplicity activity data and emission factors for this source are discussed in chapter 4.3.3.1 – Industrial Processes: Iron and Steel Production.

3.2.B.2 ACTIVITY DATA

Activity data comprehends consumption of fuels and industrial production rates.

COMBUSTION DATA

Data on fuel consumption for the Larger Point Sources (LPS) were obtained directly from Large Combustion Plants (LCP) submitted to the IA under the provisions of the LCP Directive or from information received by IA from special surveys or from the EPER inventory. Presently LPS comprehend one iron and steel industry, one petrochemical unit, one carbon black industrial plant, eight (all) paper pulp plants and six cement plants (covering all clinker producing units). 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 DGGE and with detailed consumption data for each industrial sector and for each fuel. This procedure is synthesized in Figure 3.16 and in the following formula set:

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

Where,

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

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

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

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

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

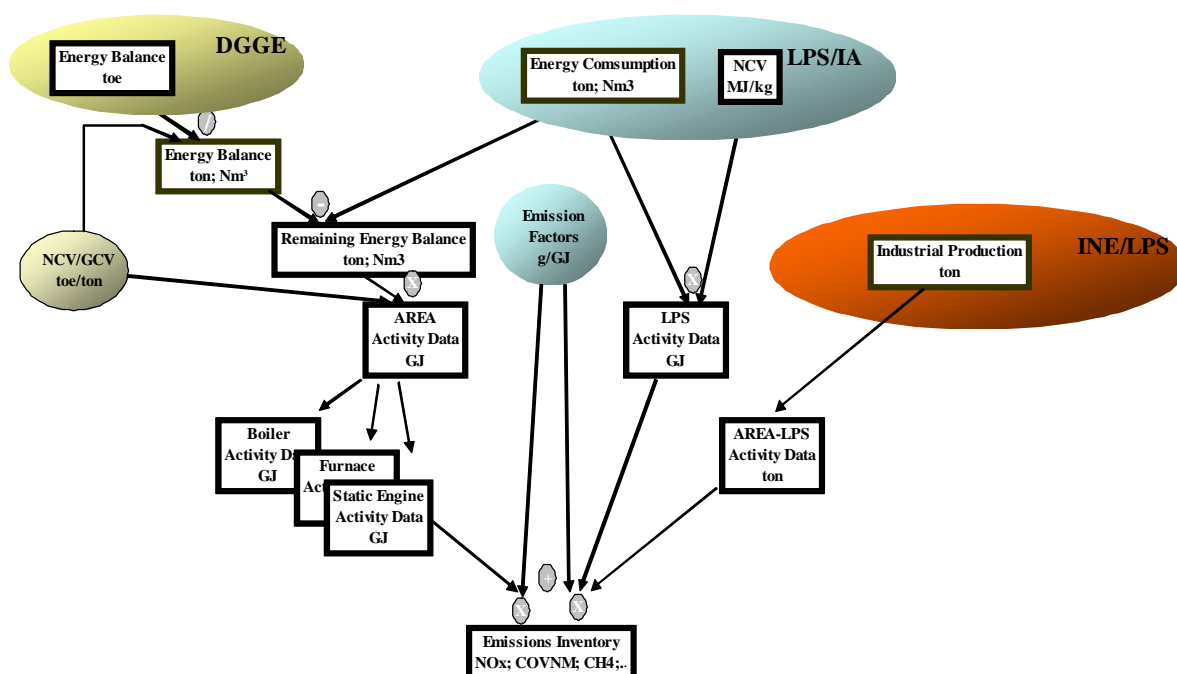
$Frac_{Equi(s,f)}$ – fraction of consumption of fuel f in sector s that is used in equipment e (0..1);

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

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

$LHV_{AREA(f,s,e)}$ – Low Heating Value/ Net Calorific Value used in the Inventory for fuel f in equipment e for area sources (combustion in non LPS) (MJ/kg or MJ/ Nm^3)¹⁷.

Figure 3.16 – General procedure for emissions estimate



¹⁷ In most cases similar values to Energy Balance are used

Characterization of the combustion equipments was also taken from LPS sources, as well as the characteristics of the fuels. For the non LPS sources, or the remaining energy consumed that are accounted in the energy balances, there is no detailed information about in which equipment combustion takes place, apart from division between co-generation and non co-generation. Thence separation of fuel consumption among boilers, furnaces and engines was made by expert judgment according to each economic sector, and also considering that the original data of fuel consumption in the DGGEs energy balances make a separation between quantities used in co-generation and quantities used without co-generation.

The sub classes presented below represent the most detailed information available limited by the detail reported in the National Energy Balances from DGGE. Each group represents an aggregation of specific Economic Activities Classes, presented in below.

Table 3.24 – Definition of Sectors in accordance with Economic Activity Classes

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

For confidential reasons, LPS data on fuel consumption for the iron and steel industry, the petrochemical and carbon black units are presented lumped together with data in energy balances, with no separation from the other non-LPS sources within the respective sector. Data on paper pulp plants are presented for the six LCP units summed together.

Table 3.25 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Iron and Steel Industry (MJ/kg)

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Coke oven gas (MJ/Nm3)	Blast furnace gas (MJ/Nm3)	Tar	Waste Oil	Gasoline
46.1-47.3	43.7	43.3	40.2-40.4	38.7	18.8	2.87	34.1	40.4	44.8

Table 3.26 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (1/2)

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

Table 3.27 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (2/2)

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

Table 3.28 – Fuel consumption in the Iron and Steel industry in Static Engines (GJ)

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

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

Figure 3.17 – Total Energy Consumption in the Iron and Steel Industry between 1990 and 2004

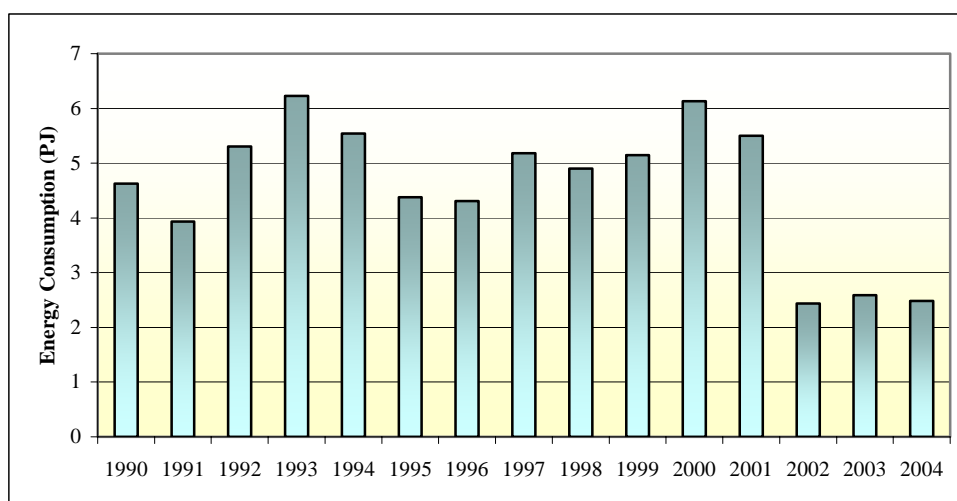


Figure 3.18 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2004

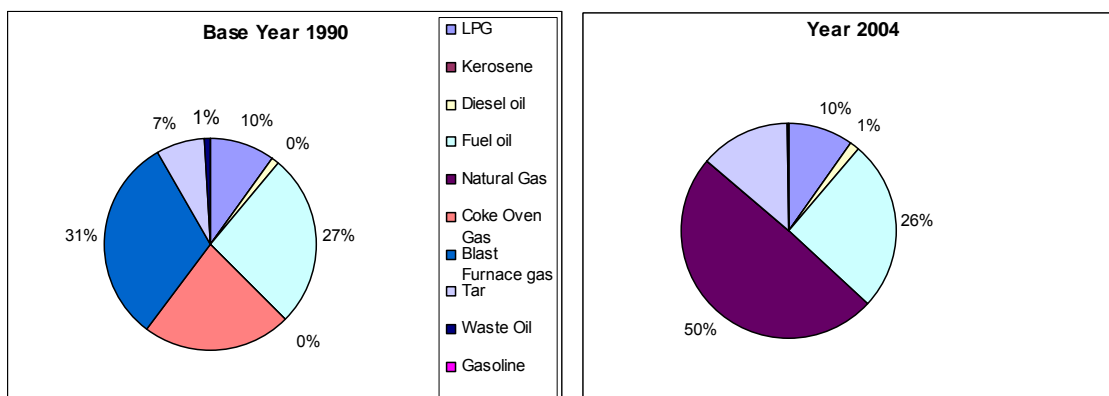


Table 3.29 – Low Heating Values/ Net Calorific Value (LHV/NCV) in Metallurgy Industry

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

Table 3.30 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ)

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

Table 3.31 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ)

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

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

Figure 3.19 – Total Energy Consumption in the Metallurgy Industry between 1990 and 2004

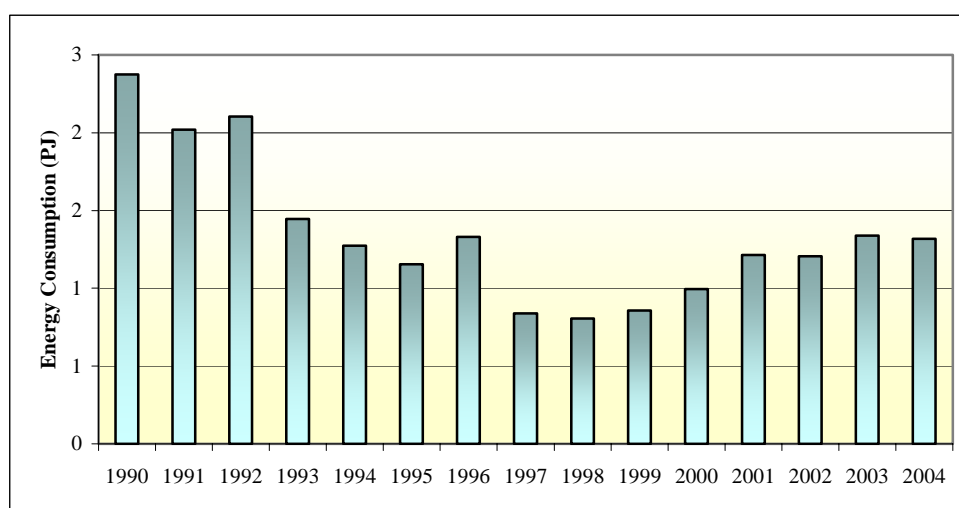


Figure 3.20 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2004

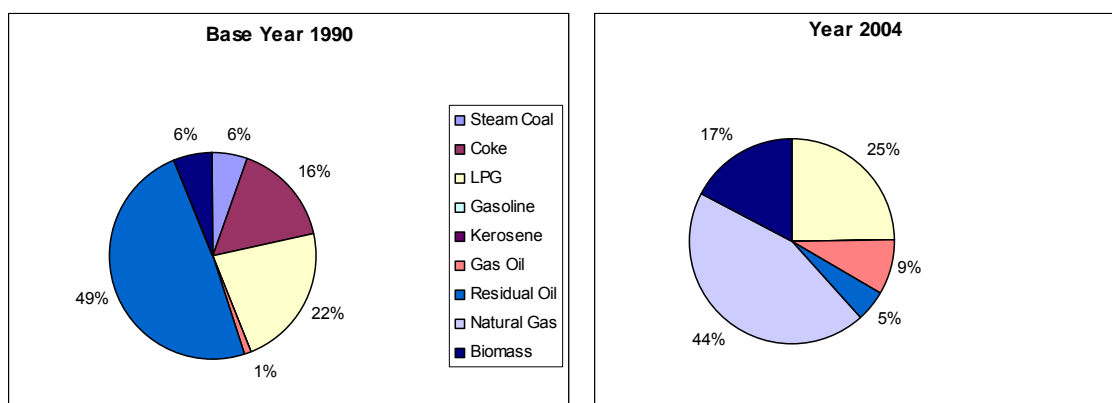


Table 3.32 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Chemical and Plastics Industry

	Coal	Coal Coke	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (MJ/Nm ³)	Biomass	Fuel Gas ¹⁸	Flare Gas ¹⁹
LHV (MJ/kg)	29.3	28.0	47.3	44.8	43.7	43.3	39.3-40.2	38.7	12.6	2.0-52.8	47.8-53.1

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

Table 3.33 - Fuel consumption in Chemical and Plastics Industry – Boilers and Furnaces (GJ)

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

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

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

Table 3.34 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ)

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

Table 3.35 - Fuel consumption in Chemical and Plastics Industry – Flares (GJ)

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

Two industrial plants in this sector were treated as Large Point Sources in this source sector, representing a substantial component of total energy consumption, but for confidentiality constrains plant specific information can not be published individually. In the beginning of the period under analysis, fuel consumption²⁰ was based on residual fuel oil, traded or by product of the unit, and residual gases, also obtained as by product from the production processes. More recently, natural gas was gained a relevant importance as the third energy source. An increasing trend in total energy consumption - although irregular - is verifiable in Figure 3.21.

²⁰ 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 3.21 – Total Energy Consumption in the Chemical and Plastic Industry between 1990 and 2004

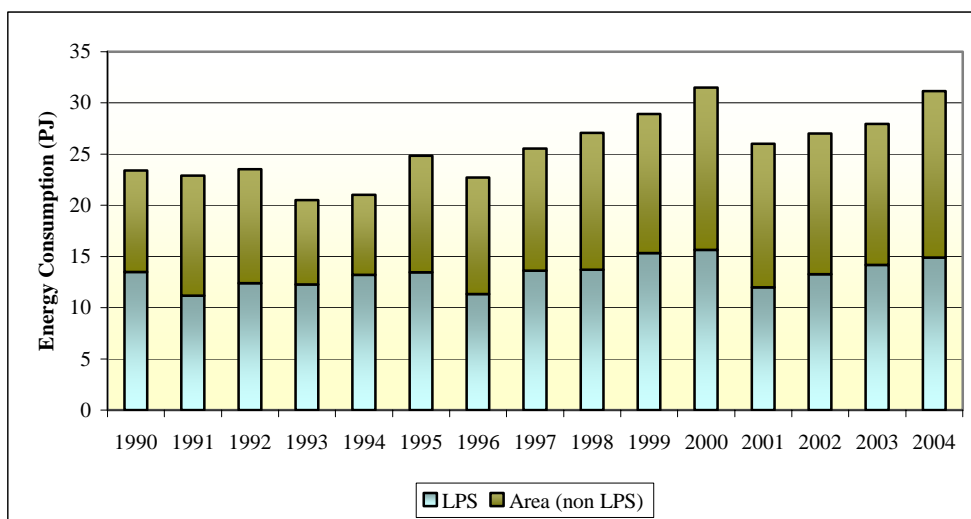


Figure 3.22 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2004

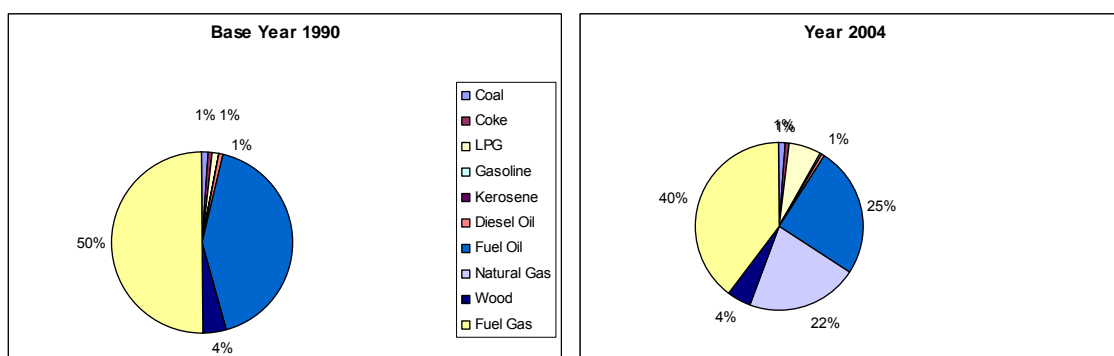


Table 3.36 – Low Heating Values / Net Calorific Values (LHV/NCV) in the Paper and Paper Pulp Industry (MJ/kg)

LPG	Gasoline	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas (MJ/Nm ³)	Wood & Wood Wastes	Liquor	Biogas	Other ²¹
47.3	44.8	43.7	43.3	39.7-40.2	38.7	10.5-35.6	7.4-15.8	34.7	34.2-52.7

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

²¹ Tall Oil, non condensable gases and other sub-products

Table 3.37 - Fuel consumption in the Paper and Paper Pulp Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Liquors	Wood & Wood wastes	Other
1990	103 357	7	90 115	9 445 240	0	24 607 749	5 105 745	39 843
1991	190 436	51	78 814	10 256 575	0	28 333 851	5 982 805	353 670
1992	236 264	32	76 148	11 226 864	0	28 687 604	7 348 581	364 647
1993	199 374	7	70 927	11 614 769	0	27 141 730	8 660 247	350 407
1994	271 869	4	66 278	13 357 405	0	26 583 344	6 868 103	374 799
1995	282 906	23	72 499	11 179 480	0	27 204 795	7 656 588	378 662
1996	301 572	5	71 699	12 159 666	0	27 078 923	7 115 364	380 045
1997	325 960	6	80 280	12 433 356	0	30 006 253	7 684 886	381 443
1998	345 875	0	60 994	11 822 305	7 065	29 923 805	7 616 532	382 292
1999	265 142	0	59 581	11 954 494	305 186	30 849 031	8 180 982	382 096
2000	248 947	26	54 727	12 609 863	2 145 436	32 197 744	6 823 719	376 907
2001	240 115	109	79 587	9 734 471	4 342 236	31 438 403	6 221 961	439 571
2002	103 112	78	76 841	8 893 658	5 232 845	31 329 288	6 852 148	456 284
2003	99 442	79	77 100	8 002 624	5 981 049	24 071 117	5 909 725	472 998
2004	96 921	81	75 006	7 278 233	5 977 691	33 963 543	7 754 940	489 712

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal in the period (six Kraft plants and two bisulphite smaller plants), but also smaller units dedicated to paper production. The increasing trend in total fuel consumption is evident and was almost continuous in the period. The lower temporary value in 2003 reflects a re-qualification period for one unit. Considering the share of energy sources, there is a dominance of liquor, followed by residual fuel oil and natural gas - this last only recently - as auxiliary primary energy sources.

Table 3.38 - Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ)

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

Figure 3.23 – Total Energy Consumption in the Paper and Paper Pulp Industry between 1990 and 2004

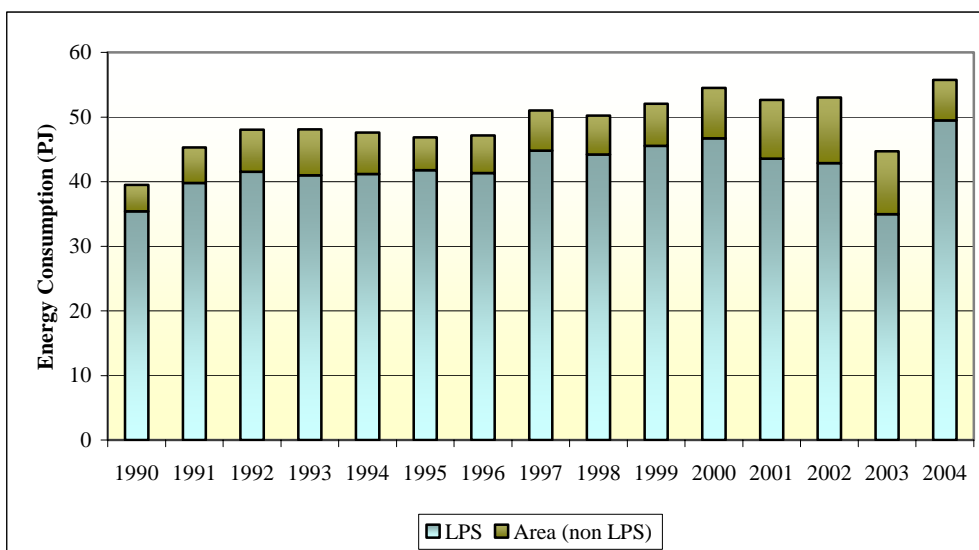


Figure 3.24 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2004

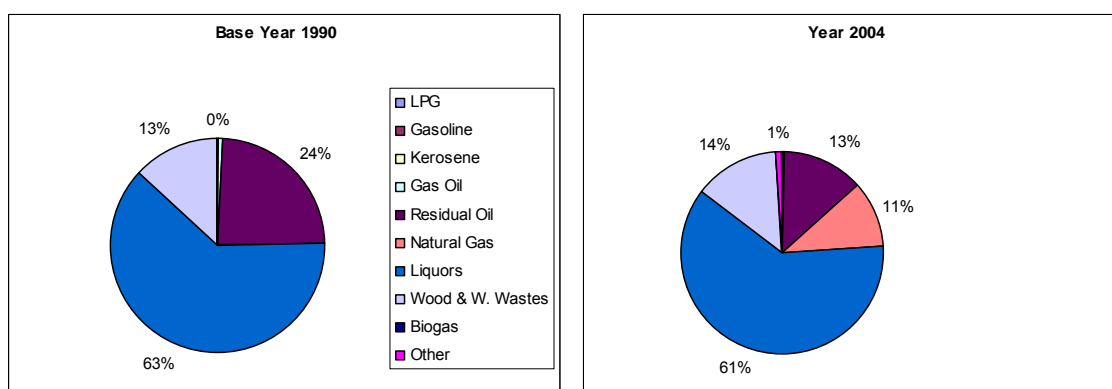


Table 3.39 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Food processing, Beverages and Tobacco Industries

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

Table 3.40 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

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

Table 3.41 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Static Engines (GJ)

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

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 and is in 2004 the second fuel in importance.

Figure 3.25 – Total Energy Consumption in the Food processing, Beverages and Tobacco Industry between 1990 and 2004

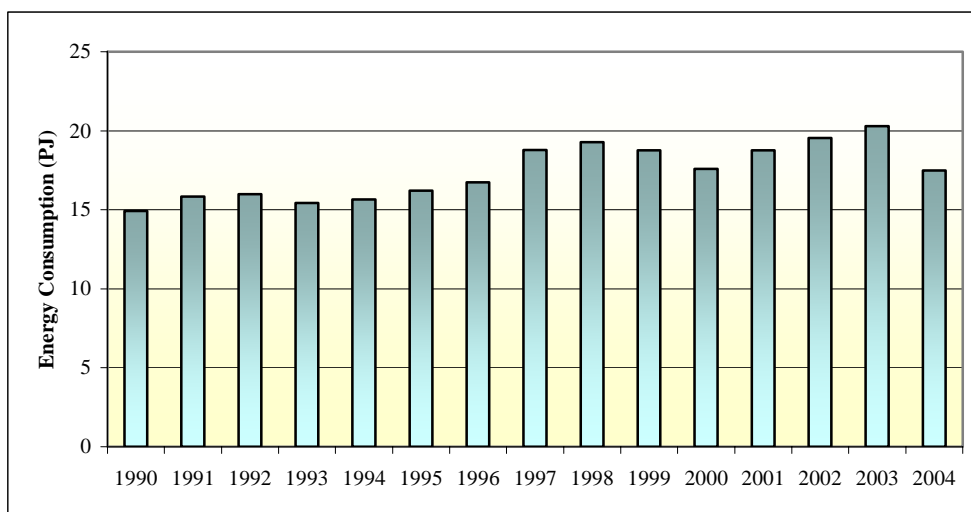


Figure 3.26 - Fuel consumption per fuel type in the Food processing, Beverages and Tobacco Industries in 1990 and 2004

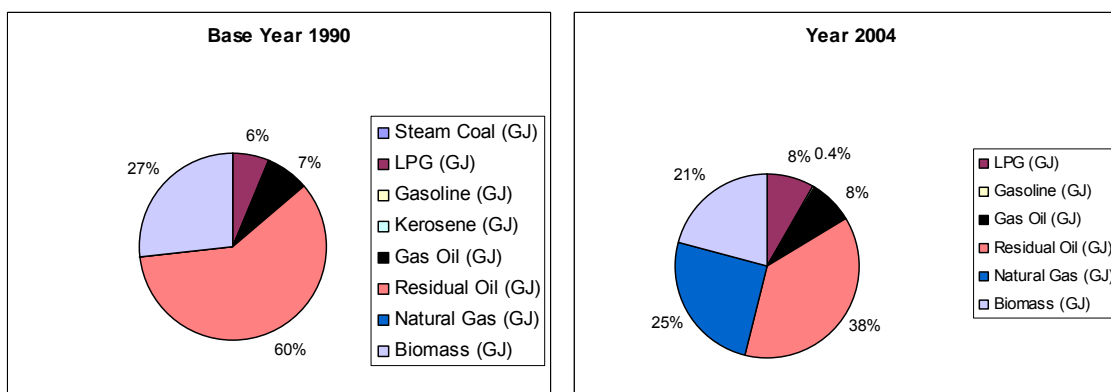


Table 3.42 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Textile Industry

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

Table 3.43 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces (GJ)

Year	LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Biomass
1990	211 079	125	27 561	10 398 463	0	1 136 569
1991	260 039	113	28 133	8 869 912	0	1 116 695
1992	313 352	104	31 054	8 137 910	0	1 099 874
1993	308 947	65	31 611	7 368 260	0	1 077 866
1994	326 923	24	37 253	8 355 456	0	1 077 866
1995	375 672	4	37 309	8 873 230	0	1 077 866
1996	446 316	6	40 465	11 399 097	0	1 143 933
1997	554 583	180	50 824	14 710 345	0	1 143 933
1998	658 367	175	52 454	14 158 114	14 207	1 146 353
1999	714 187	8	51 536	11 696 369	565 827	2 033 077
2000	507 677	0	75 300	11 329 974	3 789 968	2 059 507
2001	450 357	0	67 930	9 257 887	5 583 570	2 059 498
2002	405 987	0	90 966	9 173 383	7 160 629	2 059 498
2003	394 399	0	100 352	7 734 712	8 183 262	2 140 028
2004	580 103	0	91 224	10 803 272	6 171 846	2 321 480

Table 3.44 – Fuel consumption in Textile Industry – Static Engines (GJ)

Year	Gasoline (GJ)	Gas Oil (GJ)
1990	4 313	27 561
1991	4 723	28 133
1992	12 058	31 054
1993	9 225	31 611
1994	18 616	37 253
1995	18 900	37 309
1996	19 241	40 465
1997	21 787	50 824
1998	22 716	52 454
1999	18 431	51 536
2000	66 347	75 300
2001	60 095	67 930
2002	59 015	90 966
2003	63 433	100 352
2004	64 939	91 224

Figure 3.27 – Total Energy Consumption in the Textile Industry between 1990 and 2004

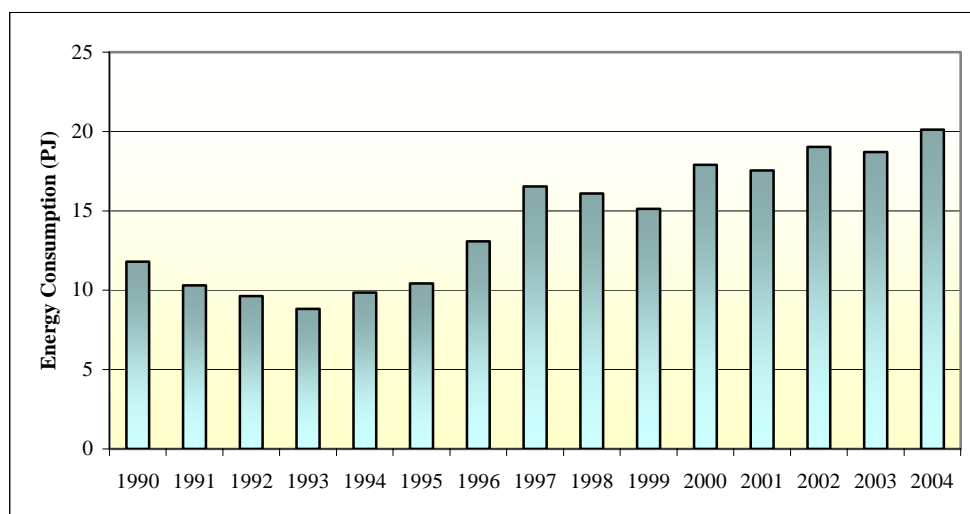


Figure 3.28 – Fuel consumption per fuel type in Textile Industry in 1990 and 2004

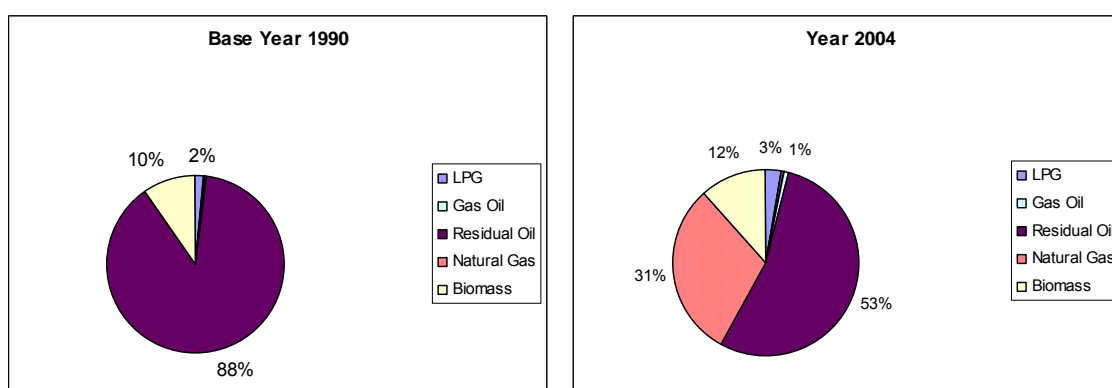


Table 3.45 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Ceramic Industry

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

Table 3.46 - Fuel consumption in the Ceramic Industry – Boilers and Furnaces (GJ)

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

Table 3.47 – Fuel consumption in the Ceramic Industry – Static Engines (GJ)

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

After the period 1990 until year 2001 when consumption of energy has increased steadily over the years, it is now observable a decline in total consumption in this sector. The pattern of fuel consumption has also changed, with the abandonment of residual fuel oil and LPG and their substitution by natural gas in more recent years. This sector, together with the glass industry, is in fact one in which the substitution was more visible. The decrease in use of biomass is only apparent in per cent, because values of consumption of these fuels did in fact increased slightly.

Figure 3.29 – Total Energy Consumption in the Ceramic Industry between 1990 and 2004

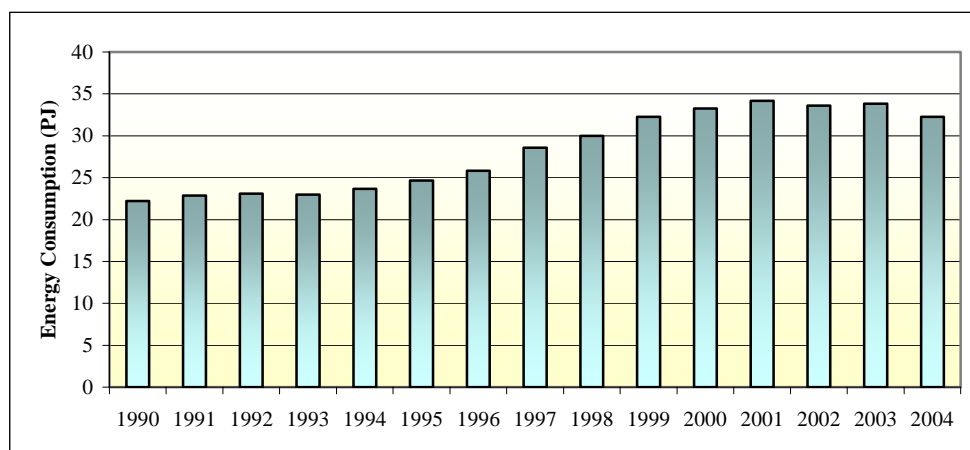


Figure 3.30 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2004

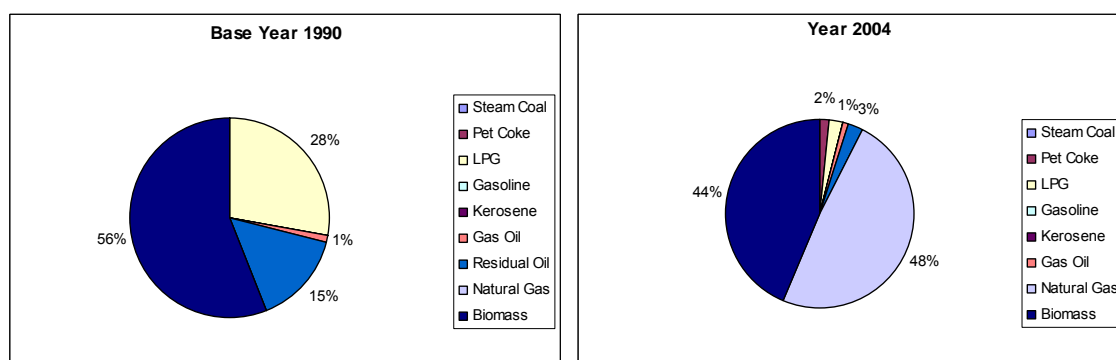


Table 3.48 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Glass Industry

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

Table 3.49 – Fuel consumption in the Glass Industry – Boilers and Furnaces (GJ)

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

Table 3.50 – Fuel consumption in the Glass Industry – Static Engines (GJ)

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

The consumption of energy in this sector has suffered a stagnation in the most recent years after 1999. The introduction of natural gas has almost replaced fully the consumption of LPG and most of the consumption of residual fuel oil, that was in dominance in 1990.

Figure 3.31 – Total Energy Consumption in the Glass Industry between 1990 and 2004

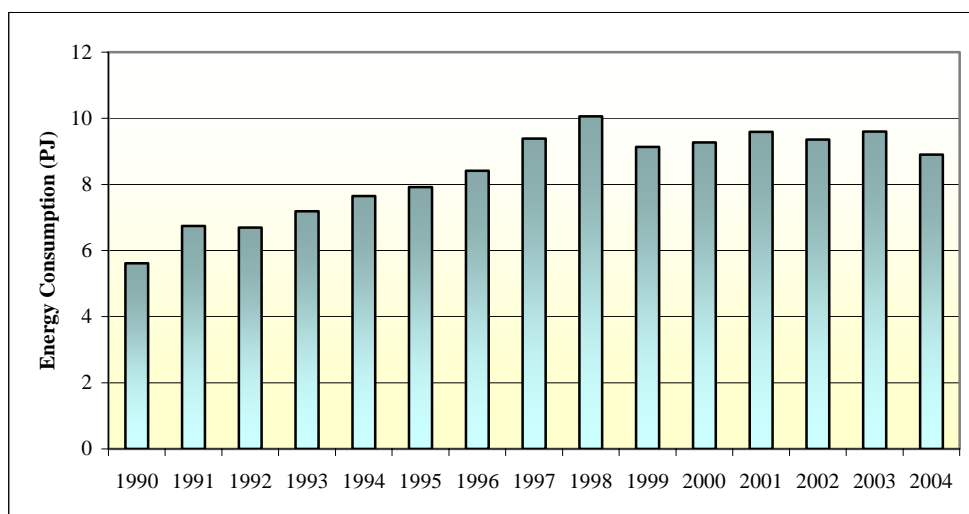


Figure 3.32 – Fuel consumption per fuel type in Glass Industry in 1990 and 2004

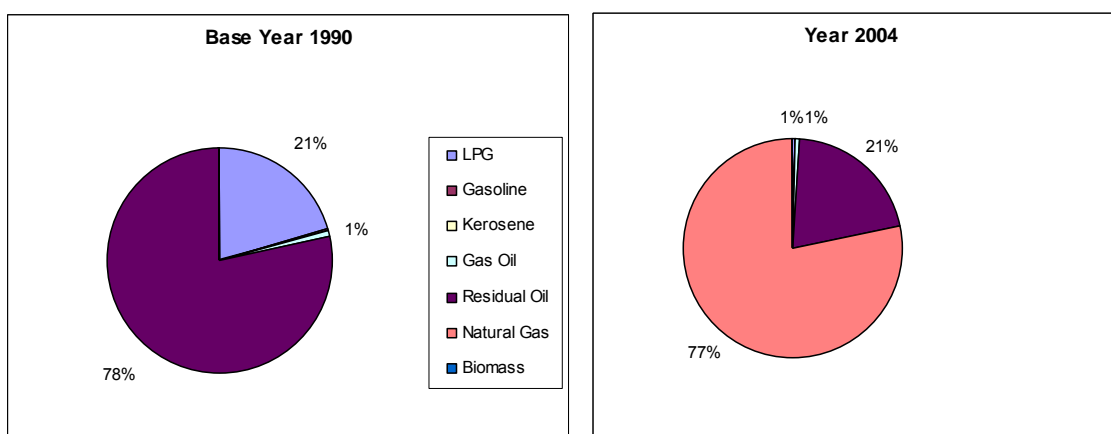


Table 3.51 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry (MJ/kg)

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

Table 3.52 – Fuel consumption in the Cement Industry – Boilers and Kilns (GJ)

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

Table 3.53 – Fuel consumption in the Cement Industry – Static Engines (GJ)

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

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

Figure 3.33 – Total Energy Consumption in the Cement Industry between 1990 and 2004

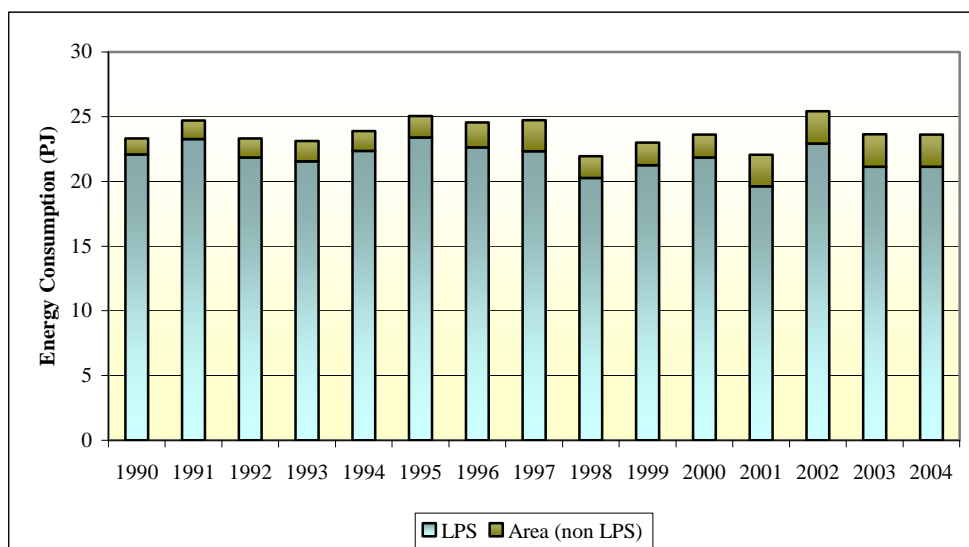


Figure 3.34 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2004

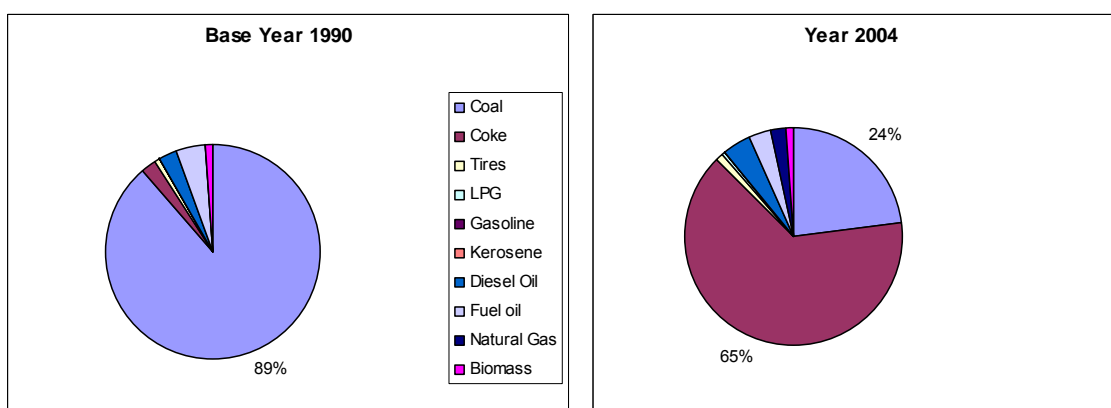


Table 3.54 – Low Heating Values/ Net Calorific Values (LHV/NCV) in clothing, shoes and leather Industries

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

Table 3.55 – Fuel consumption in the clothing, shoes and leather Industries – Boilers and Furnaces (GJ)

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

Table 3.56 – Fuel consumption in the clothing, shoes and leather Industry – Static Engines (GJ)

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

Figure 3.35 – Total Energy Consumption in the clothing, shoes and leather Industries between 1990 and 2004

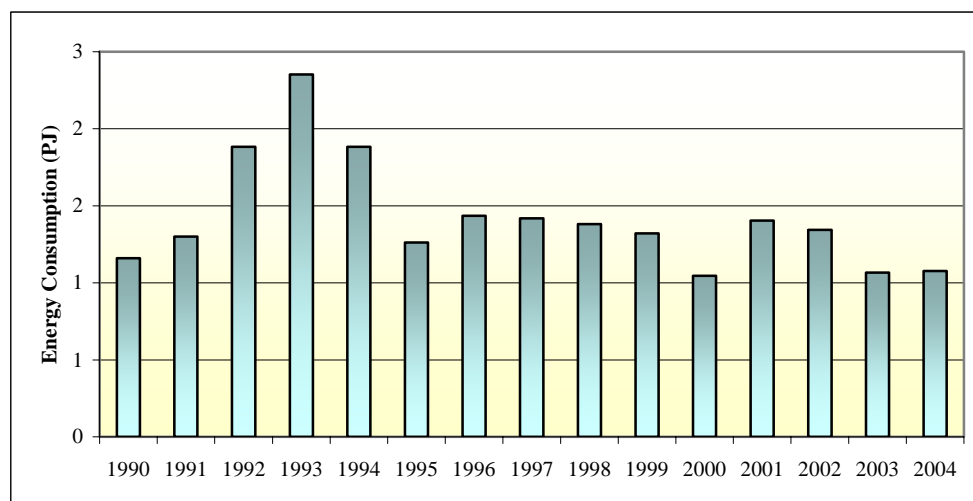


Figure 3.36 - Fuel consumption per fuel type in the clothing, shoes and leather Industries in 1990 and 2004

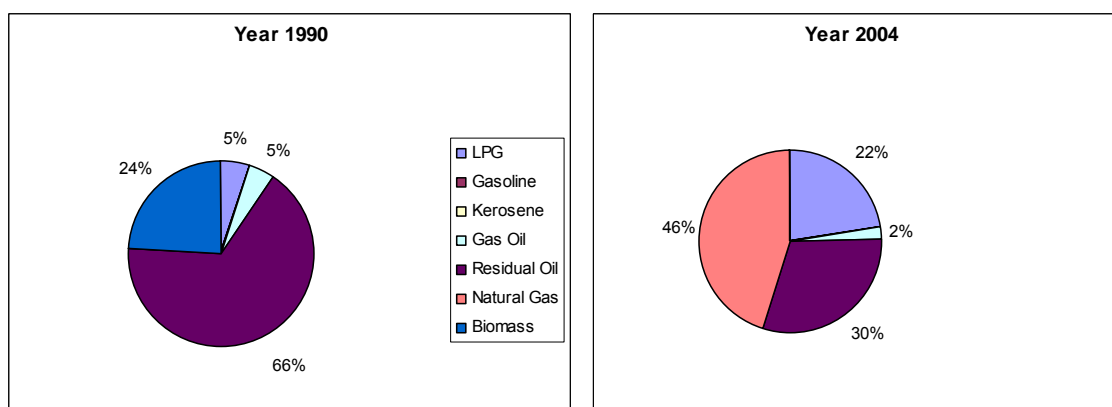


Table 3.57 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Wood Industry

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

Table 3.58 – Fuel consumption in the Wood Industry – Boilers and Furnaces (GJ)

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

Table 3.59 – Fuel consumption in the Wood Industry – Static Engines (GJ)

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

Although total consumption of energy from combustion has increased from 1990 to 2004, 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 3.37 – Total Energy Consumption in the Wood Industry between 1990 and 2004

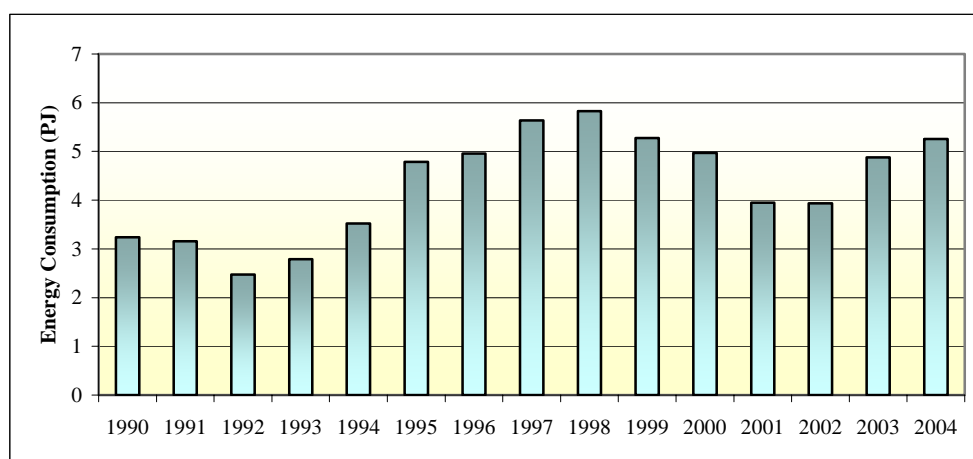


Figure 3.38 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2004

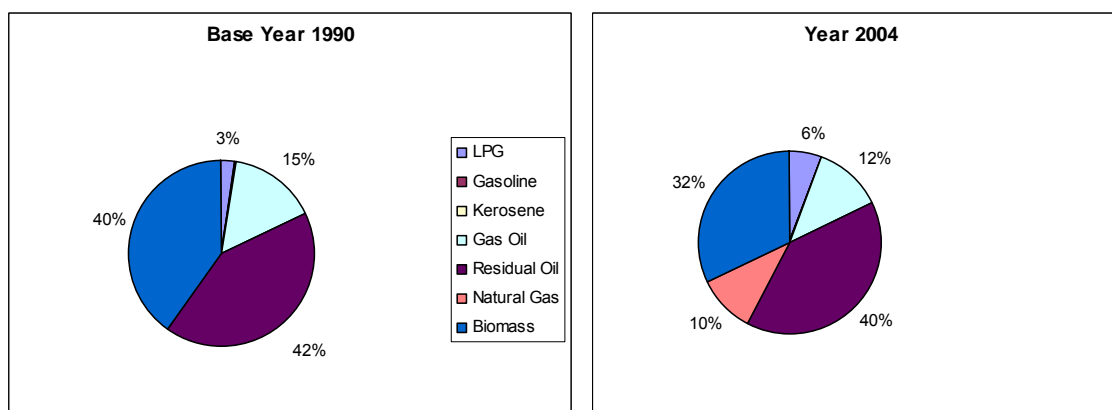


Table 3.60 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Rubber Industry

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

Table 3.61 – Fuel consumption in the Rubber Industry – Boilers and Furnaces (GJ)

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

Table 3.62 – Fuel consumption in the Rubber Industry – Static Engines (GJ)

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

Figure 3.39 – Total Energy Consumption in the Rubber Industry between 1990 and 2004

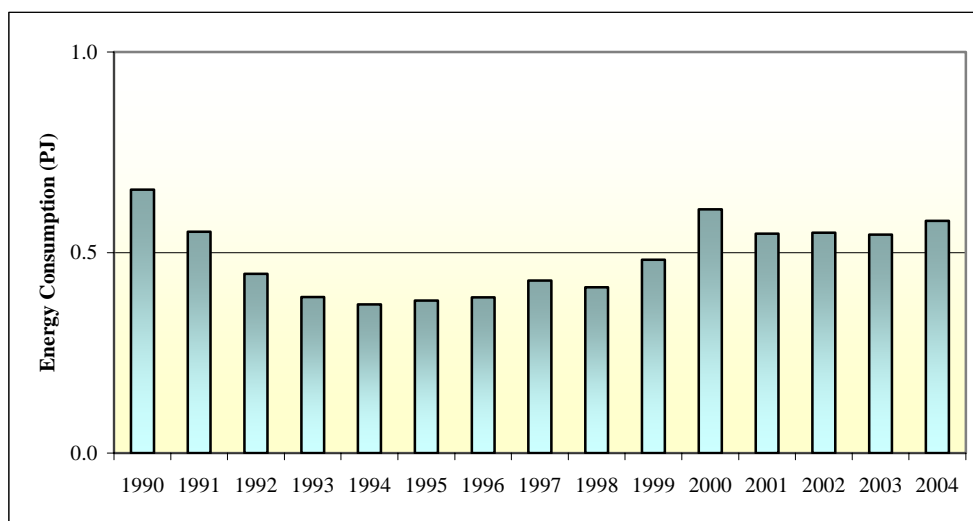


Figure 3.40 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2004

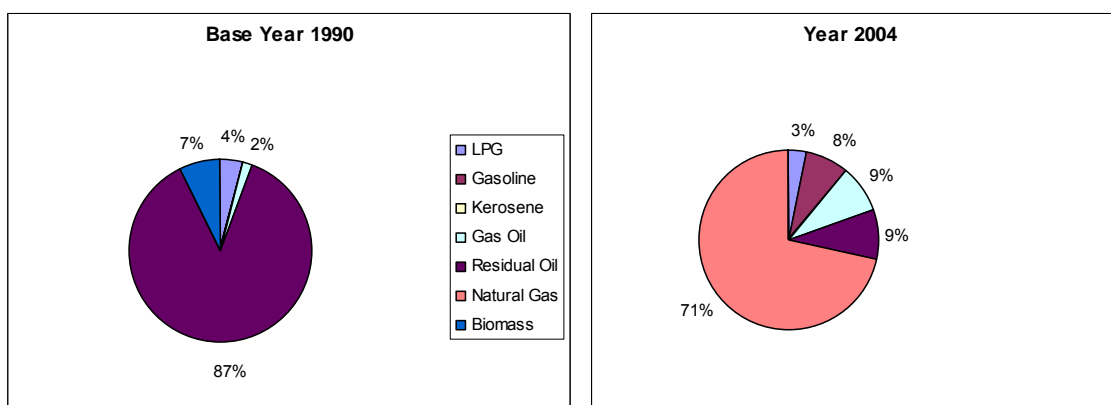


Table 3.63 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Manufacturing of Machines and Metallic Equipments Industry (GJ)

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

Table 3.64– Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Boilers and Furnaces (GJ)

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

Table 3.65 – Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Static Engines (GJ)

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

Figure 3.41 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry between 1990 and 2004

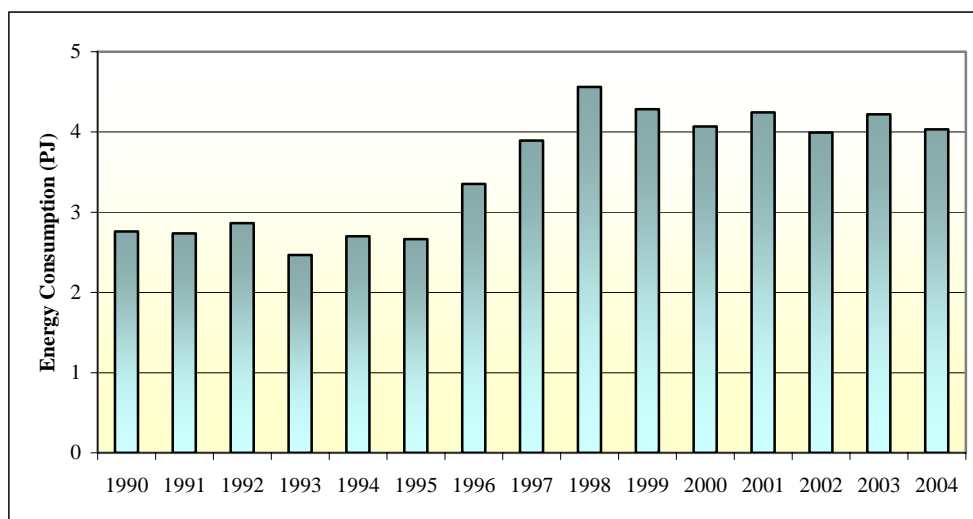


Figure 3.42 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2004

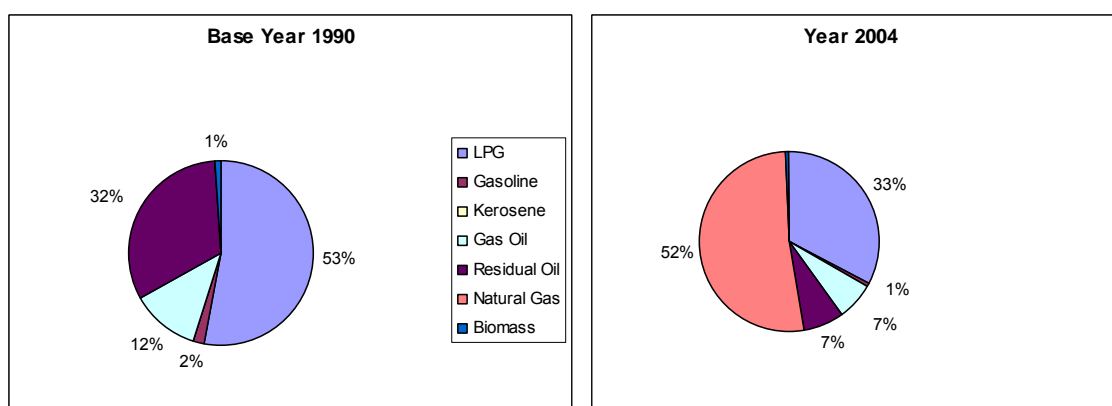


Table 3.66 – Low Heating Values/ Net Calorific Values (LHV/NCV) in other transformation industry

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

Table 3.67 – Fuel consumption in other transformation industry – Boilers and Furnaces (GJ)

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

Table 3.68 – Fuel consumption in other transformation industry – Static Engines (GJ)

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

Figure 3.43 – Total Energy Consumption in other transformation Industry between 1990 and 2004

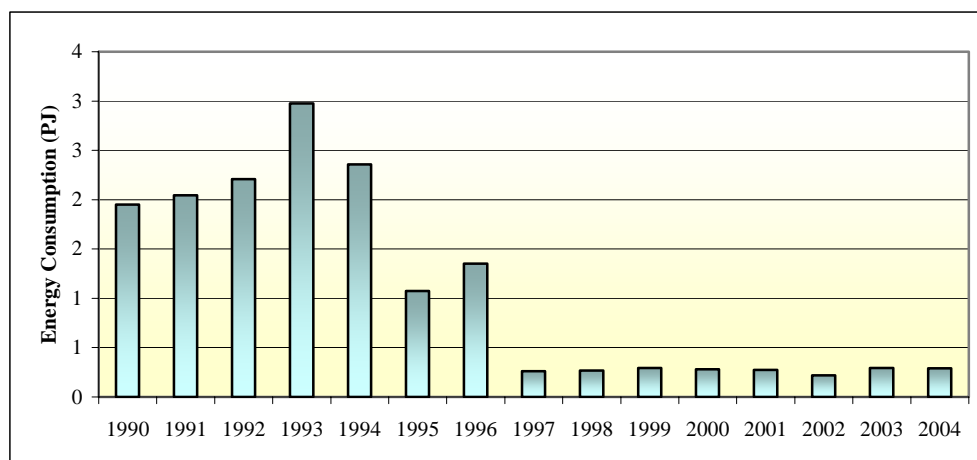


Figure 3.44 – Fuel consumption per fuel type in other transformation industry in 1990 and 2004

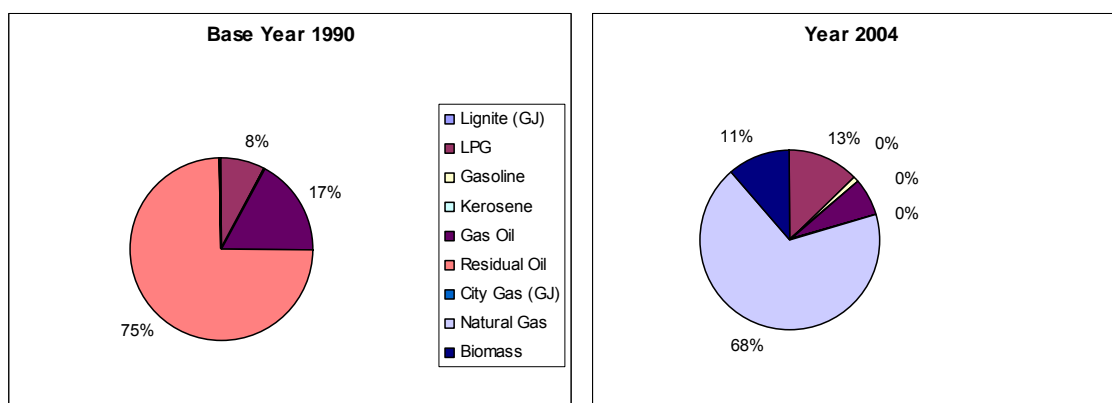


Table 3.69 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the extractive industry

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

Table 3.70 – Fuel consumption in the extractive industry – Boilers and Furnaces

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

Table 3.71– Fuel consumption in the extractive industry – Static Engines

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

Figure 3.45 – Total Energy Consumption in the Extractive Industry between 1990 and 2004

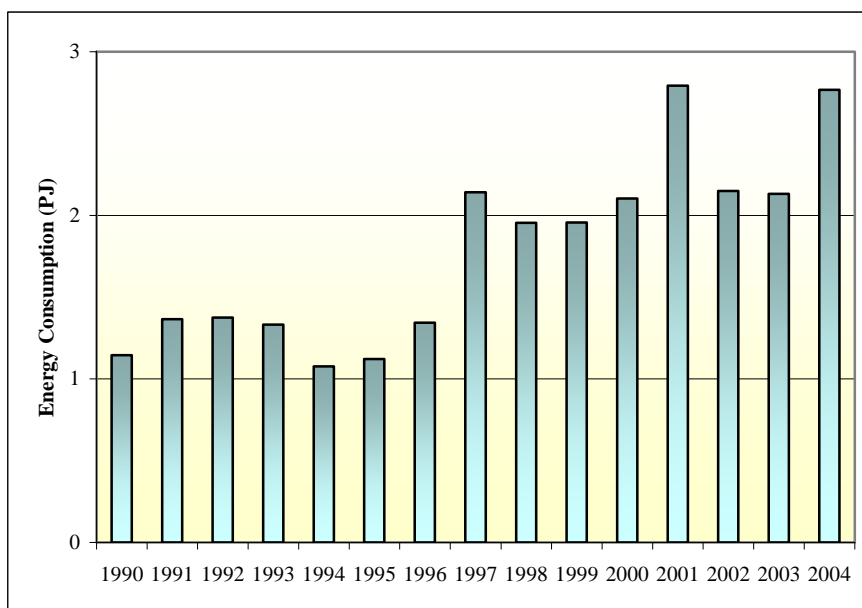


Figure 3.46– Fuel consumption per fuel type in the extractive industry in 1990 and 2004

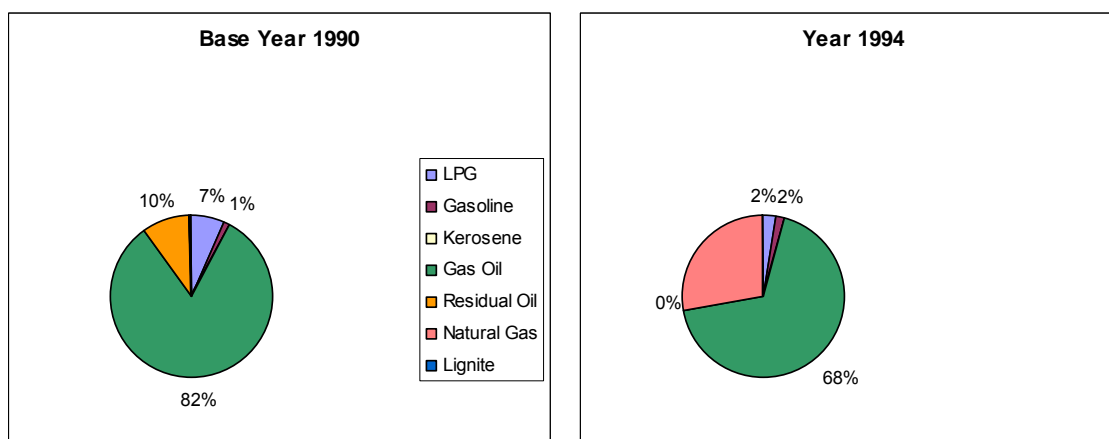


Table 3.72 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Construction and Building Industry

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

Table 3.73 – Fuel consumption in the Construction and Building Industry (GJ)

Year	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas
1990	233 005	28 161	6 855	5 961 423	671 304	0
1991	206 098	54 264	333	6 751 708	884 706	0
1992	264 421	168 067	2 106	6 463 826	876 008	0
1993	462 221	217 517	2 772	6 589 927	1 775 969	0
1994	696 370	363 631	1 179	7 154 205	1 412 975	0
1995	912 385	455 546	640	7 705 986	1 763 816	0
1996	1 066 771	682 700	177	7 929 141	1 353 841	0
1997	646 260	380 360	1 796	8 255 251	1 892 148	0
1998	574 093	355 521	11 044	8 251 931	2 008 223	610
1999	578 294	301 584	228	8 116 581	1 429 069	2 718
2000	560 826	73 801	130	7 673 442	1 473 144	7 637
2001	843 368	396 140	389	9 525 562	1 637 796	286 481
2002	547 284	61 620	279	9 463 552	1 856 172	570 473
2003	495 233	57 695	104	8 773 984	1 295 338	823 671
2004	496 078	55 810	93	10 191 948	1 572 038	257 023

Figure 3.47 – Total Energy Consumption in the Construction and Building Industry between 1990 and 2004

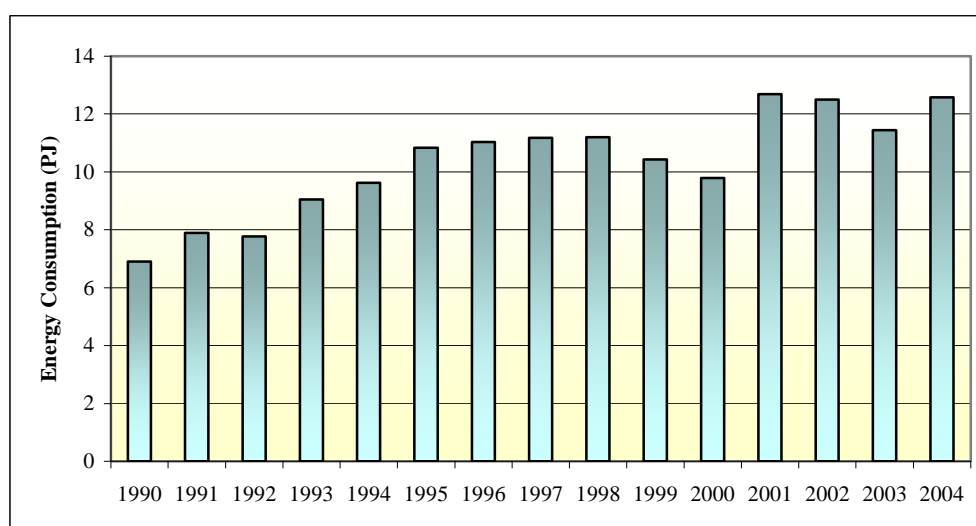
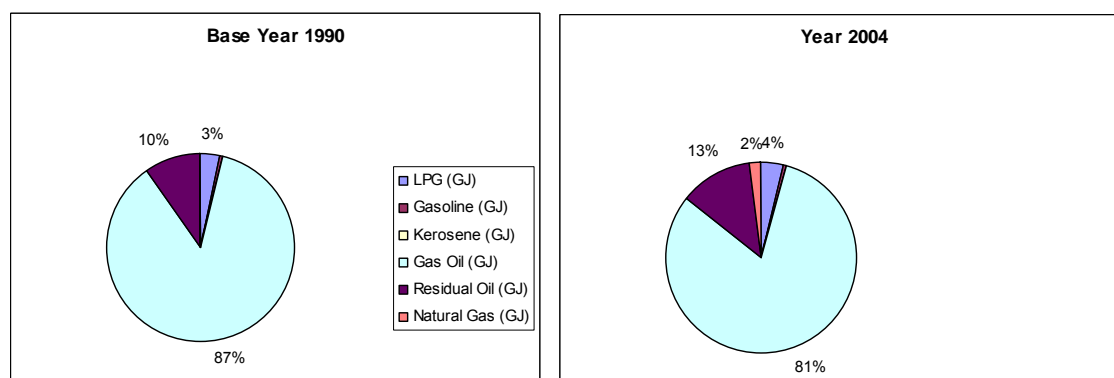


Figure 3.48 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2004



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.

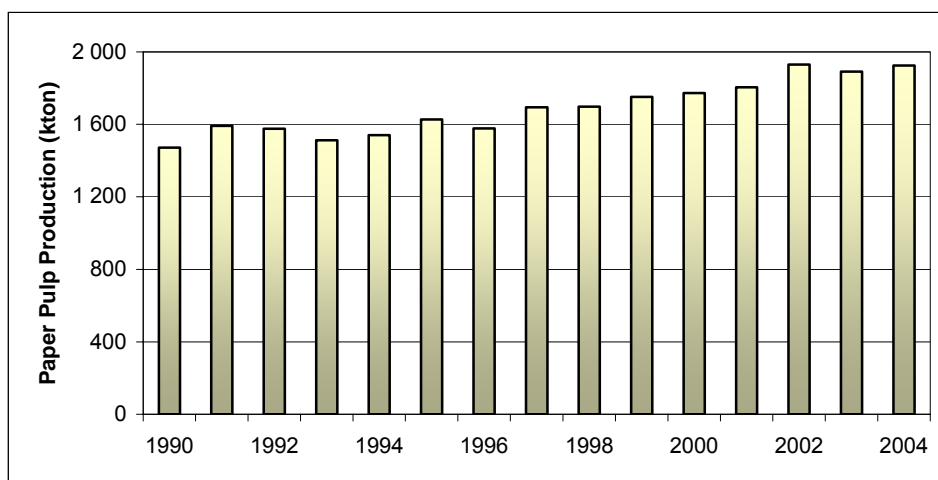
Total production of paper pulp is reported in Table 3.74. Production data for Kraft paper pulp from year 1990 to year 2000 was made available to IA directly from the six operating units, while data for 2001 till 2002 for the same units and the total time series of paper pulp by the acid sulphide process is from CELPA.

Table 3.74 – Total Paper Pulp Production (Kraft and sulphide paper pulp)

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

Year	1997	1998	1999	2000	2001	2002	2003	2004
Pulp Production (kton)	1 694	1 698	1 752	1 772	1 805	1 929	1 890	1 925

Figure 3.49 – Total paper pulp production: Kraft and sulphide paper pulp (1990-2004)



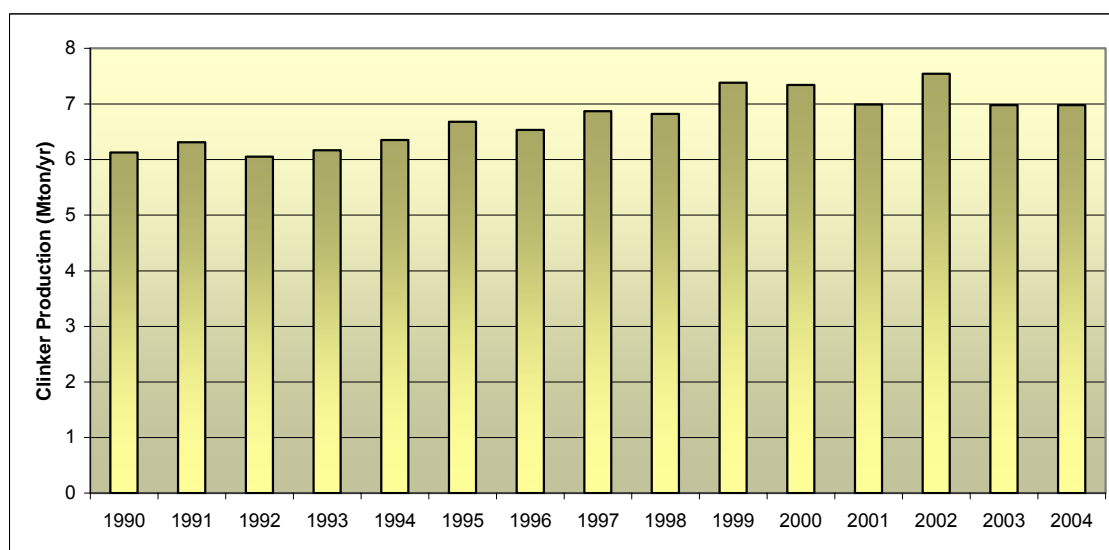
Production of clinker, presented in Table 3.75 and in Figure 3.50, results from data collected directly from the industrial plants.

Table 3.75 – Total clinker production (1990-2004)

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

Year	1997	1998	1999	2000	2001	2002	2003	2004
Clinker (kton)	6 870	6 821	7 380	7 343	6 992	7 544	6 980	6 980

Figure 3.50 – Total clinker production (1990-2004)



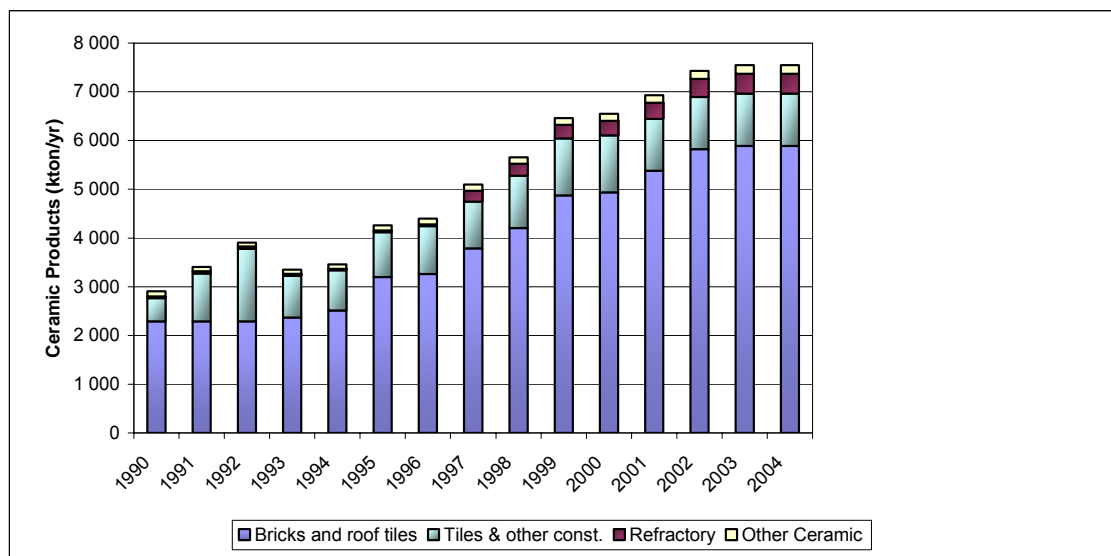
Data on annual manufacturing of ceramic products is available from 1990 to 2000 from INE statistical database. Values from 2001 to 2004 are provisional forecasts made by IA, in some cases relying also on data from the EU-ETS for 2002. Time series for total production may be seen in Table 3.76 and Figure 3.51, according to type of ceramic.

Table 3.76 – Ceramic Production according to type of ceramic (kton)

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

	1997	1998	1999	2000	2001	2002	2003	2004
Bricks & roof tiles	3 786	4 203	4 874	4 932	5 376	5 820	5 887	5 887
Tiles & other const	958	1 077	1 170	1 170	1 069	1 072	1 076	1 076
Refractory	225	241	275	300	329	368	406	406
Other ceramic	124	135	141	143	158	167	176	176

Figure 3.51 – Ceramic Production according to type of ceramic



The Production values for container glass, lead crystal glass and other glass are presented in Figure 3.52 and in Table 3.77, 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 3.52 - Glass production by glass type (excluding flat glass production)

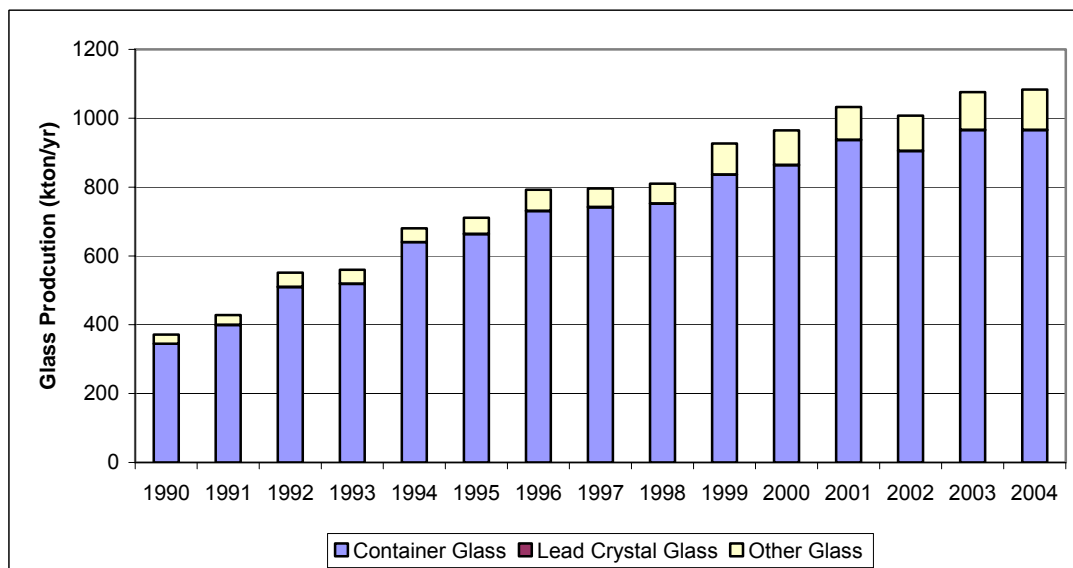


Table 3.77- Glass production by glass type (kton/yr) excluding flat glass production

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

Type of Glass	1997	1998	1999	2000	2001	2002	2003	2004
Container Glass	741	751	835	864	936	904	965	965
Lead Crystal Glass	0.9	0.8	0.9	1.0	1.1	1.2	1.2	1.3
Other Glass	54	58	90	100	95	102	109	116

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

3.2.B.3 EMISSION FACTORS

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

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

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

Table 3.78 to Table 3.83 present the emission factors that were used as default national emission factors in all cases where no specific emission factors may be used, either because there are specific methodologies and emission factors available in the bibliography or either because country specific emission factors were developed from national studies and monitoring data. They are presented in the subsequent tables.

Table 3.78 – Default emissions factors of Greenhouse gases for combustion equipments in Manufacturing Industry

Equipment	Fuel	Code	CO ₂ ⁽ⁱ⁾ (kg/GJ)	Oxidation factor ⁽ⁱ⁾ (ratio)	% C fossil	CH ₄ ⁽ⁱⁱ⁾ (g/GJ)	N ₂ O ⁽ⁱ⁾ (g/GJ)
Boilers	Steam Coal	S 102	96.1	0.980	100	2.4	⁽ⁱⁱ⁾ 0.7
	Brown Coal/Lignite	S 105	101.2	0.980	100	2.4	⁽ⁱⁱ⁾ 0.7
	Coke from Coal	S 107	⁽ⁱⁱ⁾ 102.0	0.980	100	2.4	⁽ⁱⁱ⁾ 0.7
	LPG	L 303	63.1	0.995	100	1.4	1.4
	City Gas	G 308	⁽ⁱⁱ⁾ 60.0	0.995	100	2.4	0.7
	Coke Oven Gas	S 304	⁽ⁱⁱ⁾ 46.5	0.995	100	2.4	0.7
	Blast Furnace Gas	S 305	⁽ⁱⁱ⁾ 102.5	0.995	100	2.4	0.7
	Fuel Gas, Hydrogen	G 399	63.1	0.995	100	1.4	1.4
	Biomass Wood	B 111	109.6	1.000	0	⁽ⁱ⁾ 15.0	⁽ⁱⁱ⁾ 4.3
	Kerosene	L 206	71.9	0.990	100	0.1	0.6
	Diesel Oil	L 204	74.1	0.990	100	0.1	0.6
	Residual Oil	L 203	77.4	0.990	100	2.9	0.6
	Natural Gas	G 301	56.1	0.995	100	1.4	1.4
	Gasoline	L 208	69.3	0.990	100	9.9	0.6
	Gas Oil	L 204	74.1	0.990	100	9.9	0.6
Static Engines	Biogas	B 309	⁽ⁱⁱ⁾ 52.0	1.000	0	1.4	1.4

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

Table 3.79 – Default emissions factors of Indirect precursor gases for combustion equipments in the Manufacturing Industry

Equipment	Fuel	Code	NO _x (g/GJ)	NM VOC (g/GJ)	CO (g/GJ)
Boilers	Steam Coal	S 102	170	190.0	150
	Brown Coal/Lignite	S 105	200	190.0	160
	Coke from Coal	S 107	300	12.0	160
	LPG	L 303	90	2.5	17
	Gasoline	L 208	60	1.0	12
	City Gas	G 308	140	25.0	160
	Coke Oven Gas	S 304	90	2.5	160
	Blast Furnace Gas	S 305	55	0.0	160
	Fuel Gas, Hydrogen	G 399	90	2.5	17
	Biomass Wood	B 111	70	150.0	500
	Kerosene	L 206	60	1.0	12
	Diesel Oil	L 204	60	1.0	12
	Residual Fuel Oil	L 203	160	3.0	15
	Natural Gas	G 301	67	5.0	13
	Gasoline	L 208	1 300	100.0	12
	Gas Oil	L 204	1 100	100.0	12
Static Engines	Biogas	L 204	90	2.5	17

Table 3.80 – Default sulphur content of fuels for combustion equipments in the Manufacturing Industry (1990-1996)

Fuel	NAPFUE	Unit	1990	1991	1992	1993	1994	1995	1996
Steam Coal	S 102	%	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Brown Coal/Lignite	S 105	%	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Coke from Coal	S 107	%	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LPG	L 303	%	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Gasoline	L 208	%	0.100	0.100	0.100	0.100	0.100	0.100	0.050
City Gas	G 308	^g S/Nm3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coke Oven Gas	S 304	^g S/Nm3	7.05	7.05	7.05	7.05	7.05	7.05	7.05
Blast Furnace Gas	S 305	^g S/Nm3	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Fuel Gas, Hydrogen	G 399	%	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Biomass Wood	B 111	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogas	B 309	%	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Kerosene	L 206	%	0.15	0.03	0.04	0.05	0.03	0.03	0.03
Diesel Oil	L 204	%	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Residual Fuel Oil	L 203	%	2.84	2.30	2.50	2.23	2.26	2.26	2.26
Natural Gas	G 301	^g S/Nm3	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3.81 - Default sulphur content of fuels for combustion equipments in the Manufacturing Industry (1997-2004)

Fuel	NAPFUE	1997	1998	1999	2000	2001	2002	2003	2004
Steam Coal	S 102	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Brown Coal/Lignite	S 105	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Coke from Coal	S 107	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LPG	L 303	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Gasoline	L 208	0.050	0.050	0.050	0.050	0.015	0.015	0.015	0.015
City Gas	G 308	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coke Oven Gas	S 304	7.05	7.05	7.05	7.05	7.05	7.05	7.05	7.05
Blast Furnace Gas	S 305	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Fuel Gas, Hydrogen	G 399	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Biomass Wood	B 111	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogas	B 309	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Kerosene	L 206	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Diesel Oil	L 204	0.30	0.30	0.30	0.25	0.20	0.20	0.20	0.20
Residual Fuel Oil	L 203	2.26	2.26	2.26	2.26	2.26	2.26	1.00	1.00
Natural Gas	G 301	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3.82 – Default emissions factors of Particulate Matter for combustion equipments in the Manufacturing Industry

Equipment	Fuel	Code	TSP (g/GJ)	PM ₁₀ (%TSP)	PM _{2.5} (%TSP)	PM _{1.0} (%TSP)
Boilers	Steam Coal	S 102	68.3	20	20	20
	Brown Coal/Lignite	S 105	1 165.9	35	10	6
	Coke from Coal	S 107	68.3	20	20	20
	LPG	L 303	3.0	100	100	100
	City Gas	G 308	0.8	100	100	100
	Coke Oven Gas	S 304	0.8	100	100	100
	Blast Furnace Gas	S 305	0.8	100	100	100
	Fuel Gas, Hydrogen	G 399	0.8	100	100	100
	Biomass Wood	B 111	172.0	90	76	67
	Kerosene	L 206	6.5	50	12	8
	Diesel Oil	L 204	6.5	50	12	8
	Residual Fuel Oil ^(a)	L 203	53.0	86	56	36
	Natural Gas	G 301	0.8	100	100	100
Static Engines	Gasoline	L 208	43.0	100	100	100
	Gas Oil	L 204	133.3	100	100	100
	Biogas	B 309	6.9	100	100	100

(a) Decreasing function of sulphur content (USEPA)

Table 3.83 – Default emissions factors of Heavy Metals for combustion equipments in Manufacturing Industry

Equipment	Fuel	NAPFUE	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
			g/ton							
Boilers	Steam Coal	S 102	5.2E-02	1.7E-01	4.5E-01	3.6E-01	4.7E-01	7.2E-01	2.7E-01	1.3E+00
	Brown Coal/Lignite	S 105	4.0E-03	6.0E-02	4.0E-02	3.0E-02	2.0E-02	4.0E-02	0.0E+00	1.0E-01
	Coke from Coal	S 107	5.2E-02	1.7E-01	4.5E-01	3.6E-01	4.7E-01	7.2E-01	2.7E-01	1.3E+00
	LPG	L 303	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	City Gas	G 308	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Coke Oven Gas	S 304	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Blast Furnace Gas	S 305	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Fuel Gas, Hydrogen	G 399	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Biomass Wood	B 111	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
	Kerosene	L 206	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Diesel Oil	L 204	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
	Residual Fuel Oil	L 203	6.8E-01	5.1E-01	5.6E-01	1.7E+00	7.4E-01	2.7E+01	6.8E-02	1.9E+00
	Natural Gas	G 301	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Static Engines	Gasoline	L 208	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Gas Oil	L 204	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
	Biogas	B 309	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04

The following emission factors were used for specific industrial sectors.

Table 3.84 –Emission factors of Greenhouse gases in the extractive industry

Equipment	Fuel		NAPFUE	CO ₂ (kg/GJ)	Oxidation factor (ratio)	% C fossil	CH ₄ (g/GJ)	N ₂ O (g/GJ)
Boilers	LPG	L	303	62.8	0.995	100	1.5	1.4
	Gasoline	L	208	68.6	0.990	100	0.1	0.6
	Kerosene	L	206	71.1	0.990	100	0.6	0.6
	Diesel Oil	L	204	73.3	0.990	100	0.6	0.6
	Residual Oil	L	203	76.6	0.990	100	1.4	0.6
	Natural Gas	G	301	55.8	0.995	100	1.4	1.4
	Lignite	S	105	99.2	0.980	100	2.4	0.7
Static Engines	Gasoline	L	208	68.6	0.990	100	60	0.6
	Gas Oil	L	204	73.3	0.990	100	60	0.6

Table 3.85 – Emission factors of Indirect precursor gases in the extractive industry

Equipment	Fuel		NAPFUE	NO _x (g/GJ)	NMVOC (g/GJ)	CO (g/GJ)
Boilers	LPG	L	303	65	2.5	50
	Gasoline	L	208	60	1	12
	Kerosene	L	206	60	1	20
	Diesel Oil	L	204	60	1	20
	Residual Oil	L	203	160	3	20
	Natural Gas	G	301	67	5	13
	Lignite	S	105	200	190	160
Static Engines	Gasoline	L	208	1300	100	20
	Gas Oil	L	204	1100	100	20

Table 3.86 – Sulphur content in fuels used in the extractive industry (%S)

Year	LPG	Lead Gasoline	Unlead Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Lignite
1990	0.0016	0.10	0.100	0.15	0.30	2.84	0.0007	0.65
1991	0.0016	0.10	0.100	0.15	0.30	2.30	0.0007	0.65
1992	0.0016	0.10	0.100	0.15	0.30	2.50	0.0007	0.65
1993	0.0016	0.10	0.100	0.15	0.30	2.23	0.0007	0.65
1994	0.0016	0.10	0.100	0.15	0.30	2.26	0.0007	0.65
1995	0.0016	0.10	0.100	0.15	0.30	2.26	0.0007	0.65
1996	0.0016	0.10	0.050	0.15	0.30	2.26	0.0007	0.65
1997	0.0016	0.10	0.050	0.15	0.30	2.26	0.0007	0.65
1998	0.0016	0.10	0.050	0.15	0.30	2.26	0.0007	0.65
1999	0.0016	0.10	0.050	0.15	0.30	2.26	0.0007	0.65
2000	0.0016	0.10	0.050	0.15	0.25	2.26	0.0007	0.65
2001	0.0016	0.02	0.015	0.15	0.20	2.26	0.0007	0.65
2002	0.0016	0.02	0.015	0.15	0.20	2.26	0.0007	0.65
2003	0.0016	0.02	0.015	0.15	0.20	1.00	0.0007	0.65
2004	0.0016	0.02	0.015	0.15	0.20	1.00	0.0007	0.65

Table 3.87 – Emission factors of Particulate Matter gases in the extractive industry

Equipment	Fuel		Code	TSP (g/GJ)	PM ₁₀ (% TSP)	PM _{2.5} (% TSP)	PM _{1.0} (% TSP)
Boilers	LPG	L	303	3	100	100	100
	Gasoline	L	208	43	100	100	100
	Kerosene	L	206	7	50	12	8
	Gas Oil	L	204	6.5-133.3	50	12	8
	Residual Oil	L	203	53.0-88.9	86	56	36
	Natural Gas	G	301	1	100	100	100
	Lignite	S	105	1 166	35	10	6
Static Engines	Gasoline	L	208	43	100	100	100
	Gas Oil	L	204	133	100	100	100

Table 3.88 – Emission factors of Heavy Metals in the extractive industry

Equipment	Fuel		Code	Cd	Hg	Ar	Cr	Cu	Ni	Se	Zn
				g/ton							
Boilers	LPG	L	303	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Gasoline	L	208	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Kerosene	L	206	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
	Gas Oil	L	204	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
	Residual Oil	L	203	6.8E-01	5.1E-01	5.6E-01	1.7E+00	7.4E-01	2.7E+01	6.8E-02	1.9E+00
	Natural Gas	G	301	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Lignite	S	105	4.0E-03	6.0E-02	4.0E-02	3.0E-02	2.0E-02	4.0E-02	0.0E+00	1.0E-01
Static Engines	Gasoline	L	208	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Gas Oil	L	204	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01

Table 3.89 – Emission factors for Greenhouse gases in the building and construction industry

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

Table 3.90 – Emission factors for Indirect Precursor gases in the building and construction industry

Fuel		NAPFUE	NO _x g/GJ	NMVOC g/GJ	CO g/GJ
Residual Oil	L	203	160	3	20
Gas Oil	L	204	1 100	51	20
Kerosene	L	206	60	51	20
Motor Gasoline	L	208	1 300	100	20
LPG	L	303	1 200	3	50
Natural Gas	G	301	1 200	100	20

Table 3.91 – Sulphur content in the fuels used in the building and construction industry (%S)

Year	LPG	Motor Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas
1990	0.0016	0.10	0.15	0.30	2.84	0.0007
1991	0.0016	0.10	0.15	0.30	2.60	0.0007
1992	0.0016	0.10	0.15	0.30	2.60	0.0007
1993	0.0016	0.10	0.15	0.30	2.60	0.0007
1994	0.0016	0.10	0.15	0.30	2.60	0.0007
1995	0.0016	0.10	0.15	0.20	2.60	0.0007
1996	0.0016	0.10	0.15	0.05	2.60	0.0007
1997	0.0016	0.10	0.15	0.05	2.60	0.0007
1998	0.0016	0.10	0.15	0.05	2.60	0.0007
1999	0.0016	0.10	0.15	0.05	2.60	0.0007
2000	0.0016	0.10	0.15	0.05	2.60	0.0007
2001	0.0016	0.02	0.15	0.05	2.60	0.0007
2002	0.0016	0.02	0.15	0.04	2.60	0.0007
2003	0.0016	0.02	0.15	0.04	1.00	0.0007
2004	0.0016	0.02	0.15	0.04	1.00	0.0007

Table 3.92 – Emission factors for Particulate Matter in the building and construction industry

NAPFUE	Fuel		TSP g/GJ	PM ₁₀ (% TSP)	PM _{2.5} (% TSP)	PM _{1.0} (% TSP)
Residual Oil	L	203	53.0	62	23	14
Gas Oil	L	204	6.5	55	42	37
Kerosene	L	206	6.5	55	42	37
Motor Gasoline	L	208	43.0	100	100	100
LPG	L	303	2.5	100	100	100
Natural Gas	G	301	0.8	100	100	100

Table 3.93 – Emission factors for Heavy Metals in the building and construction industry

Fuel		NAPFUE	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
			g/ton								
Residual Oil	L	203	1.30E+00	4.02E-04	5.07E-01	1.21E-03	4.02E-03	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Gas Oil	L	204	2.00E-01	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
Kerosene	L	206	2.00E-01	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
Motor Gasoline	L	208	5.26E+02	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
LPG	L	303	0.00E+00	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Natural Gas	G	301	0.00E+00	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04

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

Table 3.94 – Emission factors for use in LPS units in the Iron and steel Industry: Greenhouse Gases from combustion

Equipment	Fuel		NAPFUE	CO ₂			CH ₄ (g/GJ)	N ₂ O (g/GJ)
				kg/GJ	Oxidation Factor (ratio)	% C fossil		
Coquerie	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
Sintering	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
Blast Furnace Cowpers	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
	Blast furnace gas	S	305	296.23	0.995	100	2.5	1.4
Rolling mills	Residual oil	L	203	76.59	0.990	100	3.0	0.6
	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
Thermo-Electric Power plant	Coke oven gas	S	304	40.79	0.995	100	2.5	1.4
	Blast furnace gas	S	305	296.23	0.995	100	2.5	1.4
	Residual oil	L	203	76.59	0.990	100	3.0	0.6
	Tar	L	299	79.86	0.990	100	3.0	0.6
Heat power plant	LPG	L	303	62.75	0.995	100	4.0	1.4
	Tar	L	299	79.86	0.990	100	3.0	0.6
	Waste oils	O	115	76.59	0.990	100	3.0	0.6
Lime kiln	Residual Oil	L	203	76.59	0.990	100	3.0	0

Table 3.95 – Emission factors (Energy Approach) for use in LPS units in the Iron and steel Industry: Indirect Precursors from combustion

Equipment	Fuel		NAPFUE	NO _x g/GJ	%S		NMVOC g/GJ	CO g/GJ
					%	Units		
Coquerie	Coke oven gas	S	304	120	7.05	g S/Nm3	2.5	17
Sintering	Coke oven gas	S	304	PA	7.05	g S/Nm3	PA	PA
Blast Furnace Cowpers	Coke oven gas	S	304	120	7.05	g S/Nm3	2.5	17
	Blast furnace gas	S	305	70	0.045	g S/Nm3	2.5	17
Rolling mills	Residual oil	L	203	190	3.5	% S	3	15
	Coke oven gas	S	304	120	7.05	g S/Nm3	2.5	17
Thermo Electric Power plant	Coke oven gas	S	304	120	7.05	g S/Nm3	2.5	17
	Blast furnace gas	S	305	70	0.045	g S/Nm3	2.5	17
	Residual oil (3.5%)	L	203	190	3.5	% S	3	15
	Residual oil (1%)	L	203	190	1	% S	3	15
	Tar	L	299	300	0.6	% S	3	15
Heat power plant	LPG	L	303	160	0.005	% S	4	17
	Tar	L	299	300	0.6	% S	3	15
	Waste Oils	O	115	190	0	% S	3	15
Lime kiln	Residual Oil	L	203	PA	3.5	% S	3	PA

Note: PA = Process Approach

Table 3.96 – Emission factors (Production Approach) for use in LPS units in the Iron and steel Industry: Indirect Precursors from combustion

Equipment	Fuel		NAPFUE	NO _x (kg/ton)	SO _x (kg/ton)	NMVOC (kg/ton)	CO (kg/ton)
Sintering	Coke oven gas	S	304	0.5	1.0	0.10	30
Lime kiln	Residual Oil	L	203	0.1	0.42	-	2

Table 3.97 – Emission factors (Energy Approach) for use in LPS units in the Iron and steel Industry: Particulate Matter from combustion

Equipment	Fuel		NAPFUE	TSP g/GJ	PM ₁₀ (% TSP)	PM _{2.5} (% TSP)	PM _{1.0} (% TSP)
Cokery	Coke oven gas	S	304	3	96	94	77
Sintering	Coke oven gas	S	304	PA	15	7	4
Blast Furnace Cowpers	Coke oven gas	S	304	3	100	100	100
	Blast furnace gas	S	305	3	100	100	100
Thermo Electric Power plant	Coke oven gas	S	304	3	100	100	100
	Blast furnace gas	S	305	3	100	100	100
	Residual oil (3.5%)	L	203	108	86	56	36
	Residual oil (1%)	L	203	37.5	86	56	36
	Tar	L	299	108	86	56	36
Heat power plant	LPG	L	303	3	100	100	100
	Tar	L	299	108	86	56	1
	Waste Oils	O	115	108	86	56	36
Lime kiln	Residual Oil	L	203	PA	100	100	100

Note: PA = Process Approach

Table 3.98 – Emission factors (Production Approach) for use in LPS units in the Iron and steel Industry: Particulate Matter from combustion

Equipment	Fuel		NAPFUE	TSP (kg/ton)	PM ₁₀ (% TSP)	PM _{2.5} (% TSP)	PM _{1.0} (% TSP)
Sintering	Coke oven gas	S	304	3.9	15	6.5	4
Lime kiln	Residual Oil	L	203	6.8	100	100	100

Table 3.99 – Emission factors for use in LPS units in the Chemical Industry: Greenhouse Gases from combustion

Equipment	Fuel		NAPFUE	CO ₂ (kg/GJ)	Oxidation Factor (ratio)	% C fossil	CH ₄ (g/GJ)	N ₂ O (g/GJ)
Boilers	Residual Fuel Oil	L	203	77.37	0.990	100	3	0.6
	Pyrolysis Fuel Oil	L	203	77.37	0.990	100	3	0.6
	Fuel Gas	L	307	50.05	0.995	100	2.5	1.4
Furnaces	Fuel Gas	L	307	50.05	0.995	100	2.5	1.4
	Propane	L	303	63.07	0.995	100	2.5	1.4
Static Engines	Residual Fuel Oil	L	203	77.37	0.990	100	60	0.6
	Diesel Oil	L	204	74.07	0.990	100	60	0.6
Flares	Flare Gas	L	307	59.2-65.6	0.995	100	-	-

Table 3.100 – Emission factors for use in LPS units in the Chemical Industry: Indirect Precursor Gases from combustion

Equipment	Fuel		Code	NO _x (g/GJ)	NM VOC (g/GJ)	CO (g/GJ)
Boilers	Residual Fuel Oil	L	203	140-170	3.0	15
	Pyrolysis Fuel Oil	L	203	170	3.0	15
	Fuel Gas	L	307	147	2.5	13
Furnaces	Fuel Gas	L	307	88	2.5	13
	Propane	L	303	88	2.5	13
Static Engines	Residual Fuel Oil	L	203	900	60	15
	Diesel Oil	L	204	900	60	12

Table 3.101 – Emission factors for use in LPS units in the Chemical Industry: Sulphur content of fuels

Year	Residual Oil	Pyrolysis Fuel Oil	Fuel Gas	Gas Oil	Propane
1990	2.5	0.35	0.0005	0.30	0.0005
1991	2.5	0.35	0.0005	0.30	0.0005
1992	2.5	0.35	0.0005	0.30	0.0005
1993	3.0	0.35	0.0005	0.30	0.0005
1994	3.0	0.35	0.0005	0.30	0.0005
1995	3.0	0.35	0.0005	0.30	0.0005
1996	3.2	0.35	0.0005	0.30	0.0005
1997	3.5	0.35	0.0005	0.30	0.0005
1998	2.8	0.35	0.0005	0.30	0.0005
1999	1.9-2.8	0.35	0.0005	0.30	0.0005
2000	1.6	0.35	0.0005	0.25	0.0005
2001	1.8	0.35	0.0005	0.20	0.0005
2002	1.7	0.35	0.0005	0.20	0.0005
2003	1.1-1.7	0.35	0.0005	0.20	0.0005
2004	1.1-1.7	0.35	0.0005	0.20	0.0005

Table 3.102 – Emission factors for use in LPS units in the Chemical Industry: Particulate Matter from combustion

Equipment	Fuel		Code	TSP (g/GJ)	PM ₁₀ (% TSP)	PM _{2.5} (% TSP)	PM _{1.0} (% TSP)
Boilers	Residual Fuel Oil	L	203	41-105 (a)	86	56	36
	Pyrolysis Fuel Oil	L	203	19-20 (a)	86	56	36
	Fuel Gas	L	307	3	100	100	100
Furnaces	Fuel Gas	L	307	3	100	100	100
	Propane	L	303	3	100	100	100
Static Engines	Residual Fuel Oil	L	203	30	82	77	77
	Diesel Oil	L	204	133	100	100	100
Flare	Flare Gas	L	204	0	0	100	100

(a) Function of sulphur content and year (USEPA), as presented in next table

Table 3.103 – Emission factors for use in LPS units in the Chemical Industry: Total Particulate Matter as function of year

Year	Boilers	
	Residual Oil (g/GJ)	Pyrolysis Fuel Oil (g/GJ)
1990	77.7	19.2
1991	77.7	19.2
1992	77.7	19.2
1993	91.4	19.2
1994	91.4	19.2
1995	91.4	19.2
1996	96.1	19.2
1997	105.2	19.2
1998	85.1	19.2
1999	62.9-87.4	19.6
2000	54.4	19.6
2001	60.0	19.2
2002	57.2	19.2
2003	41.2	19.2
2004	41.2	19.2

Table 3.104 – Emission factors for use in LPS units in the Chemical Industry: Heavy Metals

Fuel		Code	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
		g/ton								
Residual Oil	L	203	6.84E-01	5.07E-01	5.56E-01	1.70E+00	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Gas Oil	L	204	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01

Table 3.105 – Emission factors used in LPS units in the Paper Pulp Industry: Greenhouse Gases from combustion

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

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

Table 3.106 – Emission factors used in LPS units in the Paper Pulp Industry: Indirect Gases from combustion

Equipment	Fuel	NO _x			NMVOC			CO
		Approach	EF	Unit	Approach	EF	Unit	g/GJ
Recovery Boilers	Residual Oil	EA	180 - 210	g/GJ	EA	3	g/GJ	15
	Black Liquor	PA	1.16	kg/ton pulp	PA	0.49	kg/ton pulp	15
	Bisulfite Liquor	PA	1.25	kg/ton pulp	PA	0.625	kg/ton pulp	15
Biomass Boilers	Bark/ Wood wastes	EA	200	g/GJ	EA	80	g/GJ	500
	Residual Oil	EA	180 - 210	g/GJ	EA	3	g/GJ	15
	Natural Gas	EA	67	g/GJ	EA	5	g/GJ	13
	LPG	EA	80	g/GJ	EA	2.5	g/GJ	15
Auxiliary Boilers	Residual Oil	EA	180 - 190	g/GJ	EA	3	g/GJ	15
Lime Kiln	Residual Oil	PA	0.5	kg/ton pulp	PA	0.065	kg/ton pulp	15
	Gasified Biomass							500
	Tall-Oil							15
	NCG							15
Flares	LPG	EA	80	g/GJ	EA	2.5	g/GJ	15

Table 3.107 – Emission factors used in LPS units in the Paper Pulp Industry: Sulphur Oxides (SO_x) emissions

Equipment	Fuel	SO _x		
		Approach	EF	Unit
Recovery Boilers	Residual Oil	EA	1-3.5	%
	Black Liquor	PA	3.5	kg/ton pulp
	Bisulfite Liquor	PA	12.5	
Biomass Boilers	Bark/ Wood wastes	EA	0	%
	Residual Oil	EA	1-3.5	
	Natural Gas	EA	0	
	LPG	EA	0	
Auxiliary Boilers	Residual Oil	EA	1-3.5	
Lime Kiln	Residual Oil	PA	0.15	kg/ton pulp
	Gasified Biomass	PA	0.15	
	Tall-Oil	PA	0.15	
	NCG	PA	0.15	
Flares	LPG	EA	0	g/GJ

Table 3.108 – Emission factors used in LPS units in the Paper Pulp Industry: Particulate Matter

Equipment	Fuel		NAPFUE	TSP			PM ₁₀	PM _{2.5}	PM _{1.0}
				Approach	EF	Unit	(%TSP)		
Recovery Boilers	Residual Oil	L	203	PA	1	kg/ton pulp	93.5	83.5	45.3
	Black Liquor	B	215	PA					
	Bisulfite Liquor	B	215	PA	2		100	100	100
Biomass Boilers	Bark & wood wastes	B	111	EA	23-172*	g/GJ	74-90	65-76	65-67
	Residual Oil	L	203	EA	108		86	56	36
	Natural Gas	G	301	EA	0.8		100	100	100
	LPG	L	303	EA	3		100	100	100
Auxiliary Boilers	Residual Oil	L	203	EA	108		86	56	36
Lime Kiln	-	L	203	PA	0.25-28*	kg/ton pulp	16.8	10.5	7.1

Table 3.109 – Emission factors used in LPS units in the Paper Pulp Industry: Heavy Metals

Fuel	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
	g/GJ								
Residual Oil	9.31E-01	6.84E-01	5.07E-01	5.56E-01	1.70E+00	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Black Liquor	5.00E-02	1.47E-02	1.00E-01	4.27E-02	5.00E-04	1.00E-01	6.03E-03	2.30E-02	2.00E+00
Bisulfite Liquor	5.00E-02	1.47E-02	1.00E-01	4.27E-02	5.00E-04	1.00E-01	6.03E-03	2.30E-02	2.00E+00
Bark/Wood	5.00E-02	1.47E-02	1.00E-01	4.27E-02	5.00E-04	1.00E-01	6.03E-03	2.30E-02	2.00E+00
Natural Gas	8.00E-06	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
LPG	8.00E-06	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04

For the cement source, sector emissions were estimated using either activity data as energy consumption (energy approach) or either cement produced (production approach), although both represent similar emissions in cement kiln. Emission factors are presented in Table 3.110 to Table 3.114. Most emission factors result from plant specific emission factors developed from monitoring at each installation, as reported to EPER exercise.

Table 3.110 – Emission Factors for clinker production units (LPS) using the Energy Approach
(a)

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

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

Table 3.111 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Greenhouse Gases

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

Table 3.112 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Indirect Precursors and SO_x

Parameter	EF (kg/ton clinker)
SO _x	0.05 - 4.10
NO _x	1.11 - 3.70
NMVOC	0.007 - 2.570
CO	0.06 - 1.80
NH ₃	0.005 - 1.041

Table 3.113 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Particulate Matter

Parameter	EF
TSP (kg/ton clinker)	0.014 - 0.309
PM ₁₀	100%
PM _{2.5}	100%
PM ₁	100%

Table 3.114 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Heavy Metals

Parameter	EF (kg/ton clinker)
Pb	3.0E-05 - 1.5E-03
Cd	1.1E-06 - 2.8E-03
Hg	1.9E-06 - 2.5E-05
As	2.2E-07 - 5.6E-04
Cr	1.5E-05 - 1.6E-03
Cu	2.8E-05 - 2.6E-03
Ni	3.6E-05 - 1.9E-03
Se	7.5E-05 - 1.0E-04
Zn	2.7E-05 - 8.8E-04

Table 3.115 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Greenhouse gases

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

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

Table 3.116 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Indirect Precursor gases and SO_x

	Fuel		NAPFUE	NO _x (kg/ton)	SO _x (kg/ton)	NM VOC (kg/ton)
Bricks and roof tiles ^(a)	LPG	L	303	0.45	1.50	0.03
	Residual Oil	L	203	0.45	1.13	0.03
	Natural Gas	G	301	0.45	1.50	0.03
	Biomass Wood	B	111	0.47	0.39	0.09
Tiles & other construction materials ^(a)	LPG	L	303	0.27	0.01	0.22
	Residual Oil	L	203	0.27	62.48	0.22
	Natural Gas	G	301	0.27	0.05	0.22
	Biomass Wood	B	111	0.27	0.00	0.22
Refractory ^(b)	LPG	L	303	0.87	3.80	0.03
	Residual Oil	L	203	0.87	3.80	0.03
	Natural Gas	G	301	0.87	3.80	0.03
	Biomass Wood	B	111	0.87	3.80	0.09
Other Ceramic ^(c)	LPG	L	303	0.27	0.01	0.22
	Residual Oil	L	203	0.27	62.48	0.22
	Natural Gas	G	301	0.27	0.05	0.22
	Biomass Wood	B	111	0.27	0.00	0.22

Source: (a) USEPA(1997); (b) USEPA(1995f); (c) USEPA (1996c)

Table 3.117 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Particulate Matter

	Fuel		Code	TSP (g/GJ)	PM ₁₀ (% TSP)	PM _{2.5} (% TSP)	PM _{1.0} (% TSP)
Bricks and roof tiles ^(a)	LPG	L	303	0.14	100	100	100
	Residual Oil	L	203	0.14	88	88	88
	Natural Gas	G	301	0.14	100	100	100
	Biomass Wood	B	111	0.13	62	62	62
Tiles & other construction materials ^(a)	LPG	L	303	11	27	27	27
	Residual Oil	L	203	11	27	27	27
	Natural Gas	G	301	11	27	27	27
	Biomass Wood	B	111	11	27	27	27
Refractory ^(b)	LPG	L	303	68	25	25	25
	Residual Oil	L	203	68	25	25	25
	Natural Gas	G	301	68	25	25	25
	Biomass Wood	B	111	68	25	25	25
Other Ceramic ^(c)	LPG	L	303	11	27	27	27
	Residual Oil	L	203	11	27	27	27
	Natural Gas	G	301	11	27	27	27
	Biomass Wood	B	111	11	27	27	27

Source: (a) USEPA(1997); (b) USEPA(1995f); (c) USEPA (1996c)

Table 3.118 – Emission Factors for glass production using the Production Approach: Greenhouse Gases

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

Source: CH₄ USEPA (1986); CO₂ EUTS dataTable 3.119 – Emission Factors for glass production using the Production Approach: SO_x and Indirect Precursor gases

Type of Glass	SO _x	NO _x	NMVOC	CO
	kg/ton glass			
Flat Glass	1.5	4	0.1	0.1
Container Glass	1.7	3.1	4.5	0.1
Lead Crystal Glass	2.8	4.3	4.7	0.1
Other Glass	2.8	4.3	4.7	0.1

Source: USEPA (1986)

Table 3.120 – Emission Factors for glass production using the Production Approach:
Particulate Matter

	TSP	PM10	PM2.5	PM1.0
Type of Glass	kg/ton glass			
Flat Glass	1	0.95	0.91	0.91
Container Glass	0.7	0.67	0.64	0.64
Lead Crystal Glass	8.4	7.98	7.64	7.64
Other Glass	8.4	7.98	7.64	7.64

Source: USEPA (1986)

Table 3.121 – Emission Factors for glass production using the Production Approach:
Heavy Metals

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Type of Glass	kg/ton glass produced								
Flat Glass	1.2E-02	1.5E-04	5.0E-05	1.2E-04	2.4E-03	6.0E-04	1.9E-03	1.8E-02	1.1E-02
Container Glass	1.2E-02	1.5E-04	5.0E-05	1.2E-04	2.4E-03	6.0E-04	1.9E-03	1.8E-02	1.1E-02
Lead Crystal	2.7E+00	1.5E-04	5.0E-05	1.4E-01	2.5E-03	5.0E-04	2.0E-03	2.0E-02	1.0E-02
Other Glass	1.0E-02	1.5E-04	5.0E-05	1.0E-04	2.5E-03	5.0E-04	2.0E-03	2.0E-02	1.0E-02

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

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

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

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

3.2.C Transport (CRF 1A3)

3.2.C.1 ROAD TRANSPORTATION

Overview

Road transportation is one of the most important emitter of greenhouse gases (GHG) such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). It is also a significant emission source of pollutants associated with trans-boundary, regional and local air problems, comprehending sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), non volatile organic compounds (NMVOC) and are indirectly responsible for the formation of ozone (O₃) in the lower troposphere. Substantial emissions of ammonia, particulate matter and heavy metals result also from this activity.

Exhaust emissions result from the combustion gases in the engine and include all the gases considered in the inventory. Exhaust emissions were estimated for each of the following vehicle classes²²:

Table 3.122 - Vehicle category split for road transportation

Vehicle	Vehicle Class
Passenger Cars (PC)	Gasoline <1.4 l;
	Gasoline 1.4 – 2.0 l;
	Gasoline >2.0 l;
	Diesel <2.0 l;
	Diesel >2.0 l;
	LPG;
Light Duty Vehicles <3.5 t (LDV)	Gasoline
	Diesel
Heavy Duty Vehicles (HDV)	Gasoline
	Diesel <7.5 t
	Diesel 7.5 – 16 t
	Diesel 16 – 32 t
	Diesel >32 t ²³
	Urban Buses
	Coaches
Mopeds & Motorcycles < 50cm ³	
Motorcycles	Two stroke >50 cm ³
	Four stroke 50 – 250 cm ³
	Four stroke 250 – 750 cm ³
	Four stroke >750 cm ³

For each vehicle class, exhaust emissions were further disaggregated by:

- Vehicle age or emission abatement technology;
- Fuel type: gasoline, diesel, liquefied petroleum gases (LPG) and compressed natural gas (CNG);

²² Categories from EMEP/CORINAIR Methodology (3 rd ed)

²³ Heavy duty vehicles with weight greater than 32 t were assumed not representative within national fleet.

- Driving mode: highway, rural and urban;

Road vehicles equipped with petrol-engines are also responsible for evaporative emissions which were also included in this source sector. They consist of losses of the most volatile organic components in the fuel and are associated with:

- Diurnal emissions, resulting from the thermal expansion of the air/fuel vapour volume inside the gasoline tank as consequence of diurnal variation in ambient temperature;
- Running losses, resulting of vapour outflow from the gasoline tank but occurring during vehicle operation, and as result of the combined effect of high air temperature and the heat from engine and exhaust system;
- Hot soak emissions, occurring when the engine is turned off, and the fuel that remains in the system is no longer flowing and increases in temperature from the heat that is generated in the engine and exhaust system.

Exhaust greenhouse gases emissions from road transportation were estimated at about 19 348 kton CO₂ eq. in 2004 representing an increase of 104.5% when compared to 9 462 kton CO₂eq., estimated for 1990 (see Table 3.123). From 2002 to 2004 GHGs emissions registered a slight decrease from 19 499 to 19 348 kton CO₂eq. CO₂ is the most important gas, representing in 2004, 96.8% of total emissions from this sector. N₂O and CH₄ are responsible for, respectively, 2.9% and 0.3% of the GHG emissions in 2004.

Emissions of N₂O have increased by a factor of 4.1 since 1990 due to the introduction of catalytic converters. Some authors suggested that in some cases N₂O emissions could increase by as much as a factor of 10 (Wade et al., 1994; de Soete and Sharp, 1991; Dasch, 1992). As could be observed the introduction of catalytic converters have some disadvantages including also the increase of CO₂ and NH₃ emissions which contribute to climate change and acid deposition. It is difficult to assess the extent to which CO₂ emissions have increased as a result of fitting catalytic converters, because improvements in fuel economy have been made at the same time as development of the engine management systems that are required to minimise NO_x and VOC emissions.

Estimated emissions from road transportation for the period between 1990 and 2004 are summarised in Table 3.123.

Table 3.123 – Estimated emissions from road transport [1990-2004] and annual variation rates

	1990	1991	1992	1993	1994	1995	1996	1997
Kt CO₂ eq.	9 462	10 098	10 992	11 493	12 139	12 805	13 493	14 281
Δ(%)		6.7%	8.9%	4.6%	5.6%	5.5%	5.4%	5.8%
Δ1990(%)		6.7%	16.2%	21.5%	28.3%	35.3%	42.6%	50.9%
	1998	1999	2000	2001	2002	2003	2004	2005
Kt CO₂ eq.	16 047	16 914	18 686	19 003	19 499	19 425	19 348	-
Δ(%)	12.4%	5.4%	10.5%	1.7%	2.6%	-0.4%	-0.4%	-
Δ1990(%)	69.6%	78.8%	97.5%	100.8%	106.1%	105.3%	104.5%	-

Methodology

Exhaust emission estimate follows a country specific integrated methodology which was developed according with the following main objectives:

- Ameliorate emission estimates for those pollutants that are most dependent on vehicle class and abatement technology, such as N₂O, NO_x and NMVOC;
- Improve attribution of total emission estimates for each vehicle type and driving mode;
- Integrate emission inventory models with projection and management models (Policies and Measures)

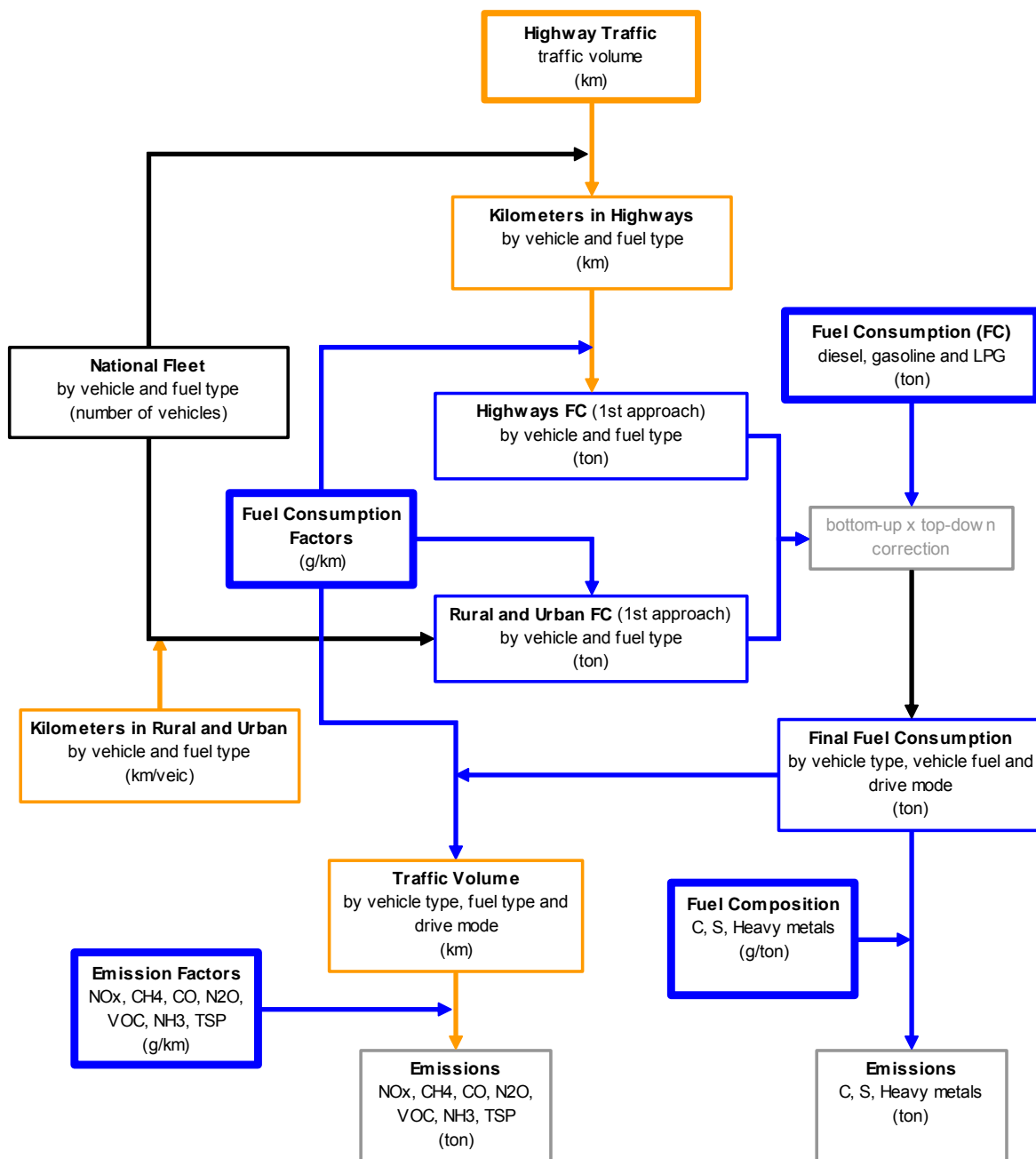
The inventory team has programmed two estimate models, or tools, using Visual Basic programming language combined with Excel: one comprehending a model for road transport emission calculation – BURNN; together with a module to determine the national vehicle fleet – KAR. This last module estimates annual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

BURNN model is compatible and based extensively in the methodology and emission factors from EMEP/CORINAIR Emission Inventory Guidebook. KAR and BURNN data flow is summarized in Figure 3.53 from where main following steps may be identified:

- Estimate national fleet per vehicle type²⁴ (KAR module output);
- Estimate kilometres driven per vehicle type, driving conditions and vehicle technology;
- Estimate fuel consumption per vehicle type, driving conditions and vehicle technology (bottom-up approach);
- Correct fuel consumption using bottom-up approach in conjunction with top-down approach;
- Emission factors, corrected for hot and cold-start emissions;
- Estimate emissions from kilometres travelled or fuel consumption.

²⁴ Vehicle type is disaggregated by vehicle category, age and fuel type. Vehicle technology is function of vehicle age (see Table 3.131).

Figure 3.53 – General scheme of methodology applied for road transport emission estimate



Vehicle Fleet*Light vehicles*

National fleet comprehending light vehicles was estimated according to a module derived from data provided by the *Associação do Comércio Automóvel de Portugal* (ACAP). This module determines active fleet of the following vehicle types:

- Passenger cars;
- Light duty vehicles (LDV);
- Two wheelers.

Annual sales for passenger cars and light duty vehicles were available for each car model and engine size and fuel type since 1975. All light duty vehicles were assumed to be equipped with diesel engines.

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, derived from ACAP data, is summarized in the following couple equations:

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

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

Where,

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

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

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

The number of light vehicles using LPG fuel derives from vehicle registration data provided by the *Direcção Geral de Viação* (DGV).

Heavy Vehicles

The heavy duty vehicles (HDV) fleet was derived from ACAP data and expressed in number of vehicles in moving fleet per year. Disaggregation of vehicle weight was also necessary in order to perform the calculation. Data on heavy duty vehicles sales in 2001 and 2002 was available from ACAP with adequate weight disaggregation as needed for calculation. The ratio per weight class was therefore adapted and applied to active fleet for all years of the emission estimation period (1990 to 2004). Fleet disaggregation by vehicle age was also performed according with fleet data available from ACAP for the years of 2000 and 2002, which is presented in Table 3.125.

Table 3.124 – Percentage of heavy duty vehicles per weight class

Weight Class	Fleet (%)
< 7.5 t	11
7.5 – 16 t	68
16 – 32 t	20
> 32 t	-

Table 3.125 – Percentage of heavy duty vehicles by age

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

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

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

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

Distance Travelled

Distance driven was established from national statistics and technical expertise taking also into account the amount of fuel sold each year. Data regarding vehicle activity is collected periodically at the vehicle inspection centres which are under the DGV authority. The data from the inspection centres is believed to be a significant input parameter to estimate emissions since relies on real vehicle activity. However this data is still not provided by the DGV.

Distances travelled were estimated for two driving conditions:

- Urban;
- Long-distance (LD).

Rural distance was later estimated by subtracting the activity measured in highways from the long-distance activity.

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

Table 3.126 – Input vehicle activity (km/veic).

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

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

- Activity from HDV varies according with vehicle weight and driving mode;
- Activity from passenger cars and LDV used for passenger transportation varies according with vehicles age – newer vehicles tend to run more miles than older vehicles – in such a way that the average activity equals the value from Table 3.126. Since information on age and distance driven is not available for national fleet an age distribution function was adapted from TRENDS data.

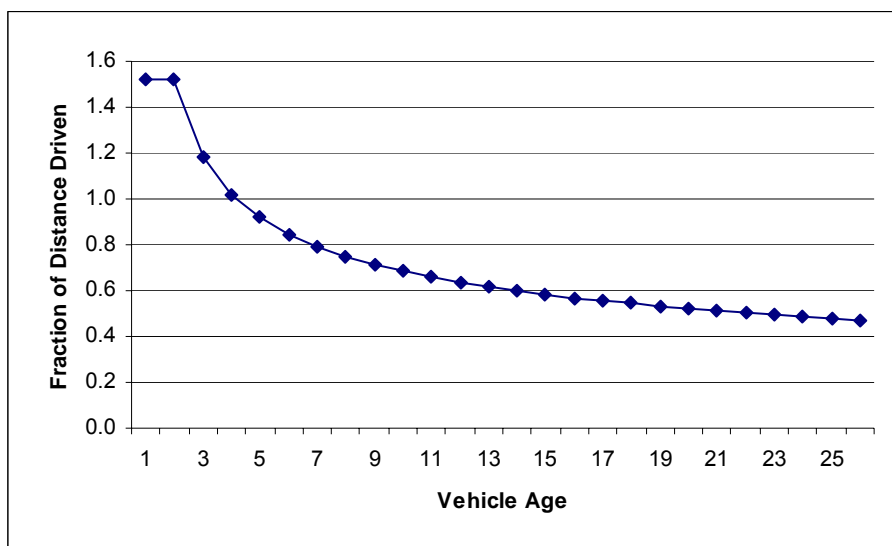


Figure 3.54 – Annual mileage fraction as a function of passenger vehicle age.

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

As referred above, rural activity is estimated by subtracting the activity measured in highways from the long-distance activity. The methodology used to estimate highway activity is presented hereafter.

For passenger cars distances driven are further distributed according with vehicle age. Since information on age and distance driven is not available for national fleet a distribution function was adapted from TRENDS data.

Highway traffic

Distance driven on highways was estimated in kilometres. Information about traffic volume is available annually for highways, either subject to toll or not, for each specific link with a constant vehicle flow. The length of the highway system and its evolution between 1990 and 2004 period was available from IEP.

The fraction of HDV in highways was proposed by IEP and is based on highway toll data. For highways where toll data was not available it was assumed 10% of HDV (see Table 3.127).

Table 3.127 – Fraction of heavy duty vehicles per highway (Source: IEP)

Highway	HDV (%)	Highway	HDV (%)
A01	15	A13	22
A02	9	A14	11
A03	11	A15	16
A04	11	A22	10
A05	5	A23	10
A06	15	A24	10
A07	10	A25	10
A08	10	A27	10
A09	11	A28	10
A10	10	A28	10
A11	7	A29	10
A12	11	-	-

Highway traffic data includes distances travelled for all vehicle categories of national fleet which were later divided in heavy and light vehicle traffic according with IEP estimations for the majority of the highway links.

Since light vehicle traffic includes also motorcycles which represent a small fraction of distances travelled in highways it was necessary to distinguish the share of distances driven by two wheelers from light vehicles traffic. As proposed by Joumard, 1999, the fraction of distances driven by two wheelers in highways was assumed to be 3% of total light vehicles traffic.

Table 3.128 – Fraction of distances travelled per vehicle type (Source: Joumard, 1999)

Vehicle Type	%
PassCar	93%
Moped	4%
Moto	3%

The methodology used to determine distances driven on highways implies earlier evaluation of the national fleet which was already described. Kilometres driven in highways were therefore estimated from:

$$\begin{aligned}
 Km_{LVhighway}(LV,t,f,y) &= C_{LV}(c,t,f,y) \times \sum_{(l,r)} [L_{Length}(l,r) \times L_{Traffic}(l,r,y) \times (1 - F_{HV}(l,r)) \times (1 - F_{2W})] \\
 Km_{2Whighway}(2W,t,f,y) &= C_{2W}(c,t,f,y) \times \sum_{(l,r)} [L_{Length}(l,r) \times L_{Traffic}(l,r,y) \times (1 - F_{HV}(l,r)) \times F_{2W}] \\
 Km_{HVhighway}(HV,t,f,y) &= C_{HV}(c,t,f,y) \times \sum_{(l,r)} [L_{Length}(l,r) \times L_{Traffic}(l,r,y) \times F_{HV}(l,r)]
 \end{aligned}$$

Where,

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

$Km_{2W-highway(LV,t,f,y)}$ = total kilometres driven in highway net-road by motorcycles of class c, equipped with technology t, using fuel f in year y (km/yr);

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

$C_{LV(c,t,f,y)}$ = ratio of class c light vehicles using fuel f in year y within light vehicle national fleet (motorcycles excluded);

$C_{2W(c,t,f,y)}$ = ratio of class c motorcycles using fuel f in year y within motorcycles national fleet;

$C_{HV(c,t,f,y)}$ = ratio of class c heavy vehicles using fuel f in year y within heavy vehicles national fleet;

$F_{HV(l,r)}$ = Estimated fraction of heavy vehicles in inter-nodal link l from highway road r;

F_{2W} = Fraction of distance driven by motorcycles within light vehicles;

$L_{Length(l,r)}$ = full length of inter-nodal link l from highway road r (km);

$L_{Traffic(l,r,y)}$ = traffic volume (vehicles per year) registered in link l in year y (vehicles per year);

l = link that connects two nodes of the highway. Traffic volume is constant along each link;

r = highway code;

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

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

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

y = civil year.

Speed

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

Table 3.129 – Assumed vehicle speeds by driving mode and vehicle type.

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

Fuel consumption*Highway Fuel Consumption*

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

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

where,

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

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

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

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

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

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

y = civil year.

Individual fuel consumption for each vehicle type was estimated from:

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

Urban and Rural Fuel Consumption

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

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

where:

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

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

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

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

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

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

where,

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

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

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

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

Adjustment of bottom-up and top-down approaches

Fuel adjustments are necessary so that the sum of estimated fuel consumption equals the original statistical data from the *Direcção-Geral de Geologia e Energia* (DGGE). Urban and rural fuel consumption estimates were corrected with the following factor for car type c, technology t, fuel f, driving mode d and year y.

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

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

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

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

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

Adjustment of Distances Travelled

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

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

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

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

Where,

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

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

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

Table 3.130 – Vehicle activity after adjustments.

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

Emission Factors

Emission Functions

Emissions factors for NO_x, CO, NMVOC, CH₄, N₂O and NH₃ were determined from the available set of algorithms reported in EMEP/CORINAIR, 2002, which results from a compilation for the CORINAIR85 and CORINAIR90 programs and updated with results from the MEET project and the COST319 action. This set of equations allows the estimation of emission factors as function of driving conditions and vehicle properties:

- Vehicle class: light passenger vehicles, LDV, HDV, Mopeds with cylinder capacity under 50 cc and; Motorcycles with cinder capacity greater than 50 cc;
- Fuel type: gasoline, diesel and LPG;
- Technology standard;

- Vehicle dimensions: motor size (cubic centimetres) for light vehicles and two wheelers and vehicle weight for heavy vehicles;
- Average vehicle speed under each driving mode.

Although vehicle load and road slope have a significant influence on heavy duty vehicles emissions (Journard, 2003), these variables were not considered in this inventory.

European technology standards were determined according with the vehicle built year as present in Table 3.131.

Fuel consumption factors here presented are similar in development and use to emission factors and constitute the first step of the methodology to help sharing total fuel consumption by vehicle class.

Table 3.131 – Technology classification according to built year

Vehicle Category	Legislation	Built year	
		from	to
Passenger Cars	PRE ECE	...	1971
	ECE 15/00-01	1972	1977
	ECE 15/02	1978	1980
	ECE 15/03	1981	1985
	ECE 15/04	1986	1991
	Euro I	1992	1996
	Euro II	1997	2000
	Euro III	2001	2004
	Euro IV	2005	...
Light Duty Vehicles	Conv	...	1991
	Euro I	1992	1997
	Euro II	1998	2001
	Euro III	2002	2006
	Euro IV	2006	...
Heavy Duty Vehicles	Conv	...	1991
	Euro I	1992	1995
	Euro II	1996	2000
	Euro III	2001	2005
	Euro IV	2006	2008
	Euro V	2009	...
Mopeds	Conv	...	1999
	97/24/EC Stage I	2000	2003
	97/24/EC Stage II	2004	...
Motorcycles	Conv	...	1999
	97/24/EC	2000	...

Hot and Cold emission factors

Final emission factors and fuel consumption factors were estimated in two steps:

- Hot emission factors: representing emission factors (g/km) when vehicles have warmed up to normal operating conditions;
- Cold-start extra emissions: exhaust emissions from vehicles during a certain time, until engine temperature²⁵ increases to normal operation temperature, have generally increased emissions over *normal* hot emissions.

Total emission factor (ef^T) is estimated from:

$$ef_{(c,t,d,f,p)}^T = \frac{\sum_m \{ef_{(c,t,d,f,p)}^{hot} \times [1 + \beta_m \times (cf_{(c,t,d,f,p)}^{cold/hot} - 1)]\}}{12}$$

where,

$ef_{(c,t,d,f,p)}^T$ = average annual total (hot and cold-start) emissions from vehicle type c with technology t and using fuel type f (g/km);

m = Month;

$ef_{(c,t,d,f,p)}^{hot}$ = hot emission factor from vehicle type c with technology t and using fuel type f (g/km)

β_m = average monthly value for the fraction of mileage driven with cold engines or catalyst operated below the light-off temperature²⁶.

$cf_{(c,t,d,f,p)}^{cold/hot}$ = cold to hot ratio of emissions (g/g).

Cold-start corrections were applied for cars using gasoline, diesel and LPG, and for urban and rural modes. Correction factors $cf^{cold/hot}$, were set from EMEP, 2002.

Disaggregation of fleet for evaporative emission calculation was derived from KAR output.

Exhaust Emissions

Two different sets of pollutants are distinguishable:

- Pollutants for which a mass balance may be performed such as CO₂, SO_x and heavy metals;

²⁵ Cold engines are defined as those with water temperature below 70°C (EMEP/CORINAIR)

²⁶ β_m parameter is calculated from average monthly temperature T_a (°C) and average trip length (km/trip) (Table 8.6 of 3^{ed} EMEP/CORINAIR)

- Pollutants for which emissions are best estimated from kilometres driven: NO_x, CO, NMVOC, N₂O and NH₃.

Emissions of ultimate carbon dioxide were estimated from:

$$U_{CO_2(y)} = \sum_c \sum_t \sum_d \sum_f [Fuel_{FC(c,t,d,f,y)} \times EF_{CO_2(f)}] \times 10^{-3}$$

Where,

$U_{CO_2(y)}$ = ultimate or final emission of carbon dioxide in year y (kt/yr);

$FC_{(c,t,d,f,y)}$ = fuel consumption in year y allocated to vehicle type c, with technology t, using fuel type f and under driving conditions d (t/yr);

$EF_{CO_2(f)}$ = emission factor for fuel type f (t/t).

Emissions of SO_x are also estimated by a mass balance approach:

$$SO_{x(y)} = 2 \times \sum_c \sum_t \sum_d \sum_f [Fuel_{Cons(c,t,d,f,y)} \times S_{(f,y)} \times 10^{-2}]$$

where,

$SO_{x(y)}$ = sulphur oxide emission estimated in exhaust gas from road vehicles in year y (ton/yr);

$Fuel_{Cons(c,t,d,f,y)}$ = fuel consumption in year y allocated to vehicle type c, with technology t, using fuel type f and under driving conditions d (ton/yr);

$S_{(f,y)}$ = sulphur content of fuel (mass percentage).

Emissions of heavy metals are estimated in a similar way:

$$Emission_{HM(p,y)} = \sum_c \sum_t \sum_d \sum_f [Fuel_{Cons(c,t,d,f,y)} \times HM_{(f,y)} \times 10^{-6}]$$

where,

$Emission_{HM(p,y)}$ = emission of heavy metal p in year y (t/yr);

$Fuel_{Cons(c,t,d,f,y)}$ = fuel consumption in year y allocated to vehicle type c, with technology t, using fuel type f and under driving conditions d (t/yr);

$HM_{(p,f,y)}$ = mass content in heavy metal p in fuel f (g/t).

Emission estimate for pollutants function of distance driven are estimated from:

$$Emission_{(p,y)} = \sum_c \sum_t \sum_d \sum_f [Km_{(c,t,d,f,y)} \times EF_{(c,t,d,f,p)} \times 10^{-6}]$$

where,

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

$Km_{(c,t,d,f,y)}$ = total distance driven in year y by vehicles of type c, with technology t, using fuel type f and under driving conditions d (km/yr);

$EF_{(c,t,d,f,p)}$ = emission factor for pollutant p for vehicles of type c, with technology t, using fuel type f and under driving conditions d (g/km).

Evaporative Emissions

Calculation of evaporative emissions was adapted from the methodology presented in section B760 from EMEP/CORINAIR Handbook. Evaporative emissions were determined for powered gasoline vehicles of classes j present in Table 3.132

Table 3.132 – Gasoline powered vehicles categories

Vehicle Class	SNAP	Fuel	Category	Environmental Technology
Passenger Car	070101	Gasoline	< 1.4 l	Canister
Passenger Car	070102	Gasoline	1.4 – 2.0 l	Canister
Passenger Car	070103	Gasoline	> 2.0 l	Canister
Passenger Car	070101	Gasoline	< 1.4 l	Conventional
Passenger Car	070102	Gasoline	1.4 – 2.0 l	Conventional
Passenger Car	070103	Gasoline	> 2.0 l	Conventional
Light Duty Vehicle	070201	Gasoline		Conventional
Moped	0704	Gasoline		Conventional
Moto_2t	070501	Gasoline	> 50 cc	Conventional
Moto_4t	070503	Gasoline	50 – 250 cc	Conventional
Moto_4t	070504	Gasoline	250 – 750 cc	Conventional
Moto_4t	070505	Gasoline	> 750 cc	Conventional

Reliable statistical information concerning vehicles equipped with canister was not available. Therefore it was assumed that all new vehicles built after 1992 were equipped with canister, year in which EURO I was implemented.

Total evaporative emissions are estimated from:

$$Evap_{NMVOC(y)} = \{365 \times [(a_j \times e^d) + S^c + S^{fi}] + R\} \times 10^{-6}$$

where,

$Evap_{NMVOC(y)}$ = NMVOC evaporative emissions in year y (t/yr);

a_j = number of gasoline vehicles of category j;

e^d = mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly ambient temperature, temperature variation and fuel volatility (RVP) (g/day);

S^c = hot and warm soak emission of gasoline powered vehicles equipped with carburettor (g/day);

S^{fi} = hot and warm soak emission of gasoline powered vehicles equipped with fuel injection (g/day);

R = hot and warm running losses (g).

and,

$$S^c = (1 - q) \times (p \times x \times e^{s,hot} + w \times x \times e^{s,warm})$$

$$S^{fi} = q \times e^{fi} \times x$$

$$R = m_j \times (p \times e^{r,hot} + w \times e^{r,warm})$$

where,

q = fraction of gasoline powered vehicles equipped with fuel injection;

p = fraction of trips finished with hot engine (dependent of the average monthly ambient temperature);

w = fraction of trips finished with cold or warm engine (shorter trips) or with catalyst below its light-off temperature²⁷;

x = mean number of trips of a vehicle per day, average over the year;

$e^{s,hot}$ = mean emission factor for hot soak emission (g/day/vehicle), function of fuel volatility RVP and estimated from EMEP/CORINAIR Emission Inventory Guidebook;

$e^{s,warm}$ = mean emission factor for cold and warm soak emission (g/day/vehicle). This parameter is also dependent on fuel volatility RVP and average monthly temperature. Estimated from EMEP, 2002;

e^{fi} = mean emission factor for hot and warm soak emission of gasoline powered vehicles equipped with fuel injection. Estimated from EMEP, 2002;

$e^{r,hot}$ = average emission factor for hot running losses of gasoline powered vehicles, dependent on fuel volatility RVP and average monthly ambient temperature. Estimated from EMEP, 2002;

$e^{r,warm}$ = average emission factor for warm running losses of gasoline powered vehicles, dependent on fuel volatility RVP and average monthly ambient temperature. Estimated from EMEP, 2002;

m_j = total annual mileage of gasoline powered vehicles of category j

²⁷ Fraction of trips finished with cold and warm engine, w , is linked with the parameter β used in calculation of cold start emissions. The assumed relation between w and β is: $w \approx \beta$

It was considered that fuel injection vehicles started to enter the market in 1997 (year in which EURO II entered into force) and it was assumed that all new gasoline passenger cars sold in 1997 were equipped with fuel injection systems whereby a fraction of fuel injection vehicles can be derived for the following year. Gasoline LDV and two-wheelers were treated as non-fuel injected vehicles.

The fraction of trips finished with hot engine, p , was obtained by subtracting to one the fraction of trips finished with cold or warm engine.

$$p = 1 - \left[0.647 - 0.025 \times l_{trip} - (0.00974 - 0.000385 \times l_{trip}) \times t_a \right]$$

where,

p = fraction of trips finished with hot engine;

t_a = ambient temperature;

l_{trip} = average trip length (12 km)²⁸.

Distance travelled, in kilometres per vehicle, was determined for each vehicle category from Table 3.132 in the following manner:

$$V_{i(c,t,y)} = \frac{Km_{(c,t,y)}}{N_{(c,t,y)}}$$

where,

$V_{j(c,t,y)}$ = distance driven, in kilometres per vehicle, by vehicles of class c , equipped with environmental technology t in year y (km/vehicle);

$Km_{(c,t,y)}$ = kilometres driven by vehicles of class c , equipped with environmental technology t in year y for all driving modes (km);

$N_{(c,t,y)}$ = number of vehicles of class c , equipped with environmental technology t in year y

Mean number of trips of a vehicle per day (x) can then be obtained from:

$$x = \frac{V_i}{365 \times l_{trip}}$$

Finally, emission factors for motorcycles were estimated from the light passenger vehicles emission factor but assuming these as only 20% in the case of Motorcycles <50 cm³ and 40% for the other two wheelers, as proposed in EMEP, 2002.

²⁸ Obtained from Table 6.3 (Chapter B710) of EMEP/CORINAIR Emission Inventory Guidebook.

Temperatures used in evaporative emissions estimation were averaged according with gasoline sales per NUTIII for years 1990, 1996 and 2000 and interpolated for intermediate years.

The average trip length was set at 10 km (L_{trip}), which results in an annual β factor of 0.305. It was considered, according to EMEP, 2002 recommendations to set w (fraction of trips finished with cold or warm engine) equal to β .

Reid vapour pressure values needed to calculate evaporative emissions are given in national legislation and summarised in Table 3.139.

Meteorological data necessary for evaporative emission calculation (annual average minimum temperature and maximum temperature) was received from 49 monitoring stations of the National Meteorological Institute (IM) for 1951 to 1980. Adequate values of annual average minimum temperature and maximum temperature were established for each NUT III territorial unit resulting from individual stations that were assumed be representative of the meteorological conditions.

A global national correction factor was then obtained after weighting each individual NUT III area with fuel consumption for each specific territorial unit thus estimating a representative national average temperature T_a (°C) for each year.

Table 3.133 – Estimated ambient temperature for evaporative emissions calculation

1990 to 1995	1996 to 1999	2000 to 2002
14.836 °C	14.874 °C	14.885 °C

Emission Factors

Carbon Dioxide

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

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

Where

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

$R_{H/C}$ = the ratio of hydrogen to carbon atoms in the fuel. Values for this ratio and the resulting CO₂ emission factor are presented in Table 3.134.

Table 3.134 - $R_{H/C}$ ratio and CO₂ emission factor

Fuel	$R_{H/C}$	EF_{CO_2} (t CO ₂ /t)
Diesel-oil	2.00	3.14
Petrol	1.80	3.18
LPG	2.58	3.01

Sulphur Dioxide

Following legal constraints, the sulphur content of diesel oil and petrol was reduced in the 1990-2004 period. The sulphur contents were set as presented in Table 3.135.

Table 3.135 – Levels for sulphur and lead content (%).

Fuel	Description	1990 to 1994	1995	1996	1997	1998	1999	2000 to 2004	>2005
Gasoline	With Pb	0.100	0.100	0.100	0.100	0.100	0.100	-	-
Gasoline	Without Pb	0.100	0.100	0.050	0.050	0.050	0.050	0.015	0.005
Gasoline	Averaged	0.100	0.100	0.080	0.077	0.074	0.062	-	-
Diesel	-	0.300	0.200	0.050	0.050	0.050	0.050	0.035	0.005
GPL	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: DGGE

Emission Factor Functions*Variable Emission Factors*

Emission factors were subjected to variations as the result of the use of new technologies, particularly the introduction of catalyst converter in passenger cars. The use of new technologies is function of vehicle built year, which was used as a variable for emission factor estimation (see Table 3.131).

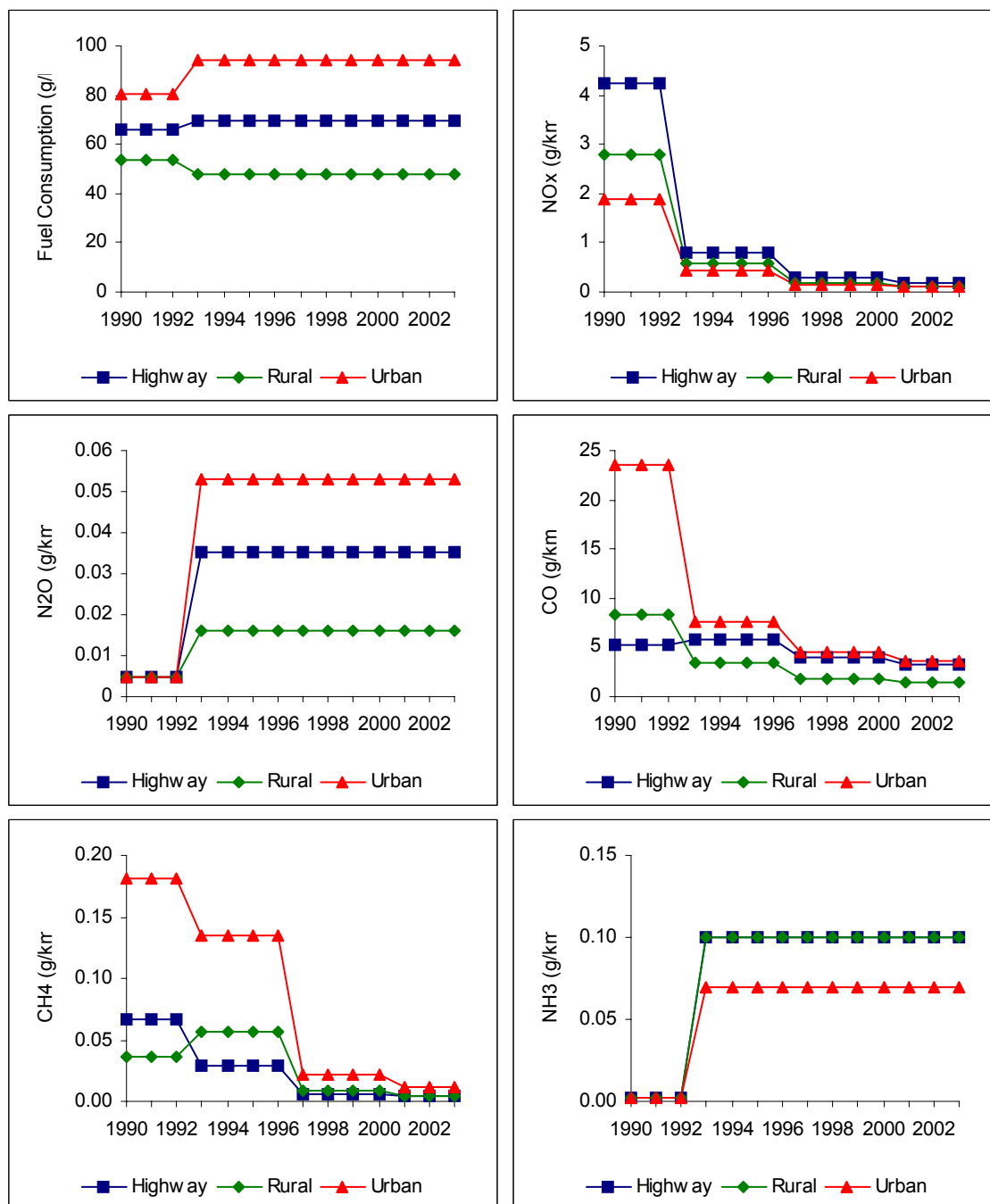
Emission factors were determined for:

- 10 pollutants²⁹ (CO, NO_x, N₂O, SO₂, VOC, CH₄, CO₂, NH₃, diesel particulates and lead);
- 9 vehicle types (gasoline passenger cars, diesel passenger cars, LPG passenger cars, LDV, HDV, diesel and CNG buses, coaches and two wheelers) and each correspondent category (<1.4 l, 1.4 - 2.0 l, etc);
- 3 driving conditions (urban, rural and highways).

For gasoline passenger cars with cylinder capacity 1.4l<cc<2.0l the influence of a catalyst results in a significant decrease of pollutants dependent on driving conditions such as CO, NO_x and CH₄. For example, the introduction of catalyst resulted in a decrease of NO_x emission factor of about 80% on average and to a decrease of 55% of CO averaged emission factor. On the other hand, NH₃ and N₂O increased by a factor of 45 and 7, respectively.

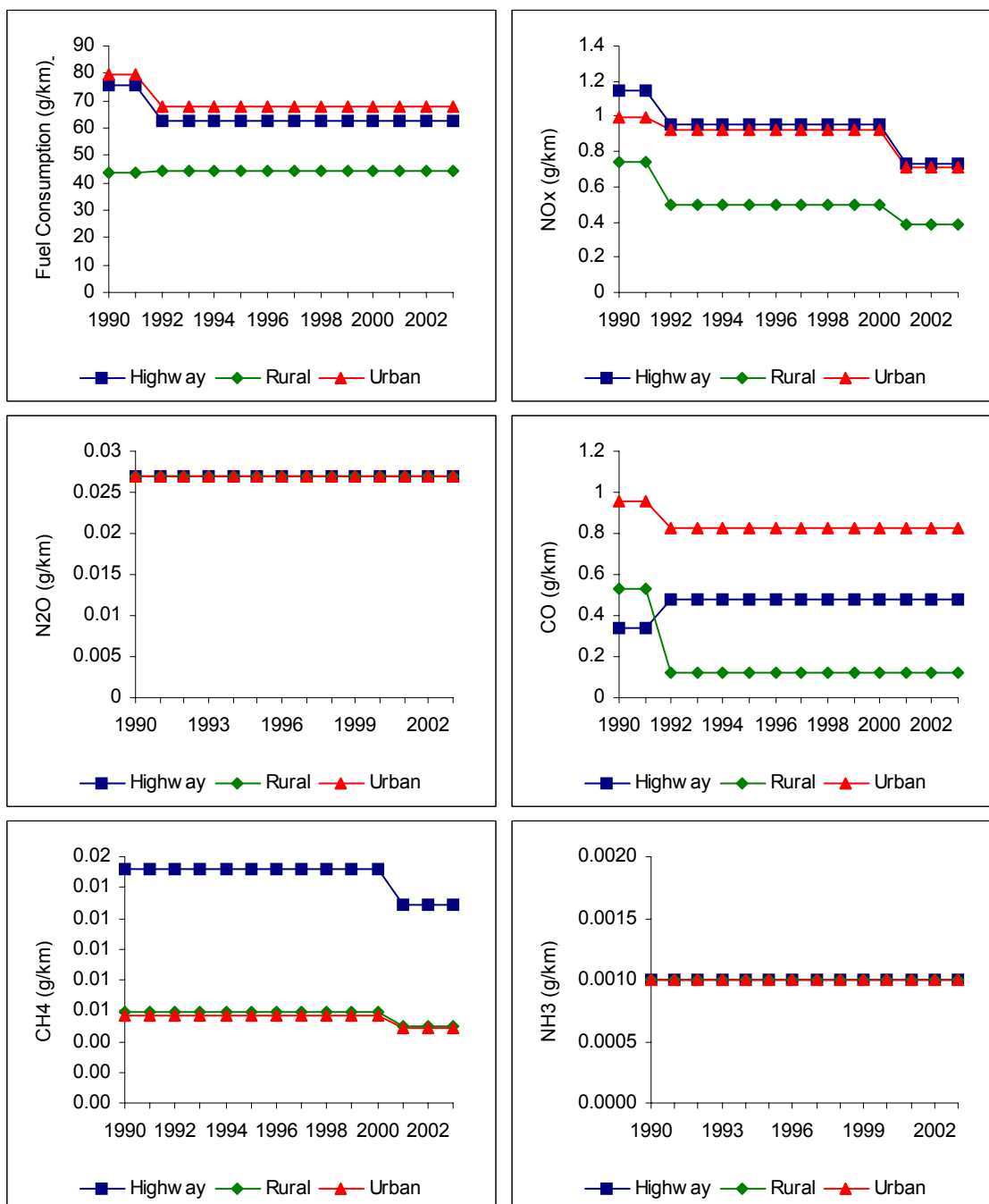
²⁹ For some pollutants (SO₂, CO₂, Heavy Metals) very simply "bulk" emission factors or equations are provided in EMEP/CORINAIR.

Figure 3.55 –Fuel consumption and emission factors for new gasoline passenger cars in each year (1.4 l < CC < 2.0 l)



For passenger diesel vehicles with cylinder capacity less than 2.0l the introduction of Euro I technology in 1992 lead to an average reduction of CO, NO_x and fuel consumption of about, 22%, 17% and 12%, respectively. From EURO I to EURO II decreases in averaged emissions factors are only observed for NO_x (-23% when compared to EURO I averaged emission factor) and CH₄ (-15% of EURO I averaged emission factor).

Figure 3.56 –Fuel consumption and emission factors for new diesel passenger cars in each year (CC < 2.0 l)



Evaporative Emissions

Emission factors for evaporative emissions were set in accordance with the methodology proposed in EMEP/CORINAIR Handbook. Parameters for the algorithms were calculated with the set of equations in Table 8.1 of Chapter B760 of EMEP/CORINAIR Emission Inventory Guidebook.

Table 3.136 – Mean evaporative emission factors (values in g/vehicle/day)

Emission Factor	Category	1990 to 1995	1996 to 1999	2000 and beyond
e^d	Conventional	5.860	5.841	5.841
	Canister	1.172	1.168	1.168
$e^{s,warm}$	Conventional	3.235	3.220	3.220
	Canister	0.521	0.520	0.520
$e^{s,hot}$	Conventional	16.897	16.584	16.584
	Canister	0.782	0.780	0.780
$e^{fi,hot}$ & $e^{fi,warm}$	Conventional	0.7	0.7	0.7
	Canister	-	-	-
$e^{r,warm}$	Conventional	0.141	0.143	0.143
	Canister	0.014	0.014	0.014
$e^{r,hot}$	Conventional	0.192	0.195	0.195
	Canister	0.019	0.019	0.019

Activity Data

Vehicle Fleet

The number of vehicles between 1990 and 2004 was based in data available from ACAP, DGV, ISP and INE.

Vehicle data was adapted in accordance with the methodology described in Methodology - Vehicle Fleet. A national fleet was determined for each year of the calculation period.

Table 3.137 – Vehicle fleet synthesis: 1990-2004

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

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

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

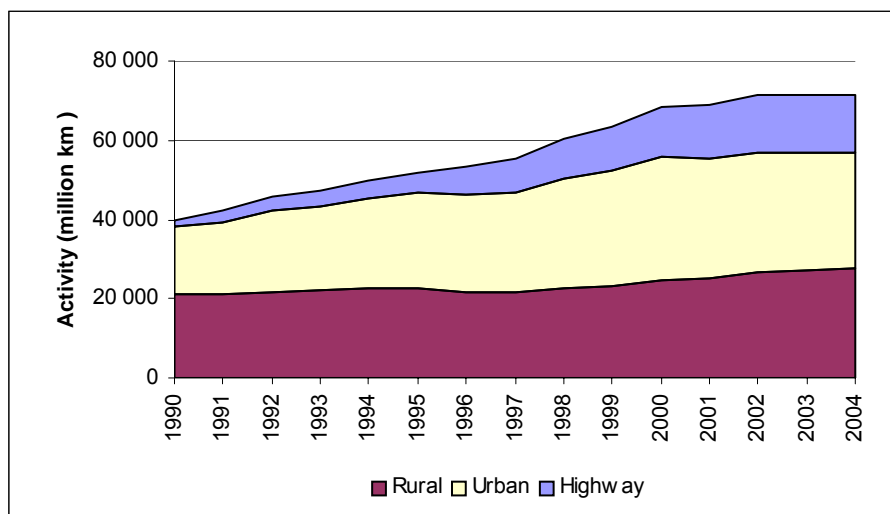
Distances Travelled

Total distance driven in highways was obtained from highway commissioners data collected by IEP. Time evolution road length was set from IEP's GIS system and concerns the date from which each link was set open to road traffic circulation.

Total national figures have increased steadily between 1990 and 2004. The increase in highway circulation of about nine times from 1990 to 2004, reflects not only the growth of the Portuguese highway road-net but also an increase in intensity of road use. For the same period, rural and urban circulation had increased 1.3 and 1.7 times, respectively. Total road traffic activity has increased 79.7% since 1990. In 2002 and 2003 total road traffic activity is very similar.

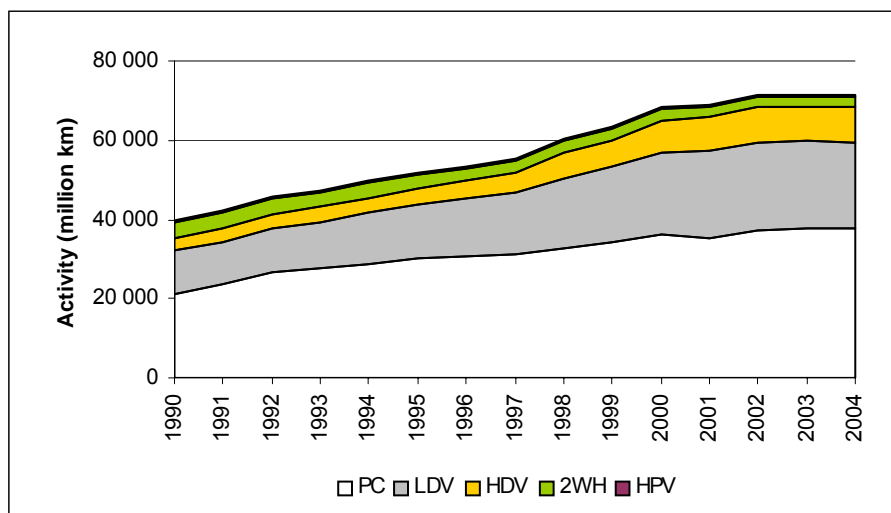
Urban activity is the most significant share of total distance travelled being responsible for 40.5% of the overall kilometers travelled in 2004 followed by rural and highway activity with 38.9% and 20.6%, respectively.

Figure 3.57 – Kilometres travelled by driving mode



Over the 1990-2004 period the distance driven grew for all vehicle types except for two wheelers. As presented in Figure 3.58, HDV and LDV vehicles registered the biggest increase in distance driven, 103% and 185%. It should be emphasized that a fraction of the kilometres driven by LDV (34% in 2004) are actually used as passenger cars. Nevertheless, passenger cars are the vehicles travelling more kilometres with a share of 52.9% from the total distance driven in 2004.

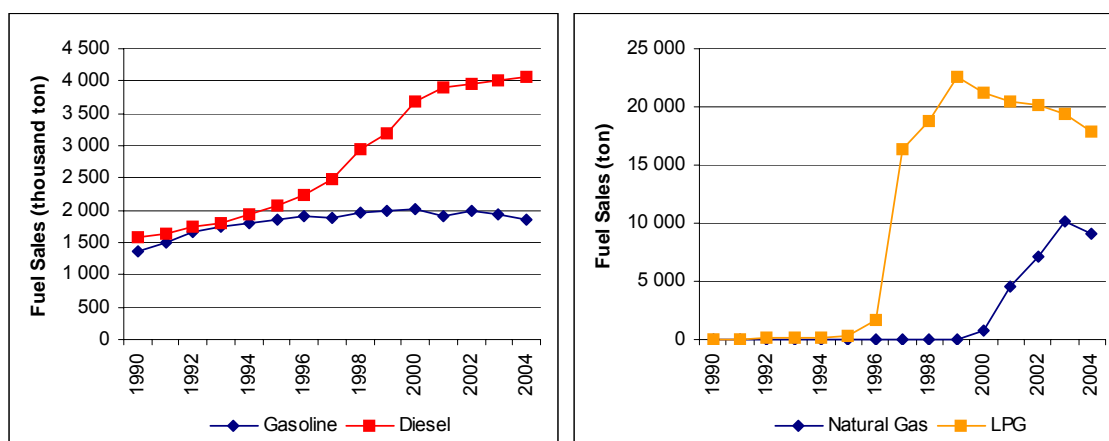
Figure 3.58 – Kilometers travelled by vehicle type: passenger cars (PC); light duty vehicles (LDV); heavy duty vehicles (HDV), two wheelers (2WH) and heavy passenger vehicles (HPV)



Fuel Consumption

Fuel consumption from road transport sector is available for the years from 1990 to 2004 from the revised energy balances from DGGE. Total consumption of petrol, diesel-oil and LPG are shown in Figure 3.59. LPG and CNG represent only a small fraction of the total fuel consumption.

Figure 3.59 – Fuel consumption from road transport sector



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

Table 3.138 – Low Heat Values (LHV) in Road Transportation

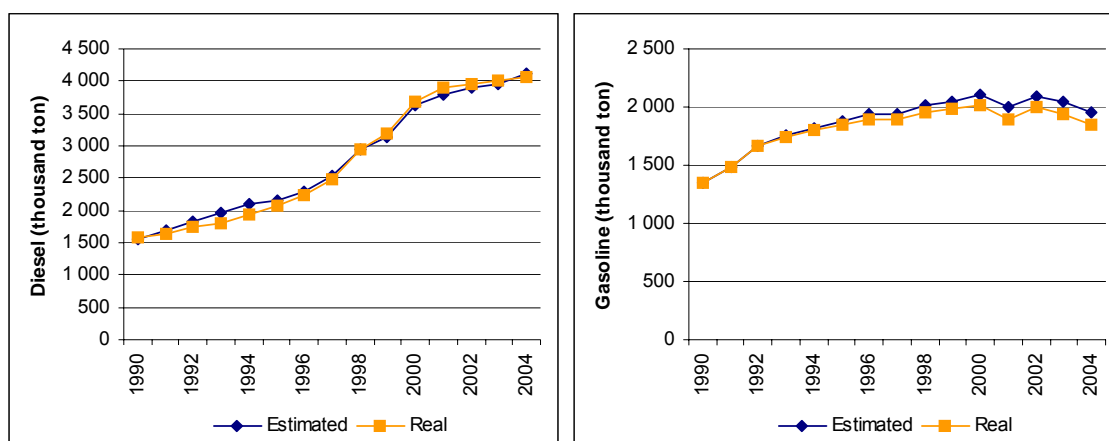
Fuel	toe/ton	MJ/kg
Diesel oil	1.035	43.31
Petrol	1.070	44.77
LPG	1.160	47.28

CNG	1.031	45.97
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Fuel consumption was also estimated from the fuel consumption factors given from EMEP CORINAIR Emission Inventory Guidebook. The bottom-up versus top-down correction factor was derived from the differences between estimated and real fuel consumption as explain in sector Methodology - Fuel consumption.

Estimated diesel and gasoline consumption varies within a maximum of $\pm 9\%$ from real fuel consumption for all period of analysis. Figure 3.60 shows the measured and estimated figures for gasoline and diesel consumption.

Figure 3.60 – Measured and predicted gasoline fuel consumption



Evaporative Emissions and Cold Start Parameters

Evaporative Emissions

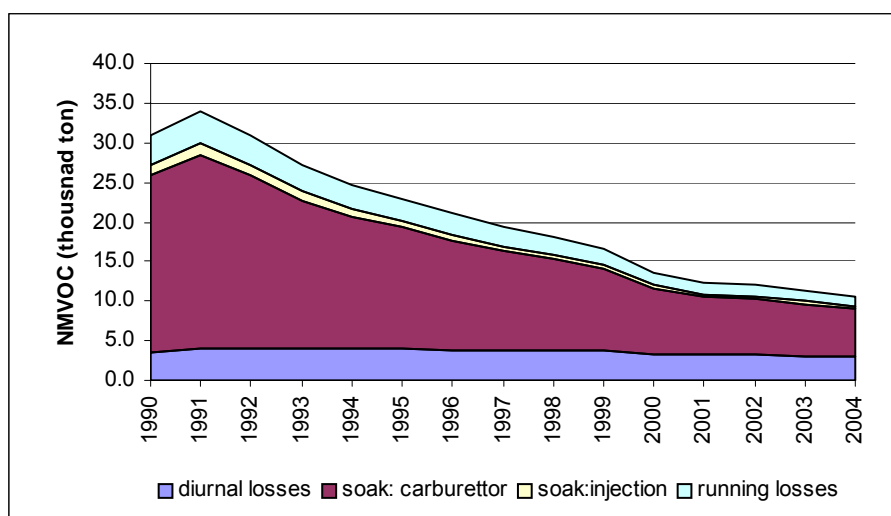
The average trip length was set at 10 km (L_{trip}), which results in an annual β factor of 0,305. It was considered, according to EMEP/CORINAIR recommendations to set w (fraction of trips finished with cold or warm engine) equal to β . Monthly values of fuel volatility (RVP - Reid Vapour Pressure) were established from Portuguese legislation (Decreto-lei n.º 104/2000; Portaria 1489/95; Portaria 125/89). RVP values considered in national legislation 104/2000 are applicable since the beginning of year 2000 although the regulatory document was valid only after May 2000.

Table 3.139 - Legal values for RVP (values in kPa)

Month	Year		
	1989 to 1995	1996 to 1999	≥ 2000
Jan	98	95	90
Feb	98	95	90
Mar	98	95	90
Apr	83	80	90
May	83	80	60
Jun	70	70	60
Jul	70	70	60
Aug	70	70	60
Sep	70	70	60
Oct	83	95	90
Nov	98	95	90
Dec	98	95	90

Major reductions were estimated for evaporative emissions for the period between 1990 and 2004 as new fuel injection vehicles replace old carburettor vehicles. Figure 3.61 shows that soak emissions from carburettor vehicles have contributed significantly for evaporative emission reduction, decreasing about 73.2% since 1990. Soak emissions from fuel injection vehicles represent a small fraction of evaporative emissions (less than 3.6% in 2004).

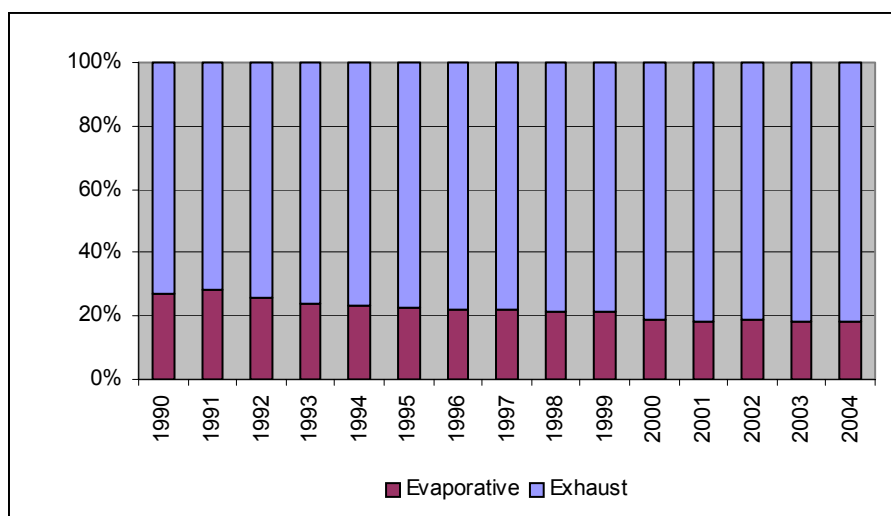
Figure 3.61 – Estimated evaporative emissions



From 1990 to 2000 the trend of evaporative emissions for diurnal and running losses and soak emissions from carburettor vehicles decreases faster. This results from the evaporative emission factors which are function of the fuel RVP. Therefore, reduction of evaporative emissions was achieved not only by the introduction of new vehicle technologies but also by fuel improvements.

The share of evaporative emissions from total NMVOC is decreasing as shown in Figure 3.62.

Figure 3.62 – Share of evaporative and exhaust NMVOC.



Uncertainty Assessment

In accordance with the chapter of Road Vehicles in the GPG, the uncertainty of methane emission factor is 40% and the uncertainty for nitrous oxide should be at least 50%. The uncertainty in CO₂ is 5%, also in accordance with the same source of information. The uncertainty of activity data was assumed to be 10%.

3.2.C.2 RAILWAYS

OVERVIEW

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

METHODOLOGY

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

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

where

$\text{Fossil}_{\text{CO}_2(\text{y})}$ - Emissions of carbon dioxide to atmosphere from combustion of fossil fuel f (ton);

$\text{EF}_{\text{CO}_2(\text{f})}$ – Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

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

$\text{Fac}_{\text{OX}(\text{f})}$ – Oxidation factor for fuel f (ratio 0..1);

$\text{Cons}_{\text{Fuel}(f,y)}$ - Consumption of fuel f in year y (ton/yr);

$\text{LHV}_{(f)}$ - Low Heating Value (MJ/kg).

Sulphur oxides emission from combustion are estimated from fuel consumption quantities and sulphur content:

$$\text{SO}_{x(y)} = 2 * \sum_f [\text{Fuel}_{\text{Cons}(f,y)} * S_{(f,y)} * 10^{-2}]$$

where

$\text{SO}_{x(y)}$ - Sulphur oxide emission in year y (ton/yr);

$\text{Fuel}_{\text{Cons}(f,y)}$ - Consumption of fuel f in railway sector in year y (ton/yr);

$S_{(f,y)}$ - Sulphur content of fuel f (mass percentage).

For all other pollutants the following formula was used:

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

where

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

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

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

EMISSION FACTORS

Emission factors, expressed in kg/ton of fuel, were set from available proposed emission factors in EMEP/CORINAIR Handbook (EEA,2002), IPCC 1996 Revised Guidelines (IPCC,1997) and MEET project, and are presented in next table.

Table 3.140 - Emission factors in Railways (in kg/ton of fuel)

	Coal	Coke	Diesel-oil	Fuel-oil
LHV ^(a)	29.3	28.0	43.3	40.2
NO _x	55.6 ^(v)			
NMVOC	5.1 ^(iv)			
CH ₄	0.22 ^(iv)			
CO	20 ^(v)			
U _{CO2}	3 168 ^(v)			
FAC _{OX} ^(b)	0.980	0.990		
N ₂ O	0.66 ^(iv)			
NH ₃ ⁽ⁱ⁾	0.01		0.007	0.01
PM	3.79 ^(vi)			
Cd ^{(c) (i)}	1.00E-02	1.00E-02	1.00E-02	1.00E-02
As ^{(c) (vii)}	5.00E-02	5.00E-02	5.00E-02	5.00E-02
Cr ^{(c) (i)}	5.00E-02	5.00E-02	5.00E-02	5.00E-02
Cu ^{(c) (i)}	1.70E+00	1.70E+00	1.70E+00	1.70E+00
Ni ^{(c) (i)}	7.00E-02	7.00E-02	7.00E-02	7.00E-02
Se ^{(c) (i)}	1.00E-02	1.00E-02	1.00E-02	1.00E-02
Zn ^{(c) (i)}	1.00E+00	1.00E+00	1.00E+00	1.00E+00

(a) LHV/NCV expressed in MJ/kg; (b) Oxidation Ratio expressed as ratio; (c) expressed in g/ton

(i) EMEP/CORINAIR Handbook (EEA, 2002);

(ii) IPCC 1996 Revised Guidelines (IPCC, 1997); (iii) MEET Project;

(iv) Average of EMEP/CORINAIR and IPCC;

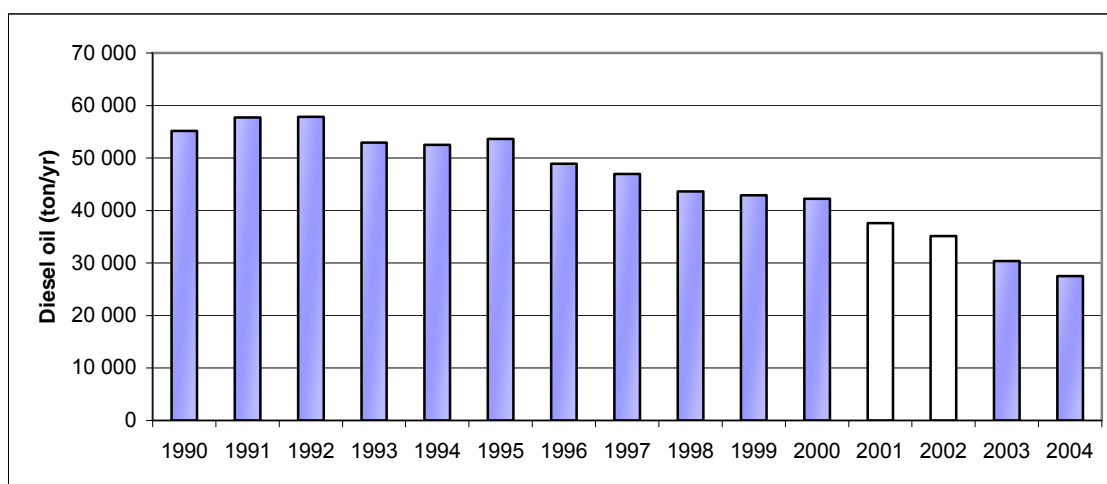
(v) Average of EMEP/CORINAIR, IPCC and MEET;

(vi) Average of EMEP/CORINAIR and MEET, (vii) OSPAR/PARCOM

ACTIVITY DATA

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2003 from the energy balance produced by General-Directorate of Geology and Energy (DGGE). Besides some very small use of coal and coke until 1996, the majority of combustible energy refers to use of gas oil³⁰. The quantities that were consumed have been decreasing steadily since 1992, as can be seen in Figure 3.63.

Figure 3.63 - Consumption of diesel oil in the railway transport sector: 1990-2004



³⁰ Gas oil represents no less than 99.9% of total annual use of combustible energy.

UNCERTAINTY ASSESSMENT

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

3.2.C.3 AVIATION

Overview

Emissions from combustion in aircraft mobile activities comprehend all air emissions associated with fuel combustion in airplanes, either realized in passenger or freight planes, and either realized during flight or in land activities: idle and taxi. Emissions from military aircraft are not included in this inventory.

The inventory of greenhouse gas emissions is not concerned with spatial allocation of emissions, not being concerned about the place where the emissions are realized. However, as the same national inventory is done in an integrated way to obtain estimates for other purposes, such as to access local and regional air problems, the CAFE program or the CLRTAP convention, emissions estimates must differentiate between two different components:

- Landing and Take-off emissions (LTO). Emissions from activities realized near airport in the ground and on flight under an altitude of 3000 feet (914 m): idle, taxi-in, taxi-out, take-off, climbing and descending.
- Cruise emissions. All emissions realized above 3000 feet, including ascend and descend between cruise altitude and 3000 feet.

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

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

Table 3.141 – IPCC criteria for distinction of bunker aviation emissions in domestic and international

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

Source: IPCC (2000)

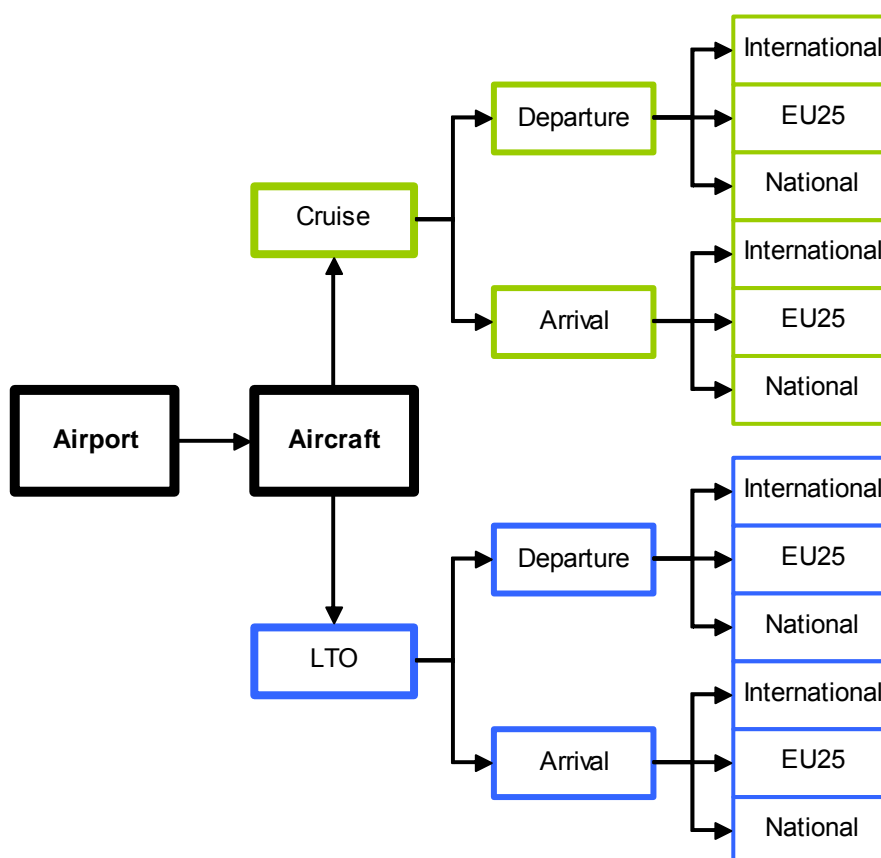
However, the Portuguese inventory presently can not fully achieve this level of detail and separation is done exclusively according to the location of departing and arriving airport, being domestic if they are both in national territory. Despite the fact that this scheme does not fully agrees with Good Practices, it represents an important improvement since last submission.

Portuguese territorial area comprehends, in what concerns definition of domestic, mainland continental area and the autonomous regions of Azores and Madeira islands³¹.

Disaggregation of emission is presently at the level expressed in Figure 3.64 below.

³¹ The inventory did not consider as domestic, however, movements to Macau city in China until 2000, when this territory was considered Chinese territory under Portuguese administration.

Figure 3.64 – Available disaggregation of total aviation emissions



Methodology

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

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

Landing/Take-off

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

$$\text{Emission}_{\text{LTO}(p,d,a,s,y)} = \text{Emission}_{\text{Arrival}(p,d,a,s,y)} + \text{Emission}_{\text{Departure}(p,d,a,s,y)}$$

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

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

where

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

$Emission_{Arrival(p,d,a,s,y)}$, $Emission_{Departure(p,d,a,s,y)}$ – Arrival and departure emissions of pollutant p from, respectively, origin and destiny d in airport a performed by aircraft s during year y (ton/yr);

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

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

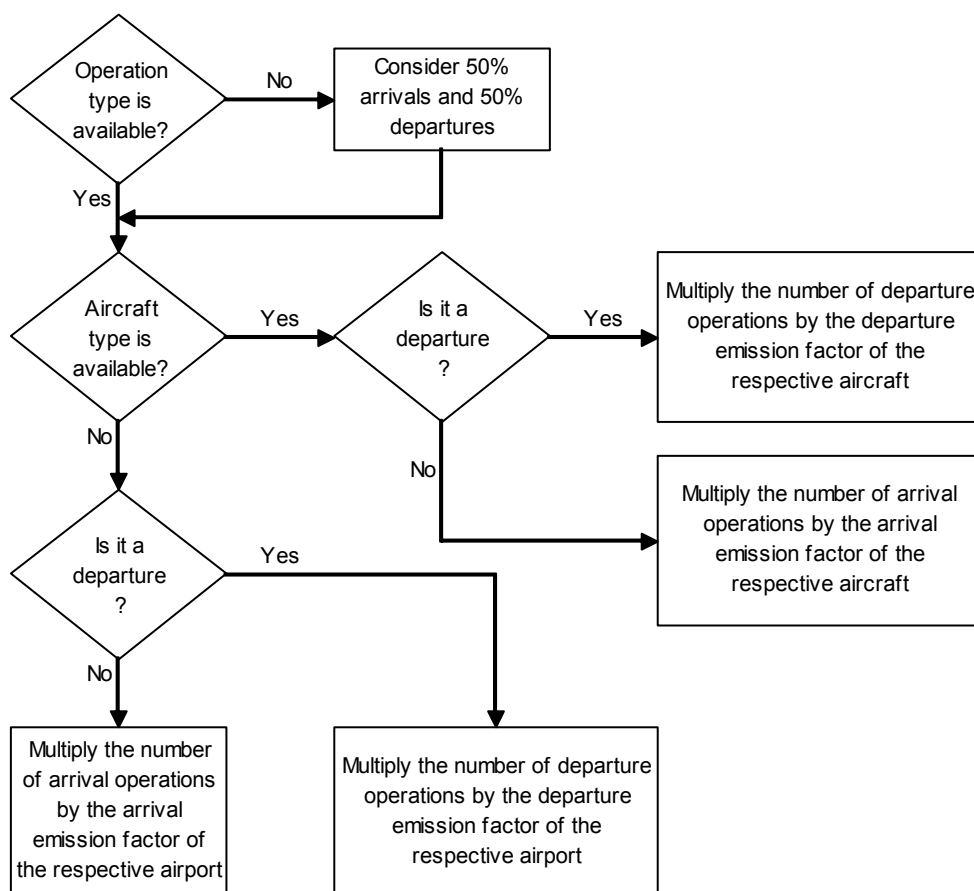
$EF_{Departure(p,s)}$ – Sum of taxi-out, take-off and climb emission factor for pollutant p and aircraft s (kg/movement);

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

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

Figure 3.65 outlines the process whereby LTO emissions are estimated.

Figure 3.65 – Decision tree for LTO emission calculation



Cruise

Cruise emissions are estimated based on aircraft movement data. The approach relies on a origin and destiny matrix crossed with time table information. Emission factors are given for each aircraft type and for a specific flight time.

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

where

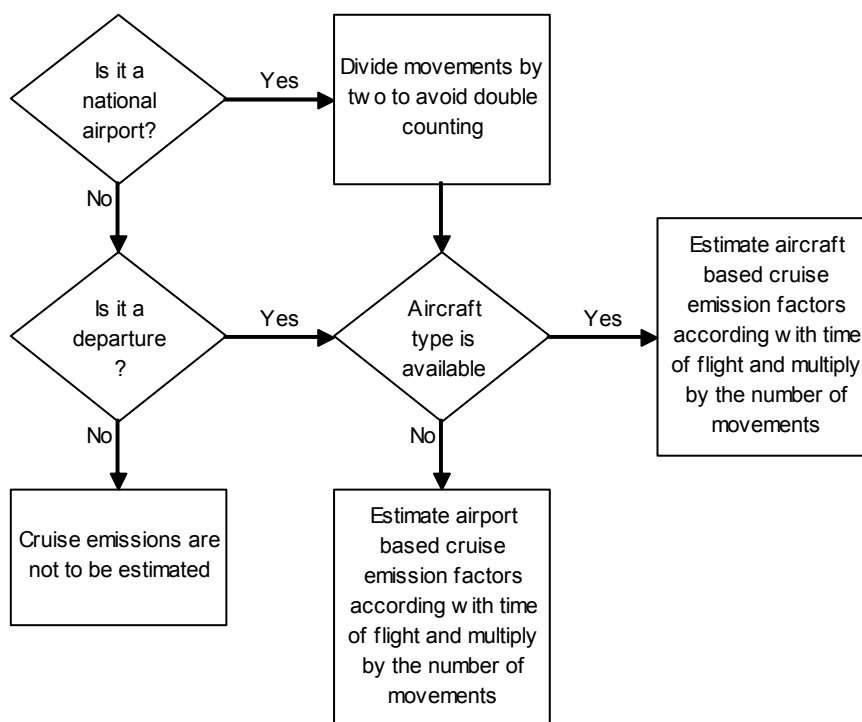
$\text{Emission}_{\text{cruise}(p,d,a,s,y)}$ – Cruise emissions of pollutant p resulting from flight with origin/destiny d in airport a performed by aircraft s during year y (ton/yr);

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

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

In national airports the same national flight is registered in origin airport as a departure and in destiny airport as an arrival therefore the number of national movements must be divided by two to avoid double counting. Cruise emissions from international and EU25 arrival movements are not to be estimated since these emissions result from the fuel sold in country of origin country.

Figure 3.66 – Decision tree for cruise emission calculation



Emission Factors

LTO

Aircraft Based LTO Emission Factors

Emissions factors for LTO were set for each aircraft type according to information from FAEED database which contains emission factors for each operation condition: idle, take off, climb out and approach conditions. Emissions factors for arrival and departure were then set from the time in mode FAEED table and from the emission factor for each operation condition where:

- Departure includes taxi-out (idle), take off and climb out modes;
- Arrival includes approach and taxi in (idle) conditions.

Table 3.142 - Emissions factors for most common aircraft movements in national airports³² (kg/movement).

IATA Code	Departure						Arrival					
	FC	CO	NO _x	PM	NMVOC	CH ₄	FC	CO	NO _x	PM	NMVOC	CH ₄
100	520	8.8	5.0	4.8	1.0	0.1	217	3.8	0.8	2.3	0.4	<0.1
310	1 109	13.3	19.5	10.3	2.5	0.3	463	5.4	3.8	5.1	1.0	0.1
320	579	4.2	9.2	5.4	0.3	<0.1	241	1.8	1.9	2.6	0.1	<0.1
321	694	6.4	13.6	6.5	0.6	0.1	283	2.6	2.4	3.1	0.2	<0.1
330	1 373	13.8	30.6	12.8	2.5	0.3	564	5.5	5.3	6.2	1.0	0.1
340	1 359	18.7	25.7	12.7	3.0	0.3	551	7.2	4.5	6.0	1.1	0.1
727	893	9.9	8.6	8.2	2.8	0.3	370	4.6	1.8	3.9	1.2	0.1
737	629	7.8	6.4	5.8	1.5	0.2	264	3.5	1.5	2.8	0.6	0.1
747	2 520	68.7	49.2	23.3	31.0	3.4	1 053	29.7	6.9	11.4	12.3	1.4
757	904	8.0	18.3	8.4	0.6	0.1	380	3.2	2.6	4.1	0.3	<0.1
767	1 216	13.6	22.4	11.3	2.5	0.3	510	5.5	4.1	5.6	1.0	0.1
72F	902	14.1	8.1	8.3	3.9	0.4	375	6.6	1.7	4.0	1.7	0.2
75F	953	7.9	22.0	8.8	0.6	0.1	411	3.2	2.8	4.5	0.2	<0.1
ABF	1 196	19.8	22.4	11.2	4.2	0.5	481	7.8	3.8	5.3	1.6	0.2
ARJ	402	7.7	3.2	3.7	1.0	0.1	168	3.5	0.9	1.8	0.4	<0.1
ATR	794	7.6	13.7	7.5	0.7	0.1	334	3.2	2.7	3.6	0.3	<0.1
BE1	64	5.0	0.2	0.6	4.3	0.5	34	2.4	0.1	0.4	2.0	0.2
BET	64	5.0	0.2	0.6	4.3	0.5	34	2.4	0.1	0.4	2.0	0.2
CCJ	76	1.7	0.6	0.7	0.2	<0.1	60	1.8	0.3	0.6	0.2	<0.1
CNA	7	5.5	<0.1	0.1	0.3	<0.1	4	3.9	<0.1	<0.1	0.1	<0.1
CNJ	37	2.0	0.2	0.3	0.8	0.1	32	2.3	0.1	0.3	0.9	0.1
DH8	794	7.6	13.7	7.5	0.7	0.1	334	3.2	2.7	3.6	0.3	<0.1
DHT	51	2.1	0.2	0.5	1.6	0.2	27	1.1	0.2	0.3	0.6	0.1
F27	176	11.0	0.4	1.6	2.8	0.3	87	5.4	0.1	0.9	1.0	0.1
GRJ	173	2.9	1.8	1.5	0.3	<0.1	141	2.8	0.6	1.4	0.3	<0.1
H25	42	1.0	0.5	0.4	0.2	<0.1	34	1.2	0.2	0.3	0.2	<0.1
LOH	134	9.3	0.7	1.3	5.1	0.6	173	9.5	0.9	1.9	5.1	0.6
LRJ	42	1.0	0.5	0.4	0.2	<0.1	34	1.2	0.2	0.3	0.2	<0.1
M80	700	4.3	9.7	6.5	1.2	0.1	296	2.2	2.1	3.2	0.7	0.1
S20	134	9.3	0.7	1.3	5.1	0.6	173	9.5	0.9	1.9	5.1	0.6
SH6	64	5.0	0.2	0.6	4.3	0.5	34	2.4	0.1	0.4	2.0	0.2
SWM	129	2.9	1.4	1.2	0.5	0.1	61	1.6	0.4	0.7	0.2	<0.1

Airport Based LTO Emission Factors

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

³² The complete list of aircraft LTO emission factors can be found in annex.

Cruise*Aircraft Based Cruise Emission Factors*

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

Cruise emission factors are given for typical cruise distances. This information was used to derive equations relating distances with emissions for representative aircrafts³³. Using aircraft speeds it was possible to estimate cruise fuel consumption and emissions for a given flight time.

Table 3.143 – Aircraft cruise speeds.

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

Source: www.airliners.net

Table 3.144 gives representative aircraft cruise consumption and emission factors for one hour cruise flight.

³³ Correspondence between representative aircraft and other aircraft types was obtained from EMEP/CORINAIR Emission Inventory Guidebook.

Table 3.144 – Aircraft cruise emission factors for one hour cruise flight (kg/1hour).

Aircraft	FC	CO	NO _x	NM VOC	CH ₄
De Havilland Canada DHC-6	90	1.07	0.47	0.07	0.01
Embraer EMB.110	154	0.60	0.90	0.03	<0.01
Gates Learjet	191	1.50	1.80	-	-
Fairchild (Swearingen) SA26	195	1.56	1.93	0.10	0.01
BAe Jetstream 31	226	1.59	2.33	0.10	0.01
Beechcraft 1900	250	10.68	1.06	2.21	0.25
Shorts SD.360	333	8.19	1.79	1.24	0.14
Saab SF340A/B	356	1.61	3.64	0.77	0.09
Embraer RJ135	414	1.60	2.40	0.08	0.01
De Havilland Canada DHC-7	422	4.25	2.22	0.36	0.04
Fokker F-27	461	27.76	0.58	4.61	0.51
Fokker 50	547	2.95	6.85	-	-
Antonov AN-26	661	42.47	0.93	18.31	2.03
Fokker F-28	1 724	3.32	18.27	3.05	0.34
Lockheed L-182	2 081	4.66	22.82	1.19	0.13
BAe 146	2 123	2.98	17.46	0.74	0.08
Fokker 100	2 289	3.58	19.88	0.83	0.09
BAe 111	2 324	3.51	25.25	0.41	0.05
Airbus A319	2 543	2.56	39.12	0.40	0.04
Airbus A320	2 543	2.56	39.12	0.40	0.04
Boeing 737-200	2 584	5.50	23.76	1.87	0.21
Boeing 737-500	2 584	5.50	23.76	1.87	0.21
McDonnell Douglas DC-9	2 792	5.10	26.09	1.53	0.17
McDonnell Douglas M81-88	3 107	4.62	44.13	1.41	0.16
Boeing 757	3 488	5.94	63.66	3.17	0.35
Airbus 310	3 947	3.43	59.55	0.61	0.07
Boeing 727-300	4 163	8.51	37.91	2.12	0.24
Boeing 727-100	4 163	8.51	37.91	2.12	0.24
Boeing 727-200	4 163	8.51	37.91	2.12	0.24
Boeing 767	4 653	7.92	60.09	1.21	0.13
McDonnell Douglas DC-8	4 653	7.92	60.09	1.21	0.13
Airbus A330	5 676	10.75	103.24	5.30	0.59
Airbus A340	6 295	21.22	105.11	18.29	2.03
Boeing 777	7 237	22.32	134.21	17.49	1.94
McDonnell Douglas DC-10	7 831	20.12	153.64	20.47	2.27
Boeing 747	10 546	21.44	207.94	7.36	0.82

Airport Based Cruise Emission Factors

Specific airport cruise emission factors were needed for movements where information about the aircraft type was not available. Therefore weighted averaged cruise emission factors were estimated from the fleet composition for each airport, year and origin/destiny (international, EU25 and domestic), considering that preferably aircraft types are used according with the flight length.

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

Fuel dependent emission factors

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

Table 3.145 – Fuel dependent emission factors.

Pollutant	AG	JP
LHV (MJ/kg)	44.77	44.56
CO ₂ (kg/ton)	3 117	3 117
N ₂ O (kg/ton)	0.04	0.04
SO _x (%)	0.04	0.04
Pb (g/ton)	304	304
Cd (g/ton)	0.25	0.25
Cr (g/ton)	0.05	0.05
Cu (g/ton)	1.10	1.10
Ni (g/ton)	0.28	0.28
Se (g/ton)	0.03	0.03
Zn (g/ton)	3.00	3.00

Source: IPCC, 1997

Activity DataFlight movements in Airports

The determinant activity data for this source activity is the number of arrival and departure movements. The number of movements by airport, aircraft, origin/destiny and movement type (arrival or departure) for the period between 1990 and 2004 was provided by the *Instituto Nacional de Aviação Civil* (INAC).

Table 3.146 – LTO per airport

Airport Name	Airport Code	1990	1995	2000	2004
Lisboa	LIS	30 862	34 932	56 073	63 772
Porto	OPO	11 574	13 348	23 277	22 833
Faro	FAO	11 252	13 067	18 243	18 241
Funchal	FNC	6 475	9 460	12 037	12 375
Terceira	TER	3 801	4 049	4 501	4 493
Ponta Delgada	PDL	2 954	3 382	4 134	5 833
Porto Santo	PXO	2 403	4 243	3 774	3 555
Horta	HOR	1 237	1 542	1 756	2 407
Santa Maria	SMA	634	893	1 552	1 064
Flores	FLW	281	357	552	719
Total		71 473	85 271	125 898	135 290

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

An alternative database was however available with information on the number of operations and the aircraft types. This data was very useful in determining the aircraft fleet composition between 1990 and 1999 for each of the national airports in order to determine airport representative arrival and departure emission factors.

On the other hand, for records with missing information on origin and destiny, an yearly fraction of international, domestic and European flights was derived for each airport relying on the movements which had this information. This was necessary to differentiate emissions between domestic and international.

Figure 3.67 – Decision tree for distinction between domestic and international emissions.

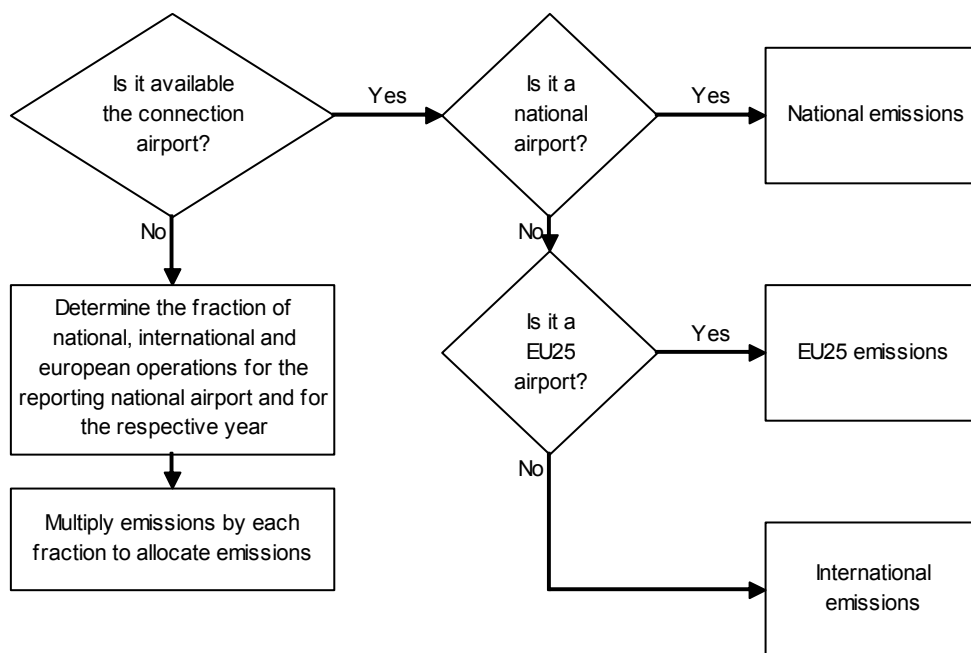
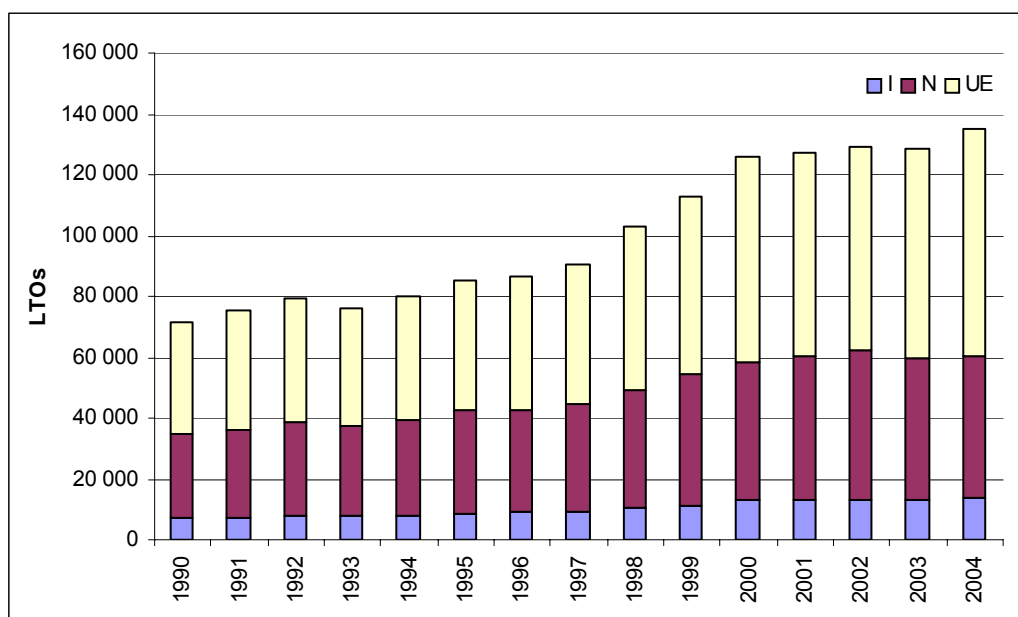


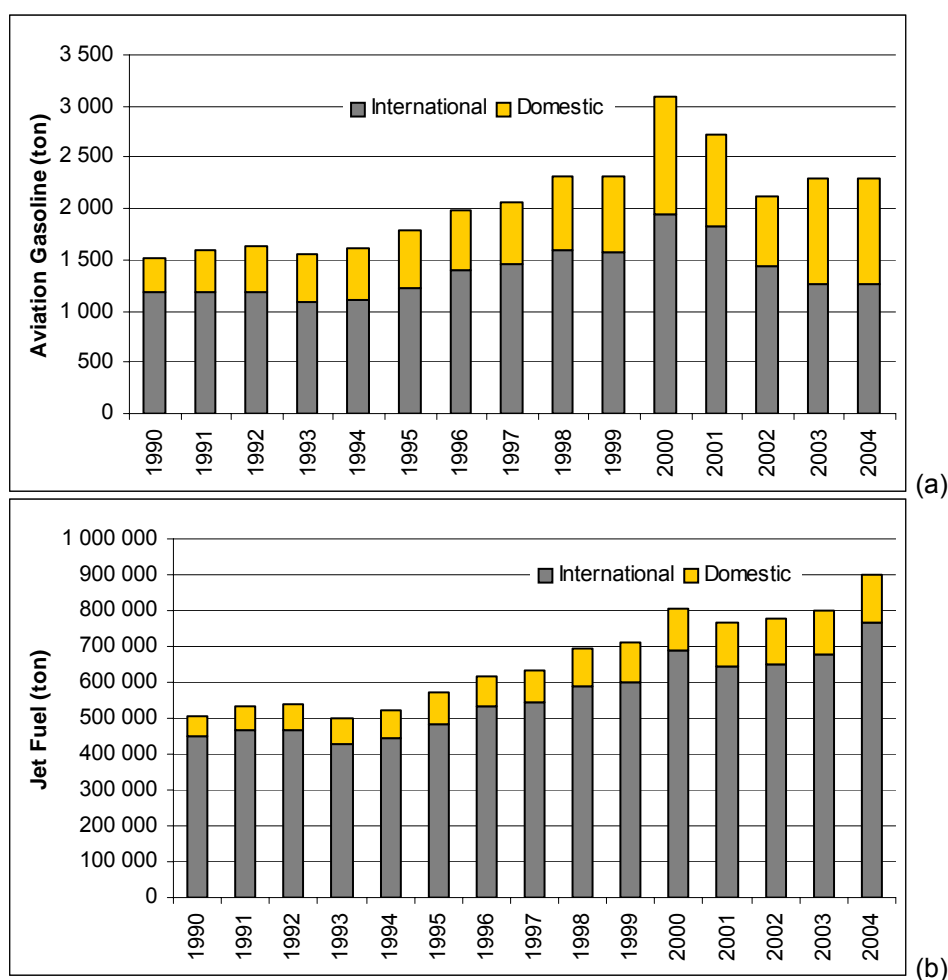
Figure 3.68 – Domestic (N), EU25 (UE) and international (I) LTOs



Fuel Consumption

Although fuel consumption was available from fuel sales statistics from DGGE, fuel estimations had to be estimated from aircraft fuel consumption factors (fuel used per LTO and kilometre cruised) and the number of aircraft movements since the available fuel data was not adequate for IPCC domestic and international disaggregation (Table 3.141). This approach is equivalent to the one used for estimate pollutants such as CO, NO_x, PM, NMVOC and CH₄.

Figure 3.69 – Estimated aviation gasoline (a) and jet fuel (b) consumption



To test the model accuracy, estimated fuel consumption was compared to actual fuel sales.

Figure 3.70 – Estimated consumption and actual aviation gasoline fuel sales

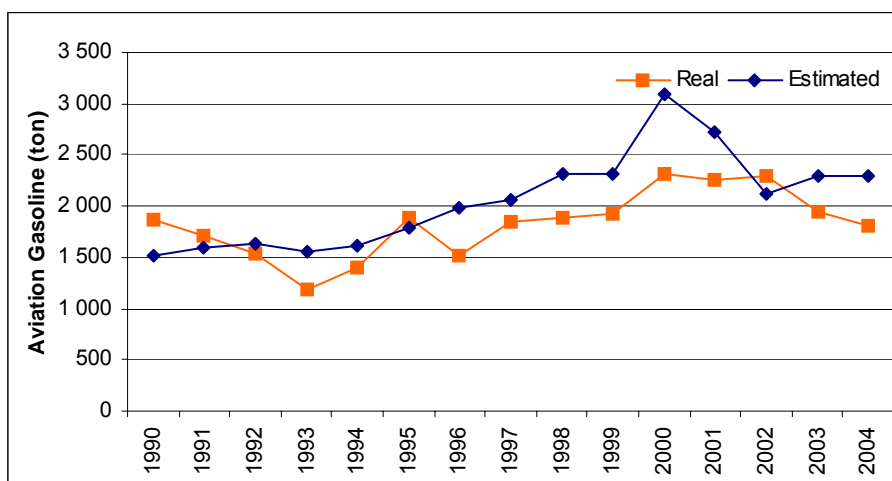
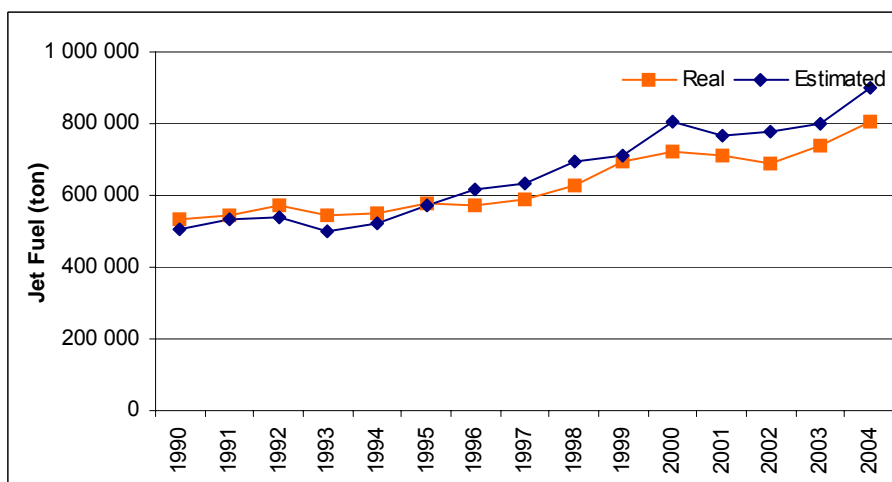
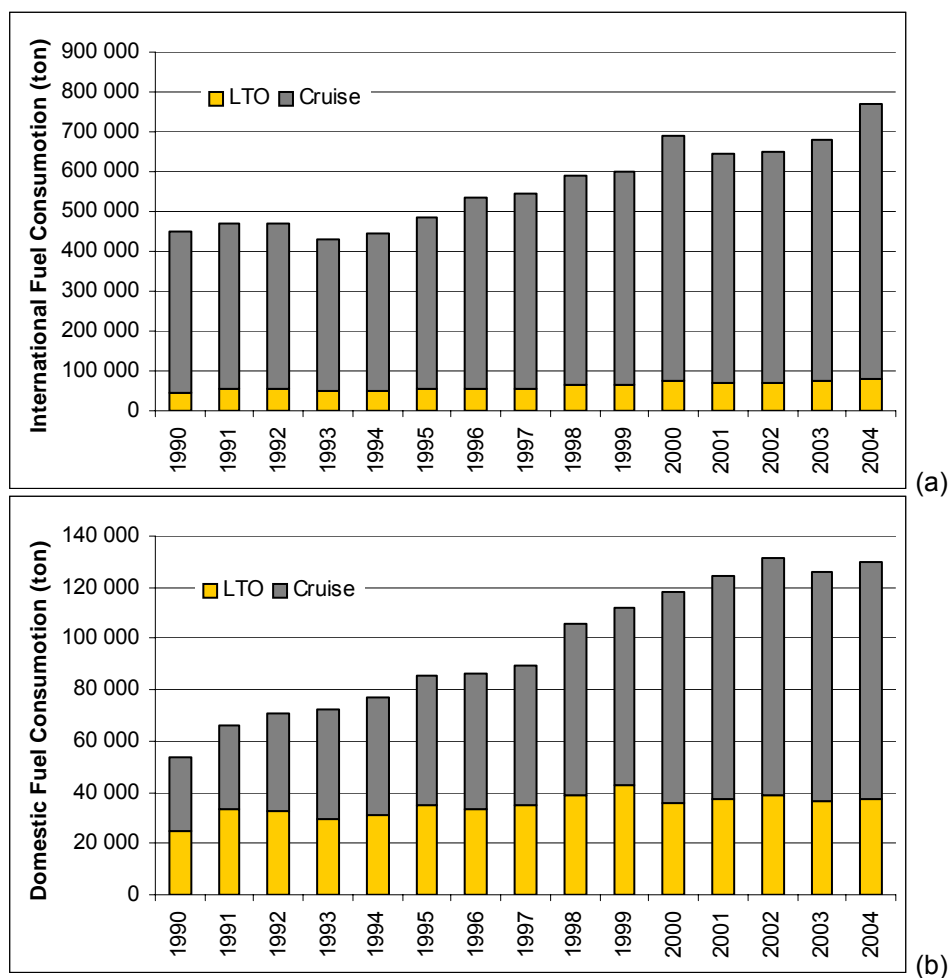


Figure 3.71 – Estimated consumption and actual jet fuel sales



For LTO and cruise fuel use, Figure 3.72 provides the fuel consumption during each mode. The majority of the fuel is consumed under international cruising. Domestic LTO fuel consumption in 2004 was 37 208 ton compared to 24 737 in 1990 (50,4% increase) while consumption under domestic cruise in 2004 was 92 912 ton compared to 27 783 ton in 1990 (234% increase).

Figure 3.72 – LTO and cruise fuel consumption for international (a) and domestic (b) use.



The difference between LTO and cruise fuel growth results in one hand from the increase in LTO fuel efficiency and, in the other hand, from the increase in net flight time under domestic cruise and an increase of energy consumption per cruising hour.

Figure 3.73 – Domestic LTO fuel consumption per LTO.

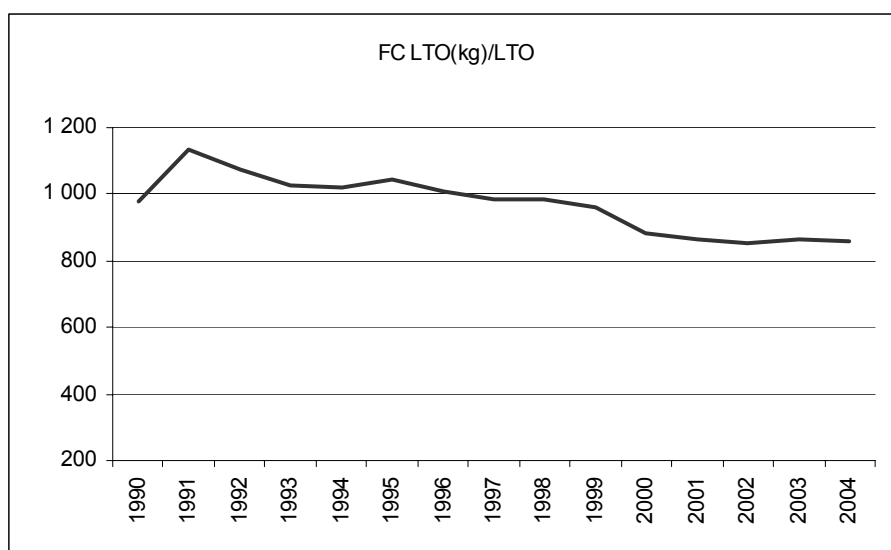
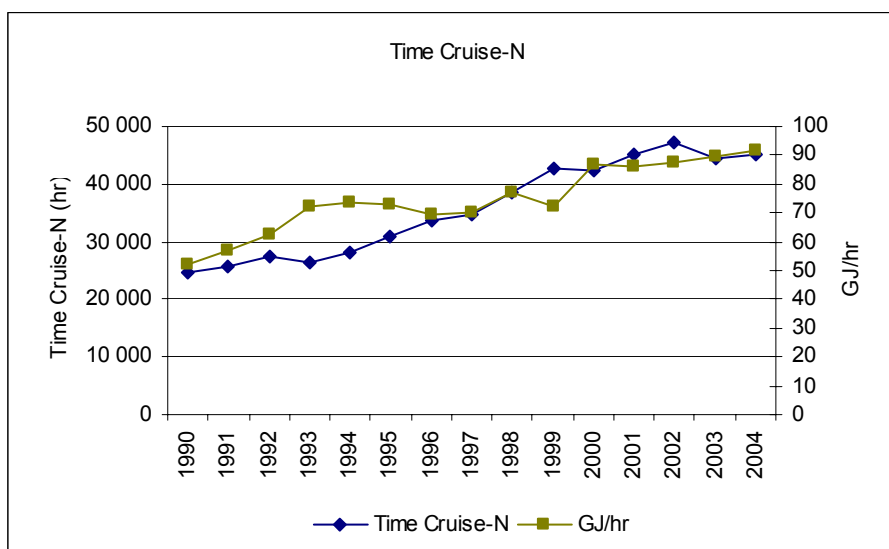


Figure 3.74 – Domestic cruising time and energy consumption per hour.



Uncertainty Assessment

Activity level refers to the fuel domestic consumption which was estimated for LTO and Cruise separately according with the following couple equations.

$$U_{cruise} = \sqrt{U_{movements}^2 + U_{time}^2 + U_{FCcruise}^2}$$

$$U_{lto} = \sqrt{U_{movements}^2 + U_{FClto}^2}$$

The activity level uncertainty (U_{global}) is therefore obtained from:

$$U_{global} = \frac{\sqrt{(E_{cruise} \times U_{cruise})^2 + (E_{lto} \times U_{lto})^2}}{E_{cruise} + E_{lto}}$$

Where,

E_{cruise} , E_{lto} = domestic energy consumption under cruise and LTO (GJ).

Table 3.147 – Aviation activity level uncertainty.

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

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

The uncertainties of emissions factors were set at 5% for CO₂, 100% for methane and one order of magnitude for N₂O, following the recommendations from GPG.

3.2.C.4 WATER BORNE NAVIGATION

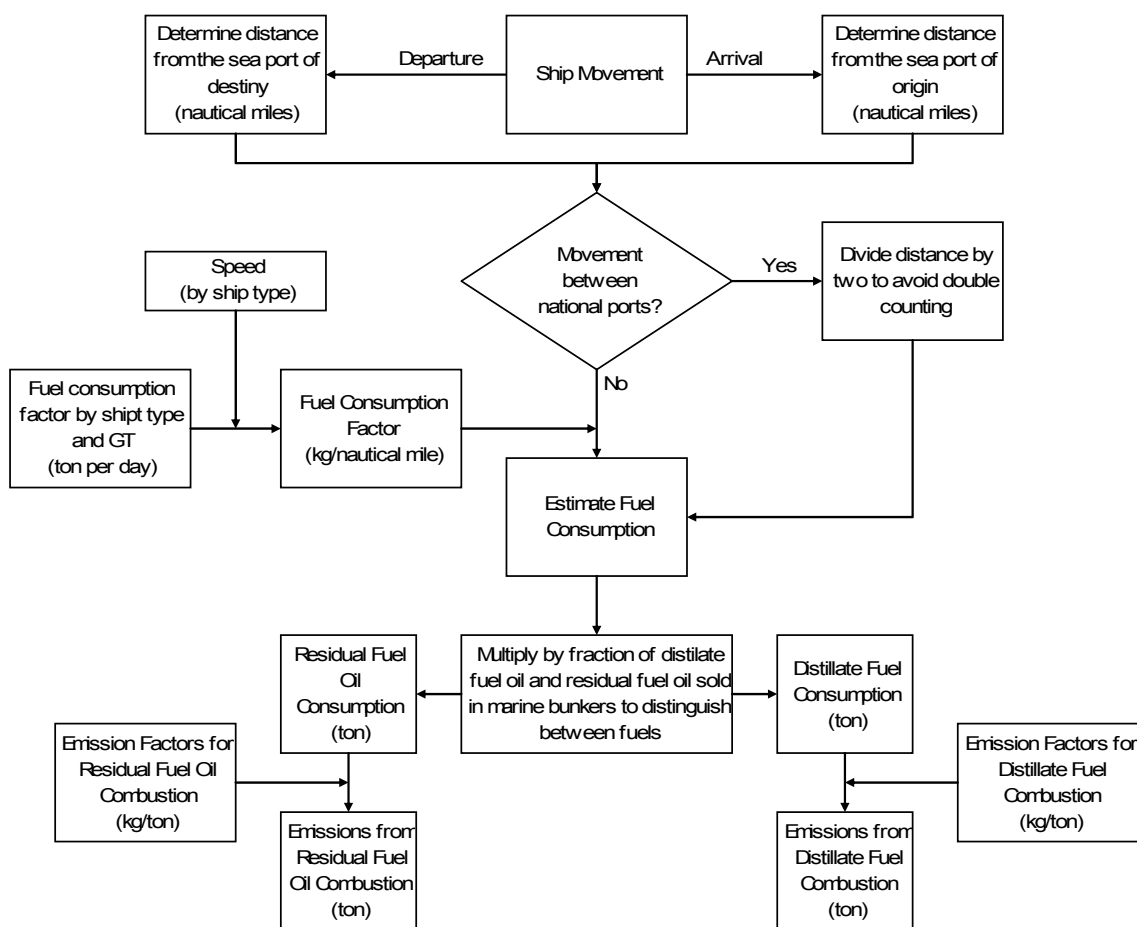
Overview

This sector refers to national ship transport, irrespective of ship flag, between Portuguese ports including traffic to the Azores and Madeira islands. Although excluded from national inventories, international emissions were also estimated considering only 50% of the total distance to the international seaport.

Methodology

Emissions from navigation were calculated according to the EMEP/CORINAIR methodology, an improved tier 1 methodology. First fuel consumption is calculated based on ship movements between ports then emissions are estimated from the fuel use. The distinguish between domestic and international traffic is not fully according with IPCC Good Practices since there is no complete information on passenger and freight. The distinguish was based in the origin and destiny country (see Table 3.141). The general approach could be described as follows:

Figure 3.75 – Generic methodology flowchart.



Emission Factors

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

Table 3.148 – Emission factors for navigation

Pollutant	Unit	Gas-oil	Residual fuel oil
LHV	MJ/kg	40.170	43.310
CO ₂	ton/TJ	74.067	77.367
NO _x	kg/tonne fuel	72.000	72.000
SO _x	kg/tonne fuel	⁽¹⁾ 4.000 ⁽²⁾ 2.000	53.400
CO	kg/tonne fuel	7.400	7.400
NM VOC	kg/tonne fuel	2.400	2.400
CH ₄	kg/tonne fuel	0.050	0.050
N ₂ O	kg/tonne fuel	0.080	0.080
PM	kg/tonne fuel	1.200	7.600
Pb	g/tonne fuel	1.300	0.200
Cd	g/tonne fuel	0.010	0.030
Hg	g/tonne fuel	0.050	0.020
As	g/tonne fuel	0.050	0.500
Cr	g/tonne fuel	0.040	0.200
Cu	g/tonne fuel	0.050	0.500
Ni	g/tonne fuel	0.070	30.000
Se	g/tonne fuel	0.200	0.400
Zn	g/tonne fuel	0.500	0.900
PAH	g/tonne fuel	2.000	2.000

⁽¹⁾ Until year 2000, inclusive;⁽²⁾ After year 2000

Source: EMEP/CORINAIR, IPCC

In order to estimate fuel consumption for use with emission factors from Table 3.148 default consumption factors suggested by EMEP/CORINAIR were used.

Table 3.149 – Consumption factors

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

Legend:

gt – gross tonnage

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

Source: EMEP/CORINAIR

Activity DataShips movements in national sea ports

The activity data from navigation is based on ship movement for individual ships in each national seaport comprehending nine ports in Portugal mainland and four in islands of Madeira and Azores.

The data provided by national seaports reports to the years 1990 and 1995; and to the period between 2000 and 2004. The number of movements and the distances travelled for the period 1991-1994 and 1996-1999 were estimated according with a trend line established between years with available data.

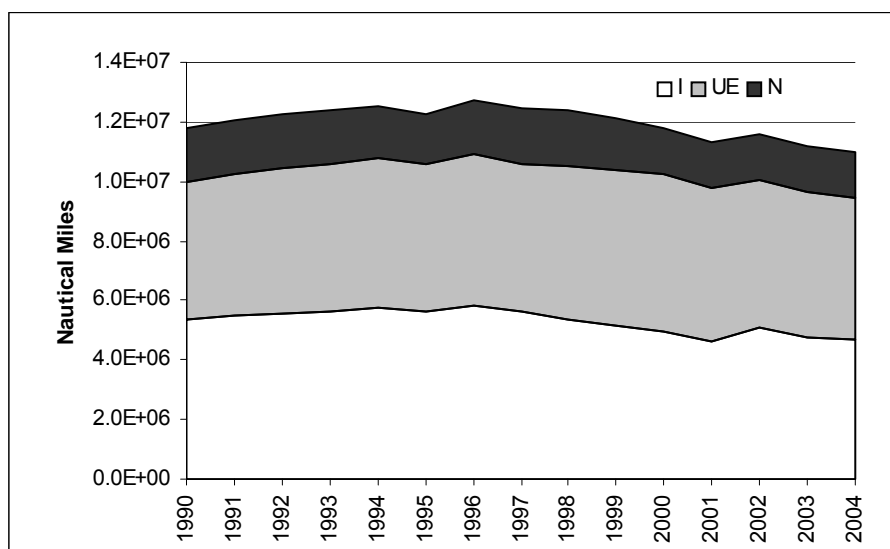
For most cases, data on origin and destiny was also available per movement which allowed to estimate the distances travelled and to distinguish between domestic and international movements.

Table 3.150 – Ship movements

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

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

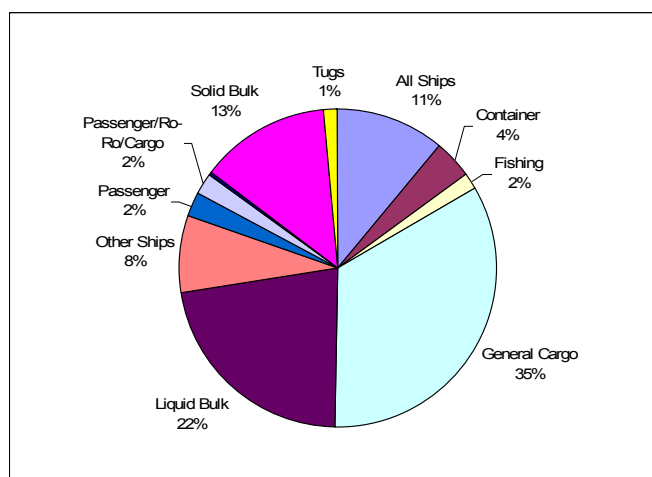
Figure 3.76 – Nautical miles travelled.



Ship Fleet

The fleet is composed mainly by general cargo ships. The fleet from Figure 3.77 refers to all ships that docked in national seaports between 1990 and 2004 irrespective of domestic or international movements.

Figure 3.77 – Ship fleet.



Fuel consumption

Fuel consumption was estimated from fuel consumption factors from Table 3.149. Fuel used in domestic movements corresponds to a fraction of about 12% of the total fuel consumption. International fuel from Table 3.151 is the necessary fuel to perform 50% of the total distance, the remaining 50% is assumed to be allocated to the international country of origin or destiny.

Table 3.151 – Fuel consumption

Fuel Type	Definition	Unit	1990	1991	1992	1993	1994	1995	1996	1997
Residual Fuel Oil	Domestic	kton	56	55	55	55	54	51	54	56
	International	kton	412	425	435	444	447	448	457	443
Distillate Fuel	Domestic	kton	21	21	21	21	20	19	20	21
	International	kton	156	160	164	168	169	169	172	167

Fuel Type	Definition	Unit	1998	1999	2000	2001	2002	2003	2004	2005
Residual Fuel Oil	Domestic	kton	58	52	47	45	48	48	49	-
	International	kton	430	433	435	417	426	417	426	-
Distillate Fuel	Domestic	kton	22	20	18	17	18	18	18	-
	International	kton	162	163	164	157	161	158	161	-

Tugs Fuel consumption

Data concerning tugs assistance operations within the national seaports allowed the incorporation of these emissions in the inventory. Tug fuel consumption was estimated for each manoeuvring ship in a seaport following the criteria shown in the Table 3.152. Specific tug fuel consumption factors were supplied by IPTM.

Table 3.152 – Criteria employed in the tugs fuel consumption estimation.

Ship Type	Seaport	Assisted Arrivals (%)	Assisted Departures (%)	N.º Of Tugs/Arrival	N.º Of Tugs/Departure
Small Size	All	20	0	1	0
Medium Size	All	50	25	1	1
Large Size	All	100	100	2	1
Super Large Size	Sines and Leixões	100	100	3	2
Super Large Size	All except Sines and Leixões	100	100	2	2

This estimation required the ship size classification expressed in table (Table).

Table 3.153 – Ship type classification for tugs fuel consumption estimation.

Ship Type	GT
Small Size	GT≤1000
Medium Size	10000≤GT<10000
Large Size	50000≤GT<100000
Super Large Size	GT>50000

GT: gross tonnage

Finally the fuel consumption was added to the ship that needed the tugs service.

Uncertainty Assessment

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

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

Movements uncertainty was assumed to be 5% as suggested in IPCC Good Practice Guidance and Uncertainty Management. The distance uncertainty was calculated assuming that ships speeds were constant between origin and destiny seaports. This allows the indirect assessment of the uncertainty through the travelling time between seaports. For the same OD it is possible to estimate uncertainty according with differences between travelling times performed by the same type of ships. Finally, it was assumed an uncertainty of 50% for fuel consumption factors proposed by EMEP/CORINAIR. Activity level uncertainty was estimated about 51% as referred in Table 3.154.

Table 3.154 – Navigation activity level uncertainty.

Source	Parameter	Value
All	Uglobal	51%
Movements	Umovements	5%
Distance Travelled	Udistance	16%
Fuel Consumption Factor	Ufc	48%

Following the recommendations of GPG the uncertainties of emission factor for CH₄ and N₂O, and for all types of vessels and navigation, were set respectively to 100% and 1000%.

3.2.C.5 OTHER MOBILE SOURCES

OVERVIEW

There is no much information allowing the estimation of emissions from off-road vehicles and machines, mainly because they are not individualized in the energy balances from DGGE. The only exception are the agriculture/forestry sector where it is more or less evident that all gas-oil is used as energy source to vehicles and machines, and the fishing vessels.

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

AGRICULTURE

Overview

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

Only gas-oil is assumed to be a energy source for mobile equipments in this activity. Although emissions from mobile sources in agriculture and forestry are reported under category source 1A4c, methodology used to estimate emissions from this activity is better presented here together with the other individualized mobile sources.

Methodology

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

$$\text{Fossil}_{\text{CO}_2(y)} = \sum_f [\text{EF}_{\text{CO}_2} * \text{Fac}_{\text{OX}} * \text{Cons}_{\text{Fuel}(y)} * \text{LHV}] * 10^{-5}$$

where

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

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

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

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

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

Sulphur oxides emission from combustion are estimated from fuel consumption quantities and sulphur content from:

$$\text{SO}_{x(y)} = 2 * \text{Fuel}_{\text{Cons}(y)} * \text{S}_{(y)} * 10^{-2}$$

where

SO_{x(y)} - Sulphur oxide emission in year y (ton/yr);

FuelCons_(y) - Consumption of gas oil in off-road vehicles and machines in agriculture/forestry sector in year y (ton/yr);

S_(y) - Sulphur content of gas oil (mass percentage).

Emissions for other pollutants are estimated with the following formula:

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

where

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

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

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

Emission Factors

The set of emission factors utilized to estimate air emissions from use of gas oil in agriculture machines and other off-road vehicles were determined as the average value of the values proposed in tables I-47 and I-49 of the Revised 1996 IPCC Guidelines (IPCC,1997), except the emission factor for Particulate Matter, set from the EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002).

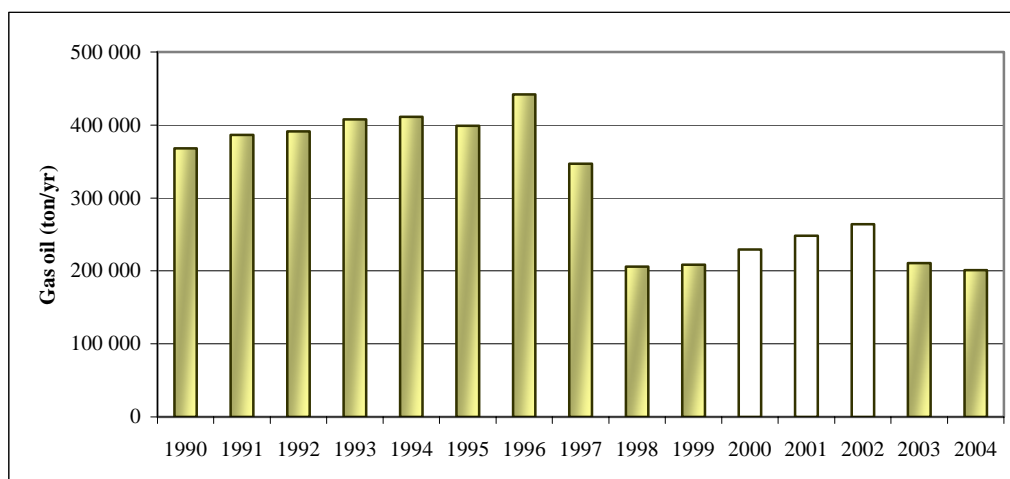
Table 3.155 – Emission factors for gas oil use in agriculture machines and other off-road vehicles

Parameter	EF	Unit
LHV	43.3	MJ/kg
SOx	0.3	%
NOx	56.9	g/kg
NM VOC	8.4	
CH ₄	0.3	
CO	20.7	
U CO ₂	3 136	
Fac _{ox}	0.990	0..1
N ₂ O	1.3	g/kg
NH ₃	0.007	
PM	5.87	
As	0.05	
Cr	0.05	g/ton
Cu	1.7	
Ni	0.07	
Se	0.01	
Zn	1	

Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to 2004 from General-Directorate of Geology and Energy (DGE) in the energy balance. Although there is no clear specification, in original database, in which combustion equipment each fuel is used it was assumed that all gas-oil is used in machines and other off-road vehicles. Quantities that were consumed are presented in Figure 3.78.

Figure 3.78 - Consumption of gas-oil in machines and other off-road vehicles (1990-2004)



Uncertainty Assessment

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

FISHING VESSELS

Overview

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

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

Methodology

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

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

where

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

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

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

Emissions of carbon dioxide are estimated from:

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

Where,

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

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

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

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

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

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

Sulphur oxides emission from combustion are estimated from fuel consumption quantities and sulphur content from:

$$SO_{x(n,y)} = 2 * \sum_f [Fuel_{Cons(n,f,y)} * S_{(f,y)} * 10^{-2}]$$

where

$SO_{x(n,y)}$ - Sulphur oxide emission estimated from consumption from navigation or fishing in year y from ships of class n (ton/yr);

$Fuel_{Cons(n,f,y)}$ - Consumption of fuel f in ship n in year y (ton/yr);

$S_{(f,y)}$ - Sulphur content of fuel (mass percentage).

Emission Factors

Except for carbon dioxide and sulphur oxide, emissions were estimated using default emission factors (kg/ton) from IPCC 1996 Revised Guidelines (table I-47 in IPCC,1997) for most pollutants. The following criteria was used to chose the most suitable emission factors:

- "Ocean-going ships" for national and international transport navigation, deep-sea fishing and cod fishing;
- "Boat" in the case of coastal fishing vessels.

For carbon dioxide emission factors are in kg/GJ in a similar mode to other combustion activities. Sulphur oxide emissions are dependent on sulphur content of fuel. Particulate matter emission factors are from Lloyd's register (1995) and EMEP/CORINAIR (EEA,2002), and are function of type of fuel. Emission factors are presented in next table.

Table 3.156 – Emission factors for Water Borne Navigation and Fishing Vessels

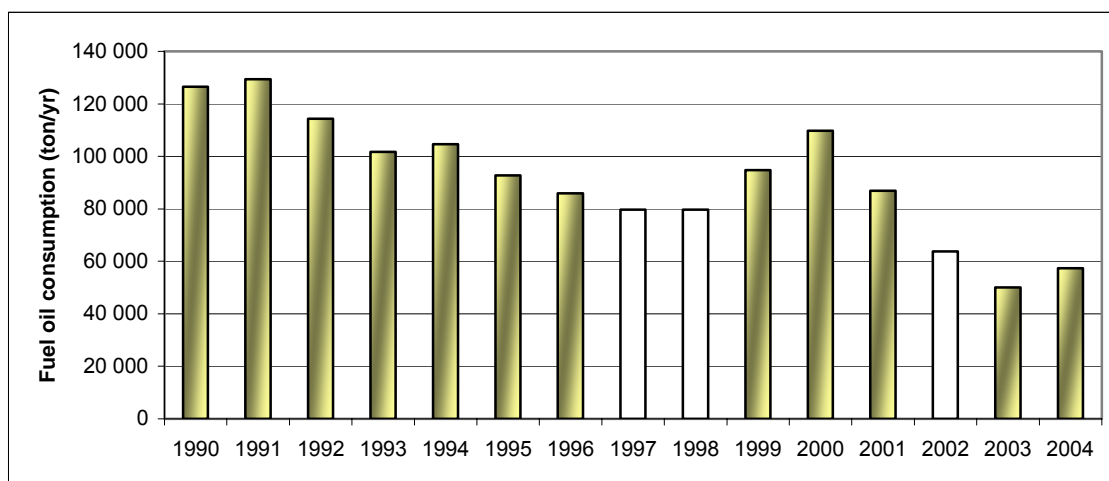
EF	Units	Coastal Fisheries	Other Fisheries	Coastal Fisheries	Other Fisheries
		Gas-oil		Fuel-oil	
LHV	MJ/kg	43.31		40.17	
SO _x	%	0.3		3	
NO _x	g/kg	67.5	87	67.5	87
NM VOC	g/kg	4.9			
CH ₄	g/kg	0.23			
CO	g/kg	21.3	1.9	21.3	1.9
EF _{CO2}	kg/GJ	74.07		77.37	
C _{Fossil}	%	100			
Fac _{OX}	0..1	0.99			
N ₂ O	g/kg	0.08			
PM	g/kg	1.2		7.6	
As	g/ton	0.05		0.5	
Cd	g/ton	0.01		0.03	
Cr	g/ton	0.04		0.2	
Cu	g/ton	0.05		0.5	
Hg	g/ton	0.05		0.02	
Ni	g/ton	0.07		30	
Pb	g/ton	0.2		1.3	
Se	g/ton	0.2		0.4	
Zn	g/ton	0.5		0.9	

Activity Data

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

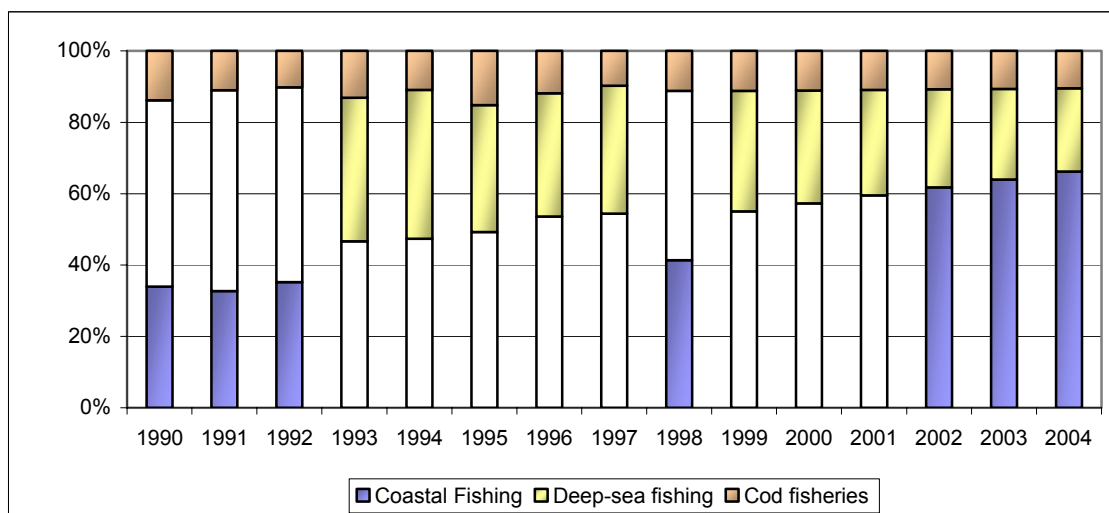
³⁴ Use of diesel oil and fuel oil is insignificant, always less than 2.5% of gas oil consumption.

Figure 3.79 – Consumption of fuel oil in fishing bunkers (1990-2004)



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

Figure 3.80 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries (1990-2004)



³⁵ The same situation that was described for transport navigation is true here. It was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha, gas-oil and diesel oil, but available emission factors again do not distinguish these fuel types

³⁶ All fishing activities were allocated to national total although it is true that some may not be realized in territorial waters or EMEP area. That is clearly the case of cod-fish fishing and it is also partly true for deep-sea fishing.

Uncertainty Assessment

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

Following the recommendations of GPG the uncertainties of emission factors for CH₄ and N₂O, and for all types of vessels and navigation, were set respectively to 100 per cent and 1000 per cent.

3.2.C.6 ANNEXES

AVIATION

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

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

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

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

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

Airport	Parameter	Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
FAO	CH ₄	I	0.29	0.30	0.27	0.26	0.29	0.19	0.28	0.25	0.18	0.13
FAO	CH ₄	N	0.28	0.11	0.11	0.15	0.15	0.14	0.13	0.13	0.12	0.12
FAO	CH ₄	UE	0.26	0.25	0.24	0.25	0.26	0.22	0.23	0.20	0.20	0.20
FAO	CO	I	7.23	6.97	6.51	5.98	5.94	4.99	5.75	5.42	5.01	4.10
FAO	CO	N	11.83	4.70	4.58	4.51	4.51	4.29	4.19	4.15	4.00	3.82
FAO	CO	UE	6.43	5.97	5.78	5.74	5.54	5.28	5.37	5.01	4.89	4.78
FAO	FC	I	4 036	3 956	3 762	3 411	3 661	3 454	3 529	3 385	3 491	3 073
FAO	FC	N	2 213	1 926	1 980	2 515	2 790	2 839	2 618	2 519	2 823	2 731
FAO	FC	UE	3 082	3 051	2 980	2 966	2 993	2 938	2 957	2 777	2 748	2 713
FAO	NMVOC	I	2.63	2.66	2.45	2.36	2.64	1.68	2.54	2.21	1.65	1.21
FAO	NMVOC	N	2.48	1.02	1.02	1.35	1.39	1.24	1.16	1.13	1.11	1.04
FAO	NMVOC	UE	2.34	2.28	2.19	2.29	2.34	1.99	2.10	1.83	1.78	1.78
FAO	NO _x	I	53.18	53.61	51.81	48.70	56.28	51.10	53.44	51.35	54.57	46.74
FAO	NO _x	N	23.81	21.38	21.82	28.25	33.55	34.96	33.12	32.37	37.01	36.59
FAO	NO _x	UE	35.83	36.37	35.60	36.63	39.03	37.54	38.15	35.74	35.91	36.18
FLW	CH ₄	I	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	CH ₄	N	0.51	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	CH ₄	UE	0.51	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	CO	I	27.76	3.86	1.59	1.52	1.54	1.58	1.58	1.59	1.65	1.65
FLW	CO	N	27.76	3.86	3.81	2.65	2.98	3.36	3.32	3.41	3.56	3.57
FLW	CO	UE	27.76	3.86	2.28	1.63	1.76	1.99	1.96	2.05	2.27	2.30
FLW	FC	I	461	403	193	191	194	198	197	199	203	204
FLW	FC	N	461	403	295	283	324	357	354	362	375	376
FLW	FC	UE	461	403	209	191	213	235	232	240	260	262
FLW	NMVOC	I	4.61	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLW	NMVOC	N	4.61	0.00	0.16	0.01	0.00	0.00	0.00	0.00	0.00	0.00
FLW	NMVOC	UE	4.61	0.00	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00
FLW	NO _x	I	0.58	3.37	1.81	1.78	1.83	1.85	1.85	1.86	1.90	1.90
FLW	NO _x	N	0.58	3.37	2.39	2.38	2.78	3.03	3.01	3.07	3.17	3.17
FLW	NO _x	UE	0.58	3.37	1.85	1.70	1.97	2.13	2.10	2.16	2.31	2.33
FNC	CH ₄	I	0.22	0.14	0.14	0.09	0.12	0.15	0.15	0.24	0.45	0.17
FNC	CH ₄	N	0.45	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
FNC	CH ₄	UE	0.28	0.17	0.17	0.14	0.12	0.17	0.14	0.14	0.16	0.19
FNC	CO	I	6.98	4.61	4.66	3.47	4.07	4.57	4.17	5.04	7.44	5.09
FNC	CO	N	23.75	3.91	4.01	3.70	3.59	3.91	3.61	3.64	3.71	3.97
FNC	CO	UE	11.14	5.12	5.26	4.51	4.08	4.92	4.25	4.30	4.56	5.32
FNC	FC	I	4 194	3 752	3 397	2 252	3 082	3 719	3 261	3 444	4 158	3 693
FNC	FC	N	1 019	784	747	738	770	881	796	793	876	759
FNC	FC	UE	2 610	2 594	2 561	2 165	1 997	2 658	2 124	2 144	2 316	2 598
FNC	NMVOC	I	1.96	1.24	1.23	0.82	1.12	1.38	1.33	2.20	4.08	1.56
FNC	NMVOC	N	4.07	0.13	0.15	0.14	0.14	0.17	0.15	0.15	0.20	0.17
FNC	NMVOC	UE	2.54	1.49	1.52	1.30	1.12	1.52	1.27	1.29	1.41	1.70
FNC	NO _x	I	60.60	55.84	49.14	32.97	47.39	58.27	49.63	52.36	66.71	55.00
FNC	NO _x	N	9.38	9.00	8.39	8.38	9.15	10.70	9.34	9.29	10.69	8.33
FNC	NO _x	UE	28.73	31.46	30.52	26.01	25.41	35.29	26.91	26.93	30.32	30.54
HOR	CH ₄	I	0.32	0.10	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
HOR	CH ₄	N	0.50	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01
HOR	CH ₄	UE	0.33	0.14	0.11	0.10	0.10	0.13	0.10	0.11	0.11	0.08
HOR	CO	I	13.65	4.62	2.30	2.19	1.96	1.81	2.04	2.11	2.12	2.15

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

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

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

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

3.2.D Other Sectors (CRF 1A4)

3.2.D.1 OVERVIEW

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

3.2.D.2 METHODOLOGY

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

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

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

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

where,

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

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

EF_C - Carbon content of fuel f expressed in total Carbon Dioxide emissions (kg CO₂/GJ);

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

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

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

Emissions of other pollutants that were also calculated from energy activity rate use the following basic formula (Energy Approach):

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

where:

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

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

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

Emissions of SO_x are directly related to the fuel content of the fuel, and were estimated from:

$$Emi_{SOx(s)} = 2 * \sum_f \sum_t [S_{(f,s,t,y)} / 100 * Fuel_{Cons(f,s,t)}]$$

where:

$Emi_{SOx(s)}$ - Total emissions of SO_x from sub-sector s (ton/yr);

$S_{(f,s,t)}$ - Sulphur content of fuel f used in sub-sector s and equipment t in year y (%);

$Fuel_{Cons(f,s,t)}$ - Fuel consumption for each particular fuel and in each equipment of technology t (ton/yr).

In the case of emissions of Heavy Metals the following equation was used:

$$HM_{p(f,s)} = Fuel_{Cons(f,s)} * CF_{(f)} * EF_{HM(f,y,p)} * 10^{-6} * (1 - AshRet_{(f,s,p)} * 10^{-2})$$

and,

$HM_{p(f,s)}$ - Heavy Metal p emission estimated from consumption of fuel f in sub-sector s (ton/yr);

$Fuel_{Cons(f,s)}$ - Consumption of fuel f in sub-sector s (any unit in agreement with CF);

$EF_{HM(f,y,p)}$ - Emission Factor for heavy metal p from fuel f in year y (g/ton);

$CF_{(f)}$ - Factor to convert FuelCons from original units into metric tons. Equals 1 except to natural gas where it refers to density (ton/original unit);

$AshRet_{(f,s,p)}$ - Retention of Heavy Metal p in ash from fuel f under burning conditions in sub-sector s (mass percentage).

3.2.D.3 ACTIVITY DATA

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

Table 3.157 - Fuels consumption in the residential sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996
Residual Oil	L	203	63 530	62 097	55 535	51 459	66 691	42 565	43 312
Diesel/Gas Oil	L	204	158 214	210 819	285 505	205 027	190 282	200 936	132 606
Kerosene	L	206	793 373	753 052	626 060	530 505	513 747	355 816	415 879
Motor Gasoline	L	208	6 185	7 785	5 900	5 649	6 252	9 577	13 749
LPG	L	303	22 837 620	24 057 966	25 680 840	27 229 913	27 655 381	27 940 723	30 167 625
City Gas	L	308	1 923 876	1 950 110	1 984 435	2 073 096	1 984 456	1 929 958	1 977 160
Natural Gas	G	301	0	0	0	0	0	0	0
Wood	B	111	53 770 921	51 344 184	49 611 501	48 513 399	48 000 716	48 033 473	48 172 943
Charcoal	B	112	749 950	738 791	727 632	716 473	705 314	694 155	682 996

Fuel	1997	1998	1999	2000	2001	2002	2003	2004
Residual Oil	40 271	10 915	3 880	2 594	0	0	0	0
Diesel/Gas Oil	91 896	105 979	144 221	90 426	82 408	120 300	380 121	666 824
Kerosene	728 302	761 508	705 271	365 327	194 406	147 838	89 780	88 601
Motor Gasoline	14 898	14 691	6 077	772	93	24 848	36 159	37 346
LPG	29 240 674	30 788 636	32 600 574	33 436 221	30 740 137	30 729 805	29 733 968	29 234 481
City Gas	1 991 632	2 106 088	2 039 388	1 212 913	156 763	0	0	0
Natural Gas	31 980	361 961	1 360 508	2 883 241	4 450 418	5 568 369	6 640 771	6 880 762
Wood	48 326 360	47 907 950	47 280 335	47 071 130	47 280 335	47 280 335	48 127 150	48 477 991
Charcoal	671 837	660 678	649 519	638 360	627 201	616 042	604 883	593 724

Figure 3.81 – Total Energy Consumption in fuels in the residential sector between 1990 and 2004

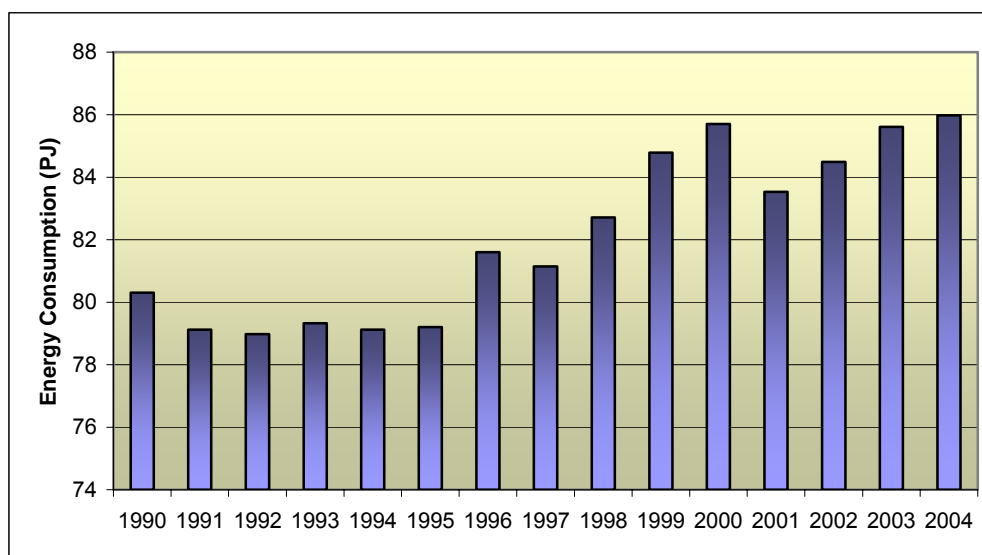


Figure 3.82 – Consumption of energy in fuels in the residential sector in 1990 and 2004

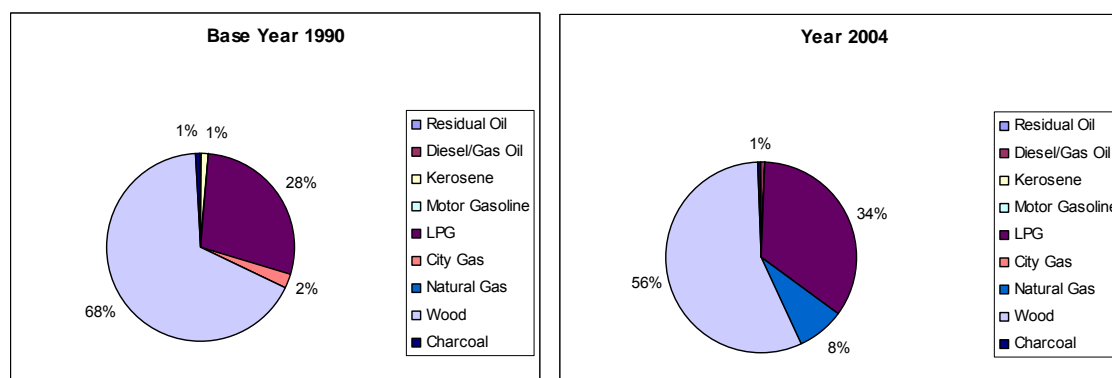


Table 3.158 - Fuels consumed in the commercial, services and institutional sector (GJ)

Fuel		NAPFUE	1990	1991	1992	1993	1994	1995	1996
Residual Oil	L	203	2 376 335	2 081 213	1 985 815	2 066 483	3 667 114	4 271 661	3 302 636
Diesel/Gas Oil	L	204	5 636 269	6 913 150	8 274 873	8 440 117	8 586 149	7 883 856	8 720 784
Kerosene	L	206	74 874	33 376	64 163	73 739	24 495	13 459	12 677
Motor Gasoline	L	208	579 235	638 264	617 276	604 690	1 035 873	1 174 153	1 418 403
LPG	L	303	1 166 321	1 337 385	1 538 519	1 847 562	1 821 391	1 234 531	2 494 179
City Gas	L	308	504 399	556 773	528 075	643 808	647 871	732 803	785 507
Natural Gas	G	301	0	0	0	0	0	0	0
Biogas	B	309	0	0	0	0	0	0	0

Fuel	1997	1998	1999	2000	2001	2002	2003	2004
Residual Oil	1 387 822	2 836 712	3 438 705	3 312 313	3 447 019	3 532 016	2 905 392	3 150 365
Diesel/Gas Oil	13 097 397	16 708 519	18 339 696	18 379 823	21 943 150	24 179 733	29 752 522	33 040 833
Kerosene	25 053	27 126	17 190	6 133	7 568	9 489	7 340	7 202
Motor Gasoline	2 592 133	3 260 397	3 216 908	2 215 997	2 852 911	2 485 291	2 362 703	2 424 946
LPG	3 734 954	3 904 492	4 121 761	4 297 205	5 068 917	4 978 362	5 147 243	5 270 092
City Gas	777 866	908 944	1 044 085	732 238	69 195	0	0	0
Natural Gas	14 258	509 290	1 438 849	2 330 208	3 651 585	4 653 783	5 932 664	5 954 088
Biogas	0	0	49 772	101 885	54 356	60 473	48 419	100 729

Figure 3.83 – Total Energy Consumption in fuels in the commercial/services/institutional sector between 1990 and 2004

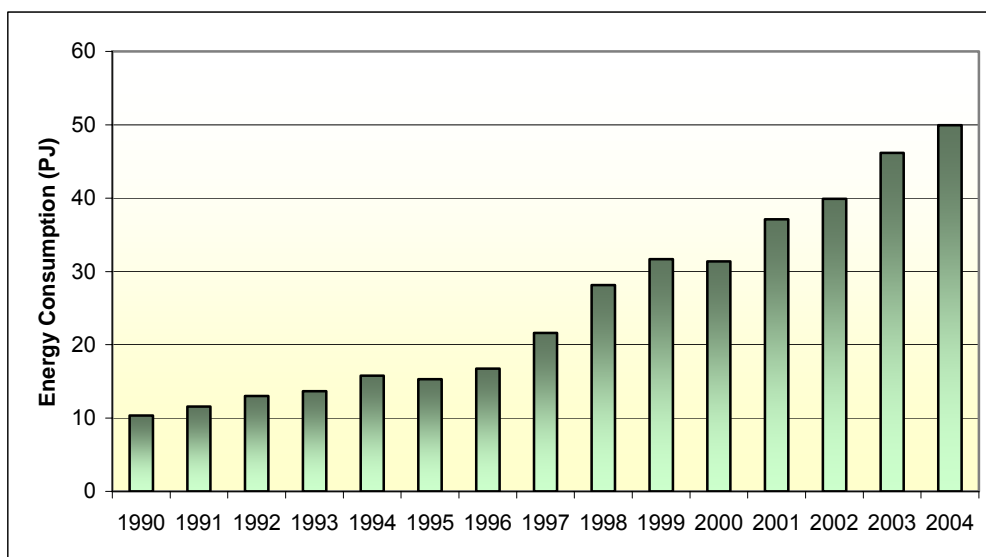


Figure 3.84 – Consumption of energy in fuels in the commercial/services/institutional sector in 1990 and 2004

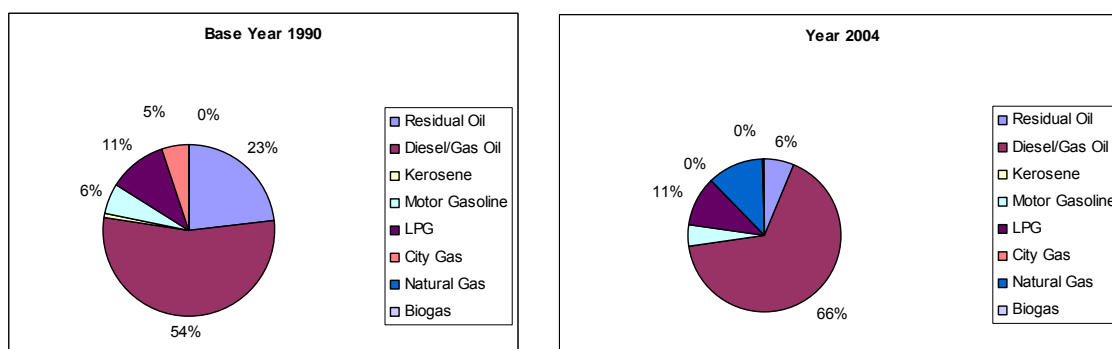


Table 3.159 - Fuels consumed in agriculture and forestry sector (GJ) (excluding mobile sources)

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

Fuel	1997	1998	1999	2000	2001	2002	2003	2004
Residual Oil	548 092	475 768	678 844	891 798	802 636	1 210 609	1 086 402	983 776
Kerosene	426 745	493 714	24 152	44 370	47 054	50 254	47 209	48 886
Motor Gasoline	197 454	174 300	159 631	42 694	119 459	106 749	116 899	117 357
LPG	559 823	713 407	674 208	496 566	672 831	639 244	532 167	523 118
Natural Gas	0	32	158	4 423	192 700	257 274	276 779	266 981
Biogas	0	0	0	9 294	7 773	5 939	6 344	11 122

Figure 3.85 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources) between 1990 and 2004

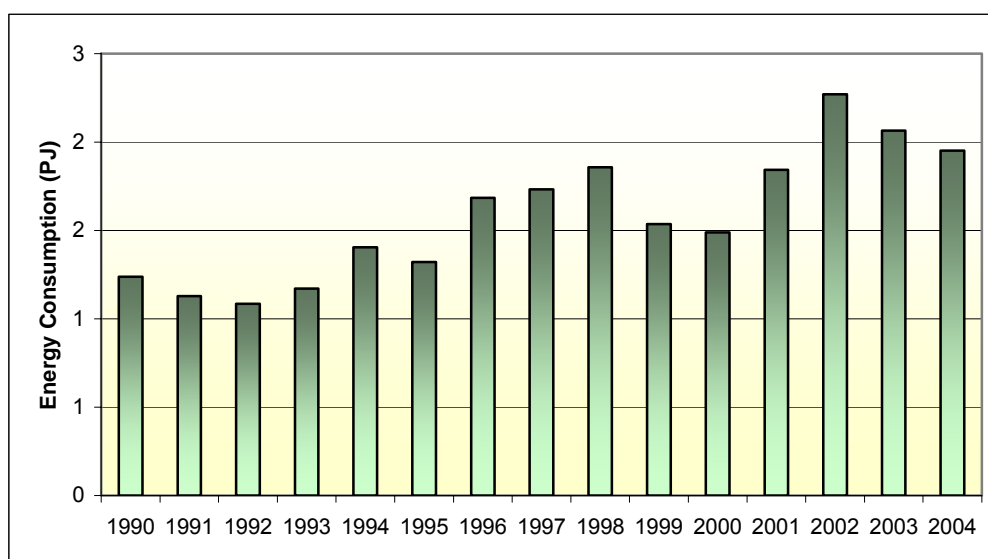


Figure 3.86 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2004

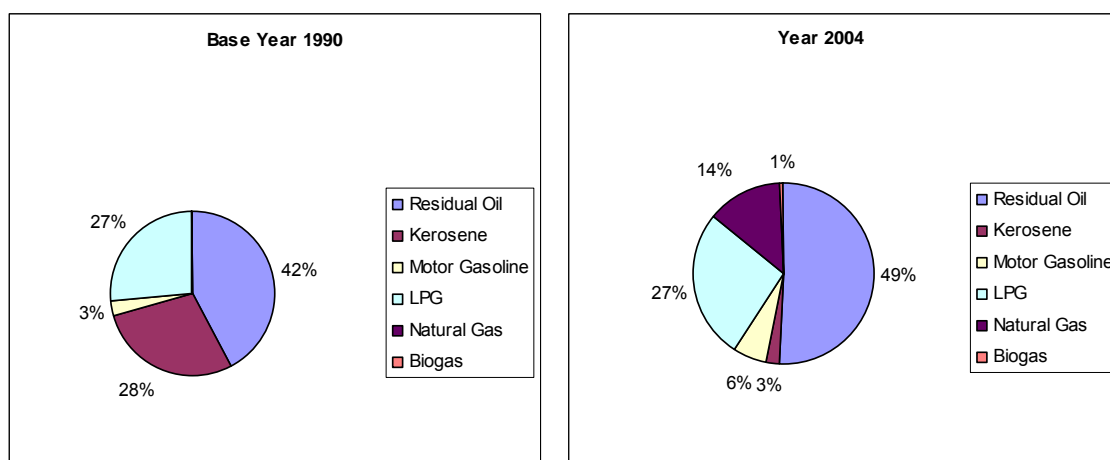
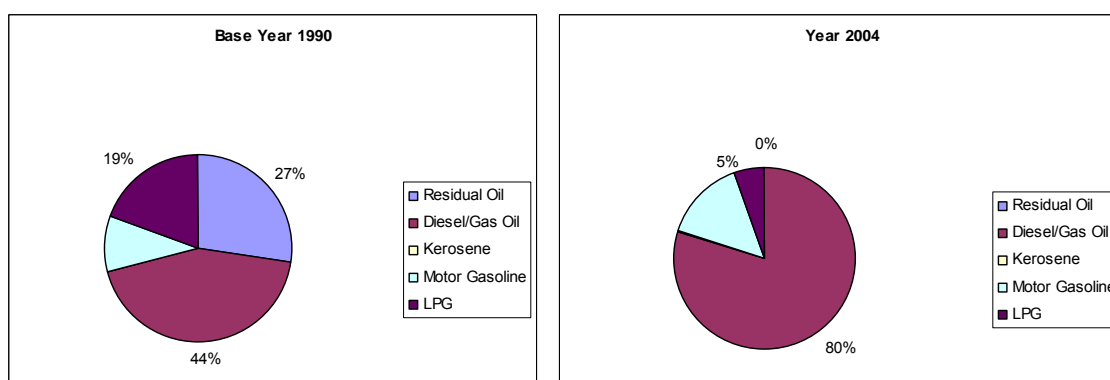


Table 3.160 - Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ)

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

Fuel	1997	1998	1999	2000	2001	2002	2003	2004
Residual Oil	8 782	6 225	49 567	6 469	18 044	28 112	25 325	0
Diesel/Gas Oil	150 903	539 112	769 712	1 000 313	2 114 053	1 553 975	1 220 053	1 396 791
Kerosene	0	2 651	74 915	10 073	94	47	47	319
Motor Gasoline	727	4 038	61 546	278 979	286 123	280 695	278 521	260 737
LPG	3 900	2 529	8 429	20 796	32 627	21 126	20 695	91 236

Figure 3.87 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2004



3.2.D.4 EMISSION FACTORS

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Table 3.161– Emissions factors for the domestic sector: Low Heating Value (LHV)/Net Calorific Value (NCV) and Greenhouse gases

Fuel		NAPFUE	LHV	CO ₂			CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.17	77.4	0.990	100	5.1	0.14
Diesel/Gas Oil	L	204	43.31	74.1	0.990	100	5.0	1.55
Kerosene	L	206	43.72	71.9	0.990	100	5.0	1.55
Motor Gasoline	L	208	44.77	69.3	0.990	100	9.9	0.6
LPG	L	303	47.28	63.1	0.995	100	1.5	1.4
City Gas	L	308	15.69	60.0	0.995	100	1.5	1.4
Natural Gas	G	301	45.97	56.1	0.995	100	2.5	0
Wood	B	111	12.55	109.6	1.000	0	300	4.3
Charcoal	B	112	25.10	109.6	1.000	0	300	4.3

Table 3.162– Emissions factors for the domestic sector: Indirect Precursor gases

Fuel		NAPFUE	NO _x	NMVOC	CO
			g/GJ	g/GJ	g/GJ
Residual Oil	L	203	160	3	5.1
Diesel/Gas Oil	L	204	577.5	51	5
Kerosene	L	206	55	51	5
Motor Gasoline	L	208	1300	100	9.9
LPG	L	303	65	3	1.5
City Gas	L	308	65	3	1.5
Natural Gas	G	301	40	3	2.5
Wood	B	111	67	400	300
Charcoal	B	112	67	400	300

Table 3.163– Emissions factors for the domestic sector: Sulphur content of fuel (%S)

Year	Motor Gasoline	Kerosene	Gas Oil	Residual Fuel Oil	LPG/ city gas	Wood/ Charcoal	Natural Gas
1990	0.100	0.15	0.300	2.84	0.0016	0	0.0007
1991	0.100	0.15	0.300	2.60	0.0016	0	0.0007
1992	0.100	0.15	0.300	2.60	0.0016	0	0.0007
1993	0.100	0.15	0.300	2.60	0.0016	0	0.0007
1994	0.100	0.15	0.300	2.60	0.0016	0	0.0007
1995	0.100	0.15	0.200	2.60	0.0016	0	0.0007
1996	0.100	0.15	0.050	2.60	0.0016	0	0.0007
1997	0.100	0.15	0.050	2.60	0.0016	0	0.0007
1998	0.100	0.15	0.050	2.60	0.0016	0	0.0007
1999	0.100	0.15	0.050	2.60	0.0016	0	0.0007
2000	0.100	0.15	0.050	2.60	0.0016	0	0.0007
2001	0.015	0.15	0.050	2.60	0.0016	0	0.0007
2002	0.015	0.15	0.035	2.60	0.0016	0	0.0007
2003	0.015	0.15	0.035	1.00	0.0016	0	0.0007
2004	0.015	0.15	0.035	1.00	0.0016	0	0.0007

Table 3.164– Emissions factors for the domestic sector: Particulate Matter

Fuel		NAPFUE	TSP g/GJ	PM ₁₀	PM _{2.5}	PM _{1.0}
				(% TSP)		
Residual Oil	L	203	53.0	62	23	14
Diesel/Gas Oil	L	204	6.5	55	42	37
Kerosene	L	206	6.5	55	42	37
Motor Gasoline	L	208	43.0	100	100	100
LPG	L	303	2.2	100	100	100
City Gas	L	308	2.2	100	100	100
Natural Gas	G	301	0.8	100	100	100
Wood	B	111	405.1	100	100	100
Charcoal	B	112	405.1	100	100	100

Table 3.165– Emissions factors for the domestic sector: Heavy Metals

Fuel		NAPFUE	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
			g/ton								
Residual Oil	L	203	1.3E+00	4.0E-04	5.1E-01	1.2E-03	4.0E-03	7.4E-01	2.7E+01	6.8E-02	1.9E+00
Diesel/Gas Oil	L	204	2.0E-01	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
Kerosene	L	206	2.0E-01	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
Motor Gasoline	L	208	5.3E+02	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
LPG	L	303	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
City Gas	L	308	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Natural Gas	G	301	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Wood	B	111	0.0E+00	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
Charcoal	B	112	0.0E+00	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00

Table 3.166 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Low Heating Value (LHV) and Greenhouse Gases

Fuel		NAPFUE	LHV	CO ₂			CH ₄	N ₂ O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
Residual Oil	L	203	40.17	77.4	0.990	100	1.6	0.6
Gas Oil	L	204	43.31	74.1	0.990	100	5.0	0.6
Diesel Oil	L	205	43.31	74.1	0.990	100	0.6	0.6
Kerosene	L	206	43.72	71.9	0.990	100	5.0	0.6
Motor Gasoline	L	208	44.77	69.3	0.990	100	9.9	0.6
LPG	L	303	47.28	63.1	0.995	100	1.5	1.4
City Gas	L	308	15.69	60.0	0.995	100	1.5	1.4
Natural Gas	G	301	45.97	56.1	0.995	100	1.2	1.4
Biogas	B	309	34.70	52.0	1.000	0	0.72	1.4

Table 3.167 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Indirect Precursor Gases

Fuel		NAPFUE	NO _x	NMVOC	CO
			g/GJ		
Residual Oil	L	203	160	3	20
Gas Oil	L	204	580	50.5	20
Diesel Oil	L	205	60	1	20
Kerosene	L	206	60	51	20
Motor Gasoline	L	208	1300	100	20
LPG	L	303	65	3	50
City Gas	L	308	65	3	50
Natural Gas	G	301	48	10	20
Biogas	B	309	65	3	17

Table 3.168 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Sulphur content of fuels

Year	Residual Fuel Oil	Diesel/ Gas Oil	Kerosene	Motor Gasoline	LPG/ city gas	Natural Gas	Biogas
1990	2.84	0.30	0.15	0.100	0.0016	0.0007	0
1991	2.60	0.30	0.15	0.100	0.0016	0.0007	0
1992	2.60	0.30	0.15	0.100	0.0016	0.0007	0
1993	2.60	0.30	0.15	0.100	0.0016	0.0007	0
1994	2.60	0.30	0.15	0.100	0.0016	0.0007	0
1995	2.60	0.25	0.15	0.100	0.0016	0.0007	0
1996	2.60	0.18	0.15	0.100	0.0016	0.0007	0
1997	2.60	0.18	0.15	0.100	0.0016	0.0007	0
1998	2.60	0.18	0.15	0.100	0.0016	0.0007	0
1999	2.60	0.18	0.15	0.100	0.0016	0.0007	0
2000	2.60	0.15	0.15	0.100	0.0016	0.0007	0
2001	2.60	0.13	0.15	0.015	0.0016	0.0007	0
2002	2.60	0.12	0.15	0.015	0.0016	0.0007	0
2003	1.00	0.12	0.15	0.015	0.0016	0.0007	0
2004	1.00	0.12	0.15	0.015	0.0016	0.0007	0

(a) Weighted average of gas oil and diesel oil for heating

Table 3.169 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Particulate Matter

Fuel		NAPFUE	TSP g/GJ	PM ₁₀	PM _{2.5}	PM _{1.0}
			(% TSP)			
Residual Fuel Oil	L	203	53.0	62	23	14
Diesel/Gas Oil	L	204	69.9	78	71	69
Kerosene	L	206	69.9	78	71	69
Motor Gasoline	L	208	43.0	100	100	100
LPG	L	303	2.5	100	100	100
City Gas	L	308	2.5	100	100	100
Natural Gas	G	301	0.8	100	100	100
Biogas	B	309	0.8	100	100	100

Table 3.170 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Heavy Metals

Fuel		NAPFUE	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
			g/ton								
Residual Oil	L	203	1.30E+00	4.02E-04	5.07E-01	1.21E-03	4.02E-03	7.41E-01	2.69E+01	6.84E-02	1.90E+00
Diesel/Gas Oil	L	204	2.00E-01	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
Kerosene	L	206	2.00E-01	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
Motor Gasoline	L	208	5.26E+02	3.96E-02	1.69E-02	6.38E-02	2.61E-01	6.50E-01	6.00E-02	3.66E-02	4.33E-01
LPG	L	303	0.00E+00	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Refinery Gas	L	308	0.00E+00	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Natural Gas	G	301	0.00E+00	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04
Biogas	B	309	0.00E+00	1.76E-05	4.18E-03	3.20E-06	2.24E-05	1.36E-05	3.36E-05	3.84E-07	4.64E-04

3.2.D.5 UNCERTAINTY ASSESSMENT

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

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

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

1.1.A.4 FUGITIVE EMISSIONS FROM SOLID FUELS (CRF 1B1)

COAL MINING AND HANDLING

Overview

Coal contains some proportion of methane trapped in its structure that it is usually emitted to atmosphere during and after extraction of coal from mines to open air. Emissions at extraction result from ventilation of mine gas which is done for safety reasons at underground mines. Emissions at open cast mines are usually lower and result from coal mobilization and blasting operations. Post-mining emissions result from the slower liberation of methane still entrapped in coal after it is extracted and stored at surface in piles, or from crushing and drying operations applied to modified and ameliorate coal characteristics. In underground mines, post-mining emissions may occur in fact during extraction if degasification systems are installed but, nevertheless, total emissions remain more or less unaffected.

Since 1990 in Portugal there was extraction of coal at only two coal mines, but both were latter closed down in 1992 and 1994 and did not resume activity since. Both mines - *Pejão* and *S. Pedro da Cova* - are located in northern region of Portugal. Coal from these mines is classified as lignite, it has a low energy value and it was used mainly as fuel for one public power energy plant near Oporto (*Tapada do Outeiro* power plant). One mine - *Pejão* - is an underground mine and the other is an open cast type.

Emissions of carbon dioxide and sulphur oxides may occur from mining activity when burning of coal deposits occurs or when flaring is used to control air emissions or recover energy. Because the occurrence of coal burning on-site or flaring is unknown for both Portuguese mines, emissions of these pollutants from this source are not included in the inventory.

Emissions of methane from abandoned mines may still continue after mine closure, even if mines are sealed, as it is recognized in the GPG. Because no methodology is available to calculate present day flux from abandoned mines - which would require knowledge of all abandoned mines, not only *Pejão* and *S. Pedro da Cova* - no estimates are included in the inventory.

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

Methodology

Emission estimates include both emissions occurring during extraction of coal as well as those resulting from processing.

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

$$Emi_{CH_4} = [(EF_U^{ex} + EF_U^{post}) * Coal_U + (EF_S^{ex} + EF_S^{post}) * Coal_S] * 0.67 * 10^{-3}$$

where

Emi_{CH_4} - Methane emissions in year y (ton);

$Coal_U$, $Coal_S$ - quantity of coal extracted from underground mines and open cast/surface mines, respectively (ton/yr);

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

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

EF_S^{ex} - emission factor for extraction emissions in surface mining (m^3/ton);

EF_S^{post} - emission factor for post-extraction emissions in surface mining (m^3/ton);

0.67 is the conversion factor, the density of methane at 20°C and at atmospheric pressure (kg/m^3).

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

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

Emission Factors

Although it is known that high rank coals contain usually more methane than lower rank coals such as lignite, average emission factors from IPCC96 (IPCC,1997) defaults were used for both mines, which are presented in next table. The same emission factor range was maintained in GPG (IPCC,2002).

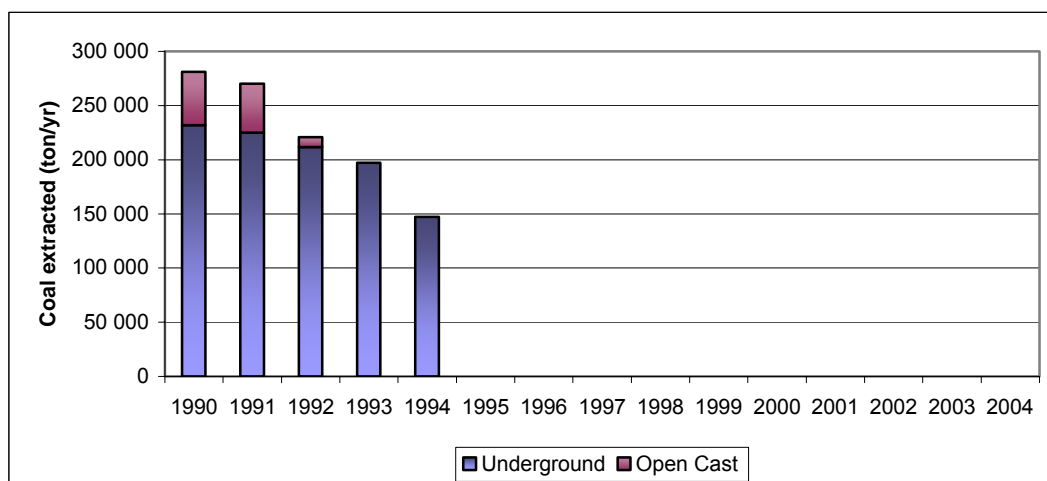
Table 3.171– Emission Factors for coal extraction and processing

Mine	Type of Emission	Emission Factor	Value (m^3/ton)
Underground	Extraction	EF_U^{ex}	11.73
	Post-mining	EF_U^{post}	1.64
Open cast	Extraction	EF_S^{ex}	0.77
	Post-mining	EF_S^{post}	0.07

Activity data

The quantity of extracted coal was always more expressive in underground mining but, nevertheless has decreased as a whole towards the final closure of both mines in 1994, as may be seen in next figure. Statistical information is from annual energy reports from General-Directorate of Geology and Energy (DGGE).

Figure 3.88 – Quantities of coal extracted from mines in Portugal (1990-2004)



Uncertainty Assessment

A value of 5% was considered for the uncertainty of coal production (activity data) which is a conservative factor according to the proposed values by IPCC (2000). Also in accordance with table 2.14 of the GPG, the uncertainty values for methane emission factors were set at 100% for underground mines and 200% for surface mines. The uncertainty in CO₂ emission factors were set equal to uncertainties of CH₄ emission factor, considering that CO₂ emissions are simply atmospheric conversion of methane emissions.

Recalculations

No recalculations of emissions were made on this source sector.

Further Improvement

Although this activity has stopped in 1994 it is possible that emissions after closure may continue for some time. Efforts will be done in next submissions to improve estimates of that origin, although it is probable that they will not affect substantially the inventory during the commitment period of the Kyoto Protocol.

1.1.A.5 FUGITIVE EMISSIONS FROM OIL PRODUCTION AND REFINING (CRF 1B2A)

Overview

Extraction and production of crude oil did never occur in the Portuguese territory. Therefore, fugitive emissions comprehend only those resulting from refining, storage and transport of crude oil, other raw materials, intermediate products and final products - particularly gasoline - from terminal receiving of crude oil and other petroleum products till delivering to final consumer. According to available methodologies air emissions considered include:

- Marine Terminals and Ballast water;
- emissions from refinery operations not including emissions from combustion of fuels, such as : (1) flaring and venting in oil refining; (2) emissions due to storage of raw materials, intermediate products and final products in the refinery;
- emissions from refinery dispatch station;

- emissions from the transport and distribution of petroleum products in the Portuguese Territory, including transport depots and service stations.

TRANSPORT OF CRUDE/ MARINE TERMINALS

Overview

Emissions from this source consist mainly of volatile organic compounds, including methane, that escape to atmosphere during transport of crude oil to refineries for processing. The three oil refineries considered in the inventory where all located at a small distance from the sea coast. Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

Methodology

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

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

where

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

Crude_{InFlow} - is total crude oil received at each refinery plant for processing (ton/yr);

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

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

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

Emission Factors

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

Table 3.172 – Emission Factors for marine terminals and crude oil transportation

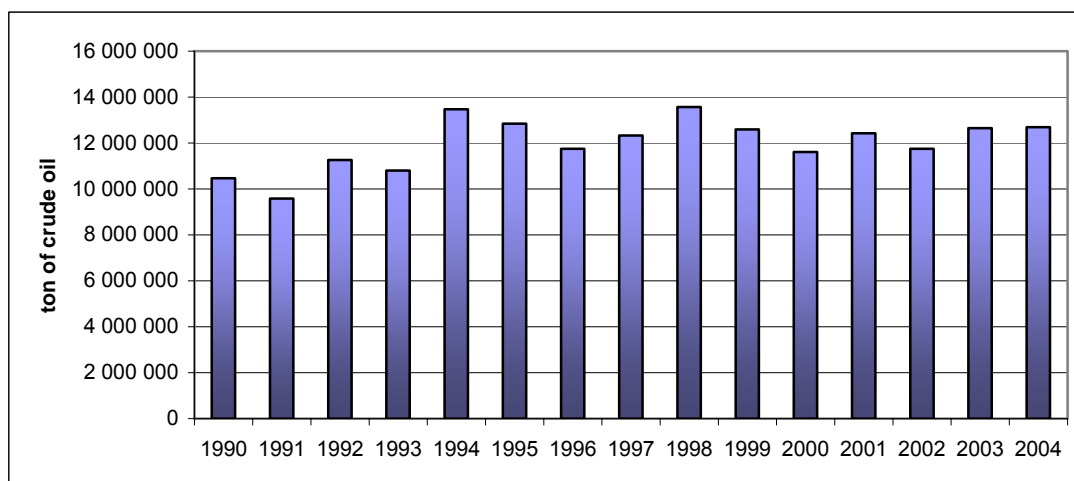
Component	Emission Factor (g/ton crude oil)
NMVOC	300
CH ₄	60 (2500 kg CH ₄ /PJ ^(a))
Ultimate CO ₂	1 100

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

Activity data

Quantity of crude oil entered into the Portuguese refining system is available from annual publications from General-Directorate of Geology and Energy (DGGE), with detailed information on the crude received at each individual refinery, and have increased unsteadily since 1990, as may be seen in next figure. Total use of crude in 2004 is 21 per cent higher than the quantity used in year 1990.

Figure 3.89 – Total consumption of crude oil: 1990-2004



Uncertainty Assessment

An uncertainty value (3%) similar to that that was considered for fuel consumption data in industrial LPS was also used for quantification of uncertainty of activity data for this source sector reflecting the fact that in this case data was also collected directly from refinery plants, where crude oil is uploaded, and used to build the energy balance of DGGE. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO₂ emissions, was considered to be 50%, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases. The uncertainty of methane emission factor was set to 100%, the double of the emission factor for CO₂/NMVOC in accordance with the fact that methane is obtained as a VOC fraction and hence with double uncertainty.

Recalculations

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

REFINING AND STORAGE

Overview

In 1990 there were three oil refining plants in Portugal, located in Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed for all activity and only two units remain now operating.

The refining process converts crude oil - which is a complex mixture of hydrocarbon compounds with impurities of sulphur, nitrogen, oxygen and heavy metals - into oil products used as fuels, asphalts, lubricants or feedstock for the organic and inorganic chemical industry. Processes included in Portuguese refineries include:

- Separation process: isolation of individual constituents of crude using differences in boiling-point, using atmospheric and vacuum distillation and recovery of light end gases;
- Conversion process. These may be also classified as: (1) Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular height into smaller ones, including visbreaking; (2) Polymerisation of small molecules combined in bigger molecules with different characteristics. Alkylation has similar objectives and (3) chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing;
- Treatment processes. Operations which include hydrosulfurization, hydrotreating, chemical sweetening, acid gas removal, deasphalting and desalting, that are used to remove impurities, the most important is sulphur;
- Blending of individual fractions and intermediate products to obtain final commercial products with characteristics as desired.

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

NM VOC and methane emissions may also result from “normal” leaks³⁷ scattered trough the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NM VOC emissions resulting from non-condensable fraction at the steam ejectors or vacuum pumps of the Vacuum distillation. Emissions in flares are discussed in “Venting and Flaring in Oil Industry” below.

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

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

Methodology

Storage and Tanks

Detailed information of individual tanks in Oporto and Sines refinery for years 2002, 2003 and 2004 lead to the establishing of plant specific emission factors for NM VOC losses from crude oil

³⁷ Sometimes only these emissions are referred as fugitive emissions from refineries.

and oil products storage. Annual emissions of NMVOC (ton/yr) for the remaining time series are estimated using the emission factor (EF in g/ton) and relying in the time series of total throughput petroleum materials processed (ton/yr) as an indicator of activity³⁸.

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

Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations were estimated from:

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

where

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

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

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

Total crude use was used as activity data to estimate fugitive emissions from leakages, according to the available emission factors in literature. Concerning Catalyst recovery activity data is coke burnt during catalyst regeneration.

Sulphur Recovery

Emissions of SO_x occurring due to limitations of the sulphur recovery system were estimated annually according to the following procedure:

$$\text{Emi}_{\text{SO}_x} = 64/32 * [\text{S}_{\text{Inc}} + \text{S}_{\text{Prod}} * (100 - \text{Claus}_{\text{EFIC}})/\text{Claus}_{\text{EFIC}}]$$

where

Emi_{SO_x} – Emissions of sulphur oxides from sulphur recovery in tail gas (ton S/yr);

S_{Inc} - sulphur in tail gas that is incinerated to SO_x because Claus unit was not operational (ton S/yr);

Claus_{EFIC} – percent efficiency of overall Claus unit (%);

S_{Prod} - total elemental sulphur produced in the Claus unit (ton S/yr).

Ultimate Carbon Dioxide Emissions

All carbon in emitted compounds, such as CO, NMVOC and methane, have fossil origin and must be included in ultimate emissions inventory. Individual pollutants (ton/yr) are converted into ultimate CO₂ (kton/yr) by:

³⁸ This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

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

Emission FactorsStorage/ Tanks

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

The background information that was used to estimate storage and tank emissions is not available and, therefore, only a short summary is presented here in the National Inventory Report.

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

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

- Site information: meteorological data such as the daily average ambient temperature, the annual average minimum and maximum temperatures, the annual average wind speed, the annual average solar insolation factor, and the atmospheric pressure;
- Liquid characterization: For individual substances the model requires chemical nomenclature, average liquid temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. For mixtures, the information may be as detailed as the mixture name, average, minimum and maximum liquid surface temperatures, bulk temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights;
- tank information is slightly different according to tank type, but in general terms comprehends: shell and roof colour and condition, height, diameter, average and maximum liquid height, working volume, turnover rate and net output, heating conditions and pressure and vacuum settings and the existence and type of seals³⁹.

Emissions are 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 2002 in Oporto and Sines refineries are presented in Figure 3.90.

³⁹ This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

Table 3.173 – Type of tanks classes distinguished in TANKS4.0 model and percentage of tanks per tank type in Oporto and Sines refineries in 2002 (%).

Tank Type			Description	Oporto	Sines (a)
External	Floating	Roof	cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid	19	69
			above-ground or underground storage with the axis parallel to the foundation	2	0
Internal	Floating	Roof	permanent fixed roof and a floating deck	10	10
			cylindrical shells with permanently affixed roofs; the tank axis is perpendicular to the foundation. The fixed roof may be dome-shaped or coneshaped	69	21
Vertical Fixed Roof			external floating roof tank that		
Domed	External	Floating Roof.	has been retrofit with a domed fixed roof	0	0

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

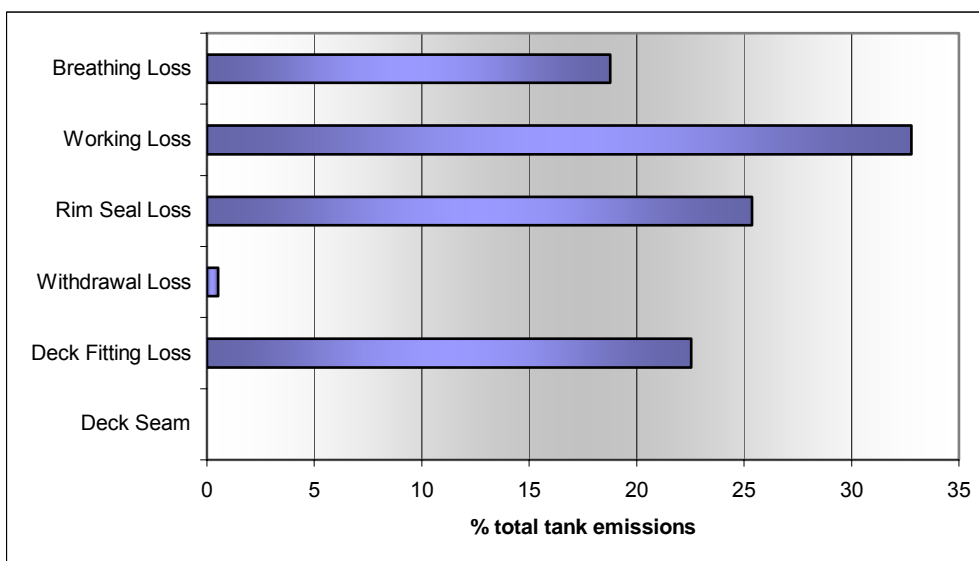
TANKS4.0 methodology differentiates the following emissions, according to the cause of release:

Table 3.174 – Types of losses from tanks for storage of organic compounds and petroleum products

Tank	Loss	Description
Fixed Roof	Breathing	Expulsion of vapour from a tank through vapour expansion and contraction, which are the results of changes in temperature and barometric pressure
	Working	Combined loss from filling and emptying. Evaporation during filling operations is a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapours are expelled from the tank. Evaporative loss during emptying occurs when air drawn into the tank during liquid removal becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space.
Floating Roof	Rim Seal	The majority of rim seal vapour losses have been found to be wind induced.
	Withdrawal	Occur as the liquid level, and thus the floating roof, is lowered. Some liquid remains on the inner tank wall surface and evaporates.
	Deck Fitting	Deck fittings can be a source of evaporative loss when they require openings in the deck, such as: access hatches, gauges, rim vents, deck drains, guide-poles, columns, wells, vacuum breakers and ladders.
Internal Floating	Deck Seam	Seams may not be completely vapor tight if the deck is not welded

The percentages of emission from each type of loss, from both Sines and Oporto refineries, are presented in Figure 3.90.

Figure 3.90 – Percentage of NMVOC emissions per type of emission from storage and tanks of petroleum products in 2002



Finally the resultant emission factors, obtained dividing total tank emissions by total throughput⁴⁰ in each refinery, are presented in next table.

Table 3.175 – Final emission factor for evaporation of NMVOC from storage and tank in refineries

Refinery	Emission Factor		
	(g NMVOC/ton throughput)		
	2002 and before	2003	2004 and beyond
Sines	118	115	115
Oporto ⁴¹	57	41	40
Lisbon	88 ^(a)	NA	NA

(a) Average value from Sines and Oporto refineries

Fugitive Emissions

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

⁴⁰ Crude oil input added to input of other materials.

⁴¹ The final estimated emission factor for 2003 was still being developed at the time the inventory was finalized.

Table 3.176 – Emission Factors for fugitive emissions of NMVOC in operation processes in petroleum refineries

Pollutant	EF
	Kg NMVOC/ ton crude
NMVOV	0.9
CH4	0.1

Recovery of Catalysts

From information collected from the refinery at Sines (quantities of coke burnt in FCC unit during 2002 and monitoring data for NO_x, SO_x and particulate matter) plant specific emission factors were established for this process. For carbon monoxide emission factors from USEPA (1995) were used, but because original emission in the original reference source are expressed in volume of fresh feed – and this activity rate it is not available from the refinery – the original emission factor was corrected, by multiplication by the ratio of the NO_x emission factor in both information sources (monitoring data and USEPA). Carbon dioxide emission factor was set assuming that coke is 92% carbon. Final emission factors may be verified in **Error! Reference source not found.**

Table 3.177 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Parameter	Emission Factor
	kg/ton coke
SO _x	31.9
NO _x	3.6
CO	5.8
UCO ₂	3 373
PM	6.8

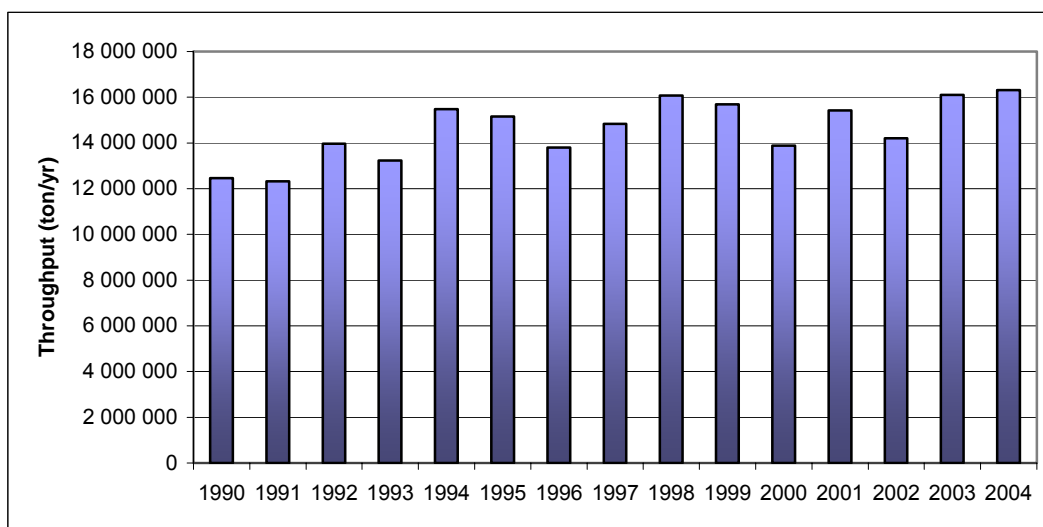
This set of emission factors was also applied to coke burning in the platforming unit, also in Sines refinery, and regeneration of catalysts at Oporto refinery.

Activity data

The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed and it was already presented in “Transport of Crude” (Figure 3.89).

Total throughput in each refinery was used to estimate NMVOC emissions from storage and tanks. Total throughput represents not only crude oil entered into the refinery but also other petroleum products that are imported or moved between refineries. This indicator was considered the most suitable variable to be multiplied by the national emission factor. Total throughput for all refineries, according to information delivered by GALP, is presented in Figure 3.91.

Figure 3.91 – Total throughput entered in Lisbon, Oporto and Sines refineries: 1990-2003



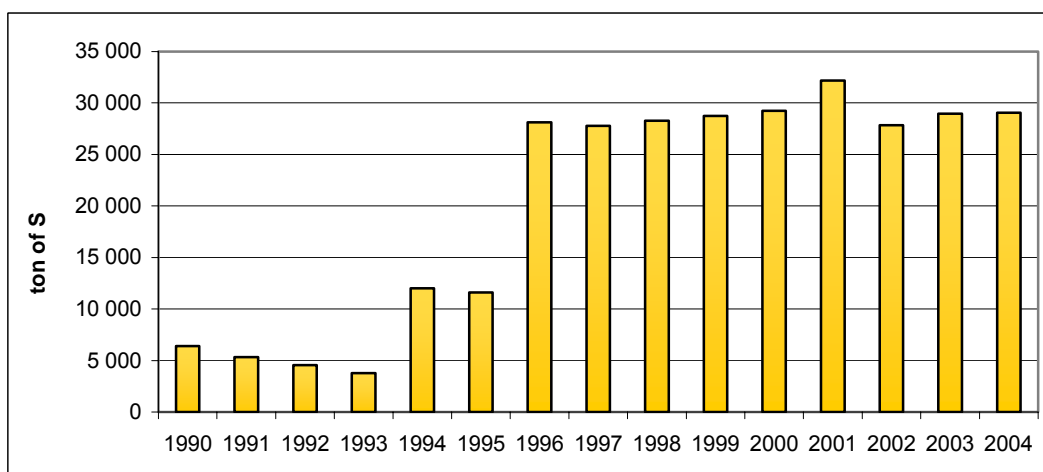
Source: Petrogal

For FCC, and other processes where there is recovery of catalysts, activity data is total coke burnt. Annual burning of coke in Sines refinery, both in FCC and in Platforming is available from PETROGAL up to 2003. Combustion of coke from catalysts in Oporto refinery was only available for 2001-2002, and was assumed constant over the all 1990-2003 period. Total coke burning was obtained from the industrial units and it is considered confidential data.

Total sulphur recovered in the refineries was available from the balance of petroleum products in annual publications from DGGE, from 1990 to 2004. Production of sulphur has been increasing, particularly after 1996, as could be seen in Figure 3.92, expressing the technology changes set by the auto-oil program. The efficiencies of Claus units vary from 95 to 98%, according to each refinery.

Incineration of sulphur is estimated by comparison of sulphur productions with estimated production and being aware of the expected ratio of sulphur production against crude processing.

Figure 3.92 – Total sulphur produced in Portuguese refineries recovered in Claus units



UNCERTAINTY ASSESSMENT

Most of the activity data that was obtained to estimate emissions come directly from the refinery units or indirectly by the Energy Balance of DGGE (which is based also in information surveyed from the industrial plants). Therefore a low uncertainty of 3% may be assumed for this sub-source in a similar mode to other LPS combustion data.

Uncertainty of emission factors for NMVOC⁴² were set as 50%, at the higher range of possible uncertainties proposed by IPCC (2000), although the fact that some emission factors use plant specific information. Estimates of methane emissions were assumed to have the double uncertainty that was determined for CO₂.(100%)

RECALCULATIONS

The only improvement in emission estimates that was done since last submission resulted from the update of the emission factor for NMVOC emissions from both crude oil refinery, considering the revisions made by GALP on the calculations made using TANKS. No other modifications were made to this source sector.

FURTHER IMPROVEMENTS

The efforts that the refineries are doing, in order to ameliorate emission estimates of storage in tanks, fugitive emissions, emissions from catalysts regeneration and from sulphur recovery, are expected to be reflected in improvements in the inventory methodologies and emission factors for the coming years.

DISTRIBUTION OF OIL PRODUCTS

Overview

This sub-source sector include emissions of volatile organic compounds resulting from distribution of refinery products, mainly gasoline:

- (1) Terminal Dispatch Stations in Refineries. Emissions of volatile organic compounds occurring inside refineries during filling of transport equipments - trucks, rail cars - when dispatching products of the refining unit. Most emissions occur when light products with high level of volatile compounds are dispatched;
- (2) Transport and Depots, occurring in storage tanks outside the refineries and over the country;
- (3) Service Stations, including emissions from tank loading from trucks and when refuelling consumer cars.

Emissions may result from:

- Leakage. Evaporation of liquid products by flaws and seal leakage, pumps and valve systems;
- Displacement emissions, due to displacement of air in tanks by the incoming liquid;
- Breathing emissions in tanks;

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

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

Methodology

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

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

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

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

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

$$\text{Emi}_{\text{CO}_2} = 0.85 * \text{Emi}_{\text{NMVOC}}$$

Emission Factors

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

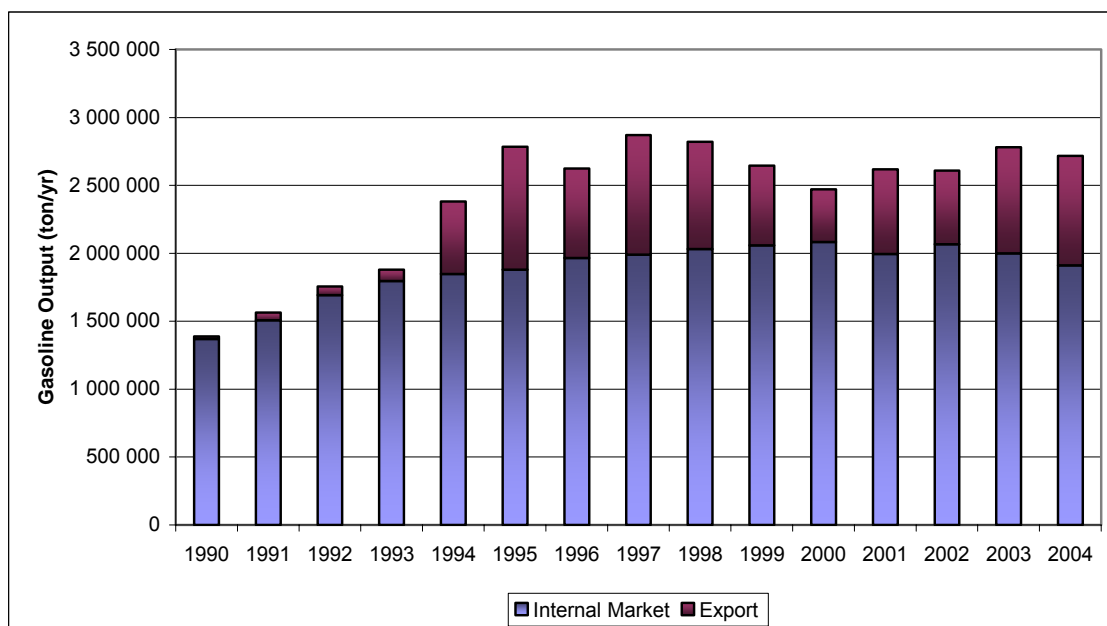
Table 3.178 – Emission Factors

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

Activity data

Activity data, in accordance to what was already defined in the methodology, for the years 1990 to 2002 is from the annual publications from the General-Directorate of Geology and Energy (DGGE). Values for 2003 are preliminary forecasts. Total gasoline output for internal market and exportation is presented in the Figure 3.93.

Figure 3.93 – Gasoline consumption in the internal market and gasoline exportation



VENTING AND FLARING IN OIL INDUSTRY

Overview

In the three refineries in Portugal flares were used to control and burn non-condensable gases recovered from leakages and blow down operations, that would otherwise be emitted as volatile organic compounds. Although smokeless and complete combustion is always an objective, sometimes the gas influx exceeds flare combustion capacity and partly unburned organic compounds are emitted: NMVOC, CH₄ and CO.

Methodology

Air emissions in flaring, resulting from combustion of gas collected from leaks and blowdown system, and were estimated either from the quantity of gas flared or total feed to refinery.

When the quantity of gas flared was used as activity data, emissions are estimated from:

$$\text{Flare}_{(p,y)} = \text{EF}_{(p)} * \text{LHV}_{\text{GAS}(y)} * \text{Flare}_{\text{GAS}(y)} * 10^{-6}$$

Where,

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

$\text{EF}_{(p)}$ – Emission factor for pollutant p (g/GJ);

$\text{LHV}_{\text{GAS}(y)}$ – Low Heating Value of flared gas in year y (MJ/kg);

$\text{Flare}_{\text{GAS}(y)}$ – Quantity of gas flared in year y (ton/yr).

SO_x emission were calculated according to emission factors based on total feed to refinery (US-EPA, 1995), because the sulphur content of flare gas is not known. The following formula was used:

$$\text{Flare}_{\text{SO}_x} = \text{Feed}_{\text{InFlow}} * \text{den}_{\text{FEED}} * \text{EF} * 10^{-6}$$

where

$\text{Flare}_{\text{SO}_x}$ – total emission of sulphur oxides in flare (ton/yr);

$\text{Feed}_{\text{InFlow}}$ - is total feed throughput received at all refinery plants for processing (m^3/yr);

den_{FEED} – Feed density (ton/m^3);

EF - emission factor ($\text{g}/\text{ton feed}$).

All carbon emitted in compounds, such as CO, NMVOC and methane, has fossil origin and must be included in the estimate of ultimate carbon dioxide emissions. Individual pollutants (end of pipe carbon dioxide, NMVOC, methane and carbon monoxide) are converted into ultimate CO₂ according to:

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

Emission Factors

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

Feed density was assumed as of 0.85 kg/L.

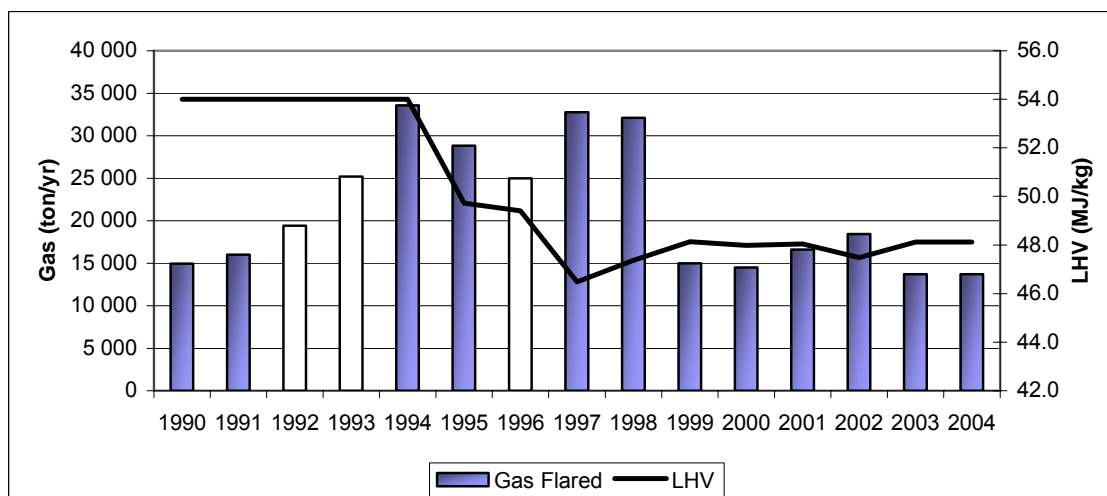
Table 3.179 – Emission Factors for flaring in refineries

Pollutant	EF (g/GJ)
SO _x (g/m^3)	65
NO _x	13
CO ₂ (kg/GJ)	60
COVNM	12
CH ₄	15
CO	70

Activity data

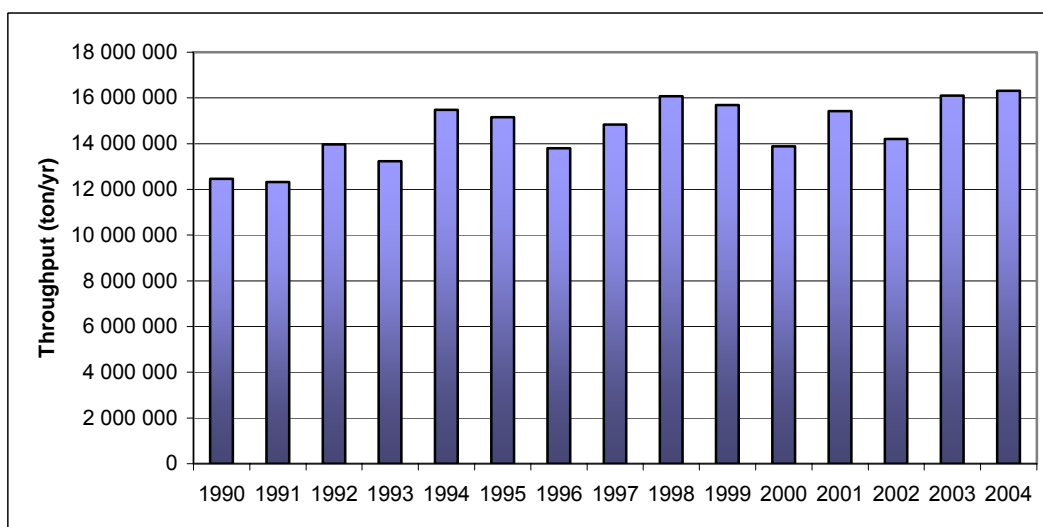
Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL and it is presented in Figure 3.94.

Figure 3.94 – Total consumption of flare gas in Portuguese refineries and Low Heating Value: (1990-2003)



Total throughput (feed) entered in refinery units is available from annual energy publications of (DGGE), and is again presented in Figure 3.95.

Figure 3.95– Total throughput entered in Lisbon, Oporto and Sines refineries (1990-2002)



Uncertainty Assessment

The uncertainty in activity data was considered to be 5%, the same value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in NMVOC/CO₂ emission factor is 50% and the double of that value for methane emissions.

Recalculations

No recalculations were done for this emission source.

1.1.A.6 FUGITIVE EMISSIONS FROM NATURAL GAS (CRF 1B2B)

Overview

There is no production of natural gas in Portugal. The use of natural gas in Portugal was initiated only in 1997 (DGGE). At that time this energy source was received by ship from Algeria and used mainly in electric power production and in combustion in industry. Since then its use has become more widespread and its now consumed also in the manufacturing industry, domestic, service, institutions, commerce, building and construction, agriculture and even a small quantity in road transport. All the gas is imported and received through shipping transport from Algeria and Nigeria as Liquefied Natural Gas (LNG). There are also no major processing operations in Portugal.

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

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

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

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

METHODOLOGY

Losses of Natural Gas are estimated equal to the quantity of gas that is lost in transport and distribution, according to the energy balance of DGGE. Therefore, total emissions are determined from:

$$Emi_{GHG(y)} = Losses_{NG(y)}$$

Where,

$Emi_{GHG(y)}$ – Emissions of total GHG from natural gas leakage, in year y;

$Losses_{NG(y)}$ – Losses of Natural Gas from the system and reported in the energy balance, in year y.

Emissions of methane, direct CO₂ and ultimate CO₂, from transmission of Natural Gas in major pipelines is estimated from:

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

Where,

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

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

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

EF_{CH_4} , $EF_{CO_2direct}$ – Emission factors, t/km;

$Pipeline_{Lenght}$ – Extension of pipeline in year y, km.

A similar procedure is used to estimate emissions in the re-gasification plant, although using total natural gas processes⁴³ as activity data:

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

Where,

EF_{CH_4} , $EF_{CO_2direct}$ – Emission factors, per cent;

$Import_{NG}$ – Import of Natural Gas, t/yr.

Finally emissions during distribution (Emi_{DIST}) are estimated from total losses (Emi_{TOTAL}), after removal of transmission emissions (Emi_{TRANS}) and emissions occurring at the re-gasification plant (Emi_{GAS}):

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

EMISSION FACTORS

The emission factors are based on the IPCC Good Practice (IPCC,2000), and are reported in Table 3.180.

Table 3.180 – Net Calorific Value and Emission Factor for fugitive emissions from natural gas

-	Transmission (t/km) [#]	NGL Plant (%) ^{\$}
CH ₄	2.5	0.05
CO ₂	0.016	0.00032

[#] - IPCC (2000), table 2.16

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

⁴³ Equals imports in Portugal

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

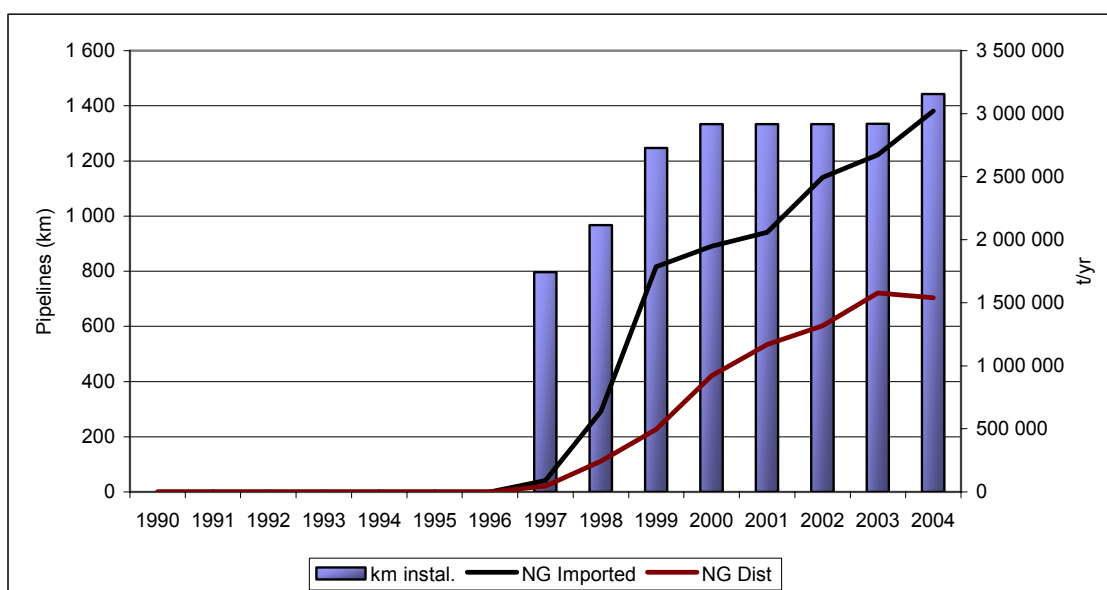
ACTIVITY DATA

According to the above explained methodology, activity data comprehends:

- extension of pipelines for transmission. Total extension of pipelines in kilometres was estimated from the date at which each major pipeline start operation, and its extension. These data was received via DGGE from TRANSGAS;
- importation of natural gas, obtained from the DGGE's Energy Balances;
- Consumption of Natural Gas. Distribution emissions were assumed to result only from small and medium size units. Therefore, total consumption was subtracted from consumption in sectors characterized for high consumptions per unit: Paper pulp; Chemical Industry; Ceramics; Cement; Glass and related products and Iron and Steel.

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

Figure 3.96 – Activity data used to estimate GHG emissions from Natural gas transmission, distribution and transformation (1990-2004)



UNCERTAINTY ANALYSIS

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

RECALCULATIONS

Emission are now estimated based on data of system losses, and using known emission factors to make a separation by transmission, gasification plant and distribution. Until now emissions were estimated using a simple methodology and a crude and insufficiently documented emission factor.

1.1.A.7 OTHER FUGITIVE EMISSIONS (GEOTHERMAL ELECTRICITY PRODUCTION) (CRF 1B2D)

OVERVIEW

A small amount of electricity is produced from two geothermic sources in Azores archipelago: *Pico Vermelho* and *Ribeira Grande* Plants, and they cause the release of carbon dioxide.

The available categories do not consider a specific place to report CO₂ emissions from geothermal electricity production. Emissions from these activity are clearly related to sector 1 (Energy) and must be better considered as fugitive emissions. Nevertheless, for fugitive emissions the nomenclature allows only the classes Solid Fuels (1B1) and Oil and Natural Gas (1B2), which are not exactly suitable for this activity. Sector 7 (Other) could be used in principle, but would imply that emissions from this category would be no longer included in the energy sector.

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

METHODOLOGY

Since 1994, in Azores, the Regional Authority of Economy (Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia) performs own estimates of carbon dioxide to atmosphere from geothermic units and these were considered in the National Inventory. For the years prior to 1994, when the only available activity data for geothermic electricity production is from General-Directorate of Geology and Energy (DGGE), emission factors estimated for the post-1994 time series were used.

EMISSION FACTORS

Measurements of carbon dioxide emissions are available from one plant (Pico Vermelho) after 1994. These results were used to establish an emission factor that was later used to estimate emissions for Pico Vermelho before 1994: 500 ton CO₂/GWh. Although this figure was not used in emission estimates for the other power plant the emission factor varied from 1994 to 1999 from 737 to 782 ton CO₂/GWh. These emission factors were set from available information from Azores Autonomous Region.

ACTIVITY DATA

Activity data consists of the quantity of carbon dioxide quantified or the production of geothermal electric energy, according to years.

RECALCULATIONS

No other changes occurred in methodology, the origin of the activity data and emission factors.

FURTHER IMPROVEMENTS

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

3.3 Recalculations

Changes in sectoral overall GHG emissions, expressed in CO₂ equivalent, since last submission, were not very significant in the energy sector, as may be seen in Figure 3.97 for base year (1990) and 2003, although substantial increment has occurred in what concerns the emission estimates of methane and nitrous oxide. The dominant change in emission estimates of methane have occurred in the category “Fugitive Emissions from Fuels”, and mostly in relation to the change in methodology in fugitive emissions from natural gas transport and delivery.

Figure 3.97 – Differences between submissions 2005 and 2006 (CO₂, CH₄ and N₂O)

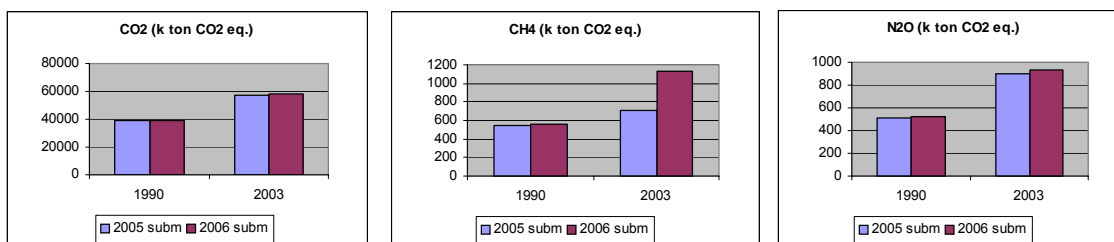


Figure 3.98 – Differences between submissions 2005 and 2006 (CO₂ equivalent)

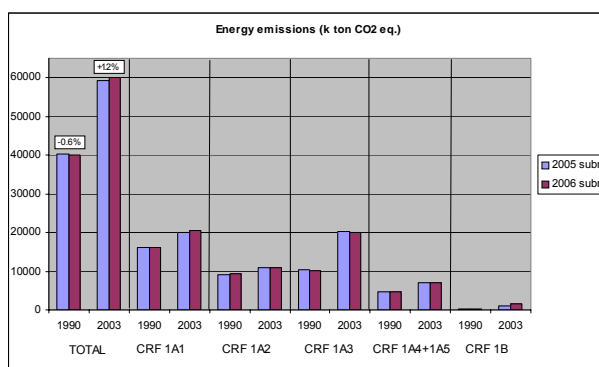


Table 3.181 – Recalculations (differences between submissions 2005 and 2006)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2005 subm.	2006 subm.	Difference	2005 subm.	2006 subm.	Difference	2005 subm.	2006 subm.	Difference
	CO ₂ eq (Gg)	CO ₂ eq (Gg)	(1)	CO ₂ eq (Gg)	CO ₂ eq (Gg)	(1)	CO ₂ eq (Gg)	CO ₂ eq (Gg)	(1)
1990									
1. Energy	39 344	39 087	-0.65	547.08	564.48	3.18	509.78	517.28	1.47
1.A. Fuel Combustion Activities	39 218	38 963	-0.65	445.87	463.27	3.90	509.78	517.28	1.47
1.A.1. Energy Industries	15 944	15 944	0.00	4.33	4.33	0.00	61.04	61.04	0.00
1.A.2. Manufacturing Industries and Construction	9 103	9 158	0.60	35.33	38.03	7.65	67.25	67.25	0.00
1.A.3. Transport	10 137	9 828	-3.05	57.76	72.46	25.45	144.56	152.06	5.19
1.A.4. Other Sectors	4 025	4 025	0.00	348.30	348.30	0.00	236.92	236.92	0.00
1.A.5. Other	8	8	0.00	0.15	0.15	0.00	0.02	0.02	0.00
1.B. Fugitive Emissions from Fuels	126	124	-1.85	101.21	101.21	0.00	0.00	NEN	
1.B.1. Solid fuel	9	9	0.00	66.02	66.02	0.00	0.00	NO	
1.B.2. Oil and Natural Gas	118	115	-1.99	35.19	35.19	0.00	0.00	NEN	
2003									
1. Energy	57 664	57 947	0.49	710.88	1 127.34	58.58	895.50	937.21	4.66
1.A. Fuel Combustion Activities	56 909	57 109	0.35	424.46	439.55	3.56	895.50	937.21	4.66
1.A.1. Energy Industries	20 009	20 330	1.60	5.56	5.80	4.39	95.93	97.49	1.62
1.A.2. Manufacturing Industries and Construction	10 722	10 736	0.13	51.81	55.24	6.61	92.98	91.18	-1.94
1.A.3. Transport	19 583	19 473	-0.56	52.81	64.25	21.65	530.54	572.70	7.95
1.A.4. Other Sectors	6 595	6 570	-0.38	314.27	314.26	0.00	176.05	175.85	-0.11
1.A.5. Other	0	NO		0.00	NO		0.00	NO	
1.B. Fugitive Emissions from Fuels	754	838	11.04	286.42	687.79	140.13	0.00	NEN	
1.B.1. Solid fuel	0	ENO		0.00	ENO		0.00	NO	
1.B.2. Oil and Natural Gas	754	838	11.04	286.42	687.79	140.13	0.00	NEN	

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = $100\% \times [(LS-PS)/PS]$, where LS = Latest submission and PS = Previous submission).

Cross-cutting issues

The major modifications in the inventory, in what concerns, the energy sector, were:

- substantial improvements were made in the methodologies and activity data used to make estimates of emissions from air traffic and maritime movements. Detailed information from the air traffic authority (INAC) and port authorities, have resulted in very detailed databases. Emissions of traffic movements are now estimated year by year by origin-destiny and aircraft type. Emissions from maritime transportation are estimated for each individual movement arriving or departing from Portuguese ports. These modifications have resulted in substantial improvements toward the goal of making a national/international differentiation of emissions in accordance with the rules set by the Good Practice Guidebook;
- First time estimate of emissions of road traffic due to the consumption of natural gas in vehicles;
- revision of parameters in the road traffic model, including kilometres driven per vehicle, per vehicle type, and the abatement curve of old vehicles. These changes have caused mostly alterations in emission estimates for other non CO₂ GHG, ozone precursors, acidifying substances, particulate precursors and particulate matter;
- Emissions of methane from leakages in the storage and distribution system have improved substantially, using information of the length of the distribution network and losses of gas in the system;

3.4 Further Improvements

Because the energy sector is the most prevalent emission source, special efforts must always be made to improve emission estimates, even if they affect smaller energy sub-sectors. Future improvements to the inventory will depend on the conclusions of the Methodological Development Plan for the implementation of the National System, which is being made with direct contact with the main intervenients of the energy sector, and in close collaboration of the inventory team from IA. Although the main conclusions from this report are still not set in a final report and plan, the following preliminary routes may be here identified.

- Better integration between activity data in the air emissions inventory and other surveys such as LCP directive, *Autocontrolo* program, EPER, the Carbon Market and the energy surveys (co-generation) made annually by DGGE. Contacts are being made to implement it;
- Determination of country-specific emission factors (SO_x, NO_x and PM) from monitoring data collected from the *Autocontrolo* program and CO₂ emission factors for information collected under carbon market;

Some particular issues still need a more detailed improvement in the road transportation sector:

- consideration of annual distance driven per vehicle using information from the Inspection centres;
- incorporation of traffic monitoring data recorded in rural roads to estimate traffic emissions under rural driving mode and to improve specialisation of emissions;
- update of meteorological data for each specific emission year;

- incorporation of factors in emission factors calculation such as vehicle aging and maintenance;
- incorporation of regional and local emission estimates.

Although it is considered that the changes made in the aviation and maritime sectors have improved the inventory substantially, additional efforts must be done to maintain the improvement in the database and methodologies, namely in what concerns:

- using specific durations for idle, taxi, take-off, for the individual airports considered and being aware of airplane age;
- use of more detailed determination of emissions resulting from small airplanes, private jets and helicopters;
- better knowledge of ships and emissions. Information is already being collected to achieve that goal;
- water-borne navigation emissions are still not disaggregated in adequate categories to answer the LRTAP convention and the UE's ceilings directive, and efforts are being made to separate emissions realized in the EMEP area from international sea traffic

3.5 Reference Approach

3.5.A Overview

The reference approach consists in the estimate of CO₂ emissions using the simple approach tier 1 of IPCC (1997). Although the Portuguese National Inventory uses an sectoral approach (National Approach) of higher tier level, nevertheless the UNFCCC reporting guidelines request that parties make also a top-down "reference approach"⁴⁴ for estimation of CO₂ emissions from fossil fuel combustion, in addition to the bottom-up sectoral methodology.

The Reference approach uses a very simple methodology, assuming that all carbon input to the national economy in fuel form, it is either stored in some way (fuel stocks, products or even left unoxidized in ash) or it must be released to the atmosphere. In order to calculate the carbon released it is not necessary to know exactly how and where the fuel was used or what intermediate transformations it underwent. In this respect the methodology may be termed a "top-down" approach compared with the "bottom-up" methods used for other gases. (IPCC, 1997)

The Reference Approach requires simple statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of values for the consumption of fossil products used for non-energy purposes, where carbon may be stored.

3.5.B Methodology

The following methodological steps were made in accordance with IPCC (1997):

- 1 Estimate consumption of fuels by fuel/product type;
- 2 Convert the fuel data to a common energy unit (TJ), if necessary;

⁴⁴ This does not mean that a "bottom-up" approach should not be followed for estimating CO₂ emissions but the total emissions must be compared with those obtained from the Reference Approach.

- 3 Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels;
- 4 Estimate the amount of carbon stored in products for long periods of time;
- 5 Account for carbon not oxidized during combustion;
- 6 Convert emissions of carbon to full molecular weight of CO₂.

3.5.B.1 FUEL CONSUMPTION

Apparent consumption was estimated from the National Energy Balances produced by the General Directorate of Energy and Geology (DGGE) according to:

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{Stock Change.}$$

for primary fuels and,

$$\text{Apparent Consumption} = \text{Imports} - \text{Exports} - \text{Bunkers} - \text{Stock Change.}$$

for secondary fuels.

National production is not considered because the carbon in these fuels was already included in the supply of primary fuels from which they were derived.

3.5.B.2 ENERGY CONSUMPTION

The Portuguese National Balance reports consumption in energy units (toe⁴⁵), apparent consumption needs only to be converted to TJ using the multiplier 41.868 GJ/toe.

3.5.B.3 CARBON CONTENT OF FUELS

Carbon content in apparent consumption is estimated in reference approach from:

$$\text{Apparent Consumption}_{(\text{Gg C})} = \text{Apparent Consumption}_{(\text{TJ})} * \text{Carbon Content}_{(\text{MgC} / \text{TJ})} * 10^{-3}$$

The carbon content of fuels was determined using the Carbon Emission Factors used in the sectoral approach, which are presented in Table 3.182.

⁴⁵ Ton of oil equivalent

Table 3.182 – Carbon content of fuels and Oxidation Factor used in the Reference Approach

Fuel			C content (t C/TJ)	Fac _{ox} 0..1
Liquid Fossil	Primary Fuels	Crude Oil	20.0	0.99
		Orimulsion	22.0	0.99
		Natural Gas Liquids	17.2	
	Secondary Fuels	Gasoline	19.4	0.99
		Jet Kerosene	19.9	0.99
		Other Kerosene	20.0	0.99
		Gas / Diesel Oil	19.9	0.99
		Residual Fuel Oil	20.7	0.99
		LPG	17.7	0.99
		Naphtha	20.0	0.99
		Bitumen	22.0	0.99
		Lubricants	20.0	0.99
		Petroleum Coke	27.5	0.99
		Refinery Feedstocks	20.0	0.99
		Other Oil	20.0	0.99
Solid Fossil	Primary Fuels	Anthracite (a)	26.8	0.98
		Coking Coal	25.8	0.98
		Other Bit. Coal	25.1	0.98
		Sub-bit. Coal	26.2	0.98
		Lignite	27.3	0.98
		Oil Shale	29.1	0.99
		Peat	28.9	0.99
	Secondary Fuels	BKB & Patent Fuel	27.0	0.98
		Coke Oven/Gas Coke	29.5	0.98
Gaseous Fossil		Natural Gas (Dry)	15.3	1.00
Biomass		Solid Biomass	29.9	1.00
		Liquid Biomass	20.0	1.00
		Gas Biomass	30.6	1.00

3.5.B.4 CARBON STORED IN PRODUCTS

For the IPCC Reference Approach, the suggested formula for estimating carbon stored in products for each country is:

$\begin{aligned} \text{Total Carbon Stored (Mg C)} &= \text{Non-Energy Use (toe)} \\ &\times \text{Conversion Factor (TJ/toe)} \\ &\times \text{Emission Factor (t C/TJ)} \\ &\times \text{Fraction Carbon Stored} \end{aligned}$

Presently the following products are taken from the National Energy Balance: lubricants, bitumen, and naphtha and residual fuel oils used as raw materials. Original statistical

information was already expressed in toe. Emission factors and the fraction of carbon stored is reported in Table 3.183.

Table 3.183 – Reference Approach. Carbon Emission Factor and Fraction of carbon stored

Fuel	C content (t C/TJ)	FacOX 0..1
Naphtha	20	0.8
Lubricants	20	0.5
Bitumen	22	1
Fuel Oil	21.1	0.8

3.5.C Actual Carbon Dioxide Emissions

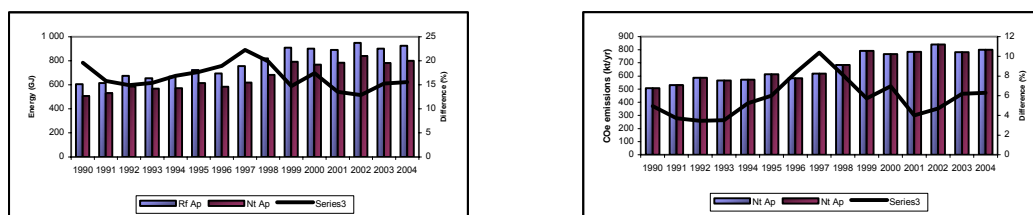
Estimated simply from:

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

3.5.D Results. Comparison of Reference Approach and Sectoral Approach

Detailed data used in the reference approach calculation is reported in CRF tables and is not duplicated in NIR. The emissions estimated according to reference approach and national approach show differences in both energy consumption and carbon emissions, and are presented in Figure 3.99. They are mostly explained from 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.

Figure 3.99 – Comparison of Energy Consumption and CO₂ emissions between the National approach and the Reference Approach



3.6 Feedstock

Emissions of greenhouse gas emissions from feedstock use are only clearly accounted in the inventory in the following situations:

- emission of CO₂ resulting from use of feedstock sub-products as energy sources. That is the case of emissions from consumption of fuel gas in refinery and petrochemical industry;
- emission of CO₂ liberated as sub-product in production processes such as ammonia production;

- emission of NMVOC from fossil fuel origin, and occurring from solvent use and evaporation. Although in this case it is not possible to establish which part results from feedstock consumption in Portugal in the energy balance;

However, some potential emissions are not estimated or are only partly estimated. Those that are estimated in the reference approach but not in sectoral approach are:

- emissions from mineral oil use as lubricants;
- emissions from wear of bitumen in roads.

It is evident that more efforts should be made to estimate other emissions from feedstock use, although it is expected that reporting guidelines should give more clear guidance in the future.

CHAPTER: 4 : INDUSTRIAL PROCESSES (CRF 2)

4.1 Overview

In this source sector are included the GHG emissions resulting from the chemical and physical transformation of raw materials in the industrial transformation processes excluding emissions that result from combustion for energy production. According to UNFCCC reporting guidelines, also are included in this sector the emissions of fluorinated compounds (HFC, PFC and SF₆) that are used in different applications - not solely industrial, but also in domestic and services sector - as substitutes to ozone depleting substances (ODS). Emissions occurring in production processes in industry but involving the use of solvents or solvent bearing substances (such as paint) are included in source sector "Use of solvent and other uses – CRF 3" and discussed in chapter "Solvent Use".

Industrial processes, either involving combustion⁴⁶ 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 relevant sources of particulate matter (PM, PM₁₀, PM_{2.5} and PM₁) and local air pollutants such CO and Heavy Metals. The methodologies and emission factors that are used in the Portuguese air emission inventory for the estimate of emission from these sources are also discussed in this report as complementary information.

In terms of total GHG, emissions from the industrial production sector have increased from about 4.6 Mton CO₂e in 1990 to 7.1 Mton CO₂e in 2004, as may be seen from Figure 4.1, i.e. emissions estimated for 2004 are about 54 per cent higher than the emissions estimated for base year (1990). The majority of emissions, expressed in CO₂ equivalent (GWP), are associated with mineral industry, with 73.2 per cent of total emissions from this sector in 1990, and 59.4 per cent of total emissions from this sector in 2004, as may be seen in Figure 4.2. In second place of importance are the emissions from the chemical industry, which have increased from 26.1 per cent of emissions from this sector in 1990 toward 34.8 per cent of emissions in 2004. The remaining sub-source sectors (2C, 2D and 2F⁴⁷) have a lower importance in the beginning years, but they became more relevant toward the end of the period, when they amount to 5.8 per cent of emissions. This increase occurs mostly because of sub-category 2F, consumption of Halocarbons and SF₆, which represented in 2004 about 5.3 per cent of total GHG emissions from this source sector.

⁴⁶ 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.

⁴⁷ No emissions were allocated to sub-category 2G – Other. Emissions for category 2 F - Production of Halocarbons and SF₆, did not occur in Portugal.

Figure 4.1 – Total GHG emissions from Industrial Processes per source sub-sector (1990-2004)

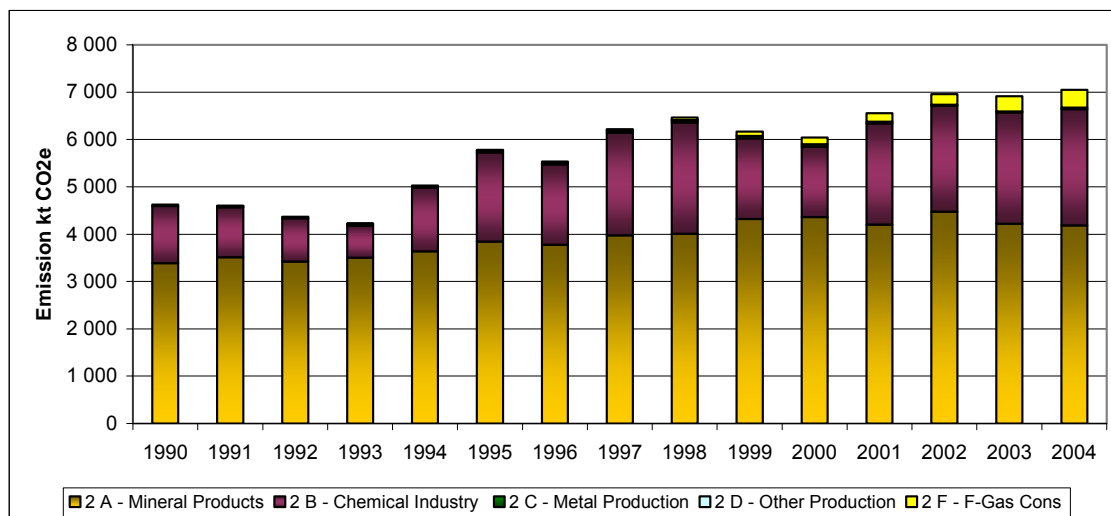
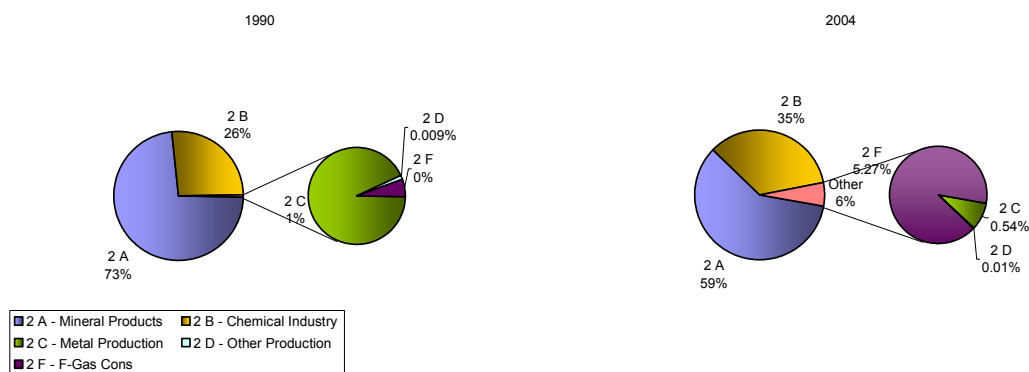
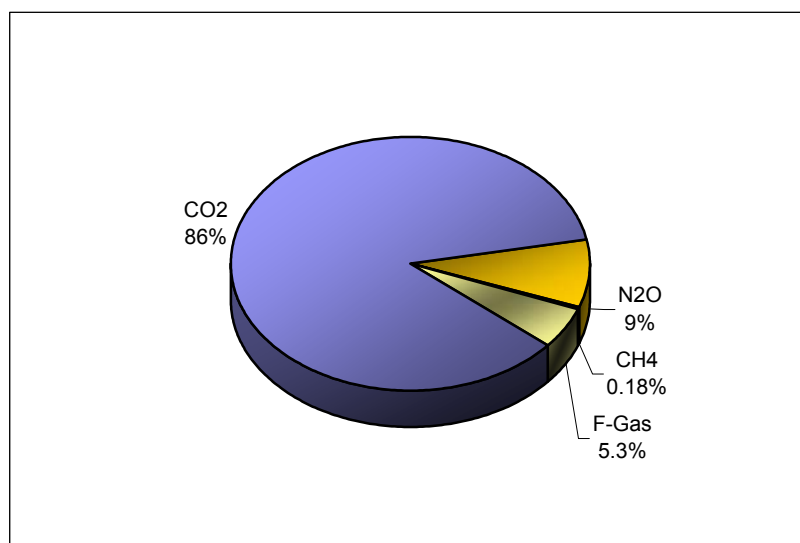


Figure 4.2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2003



The great major part of green-house gas emissions are realized directly as CO₂; while N₂O represents a smaller proportion of emissions and methane emissions are a non relevant part, as may be seen in Figure 4.3 for year 2004.

Figure 4.3 - GHG emissions from Industrial Processes per green-house gas in 2004



4.2 Recalculations

The changes made in emission estimates of CO₂, CH₄ and N₂O for the industrial sector, were very small, as may be seen below for base year and 2003, and restricted to CO₂.

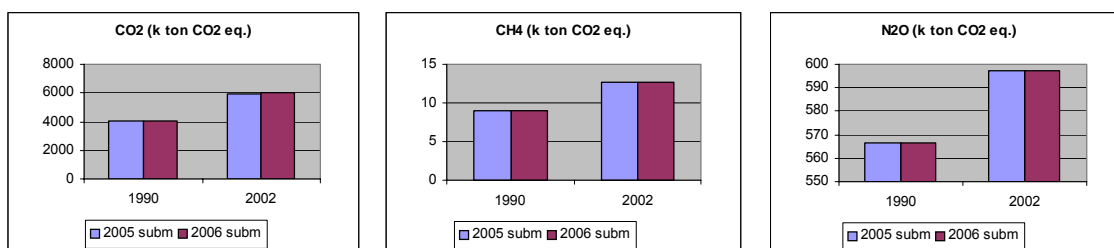
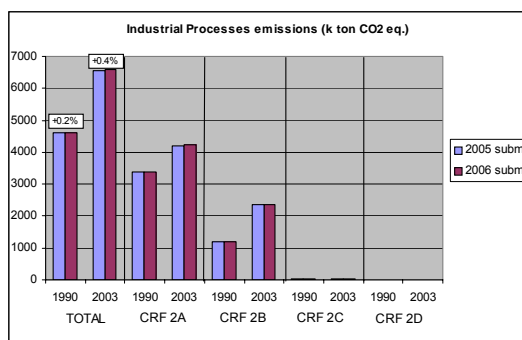
Figure 4.4 - Differences between submissions 2005 and 2006 for CO₂, CH₄ and N₂O emissionsFigure 4.5 - Differences between submissions 2005 and 2006 for CO₂ equivalent emissions

Table 4.1 - Recalculations (differences between submissions 2005 and 2006)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO2			CH4			N2O		
		2005	2006	Difference (1)	2005	2006	Difference (1)	2005	2006	Difference (1)
		subm.	subm.		subm.	subm.		subm.	subm.	
		CO2 eq (Gg)		(%)	CO2 eq (Gg)		(%)	CO2 eq (Gg)		(%)
1990										
2. Industrial Processes		4 038	4 049	0.27	9.08	9.08	0.00	566.68	566.68	0.00
2.A.	Mineral Products	3 375	3 384	0.27	0.76	0.76	0.00	0.00	0.00	0.00
2.B.	Chemical Industry	633	634	0.24	8.32	8.32	0.00	566.68	566.68	0.00
2.C.	Metal Production	29	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D.	Other Production	0	0	0.00		0.00			0.00	
2.G.	Other	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003										
2. Industrial Processes		5 962	5 985	0.39	12.61	12.61	0.00	597.21	597.21	0.00
2.A.	Mineral Products	4 198	4 219	0.49	1.74	1.74	0.00	0.00	0.00	0.00
2.B.	Chemical Industry	1 736	1 739	0.16	10.88	10.88	0.00	597.21	597.21	0.00
2.C.	Metal Production	26	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D.	Other Production	0	0	0.00		0.00			0.00	
2.G.	Other	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = $100\% \times [(LS-PS)/PS]$, where LS = Latest submission and PS = Previous submission).

4.3 Category Sources

4.3.A Mineral Industry (CRF 2A)

4.3.A.1 CEMENT PRODUCTION (CRF 2A1)

OVERVIEW

During the 1990-2003 period there were six cement production plants operating in Portugal, mostly dedicated to Portland cement production⁴⁸ and almost all localized in the southern half of the country. Five of these clinker producing units use the dry process while the remaining one uses both the dry and the semi-wet process - although the dry process is prevalent in that unit too. All dry process units have short kilns with pre-heaters, and 5 kilns in four units are provided with pre-calciners⁴⁹. The importance of clinker production for each one of the six plants is presented in Table 4.2, from where it is evident that production of clinker and CO₂ decarbonising emissions are dominated by three plant units.

Table 4.2 - Main Characteristics of Cement Production Plants in Portugal

Unit	Nut III	Average % of total Clinker Production 1990-2003
Souzelas	RC122	25.9
Maceira	RC123	12.4
Pataias	RC123	4.6
Alhmdra	RC132	25.6
Outão	RC133	23.7
Loulé	RC150	7.8

⁴⁸ There is also some production of white Portland cement, which is characterized by a lower iron and manganese content, than grey cement, and it is used mainly for decorative purposes (EPA,1995). There are also in Portugal smaller additional cement plants in Portugal but that do not produce clinker.

⁴⁹ One calciner is a false pre-calciner.

Portland cement is broadly a mixture of clinker and gypsum with some minor additives. Cement production is in essence a pyro-processing operation on calcium carbonate, aluminium-siliceous and iron-oxide materials to form a mixture of calcium silicates, aluminates and aluminoferrites that forms a binder with water.

Carbon dioxide emissions from cement production process result from the conversion of CaCO_3 and MgCO_3 , the main constituents of limestone, to lime (CaO) and MgO , while leaving CO_2 as by product to atmosphere (Decarbonisation). Sulphur oxides emissions result from sulphur existence both in fuel and in some constituent materials such as clay. However contrary to what occurs with CO_2 , usually most of the SO_x that is formed during calcination will be absorbed and long term immobilized in clinker and then in cement.

Only emissions of CO_2 from limestone decarbonising are reported here. Emissions of other pollutants, although they may result from both fuel and raw material, are reported in Energy (CRF 1A2) for simplicity sake. CO_2 emissions from liberation of carbon in fuel during combustion are reported also in Energy sector 1A2. However, although emissions are estimated separately from carbon originally present in fuel and carbon present in raw materials, they are in fact emitted at same place and are inseparable in concept.

METHODOLOGY

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to equation 3.1 of GPG, which is basically a mass balance:

$$\text{Emi}_{\text{CO}_2 (y)} = \text{EF}_{\text{Clinker}} * \text{Prod}_{\text{CLINKER (y)}} * \text{CKD} * 10^{-6}$$

where

$\text{Emi}_{\text{CO}_2 (y)}$ - emissions of CO_2 from cement production, originated from carbon in mineral constituent materials (kton/yr);

$\text{EF}_{\text{Clinker}}$ - emission factor (kg/ton clinker);

$\text{Prod}_{\text{CLINKER (y)}}$ - Total production of clinker (ton/yr);

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

EMISSION FACTORS

The CO_2 emission factor was estimated according to the following formula, equivalent to the GPG equation 3.3:

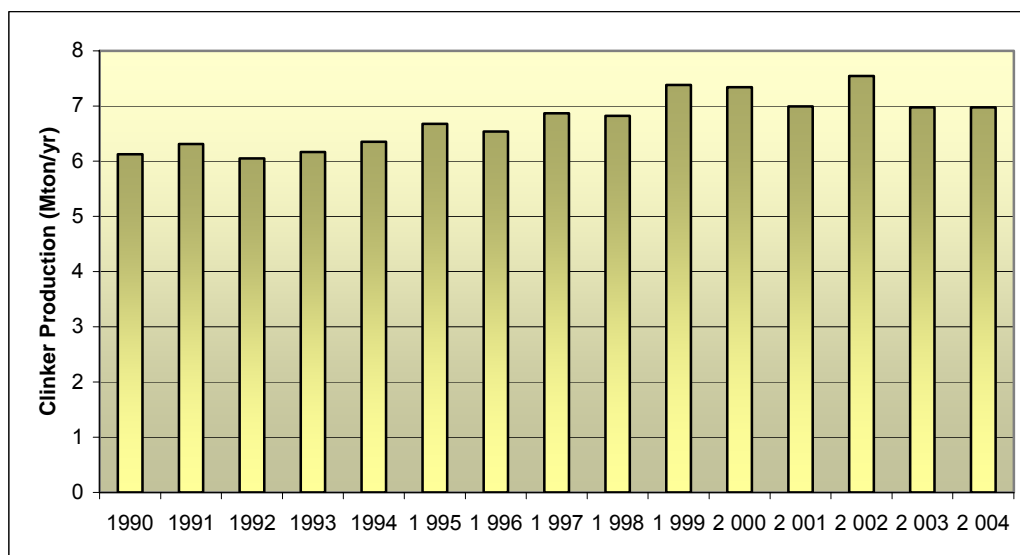
$$\text{EF}_{\text{Clinker}} = 44.01 / 56.08 * \text{Ratio}_{\text{CaO}}$$

where $\text{Ratio}_{\text{CaO}}$ is the Calcium oxide (lime) content of clinker (kg CaO / kg clinker). The default IPCC CaO fraction in clinker was considered in the inventory (64.6%). Final emission factor is therefore 0.507 ton CO_2 / ton clinker.

ACTIVITY DATA

Clinker production, for all the years from 1990 to 2003, was received directly from each industrial plant, and the correspondent time series may be observed in next figure. The value for 2004 is still a provisional figure.

Figure 4.6 – Total Production of clinker in Portugal (1990-2004)



The CKD correction factor to clinker production was not considered, in accordance to information received from industry experts that consider that in all production lines in portuguese cement plants, dust is fully returned back to the process and incorporated in final product.

UNCERTAINTY ASSESSMENT

The uncertainty value of the emission factor was determined to be 10 % for all years which results from the consideration of uncertainty error in the assumption that all CaO is from CaCO₃, CaO content of clinker and CKD parameter. In all cases the maximum values of uncertainty in the GP (IPCC,2000) was considered using a conservative approach. In a similar conservative mode the uncertainty associated with activity data was set at 2%.

RECALCULATIONS

No changes occurred for this sector apart from update of the clinker production value for 2002 with more accurate data received this year from the industrial plants. No modifications were done in what concerns methodology and emission factors.

FURTHER IMPROVEMENTS

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

$$EF_{\text{Clinker}} = 0.785 * \text{Ratio}_{\text{CaO}} + 1.092 * \text{Ratio}_{\text{MgO}}$$

The emission factors would therefore change from 0.507 ton CO₂/ton clinker to 0.525 ton CO₂/ton clinker, resulting in an increase of emissions of 3.55 %⁵⁰. This modification is still under consideration in the elaboration of the Methodology Development Plan that is part of the National System. The decision is also waiting the conclusions of the new 2006 Revised IPCC Guidelines.

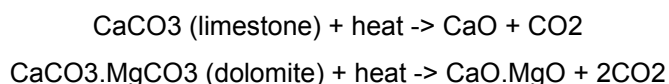
It was also envisaged that consumption of raw materials and the knowledge of its carbon content could be used to make estimates of carbon dioxide emissions from consumption of carbon in raw materials. This procedure would result in an alternative estimate method that could at least be useful to uncertainty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

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

4.3.A.2 LIME PRODUCTION (CRF 2A2)

OVERVIEW

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200°C) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving calcium oxide (CaO) or magnesium oxide (MgO) as valuable products. The following chemical conversion equation applies, where for each mol of oxide a mol of carbon dioxide is emitted.



Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy CaCO₃ content (at least 50%) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of Na₂CO₃, NaOH, steel, refractory material, SO₂ absorption, CaC₂, glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;
- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45% in content). Dolomite quicklime is a mixture of CaO and MgO;
- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime: Ca(OH)₂ It is produced from CaO and water. When an equivalent quantity of water is used is called slaked lime, when an excess water is used is milk of lime and a clear solution of

⁵⁰ Assuming CaO fraction in clinker of 64.5% and MgO 2%, the default value set by GHP Protocol (WBCSD/WRI).

$\text{Ca}(\text{OH})_2$ in water is limewater. It is used as an industrial alkali and in the preparation of mortar (slaked lime plus sand) which sets to solid by reversion of the hydroxide to CaCO_3 (Sharp, 1981);

- Hydraulic Lime. A mixture of calcium oxide (CaO) and silicates, it is an intermediate product between lime and cement.

Besides the production of lime in the lime industry to furnish market requirements, lime is also produced and consumed inside industrial sectors. That is the case of the production of lime in Kraft paper pulp plants, where quicklime is produced from carbonates in lime kilns and it is used to regenerate green liquor to white liquor. That is also the case of iron and steel production whereas emissions from this activity are also reported in this source category.

METHODOLOGY

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

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

Where,

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

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

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

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

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

EMISSION FACTORS

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

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

Where,

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

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

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

$\text{Content}_{\text{CaO}}$ – Content of CaO in high calcium lime as in final product (kg/kg)⁵¹;

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

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

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

Table 4.3 – Parameters used to derive the Emission Factors for Lime Production

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

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

In the case of the iron and steel industry all lime is high calcium quick lime and the emission factor, obtained from the above equation, is 0.75 kg CO₂/kg lime.

ACTIVITY DATA

Production of lime products in industrial plants solely dedicated to this activity is available for the period 1989-2000 from National Statistics (INE): for the period 1989-1991 from IAIT industrial survey, and for 1992-2000 from the IAPI industrial survey. In order to avoid double counting of decarbonisation (calcination), only lime sold was quantified but not lime produced for internal consumption in unit plant. Production values for 2001-2004 are simple linear forecasts from the available statistical time series. From the available information, no distinction could be made between the high calcium lime and dolomite lime for lime produced and sold to market.

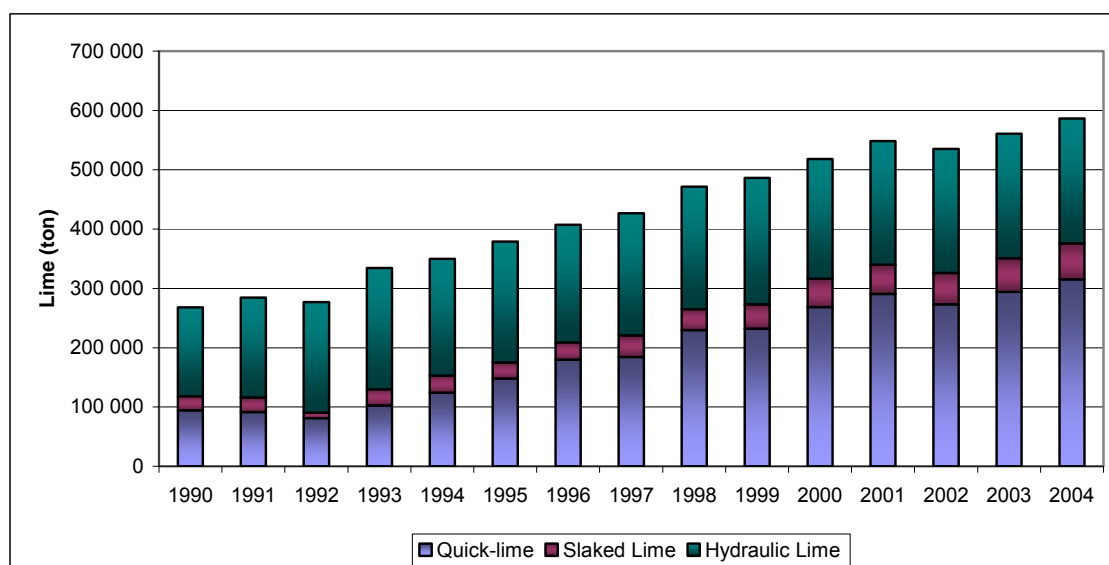
Lime production in the iron and steel industry was available from information received from the industry for the period 1991-1994. For the remaining years 1990 and 1995-2001 annual lime production, which data was unavailable, was forecasted using energy consumption as surrogate indicator. After year 2002 no more lime was produced in the industrial unit. All lime produced in the iron and steel plant is high calcium lime.

In the case of the paper pulp industry the IAIT/IAPI surveys have no available information in lime production but only of limestone and dolomite consumption. Lime production had to be estimated from consumption of those carbon bearing materials and assuming the stoichiometric ratios of limestone and dolomite rock.

The time-series of Lime production per lime type is presented in Figure 4.7, from where it is evident the pattern of production increase (119 per cent), particularly quick-lime which was more than doubled in the period, and the minor importance of slaked lime production.

⁵¹ These parameters have to be multiplied by respective oxide content because lime, or dolomite lime, are seldom composed of pure oxides, but include also a fraction of impurities.

Figure 4.7 – Production of lime in Portugal per lime type (1990-2004)



UNCERTAINTY ASSESSMENT

According to the GP the uncertainty associated with the carbon dioxide emission factor for lime production is 15% for hydraulic lime and 2% for all other lime types (IPCC,2000). The resultant uncertainty value according to the share of each lime type in Portugal was set at about 8.5%.

The GP assumes that uncertainty in activity data is very high due to problems in gathering lime data. The national inventory recognizes that this is in fact the case for Portugal, particularly because in some situations lime is not produced for market but for internal consumption in the industrial plant, and may be not properly reported in statistical surveys. The maximum uncertainty value of 105% was therefore used in the uncertainty analysis.

RECALCULATIONS

No modification was made in emission estimates for this source sector.

FURTHER IMPROVEMENTS

There is still some possibility that the inventory is doubling the estimate of CO₂ emissions, if part of the quick-lime that is produced in an industrial unit is sold and used again to produce slaked lime or hydraulic lime in a different industrial plant. To correct this effect, emissions estimated from lime production should be cross checked with emission estimates from limestone and dolomite consumption. Another contribution factor to over-estimation of emissions is the possible use of calcium materials to other used than lime⁵² production in the paper pulp industry.

A better and detailed knowledge of the proportion of lime that is high calcium lime and which is dolomite lime should be achieved – however this separation can not be done from National Statistical Databases except in the case of the paper pulp industry - allowing this differentiation to be used in activity data and not in emission factor as it was done in this submission.

⁵² Or any other process not resulting in decarbonisation.

4.3.A.3 LIMESTONE, DOLOMITE AND CARBONATE USE (CRF 2A3)

OVERVIEW

Carbon dioxide liberation to atmosphere occurs from several industrial activities that use limestone (CaCO_3), dolomite rock ($\text{CaCO}_3 \cdot \text{MgCO}_3$) or other carbonates, but only when original materials are not incorporated as inert components but suffer a chemical removal of carbon, as for example when calcium carbonate is added to nitric acid to form calcium nitrate:



Presently, in the inventory of GHG emissions, only CO_2 emissions resulting from production of calcium and magnesium nitrates and consumption of sodium carbonates in paper pulp production are reported in source category 2A3.

Use of carbonate materials in glass industry is covered in sector activity 2A7. Although the use of carbonates in iron and steel industry as flux in blast furnace result in CO_2 emissions, these were included in Energy (1A2), being assumed that the emission factor of CO_2 from blast furnace consumption⁵³ already includes the carbon from limestone that was liberated from the flux in the blast furnace. While consumption of carbonate materials is reported in the National Statistics Database (INE) for other industrial activities, some do not correspond to uses where carbon is liberated and no emissions are estimated: paint, soap, pharmaceutical and agrochemical products, cleaning products, perfumeries and hygiene products, glues and adhesives, tire and rubber products, plastic products and synthetic fibbers, and all food and beverage industry.

Lime production involves as well the consumption and decarbonising of carbonate materials, limestone or dolomite rock. Albeit the similitude of both process, carbon dioxide emissions from lime production, including production in the paper pulp industry and in the iron and steel industry, are reported in source category 2A2 and were already discussed.

Non- CO_2 process emissions in the paper pulp and fertilizer industry are reported in other source categories, respectively 2B and 2C. Combustion emissions from these industrial activities are reported in source category 1A2.

METHODOLOGY

CO_2 emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of CO_2 that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

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

where

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

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

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

⁵³ Determined from composition of Blast Furnace Gas given by industry.

EMISSION FACTORS

Carbon content of materials consumed in Portugal was set from molecular stoichiometry⁵⁴:

Table 4.4 - Carbon content of carbonate materials

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

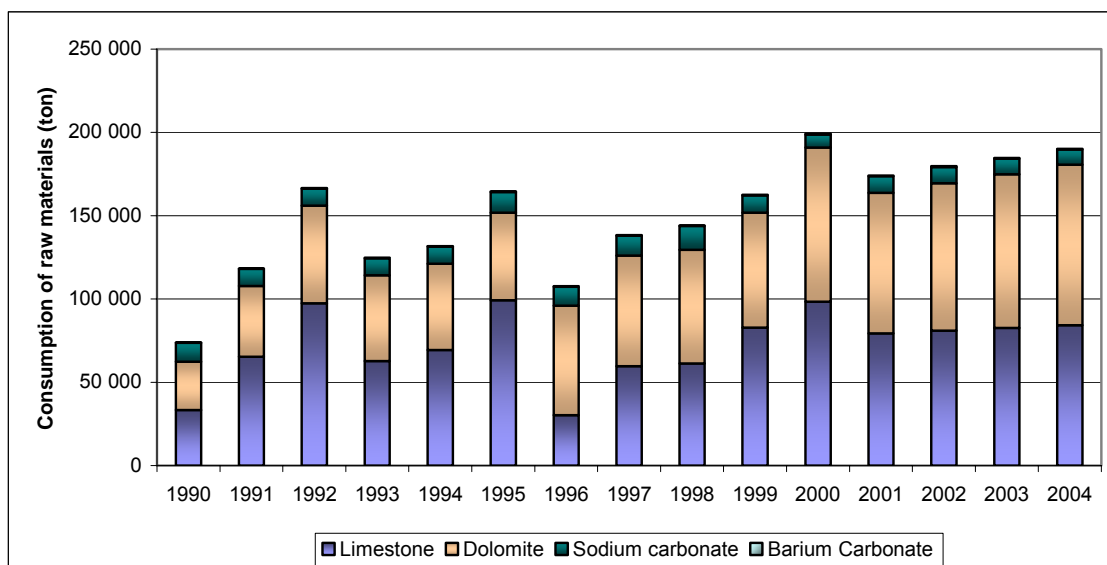
* assumed pure calcium carbonate;# Ca and Mg carbonate in equal share

ACTIVITY DATA

The consumption of sodium carbonate in the paper and pulp industry was determined from the statistical information from INE from 1990 to 2000 and thereafter forecasted. Due to the unavailability of statistical information concerning consumption of carbonaceous materials in the fertilizer industry – for the production of calcium and magnesium nitrates – they had to be estimated from fertilizer production data and considering that stoichiometrically two moles of nitrogen require one mole of either CaCO_3 or MgCO_3 . Fertilizer production per fertilizer type was also available from INE database from 1990 to 2000 and thereafter forecasted. Final total consumption of carbonaceous materials is presented in Figure 4.8 below. The ceramic industry, more particularly the brick and tile industry and the pavement industry, consumes limestone, dolomite and the carbonates of sodium and barium, and all these substances were considered to result in decarbonisation. For this industry sector, although the consumption of carbonate bearing materials is not known for the whole period, a consumption factor was developed based on the information received under the European Emission Trading Scheme (EU-ETS), and production of construction ceramics and pavement ceramics, available from INE's industry surveys IAIT and IAPI, was used to obtain the full time series. Total carbonate consumption has increase 57 per cent since year 1990.

⁵⁴ It was assumed that limestone was totally pure, which causes over-estimated emissions.

Figure 4.8 - Consumption of carbonate materials in industry (1990-2004)



UNCERTAINTY ASSESSMENT

There are no proposed values in GPG for the consideration of uncertainty values for CO₂ emission factor from consumption of carbonate materials. The same uncertainty values that are proposed for lime production (non hydrated lime) were therefore assumed (2%), considering that the conversion is only a stoichiometric mass balance and that error results only from uncertainty in Calcium and Magnesium content of raw materials. The uncertainty value of activity data, also not referred to in GPG, was assumed also equal to the uncertainty set for lime production.

RECALCULATIONS

The estimate of carbon dioxide emissions that are reported under this source category were increased because of the inclusion of new estimates for consumption of limestone, dolomite and carbonate materials in the ceramic industry.

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).

Emissions of CO₂ from use of sodium carbonate (soda ash) will be moved to category 2A4 in next submissions. Finally care must be made to avoid double counting of emissions that may be already included in other industrial sectors.

4.3.A.4 ROAD PAVING WITH ASPHALT (CRF 2A6)

OVERVIEW

Emission estimates reported in this source category include emissions occurring from paving road surfaces with asphalt materials as well as emissions occurring during operation of hot mix asphalt plants. Emissions from production of asphalt emulsions and cold asphalt mixtures are not included in the inventory estimates, being assumed that they are negligible.

Roads pavement with asphalt is done by the application of several layers over road bed. In volume, the majority of pavement is composed of layers of a compact aggregate and an asphalt binder (asphalt concrete). Asphalt concretes are classified either as hotmix or as coldmixes: cutback and emulsified asphalts. Liquefied asphalts – cutbacks and emulsions - are also used directly in seal and priming roadbed operations, sometimes in intermediate layers between applications of asphalt cement layers. Aggregate materials incorporated in asphalt concrete are usually composed of coarse unconsolidated rock fragments, either obtained from rock crushing, natural alluvial deposits or by products from metal ore refining.

Hot mix asphalts are made by mixing the aggregate material together with the asphalt cement using high temperatures (150°-160°)⁵⁵. Cold mix plants also involve mixing aggregate materials with an asphalt binder, but now the binder is an asphalt emulsion or is a cutback cement, and this process takes place at much lower temperature (40-60°).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers⁵⁶. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphta (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12% of solvents. Hot mix asphalts in the other hand, result in minimum NMVOC emissions during application, because the organic component has high molecular weight and low vapour pressure (USEPA,2001 – EIIP Volume III Chapter 17).

Asphalt pavements dominate road paving activity in Portugal, whereas rigid cement pavements are only about 5% of total paved areas (APORBET).

Emissions during fabrication of asphalt concretes are estimated only for hot mix asphalt and comprehend NMVOC and Particulate Material that escape mostly from the drier. Other pollutants are also emitted but they result mostly from combustion of fuels and are considered in chapter Energy (1A2)⁵⁷. Emission estimates for hot-mix are only made here for pollutants COVNM and PM, while emission of other pollutants are covered in emission estimates made for Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity⁵⁸.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible⁵⁹.

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

⁵⁵ That are needed to fluidize the asphalt cement.

⁵⁶ And also a solvent in several emulsion types.

⁵⁷ To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

⁵⁸ It is not possible to distinguish fuel combustion in hot mix production activity.

⁵⁹ 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.

METHODOLOGY

Different methodologies were used to estimate emissions during asphalt application or from asphalt production.

Application of Asphalt Concretes and Liquefied Asphalts

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA,1997; USEPA,2001):

$$Emi_{NMVOC(y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Emi_{NMVOC(y)}$ - Emissions of NMVOC from asphalt application during year y (ton/yr);

$Binder_{(y)}$ – Total quantity of asphalt binder used in road paving during year y (ton/yr);

SLV_{Fac} - Fraction of distillate (solvent) in asphalt (m^3/m^3);

d_{SLV} - density of solvent added to liquefied asphalt (kg/l);

d_{BIN} - density of bitumen binder mixture (kg/l);

$Cure_{FC}$ - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100% composed of VOC (USEPA,2001) and that emitted VOC have on average 85% of carbon:

$$Emi_{CO2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

Hot Mix Asphalt Production

For calculation of hot mix production emissions, emission calculation is based on total product:

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

Where,

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

$Hotmix_{Batch(y)}$ and $Hotmix_{Drum(y)}$ – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

$EF_{(p)}$ and $EF_{(p)}$ – Emission Factors for pollutant p used respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

Although available methodologies allow the calculation of emissions of several other pollutants from Hot mix asphalt production, in order to avoid double counting – and because fuel consumption in this activity could not be individualized from total fuel use in construction and building – only emissions of NMVOC and PM were estimated here. Although double counting could nevertheless be made for these pollutants, it was considered that the production process results in specific emissions of these two pollutants, that would be under-estimated if they would be estimated solely from fuel combustion. Particulate matter is enhanced by manipulation of aggregate materials and some NMVOC result not from incomplete combustion of fuel but also from partial evaporation of bitumen components.

EMISSION FACTORS AND PARAMETERS

The following parameters were chosen to determine emission factors for application of emulsified and cutback asphalts. These values were chosen according to recommendations in AP-42, EMEP/CORINAIR or industrial expert guess.

Table 4.5 - Emission Parameters for road paving with asphalt

Parameter	Cutback	Emulsions
SLV_{Fac}	25 %	3 %
d_{SLV}	0.95 kg/l	0.85 kg/l
d_{Bin}	0.95 kg/l	0.85 kg/l
Cure type	Medium Cure (MC)	-
$Cure_{FC}$	0.75 kg/kg	1 kg/kg

Emission factors used to estimate NMVOC and PM emissions from Hot mix plants are from USEPA (2000) and are presented in next table.

Table 4.6 - Emission Parameters for Hot Mix asphalt production

Pollutant	Continuous	Batch	Unit EF
PM	14	16	kg/ton
PM10	23	14	%
PM2.5	5.5	1	%
NMVOC	32.0	22.1	g/ton
CH4	12.0	7.4	g/ton

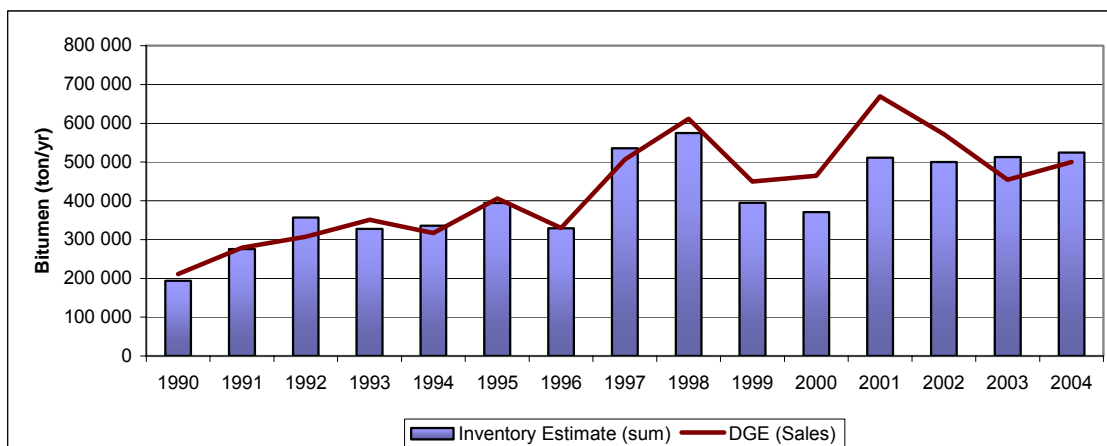
Source: USEPA (2000)

ACTIVITY DATA

The total quantity of bitumen sold to construction and building economic sector is available from the Energy Balance and was collected by the General Directorate of Geology and Energy (DGGE) based on surveys⁶⁰, and it is presented in Figure 4.9. 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.

⁶⁰ Original data from DGE is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGE

Figure 4.9 - Total consumption of bitumen in the construction sector according to sales from DGGE and sum of values of asphalt used, according to the inventory (1990-2004)



Cutback asphalt is seldom used in Portugal and it is sold only by two companies, according to information gathered at APORBET, the Portuguese Association of Producers of Bitumen Materials. Annual sales were assumed equal to annual consumption and may be seen in Table 4.7 and Figure 4.10. Total emulsions applied are available from EAPA for 1997 and beyond. For previous years use of emulsions was estimated from the total quantity of asphalt materials applied as road pavement, also from EAPA, and considering a percentage of that bitumen that is emulsions. It was also assumed that this percentage was zero in 1990 and has increased to 19% in 1996. Data for Hot mix concrete asphalt production is from EAPA for 1991-2001 and forecasted for the remaining years. 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 DGGE, match the sum of individual estimates, and both values agree reasonably well as may be seen from Figure 4.9 above. Total production of Hot mix concrete asphalts is presented in Figure 4.10.

Table 4.7 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (ton)

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

Asphalt	1998	1999	2000	2001	2002	2003	2004
Cutback	933	162	576	824	501	340	0
Emulsified	130 000	95 000	86 000	107 000	116 000	116 000	116 000

Figure 4.10 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (1990-2004)

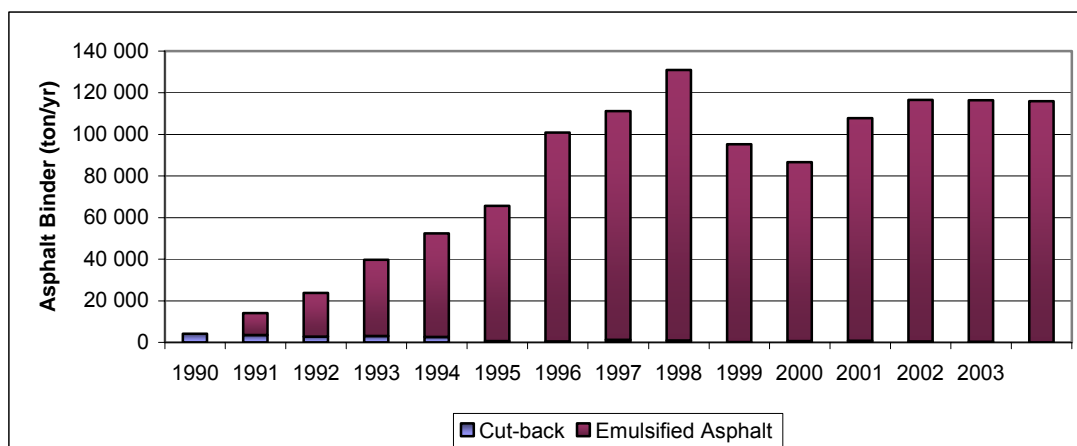
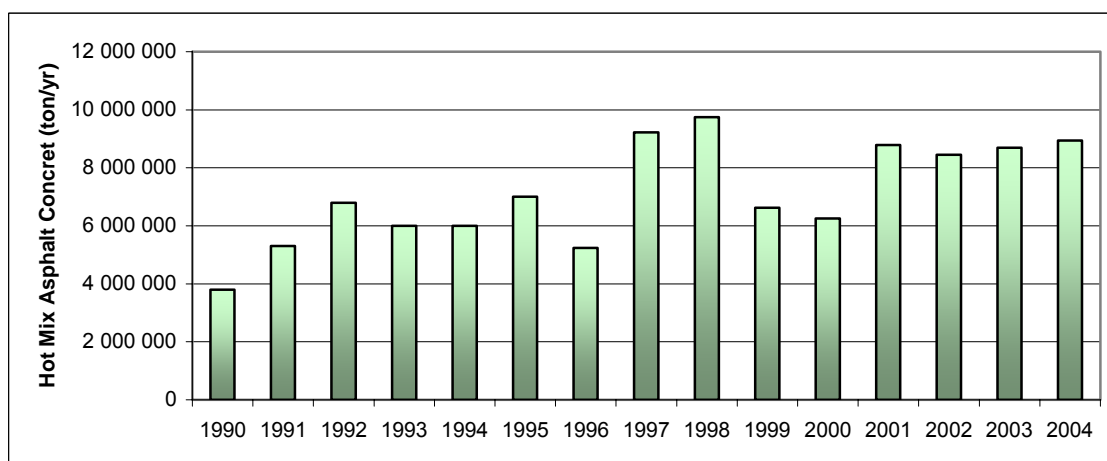


Figure 4.11 – Total Production of Hot Mix Asphalt (1990-2004)



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).

UNCERTAINTY ASSESSMENT

There is no specific information in the GPG concerning uncertainty values for this source sector. Uncertainty in activity data was estimated as the maximum difference between the total bitumen quantities estimated by the inventory and reported in the DGGE energy balance: 31 %.

The uncertainty in the emission factor for NMVOC/CO₂ is higher and mostly associated with the uncertainty in the share of asphalt that is applied as cut-back, emulsion of as hot mix. Because of the very variable emission factor according to which asphalt type is being considered two orders of magnitude was considered for the uncertainty value of the emission factors for NMVOC and CO₂.

RECALCULATIONS

Following the extensive improvements that were done last year (between submissions 2003 and 2004) in the emission estimates for this source sector, only minor details improved this

year's submission estimates: correction of a formula error for solvent content in cut-back in the spreadsheets and correction of the values of binder density for emulsions.

FURTHER IMPROVEMENTS

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

A special inquiry is also being made concerning the share of each type of hot mix equipments in use: batch and continuous production plants.

It was still however not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation and asphalt roofing. Improvements in this separation are expected in following submissions.

4.3.A.5 GLASS PRODUCTION (CRF 2A7)

OVERVIEW

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. It is made submitting this materials to a high temperature which are thereafter made solid without crystallization (semi-solid state).

Glass involves carbon dioxide emissions, from decarbonising of limestone and carbonate materials under high temperature conditions. Carbonate materials vary with the desired product and comprehend typically limestone, dolomite, soda ash (sodium carbonate) and other carbonate compounds of potassium, barium or strontium.

Combustion emissions from glass production were already considered in source sector 1A2, estimated from fuel consumption data or production data. Some anthracite coal is used also as additive in glass production. However, because the consumption of this material is already considered in the energy balance, to avoid double counting of emissions emissions from coal use are not considered here⁶¹.

METHODOLOGY

Carbon dioxide emissions from glass production were estimated from:

$$\text{Emission}_{\text{CO2}(t,y)} = \text{EF}_{\text{CO2}(t)} * \text{ActivityRate}_{(t,y)} * 10^{-3}$$

where

$\text{Emission}_{\text{CO2}(t,y)}$ - annual emission of carbon dioxide from specific glass type t in year y (ton/yr);

⁶¹ They were not used to derive the country specific emission factors for instance.

ActivityRate_(t,y) - Glass of type t produced in a given year y (ton/yr);

EF_{CO2(t)} - emission factor from production of glass of type t (kg/ton)

EMISSION FACTORS

The following emission factors were considered:

Table 4.8 - Carbon Dioxide Emission Factors for Glass Production

Material	EF	Unit EF	Reference
Flat Glass	126	kg/ton	CS
Container Glass	130	kg/ton	CS
Lead Crystal Glass	239	kg/ton	EMEP/CORINAIR
Other Glass	239	kg/ton	

Country specific emission factors were calculated using data from 10 industrial plants in Portugal under the studies for the development of the Allocation Plan for the implementation of the European Union Emission Trading Scheme (EU-ETS). These units reported annual production quantities together with consumption of carbonate materials: limestone, dolomite, sodium, barium and potassium carbonates, from where average emission factors could be estimated.

ACTIVITY DATA

There are some problems with the use of statistical information from INE because not all products are reported in weight, but instead are measured in area-units (m²) or number of produced pieces. Because the available emission factors are expressed on weight basis, an effort was made to build time series in common weight units, converting production estimates from INE databases and also making use of information collected directly from industrial plants. The following assumptions were made:

- Flat glass. Presently there is only one industrial unit producing flat glass in Portugal. Activity data was set for 1992 to 2001 from information collected directly from that unit, while for 1990 and 1991 this value was available from INE databases (IATI industrial survey). Statistical information from INE for the period 1992-2000 (IAPI industrial survey) was available in area units (m²) but was not used because conversion to weight units would lead to high uncertainties. Production value for 2002 and 2003 were forecasted by IA;
- Container Glass. Also for this type of glass product the information available in INE databases (IAIT and IAPI industrial surveys) was not well suited to be used in the inventory because production was measured in produced object umbers units and not weight. Production of container glass was available from Technology Centre for Ceramics and Glass (CTCV) for the period 1994 to 2003. Production in the period 1990 to 1993 was estimated by IA extrapolating CTCV time series and using the full time series of INE as surrogate data;
- Lead Crystal Glass production from 1992 to 2000 was available from INE IAPI industrial survey and was extrapolated, from the available time series, for 1990-1991 and 2001-2003. Original data in INE time series had to be converted from number units to weight units assuming typical weight per object;

- Other glass. This category comprehends several parts such as blocks, bricks, tiles, kitchen-ware, medical and pharmaceutical equipment and decoration articles. Time series was set from INE statistical database (IAIT and IAPI industrial surveys).

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

Table 4.9 – Unit conversion factors for glass products in INE statistical databases

Product	Conversion Factor (kg/unit)
Glasses	0.2
Bottles	0.5
Small containers (Jars)	0.2
Large Containers	3
Medical equipment	0.01
Other objects	0.5

Production values for container glass, lead crystal glass and other glass is presented in Figure 4.12. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 4.12 - Glass production by glass type (excluding flat glass production)

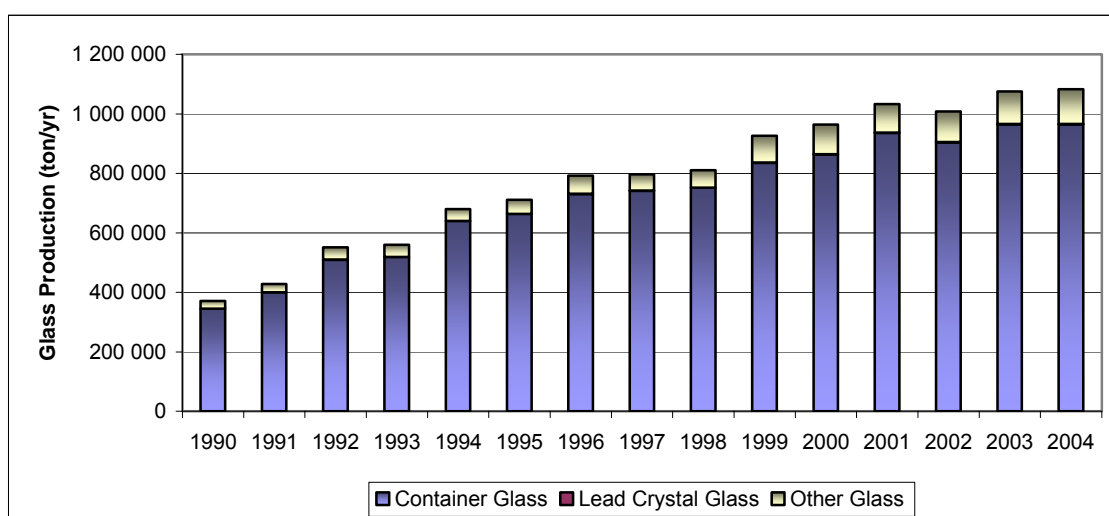


Table 4.10 - Glass production by glass type (excluding flat glass)

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

Type of Glass	1998	1999	2000	2001	2002	2003	2004
Container Glass	751	835	863	936	904	965	965
	333	451	502	471	433	279	279
Lead Crystal Glass	837	903	1 009	1 078	1 163	1 247	1 332
Other Glass			100		102	109	116
	58 115	90 141	059	94 912	081	251	421

UNCERTAINTY ASSESSMENT

A 100 % uncertainty value was set for activity data expressing the fact that for some glass types the activity data in statistical databases was expressed in non weight units, number of pieces or area. The double value of the standard deviation of the set of emission factors available for Portuguese units, and estimated from carbon market data, allows the consideration of an uncertainty value of 54%.

RECALCULATIONS

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

FURTHER IMPROVEMENTS

Estimates of emissions due to the production of glass wool and rock wool are still not available due to lack of statistical information for activity data. Although it is foreseen that this are minor emission sources, efforts are being made to obtain this information and establish emission estimates for this source.

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

4.3.B Chemical Industry (CRF 2B)

4.3.B.1 AMMONIA PRODUCTION (CRF 2B1)

OVERVIEW

Presently only one fertilizer industrial plant manufactures ammonia in Portugal, using Vacuum Residual Fuel Oil (VRF) and source of hydrogen (feedstock). Ammonia is formed after reaction of hydrogen with nitrogen from air. In the start of year 1990 there was another unit operating in Portugal, but has stopped activity already in the beginning of that year. The conversion of feedstock to hydrogen results in the liberation of the associated carbon as ultimate CO₂ which is vented to atmosphere. Although actually some part of CO₂ liberated from VRF, during ammonia production, is in fact used in urea production and it is not immediately emitted to atmosphere. However, because liberation to atmosphere is eventually achieved after the application of urea in agricultural soils as amendment, and also because some other sources of CO₂ may be used in urea manufacturing, the option was not to deduce this CO₂ fixation in feedstock.

Other pollutants result from the process, either from escape of ammonia (NH₃) or either from release of products from feedstock: CO and NMVOC.

METHODOLOGY

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

$$\text{Emi}_{\text{CO}_2(y)} = 44/12 * \text{Feedstock}_{(y)} * C_{\text{Feed}(y)} * 10^{-5}$$

where

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

$\text{FeedStock}_{(y)}$ - Annual consumption of feedstock (ton/yr)

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

Emissions estimates for the other pollutants are estimated by the use of emission factors multiplied by the quantity of material manufactured:

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

where

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

$\text{ActivityRate}_{(y)}$ - quantity of ammonia produced in year y (ton/yr);

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

A specific procedure applies to NMVOC emission estimate, whereas an additional fraction of methanol emissions were estimated from annual consumption of this compound in the industrial plant and assuming that this annual input was used to replenish annual losses to atmosphere. Emissions calculated that way are added to NMVOC emission estimates calculated from multiplication of ammonia production by an emission factor.

EMISSION FACTORS

The following emissions factors were applied to production data for each substance. They were mostly set from emission factors in CORINAIR/EMEP and AP-42.

Table 4.11 - Emission Factors for ammonia production

Pollutant	EF kg/ton NH ₃
U _{CO₂}	3.20 ^(a)
NMVOC	0.60 ^{(b)(c)}
CO	7.9 ^(c)
NH ₃	2.10 ^(c)

(a) expressed in ton CO₂/ ton VFR. Carbon content in feedstock was assumed to be 86%

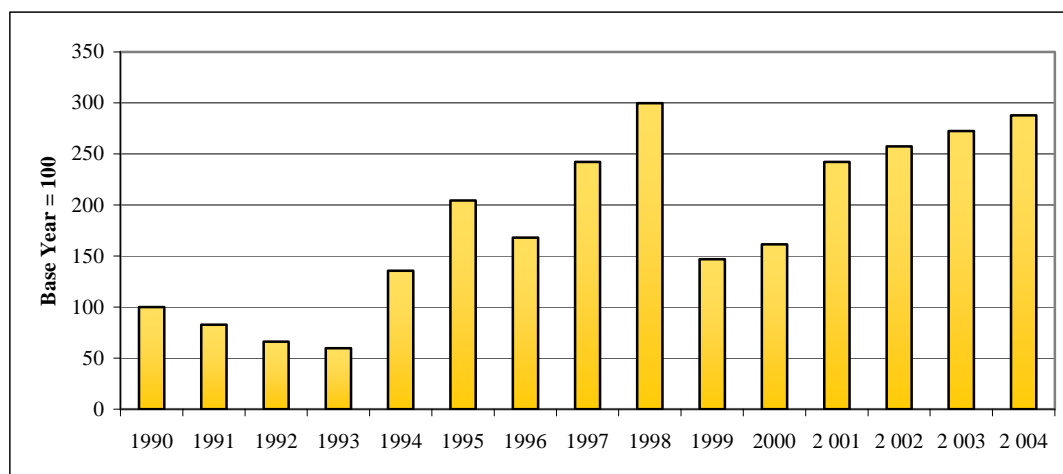
(b) USEPA (1993)

(c) Not including methanol emissions, estimated by mass balance

ACTIVITY DATA

Because there is only one industrial plant in operation, it is not possible to present any absolute information concerning activity data for this source activity, neither ammonia production nor feedstock and methanol consumption. The overall trend in the quantity of ammonia produced in the period may be however depicted in Figure 4.13, from where it is evident the significant increase of production since 1990 but with substantial inter-annual changes.

Figure 4.13 - Trend in Ammonia production (1990-2004)



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

- total production of ammonia in Portugal is available from INE for the period 1990-2000, resulting from the IAIT survey for 1990 and 1991, and from the IAPI survey thereafter. These correspond to a methodological change done by INE in what concerns industrial surveys. The IAIT industrial survey is available for years 1990-91 and IAPI industrial survey was used thereafter. Changes from IAIT to IAPI include modification in questionnaire, classification of economic activities, product and materials codification. Spatial allocation of economic data has also changed between these two survey processes;

- consumption of VRF feedstock could not however be determined from INE statistical database, because differentiation of residual fuel oil for feedstock and energy source was not clarified for this economic activity. Therefore, as explained before, consumption of feedstock VRF was estimated from limited information and relying on a linear correlation: the quantity of VRF that was used was set from data collected at the only industrial plant in Portugal for a limited number of years – 1990 till 1994 – and a strong linear relation between feedstock consumption and ammonia production could be established from available data;

- use of methanol was also estimated for the full time period from a linear regression which was determined from available information for a limited number of years.

UNCERTAINTY ASSESSMENT

No specific guidelines exist in GPG (IPPC,2000) to estimate the uncertainty of this source sector. The greatest uncertainty of emission estimates for this source sector results from the uncertainty in knowledge of activity data (Feedstock consumption). Because the ratio of feedstock consumption over ammonia production was used to estimate feedstock consumption, the standard deviation of these ratios was used to estimate the error and then doubled to

include an additional factor of conservativeness⁶². The final uncertainty value for activity data was set as 31 %.

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

RECALCULATIONS

No changes were made in inventory estimates for this source sector either in methodology, emission factors or activity data.

FUTURE IMPROVEMENTS

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

Information from Regional inventory surveys, EPER, E-PRTR and monitoring under *Autocontrolo* program may also allow better insight of technologies of this sector and may possibly improve methodologies and emission factors for gases other than CO₂.

4.3.B.2 NITRIC ACID (CRF 2B2)

OVERVIEW

Only three industrial plants did produced nitric acid in Portugal between 1990 and 2004, located in Estarreja, Alverca and Lavradio. In all weak nitric acid (60%) is produced from ammonia, using catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to NO₂ at medium pressure, and subsequent absorption with water to form nitric acid in a dual-stage process.

Nitric Acid manufacture results in air emissions primarily of NO_x (NO and NO₂), trace amounts of HNO₃ acid mist, ammonia (NH₃) and Nitrous Oxide (N₂O). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of NO_x are controlled by catalytic reduction. Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

METHODOLOGY

For all pollutants emissions are estimated using the following equation:

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

where

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

ActivityRate_(y) – production of Nitric Acid in year y (ton/yr);

⁶² A further doubling was used to convert from standart deviation to 95% confidence interval.

EF_(p) - emission factor for pollutant p (kg/ ton)

EMISSION FACTORS

The emission factors that were used are presented in Table 4.12, with a short explanation of their origin. All emissions were estimated using monitoring data for industrial plants in Portugal and used for the overall production.

Table 4.12 – Emission Factors for emission estimate for Nitric Acid Production

Pollutant	EF kg/ton HNO ₃
N ₂ O	7.52 ^(a)
NO _x	1.2 – 1.3 ^(b)
NH ₃	NE ^(c)

(a) From plant specific monitoring data at one (of a total of three industrial plants)

(b) From plant specific monitoring data at two (of a total of three industrial plants)

(c) Emission Factor not available from bibliography reference or emission monitoring

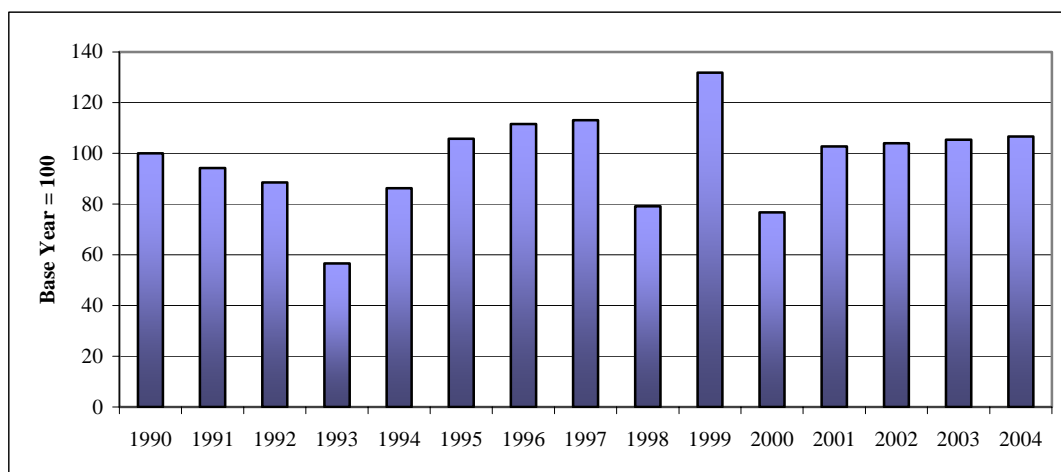
ACTIVITY DATA

The activity data that was used to estimate emissions from this sub-source sector is subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends). The sources of information that were used to establish activity data time series are discussed below in Figure 4.14, together with the presentation of time trend. Albeit inter-annual variations the average annual production did not show a sustained trends in the period.

The time series was determined according to the following mode:

- Quantities of Nitric acid for year 1990 are available from a specific questionnaire that had been sent to industrial units by IA under Corinair90 project;
- From 1992 to 2000, total national production of Nitric Acid was set from INE statistical database (IAPI survey);
- For 1989-1991 statistical information of Nitric Acid Production is available from the IAIT survey.

Figure 4.14 - Trend in Nitric Acid production (1990-2004)



UNCERTAINTY ANALYSIS

The uncertainty value for activity data is 3%, considering that the restricted number of units allows a good knowledge of production data. The uncertainty value of the emission factor of Nitrous Oxide a value of 10 % was chosen, which is in accordance with references to uncertainty ranges in GPG and also in accordance with the difference between the country specific emission factor determined from monitoring data and the proposed emission factor.

RECALCULATIONS

Emission estimates for this source did not suffer modifications in either in methodology, emission factors or activity data.

FUTURE IMPROVEMENTS

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

4.3.B.3 NON GHG EMISSIONS FROM INORGANIC CHEMISTRY AND FERTILIZER INDUSTRY

OVERVIEW

Discussed here are the air emissions, excluding greenhouse gases, resulting from sulphuric acid production, sulphur recovery and fertilizer industry. GHG emissions from chemical industry are discussed in previous chapters: Ammonia production and Nitric Acid production. Emissions of greenhouse gases and other pollutants from the organic chemistry are discussed in next chapter.

Sulphuric Acid Production

In 1990 in Portugal there were two industrial units producing sulphuric acid from mineral processing and more two additional industrial plants producing H_2SO_4 by recovery of sulphur. In 1990 and 1991 both industrial plants producing sulphuric acid from pyrites were closed and thereafter only sulphur recovery process remained active. Presently, emissions of SO_x from

sulphuric acid production result from recovery of sulphur - and abatement of air emission - in an ammonia industrial plant that uses a high sulphur content raw material, Vacuum Residual Fuel oil (VRF), as feedstock.

Production of sulphuric acid (Contact Process) comprehends a first step, where SO_2 is formed from oxidation of elemental sulphur with air, followed by conversion to SO_3 , in a catalytic converter, and finally the absorption of this gas in a strong acid solution.

In the case of sulphur recovery units, a flux of hydrogen sulphide, coming from the partial oxidation of the feedstock, is converted into H_2SO_4 , also by air oxidation, but without previous conversion to elemental sulphur. The process then proceeds in a similar fashion to sulphuric acid production. Although emissions of SO_x from recovery of sulphur occur in the Claus unit and in the flare, all are reported in the same source category (2B5-Other Chemical Industry) in CRF tables. For reporting of acidification emissions, in NFR reporting format, only emissions in the Claus unit are reported in 2B5, while emissions in the flare – a lesser source however – are reported in 1AC – Flaring in chemical industries.

Other Emission Sources in Chemical Industry and Fertilizer industry

Other industrial inorganic chemical activities that contribute to air emissions and which are included in the inventory comprehend the manufacturing of:

- urea;
- ammonium sulphate;
- ammonium nitrate;
- calcium nitrate;
- other nitrogen inorganic fertilizers: calcium ammonium nitrate (CAN), Ammonium Sulphate Nitrate (ASN); Calcium Nitrate (CN); Calcium-magnesium nitrate (CMN)
- super phosphates, normal (NSS) and triple (TSS);
- di-ammonium phosphate;
- NPK fertilizers.

Production of some of these materials involve chemical reactions, such as ammonium nitrate neutralization, calcium nitrate, ammonium sulphate, super-phosphate production, but others, such as production of NPK fertilizers, merely include composing, mixing, granulation or prilling, cooling and drying.

METHODOLOGY

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

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

where

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

ActivityRate_(y) - Indicator of activity in the production process: quantity of product produced in year y, as a general rule for this emission source sector (ton/yr);

EF_(p) - emission factor for pollutant p (kg/ ton)

In the case of sulphur recovery with sulphuric acid production, total SO_x emissions are estimated from the knowledge of sulphur content in original feedstock, considering the recovery efficiency and assuming that all sulphur in feedstock is recovered or goes to atmosphere⁶³:

$$\text{Emi}_{\text{SOx}(y)} = 2 * \text{Feedstock}_{(y)} * S_{\text{Feed}(y)} * 10^{-2} - 32/98 * \text{Prod}_{\text{H}_2\text{SO}_4(y)}$$

where

EmiSO_x(_y) - Emission of sulphur oxides⁶⁴ (ton/yr);

FeedStock_(y) - Annual consumption of feedstock (ton/yr)

S_{Feed(y)} - Sulphur content of feedstock (%);

Prod_{H₂SO₄ (y)} - production of sulphuric acid from sulphur recovery in year y (ton/yr).

EMISSION FACTORS

The following emissions factors were applied to production data for each substance. They were mostly set from emission factors in CORINAIR/EMEP and AP-42.

Table 4.13 - Emission Factors for inorganic chemical industry processes (1/2)

Pollutant	Sulphuric Acid kg/ton H ₂ SO ₄	Urea kg/ton Urea	Ammonium Sulphate kg/ton (NH ₄) ₂ SO ₄	Ammonium Nitrate kg/ton NH ₄ O ₃
SO _x	16.4-30.7 ^(a)			
NM VOC			1.04 ^(f)	
NH ₃		9.66 ^(d)		2.0 ^(g) + 1.4 ^(b)
PM		2.01 ^(d)	0.02 ^(f)	2.4 ^(h) + 2.5 ^(b+h)
PM ₁₀		1.82 ^(d)	0.02	2.4 + 2.0 ^(h)
PM _{2.5}		1.61 ^(d)	0.02	2.4 + 2.0 ^(h)
PM _{1.0}		1.61	0.02	2.4 + 2.0

⁶³ For the time being this procedure is only feasible for two years: 1990 and 1993. For the remaining years the average emission factor (kg SO_x/kg S in VRF) for 1990 and 1993 was used to estimate emissions.

⁶⁴ In fact, this emissions include also H₂S and other sulphur compounds, but it is assumed that they are converted to SO_x in atmosphere.

Table 4.14 - Emission Factors for inorganic chemical industry processes (2/2)

Pollutant	NPK kg/ton	CN, CMN kg/ton	Normal SS kg/ton	Triple SS kg/ton	DAP kg/ton
NH ₃	1.89 ^(c)	0.1 ^(b)	4.91 ^(c)	0.82 ⁽ⁱ⁾	1.0 ^(g)
PM	4.2 ^(c+h)	0.6 ^(b)	4.09 ^(c)	0.73 ⁽ⁱ⁾	0.3 ^(g)
PM10	3.4	0.5	4.09	0.73	0.3
PM2.5	3.4	0.5	4.09	0.73	0.3
PM1.0	3.4	0.5	4.91	0.82	0.3

(a) Only from Claus unit, representing individual units production efficiency. Total emissions from VRF consumption are estimated by mass balance from sulphur content of feedstock. According to US-EPA (xpto)

(b) From plant specific monitoring data at one (of a total of three industrial plants)

(c) From plant specific monitoring data at two (of a total of three industrial plants)

(d) USEPA (1993)

(f) USEPA (1993). Rotary driers controlled (wet scrubber)

(g) UNEP/UNIDO/IFA (1998)

(h) USEPA (1993)

(i) USEPA (1993) Controlled

Sulphur content of feedstock used in the ammonia plant can not be made explicit in NIR due to confidential constraints.

ACTIVITY DATA

All activity data that was used to estimate emissions from these sources are subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends). The information sources that were used to establish activity data time series are discussed below, together with the presentation of time trends.

General

- National Statistical Information. IAIT industrial survey was available for years 1990-91 and IAPI industrial survey was used thereafter. Change from IAIT to IAPI represents a methodological shift made by INE, involving change in questionnaire, classification of economic activities, product and materials codification. Spatial allocation of economic data has also changed between these two survey processes;

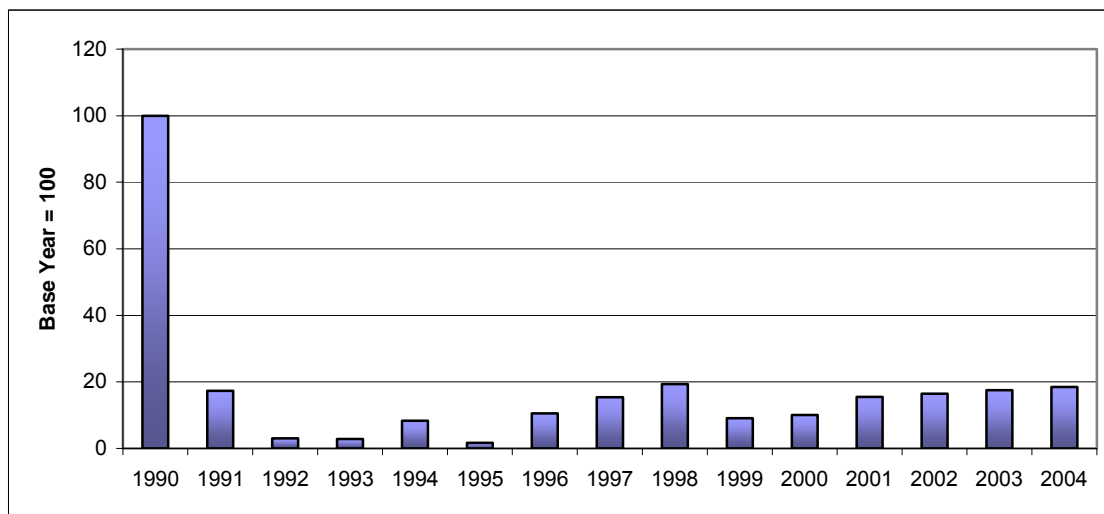
- Quantities of sulphuric acid production in year 1990 are available from a specific questionnaire that had been sent to industrial units by IA under Corinair90 project;

- some information is available for particular years for several fertilizer industrial plants, and as result of questionnaires made under regional air emission inventory surveys;

- production figures for years subsequent to 2001 are estimated from IA, forecasted from previous time series.

Sulphuric Acid

Figure 4.15 – Trend in total sulphuric acid production, including sulphur recovery (1990-2004)



The quantity of sulphur recovered and transformed into sulphuric acid is only available for a limited number of years (1990, 1993 and 1995). The remaining time series was estimated from consumption of VRF and ammonia production in the following mode:

- Consumption of feedstock VRF, and its sulphur content, was available from the only industrial plant in Portugal also for a limited number of years – 1990 till 1994 – but a strong linear relation between feedstock consumption and ammonia production could be established from available data⁶⁵;
- Production of ammonia was available from INE statistical databases from 1990 to 2000, and figures for 2001 and 2002 were forecasted by IA. This time series was used to fill gaps in the time series of annual consumption of VRF, using the above mentioned relation;
- Finally a linear relation was also set between VRF consumption and the quantity of H₂SO₄ that was recovered.

Urea manufacturing

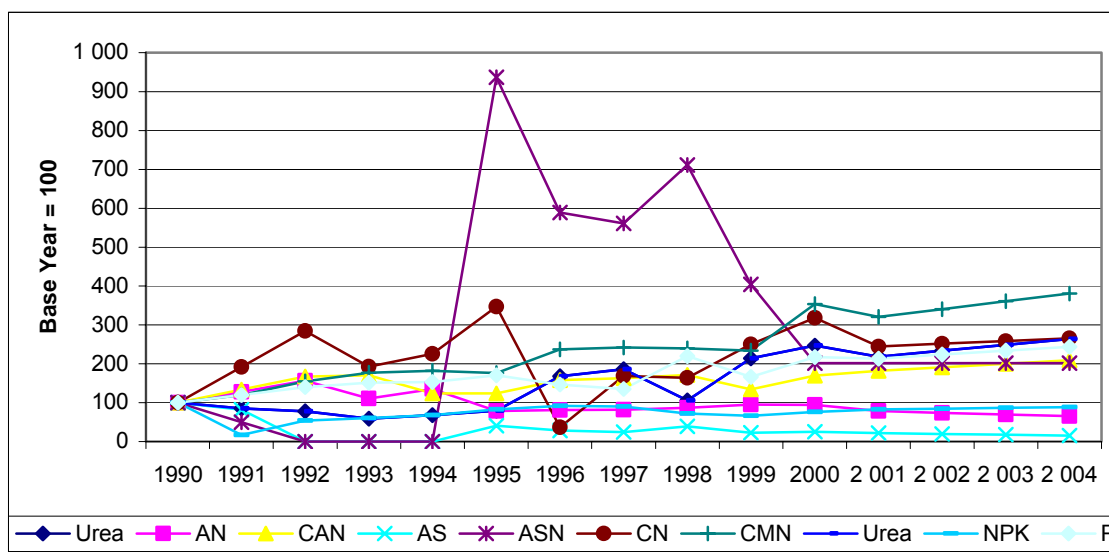
For the same reason that was explained for ammonia manufacturing, the existence of only one industrial plant producing urea in Portugal, prohibits the publication of any activity data.

Fertilizer production

Production data for ammonium sulphate (AS), ammonium nitrate (AN) (liquid and solid), calcium ammonium nitrate (CAN), ammonium sulphate nitrate (ASN), Calcium Nitrate (CN), Calcium Magnesium Nitrate (CMN), normal and triple superphosphates, and Di-ammonium phosphate (DAP) are from INE's statistical database (IAIT and IAPI surveys according to year). Due to confidential issues it may not be reported here, and only trend evolution is presented in Figure 4.16.

⁶⁵ For confidentiality reasons original data and relation may not be reported in NIR

Figure 4.16 – Trend evolution in fertilizer production (1990-2004)



RECALCULATIONS

Emission estimates for these sources did not suffer modifications in either in methodology, emission factors or activity data, apart from forecasting activity data to year 2004.

FURTHER IMPROVEMENTS

Although country-specific emission factors are now used more extensively, more work is necessary in order to improve emission factors and their documentation. This work is already planned under: the Methodology Development Plan that is being developed for the development of the National System; and through cooperation with other entities such as Regional Environment Departments doing regional air emission inventories, the General-Directorate of Industry, Industry Associations and EPER registry. Best Available Technologies (BAT) should be considered also in the determination of future emission factors. In general, information from Regional inventory surveys, EPER, E-PRTR and monitoring under *Autocontrolo* program may also allow better insight of technologies of this sector and may possibly improve methodologies and emission factors.

For some fertilizers, FAO database has statistical information concerning production, but which do not agree with national statistical databases. Efforts will be made to explain differences, and compatibilize both information sources if possible. Also, efforts must be done to clarify incorporation of some basic fertilizer in mixtures, obtained by granulation, in order to avoid double counting. Preferably information should be collected directly from industrial plants.

Specific issues to improve comprehend the revision of the different reporting placement for SOx emissions from flaring in sulphur recovery.

4.3.B.4 ORGANIC CHEMICAL INDUSTRY

OVERVIEW

The organic chemical industry is responsible for greenhouse gas emissions in consequence of the release of carbon compounds that are transformed in carbon dioxide in the atmosphere. These emissions are mostly part of the carbon that is release from feedstocks.

For this source sector emissions for some industrial units were estimated at individual unit plants – Large Point Sources (LPS) - and using detailed characterization of the plants and their industrial activities. Chemical organic industry in Portugal is not very extensive, however. The major organic chemical plant in Portugal is BOREALIS unit, a petrochemical unit situated in the southern part of the country, near Sines. The basic process in this unit is Ethylene production by Thermal Steam Cracking of petroleum feedstock. From ethylene this unit produces Low Density Poly Ethylene (LDPE) and High Density Poly Ethylene (HDPE). As by product of ethylene production other organic compounds are produced, such as propylene, butadiene and C4 fraction, aromatics and a residual fuel oil used in the unit as energy source.

The second chemical industry LPS is the sole Carbon Black plant in Portugal. It is also situated in the southern part of the country, near Sines. CARBOGAL unit produces Carbon Black by the Oil Furnace Process, a partial combustion process where feedstock with a high content of aromatic material is converted by incomplete combustion, thermal cracking and dehydrogenation to carbon black. Emissions result from Gas Vent, combined dryer vent and fugitive emission in the vacuum system vent.

Finally the last individualized unit (LPS) is an industrial plant located in Lisbon producing Phthalic Anhydride from aromatic compounds.

Apart from those individualized industrial plants other chemical industrial activities were included as area sources in this sub-source sector⁶⁶:

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

METHODOLOGY

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

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

where

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

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

⁶⁶ This list is not extensive to chemical production in Portugal, but comprehends only those products for which there are emission estimate methodologies and emission factors

EF_(p) - emission factor (kg/ ton)

In the case of carbon black, where CO₂ emissions result from liberation of carbon in tail gas to atmosphere, emissions were estimated using a simple mass balance:

$$44 / 12 * C_{\text{TailGas}} = C_{\text{Feedstock}} + C_{\text{AuxFuels}} - C_{\text{CarbonBlack}}$$

Where,

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

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

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

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

EMISSION FACTORS

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994⁶⁷. Emissions estimated for this period were used to determine plant-specific process emission factors that were used to estimate emissions for all time series from 1990 to 2001 and using ethylene production as activity rate indicator⁶⁸. Emissions from flares and flue gas combustor were included in the emission factors.

Table 4.15 – Emission Factors for determination of process emissions in Borealis (kg/ton)

Fábrica	NM VOC	CH ₄
Ethylene	0.8	1.2
Butadiene	1.2	-
HDPE	9.6	-
LDPE	4.8	-
PP	8.0	-

In the same way, the carbon black industrial unit was subjected, also for period 1993-94, to a detailed survey and inventory exercise. Consequently mission factors were established for carbon black unit and emission estimates were extended for the rest of the time series using carbon black production as indicator of activity rate. Carbon Gas emissions include also emissions suffering partial combustion.

⁶⁷ Unpublished.

⁶⁸ This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Table 4.16 – Emission Factors in calculation of Carbon Black process emissions

Pollutant	Main Process Vent Gas (kg/ton gas)	Combined Dryer Vent Gas (kg/ton gas)	Process and Fugitive (kg/ton Carbon Black)
SOx	0.20	0.20	-
NOx	0.01	0.36 ^(a)	-
COVNM	33.3 ^(a)	2.50 ^(b)	-
CH ₄	0.80	0.8 + 1.4 ^(b)	-
CO	104	100 + 17 ^(b)	-
N ₂ O	-	1.40 ^(b)	-
PM	0.20 ^(c)	0.12 ^(a)	0.42 ^(a)

(a) kg/ton Carbon Black

(b) g/GJ

(c) g/Nm³ tail gas

Emission factors for the Phthalic Anhydride Plant are from US-EPA (1983) and are presented in table 4.8:

Table 4.17 - Emission Factors for the production of Phthalic Anhydride

Pollutant	kg/ton
SOx	4.7
COVNM	1.2
CO	151
PST	120.4

Source: USEPA (1983)

Concerning explosives: Emission estimate methodologies are available from USEPA (1995) but only for the production of: TNT and Nitrocellulose. But because it is expected that the production of other explosives result in similar emissions the following assumptions were made:

- The most probable emission factors for Nitrocellulose production were set as:

Table 4.18 - Emission Factors for Nitrocellulose production (explosives)

FE (Kg/ton)	SOx	NOx
TOTAL	34.7	14
Nitration reactors	0.7	7
Nitric acid concentrator	-	7
Sulphuric acid concentrator	34	-

Source: USEPA (1983)

- it was assumed that the production of nitroglycerin is similar, in what concerns emissions, to nitrocellulose production, and the same emission factors were used;
- Black powder is made from carbon, sulphur and saltpetre (KNO₃) mixed together. There are no reference to emissions from it production. It was assumed that the production process is basically physical and that no relevant atmospheric emissions occur;

- Emission factors for the production of TNT are also from AP-42 chapter 6.3 (USEPA, 1995):

Table 4.19 - Emission Factors for TNT production (explosives)

kg/ton	SO _x	NO _x
TNT - Batch process (Total)	36.5	78.5
Nitration reactors		
Fume recovery	-	12.5
Acid recovery	-	27.5
Nitric acid concentrators	-	18.5
Sulphuric acid concentrators (with ESP)	7	20
Red water (Sellite exhaust)	29.5	-

Source: USEPA (1983)

Emission factors for all other chemical producing units follow international bibliography sources, particularly AP42 (US-EPA).

Table 4.20 - Emission factors for chemical organic industrial processes

Compound	EF (kg/ton)	
	NMVOC	PM
VCM	2.5 ^(a)	-
LDPE	10.0 ^(b)	-
PVC	3.0 ^(c)	17.5 ^(d)
PP	8.0 ^(b)	1.5 ^(e)
PS	1.0 ^(d)	-
Formaldehyde	5.0	-

(a) ;(b) UN-ECE (1990). Old Plants

(c) TNO (1987). Emulsion; (d) USEPA (1991). Controlled (Fabric Filter)

(e) USEPA (1991); (f) USEPA (1991)

ACTIVITY DATA

Activity data used to estimate emissions may not be reported in NIR, due to confidentiality issues that result from the limited number of units concerned for each individual compound.

For BOREALIS Petrochemical Plant in Sines - produced quantities are available from 1990 to 1997 and were forecasted thereafter. Production of carbon black and explosives is available from 1990 to 2000 from INE Statistical Database (IAIT and IAPI surveys).

Statistical information for all emissions sources other than Sines industrial Plants were obtained from the National Statistical Institute (INE).

UNCERTAINTY ASSESSMENT

The uncertainty of activity data received from Large Point Sources was set as 10%. For area sources it depends if the data set is updated for the all time series or not. If it is not updated the uncertainty value was set as 100% and 20% if it is updated. The high uncertainty in the choice of emission factors from international references, which are themselves based in limited information and which conditions of determination are most of the time different from specific

national conditions, lead to the choice of an uncertainty value of an order or magnitude for area sources and 100% for Large Point Sources⁶⁹.

RECALCULATIONS

Small changes in emission estimates since the submission of last year are the result of the revision of the time-series for some sub-source categories, namely Production of Monomers, and they result from the use of more updated data from the National Statistical Institute.

FURTHER IMPROVEMENTS

Because emissions from production processes depend largely on specific conditions in each industrial plant, and because there are very few units in Portugal using a specific chemical manufacturing process, it is essential that the national inventory relays more and more in detailed plant information, i.e. increasing the number of Large Point Sources. Only deep knowledge of LPS units will allow quantification of air emission with reduced uncertainty, either using technology specific emission factors from literature or either using monitoring data. This improvement may imply coordination with EPER/PRTR exercises, the European carbon trading scheme, Regional Air Emission Inventories, cooperation with industry associations or specific inquiries.

Also, the quality of emission estimates from this sub-source sector will be improved in next submissions, following the on-going efforts to improve the inventory of NMVOC from industry, that are been done under the background works for the revision of the Ceiling Directive of the UE. Results will be however only available for the next submission. Other expected improvements include:

- Update of activity data from 1991 to 2004;
- Obtaining a deeper knowledge for the limited number of the most relevant industrial units and performing emission estimates with more detailed methodologies, similar to those performed for BOREALIS and CARBOGAL industrial units;
- Revision of emission methodologies and possible inclusion of more manufacturing processes, such as Styrene Butadiene latex or rubber; Acrylonitrile Styrene Butadiene (ABS); Acrylonitrile and MTBE. Efforts must be done to verify that production of these products, and others, did exist in Portugal;
- Estimate of emissions from storage and handling of organic liquids, which presently are only done for carbon black.

4.3.C Metal Production (CRF 2C)

4.3.C.1 IRON AND STEEL PRODUCTION (CRF 2C1)

OVERVIEW

Iron results from reduction of the iron element present in mineral ores by contact with coke - reducing agent - at high temperatures in the blast furnace. The resulting material, pig iron – and also scrap in some steel plants - is transformed into steel into subsequent furnaces which may be a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF). Coke, sinter and lime are intermediate materials necessary for iron and steel production.

⁶⁹ The uncertainty of emission factors refers to uncertainty of NMVOC determination. Uncertainty for conversion from NMVOC to CO₂ is comparatively irrelevant.

Sintering modifies the structure of ore material making it more suitable for iron formation, by converting fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product. Sintering emissions occur from the windbox, discharge and sinter crusher, coolers and screens. Emissions from sintering, which result from a combustion process with contact, are reported under 1.A.2, although the emission factors are reported in this chapter.

Coke is produced by destructive distillation of imported fossil coal in coke ovens, where coal is subjected to heat in an oxygen-free atmosphere until all volatile components in the coal evaporate, forming a fuel used in industry, the Coke Gas. Process heat comes from the combustion of gases between the coke chambers. Excluding emissions associated with coke production resulting from use of fuels in under-fired heating furnaces (which are accounted in Energy source sector 1A1), air emissions from the coquerie result from coal preparation, coal charging, oven leakage during the coking period, coke removal and hot coke quenching. Leaks may also occur from poorly sealed doors, charge lids, off take caps, collecting main and from cracks that may develop in oven brickwork (USEPA, 2000)

Coke and sinter are added to the Blast Furnace where iron oxides, coke and fluxes react with blast air to form molten reduced iron, carbon monoxide (CO), and slag. Emissions occur during casting and in the blast furnace top. However the gas resulting from process in the blast furnace, which has a high CO content, is normally not emitted to atmosphere but used as fuel in integrated units (Blast Furnace Gas). Emissions from its combustion are also quantified and discussed under chapter 1A2 – Combustion in Manufacturing Industries and Construction. The emissions that are quantified here, in source 2.C, are only those resulting from casting operations and seal leaks at top of furnace.

In Basic Oxygen Furnace original material are re-melted with the addition of substantial source of oxygen which is lanced (injected) and oxidizes part of the carbon associated with iron: This carbon is emitted mostly as CO (contributing nevertheless to ultimate CO₂ emissions). Other emissions from BOF are iron oxides, oxides of other metals and sulphur and particulate matter. In EAF the original material, which is basically scrap, is subjected to an electric discharge that also reduces carbon content. Emissions in furnaces may also result from carbon additives such as limestone and coke.

Steel is finally finished in rolling mills. Emissions from this finishing process are mostly particulate matter besides combustion pollutants which is already included in emissions from the 1.A.2 sector.

Lime is necessary for the blast furnace charging and EAF mixtures. Production of lime from limestone in this unit results in CO₂ emissions from decarbonising.

Emissions of ultimate fossil CO₂ are the result of the oxidation of carbon in coke, anodes and electrodes. Part of the carbon may be sequestered in final product and not emitted to atmosphere as carbon dioxide. Only emissions of carbon that has origin in fossil fuels should be considered as emissions of final or ultimate CO₂ and not those from the use of biomass origin carbon - charcoal. Emissions of carbon may occur as CO and NMVOC but it is assumed that they are subsequently converted in atmosphere in carbon dioxide. Some carbon may remain in pig iron after initial reducing in blast furnace and partly may be emitted from oxidation in the BOF. Also EAF furnaces may result in carbon emission but from consumption of graphite anodes in the process.

Other pollutants may be emitted during steel production as result of its presence (or presence of its precursors) in original ore or in the material used to produce coke. That is the case of SO_x and heavy metals. But because combustion occurs with contact, emissions are modified - increase or decrease - by contact of combustion gases with products and emissions can not be estimated by mass balance alone.

NOx is formed from reaction of atmospheric nitrogen at high temperatures, which may result from fuel combustion or from high temperature generated at production processes.

Finally particulate materials result from handling and storage of materials, such as coal, ore, coke and scrap, crushers and screening in raw materials preparation and finishing operations in products such as teeming into ingots and scarfing. Particulate mater results also from blast furnace during casting and oxygen blow in BOF. Particulate materials are mostly composed of iron, sulphur and other metal oxides.

During the period 1990-2001 two main industrial plants in Portugal were associated with steel production which later turn into three units as result of the split of one of the units in two separate plants. Later, during 2001, the coquerie, blast furnace and sintering were closed and only steel furnaces and trimming remain as emission sources.

METHODOLOGY

Emissions are simply calculated from multiplication of activity levels by a suitable emission factor:

$$\text{Emission}_{(p,y)} = \sum_a [\text{EF}_{(p,a)} * \text{Activity}_{\text{Indicator}_{(p,a,y)}}] * 10^{-3}$$

and,

$\text{Emission}_{(p,y)}$ - Emission of pollutant p in a specific year y from all sector activities and equipments (ton/yr);

$\text{Activity}_{\text{Indicator}_{(p,act,y)}}$ - Most suitable indicator for emissions of a particular pollutant p resulting from a specific source activity or equipment a (ton/yr);

$\text{EF}_{(p,act)}$ - Emission factor specific of pollutant and activity/ equipment a (kg/ton).

Emissions from sintering and lime production from limestone at iron and steel unit were also estimated using similar equation and using production of lime as activity data. Emissions for all pollutants from these two emission sources are reported however in source category Lime Production (2A2).

To avoid double counting, carbon dioxide emissions in coquerie and blast furnace, from oxidation of the carbon that was used as a reducing agent were not estimated from steel or coke production data but simply from use of coke derivative fuels (coke gas and blast furnace gas) in all combustion equipments. Methodology to estimate emissions from combustion of coke gas and blast furnace gas were already discussed in chapter 3.2A – Energy Industries and emissions are included in source sector 1A.2 - manufacturing industries and construction - and 1A.1.c.1 - Manufacture of Solid Fuels. Although in EAF there is a further reduction in carbon content that is accounted as CO₂ emissions, nevertheless the carbon dioxide emissions from anodes in EAF is still not contemplated in the inventory.

EMISSION FACTORS

Emissions factors for production process were set mostly from CORINAIR/EMEP also with contributions from IPCC96 and US-EPA AP42. Emission factors in kg/ton are present in next table.

Table 4.21 - Emission Factors for Iron and Steel Production

	Coke Oven	Sintering	Blast Furnace	BOF	EAF
Pollutant	(kg/ton coke)	(kg/ton sinter)	(kg/ton steel)	(kg ton/steel)	(kg/ton steel)
SOx	0.01 ^(a)	1	2	0.01	
NOx	0.02 ^(a)	0.5	0.076		
COVNM	2.1 ^(a)	0.1	0.12		
CO ₂				22.5 ^(d)	14.2-21.5 ^(e)
CO	0.635 ^(a)	30	1.412	69 ^(c)	9 ^(c)
NH ₃	0.09 ^(a)				
PM	2.01 ^(b)	3.9 ^(c)	0.45 ^(c)	0.9 ^(c)	25 ^(c)
PM ₁₀ #	39.2 ^(b)	15 ^(c)	51 ^(c)	46.60 ^(c)	58 ^(c)
PM _{2.5} #	25.4 ^(b)	6.5 ^(c)	23 ^(c)	32.98 ^(c)	43 ^(c)
PM ₁ #	16.3 ^(b)	4 ^(c)	15 ^(c)	13.83 ^(c)	23 ^(c)

expressed as % of total PM; (a) USEPA (1985) in EMEP/CORINAIR 3rd ed; (b) USEPA (2000) chapter c12s02; (c) USEPA (1986) c12s05; (d) carbon reduction from 4.25 to 2%; (e) Plant Specific Emission Factors (Carbon Market)

The CO₂ emission factors for Electric Arc Furnace, and that were used for each one of the two iron and steel plants that are included in the European Union Emission Trading Scheme (EU-ETS), were determined from consumption of carbon bearing materials in these units: limestone, calcium carbide and coke for years 2002 and 2003. It was assumed that the same carbon content exists in both scrap and final steel produced in EAF furnaces and consequently no additional emissions are estimated apart from carbon in additives.

ACTIVITY DATA

Activity data for estimation of emissions from iron and steel production comprehend coke, sinter, pig iron and steel production and also scrap consumption, and time series for each product may be seen in Figure 4.17. The following sources of information were used to establish activity data time series:

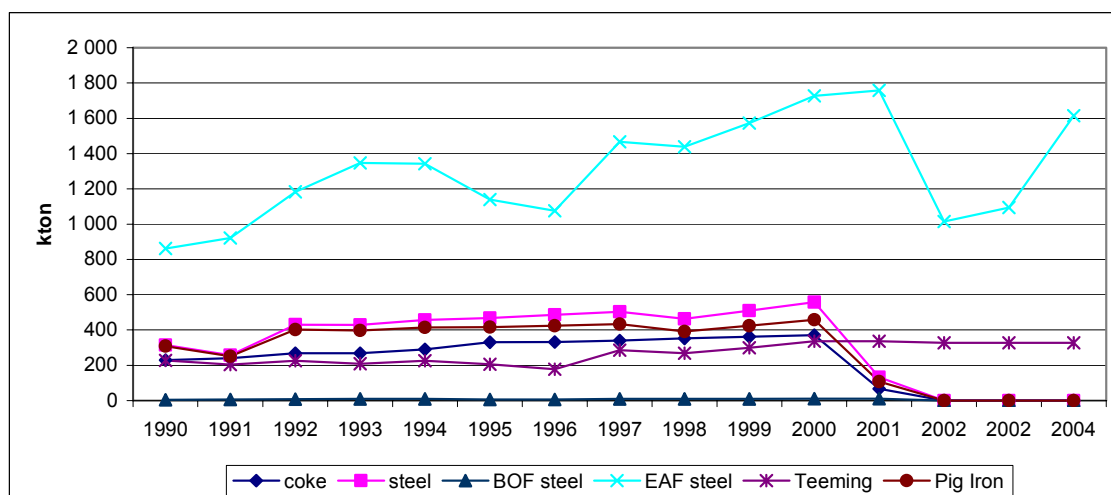
- coke production is available from DGGE (Coquerie Balance) annually from 1990 to 2001. After 2002 the production of coke has stopped;
- production time series for sinter, pig iron and steel production in blast furnace are available from industrial plant from 1990 to 1994 (IA direct survey). Thereafter annual values were estimated using coke production as surrogate data;
- steel resulting from BOF and EAF in Seixal Iron and Steel Plant were estimated from production data in both ovens types in 1990 and forecasted thereafter using fuel consumption in the electric power plant⁷⁰ as surrogate data⁷¹, for the remaining time series;
- the same procedure was used to establish the full time series of scrap use and lime consumption, although in this case information data from the industrial plant was available from 1990 to 1994;
- steel production and scrap use in the EAF oven in Maia steel plant was available for 1990, 2002 and 2003 and interpolated in between.

⁷⁰ Power plant that is part of the iron and steel plant

⁷¹ They may result not from iron produced at this industrial plant

Production of total steel and intermediate products as they are presently considered may be seen in next figure. Details about specific products and origin by furnace technology (BOF and EAF) can not be reported due to confidentiality constraints.

Figure 4.17 - Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2003)



UNCERTAINTY ASSESSMENT

The great majority of CO₂ emissions result from EAF and BOF furnaces with only a small contribution from coke oven and blast furnace, and hence furnaces data is what basically determines overall uncertainty. For year 1990 data information was collected directly from industrial plants and it is mostly probably of good quality. The same situation applies to years 2002 and 2003 after the development of carbon market (EU-ETS). In the intermediate period information had to be collected from statistical information from National Statistical Institute (INE), General Directorate of Geology and Energy (DGGE) or even estimated from surrogate data. Quality of activity data for this period decreased substantially but does not affect overall trend of the inventory. The uncertainty in activity data was set as 10% the major value in the range proposed in GPG. The uncertainty value for the emission factor was determined considering an uncertainty of 25 per cent in the carbon content of both raw materials and final steel and additional 5 per cent in the quantity of reducing agent for EAF.

RECALCULATIONS

No modifications were made in this source sector since last year's submission.

FURTHER IMPROVEMENTS

Lack of information concerning activity data and possible double counting in steel production activities may be a problem to emission estimates for this source sector. Although this sector is undergoing deep changes with closure of main source activities (coquerie, blast furnace and sintering) an effort has to be made to clarify the situation and increase the quality of emission estimates for the base year. Because 2002 is a year with substantial changes for this source sector, care must be made to update appropriately the inventory thereafter.

Possible double counting of emissions of CO, NMVOC and SO_x will be reviewed, as well as verification that accounting of CO₂ emissions from coke gas and blast furnace gas combustion does in fact include all emissions.

Finally open dust sources of particulate mater are still not included in the inventory.

4.3.C.2 FERROALLOYS PRODUCTION (CRF 2C2)

OVERVIEW

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

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

METHODOLOGY

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

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

where

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

$\text{ActivityRate}_{(y)}$ - Indicator of activity in the production process, the quantity of ferro-alloy produced in a given year y (ton/yr);

EF_{CO_2} – carbon dioxide emission factor (ton/ton)

EMISSION FACTORS

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

ACTIVITY DATA

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

UNCERTAINTY ANALYSIS

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

RECALCULATIONS

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

FURTHER IMPROVEMENTS

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

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

4.3.C.3 ALUMINIUM PRODUCTION (CRF 2C3)

OVERVIEW AND RECALCULATIONS

Aluminium production will result in carbon dioxide emissions when it is reduced using carbon electrodes in smelting pots and ultimate CO₂ emissions are the result of consumption of electrodes. This situation occurs when aluminium is manufactured from bauxite ore, using the Soderberg process, for example.

In Portugal, according to information received from the General Directorate of Industry (DGI), aluminium is produced from ingots and not from bauxite ore. Consequently emissions of CO₂ for this source sector were removed from emission inventory.

4.3.D Other Production (CRF 2D)

4.3.D.1 WOOD CHIPBOARD PRODUCTION

OVERVIEW

Chipboard manufacturing involves solvent emission but it included in this source sector.

METHODOLOGY

Emissions were estimated by the use of emission factors multiplied by the quantity of material produced:

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

where

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

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

EF_{NMVOC} - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents and these have fossil origin contributing to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$\text{Emi}_{\text{CO}_2} = 44 / 12 * 0.85 * \text{Emi}_{\text{NMVOC}}$$

EMISSION FACTORS

Emission factor is 0.9 kg/ton, from Corinair90 Default Emission Factor Handbook.

ACTIVITY DATA

Information about activity data for this sector is still scarce and limited to 1990, from National Statistics Institute (INE). In 1990 571 kilo-tons of chipboard were produced in Portugal.

RECALCULATIONS

No changes have been made since last submission.

FURTHER IMPROVEMENTS

The place where emissions from chipboard manufacture are located in the inventory should be subjected to revision and possibly moved to category "Solvent Use". Also, NMVOC emissions from this activity should be estimated according to methodologies for these source sector avoiding double counting of emissions that result in fact from solvent use.

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

4.3.D.2 FOOD AND BEVERAGES

OVERVIEW

Food and Beverage industrial processes are responsible for some NMVOC emissions resulting mostly from alcohol generation by microbial fermentation and consequent evaporation, and from evaporation of other organic compounds during processing.

The National Inventory Report includes emissions estimates for NMVOC from:

- Bread backing;
- Wine preparation;
- Beer production;
- Spirituous beverages distillation;
- Meat and fish processing;
- Sugar processing;
- Margarine and other fat production⁷²;
- Coffee roasting;
- Animal feed production.

METHODOLOGY

Emissions were estimated by the use of emission factors multiplied by quantity of material produced:

$$\text{Emission}_{\text{NMVOC}(y)} = \sum_a [\text{EF}_{\text{NMVOC}(a)} * \text{ActivityRate}_{(a,y)} * 10^{-3}]$$

⁷² Emissions of NMVOC from edible oil extractions are included in "Use of Solvents".

where

Emission_{NM VOC (y)} - annual emission of NMVOC in year y (ton/yr);

ActivityRate_(a,y) - Indicator of activity in the industrial production process for product a. Quantity of product produced per year is used as activity rate, as a general rule for this emission source sector (ton/yr);

EF_{NM VOC(a)} - emission factor for manufacturing activity a (kg/ ton)

Although NMVOC are emitted, they have biological origin and do not contribute to ultimate carbon dioxide emissions.

EMISSION FACTORS

The following emission factors were set from CORINAIR/EMEP, IPCC96 and US-EPA AP42:

Table 4.22 - NMVOC emission factors for food and beverage industrial processes

Material	EF	Unit EF
Patisserie	1.00	kg/ton
Meat	0.3	
Fish	0.3	
Sugar	10	
Margarine	10	
Animal Feed	1	
Coffee Roasting	0.55	
Wheat Bread	4.5	
Other Bread	3	
White wine	0.035	kg/hl
Red Wine	0.080	
Beer	0.035	
Spirits	6.000	

Table 4.23 – Particulate Matter Emission Factors for Grain Milling and Rice Processing

Parameter	EF	Unit
PM	11	Kg/ton (a)
PM10	49	% PM
PM2.5	49	% PM
PM1	49	% PM

Source: USEPA (1998)

(a) Implied Emission Factor, comprehending grain milling, rice processing, animal feeds milling and manufacturing and flaking.

ACTIVITY DATA

Activity data was available, for most activities only for years 1990 and 1991, from INE. Information about break backing, animal feed, coffee roasting and sugar include also information about years 1996 and 1997. Information lacking for the other years were estimated, using extrapolations and interpolations from the available time series, or else kept constant during all period. Annual activity levels that were considered in the inventory from 1990 to 2001 are presented in Table 4.24 and Table 4.25 below.

Table 4.24 – Annual production in the Food and Beverage Industry (1990-1997)

Product	1990	1991	1992	1993	1994	1995	1996	1997
White wine	454	409	322	202	277	313	427	266
Red Wine	655	574	439	268	358	393	521	325
Beer	687	689	690	692	693	694	696	677
Spirits	14	14	14	14	14	14	14	14
Wheat Bread	302	278	269	261	252	244	235	172
Other Bread	28	28	27	26	25	23	22	16
Cakes	38	38	38	38	38	38	38	38
Fish	238	238	238	238	238	238	238	238
Sugar	305	282	285	289	293	297	301	348
Margarine	71	63	67	67	67	67	67	67
Animal Feed	3 761	3 761	3 761	3 761	3 761	3 761	3 714	3 809
Coffee Roasting	28	28	28	28	28	28	28	27
Milling	4 292	4 345	4 172	4 406	4 611	4 466	5 021	4 741

* (a) Beverages expressed in million liters; food products in kton.

Table 4.25 - Production in the Food and Beverage Industry (cont: 1998-2004)

Product	1998	1999	2000	2001	2002	2003	2004
White wine	161	342	291	339	291	319	319
Red Wine	197	418	355	414	354	389	389
Beer	687	687	687	687	687	687	687
Spirits	14	14	14	14	14	14	14
Wheat Bread	187	172	158	143	129	114	114
Other Bread	17	16	14	13	11	10	10
Cakes	38	38	38	38	38	38	38
Fish	238	238	238	238	238	238	238
Sugar	323	328	334	339	344	349	349
Margarine	67	67	67	67	67	67	67
Animal Feed	3 761	3 761	3 761	3 761	3 761	3 761	3 761
Coffee							
Roasting	28	28	28	28	28	28	28
Milling	4 882	4 678	4 645	4 735	4 748	4 748	4 748

* (a) Beverages expressed in million liters; food products in kton.

RECALCULATIONS

No modifications were made for the emissions estimates of this source sector.

FURTHER IMPROVEMENTS

No improvements are expected for this source, which is responsible for minor emission quantities, besides update of activity data for the all time series using statistical information from National Statistical Institute (INE).

4.3.D.3 PAPER PULP PRODUCTION

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 fibers unbind. Apart from digestion other relevant industrial processes include pulp washing, pulp drying, chemical recovery of reactants (sulphur and quicklime) and possibly bleaching. Recovery of sulphur from the spent 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.

METHODOLOGY

Air emissions (ton/yr) for each pollutant are estimated from production of air dried paper pulp ($\text{Pulp}_{\text{PROD}}$ - ton AD/yr) after applying emission factors (EF - kg/ton AD) specific of each pollutant:

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

EMISSION FACTORS

The following emissions factors (kg/ ton AD pulp) were used to estimate process emissions, respectively for the Kraft and sulphide process plants. They were set from US-EPA AP42 and other sources and include emissions realized in:

- Kraft process: Digester, Brown Stock Washers, Black Liquor Evaporators, Non condensable gases, Smelt dissolving tank, Fluid Bed Calciner and Bleaching;
- Acid sulphide: Digester and Blow Pit.

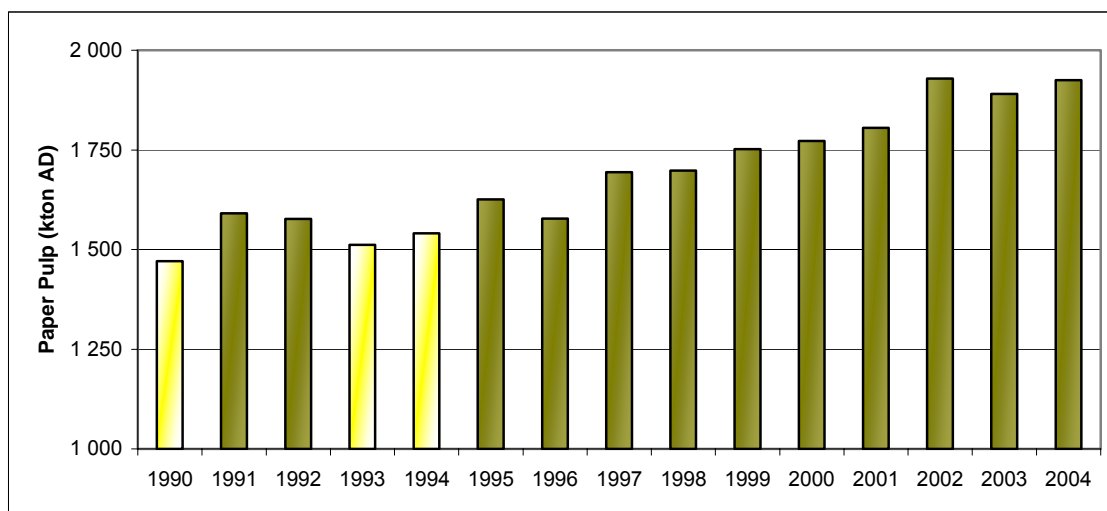
Table 4.26 - Emission Factors for paper pulp production (non combustion)

Process	SO_x	NO_x	NMVOC	TSP	PM_{10} (%)	$\text{PM}_{2.5}$ (%)	PM_1 (%)
Kraft	0.31	1.95	2.74	3.5	88.5	73	40
Sulphide	35.5	NA					

ACTIVITY DATA

Production of paper pulp expressed in air dried weight was collected directly from paper pulp plants from a direct survey, from information collected under LCP directive and from information published or delivered by CELPA, the Portuguese Paper Industry Association. Acid Sulphide production is only a minor component of total production⁷³ 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 steadily increasing during last decade, and was in 2003 twenty eight per cent higher than in 1990.

Figure 4.18 - Total production of paper pulp - Kraft and semi-sulphide (1990-2004)



RECALCULATIONS

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

FURTHER IMPROVEMENTS

Emission factors for SO_x, NO_x and NMVOC will be revised to avoid misplacement, of emissions that may in fact be the result of combustion processes, or some possible double counting of emissions that although estimated from production were already included in 1A2. A program to improve knowledge of specific technology conditions in each factory plant and of emission abatement methodologies is under way, with cooperation with industry association (CELPA).

4.3.E Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2F)

4.3.E.1 OVERVIEW

Several simple halogenated organic compounds have high warming potentials and long atmospheric residence times. These include predominantly synthetic substances that have been used mostly as inert gases in such diverse applications as refrigeration gas, aerosols propellants, foam fillers, gas insulation and fire suppressants. Chlorofluorocarbons (CFC), Hydrochlorofluorocarbons (HCFC), Perfluorinated hydrocarbons (PFC) and sulphur hexafluoride

⁷³ Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

(SF₆)⁷⁴ are the most important among those compounds. CFC and HCFC are already under control and being phased out under the Montreal Protocol, as consequence of their role as Ozone Depleting Substances (ODS). Therefore, under the United Nations Convention on Climate Change it was decided to consider in the GHG inventory those substances not included in the Montreal Protocol: HFC, PFC and SF₆.

Some emission sources are still not included in the inventory:

- Aerosols. According to information from industry importers (Carreira, 2002) fluorine gases have not been used as aerosol propellants produced in Portugal. Instead Portugal has been using R12 (CFC), hydrocarbons (butane and propane) and even N₂O. The presence of fluorine gases incorporated in imported aerosols is unknown because F gases are not reported explicitly at customs services and consequent emission cannot be estimated;
- Solvents. According from information from national importers in Portugal there is no reference of the use of HFC as solvents, but only of HCFC (Carreira, 2002). Use of HFC as a solvent represents probably a minor source in global terms;

Some emissions sources are not completely covered in the inventory, mainly as result of lack of adequate basic activity data, although there is a strong believe that they are minor sources not decisively affecting total emissions:

- some non-electrical use of SF₆ such as gas tracer in air dispersion and air emission studies.

One source, HFC-23 emissions from HCFC-22 manufacture, did not exist in Portugal during the reporting period and is reported as Not Occurring (NO)

4.3.E.2 GENERAL METHODOLOGY

For those sources for which sufficient data was available, actual emissions where estimated with a Tier 2 (advanced or actual method) approach which is considered Good Practice in accordance with GPG. This approach allows the quantification of emissions in the year in which they actually occurred accounting for the time lag between consumption and emissions. On the contrary the Tier 1, or potential approach, allocates emissions in the year that the chemical is sold into a particular end-user.

As a general rule bottom-up methodologies were used, and in fact overall methodology should be classified as Tier 2a. This approach departs from the knowledge of the number of equipments using HFC compounds and estimates emissions to atmosphere from charge (amount of chemical used in the equipment), service life, emission rate during the various periods of the equipment life and possible recovery of emissions.

Whenever possible emission estimates include:

- assembly emissions, when equipment is first filled⁷⁵;
- operation emissions, occurring during equipment lifetime or usage and resulting mainly from leaks;

⁷⁴ Other substances with greenhouse gas potential but less common are NF₃ and some halons. They are not included neither in Montreal Protocol neither in FCCC.

⁷⁵ Assembly emissions could include also emissions during refilling but no data was available to make this distinction

- disposal emissions, the remaining charge that it is released to the atmosphere at end of equipment life and where the remaining charge is neither recycled or destroyed.

4.3.E.3 RECALCULATION

No significant changes have been made since last year submission.

4.3.E.4 FURTHER IMPROVEMENT

It is expected that emission estimates will improve as a consequence of the inclusion of non quantified sources and the improvement in methodologies and parameters for the already quantified sources. Main aspects that will be subjected to future improvements comprehend:

- It is known that SF₆ was used in Portugal as a tracer in scientific studies, even in the development of air emission methodologies (VOC from forest). But the quantities used in this activity remain unknown;
- The consideration of refilling of refrigeration equipments should be better addressed in the inventory;
- Emissions from certain source sectors rely in less accurate activity data, which was estimated from surrogate data and assumptions. Efforts will be made to reduce uncertainty on activity data and parameters.

4.3.E.5 IMPORTERS DATA

The share of each F-gas used in the assemblage of refrigeration equipments was estimated for each year relying on importation data from the major national importers and suppliers of assemblage units. Although data from importers does not cover the totality of national market it was assumed to represent 60% (value discussed with importers) and there were made corrections to the total value in order to obtain a well representative situation. HFC has been imported since 1993 and has been increasingly substituting HCFC import. The share of import of each gas can be seen in the following figure.

Figure 4.19 - Percentage of imported fluorine gases in Portugal by gas type (1990-2004)

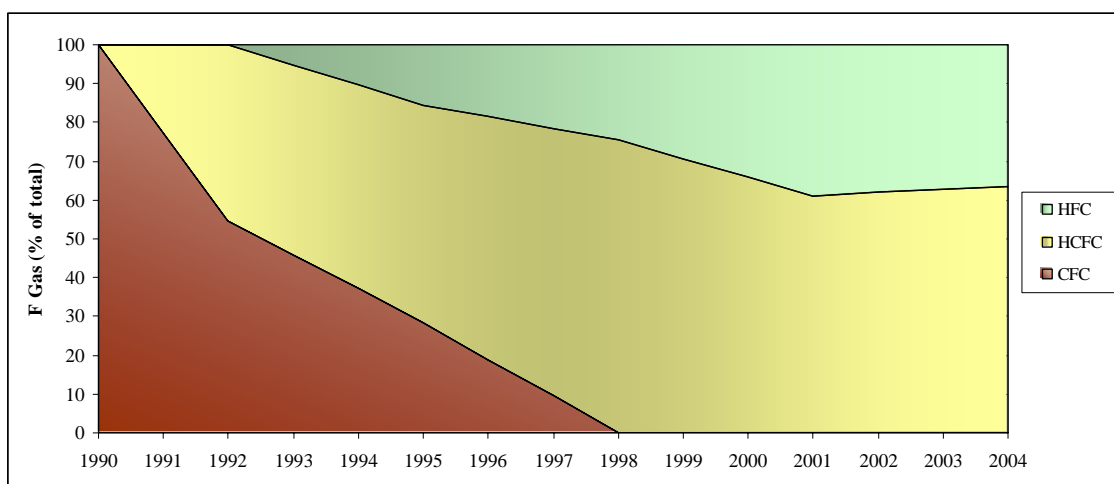


Figure 4.20 – Imported amounts of HFC in Portugal by gas type (1990-2004)

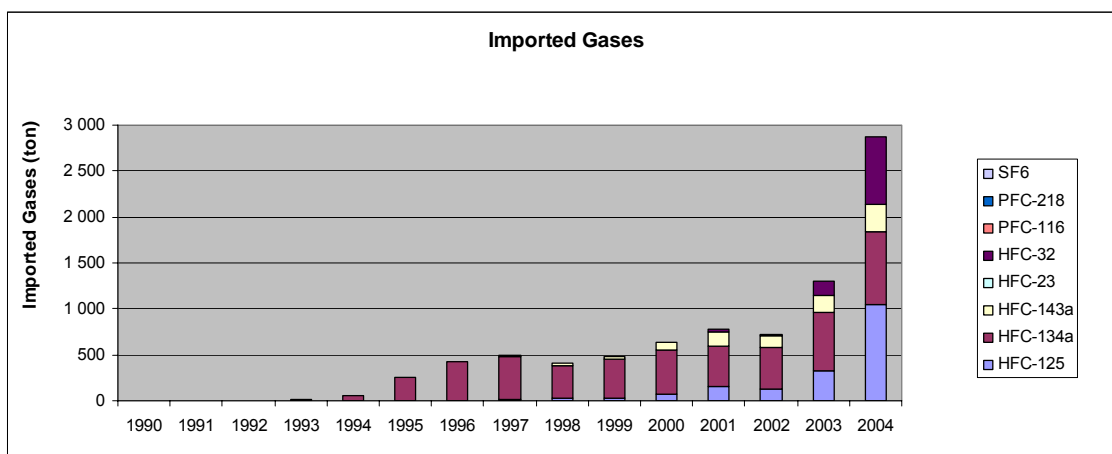


Figure 4.21 - Percentage of imported HFC in Portugal by gas type (1990-2004)

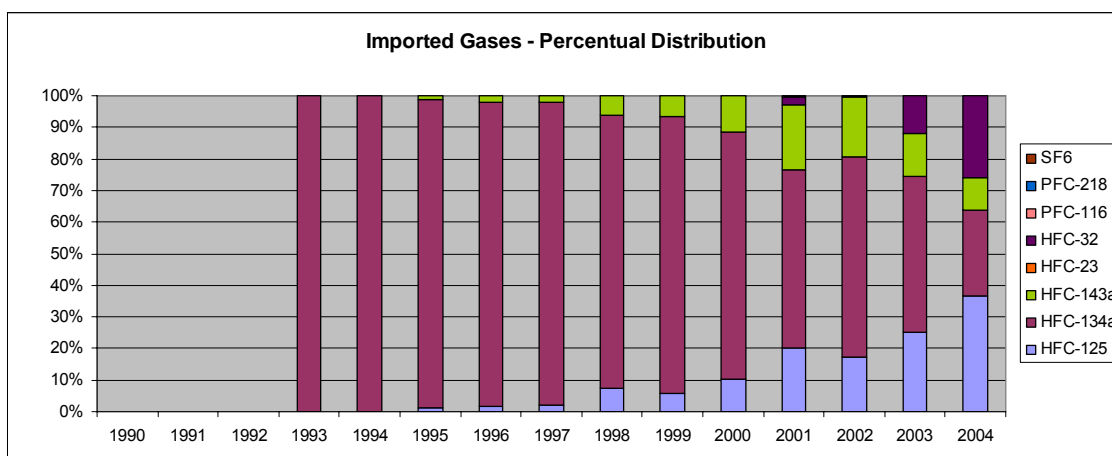
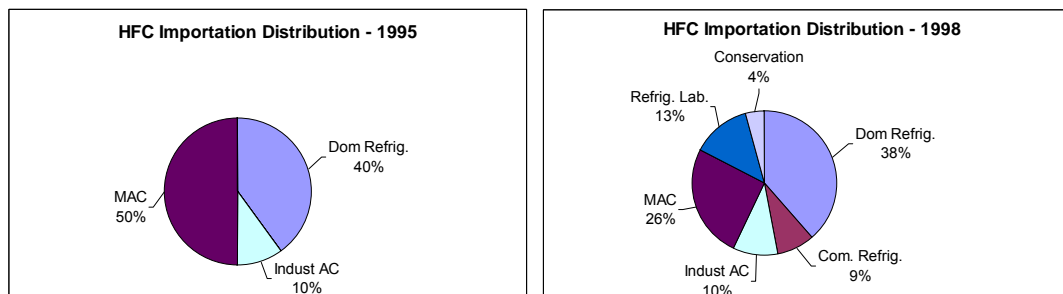
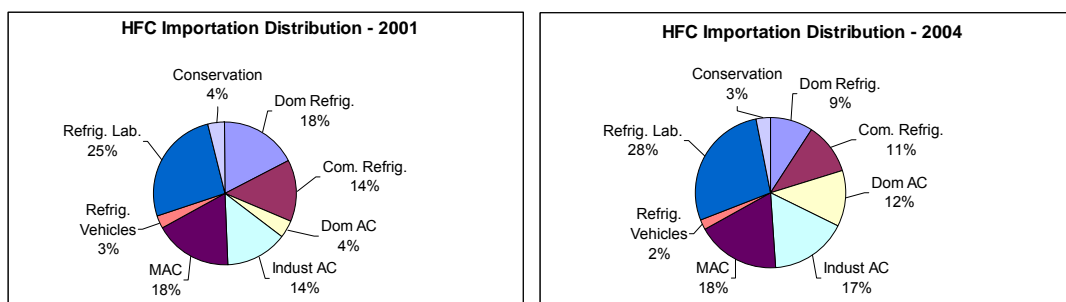


Figure 4.22 - Percentage of imported HFC in Portugal by sub sector (1990-2004)





Source: Importers

4.3.E.6 DOMESTIC REFRIGERATION

METHODOLOGY

CFC, HCFC and HFC emissions from operation and disposal of Domestic Refrigeration Equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

The emissions were estimated according to the following set of equations after GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

HFC emissions for each particular compound were estimated from total refrigeration gas emissions and considering the percentage of HFC use in total refrigeration gas use in each year according to the following equations:

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * HFC_{\% (j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\% (t,y)} * HFC_{\% (j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} [Equip_{\% (t,t-lifetime)} * HFC_{\% (j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$, $Oper_{Emi(t)}$, $Disp_{Emi(t)}$ - total HFC emissions in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$, $Oper_{Emi(t,j)}$, $Disp_{Emi(t,j)}$ - HFC emissions of compound j in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$ - Equipments assembled in year t;

$Equip_{Stock(t)}$ - Existing stock of equipment in year t;

$Equip_{Disposal(t)}$ - Number of equipments disposed at year t;

$Initial_{Charge(t)}$ - Initial charge of refrigeration gas filled in year t;

$Equip_{\%(t,y)}$ - Percentage of equipments assembled in year y in the existing stock in year t;

$HFC_{\%(j,t)}$ - Percentage of use of HFC compound j in year t;

K - percentage of initial charge that it is released during assembly;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

EMISSION FACTORS

The following emission factors were considered for this activity corresponding to the average values from the proposed range in IPCC GPG table 3.22.

Table 4.27 - Emission Factors of HFC gases from Domestic Refrigeration

Emission Factor (percentage of initial charge)	
Charging	Lifetime emission
0.60	0.20

No recovery of gas was considered at the end of product life ($z=0$). The emitted quantity to the atmosphere is therefore the residual product remaining in equipment (variable y) which was set at 90%, according to *1996 IPCC Revised Guidelines*.

ACTIVITY DATA

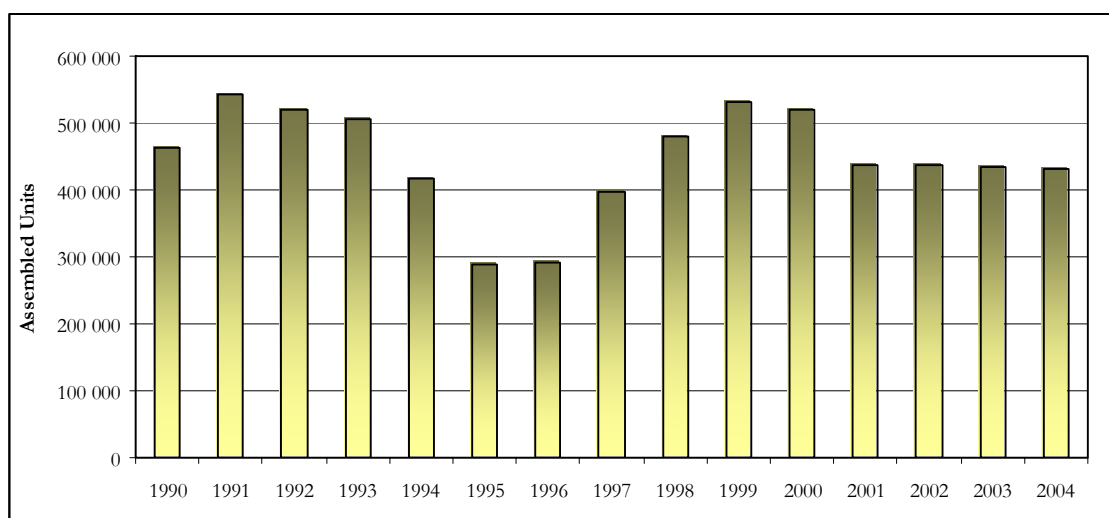
The stock of domestic refrigeration equipments was estimated from the number of households and from the percentage of households with refrigeration equipments, available for years 1990, 1995 and 2000 according to an unpublished report from INE. From year 2000 onward the percentage of equipments per household was assumed constant. The number of households was also assumed constant at about 3.1 million units, which is consistent with the stabilization of the Portuguese population in the period, and refers to 1995 (INE-Family Survey).

Table 4.28 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000
Combined (Refrigerator and Freezer)	91.9	96.1	97.1
Freezers	34.4	50.6	53.5

The number of assembled domestic refrigeration units in Portugal is available for each year from the National Statistic Institute (INE), which time series is presented in next figure. Values for 2001 to 2004 were forecasted by IA.

Figure 4.23 – Number of assembled refrigeration units (1990-2002)



Number of disposed units (scrap rate) is not available in Portugal. It was assumed that 10% of the stock is removed every year.

OTHER RELEVANT DATA AND PARAMETERS

According to data from Importers HFC used in Portugal in domestic refrigeration equipments comprehends only HFC 134a. The percentage of each gas in the existing stock in each year is estimated considering an average of the percentage of gas in assembled units during the lifetime of the equipment. For the disposal it was considered that the HFC composition equals that of the year when the equipment was assembled i.e. that of emission year less the lifetime of the equipment⁷⁶. Prior to 1993 no HFC was used in the assemblage of refrigeration units. Lifetime of domestic equipments was set at 12 years to combined equipments (refrigerator+freezer) and 14 years to freezers.

The quantity of refrigeration gas charged into the equipment was assumed at a value of 110 g/equipment unit to combined equipments (refrigerator+freezer) and 170 g/equipment unit to freezers which are well within the range set in GPG table 3.22.

⁷⁶ In consequence no emissions of HFC from disposal are estimated for the reported period.

UNCERTAINTY ASSESSMENT

An uncertainty of 10 per cent was considered for the number of assembled units by year, and 15 per cent was assumed for the number of equipments in existence. The number of disposed units was estimated from expert guess and a higher uncertainty of 35 per cent was assumed. Uncertainty values for emission factors, or F gas liberation, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime. Each individual value was determined from the range of default emission factors in GPG, except the uncertainty in initial charge that was established from the maximum range obtained from expert guess from the direct (bulk) importers of fluoride gases in Portugal. Individual uncertainty values are presented in next table.

Table 4.29 – Uncertainty of Emission Factors for HFC emissions from Domestic Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	73	67	5	0	99
Operation	73	67	13	0	99
Disposal	73	6	13	0	74

The revision of the methodology, particularly the improvements of the knowledge of initial charge, has improved the overall uncertainty substantially since last submission (combined uncertainty was estimated to vary between 227 and 235 per cent).

4.3.E.7 COMMERCIAL REFRIGERATION

METHODOLOGY

In a similar mode to other Stationary Refrigeration Equipments, CFC, HCFC and HFC emissions from operation and disposal of non domestic Refrigeration Equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

Lifetime and disposal emissions were estimated according to the following set of equations after GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

HFC emissions for each particular compound were estimated from total refrigeration gas emissions and considering the percentage of HFC use in total refrigeration gas use in each particular year (data collected from importers), according to the following equations:

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} \cdot HFC_{\% (j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\%(t,y)} \cdot HFC_{\% (j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} [Equip_{\%(t,t-lifetime)} \cdot HFC_{\% (j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$, $Oper_{Emi(t)}$, $Disp_{Emi(t)}$ - total HFC emissions in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$, $Oper_{Emi(t,j)}$, $Disp_{Emi(t,j)}$ - HFC emissions of compound j in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$ - Equipments assembled in year t;

$Equip_{Stock(t)}$ - Existing stock of equipment in year t;

$Equip_{Disposal(t)}$ - Number of equipments disposed at year t;

$Initial_{Charge(t)}$ - Initial charge of refrigeration gas filled in year t;

$Equip_{\%(t,y)}$ - Percentage of equipments assembled in year y in the existing stock in year t;

$HFC_{\%(j,t)}$ - Percentage of use of HFC compound j in year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

EMISSION FACTORS

In a similar way to domestic equipments, emission factors were set as the average values from the proposed range in IPCC GPG table 3.22.

Table 4.30 - Emission Factor for F-gas emissions from commercial, industry and services refrigeration equipments

Emission Factor (percentage of initial charge)	
Charging	Lifetime emission
1.75	5.5

It was considered that 80% of the gas remaining in the equipment at the end of lifetime is recovered ($z=0.8$) and the emitted quantity to the atmosphere is therefore the residual product remaining in equipment (variable y) which was set at 90% (data from importers).

ACTIVITY DATA

There are no available national statistics concerning the number and dimension of non-domestic refrigeration equipments used in commerce, industry, tourism, services and institutional activities. Hence activity data had to be estimated with the technical support of APIRAC, Importers and DGE (Enterprise and Industry General Directorate). The calculations for Hypermarkets were made separately.

The number of refrigeration equipments was estimated from the following economic activities, for which unit numbers were available from National Statistics Institute (INE):

Table 4.31 - Number of commercial installations in Portugal provided with refrigeration equipments

Activity	number	Period
Hotels	417	1995
Pensions (Boarding Houses)	937	1995
Other Establishments	379	1995
Camping Parks	181	1997
Restaurants	13 428	1995
Beverage stores	23 025	1995
Canteen	298	1998
Retail Commerce	49 436	1995
Gross Commerce	7 774	1995
Total	95875	-

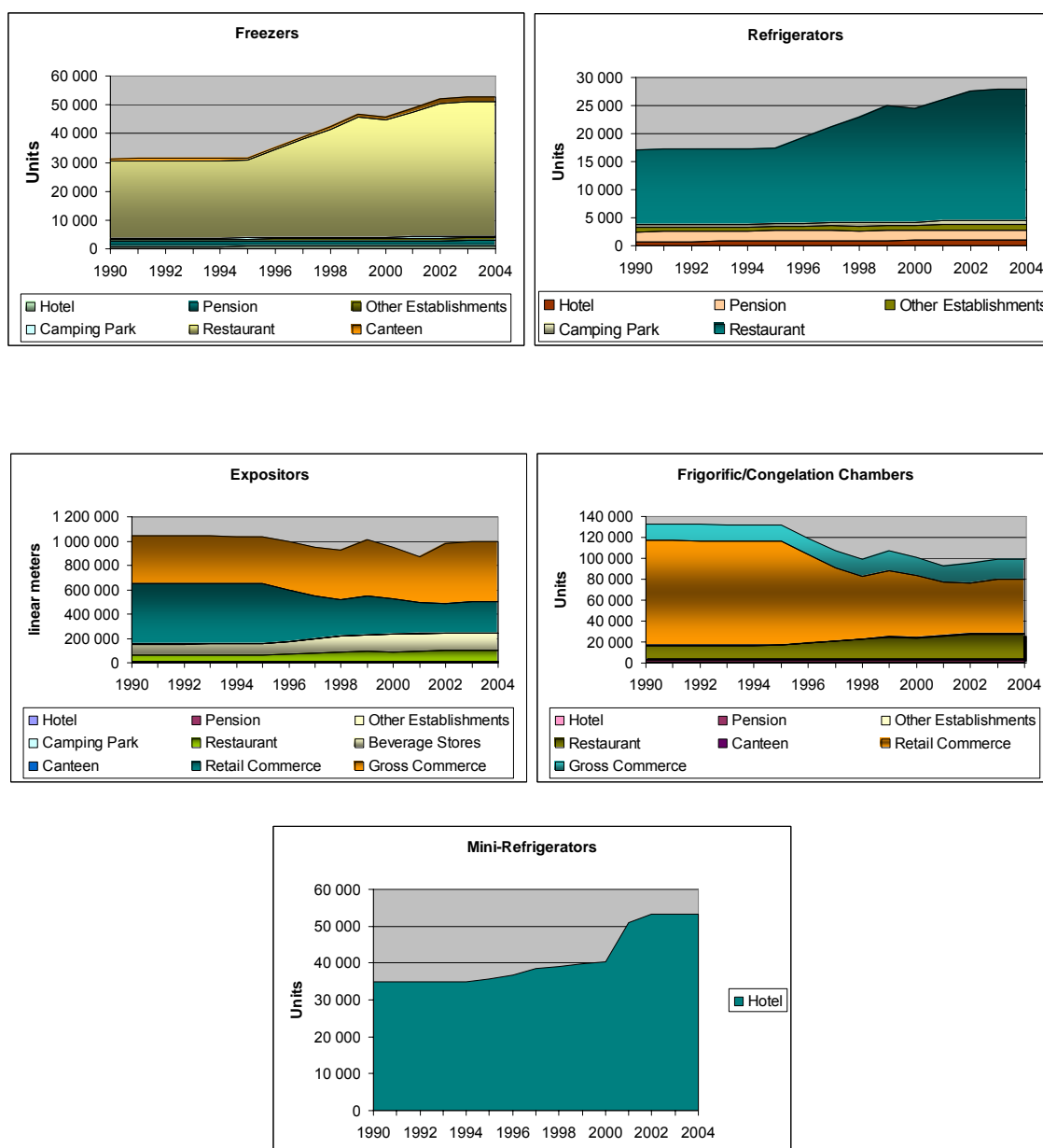
The following assumptions were made by IA:

- Retail Commerce and Gross Commerce do not include Hypermarkets (large, medium, small);
- the number of equipments per activity was set by expert judgement and by visiting some installations, according to the following table:

Table 4.32 - Number of refrigeration equipments per commercial unit in Portugal

Activity	Equipment (quantity)				
	Frigorific/Congelation Chamber (unit)	Expositors (m/unit)	Freezers (unit)	Refrigerators (unit)	Mini-refrigerators (unit/room)
Hotels	2	4	2	2	1
Pensions (Boarding Houses)	2	4	2	2	0
Other Establishments	2	4	2	2	0
Camping Parks	-	3	2	3	-
Restaurants	1	4	2	1	-
Beverage stores	-	4	-	-	-
Canteen	2	4	3	-	-
Retail Commerce	2	10	-	-	-
Gross Commerce	2	50	-	-	-

Figure 4.24 - Refrigeration Equipments in commercial activity in Portugal (1990-2004)



For Hypermarkets, calculations are made using data on average amounts of specific equipment (expositors, frigorific chambers, congelation chambers) for each category (Big, Medium, Small).

Table 4.33 – Classification of refrigeration equipments by area

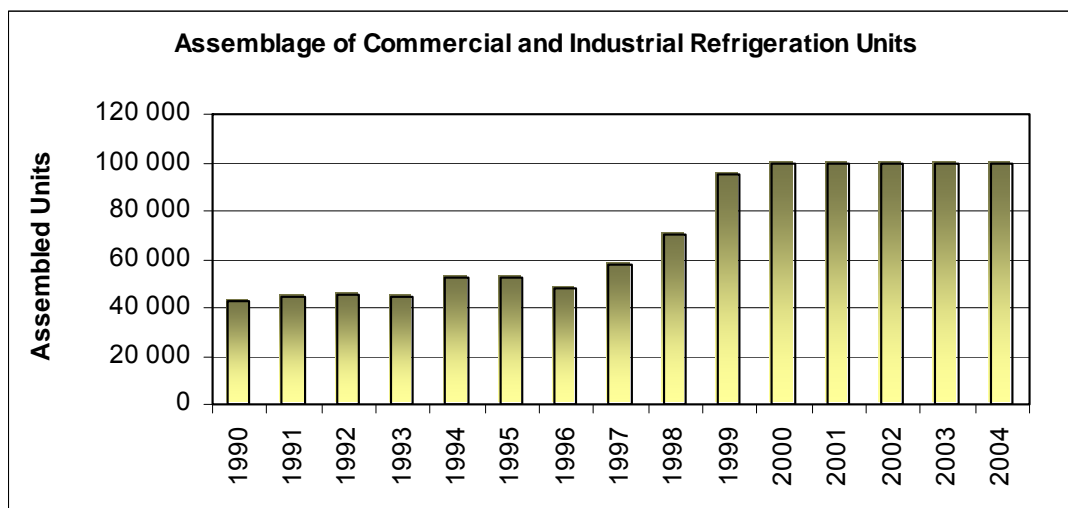
Area (m ²)	Category	Expositors (m)		Frigorific Chambers (m ²)	Congelation Chambers (m ²)
		Positive Temp.	Negative Temp.		
Area >4500	Big	218	110	550	180
1000 ≤ Area ≤ 4500	Medium	96	48	75	82
Area < 1000	Small	40	38	10	20

Table 4.34 – Number of Installations using HFC as refrigeration gas

Category		Number of Units using HFC as Refrigeration Gas									
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Positive Temperature	Big	0	0	0	0	5	8	10	12	15	15
	Medium	0	0	0	0	45	97	140	173	189	201
	Small	0	0	0	0	17	27	42	49	53	62
Negative Temperature	Big	0	0	0	0	0	3	5	7	10	10
	Medium	0	0	0	0	0	52	95	128	144	156
	Small	0	0	0	0	0	10	25	32	36	45

Assemblage of commercial and industrial refrigeration units is only available after 1992 with data collected under the new Industrial Survey (IAPI) and refers to refrigeration with a showing panel. Numbers are comparatively smaller than domestic units and are presented in next figure. Values after 2001 were forecasted by IA. Values for 1990 and 1991 were estimated concerning the Gross Domestic Product (GDP) values for each year.

Figure 4.25 - Assemblage of commercial and industrial refrigeration units in Portugal (1990-2004)



In a similar mode to domestic refrigeration equipments, the number of disposed units is not available and it was assumed that 10% of the stock is removed yearly (value confirmed by associations of equipment producers).

OTHER RELEVANT DATA AND PARAMETERS

The percentage of HFC gases in assembled equipments, existing stock and disposed units follows the same procedure and background data used for domestic equipments. Lifetime was set however at 14 years (average of values proposed by equipment producers and suppliers).

IPCC GPG admits a too much wide range for the charge in commercial stand-alone refrigeration equipments. The considered value, 440 g per linear meter of equipment unit, results from information from equipment producers and suppliers in Portugal.

UNCERTAINTY ASSESSMENT

The uncertainty in the refrigeration equipment stock was considered higher than that of domestic refrigeration. Using the same arguments that were used to derive activity data numbers, the actual values could be underestimated to half or overestimated to the double. The uncertainty of the number of disposed units per year is probably even higher, reflecting the uncertainty in life time of the equipment. That result in 30 per cent uncertainty for stock and 75 per cent for disposal. In the other hand, the uncertainty in new units results from the same source of information than that of domestic equipments and 10 per cent uncertainty was considered.

Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor, the composition of the F gas mixture⁷⁷, that affects the overall GWP, and also a component for time of discharge – expressing the uncertainty in lifetime. Individual uncertainty values are presented in next table. Overall, even with the inclusion of a new source of uncertainty - the composition of the F gas - total uncertainty was reduced by more than an order of magnitude (Combined uncertainty in previous submission range from 5 533 to 5 540 per cent). The main cause of the decrease, apart from the great effort placed in a better knowledge of the stocks, resulted from the improvement in the certitude in the initial charge, that resulted from the information received from the fluoride gas importers and the major retail operators in Portugal.

Table 4.35 – Uncertainty of Emission Factors for HFC emissions from Commercial Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	183	69	5	96	218
Operation	183	264	21	96	336
Disposal	183	11	21	96	208

4.3.E.8 TRANSPORT REFRIGERATION

METHODOLOGY

In a similar mode done for other Stationary Refrigeration Equipments, CFC, HCFC and HFC emissions from operation and disposal of transport refrigeration equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG. Lifetime and disposal emissions⁷⁸ were estimated according to the following set of equations after GPG:

⁷⁷ This factor was not considered in the submission 2005. It represents the change in final CO₂ equivalent values given the possible range in the gas composition that is used in the final mixture.

⁷⁸ Assembly emissions are not estimated and they are included in assemblage of other refrigeration equipments

Operation/Lifetime

$$\text{Oper}_{\text{Emi}(t)} = \text{Equip}_{\text{Stock}(t)} * \text{Initial}_{\text{Charge}(t)} * (x/100)$$

Disposal

$$\text{Disp}_{\text{Emi}(t)} = \text{Equip}_{\text{Disposal}(t)} * \text{Initial}_{\text{Charge}(t-\text{lifetime})} * (y/100) * (1-z/100)$$

HFC emissions for each particular F-gas compound were estimated from total refrigeration gas emissions from the percentage of HFC use in total refrigeration gas use in each particular year, according to the following equations:

Operation/ Lifetime

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

Disposal

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

Where

$\text{Oper}_{\text{Emi}(t)}$, $\text{Disp}_{\text{Emi}(t)}$ - total HFC emissions in year t from during Operation (Oper) and Disposal (Disp);

$\text{Oper}_{\text{Emi}(t,j)}$, $\text{Disp}_{\text{Emi}(t,j)}$ - HFC emissions of compound j in year t from during Operation (Oper) and Disposal (Disp);

$\text{Equip}_{\text{Stock}(t)}$ - Existing stock of equipment in year t;

$\text{Equip}_{\text{Disposal}(t)}$ - Number of equipments disposed at year t;

$\text{Initial}_{\text{Charge}(t)}$ - Initial charge of refrigeration gas filled in year t;

$\text{Equip}_{\%}(t,y)$ - Percentage of equipments assembled in year y in the existing stock in year t;

$\text{HFC}_{\%}(j,t)$ - Percentage of use of HFC compound j in year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

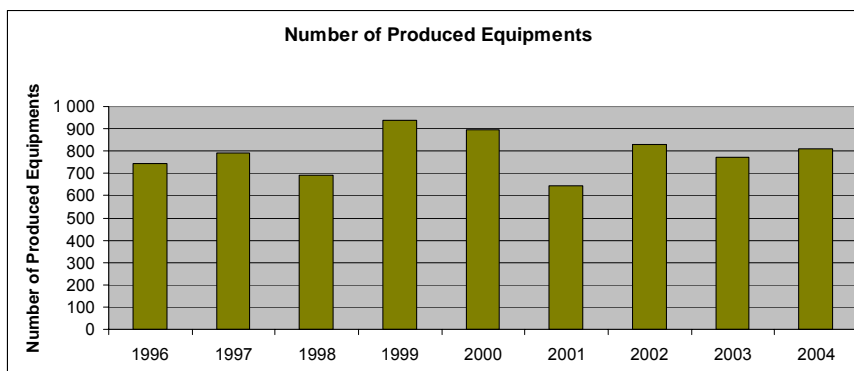
EMISSION FACTORS

Lifetime emissions are supposed to occur with a yearly rate of 32.5 % of initial charge per year in accordance with the average rate proposed in table 3.22 of the GPG. The emitted quantity to the atmosphere is the residual product remaining in equipment (variable y) which was set at 90% from 1996 IPCC Revised Guidelines and no recovery is assumed at disposal.

ACTIVITY DATA

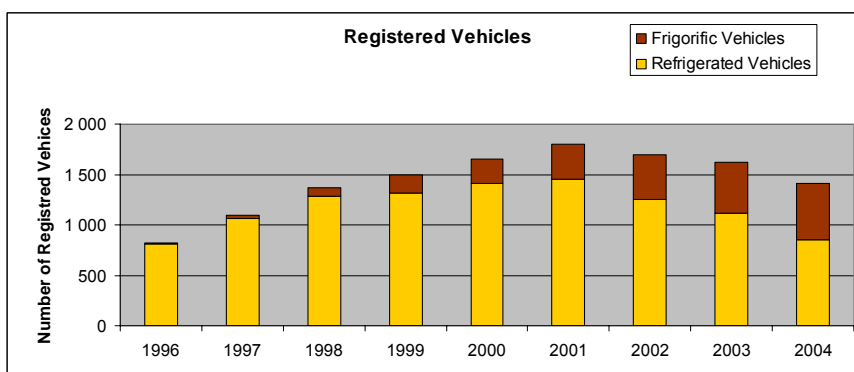
It was assumed that in Portugal, before 1996 it was not used HFC as refrigeration gas but instead CFC-12. The number of produced equipments in Portugal was collected from equipment producers.

Figure 4.26 – Number of Equipments produced in Portugal (1990-2004)



The number of existing registered vehicles was provided by the Portuguese Authority on Vehicles (DGV).

Figure 4.27 – Number of Registered Vehicles in circulation in Portugal (1990-2004)



OTHER RELEVANT DATA AND PARAMETERS

The initial charge was assumed to be 5.35 kg/unit (average of the values proposed by producers 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 producers and suppliers). It was assumed an yearly disposal of 10% of the vehicles (value discussed with Producers Association).

UNCERTAINTY ASSESSMENT

Also for this sub-source there is a high level of uncertainty in the determination of refrigeration equipment stock and it was assumed that the uncertainties grows from that of new units, set at 10 per cent, though stocks at 20 per cent and up to disposal at 50 per cent.

Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor, the composition of the F gas mixture, that affects the overall GWP, and also a component for time of discharge – expressing the uncertainty in lifetime. Each value was determined in accordance with the range of default emission factors in GPG, except the uncertainty in the initial charge that was determined from the range of values referred from the three most important providers of the refrigeration equipment for vehicles in Portugal. Individual uncertainty values are presented in next table.

Uncertainties in the previous submission were found to be underestimated.

Table 4.36 – Uncertainty of Emission Factors for HFC emissions from Transport Refrigeration

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	86	67	5	47	119
Operation	86	54	19	47	114
Disposal	86	6	19	47	101

4.3.E.9 DOMESTIC STATIONARY AIR CONDITIONING

METHODOLOGY

In a similar to other Stationary Refrigeration Equipments, fluorine gas emissions from operation and disposal of Stationary Air conditioning equipments were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.4 of the GPG.

Emissions were estimated according to the following set of equations after GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * HFC_{\% (j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\% (t,y)} * HFC_{\% (j,y)}]$$

Disposal

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

where

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

$\text{Ass}_{\text{Emi}(t,j)}$, $\text{Oper}_{\text{Emi}(t,j)}$, $\text{Disp}_{\text{Emi}(t,j)}$ - HFC emissions of compound j in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$\text{Equip}_{\text{Assembly}(t)}$ - Equipments assembled in year t;

$\text{Equip}_{\text{Stock}(t)}$ - Existing stock of equipment in year t;

$\text{Equip}_{\text{Disposal}(t)}$ - Number of equipments disposed at year t;

$\text{Initial}_{\text{Charge}(t)}$ - Initial charge of refrigeration gas filled in year t;

$\text{Equip}_{\%(t,y)}$ - Percentage of equipments assembled in year y in the existing stock in year t;

$\text{HFC}_{\%(j,t)}$ - Percentage of use of HFC compound j in year t;

K - percentage of initial charge that it is released during assembly;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

EMISSION FACTORS

Lifetime emission factor was set as 3 per cent of initial charge per year, which is the average value from the proposed range in IPCC GPG table 3.22.

It was assumed a recovery of 10% (data from importers) of the gas at end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90% from IPCC 1996 Revised Guidelines.

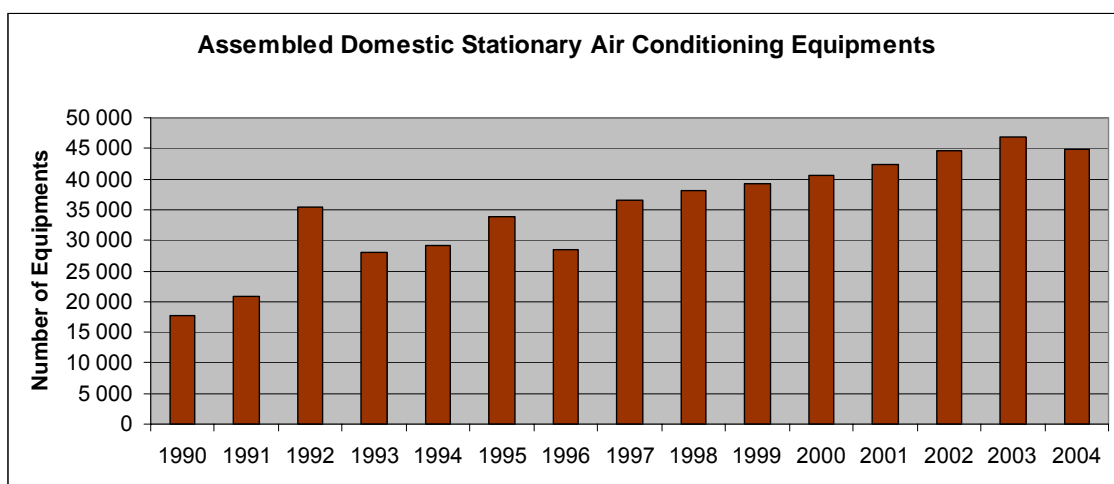
ACTIVITY DATA

From available data on industry statistics it is not possible to have a clear view of the time trend affecting the number of assembled units, as consequence of the change that occurred in the industrial survey in 1992, when IAIT was replaced by IAPI that uses different products categories. IAIT survey categories are not detailed enough to differentiate the production of refrigeration components - not resulting in emissions - from its final assemblage. The closure of an important factory in the same period complicates the exact knowledge of the time series. This situation is nonetheless irrelevant for the inventory because HFC emissions in assemblage of AC equipments did not occur at that period.

According to the available data from Luís Roriz (IST-UTL), the following time series (Figure 4.28), from 1990 to 2004, was assumed in the inventory. According to IAIT, 50 821 and 63 108 units were assembled respectively, in 1990 and 1991⁷⁹.

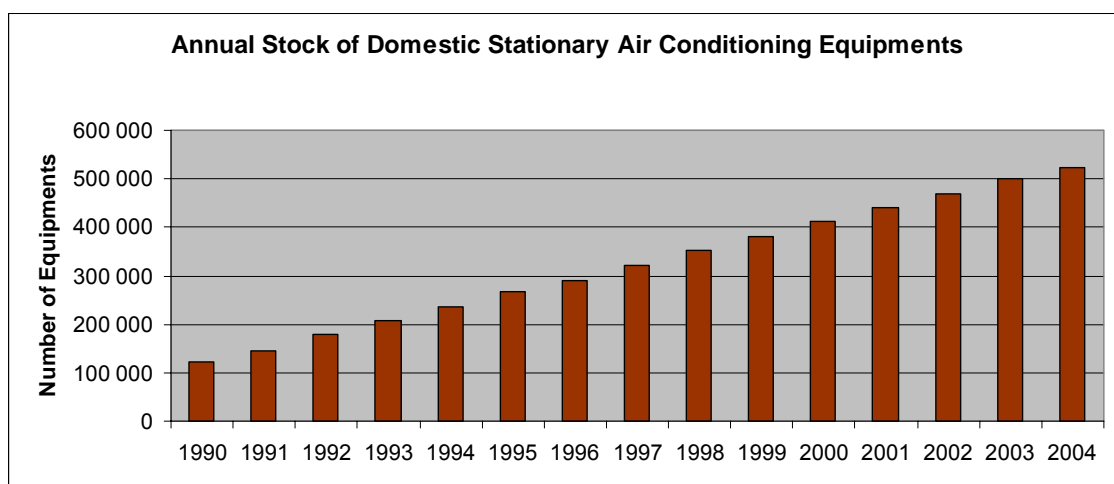
It was assumed that 90% of stocks and assembled air conditioning equipments are domestic equipments.

Figure 4.28 - Number of Domestic Stationary Air Conditioning Equipments assembled in Portugal in the period 1990-2004



The number of assembled domestic stationary air conditioning equipments is available from unpublished information received from IST-UTL (equi-stock in existence and yearly disposed units is available from unpublished information received from IST-UTL). The time series from 1990 to 2004 is presented in next figure.

Figure 4.29 - Annual Stock of Domestic Stationary Air Conditioning Equipments in Portugal (1990-2004)



⁷⁹ Due to difference in magnitude order these values from IAIT are not shown in the graph

OTHER RELEVANT DATA AND PARAMETERS

The quantity of initial gas charged per equipment, set at 300 g/unit, follows information collected from the industry association APIRAC by Seixas et al (2000). The F-gas composition was obtained by data from Importers. It was assumed that during the first filling 0.6% of the initial charge of gas is lost (arithmetic average of the values 0.2 and 1 recommended by the IPCC Good Practice Guidance).

UNCERTAINTY ASSESSMENT

The uncertainty in the number of newly assembled AC units is higher than the value that was considered for domestic refrigeration due to the incompleteness in time series. An uncertainty value of 20 per cent was assumed. An uncertainty of 30 per cent was considered for stock in existence and a higher value of 75 per cent was considered for disposal.

Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor, , the composition of the F gas mixture and also a component for time of discharge. The uncertainty in the initial charge of the equipments is based on the expert guess from the Portuguese Association of Refrigeration Equipment Providers (APIRAC). The uncertainty of other parameters was established from the range of default emission factors in GPG. Individual uncertainty values are presented in next table. Overall, due to the methodological improvements achieved since last year, the uncertainty in this source sector was reduced by about an order of magnitude concerning operation and disposal, and by half in what concerns assembly.

Table 4.37 – Uncertainty of Emission Factors for HFC emissions from A/C stationary equipments

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	20	67	5	83	108
Operation	20	67	19	83	110
Disposal	20	6	19	83	87

4.3.E.10 INDUSTRIAL STATIONARY AIR CONDITIONING

METHODOLOGY

The used methodology is the same as for Domestic Refrigeration Air Conditioning (see 4.3.E.9).

EMISSION FACTORS

Charging emission factor was set as 0.6% (average of the values suggested by IPCC Guidelines for Chillers). Lifetime emission factor was set as 3 per cent of initial charge per year, which is the average value from the proposed range in IPCC GPG table 3.22.

It was assumed a recovery of 10% (data from importers) of the gas at end of product life ($z=0.10$). The residual product remaining in equipment (variable y) was set at 90% from IPCC 1996 Revised Guidelines. It was assumed a lifetime of 15 years for the equipments (values suggested by producers and importers).

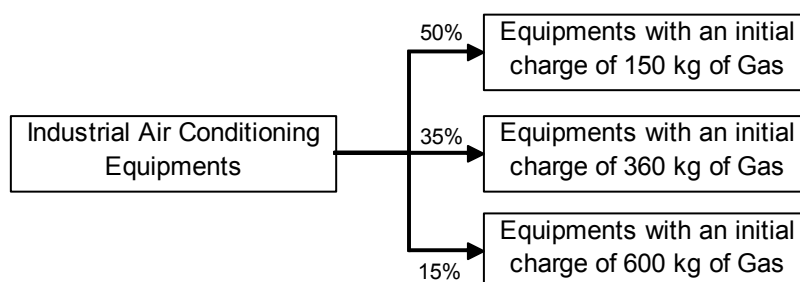
ACTIVITY DATA

From available data on industry statistics it is not possible to have a clear view of the time trend affecting the number of assembled units, as consequence of the change that occurred in the

industrial survey in 1992, when IAIT was replaced by IAPI that uses different products categories. IAIT survey categories are not detailed enough to differentiate the production of refrigeration components - not resulting in emissions - from its final assemblage. The closure of an important factory in the same period complicates the exact knowledge of the time series. This situation is nonetheless irrelevant for the inventory because HFC emissions in assemblage of AC equipments did not occur at that period.

It was assumed that 10% of stocks and assembled air conditioning equipments are included in industrial category (see Figure 4.30).

Figure 4.30 – Subdivision of Industrial Air Conditioning Equipments by type



According to the available data from Luís Roriz (IST-UTL), the following time series (Figure 4.28), from 1990 to 2004, was assumed in the inventory.

Figure 4.31 – Number of Industrial Stationary Air Conditioning Equipments Assembled in Portugal in the period 1990-2004

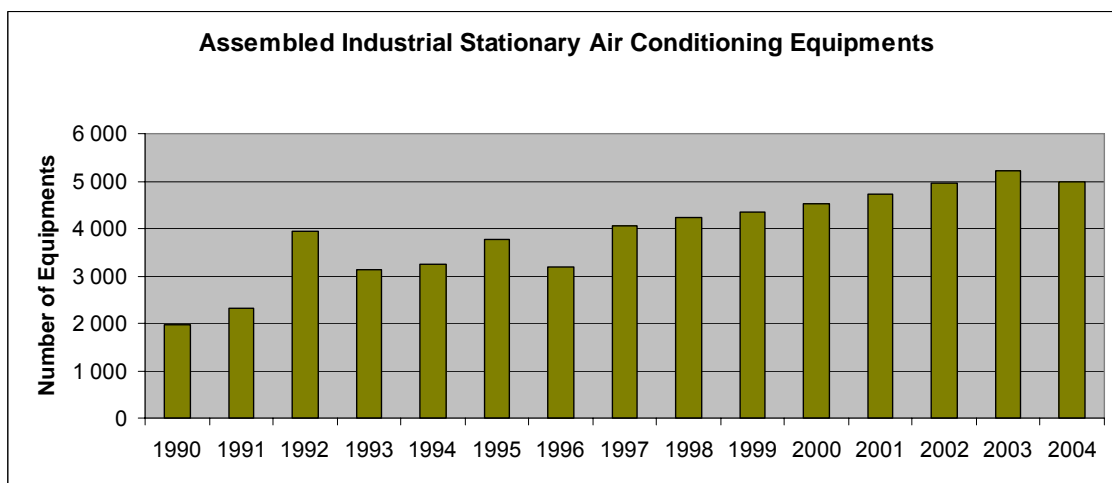
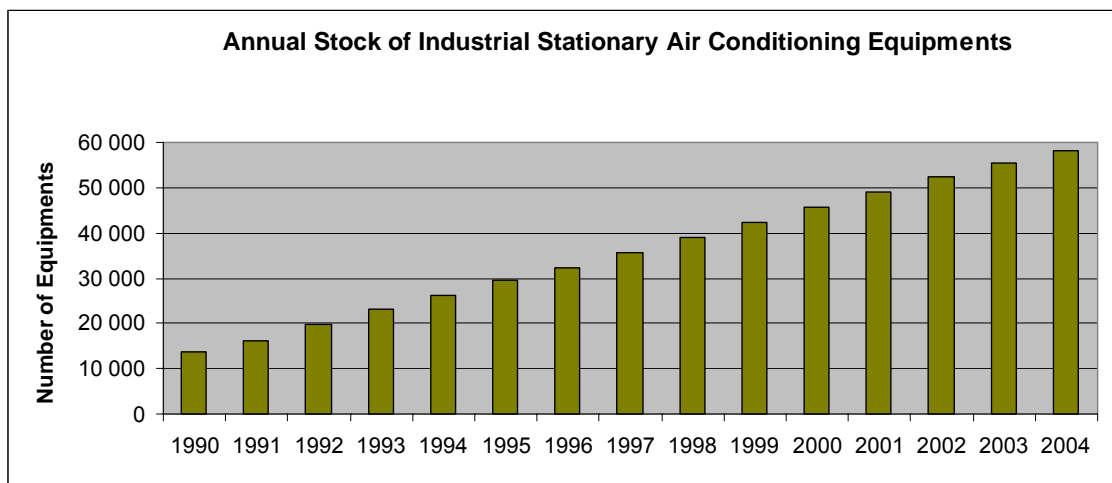


Figure 4.32 – Annual Stock of Industrial Stationary Air Conditioning Equipments in Portugal (1990-2004)



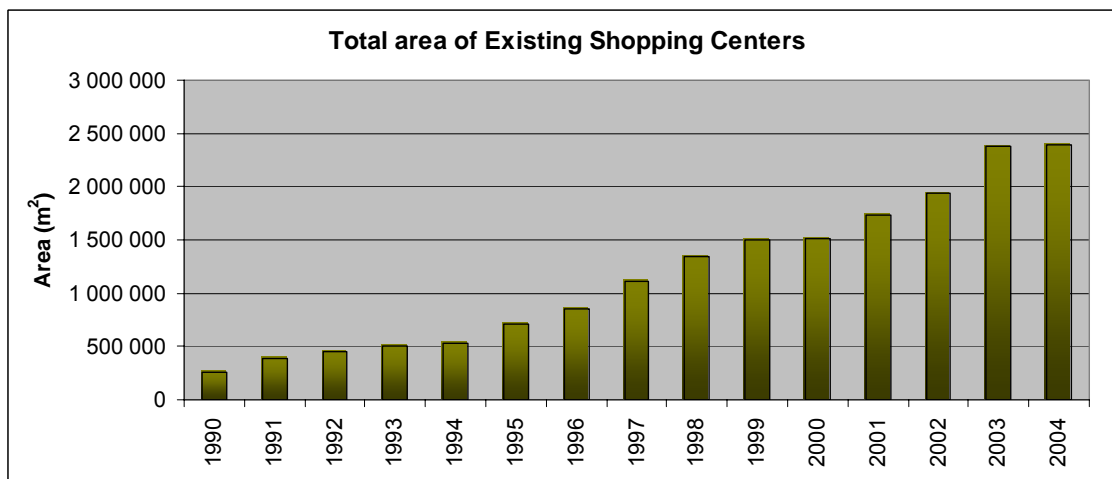
The Temporal Distribution by type of gas was obtained by data from importers.

AIR CONDITIONING EQUIPMENTS FROM SHOPPING CENTERS

When considering shopping centres with central systems of air conditioning it was used a different methodology, with specific data from each commercial area.

Data was obtained concerning the date of inauguration and total area for each unit from APCC (Portuguese Association of Shopping Centers). Figure 4.33 presents the total area of existing shopping centers for each year.

Figure 4.33 – Total Area of Existing Shopping Centers (m²)



Some Shopping Centers sent data on the amount of gas used to charge the air condition equipments. With the available information a factor was calculated that relates the area and the initial charge of gas. That factor was used to estimate the initial charge for the Shopping Centers for which there was not available any kind of information on the initial amount of gas used to fill the air conditioning equipments. It was also calculated a factor that relates the area and the annual loss of gas. Based on information collected on the type of gas it was assumed that since 2000 (included) the used gas in new installed equipments was R-407c (HFC mixture), before that HCFC-22 was the chosen gas.

UNCERTAINTY ASSESSMENT

The uncertainty assessment is explained in the chapter describing Domestic Stationary Air Conditioning..

4.3.E.11 MOBILE AIR CONDITIONING

METHODOLOGY

CFC, HCFC and HFC emissions from operation and disposal of Mobile Air Conditioning (MAC) systems were estimated using the bottom-up approach (Tier 2a or actual method) as proposed in chapter 3.7.5.1 of the GPG. The chosen methodology and emission factors choice is in accordance with the decision tree in GPG figure 3.16.

Emissions were estimated according to the following set of equations from GPG:

Operation/Lifetime

$$\text{Oper}_{\text{Emi}(t)} = \text{Equip}_{\text{Stock}(t)} * \text{Initial}_{\text{Charge}(t)} * (x/100)$$

Disposal

$$\text{Disp}_{\text{Emi}(t)} = \text{Equip}_{\text{Disposal}(t)} * \text{Initial}_{\text{Charge}(t-\text{lifetime})} * (y/100) * (1-z/100)$$

HFC emissions for each particular F-gas compound were estimated from total refrigeration gas emissions, and using the percentage of HFC use in total refrigeration gas use in each particular year, according to the following equations:

Operation/ Lifetime

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

Disposal

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

Where

$\text{Oper}_{\text{Emi}(t)}$, $\text{Disp}_{\text{Emi}(t)}$ - total HFC emissions in year t from during Operation (Oper) and Disposal (Disp);

$\text{Oper}_{\text{Emi}(t,j)}$, $\text{Disp}_{\text{Emi}(t,j)}$ - HFC emissions of compound j in year t from during Operation (Oper) and Disposal (Disp);

$\text{Equip}_{\text{Stock}(t)}$ - Existing stock of equipment in year t;

$\text{Equip}_{\text{Disposal}(t)}$ - Number of equipments disposed at year t;

$\text{Initial}_{\text{Charge}(t)}$ - Initial charge of refrigeration gas filled in year t;

$Equip_{\%(t,y)}$ - Percentage of equipments assembled in year y in the existing stock in year t;

$HFC_{\%(j,t)}$ - Percentage of use of HFC compound j in year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

EMISSION FACTORS

Operation emissions were estimated with an annual rate of 15%, the average of the updated default range (10-20%) in IPCC GPG (table 3.23). Lifetime was set at 12 years also the default value both in IPCC 96 and IPCC GPG.

Variable y was set at 40 % (default value in IPCC GPG). Variable z was set at 40% (value discussed with Gas Importers).

ACTIVITY DATA

There were made separate calculations for Road Transportation and Railways.

The number of light vehicles with MAC were estimated from the total number of light vehicles that are sold each year, using the same information that was used to establish the time series of car sales and fleet in chapter 1A3, and the percentage of new cars sold with MAC in each year according to information collected from Producers. Total number of vehicles equipped with MAC is presented in Figure 4.35. Since these numbers have suffered a substantial decrease since last submission, also the activity data time series reported in last submission is reported in the same figure.

Figure 4.34 - % of Vehicles with MAC by class of vehicle (1995-2004)

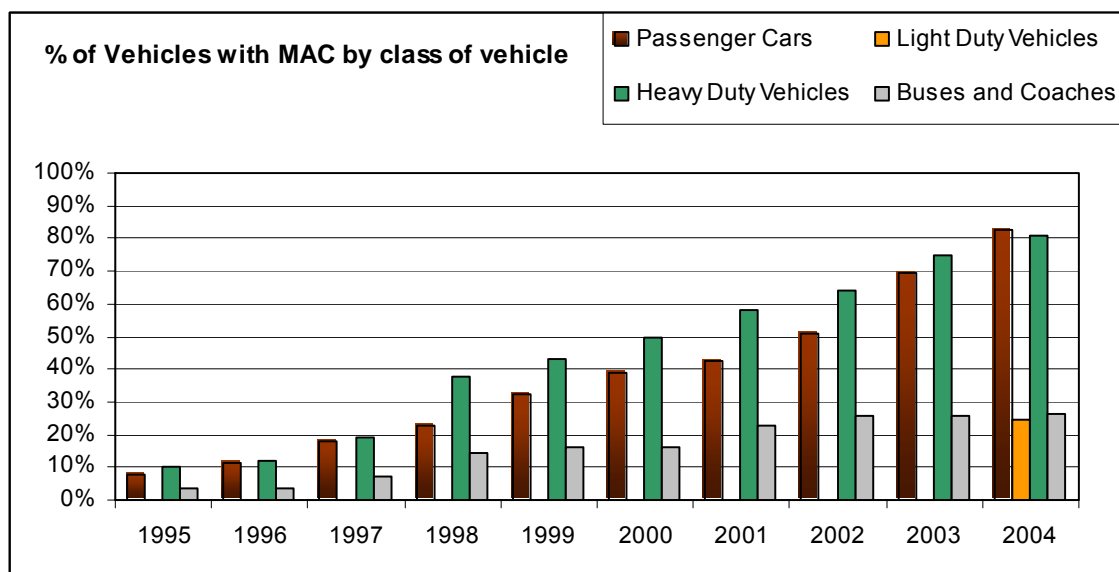
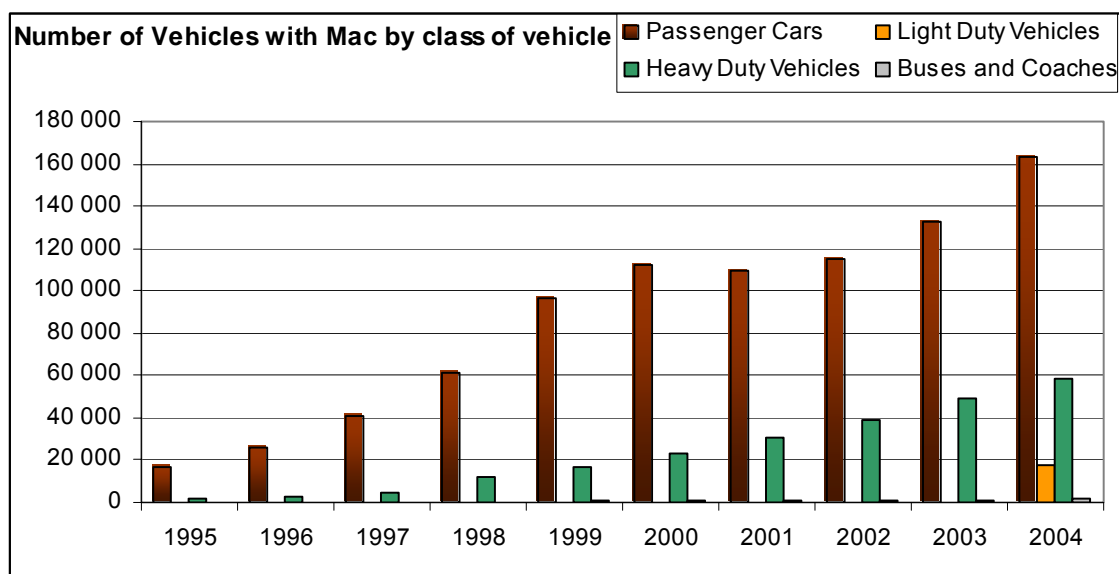


Figure 4.35 - Estimated number of Vehicles equipped with MAC systems (1995-2004)



OTHER RELEVANT DATA AND PARAMETERS

The assumed quantity of initial charge is 0.77 kg/MAC unit for Passenger Cars and Light Duty Vehicles. For Heavy Duty Vehicles the value of initial charge is 1.2 kg/MAC unit and for Buses and Coaches is assumed a value of 8 kg/MAC unit (these values were discussed with producers of equipments).

It was assumed that HFC 134a is the only HFC substituting CFCs and HCFC in MAC associated to Road Transportation, which agrees with IPCC GPG. In Portugal the use of HFC-134a associated to MAC equipments reports to year 1993.

In MAC equipments associated to Trains and Subway both HFC-134a and R-407C are used. For trains the quantity of initial charge is 1.05-1.5 kg/MAC unit on the crew room and 4-20 kg/MAC unit on passenger rooms.

UNCERTAINTY ASSESSMENT

The uncertainty in new units is higher than that of other refrigeration equipments due to the lack of specific national statistical information concerning the installation of these equipments in vehicles, and the use of a direct inquiry to vehicle sellers, that was only partial. Also for this sub-source there is a high level of uncertainty in the determination of MAC units, estimated from sales, vehicle fleet and life time and it was assumed that the actual values could be up to two times higher than the number of new equipment entering the market. The number of units disposed annually is even harder to establish and an uncertainty of 75 per cent was assumed.

Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime. Only one gas is referenced to be used in MAC systems and, therefore, no uncertainty in gas composition was considered. The uncertainty in the remaining parameters was established in accordance with the range of default emission factors in GPG, except the initial charge, that was established by comparison of the information delivered by the major car selles in Portugal. Individual uncertainty values are presented in next table.

Table 4.38 – Uncertainty of Emission Factors for HFC emissions from MAC

Origin	Uncertainty				
	Initial Charge	Emission	Time of Release	Gas Composition	Combined
Assembly	20	11	5	0	24
Operation	20	33	19	0	44
Disposal	20	44	19	0	52

4.3.E.12 FOAM BLOWING

OVERVIEW

Fluorine gases are now 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 time of manufacture. Closed-cell foams emit the HFC blowing agent during their lifetime and three phases may be individualised:

- Foam Manufacturing emissions, occurring in the first year where the foam is produced;
- Annual losses. Occurring where the foam was used, result from the slow liberation 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 estimate 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 we do our assumptions based on expert judgements.

In Portugal there exists production of Polystyrene closed-cell foams and Polyurethane open-cell foams, associated to the use of HFC-134a and HFC-152a as blowing agents.

METHODOLOGY

Methodology is classified as Tier 2a, using national data but with default emission factors. Therefore emissions comprehend:

First year losses from Foam Manufacture and Installation

$$F_{Gas_{Emi(t,j)}} = F_{FillGas_{Consumption(t)}} * HFC_{\%(j,t)} * (k/100)$$

Annual losses.

$$F_{Gas_{Emi(t)}} = F_{Gas_{inFoam(t)}} * (x/100)$$

$$F_{Gas_{inFoam(t,j)}} = \sum_{y=t}^{t-Lifetime} [F_{FillGas_{Consumption(y)}} * HFC_{\%(j,y)}]$$

Where:

$FGas_{Emit(t,j)}$ - gas emission in year t of fluorine gas j;

$FGas_{Consumption(t)}$ - Total F gas consumption in year t used in closed cell manufacturing;

$HFC_{\%(j,t)}$ - Percentage of Fluorine gas J used in year t in closed-cell manufacturing;

$FGas_{inFoam(t,j)}$ - quantity of F gas j in closed-cell existing in the country in year t⁸⁰;

K - first year loss emission factor;

X - annual loss emission factor.

This formulation is similar to equation 3.38 of the GPG.

Emissions due to decommissioning of foams were not included in estimates due to the lack of necessary information about foam stock and the expected lifetime of foams. It was assumed that the lifetime period is larger⁸¹ than the time between the first use of HFC and 2004.

EMISSION FACTORS

Due to unavailability of country-specific information default emission factors from GPG (table 3.17) were used, which are reproduced in the following table:

Table 4.39 - Emission Factors to estimate F gas emissions from foam losses

Type of Foam	Emission Factor		EF (% Original Charge)
Open Cell	K	First Year Losses	100
Closed Cell	K	First Year Losses	10
Closed Cell	x	Annual Losses	4.5

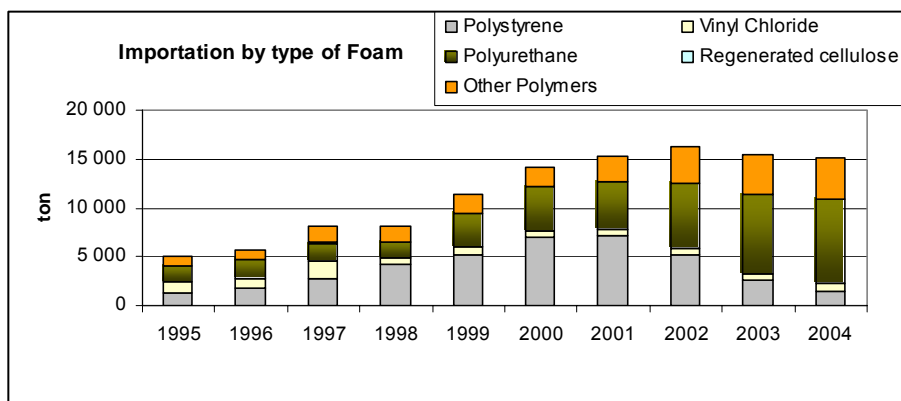
ACTIVITY DATA

It was obtained data on amounts of imported and exported foams (see Figure 4.36 and Figure 4.37) by kind of product from DGE (General Directorate for the Enterprise) as well as data on produced amounts of foam (DGE and producers).

⁸⁰ For the time being the stock is restricted to foam filled in Portugal;

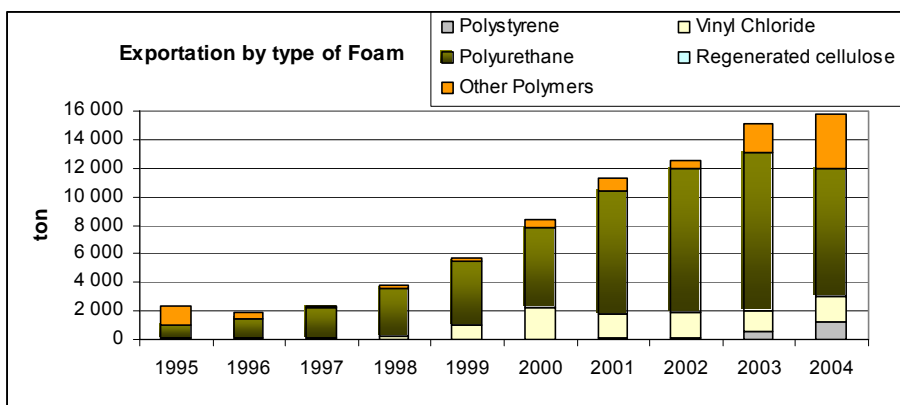
⁸¹ Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

Figure 4.36 – Importation by type of Foam



Source: DGE (General Directorate for the Enterprise)

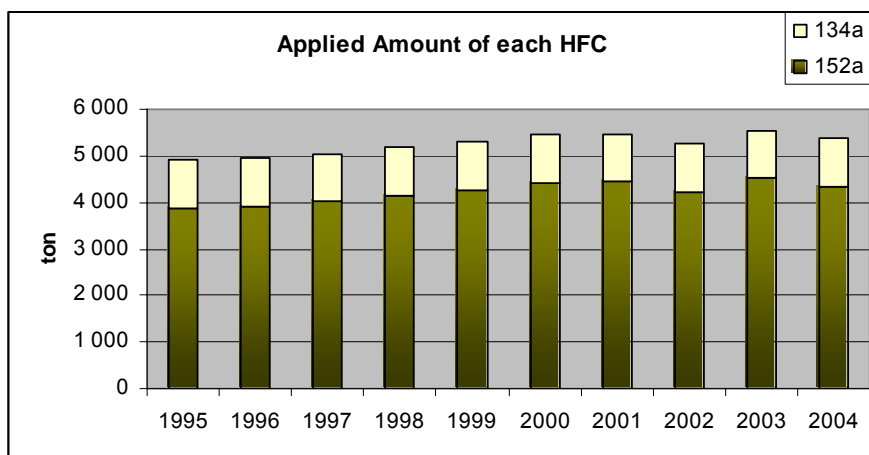
Figure 4.37 – Exportation by type of Foam



Source: DGE (General Directorate for the Enterprise)

It was only considered the use of HFC gases as foam blowing agents since 2003 for foams produced in Portugal. For foams imported and applied in Portugal it was considered the use of HFC since at least 1995. Foam industry is shifting to non-HFC agents. The share of each HFC blowing agent associated to applied foams, from 1995 to 2004 is presented in Figure 4.38.

Figure 4.38 - Total quantity of blowing agents used in Applied Foams in Portugal (ton/yr)



UNCERTAINTY ASSESSMENT

Improvements have been made in this sector since last year's submission. The uncertainty in fill gas consumption was maintained at 50 per cent, according to recommendations of GPG for country-specific top-down information. But the establishment of a better time series of foam stock allowed the reduction of uncertainty in operation from an order of magnitude to 100 per cent.

The uncertainty in emission factors result from the uncertainty in the release rate (emission), the life time, and also gas composition. The values, set from the range in GP (IPCC,2000) are presented in the next table.

Table 4.40 – Uncertainty of Emission Factors for HFC emissions Foams

Origin	Uncertainty			
	Emission	Time of Release	Gas Composition	Combined
Blowing	425	5	81	433
Leakage	44	19	81	94

4.3.E.13 METERED DOSE INHALERS

OVERVIEW

The information on this sector in Portugal is scarce. Nonetheless information was collected from some producers.

METHODOLOGY

It is assumed that the gas is emitted in the same year the inhaler is sold.

$$Emi_{HFC(t)} = \text{Number of sold equipments}_{(unit)} * K_{(g)} / (1 \times 10^{-6})$$

Where

$Emi_{HFC(t)}$ – Emission of gas (ton)

$K_{(g)}$ – Charge of gas of each equipment (g)

EMISSION FACTORS

Each producer gave values of charge for each kind of sold inhaler.

ACTIVITY DATA

There is information on sold inhalers charged with HFC for the year 2004. In that year it were sold 17 508 inhalers in Portugal with HFC-134a.

FURTHER IMPROVEMENTS

Even though is a sector that is using each less HFC as charge gas, more detailed information should be addressed by the producers in the future, in order to obtain a better characterization.

UNCERTAINTY ANALYSIS

The uncertainty in MDI was assumed as 500 per cent, given the scarce available information in the inventory.

4.3.E.14 FIRE PROTECTION

OVERVIEW

In Portugal the most used equipments are the streaming (portable) ones. The used gases are HFC-23 and HFC-227ea.

METHODOLOGY

It was used a Tier 2 comparable Top-Down approach from the IPCC Good Practice Guidance.

$$\text{Emissions} = \text{HFC}_{\text{a.s.}} - (\text{HFC}_{\text{n.e.}} - \text{HFC}_{\text{r.e.}})$$

Where:

$\text{HFC}_{\text{a.s.}}$ – HFC annual sales (ton)

$\text{HFC}_{\text{n.e.}}$ – HFC used to charge new fire protection equipments (ton)

$\text{HFC}_{\text{r.e.}}$ – HFC used to charge retiring fire protection equipments (ton)

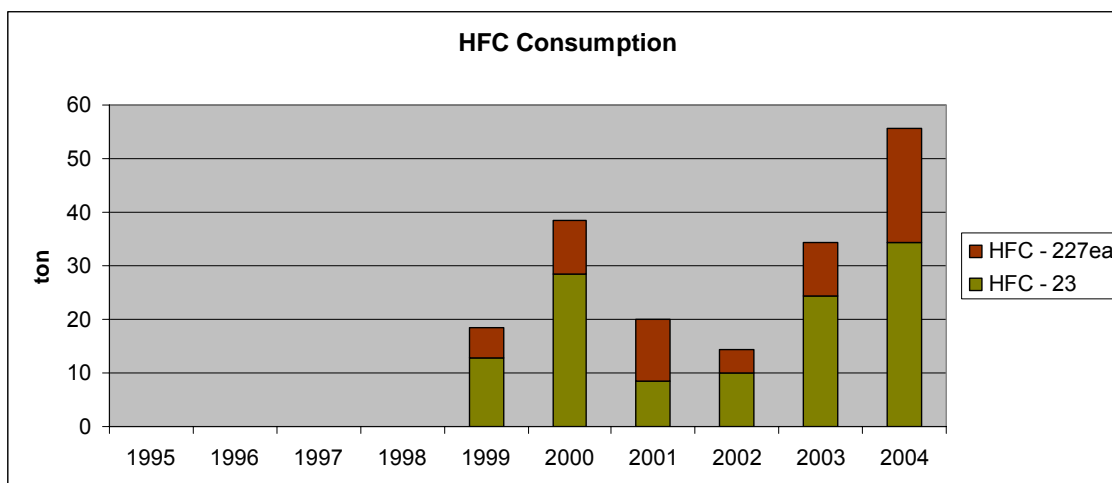
EMISSION FACTORS

It was assumed that y is 99.99% and z is 99%. Annually there are dismissed 4% of the existing equipments.

ACTIVITY DATA

Data on amounts of used gases in fire extinguishing equipments was obtained from the sellers of equipments and enterprises responsible for the filling of the equipments. The used gases are HFC-23 and HFC-227ea (see Figure 4.39).

Figure 4.39 – HFC consumption on Fire Extinguishing Equipments by type of gas (ton)



UNCERTAINTY ASSESSMENT

The uncertainty from fire protection equipment data was assumed as 20 per cent, given that only one company is importing these types of equipment in Portugal. The uncertainty in the gas, 23 or 227a, and differences in their GWP value, add 60 per cent uncertainty. The final uncertainty was set at 64 per cent.

4.3.E.15 ELECTRIC EQUIPMENT**OVERVIEW**

In Portugal, Sulphur hexafluoride (SF₆) is used in the electrical sector both as insulation gas in substations and 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 constituted by the Public Service Electric System (SEP) and by the Independent Electric System (SEI). In the second semester of 2000 it was made a separation between the net for transport of electricity at very high voltage (concession to REN – National Electric Net) and the net for distribution of electricity at low, medium and high voltage (EDP Distribuição).

Figure 4.40 - Flowchart of the National Electric System

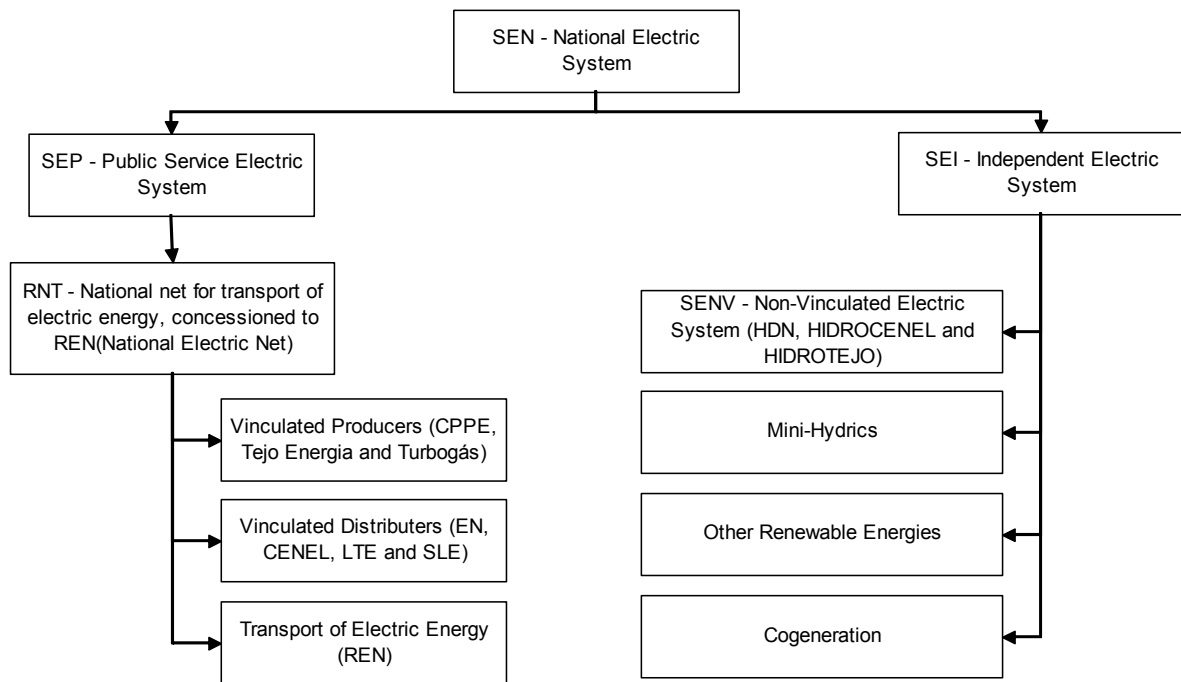


Figure 4.41 – Map of National Net for Transport of Electric Energy



Source: REN – Rede Eléctrica Nacional (www.ren.pt)

METHODOLOGY

Actual emissions of SF₆ from electrical equipment were estimated with a tier T3b, based on data from utilities, but without the details in life-cycle and using a country-specific emission factor. Emissions are determined using the following equation:

$$Emi_{SF6(t)} = Stock_{SF6(t)} * (k/100)$$

where:

$Emi_{SF_6(t)}$ - Equipment use emissions, including leakage emissions, servicing and maintenance;

$Stock_{SF_6(t)}$ - total SF_6 gas in existence in year t in all electrical equipments;

k - percentage of SF_6 in stock in year t that is emitted to atmosphere.

Disposal or retiring units are not included in the inventory as emission sources because, according to industry, the collection of gas at end of lifetime is done in a systematic and efficient mode. Manufacturing and installation emissions were assumed to be included in emissions from equipment usage.

EMISSION FACTORS

The emission factor was determined for country-specific conditions after information from the Portuguese companies responsible for electricity distribution:

- REN - responsible for distribution of electricity at Very High Voltage (>110kV), interconnections and substations;
- EDP – responsible for distribution of electricity at Low (≤ 1 kV), Medium (>1kV and ≤ 45 kV) and High Voltage (>45kV and ≤ 110 kV)

The emission factor for REN equipment was calculated comparing total SF_6 contained in equipments with the quantity of SF_6 that is used annually for losses reposition in years 1995 (0.55%), 1998 (0.58%), 1999 (0.71%), 2000 (0.92%) and 2004 (0.33%), in a similar manner to that recommended in GPG for the development of emission factors. It was assumed that reposition quantities equal losses due to equipment failure. For the years for which we didn't have any kind of information we used interpolated values as emission factor.

The emission factor for EDP equipment was calculated comparing total SF_6 contained in equipments with the quantity of SF_6 that is used annually for losses reposition in years 2003 (0.48%) and 2004 (0.51%). For the years 2001 and 2002 we used the average of 2003 and 2004 values (0.5%) as emission factor.

These values are slightly smaller than the default emission factor recommended in the 1996 *IPCC Revised Guidelines*. The GPG proposes higher values, 5% for equipments installed before 1996 and 2% thereafter.

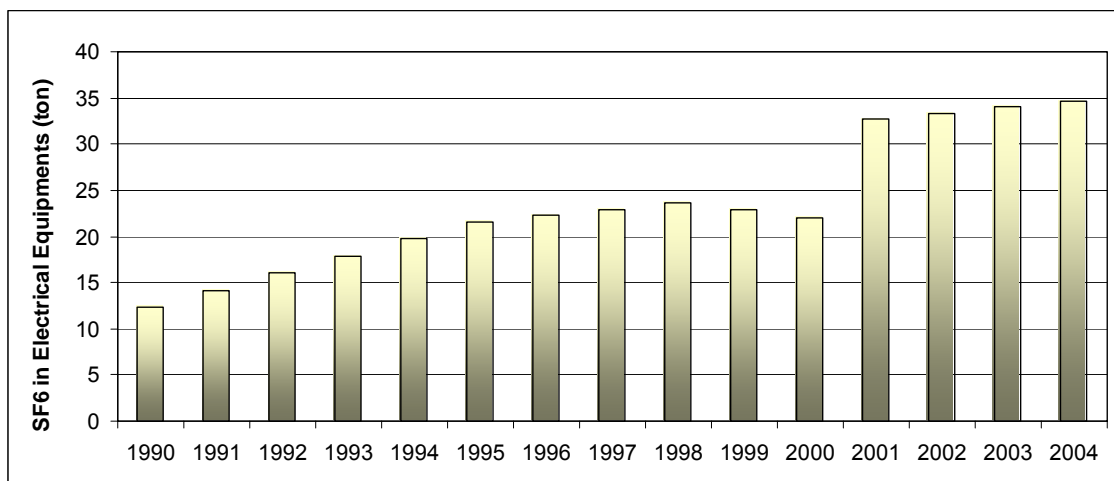
ACTIVITY DATA

Activity data was available directly from REN, the major national electricity distributor, but only for a restricted number of years (1990, 1995, 1998-2000, 2004 and Projections to 2010) and EDP (2003-2004 and Projections to 2010). Information for circuit switch breakers and substations for the available years is presented in next table. Interpolation was done to estimate SF_6 stock in equipments for intermediate years, and total SF_6 can be seen in Figure 4.42.

Table 4.41 - Quantity of Sulphur hexafluoride stock in Electric Equipments in Portugal

SF_6 (tons)	1990	1995	1998	2010
Switch Breakers	12.3	16.5	18.0	38.0
Sub-stations	0.0	5.1	5.7	11.9
Total	12.3	21.6	23.7	49.9

Figure 4.42 - Total SF6 in stock in electric equipments in Portugal (1990-2004)



UNCERTAINTY ASSESSMENT

The uncertainty in the emission factor is 15 per cent, obtained from statistical analysis of the emission factors determined for 1995, 1998, 1999 and 2000. The uncertainty in activity data was set at 25 per cent.

FURTHER IMPROVEMENTS

The use of a tier 3 methodology is to be pursued for this sector. At present it is possible to follow the amount of new SF6 used to replace leaked gas but only for that part of total stock that is managed by REN and EDP. But it is viable to extend that survey to the rest of total country use of SF₆ in electrical equipments.

CHAPTER: 5 : SOLVENT AND OTHER PRODUCT USE (CRF 3)

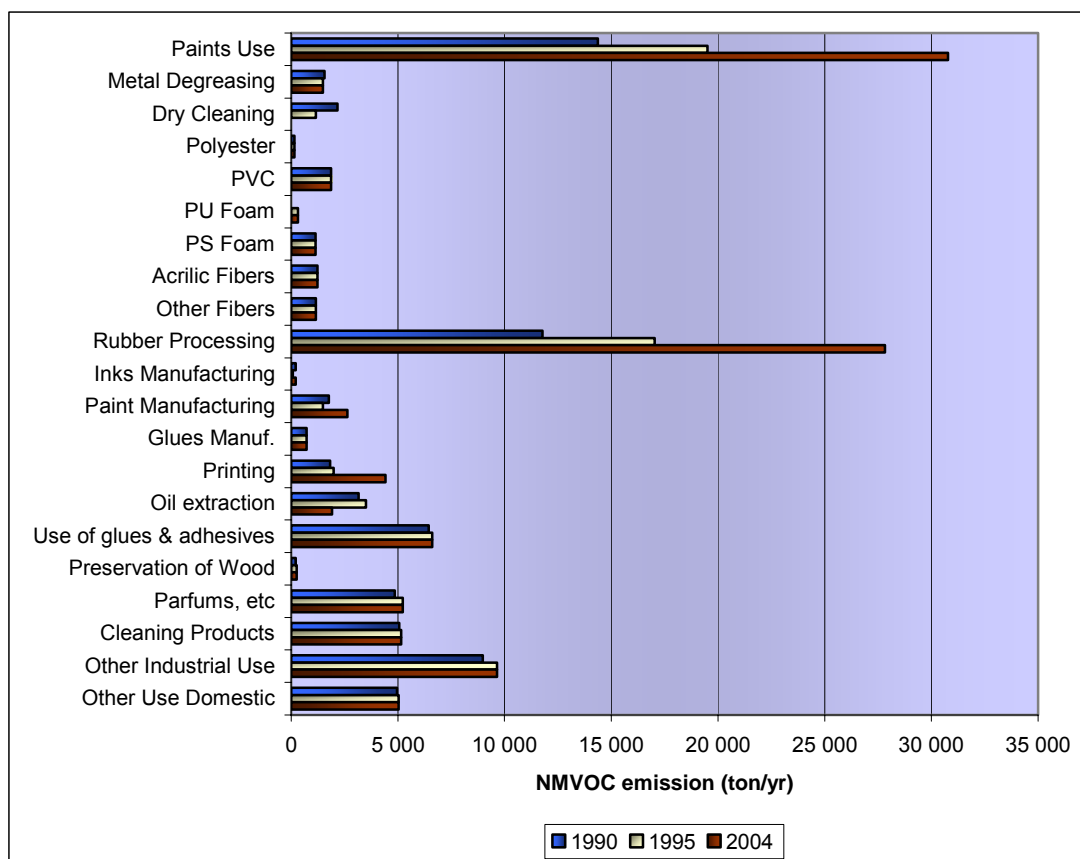
5.1 Overview

Solvents and related compounds are a significant source of emissions of non-methane volatile organic compounds (NMVOC). Although emissions of N₂O should also be included in this source, if resulting from use of this compound as component in specific applications, estimate for these sources are still un-available for Portugal. No emissions of methane are included in this source sector.

Some peculiarities apply to this source sector. In first place not all emissions occur directly to atmosphere when the production or use action takes place, as some solvents remain in product or are conveyed into wastewater. However, because eventually sooner or later these solvent fractions are liberated to atmosphere, all solvent losses may be assumed to contribute to air emissions. On the other hand, emissions of solvent may occur in three phases: during production of products containing solvents, during actual use of products containing solvent and during disposal.

The dominant sources of NMVOC from this sector in Portugal during the period 1990-2004 were Paint Application, Chemical Products Manufacture and Processing and other solvent use, while Degreasing and Dry Cleaning also contribute to emissions at a smaller scale. This may be seen in Figure 5.1, where the importance of emissions of NMVOC is shown in detail for years 1990, 1995 and 2004. From there it is evident the prevalence of emissions from paint use, rubber processing and other use of solvent products, and the substantial increase in emissions that was observable for use of paints and rubber processing.

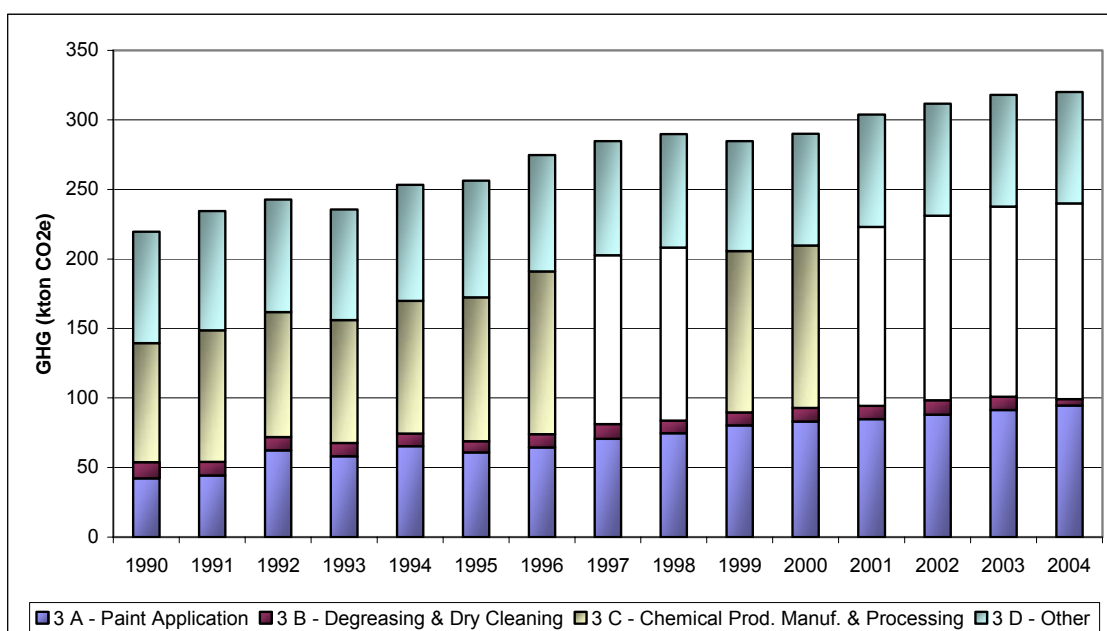
Figure 5.1 - NMVOC emissions from Solvent Use per individual source category in 1990, 1995 and 2004



NM VOC emissions estimates must be converted in CO₂ emissions whenever the carbon that is present in organic compounds has fossil fuel origin (originated from feedstocks from petroleum, coal or natural gas), and being assumed that NM VOC compounds are fully oxidized in air to carbon dioxide contributing thence to the atmospheric pool.

Total GHG emissions from this source sector have increased steadily in the period from 1990 to 2004, from 220 kton of CO₂ in 1990 (which is only 0.5 per cent of total CO₂ emissions or 0.34 per cent of total GWP CO₂e) to 320 kton CO₂ eq. in 2004 (0.39 per cent of total GHG emissions in CO₂e). All emissions, quantified as carbon dioxide, are presented in Figure 5.2 per sub-source sector.

Figure 5.2 - GHG emissions from Solvent Use per source sub-sector (1990-2004)



5.2 Recalculations

No changes have occurred in this source category since last submission (Figure 5.3).

Figure 5.3 - Differences between submissions 2005 and 2006 for CO₂ emissions from solvent use

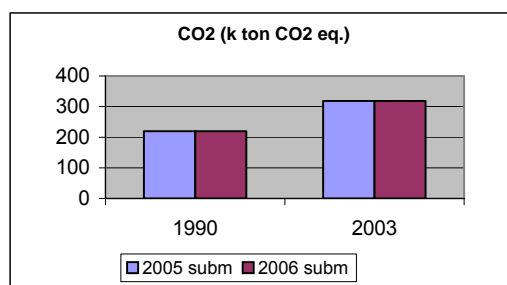


Table 5.1 - Recalculations of emissions of CO₂ from solvent use: differences between submissions 2005 and 2006

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂		
	2005	2006	Difference(
	subm.	subm.	1)
	CO ₂ equivalent (Gg)		(%)
1990			
3. Solvent and Other Product Use	219.71	219.71	0.00
2003			
3. Solvent and Other Product Use	317.93	317.93	0.00

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

5.3 Category Sectors

5.3.A Paint Application (CRF 3A)

5.3.A.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 appearance⁸² – such as paints, stains, varnishes, enamels and lacquers, either in buildings or artifacts, and either from professional activities or domestic use. Emissions due to the use of inks and textile coloring are not included here. Emissions from Paint manufacturing are discussed in chapter 5.2.C.

Emissions from paint use occur after paint is applied as a coating layer, irrespective of the application methodology: spraying (air pressure or electrostatic), spreading by roller or brush, dipping and electro-deposition, and happen from evaporation of solvent during paint cure. All organic compounds that evaporate are considered NMVOC emissions except if they are recovered and treated by any control equipment such as incineration or absorption.

All emissions from paint activity are included here, such as those arising from car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities and domestic use.

The distinction between coating operations in construction and building and domestic use is not very relevant, however, because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

5.3.A.2 METHODOLOGY

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from use/application of coating substances during year y (ton/yr);

⁸² Non continuous applications of coatings is printing industry and is included in other sub-source category. Application of continuous layers for gluing materials, by the use of glues or adhesives is also considered elsewhere.

Coating_{CONS(a,p,y)} – Use of coating substance p in economic activity a during year y (ton coater/yr);

EF_(p) – NMVOV emission factor (solvent content) resulting from application of substance p (kg/ton).

Ultimate CO₂ emissions were calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory as CO_{2e}.

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

where:

U_{CO₂} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

5.3.A.3 EMISSION FACTOR

Emission factors for NMVOC were made equal to solvent content of paints, which were established as expert guess from information collected from two of the biggest paint sellers in Portugal⁸³.

Table 5.2 - Solvent content of paints consumed in Portugal

Paint Type	Resin/ polymer	Solvent (%)
Water Based	Acrylic & Vinyl	1.5
	Alkyd & Other	1.5
Solvent Based	Acrylic & Vinyl	90
	Acrylic & Vinyl low solvent content	47
	Polyester	39
	Alkyd, celulosic & Other	51
Oil Paints, Powder Paints		0
Other Paints		29

These specific emission factors were applied to the total consumption of paint, irrespective of the application where it is used, and average emission factors were hence determined for water based paint, solvent based paint and other paints. The resulting emission factors, that were in fact used to estimate emissions for each economic activity, are presented in next table.

⁸³ Information from CIN and DYRUP. Original detailed information was given in ranges of solvent content and other paint classes and it can not be published due to confidential constraints. Choice of representative solvent content and correspondence of paint classes was done at IA

Table 5.3 – Average NMVOC emission factors from use of Paints

Paint Type	NMVOC EF (kg/ton Paint)
Water Based	1.5
Solvent Based	51
Oil and Powder Paints	0
Other Paints	29

there are small annual variations, although smaller than 1 kg/ton

5.3.A.4 ACTIVITY DATA

For most activities in Portugal there is no available and reliable statistical information concerning the use of paints. From IAIT and IAPI industrial surveys, from INE, it is only possible to determine consumption of paint in industrial activities, but the remaining, and larger part of consumption, is not known. Therefore total consume of paint and varnish in Portugal had first to be estimated from internal production, importation and exportation according to:

$$\text{Total}_{\text{Cons}(y,p)} = \text{Production}_{(y,p)} + \text{Imports}_{(y,p)} - \text{Exports}_{(y,p)}$$

where:

$\text{Total}_{\text{Cons}(y)}$ - Consumed paint and varnish of type p in year y (ton/yr);

$\text{Production}_{(y,p)}$ - National Produced paint and varnish of type p in year y (ton/yr);

$\text{Imports}_{(y,p)}$ - Imported paint and varnish of type p in year y (ton/yr);

$\text{Exports}_{(y,p)}$ - Exported paint and varnish of type p in year y (ton/yr).

The most detailed level desegregation per paint type that was possible to achieve was dependent, however on the fact that the statistical classes available for production data were dissimilar from the classes that are used for external trade. Annual production of paints by paint type⁸⁴, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 5.4 and Table 5.5.

⁸⁴ No distinction is made of end use (Wood industry, construction industry, etc) neither is made according to paint being paint, varnish, primers, enamels or lacquers, which differentiation is available at original databases

Table 5.4 – Paint Production in Portugal by Paint Type in ton/yr (1990-1996)

Type	Polymer	1990	1991	1992	1993	1994	1995	1996
Water	Acrylic & Vinyl	0	0	76 811	64 714	72 375	66 924	80 693
	Alkyd & Other	0	0	32	22	20	17	14
	Other	78 380	81 619	211	118	98	102	1 181
Solvent	Acrylic & Vinyl	0	0	248	48	23	76	134
	Acrylic & Vinyl Low solvent content	0	0	0	0	0	63	439
	Alkydic	0	0	13 013	10 622	10 946	10 956	12 941
	Celulosic	7 579	7 215	5 663	5 552	5 242	3 679	4 343
	Polyester	0	0	2 155	1 688	1 315	890	1 810
	Other	13 981	13 367	10 937	8 659	8 639	9 865	12 028
Oil		14 789	13 800	318	364	353	392	430
Powder		2 069	2 542	2 896	2 889	3 269	3 747	3 618
Other		1 164	1 357	37	2 181	2 133	2 363	2

Source: INE;
included as other

Table 5.5 – Paint Production in Portugal by Paint Type in ton/yr (1997-2004)

Type	Polymer	1997	1998	1999	2000	2001	2002	2003	2004
Water	Acrylic & Vinyl	89 371	103 585	99 909	102 718	108 629	113 530	118 431	123 333
	Alkyd & Other	3	0	41	0	6	4	2	0
	Other	1 397	1 639	671	1 883	1 872	2 084	2 296	2 508
Solvent	Acrylic & Vinyl	136	562	535	546	572	635	698	761
	Acrylic & Vinyl Low solvent content	743	2 089	2 476	2 335	2 707	3 068	3 428	3 789
	Alkydic	12 984	12 131	11 050	13 269	12 549	12 661	12 772	12 884
	Celulosic	4 367	4 401	3 971	3 144	3 167	2 903	2 640	2 376
	Polyester	1 849	2 873	3 620	4 247	3 792	4 096	4 400	4 704
	Other	13 171	13 515	14 840	12 953	14 928	15 589	16 250	16 911
Oil		423	539	556	588	612	647	681	715
Powder		3 843	4 706	5 846	5 759	6 004	6 392	6 781	7 169
Other		68	364	310	399	399	399	399	399

Source: INE;
included as other

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 5.6 and Table 5.7, respectively for imports and exports.

Table 5.6 – Import of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Water	Acrylic & Vinyl	538	957	1 705	907	2 760	3 411	3 262	2 696	3 081	2 240	1 983
	Alkyd & Other	1 204	1 731	1 789	2 151	3 357	6 493	7 924	8 661	9 066	8 751	10 104
Solvent	Acrylic & Vinyl	78	78	80	102	1 365	440	568	424	359	462	383
	Acrylic & Vinyl Low solvent	1 036	920	970	3 007	4 129	4 597	5 948	4 526	6 339	5 331	6 031
	Polyester	890	1 302	1 695	2 298	3 010	3 560	3 274	4 235	4 956	5 059	6 301
	Alkyd, celulosic & other	3 813	5 098	5 523	5 509	7 169	6 345	6 638	8 165	7 796	9 966	10 229
Oil		91	141	326	199	148	223	216	264	291	234	157
Other		31	111	123	257	48	15	17	11	24	186	247

Source: INE;

Table 5.7 –Export of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Water	Acrylic & Vinyl	387	519	858	424	519	103	435	492	183	419	503
	Alkyd & Other	783	963	1 206	980	1 439	2 020	1 717	2 547	2 082	3 396	4 649
Solvent	Acrylic & Vinyl	0	1	3	2	1	1	1	2	3	0	4
	Acrylic & Vinyl Low solvent	2 084	2 289	1 659	1 579	1 399	806	1 343	1 126	1 606	1 089	856
	Polyester	908	1 085	761	705	2 658	3 228	5 342	4 439	8 464	7 055	6 755
	Alkyd, celulosic & other	499	395	663	840	808	1 707	3 538	2 829	1 972	1 482	794
Oil		91	516	341	523	610	468	157	213	140	316	91
Other		31	158	32	113	275	242	107	266	39	45	90

Source: INE;

Hence, total consumption of paints was calculated from 1990 and 2000, and the resultant time series is presented in Table 5.8, Table 5.9 and in Figure 5.4. Values for 2001 to 2003 result from forecasts made at IA from the available time series of paint consumption.

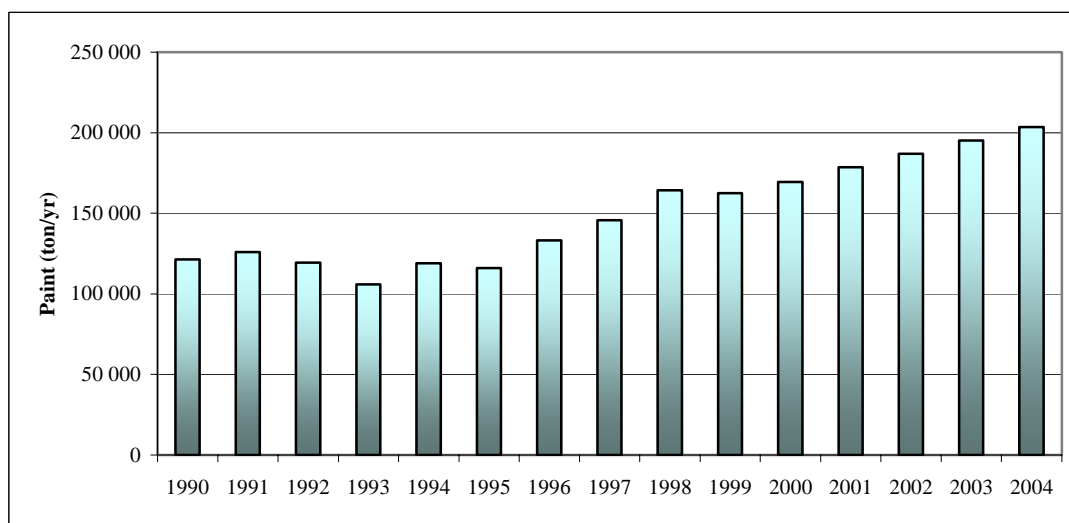
Table 5.8 –Estimated total consumption of Paints in Portugal by Paint Type (1990-1996)

Type	Polymer	1990	1991	1992	1993	1994	1995	1996
Water	Acrylic & Vinyl	151	438	77 658	65 196	74 616	70 233	83 520
	Alkyd & Other	78 800	82 388	826	1 311	2 036	4 593	7 401
Solvent	Acrylic & Vinyl	78	77	326	149	1 388	514	701
	Acrylic & Vinyl Low solvent	0	0	0	1 428	2 730	3 853	5 043
	Polyester	0	217	3 090	3 280	1 667	1 222	0
	Alkyd, celulosic & other	24 873	25 286	34 473	29 503	31 187	29 138	32 412
	Oil	14 363	13 601	122	0	33	457	433
Powder		2 069	2 542	2 896	2 889	3 269	3 747	3 618
Other		1 037	1 436	48	2 164	1 939	2 271	0
Total		121 371	125 984	119 438	105 920	118 866	116 029	133 129

Table 5.9 –Estimated total consumption of Paints in Portugal by Paint Type (1997-2004)

Type	Polymer	1997	1998	1999	2000	2001	2002	2003	2004
Water	Acrylic & Vinyl	91 575	106 483	101 730	104 198	111 204	116 218	121 232	126 246
	Alkyd & Other	7 514	8 624	6 067	7 337	9 780	10 720	11 660	12 600
Solvent	Acrylic & Vinyl	558	918	996	925	1 057	1 124	1 191	1 259
	Acrylic & Vinyl Low solvent	4 142	6 821	6 718	7 510	8 781	9 688	10 594	11 500
	Polyester	1 646	0	1 624	3 794	1 392	1 307	1 223	1 139
	Alkyd, celulosic & other	35 857	35 871	38 345	38 801	38 948	39 946	40 945	41 944
Oil		547	514	699	554	780	861	942	1 024
Powder		3 843	4 706	5 846	5 759	6 004	6 392	6 781	7 169
Other		39	343	406	576	576	576	576	576
Total		145 721	164 281	162 433	169 453	178 521	186 833	195 145	203 457

Figure 5.4 - Total consumption of Paints in Portugal (1990-2004)



Finally total consumption of paint was disaggregated by the economic activity where the paint is used. In first place, from IAIT and IAIP industrial surveys, it was possible to determine consumption of coating materials per economic activity but only for the industry sector: results from IAIT and IAPI are presented in Table 5.10 and Table 5.11. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction⁸⁵, as well as all use of oil and powder paints.

Table 5.10 - Paint and varnish consumption in industrial activities (1990-1996)

Activity	Paint Type	1990	1991	1992	1993	1994	1995	1996
Wood	Water	15	13	97	182	266	681	783
Plastic, cables		8	19	1 026	2 033	3 040	2 449	2 881
Glass and Ceramics		31	33	22	11	0	0	0
Metalic Equipment and furniture		0	0	0	0	0	0	0
Vehicles		0	0	0	0	0	0	0
Other machinery		35	33	22	11	0	2	46
Domestic, Services and Construction		78 862	82 728	77 317	64 271	73 347	71 694	87 211
Wood	Solvent	0	0	0	0	0	0	0
Plastic, cables		0	0	0	0	0	0	0
Glass and Ceramics		0	0	0	0	0	0	0
Metalic Equipment and furniture		838	996	664	332	0	0	1
Vehicles		1 581	1 242	836	430	24	28	630
Other machinery		476	444	1 936	3 428	4 920	5	12
		22 056	22 898	34 453	30 170	32 029	34 695	37 514
Domestic, Services and Construction	Oil	14 363	13 601	122	0	33	457	433
	Powder	2 069	2 542	2 896	2 889	3 269	3 747	3 618
	Other Paints	1 037	1 436	48	2 164	1 939	2 271	0

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by IA

⁸⁵ No further desegregation by this uses is possible from available statistical information

Table 5.11 - Paint and varnish consumption in industrial activities (1997-2004)

Activity	Paint Type	1997	1998	1999	2000	2001	2002	2003	2004
Wood	Water	887	794	887	1 047	1 205	1 321	1 436	1 551
Plastic, cables		230	337	597	625	1 180	1 176	1 172	1 168
Glass and Ceramics		0	64	61	161	82	90	98	106
Metalic Equipment and furniture		0	0	0	0	0	0	0	0
Vehicles		0	0	0	0	0	0	0	0
Other machinery		53	84	92	93	89	97	104	112
Domestic, Services and Construction		97 920	113 828	106 161	109 609	118 428	124 255	130 082	135 910
Wood	Solvent	0	0	0	0	0	0	0	0
Plastic, cables		0	0	0	0	0	0	0	0
Glass and Ceramics		0	0	0	0	0	0	0	0
Metalic Equipment and furniture		1	3	36	34	34	34	34	34
Vehicles		690	735	685	1 874	799	800	800	801
Other machinery		11	16	16	23	23	23	23	23
		41 501	42 857	46 946	49 099	49 321	51 209	53 096	54 984
Domestic, Services and Construction	Oil	547	514	699	554	780	861	942	1 024
	Powder	3 843	4 706	5 846	5 759	6 004	6 392	6 781	7 169
	Other Paints	39	343	406	576	576	576	576	576

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by IA

5.3.A.5 UNCERTAINTY ASSESSMENT

The uncertainty factor of the emission factor for NMVOC and CO₂ expresses the uncertainty of the solvent content of paints. From the information that was collected from national suppliers of paint the error for water based paints was estimated to be 350 per cent and the error for solvent based paints is 67 per cent. The overall uncertainty value for CO₂/NMVOC emission factor is therefore calculated to be 261 per cent for all uses of paint.

There is a great uncertainty associated with the activity data due to the fact that was estimated at IA from production data and importation and exportation. An overall uncertainty value of 30 per cent may be assumed.

5.3.A.6 RECALCULATIONS

No substantial modifications have been made in emission estimates from this source sector since last year's submission.

5.3.A.7 FURTHER IMPROVEMENTS

In future, particularly after 2007, emissions factors must take account of the procedures set in each economic sector for the reduction of NMVOC emissions from paint use, including the control of the solvent content of paint and varnishes. In fact nowadays some control measures and low solvent content paints are already being applied in some economic activities - for instance in the car building industry - but no comprehensive information allows introduction of this level of detail in emission estimates. Therefore, efforts will be done in order that more detailed information from these sectors is collected and incorporated in the emission inventory.

5.3.B Degreasing and dry cleaning (CRF 3B)

5.3.B.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, rubber⁸⁶, textiles, glass, paper and fiber-glass, etc. Usually solvents used to achieve degreasing are petroleum distillates, chlorinated hydrocarbons, ketones and alcohols, and the cleaning process is usually done in tanks, which may have some form of emissions control (solvent recovery).

In essence dry-cleaning has the same objective to degreasing, seeking to remove, by the aid of solvents, of contamination or dirt from cloths, textile, furs, leather, down leathers, textiles or other objects made of fibers.

5.3.B.2 METHODOLOGY

Assuming that all solvents consumed during degreasing and dry-cleaning evaporate, NMVOC emission will be equal to the amount of solvents used. If it is considered that annual consumption of solvents in an economic activity is used to replenish the quantity of solvent that was lost, then annual NMVOC emissions may be estimated from the annual consumption of solvent. This methodology overcomes the need of being aware of the portion of solvent that is recovered.

In the case of the dry-cleaning activity it was assumed that either the solvent is lost directly to atmosphere, or if it is conveyed to water or retained in clothes, but it will eventually reach atmosphere by evaporation.

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several sources (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

CO₂ emissions are derived by assuming that 85 percent of the mass emissions of NMVOC is carbon:

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

where:

U_{CO_2} - Ultimate CO₂ (ton);

NMVOC - Global emissions of NMVOC (ton).

5.3.B.3 ACTIVITY DATA

Statistical information concerning total solvent use, from the National Statistics Institute (INE), was used to estimate VOC emissions. Consumption of solvents, presented in Table 5.12, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

⁸⁶ Emissions from degreasing in this industry are included under rubber processing

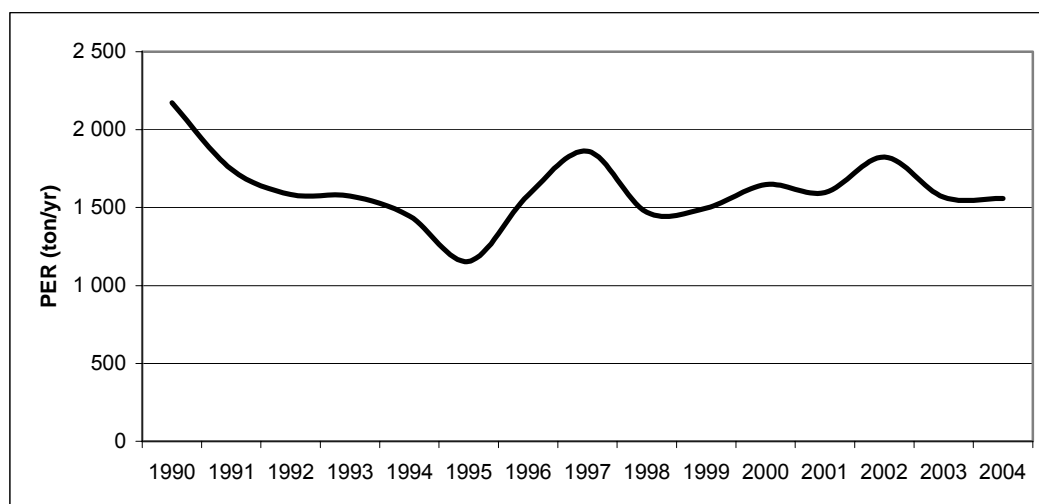
Table 5.12 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	1992-2004
Metal Degreasing	1 552	1 415	1 484

Source:IAIT industrial survey (INE)

There is no available statistical information concerning consumption of solvents and other materials in dry-cleaning activity, because this activity is not included under IAIT and IAPI industrial surveys. Therefore, it was assumed that all PER (Tetra-chloro-ethylene)⁸⁷ imported to Portugal is used in dry-cleaning⁸⁸ activity and that all PER that is used is imported (no national production). Annual importation, which is available from INE's statistical databases on external trade from 1990 to 2002, was therefore assumed as equal to solvent use. The full time series, forecasted for the years after 2002, is presented in Figure 5.5.

Figure 5.5 – Annual importation/ consumption of PER (Tetra-chloro-ethylene) in Portugal (ton/yr) 1990-2004



Source: INE;

5.3.B.4 UNCERTAINTY ASSESSMENT

The time trend of activity data for metal degreasing is very incomplete and an uncertainty of 100 per cent was considered. Because emissions from PER use in dry cleaning were established from importation of this product the error is mostly due to incorrect allocation of emission, i.e. considering in dry cleaning a fraction of PER emissions that were realized in fact in other industrial activity. The final effect in inventory totals is therefore not significant and an error of 10 per cent was used (USEPA,xpto). The uncertainty of emissions from both sectors are fully considered under activity data.

⁸⁷ 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.

⁸⁸ There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

5.3.B.5 RECALCULATIONS

No changes were made in emission estimates from this source sector since last submission.

5.3.B.6 FURTHER IMPROVEMENTS

A better knowledge of this sector should be achieved, namely to verify if other solvents are also used and in which quantities. Alternative methodologies, based on washed cloths and type of cleaning equipment should be also done, and results compared to the estimates that are now reported.

5.3.C Chemical products, manufacture and processing (CRF 3C)

5.3.C.1 OVERVIEW

This source sub-category comprehends several emission sources that are related to industrial processes involving manipulation of polymer. Although emissions for this source result mostly from the use of solvents, which are used as diluters or cleaning agents, some emissions result also from monomers leakage from the polymer, which means that these emissions should in fact be quantified under Production Processes. Nevertheless it was decided to include all those emissions here for simplicity in reporting and because it is not always possible to distinguish the part that is solvent from the part that has resulted from evaporation of monomers or from the degradation process of materials.

5.3.C.2 METHODOLOGY

Emissions were estimated by the use of emission factors that are multiplied by the quantity of material produced:

$$Emi_{NMVOC} = EF * Activity_{Rate} * 10^{-3}$$

where

Emi_{NMVOC} - annual emission of NMVOC (ton/yr);

$Activity_{Rate}$ - Indicator of activity in the production process. Quantity of product produced per year as a general rule for this emission source sector (ton/yr);

EF - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents and that they have fossil origin, therefore contributing fully to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

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

5.3.C.3 POLYMER PROCESSING

Processing of polymers to produce plastic materials involve organic compounds emission to atmosphere resulting from leakage of some monomers still present in the polymer mass, some polymer decomposing, evaporation of additives - such as phthalic anhydride - but mostly from solvents used in the production process.

Synthetic fiber production emits non-methane volatile organic compounds that result from solvent use, for example to dissolve the polymer prior to extrusion.

Emissions from foam blowing result from the application of hydrocarbons as blowing agents which are used as CFC substitutes.

ACTIVITY DATA

Information about activity data for this sector is scarce and limited to year 1990, from National Statistics Institute (INE). However, because some polymers and fibers are produced in a restricted number of industrial units, confidentiality constraints avoid their publication in NIR.

EMISSION FACTORS

Emission factors applied to polymer processing and fiber production were set from AP42 (US-EPA), and from CORINAIR/EMEP, and are presented in next table:

Table 5.13 – Emission factors of NMVOC from Polymer Processing

Material	Polymer	NMVOC
Synthetic Fibers	Rayon	0 ^(a)
	Polyamides	3.93 ^(a)
	Polyester	0.6 ^(a)
	Polyethylene	5 ^(a)
	Polypropylene	5 ^(a)
	Vynion	150 ^(a)
	Acrylics	40 ^(a)
Plastics	Polyester	40
	PVC	40
Foam Blowing	Poly-urethane	6.0 ^(b)
	Poly-Styrene	6.0 ^(c)

(a) USPEPA (1990) c06s09; (b) Rentz et al, 1993 in EMEP/CORINAIR 3r ed (File B633); (c) Achermann, 1992 in EMEP/CORINAIR 3r ed (File B633)

UNCERTAINTY ASSESSMENT

The uncertainty in activity data was considered high, 100 per cent, expressing the reduced number of available years. Although an uncertainty of 50 per cent could be considered for NMVOC/CO₂ emission factors, considering that quality rate is mostly C in original bibliographic references, the double of that value was assumed using a conservative approach and reflecting the difficulties in making a direct match between the conditions that emission factors apply and the conditions that prevail in national industry.

5.3.C.4 RUBBER PROCESSING

METHODOLOGY

Assuming that all solvents consumed during rubber processing evaporate, NMVOC emission will be equal to the amount of solvents used. This procedure could be used to estimate emissions for years 1990 and 1991. However, because statistical data on solvent consumption in this sector is not available beyond year 1992, NMVOC emissions had to be estimated from quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = \text{Solvent (y)} = \sum_p [S_{Fac(p)} * Proc_{RUBBER(p,y)}] * 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from rubber processing (ton/yr);

Solvent (y) – Total solvent use in rubber processing (ton/yr);

$S_{Fac(p)}$ – Quantity of solvent used to produce product p, either in kg/unit or kg/ton;

$Prod_{RUBBER(p,y)}$ – Production of rubber product p in year y. Units vary according to product either number/yr to ton/yr.

EMISSION FACTORS

The emission factor, or solvent use factor, that was used to estimate solvent consumption after 1992 was derived from the statistical information available from IAIT for this sector for years 1989 to 1991, which is reproduced in Table 5.14. From the several materials that were consumed in this activity only Benzene and Gasoline were considered solvents and prone to evaporation.

Table 5.14 – Statistical information used to establish solvent use factors in the rubber processing industry, in Portugal

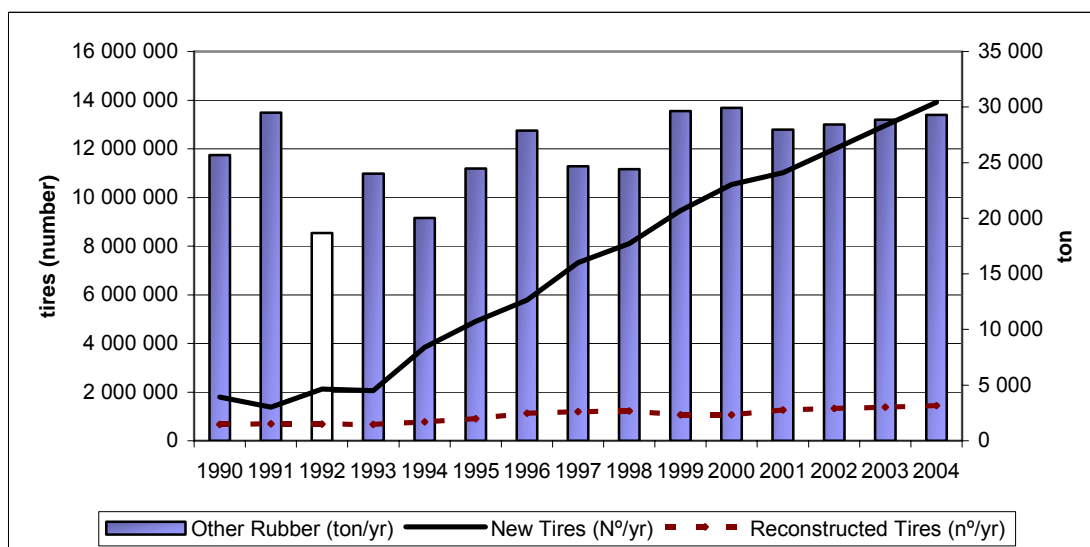
Product	Unit	1989	1990	1991	SFac
New Tires	n°	4 201 941	1 796 201	1 378 575	
Reconstructed Tires		969 972	663 772	689 342	
Other rubber products	ton	19 272	25 687	29 502	
New Tires	ton of solvent	615	312	155	
Reconstructed Tires		11 579	11 180	12 851	
Other rubber products		766	285	244	
New Tires	kg/Tire	0.146	0.174	0.112	0.143
Reconstructed Tires		12	17	19	18
Other rubber products	kg/ton	40	11	8	10

Source: Production and use of solvent from INE – IAIT industrial survey.

ACTIVITY DATA

Production data of rubber artefacts, including tires and tire reconstruction, was available from the IAIT and IAPI industrial surveys from INE. The aggregated values, collected from original INE's database, are reported in Figure 5.6.

Figure 5.6 - Processed rubber products in Portugal (1990-2003)



Source: INE (1990-2000); IA's forecasts thereafter

UNCERTAINTY ASSESSMENT

The uncertainty in activity data seems comparatively small and a value of was used. There is however a great uncertainty in the country-specific emission factors, particularly the high levels of consumption of solvent for each tyre reconstructed. Consequently an order of magnitude was attributed to uncertainty of emission factors.

RECALCULATIONS

No modifications were made in this source sector since last submission.

5.3.C.5 PAINTS MANUFACTURING

ACTIVITY DATA

Production of paints and varnish in Portugal was already presented in chapter 5.2 – Paint Application.

EMISSION FACTORS

The USEPA (1983) emission factor was used - 15 kg for each tone of paint or varnish manufactured, that includes emissions during cleaning of installations and applies to production of all coating materials. This emission factor was applied to the total value of paint and varnish produced in Portugal irrespective of type.

UNCERTAINTY ASSESSMENT

An uncertainty of 10 per cent was considered for the activity data, a higher accuracy for production when in comparison to consumption. In the original document the emission factors are reported to have a C rate quality, which translated in uncertainty value represents 50 per cent.

RECALCULATIONS

No modifications were made in this source sector since last submission.

5.3.C.6 INKS MANUFACTURING

ACTIVITY DATA

Statistical data of annual production of inks in Portugal is available from IAIT and IAPI industrial surveys (INE), for years 1990 through 2000. Linear forecast values were considered for subsequent years. Production of inks is presented in Table 5.15 and Table 5.16 by ink type.

Table 5.15 – Production of inks in Portugal, by type of ink (ton/yr) (1990-1996)

Ink	1990	1991	1992	1993	1994	1995	1996
Lithographic	1 122	1 064	135	45	69	60	448
Newspaper ink	318	185	0	0	0	0	0
Rotogravure	654	406	0	0	0	0	0
Flexography	880	999	119	119	907	1 084	2 025
Serigraphy	31	26	0	0	0	0	0
Drying by physical reaction	482	462	0	0	0	0	0
Other	40	51	99	47	50	22	109
Total	3 528	3 193	353	212	1 027	1 166	2 582

Source: INE (1990-2000); Forecast by IA (2001-2002)

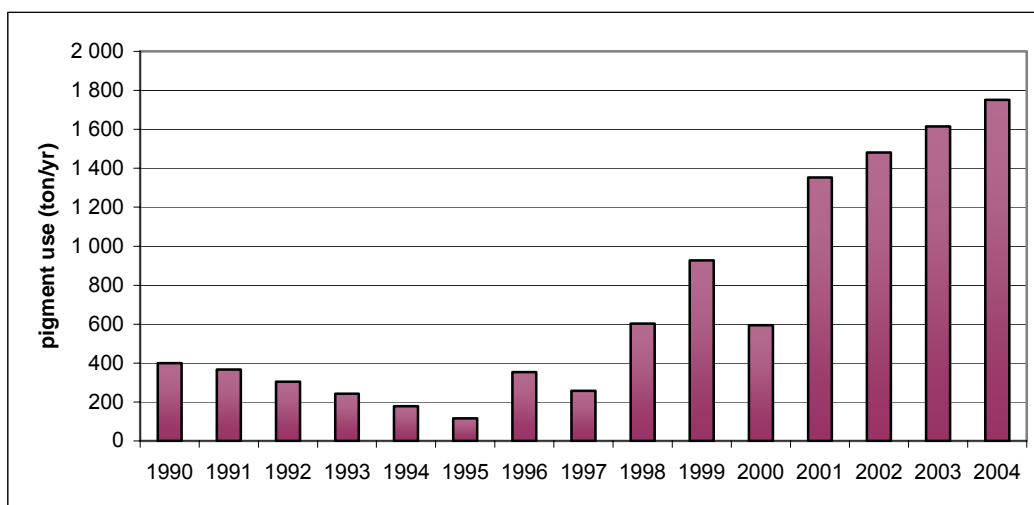
Table 5.16 – Production of inks in Portugal, by type of ink (ton/yr) (1997-2004)

Ink	1997	1998	1999	2000	2001	2002	2003	2004
Lithographic	272	266	213	175	175	175	175	175
Newspaper ink	0	0	0	0	0	0	0	0
Rotogravure	0	0	0	0	0	0	0	0
Flexography	928	039	663	008	640	857	073	289
Serigraphy	0	0	0	1	1	1	1	1
Drying by physical reaction	0	0	0	0	0	0	0	0
Other	17	11	0	82	82	82	82	82
Total	216	316	875	266	899	115	331	548

Source: INE (1990-2000); Forecast by IA (2001-2002)

Use of pigments in ink production was also available from INE's database. Total pigment consumption is presented in Figure 5.7.

Figure 5.7 – Total pigment consumed in ink manufacturing in Portugal from 1990 to 2004



Source: INE

EMISSION FACTORS

The NMVOC emission factor that was used, 60 kg for each tone of ink manufactured, refers to vehicle coking and applies to general ink type, is from USEPA (1983).

Particulate emissions during ink manufacturing were also estimated using an emission factor of 1 kg/ton pigment used (USEPA,1983).

UNCERTAINTY ASSESSMENT

An uncertainty of 10 per cent was considered for the activity data. In the original document the emission factors are reported to have a E rate quality, which translated in uncertainty value represents 1000 per cent.

RECALCULATIONS

No modifications were made in this source sector since last submission.

5.3.C.7 GLUES MANUFACTURING

ACTIVITY DATA

Production of glues and adhesives in Portugal is available in Portugal for years 1990 and 1991 from INE. Average values were considered for subsequent years. Production of glues and adhesives is reported in chapter 5.5.

EMISSION FACTORS

The CORINAIR emission factor was adopted - 20 kg for each tone of glues and adhesives manufactured, which is applied to all kind of glues and adhesives, with or without solvents in their composition, and includes the cleaning of industrial installations.

UNCERTAINTY ASSESSMENT

An uncertainty of 100 per cent was considered for the activity data, considering the lack of information, only available to some restricted years, to build a reliable time-series.

A high uncertainty in the emission factor lead, in similarity to what was done for inks manufacturing, to the choice of a uncertainty value of 1000 per cent.

RECALCULATIONS

No modifications were made in this source sector since last submission.

5.3.D Other use of solvents and related activities (CRF 3D)

5.3.D.1 OVERVIEW

In this chapter are included emission calculations for different activities, such as:

- 1) printing;
- 2) edible and non edible oil extraction;
- 3) use of glue and adhesives;
- 4) preservation of wood;
- 5) other solvents use;
- 6) use of perfume;
- 7) use of waxes and polishing products;
- 8) use of soaps and detergents.

5.3.D.2 PRINTING

OVERVIEW

Printing involves the application of an ink to several materials by presses, the most common of which is paper, but also cardboard, wood, plastics and metallic artifacts are subjected to this process. Emissions are very dependent of the printing technology because it (i.e., the type of press equipment) dictates the types of inks and coatings – and its solvent content - that can be used and defines, to a large extent, the emissions and the control techniques that are applicable (USEPA,1985). The following technologies are available:

- Lithography: the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellent to ink, by action of a dampener. In offset lithography the image is applied to a rubber-covered blanket cylinder and then transferred onto the substrate. This technique dominates the production of books and pamphlets and has been used increasing in newspapers;
- rotogravure: uses cylindrical image carrier, where the printing area is below the non printing area. The low relive is filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder. Used mostly in packaging, advertising, greeting cards, art books, catalogues, and directories;

- flexography: the image carrier, made of rubber or elastic photopolymers on which the printing areas are above the non printing areas. Used mostly in packaging, advertising newspapers, books, magazines, financial and legal document and directories;
- letterpress: similar to flexography, it uses a relief printing plate, but these plates differ from flexographic plates in that they have a rigid backing and are not "flexible." Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to non-heatset web offset;
- screen: the ink is passed onto the surface to be printed by forcing it through a porous image carrier (stencil), in which the printing area is open and the non-printing area is sealed off. It is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles;
- plateless: Images printed on paper by laser printers, photo copiers, fax machines, and ink jets

NMVOC emissions from printing result from the evaporation of solvents that are components of the ink or that are added (dilution) just prior to printing activities. Emissions may also result from the use of cleaning products and dampeners. Emissions may occur during drying at air or at ovens (heat set).

METHODOLOGY

$$Emi_{NMVOC(a,p,y)} = \sum_p \sum_t \sum_i [EF_{(i)} * INK_{CONS(p,i,t,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from printing activities during year y (ton/yr);

$INK_{CONS(p,i,t,y)}$ – Use of ink i for printing product p using technology t during year y (ton coater/yr);

$EF_{(p)}$ – Emission Factor (solvent content) of ink i (kg/ton).

Ultimate CO₂ emissions are calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory.

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

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

EMISSION FACTORS

NMVOC emission factors reflect solvent content of ink, assuming that all solvents contribute to volatile organic compounds, and that control equipment for emissions are not widespread and representative. Solvent content of ink are from USEPA (1981) and are presented in Table 5.17⁸⁹.

Table 5.17 – Solvent content and emission factors used in Printing Industry (kg/ton ink consumed)

Product	Technology	Solvent Content ok ink (%)	density of solvent (kg/l)	EF kg/ton ink
Newspaper	Web Offset Lithography	5	0.74	37
	Letterpress	0		0
Books	Web Offset Lithography	40		297
Publications	Rotogravure	75		557
Packaging	Flexography	75		557
Artifacts	Flexography	75		557
Other		-		334

Source: USEPA (1981)

ACTIVITY DATA

Consumption of inks in printing industry according to printing product is available from IAPI industrial survey, for years 1995 to 2000, from the INE's statistical database, which is summarized in Table 5.18.

Table 5.18 – Consumption of inks in industry by press product (ton/yr)

Industry	Product	1995	1996	1997	1998	1999	2000
Press	Newspaper	908	662	566	514	568	567
	Books	105	139	171	256	191	146
	Magazines & Other	19	24	16	57	109	146
	Packaging	1 062	1 228	1 280	1 234	1 350	1 646
	Other	2 513	3 113	3 312	3 548	3 822	4 003
Textile industry		0	0	0	0	0	58
Other	Artefacts	766	1 522	1 685	1 877	1 965	2 330

Source: IAPI, INE

Original data allows that total consumption of inks – but not its type – be divided by printing products. Data printing activities in other economic activities – metallic industry, plastic industry, ceramic and - is also included. Some assumptions were made concerning what technology was used for each press product, i.e.:

- newspapers are printed using web letterpress or web offset lithography, according to national sales of ink;
- books printing uses lithography;

⁸⁹ USEPA (1981) differentiates emissions during printing from those remaining in product. In the Portuguese inventory all solvents are assumed to emit NMVOC

- Magazines and other publications use rotogravure;
- Packages and metallic, plastic and other artefacts use flexography;
- serigraphy technology is used in textile processes.

For years in the period from 1990 to 1994, consumption of inks had to be estimated from national production and external trade, which is presented in Table 5.19, and according to:

$$\text{Total}_{\text{Cons}(y)} = \text{Production}_{(y)} + \text{Imports}_{(y)} - \text{Exports}_{(y)}$$

where:

$\text{Total}_{\text{Cons}(y)}$ - Total consumption of inks in year y (ton/yr);

$\text{Production}_{(y,p)}$ - National Produced inks in year y (ton/yr);

$\text{Imports}_{(y,p)}$ - Imported inks in year y (ton/yr);

$\text{Exports}_{(y,p)}$ - Exported quantity of inks in year y (ton/yr).

Because external trade classifies inks in a single class, the more detailed desegregation of inks, available for production of inks (Chapter 5.2.3), could not be used, and only total ink consumption could be assessed. The same proportion of technologies/products in 1995 was used to separate total inks consumption for the years between 1990 and 1994.

Table 5.19 - Production and External Trade of inks in 1990-1994 (ton)

Year	1990	1991	1992	1993	1994
National Production	3 528	3 193	353	212	1 027
Importation	1 481	1 745	2 705	2 720	3 051
Exportation	65	71	58	34	35
Consumption	4 944	4 868	3 000	2 898	4 044

Source: INE

Final consumption of inks per technology type is synthesized in Table 5.20 and Table 5.21. Values for 2001 and 2002 are forecasts made by IA from the previous time series.

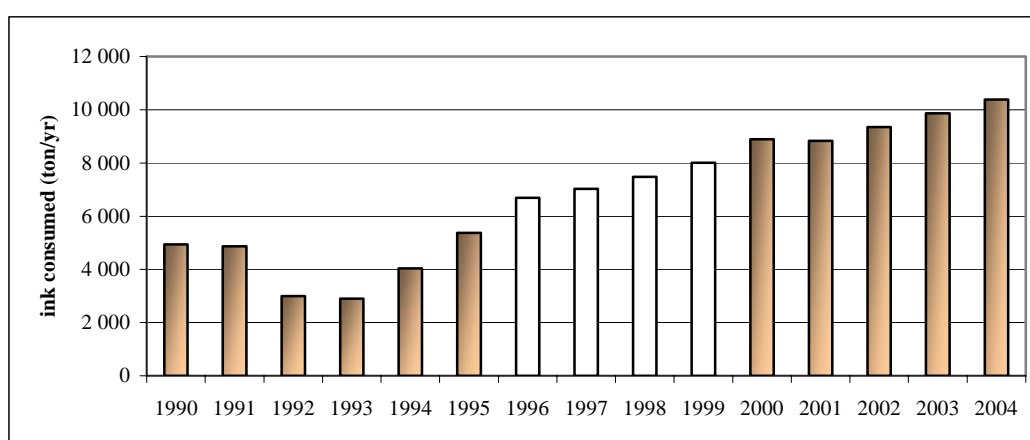
Table 5.20 – Consumption of inks by printing technology and press product (1990-1996)

Technology	Product	1990	1991	1992	1993	1994	1995	1996
Web Offset Lithography	Newspaper	701	691	426	411	574	762	548
Letterpress		3	3	2	2	3	4	5
Web Offset Lithography	Books	100	98	60	58	81	108	141
Rotogravure	Publications	18	18	11	11	15	20	24
Flexography	Packages	1 008	993	612	591	825	1 095	1 250
Flexography	Artifacts	727	716	441	426	595	790	1 550
Serigraphy	Fabric	0	0	0	0	0	0	0
Total		2 386	2 350	1 448	1 399	1 952	2 593	3 170

Table 5.21 – Consumption of inks by printing technology and press product (1997-2004)

Technology	Product	1997	1998	1999	2000	2001	2002	2003	2004
Web Offset Lithography	Newspaper	467	422	466	465	430	412	394	376
Letterpress		3	11	21	27	20	22	24	26
Web Offset Lithography	Books	174	259	193	147	211	225	239	252
Rotogravure	Publications	16	58	110	147	105	115	126	137
Flexography	Packages	1 299	1 249	1 364	1 661	1 550	1 627	1 704	1 782
Flexography	Artifacts	1 710	1 899	1 986	2 351	2 350	2 541	2 733	2 925
Serigraphy	Fabric	0	0	0	59	21	24	27	29
Total		3 361	3 589	3 864	4 039	4 153	4 388	4 623	4 858

Figure 5.8 – Total inks consumption in Portugal (1990-2003)



UNCERTAINTY ASSESSMENT

It was considered that the activity data time trend have a medium quality due to the use of different sources of information for its determination. An overall uncertainty of 25 per cent was considered. Concerning the emission factor for CO₂, or NMVOC, the original emission factors had quality rates that varied from B to C and, therefore, the worst case uncertainty of 50 per cent was considered, in conservative way.

RECALCULATIONS

No modifications were made to estimates of this source sector.

FURTHER IMPROVEMENTS

Although this source sector has suffered extensive modifications, efforts must continue in order to ameliorate emission estimates for this sub-source category. Key aspects are the improvement in consistency in the activity data time series and a better knowledge of printing processes that are used for each press product.

5.3.D.3 EDIBLE AND NON EDIBLE OIL EXTRACTION

OVERVIEW

This sub-source comprehends emissions of NMVOC from extraction of edible and non-edible oils from seeds.

Extraction of oil in Portugal may be made using mechanical processes or solvent based processes. Mechanical processes, using presses, are used to extract first olive oil from olives⁹⁰. Extraction by solvents, usually using hexane and heat, is presently done in extraction from most oil seeds or secondary extraction of olive oil. Solvent recovery, where the oil is separated from the oil-enriched wash solvent and from the steamed out solvent, is an integral part of the production processes although leakages occur continuously leading to the need of solvent stock replenishment. Losses are either made directly to atmosphere through vents or leaks or indirectly through water and residues.

Particulate matter is emitted as result of grain handling, cracking, dehulling and drying processes.

METHODOLOGY

Emissions of NMVOC were estimated considering that the annual hexane consumption by the industrial plant, hexane make-up, is due to losses to the air, and hence:

$$Emi_{NMVOC}(y) = MakeUp_{Solvents}(y)$$

where:

$Emi_{NMVOC}(y)$ - Emissions of NMVOC (ton/yr);

$MakeUp_{Solvents}(y)$ - annual consumption of solvent in edible and non-edible oil industry, to replenish losses (ton/yr).

Ultimate CO₂ emissions are calculated assuming that 85.71 percent of the mass emissions of NMVOC is carbon⁹¹ and is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO₂ emissions are included in the inventory.

$$U_{CO_2} = 44/12 * NMVOC * 0.8571$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

Particulate matter emissions are estimated from consumption of grain:

$$Emi_{PM}(y) = EF * Cons_{GRAIN}(y) * 10^{-3}$$

where:

$Emi_{PM}(y)$ - Emissions of PM (ton/yr);

⁹⁰ Classified as virgin olive oil

⁹¹ Hexane chemical formula

$Cons_{GRAIN(y)}$ - annual consumption of grain in the production of edible and non-edible oil industry (ton/yr);

EF – Emission factor (g/ton).

EMISSION FACTORS

The national emission factor for NMVOC was calculated as the ratio of the amount of solvents consumed during manufacture processes to the quantities of edible and non edible oil manufactured. However, from the available data from INE, this emission factor could be only estimated from IAIT industrial survey, i.e. from 1989 to 1991, because solvent consumption is not available from IAPI survey. Statistical information used in actual calculations of annual emission factor are presented in Table 5.22, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole 1990-2004 time period. Because in IAPI survey (1992-2000) it was not possible to distinguish production of edible oils from production of non-edible oils, it was decided just to use a global emission factor.

Table 5.22 – Calculation of the National emission factor for edible and non-edible oils extraction (kg/ton).

Oil Type	Parameter	1989	1990	1991	Average
Edible non-edible sum	Oil refined (ton)	93 401	90 686	107 163	
		113 749	110 883	113 509	
		207 150	201 569	220 672	
Edible non-edible sum	Solvent Use (ton)	2 328	1 763	1 697	
		1 394	1 257	1 408	
		3 722	3 020	3 106	
Edible non-edible sum	Emission Factor NMVOC (kg/ton)	24.9	19.4	15.8	20.1
		12.3	11.3	12.4	12.0
		18.0	15.0	14.1	15.7

The emission factor for Particulate Material, 1.34 g/kg grain handled is from (USEPA,1995).

ACTIVITY DATA

Oil production data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2000. Production data for 2001-2004 was forecasted at IA from previous years. All annual values are reported in Table 5.23, together with olive oil production, although that product does not cause NMVOC emissions. Total grain processed is also reported in Table 5.23 and Table 5.24. Total extraction of edible and non-edible oil is also shown in Figure 5.9.

Table 5.23 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1990-1996)

Parameter	1990	1991	1992	1993	1994	1995	1996
Olive Oil Production	10 253	9 883	8 368	16 948	25 269	27 691	36 404
Oil refining	201 569	220 672	184 406	161 998	222 430	223 330	208 116
Grain processed	672 382	668 734	662 759	691 625	791 687	1 042 605	969 983

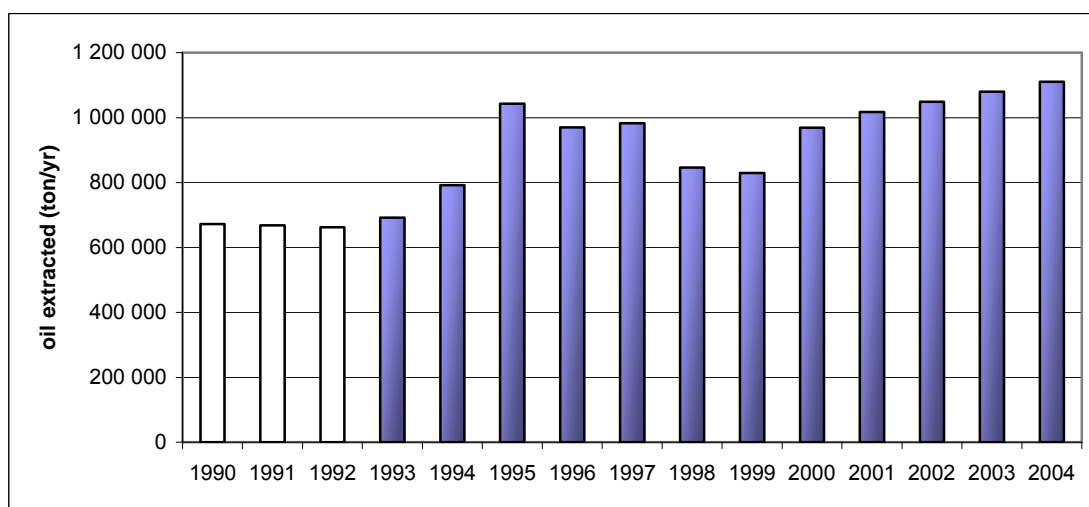
Source: National Statistics Institute (INE)

Table 5.24 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1997-2004)

Parameter	1997	1998	1999	2000	2001	2002	2003	2004
Olive Oil Production	31 839	41 190	46 673	41 912	38 796	NA	NA	NA
Oil refining	174 686	168 580	122 263	136 230	142 748	135 869	128 989	122 110
Grain processed	982 574	846 161	829 526	968 898	1 017 147	1 048 385	1 079 623	1 110 861

Source: National Statistics Institute (INE)

Figure 5.9 – Total edible and non-edible oil extraction in Portugal (ton/yr)



UNCERTAINTY ANALYSIS

The activity data time trend is reasonably complete and an uncertainty of 10 per cent was considered. The uncertainty of NMVOC/CO₂ emission factor was established by comparison of the emission factors determined from the several available years: 26 per cent.

RECALCULATIONS

No modifications were made to estimates of emissions from this source since last submission.

5.3.D.4 GLUES AND ADHESIVES

METHODOLOGY

$$\text{NMVOC} = \text{Cons}_{\text{Nat}} \times \text{FE}_{\text{Nat}} + \text{Imp} \times \text{FE}_{\text{imp}}$$

where:

NMVOC = Global emissions of NMVOC (ton)

Cons_{Nat} = Consumption of Glues and Adhesives produced in Portugal (ton)

FE_{Nat} = Emission factor for Glues and Adhesives produced in Portugal (kg NMVOC/ton Ink)

Imp = Importation of Glues and Adhesives (ton)

FE_{imp} = Emission factor associated to the use of imported Glues and Adhesives.

$$Cons_{Nat} = Prod_{Nat} - Exp$$

where:

$Cons_{Nat}$ = Consumed Glues and Adhesives produced in Portugal (ton)

$Prod_{Nat}$ = National Produced Glues and Adhesives (ton)

Exp = Exported Glues and Adhesives (ton)

EMISSION FACTORS

To estimate the emission factor applied for the use of national glues and adhesives, the ratio of the amount of solvents consumed (Table 5.25 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5.26). The emission factor for VOC emission from the manufacture of glue and adhesives was subtracted from this value to obtain the emission factors for use of national produced glue and adhesives.

Table 5.25 - Solvents consumption in glue and adhesives manufacture (ton).

	1989	1990	1991
Methyl ketone	361	328	328
Dibutyl phthalate	97	134	143
Ethyl Acetate	373	351	355
Hexane	1 567	1 357	1 277
Benzene	295	354	335
Toluene	1 839	1 690	1 799
Other solvents	1 876	2 010	2 003
Total	6 408	6 224	6 240

Table 5.26 - National emission factors (kg/ton).

	1989	1990	1991	Average
For production and use of glue and adhesives	190	172	175	179
Only for use of glue and adhesives	170	152	155	159

For non-natural imported glues and adhesives the CORINAIR90 Default Emission Factor was used: 600 kg/ton. It is considered that natural based glue does not contribute to NMVOC emission.

ACTIVITY DATA

Table 5.27 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	1992 - 2004
National Production (ton)	36 297	35 769	35 473
Importation (ton)	2 192	2 328	2 260
Exportation (ton)	707	532	620

Source: National Statistics Institute (INE)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

5.3.D.5 WOOD PRESERVATION

OVERVIEW

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts and building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

METHODOLOGY

$$Emi_{NMVOC(y)} = Consumption(y) * FE_{Consumption}$$

where:

$Emi_{NMVOC(y)}$ - Emissions of NMVOC associated to consumption of wood preservation products (ton)

$Consumption(y)$ - Consumption of wood preservation products (ton)

$FE_{Consumption}$ - Emission factor associated to the consumption of wood preservation products.

EMISSION FACTORS

CORINAIR90 Emission Factor Handbook proposes three emission factors for VOC emission from wood preservation, depending on the type of product used. The emission factor is 100

kg/ton of product applied for creosote; 900 kg/ton for solvent based products and 0 for water based products. The available data do not discriminate the share of the several types of preservation products, therefore, it was assumed that the main product used in Portugal is creosote.

ACTIVITY DATA

Table 5.28 - Wood preservation products consumption (ton)

Year	1990	1991	1992 - 2004
Wood Preservation products Consumption (ton)	2083	2900	2491

Source: National Statistics Institute (INE)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

5.3.D.6 PERFUMES AND COSMETICS USE

METHODOLOGY

Perfumes, personal hygiene and cosmetic products. Lipsticks, brilliantine, beauty creams and milks, depilatories, deodorants, hair sprays, sun lotions, tanner products, shampoos, tooth-cleaning, hair coloration and nail varnishes, among others, were considered in perfume, personal hygiene or cosmetic product. Emissions are estimated from:

$$\text{NMVOC} = \text{Use} * \text{FE}_{\text{Prod+use}}$$

where:

NMVOC - Emissions of NMVOC associated to the production and use of perfumes (ton)

Use - Use of perfumes (ton);

$\text{FE}_{\text{Prod+use}}$ - Emission factor associated to the production and use of perfumes (ton)

EMISSION FACTORS

Since there are no available VOC emission factor for this activity an emission factor for VOC emission during the production and the use of these products was calculated. It was estimated by the ratio of the amount of solvents consumed during the manufacture process with the amount of perfumes, personal hygiene and cosmetic products manufactured.

$$\text{FE}_{\text{Prod+use}} = \text{Solvents} / \text{National Production}$$

where:

$FE_{\text{Prod+use}}$ = Emissions of NMVOC associated to consumption of perfume and cosmetics use (ton)

Solvents = Solvent content of perfumes (ton)

National Production = National production values of perfumes (ton)

Table 5.29 - Calculated emission factor (kg/ton).

1989	1990	1991	Average
162	170	184	172

ACTIVITY DATA

Table 5.30 - Activity data associated to Perfumes Use (ton)

Year	1990	1991	1992-2004
National Production (ton)	21 587	19 540	20 957
Imports (ton)	10 830	15 210	13 020
Exports (ton)	3 829	4 201	4 015
Solvents (ton)	3 665	3 590	3 595

Source: National Statistics Institute (INE)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

5.3.D.7 WAXES AND POLISHING PRODUCTS

METHODOLOGY

The Methodology is similar to the one that was used for Perfume Use.

EMISSION FACTORS

The national emission factor, obtained in the same mode, was (kg/ton):

Table 5.31 – Emission factors

1989	1990	1991	Average
525	299	293	372

ACTIVITY DATA

Table 5.32- Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2004
National Production (ton)	3 963	3 781	3 312
Imports (ton)	12 390	12 429	12 410
Exports (ton)	983	403	693
Solvents (ton)	1 185	1 106	1 147

Source: National Statistics Institute (INE)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

5.3.D.8 SOAPS AND DETERGENTS**METHODOLOGY**

The Methodology is similar to the one that was used for Perfume Use.

EMISSION FACTORS

The national emission factor (kg/ton), obtained in the same mode kg/ton is:

Table 5.33 – Emission factors

1990	1991	Average
2	2	2

ACTIVITY DATA

Table 5.34 - Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2004
National Production (ton)	209 575	185 681	197 628
Imports (ton)	57 488	59 831	58 660
Exports (ton)	34 710	23 972	29 341
Solvents (ton)	461	426	437

Source: National Statistics Institute (INE)

UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

RECALCULATIONS

No recalculations were made for this source sector.

5.3.D.9 USES OF SOLVENTS FROM BIOMASS

There are two organic substances used as solvents: ethanol and rosin derivatives that may be emitted to atmosphere when used. Emissions may be estimated from consumption of these substances. However, in some activities, such as beverage and food industry, use of alcohol does not contribute to air emissions because it is ingested, and it is not included in emissions.

METHODOLOGY

Emissions are therefore estimated from:

$$\text{NMVOC} = \text{TotalConsumption} - \text{Cons}_{\text{NONEMI}}$$

Where

NMVOC – Emission (ton/yr);

TotalConsumption – Total consumption of biological solvent in all activities (ton/yr);

Cons_{NONEMI} – Consumption of biological solvents in activities where solvents are not emitted to atmosphere (ton/yr).

For rosin derivatives total consumption is obtained from industrial production corrected from imports and exports:

$$\text{TotalConsumption} = \text{IndustrialProduction} + \text{Imports} - \text{Exports}$$

Because these two compounds have a biological origin NMVOC emissions are not added to ultimate carbon dioxide emissions accounting.

ACTIVITY DATA

Industrial production of ethanol is presented in Table 5.35, which may be considered, neglecting foreign trades, equal to the consumption of alcohol. Industrial consumption of alcohol in 1989 is shown in Table 5.36 by use. Statistical data is from INE in both cases.

Table 5.35 - Industrial production of ethanol (ton).

1989	1990	1991
7 754	9 941	8 027

Table 5.36 - Industrial consumption of alcohol in 1989 (ton).

Use	ton
Food and beverage industry	2 185
Manufacture of perfumes, personal hygiene and cosmetic products	1 913
Manufacture of waxes and polishing products	235
Total	4 333

Rosin derivatives include turpentine oil, α -pinene, etc. The annual production of rosin derivatives is presented in Table 5.37 and foreign trades values in Table 5.38. Statistical information is from the National Statistical Institute (INE).

Table 5.37- Rosin derivatives production (ton).

1989	1990	1991
13 362	12 145	11 299

Table 5.38 - Foreign trades of rosin derivatives (ton).

<i>Imports (ton)</i>		<i>Exports (ton)</i>	
1990	1991	1990	1991
722	700	11 558	13 692

5.3.D.10 OTHER USES OF SYNTHETIC SOLVENTS FROM FOSSIL FUELS

METHODOLOGY

$$\text{NMVOC} = \text{Produced Solvents}$$

where:

NMVOC = Emissions of NMVOC (ton)

Consumed Solvents = quantity of produced solvents(ton)

The calculation of Global CO₂ emissions is made according to:

$$U_{\text{CO}_2} = 44/12 * \text{NMVOC} * 0.85$$

where:

U_{CO_2} - Ultimate CO₂ (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

ACTIVITY DATA

Table 5.39 - Synthetic solvents consumption in other industries (ton)

Year	1990	1991	1992 - 2004
Solvents (ton)	3 885	4 014	3 950

Source: General Directorate of Energy (DGGE)

UNCERTAINTY ASSESSMENT

Activity data is very scarce and doubtful and the overall uncertainty was assumed to be 1000 per cent.

RECALCULATIONS

No recalculations were made for this source sector.

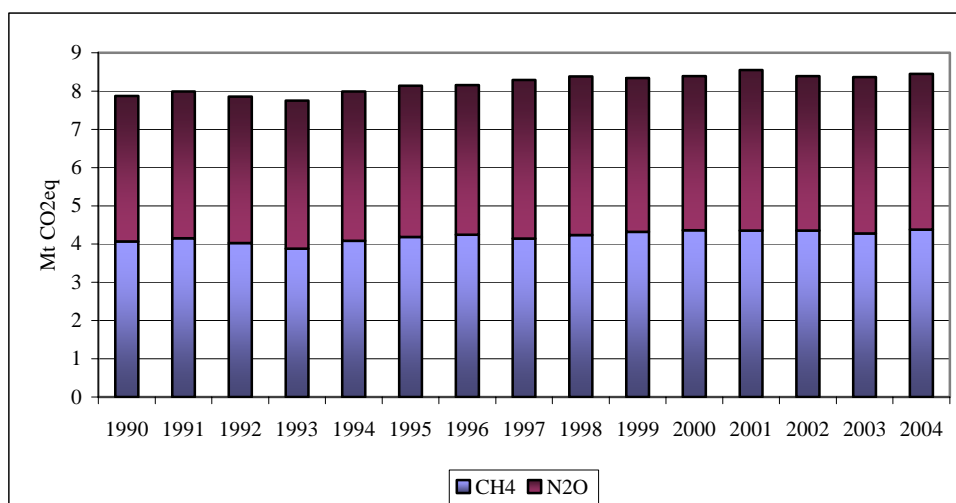
CHAPTER: 6 : AGRICULTURE (CRF 4)

6.1 Overview

Agriculture activities generate emissions of GHG from a variety of different sources. This section includes the quantification of: CH₄ emissions from enteric fermentation; CH₄ and N₂O emissions from manure management; direct and indirect N₂O emissions from agriculture soils; CH₄ from rice cultivation and CH₄ and N₂O emissions from field burning of agriculture residues. Also dealt here are the NH₃ emissions from agriculture, which are used as an intermediate step in the quantification of N₂O indirect emissions from soil, and all other non-greenhouse gas emissions from field burning of agriculture residues. There are no ecosystems in Portugal that could be considered natural savannas and no greenhouse gas emissions exist therefore for this sub-category. GHG emissions from combustion processes in agriculture are discussed in sector Energy: Other Sectors (CRF 1A4). Estimates of CO₂ release and uptake resulting from conversion of agriculture land and grazing land to other uses, conversion of other uses to agriculture land and grazing land, conversion of agriculture land to grazing land and vice versa, and substantial changes in agriculture practices, such as conversion of annual crops to perennial crops and the opposite, are estimated in the inventory but included in chapter Land Use, Land Use Change and Forestry (LULUCF).

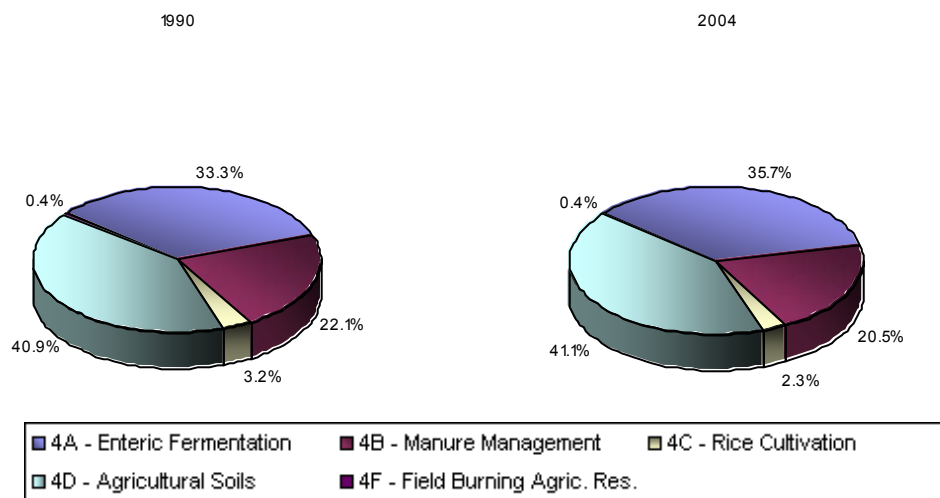
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 13.1 per cent in 1990 to 9.8 per cent in 2004. Nevertheless this uncovers the existence of an absolute increase in emissions such that emissions from agriculture in 2004 are 4.6 per cent higher than emissions from agriculture in 1990: 7.9 Mton of CO₂eq in 1990 and 8.2 Mton CO₂eq in 2004 (Figure 6.1). Total GHG emissions show an approximately equal share of methane and nitrous oxide emissions: in 2004 methane emissions were about 52 per cent of total GHG emissions from agriculture.

Figure 6.1 – Total Greenhouse Gas Emissions from Agriculture. Trends by GHG



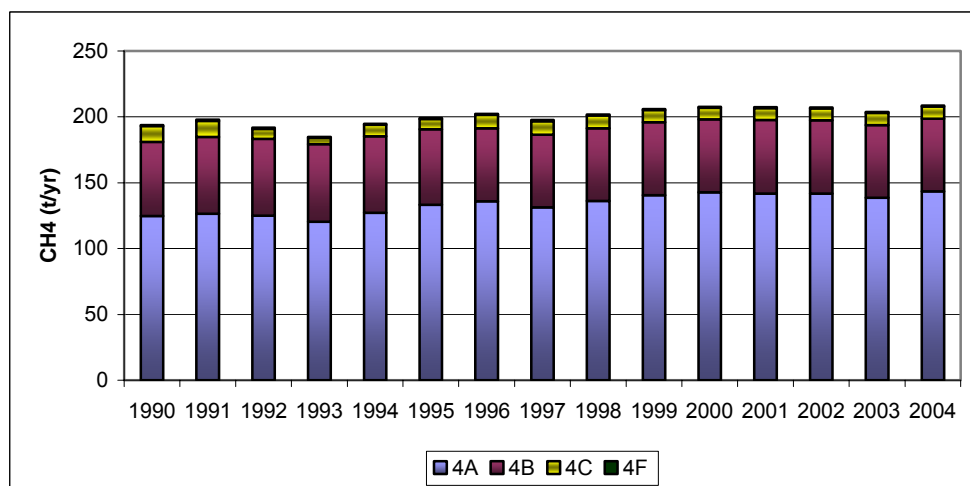
The major part of emissions from agriculture result only from 3 sub-source sectors. Agriculture Soils emissions dominate, followed from methane emissions from Enteric Fermentation and total emissions from Manure Management (Figure 6.2).

Figure 6.2 - Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2004



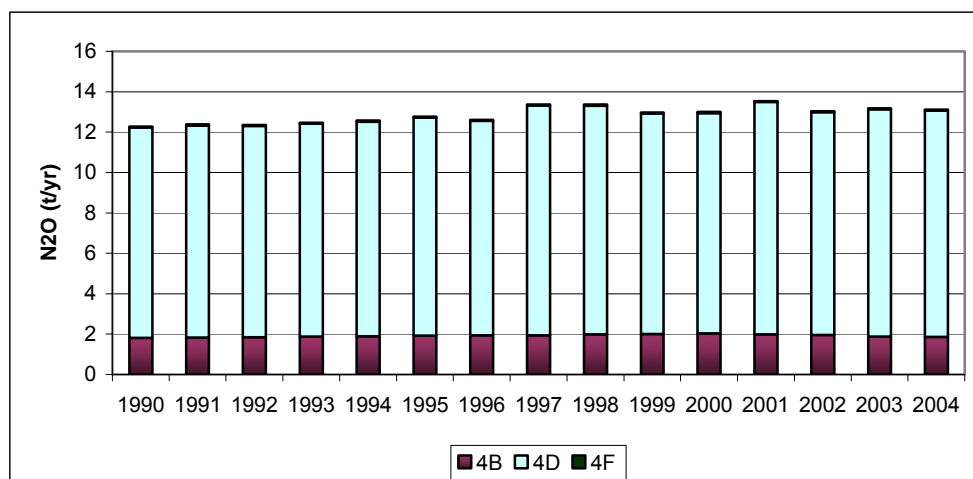
Emissions of CH₄ from agriculture have increased 7.6 per cent from 1990 to 2004 (Figure 6.3). Enteric Fermentation represents, on average in the 1990-2004 period, 66.9 per cent of the sectoral emissions and Manure Management accounts on average for 28.1 per cent of the sectoral emissions in the same period. The remaining 5.0 per cent of emissions result mostly from rice cultivation, with only a very small contribution from field burning of residues, which represents only 0.4 per cent of total emissions in the same average period.

Figure 6.3 - Methane emissions from agriculture



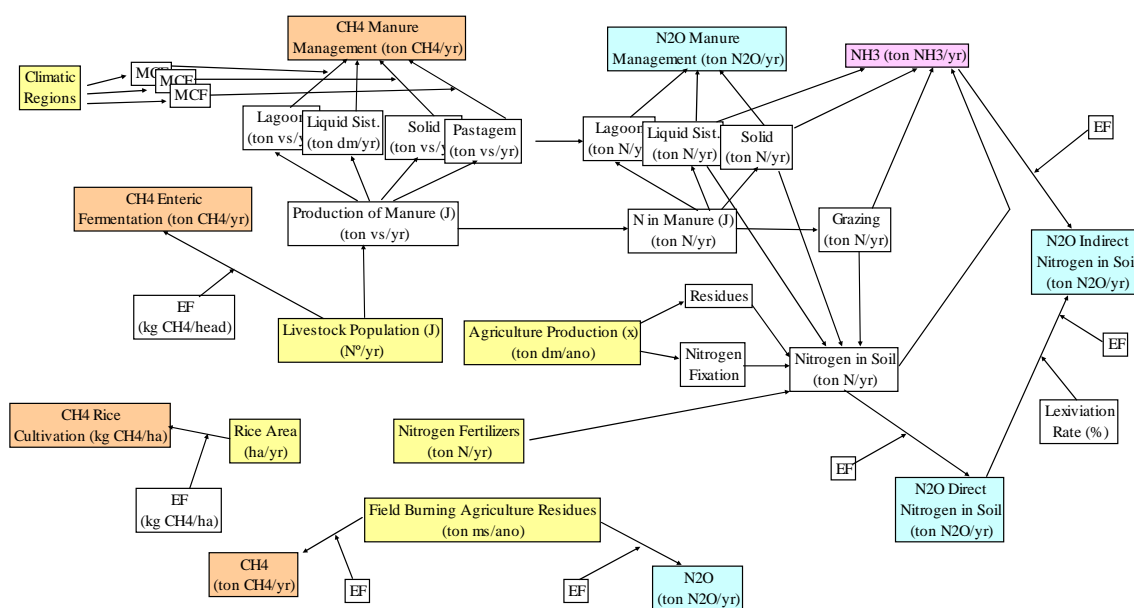
N₂O emissions were also affected by a similar augmentation, 6.8 per cent during the 1990-2004 period (Figure 6.4). The great majority of emissions are associated with direct and indirect emissions from agricultural soils (84.7 per cent), manure management is responsible for 14.9 per cent of emissions, while the small remaining fraction results from field burning of agricultural residues (0.4 per cent).

Figure 6.4 - Nitrous Oxide emissions from Agriculture



Emissions are estimated following as far as possible the methodology recommended by IPCC (1996 Revised IPCC Guidelines and Good Practice Guidebook) and are done in a consistent way: the same activity data is used and balanced for all source categories. A general overview of methodology is presented in Figure 6.5.

Figure 6.5 - Overview of Methodology



It must be emphasized that changes from submission 2005 to submission 2006 were done also in a consistent and coherent way among the several source sectors. Improvements in methodology in each source sector were reflected in changes in other related sources.

6.2 Recalculations

Total GHG emissions have suffered expressive changes since last submission, and efforts have been made, as much as possible, to follow the recommendations of the in-country review and the efforts that are being done under the Methodology Development Plan of the national inventory. Major modification resulted from the revision of the activity data for the use of synthetic fertilizers, the excretion of nitrogen in manure from livestock, the use of a new

methodology to estimate CH₄ emissions from Enteric Fermentation and the revision of the livestock numbers for certain animal sub-types. Because of the high level of connectiveness that is characteristic of this sector, indirect effects, such as change in nitrogen added to soil as manure and indirect emissions of N₂O, caused substantial changes in the emission estimates for each specific sub-category. More detailed explanation of recalculations will be presented during explanation of each sub-source category.

Figure 6.6 - Differences between submission 2005 and submission 2006 for CH₄ and N₂O emissions from agriculture

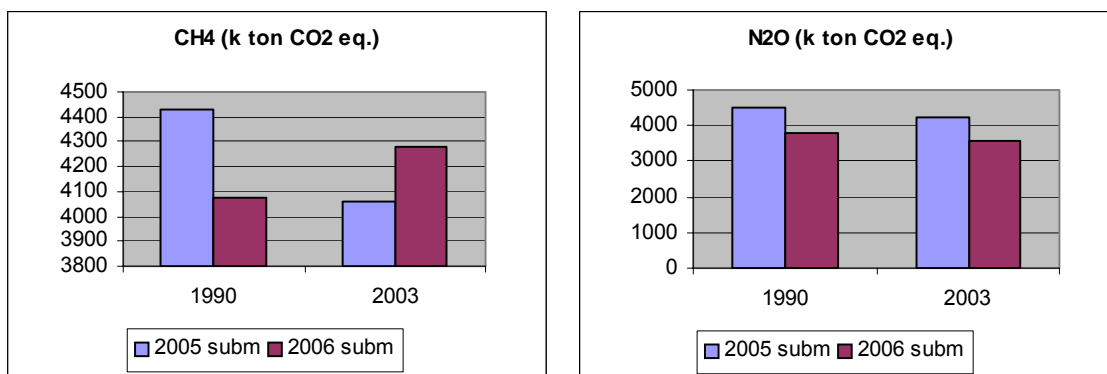


Figure 6.7 - Differences between submission 2005 and submission 2006 for CO₂ equivalent emissions from agriculture

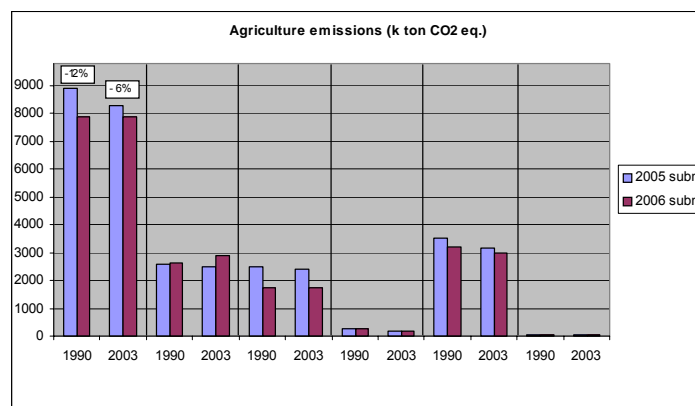


Table 6.1 – Recalculations. Differences between submission 2004 and submission 2005 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES				CO2			CH4			N2O		
				2005 subm.	2006 subm.	Difference (1)	2005 subm.	2006 subm.	Difference (1)	2005 subm.	2006 subm.	Difference (1)
				CO2 eq (Gg)		(%)	CO2 eq (Gg)		(%)	CO2 eq (Gg)		(%)
1990												
4. Agriculture							4 425.76	4 071.72	-8.00	4 494.41	3 806.54	-15.30
4.A.	Enteric Fermentation						2 594.08	2 621.88	1.07			
4.B.	Manure Management						1 558.21	1 176.37	-24.51	942.95	563.37	-40.25
4.C.	Rice Cultivation						255.71	255.71	0.00			
4.D.	Agricultural Soils						0.00	0.00		3 514.53	3 225.51	-8.22
4.E.	Prescribed Burning of Savannas						0.00	0.00		0.00	NO	
4.F.	Field Burning of Agricultural Residues						17.76	17.76	0.00	36.93	17.66	-52.17
4.G.	Other						0.00	0.00		0.00	NO	
2003												
4. Agriculture							4 057.81	4 277.23	5.41	4 236.77	3 588.30	-15.31
4.A.	Enteric Fermentation						2 493.46	2 912.06	16.79			
4.B.	Manure Management						1 388.13	1 154.92	-16.80	1 032.07	583.08	-43.50
4.C.	Rice Cultivation						159.32	193.97	21.75			
4.D.	Agricultural Soils ⁽²⁾						0.00	NE/NO		3 169.51	2 989.01	
4.E.	Prescribed Burning of Savannas						0.00	NO		0.00	NO	
4.F.	Field Burning of Agricultural Residues						16.90	16.28	-3.64	35.18	16.21	-53.92
4.G.	Other						0.00	NO		0.00	NO	

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission).

From the above information, it is noticeable that the more important change that resulted from the alterations made was the shift in trend. Considering this information in more detail for the whole time series, it can be seen that, whereas before the overall trend showed a decrease in emissions, from 1990 to 2003, now the trend shows a slight but constant increase from 1990 to 2004. The trend in total greenhouse gas emissions and individually for methane and nitrous oxide is shown in Figure 6.8, Figure 6.9 and Figure 6.10.

Figure 6.8 - Differences in trend of total GHG emissions from agriculture between submission 2005 and submission 2006

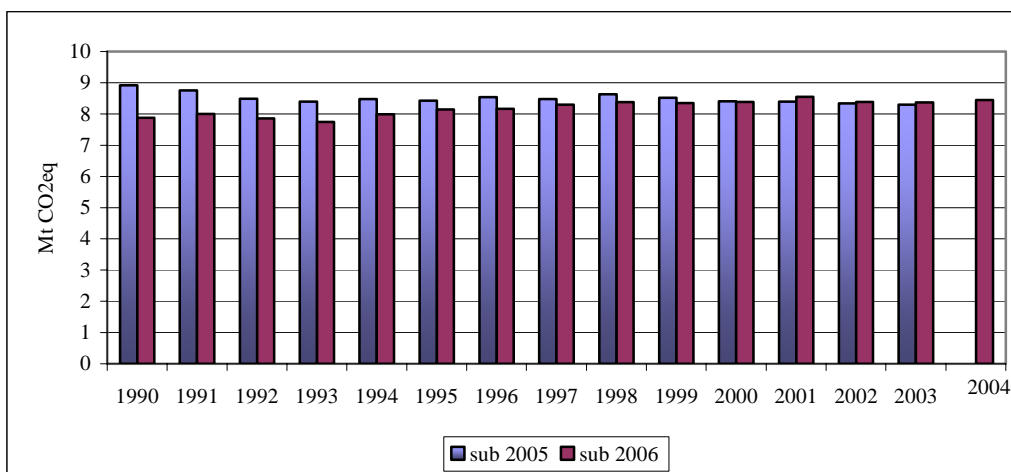


Figure 6.9 - Differences in trend of the estimated total CH₄ emissions from agriculture between submission 2005 and submission 2006

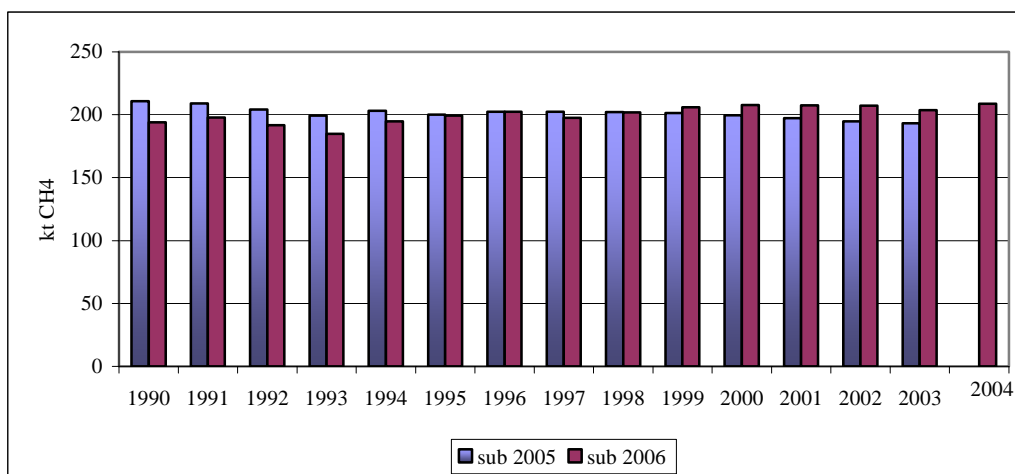
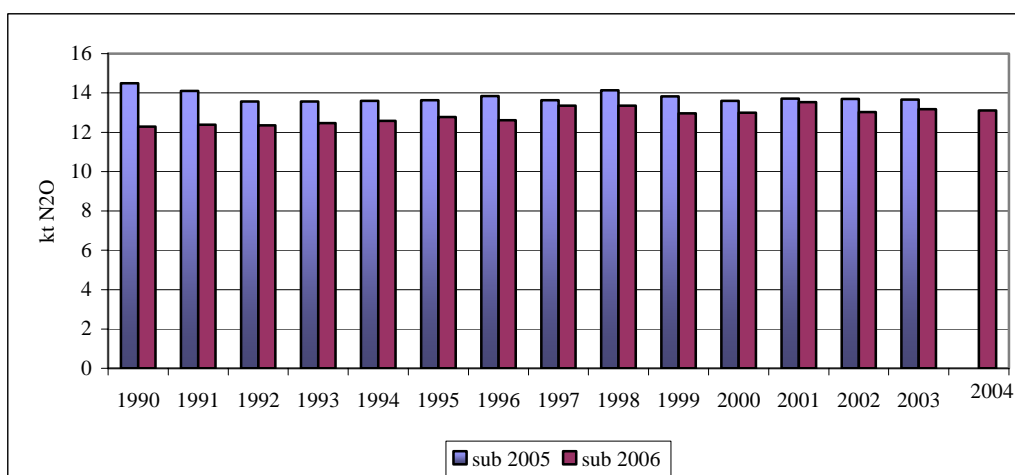


Figure 6.10 - Differences in trend of the estimated total N₂O emissions from agriculture between submission 2005 and submission 2006



6.3 Source categories

6.3.A CH₄ Emissions from Enteric Fermentation in Domestic Livestock (CRF 4A)

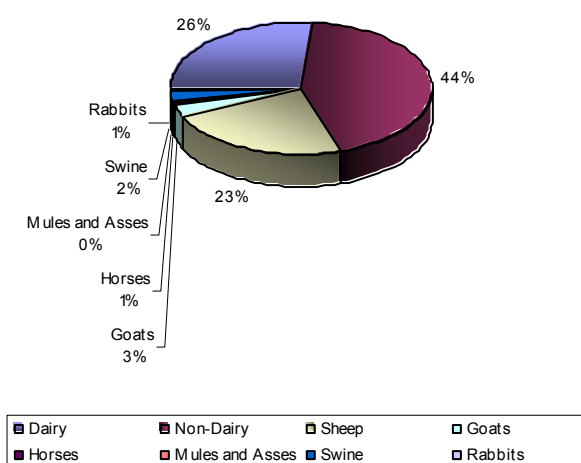
6.3.A.1 OVERVIEW

Methane emissions from enteric fermentation in animals result from this gas being produced as a by-product during the digestive process of carbohydrates by micro-organisms in the digestive system. This process occurs specially in ruminant animals, due to the activity of specific micro-organisms in their upper digestive tracts, but also in smaller quantities in monogastric animals (swine, equines and rabbits). The estimates in this inventory include only emissions in domestic animals. Emissions from wild animals and semi-domesticated game are not quantified neither there is quantification of emissions from humans or pet animals.

CH₄ emissions from enteric fermentation is a key source, both by level and trend assessment. The share of each animal type is observable in Figure 6.11. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents 26 to 30 per cent of total CH₄ emissions from Enteric Fermentation, while non-dairy cattle represents about 39 to 44 per cent of total CH₄ from

enteric fermentation. Altogether, and on average, cattle is responsible for about 70 per cent of total CH₄ emissions from enteric fermentation.

Figure 6.11 - Relative Importance of emissions of CH₄ from Enteric Fermentation per each animal specie in 2004



Sheep is also an important source of methane, for which emissions have oscillated between 21 and 23 per cent of total CH₄ from Enteric Fermentation. Emissions from goats were 2.6 to 4.4 per cent of total enteric fermentation and swine represented 2.2 to 3.0 per cent of emissions. Total emissions of methane for all other species varied between 2.4 and 2.0 per cent in the period and have a lesser importance.

6.3.A.2 METHODOLOGY

Emissions were estimated for each animal type⁹² by multiplication of the number of animals by the respective emission factor, in accordance to equation 4.12 of the Good Practice Handbook (Tier 2 method).

$$Emi_{CH_4(y)} = \sum_t [EF_{(i,y)} * N_{(i,y)}]$$

where, for each specie:

Emi_{CH_4} - methane emissions from enteric fermentation in year y, kg CH₄/year;

EF - emission factor for the specific population of animal type i in year y, kg/head/year;

⁹² 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.

N - the number of animals of type i in year y, head.

6.3.A.3 EMISSION FACTORS

Emission factors may be seen in Table 6.2, in which is presented the range of values according to time variation, which will be further discussed. In accordance with the unavailability of emissions factors in IPCC96 for broilers, laying hens, turkeys, ducks, geese, guinea fowl and other poultry, emissions from these classes were not estimated and were assumed as negligible. There are no livestock populations of Buffalo, Camels and Llamas in Portugal.

The default emission factors proposed by IPCC96 for West Europe (tables 4-3 and 4-4 in IPCC(1997)) were maintained for horses, mules and asses, due to the unavailability of a more detailed livestock characterization and specific characterization of national populations. For all other animal types the existence of an enhanced livestock population and animal characteristics allowed the use of a higher methodology level, tier 2.

Table 6.2 - Emission Factors for Enteric Fermentation (kg CH₄/head/year)

Animal type	sub-class	EF (kg CH ₄ /hd/yr)	
Dairy-Cattle	Dairy Cows	91-116	T2
non-dairy cattle	Beef calves (<1 yr)	32-36	T2
	Calves, Males for Replacements (<1 yr)	40-46	T2
	Calves, Females for Replacements (<1 yr)	34-39	T2
	Males 1-2 yrs	62-70	T2
	Beef Females 1-2 yrs	42-48	T2
	Females for Replacemet 1-2 yrs	48-55	T2
	Steers (>2 yrs)	77-88	T2
	Heifers for Beef (>2 yrs)	52-59	T2
	Heifers for Replacements (>2 yrs)	52-59	T2
	non-dairy cows	64-74	T2
Swine	Piglets (<20 kg)	0.3	T2
	Fattening Pigs (20-50 kg)	1.3	T2
	Fattening Pigs (50-80 kg)	1.9	T2
	Fattening Pigs (80-110 kg)	2.2	T2
	Fattening Pigs (> 110 kg)	2.5	T2
	Boars (>50 kg)	1.9	T2
	Sows, pregnant	1.8	T2
	Sows, non-pregnant	3.8	T2
Ovines	Ewes	8.1-10.7	T2
	Other: rams and young males	10-13.1	T2
	Lambs	4.3-5.6	T2
Caprines	Does	7.8-8.7	T2
	Other: bucks and young males	4.8-5.3	T2
	kids	2.6-2.9	T2
Equides	Horses	18	T1
	Asses, Mules and hynies	10	T1
Other	Rabbits	3.6	T2

DETERMINATION OF TIER 2 EMISSION FACTORS

Following the recommendations from previous review processes, a tier 2 analysis was seek for the most significant animal types.

According to the Good Practice Guidebook (IPCC,2000) equation 4.14, at tier 2, the emission factors for enteric fermentation are determined using the equation:

$$EF_{CH_4} = (GE * Y_m * 365 \text{ days/yr}) / (55.65 \text{ MJ/kg CH}_4)$$

Where:

EF_{CH_4} - emission factor, kg CH₄/hd/yr

GE - gross energy intake, MJ/hd/day

Y_m - methane conversion rate, the fraction of gross energy in feed that is converted to methane.

Dairy Cattle

The majority of cows used for milk production in Portugal belong to the Frisians race. Nevertheless there could not be found reliable records of animal feed intake or characteristics such as size. Therefore, emission factors were established using the following regression, which is based on the default IPCC emission factors per region and the value of annual milk production that was used in the determination of the default IPCC emission factors (Appendix A of the IPCC 1996 Guidelines (IPCC,1997)):

$$EF_{CH_4} = 0.0126 * Y + 40.207 \quad (r^2 = 0.961)$$

Where,

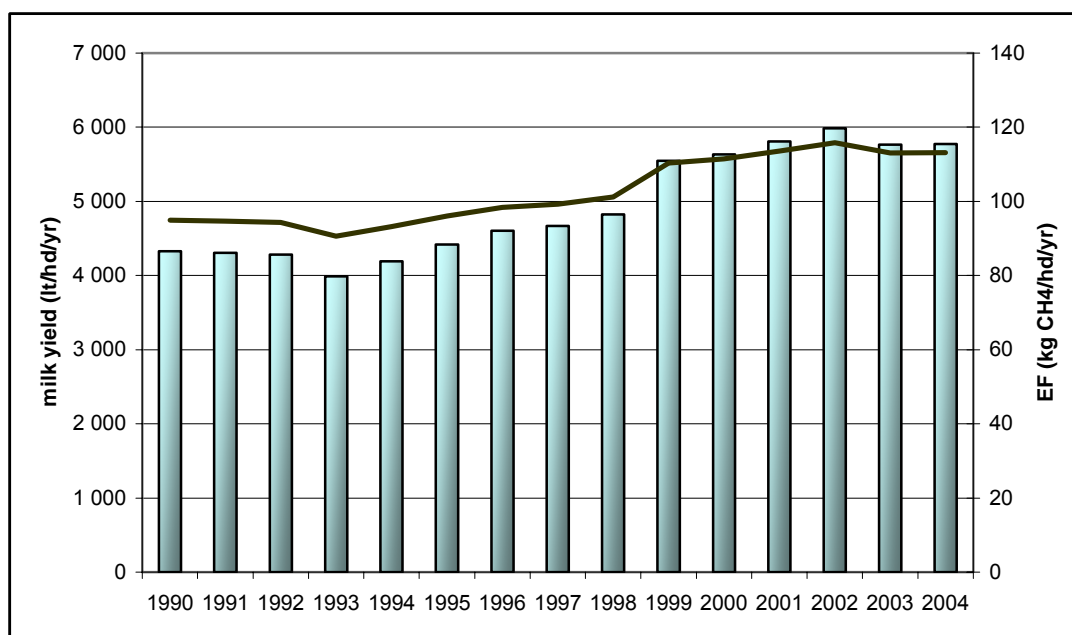
EF_{CH_4} is the Enteric Fermentation emission factor, kg CH₄/hd/yr;

Y is average milk yield per cow, lt/yr.

Milk yield was estimated dividing the annual production of milk cow over the number of cows in production⁹³, both of which are published by the National Statistical Institute (INE). The calculated milk yield and the corresponding emission factor are shown in Figure 6.12.

⁹³ The same time series used in the inventory but not averaged over 3 years.

Figure 6.12 – Annual production of milk yield per dairy cow in Portugal (bars) and the estimated emission factor of CH₄ from Enteric Fermentation (line)



Assuming a constant methane conversion rate of 0.6 per cent (default IPCC) and a energy density of the feed of 18.45 MJ/kg, the corresponding Feed Intake (FI) per day, should have increased from 13 kg dm/hd/day in 1990 to 16 kg dm/hd/day, in 2004. This trend in increase in the feed intake was used, in a consistent way, in the determination of the annual manure production per animal, in the determination of CH₄ emissions from Manure Management (see more adequate explanation in previous chapter).

Non-dairy cattle

The Ministry of Agriculture compiled in 1998, and updated recently (GPPAA,2004), information from the eighteen breeders associations existing in Portugal, this database comprehending the number of registered producers, number of animals, age at weaning, age at slaughter, use as working animal, territorial range and biometric parameters such as weight at birth, at 7 months and at adult age. Thirteen breeds have national origin and four are imported breeds. The number of registered animals represents about 20 per cent of total reproductive animals. Some animals in the remaining livestock population are the result of cross-breeding and are not registered, but it was assumed that they attain the average characteristics of the progenitors.

The calculation was made individually for each sub-category, determined from the available statistical information:

<1 yr	Beef Calfs
	Calfs, Males for Replacements
	Calfs, Females for Replacements
1-2 yr	Males
	Beef Females
	Females for Replacement
>2 yr	Steers
	Heifers for Beef
	Heifers for Replacements
	non-dairy cows

Feed intake estimates for each cattle sub-category was estimated using the energy model of the IPCC Good Practices (IPCC,2000), which is briefly presented here. First, net energy is determined from:

$$\begin{aligned}
 NE_m &= CF_i * (\text{Weight})^{0.75} \\
 NE_a &= C_a * NE_m \\
 NE_w &= 0.10 * W_{\text{hour}} \\
 NE_g &= 4.18 * \{0.0635 * [0.891 * (\text{Weight} * 0.96) * (478/(C_g * MW))]^{0.75} * (\text{WG} * 0.92)^{1.097}\} \\
 NE_l &= \text{milk}_{\text{Yield}} * (1.47 + 0.40 * \text{Fat}) \\
 NE_p &= C_{\text{pregnancy}} * NE_m
 \end{aligned}$$

Needs of digestible energy, and finally Gross Energy Intake (GE), expressed in energy, and Feed Intake (FI), expressed in dry matter ingested, are estimated from:

$$\begin{aligned}
 NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\
 NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\
 GE &= \{[(NE_m + NE_a + NE_l + NE_w + NE_p)/(NE_{ma}/DE)] + [NE_g/(NE_{ga}/DE)]\} / (DE/100) \\
 FI &= GE / ED
 \end{aligned}$$

where, the following variables are estimated:

NE_m – net energy required by the animal for maintenance, MJ/day;

NE_a – net energy for animal activity, MJ/day;

NE_w – net energy for work, MJ/day;

NE_g – net energy needed for growth, MJ/day;

NE_l – net energy for lactation, MJ/day;

NE_p – net energy required for pregnancy, MJ/day;

GE – gross energy, MJ/day;

FI – Feed Intake, kg dm/day;

Based on the knowledge of the following parameters:

NE_{ma}/DE - ratio of net energy available in a diet for maintenance to digestible energy consumed;

NE_{ga}/DE - ratio of net energy available for growth in a diet to digestible energy consumed;

DE - digestible energy expressed as a percentage of gross energy

Weight - live-weight of animal, kg/hd;

MW - the mature body weight of an adult animal, kg;

WG - the daily weight gain, kg/day;

Milk_{Yield} – milk production, kg/day;

W_{hour} - hours of work per day;

Fat - fat content of milk, %;

ED - energy density of the feed, MJ/kg dm;

C_{fi} - a coefficient for maintenance, specific of each animal class;

C_a – activity coefficient corresponding to the feeding situation of the animal;

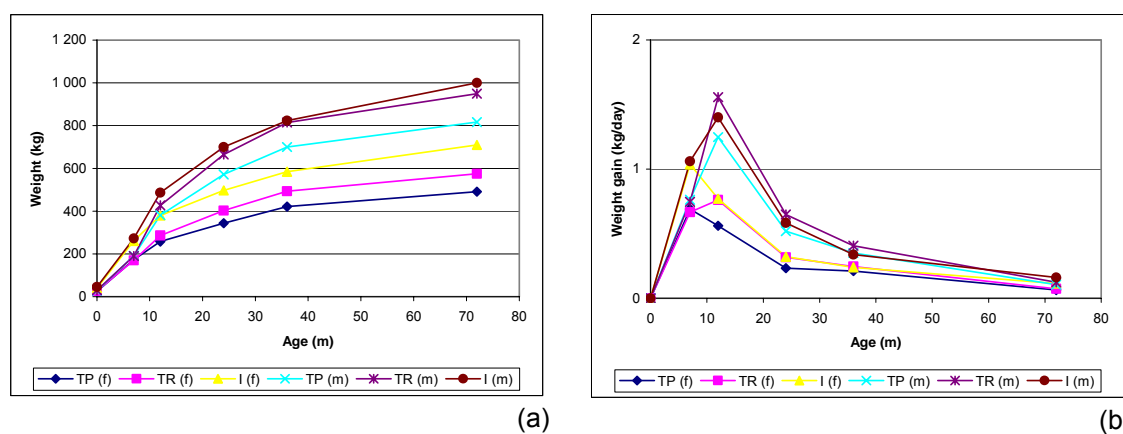
C_g – Coefficient for growth, dependent on the sex;

C_{pregnancy} = pregnancy coefficient.

For each cattle breed the values chosen for parameters, such as weight, weight gain and feeding situation, were established from the available information. Three different cattle types were considered: (1) Imported breeds; (2) Traditional breeds on pasture; (3) Traditional breeds on range⁹⁴. The difference between traditional animals on pasture and range depends on the type of terrain, being assumed range for breeds mostly existing in the south plains (“Montados”) and pasture in small grazing plots (“Prados” and “Lameiros”) in central and northern continental Portugal and in the islands.

Given that the database did not have detailed information for all age classes a model had to be derived for each breed from information at birth, 7 months and adult weight. The model, based on information collected from other countries (Jarrige, 1988), considers the following evolution pattern.

Figure 6.13 – Grow model for cattle: (I) Imported breeds; (Tp) Traditional Pasture and (Tr) Traditional Range, for males (m) and females (f).



(a) Live-weight as function of age; (b) Weight gain as function of age.

⁹⁴ Imported breeds are Charolês; Limousine; Simmental Fleckvieh and Salers. Breeds in traditional pasture are: Arouquesa, Barrosã, Marinhova, Maronesa, Minhota/ Galega, Cachena, Ramo Grande and Mirandesa. Traditional range breeds are: Alentejana, Garvonesa, Brava, Mertolenga and Preta.

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 factor⁹⁵. The average values of the parameters and the average values of the values calculated are presented in Table 6.3 through Table 6.6.

Table 6.3 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of individual breed.

sub-class	W (kg)	WG (kg/day)	Cfi	NE _m (MJ/day)	Ca	NE _a (MJ/day)	Cg	NE _g (MJ/day)
Beef calves (<1 yr)	212	0.948	0.322	17.8	0.177	2.8	0.9	8.6
Calves, Males Rep. (<1 yr)	230	1.139	0.322	19.0	0.177	3.2	1.0	8.9
Calves, Fem. Rep. (<1 yr)	182	0.757	0.322	15.9	0.177	2.6	0.8	7.9
Males 1-2 yrs	543	0.589	0.322	36.2	0.177	6.3	1.0	8.2
Beef Fem. 1-2 yrs	366	0.295	0.322	26.9	0.177	4.4	0.8	4.7
Females for R. 1-2 yrs	366	0.295	0.322	26.9	0.177	4.4	0.8	4.7
Steers (>2 yrs)	789	0.249	0.322	47.9	0.177	8.4	1.2	3.7
Heifers for Beef (>2 yrs)	462	0.160	0.322	32.1	0.177	5.4	0.8	2.9
Heifers for Rep. (>2 yrs)	462	0.160	0.322	32.1	0.177	5.4	0.8	2.9
non-dairy cows	599	0.000	0.324	39.1	0.177	6.5	0.8	0.0

Table 6.4 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Specific parameters for mother cows.

Parameter	Value
Per cent Pregnant	0.90
Milking Period (days/yr)	56
Milk Yield during milking period (kg/d)	8.0
F (Fat content of Milk) (%)	4
NE _i (MJ/day)	3.8
C _{pregnancy}	0.1
NE _p (MJ/day)	3.5

Table 6.5 – Parameters used in determination of Net Energy ingestion for non-dairy cattle. Weighted averages of Mature Weight (MW).

MW	kg
Male	930
Female	600

⁹⁵ The preference for this weighting factor other than number of animals results from the fact that the number of declared animals is probably over-estimated for traditional breeds.

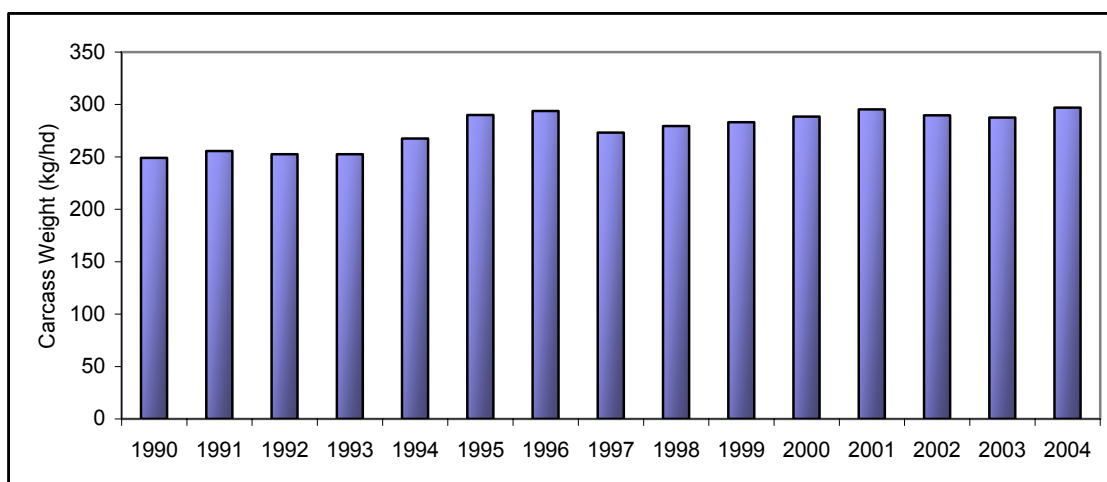
Table 6.6 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Ym) and Emission Factor of CH₄ emissions from Enteric Fermentation for non-dairy cattle. Weighted averages of individual breeds.

sub-class	NE (MJ/day)	NE _{ma} /DE	NE _{ga} /DE	DE (%)	GE (MJ/day)	FI (kg dm/day)	Ym	FE CH ₄ (g/hd/yr)
Beef calves (<1 yr)	29.2	0.514	0.308	65	105	5.7	0.06	35
Calfs, Males for Rep. (<1 yr)	31.1	0.514	0.308	65	111	6.0	0.06	44
Calfs, Females for Rep. (<1 yr)	26.3	0.514	0.308	65	95	5.1	0.06	37
Males 1-2 yrs	50.7	0.495	0.278	60	192	10.4	0.05	67
Beef Fem. 1-2 yrs	36.0	0.495	0.278	60	134	7.2	0.05	46
Females for R. 1-2 yrs	36.0	0.495	0.278	60	134	7.2	0.06	53
Steers (>2 yrs)	60.2	0.495	0.278	60	212	11.5	0.06	84
Heifers for Beef (>2 yrs)	40.3	0.495	0.278	60	143	7.8	0.06	56
Heifers for Rep. (>2 yrs)	40.3	0.495	0.278	60	143	7.8	0.06	56
non-dairy cows	53.0	0.495	0.278	60	178	9.7	0.06	70
Average (1998)	41.3	0.502	0.289	62	146	7.9	0.06	56

The situation estimated was assumed representative of the situation when the database was compiled, in 1998. The evolution of the average carcass weight at slaughter, Figure 6.14, was used to add a time trend to the estimated quantities, assuming that overall parameters at a given year (Par_x) could be approximately related to carcass weight in the same year ($Cweight_x$), from the values of the parameters and weight at base year (Par_{base} and $Cweight_{base}$) by the power function used for NEm. This procedure resulted that CH₄ emission factors per animal are in 2004 about 14 per cent higher than the corresponding values in 1990.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 6.14 – Average carcass weight at slaughtering. Total Cattle.



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Sheep and Goats

The same database from the Ministry of Agriculture that was referenced previously for non dairy cattle, includes also information for the twelve⁹⁶ native Portuguese breeds of sheep and the five native Portuguese breeds of goats⁹⁷. Three imported breeds of sheep⁹⁸ are also referenced, but no characterization data was available for them. The database includes information such as the number of registered animals, the number of producers, products (milk, meat or wool), dominant reproductive period, weaning age, age at slaughtering, weight (birth, 90 days and adult weight, distinguishing males from females), milk production, wool production (for sheep, males and females) and territorial distribution.

In a mode similar to that used for cattle, the energy model proposed in the IPCC Good Practices (IPCC,2000) for sheep was used. Net energy was estimated from the formulae set:

$$\begin{aligned} NE_m &= CF_i * (Weight)^{0.75} \\ NE_a &= C_a * Weight \\ NE_g &= \{WG_{Lamb} * [a + b * BW]\} \\ NE_l &= milk_{Yield} * EV_{milk} / 365 \\ NE_p &= C_{pregnancy} * NE_m \\ NE_{wool} &= Wool_{Prod} * EV_{wool} / 365 \end{aligned}$$

Needs of digestible energy, and finally Gross Energy Intake (GE), expressed in energy, and Feed Intake (FI), expressed in dry matter ingested, were estimated from:

$$\begin{aligned} NE_{ma}/DE &= 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE) \\ NE_{ga}/DE &= 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE) \\ GE &= \{[(NE_m + NE_a + NE_l + NE_p)/(NE_{ma}/DE)] + [(NE_g + NE_{wool}) / (NE_{ga}/DE)]\} / (DE/100) \\ FI &= GE / ED \end{aligned}$$

where, the following variables and parameters are estimated:

NE_m – net energy required by the animal for maintenance, MJ/day;

NE_a – net energy for animal activity, MJ/day;

NE_g – net energy needed for growth, MJ/day;

NE_l – net energy for lactation, MJ/day;

NE_p – net energy required for pregnancy, MJ/day;

NE_{wool} – net energy for wool production, MJ/day;

⁹⁶ 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.

⁹⁷ Algarvia, Bravia, Charnequeira, Serpentina and Serrana.

⁹⁸ Assaf, Ile de France and Merino Precoce.

GE – gross energy, MJ/day;

FI – Feed Intake, kg dm/day;

NE_{ma}/DE - ratio of net energy available in a diet for maintenance to digestible energy consumed;

NE_{ga}/DE - ratio of net energy available for growth in a diet to digestible energy consumed;

DE - digestible energy expressed as a percentage of gross energy

Weight - live-weight of animal, kg/hd;

WG_{Lamb} – weight gain of lamb, between weaning (Bi) and adult age or slaughter (Bf), kg/day;

BW – Average body weight of Lamb, between weaning and slaughter/ adult age, kg/hd;

Milk_{Yield} – milk production for lamb pre-weaning feeding and milk production, kg/year;

Wool_{Prod} – Wool production per animal and year, kg;

C_{fi} - a coefficient for maintenance, specific of each animal class;

C_a – activity coefficient corresponding to the feeding situation of the animal;

a, b – parameters dependent on sex of animal, used in the determination of $a + b \cdot BW$, the Energy Value of the Weight gain, MJ/kg;

EV_{milk} - the energy value for milk, MJ/kg;

EV_{wool} - energy value of the wool produced, MJ/kg;

C_{pregnancy} = pregnancy coefficient.

Estimates were done individually for each race and distinctly for ewes, does, lambs (for slaughtering), kids (slaughtering) and males (rams, bucks and young males). Parameters and final energy values were averaged using the number of registered animals as weighting factor and are presented in the next set of tables.

Table 6.7 – Parameters used in determination of Net Energy ingestion for sheep and goats. Weighted averages of individual breed per sub-class animal type.

Sub class	Sheep			Goats		
	Ram	Ewe	Lambs	Buck	Doe	Kids
Lifetime (day/year)	365	365	80	365	365	53
W (kg)	79.9	53.8	9.5	37.5	28.5	5.0
C _{fi}	0.250	0.217	0.254	0.315	0.315	0.315
NE _m (MJ/day)	6.64	4.30	1.36	3.57	2.97	0.93
C _a	0.017	0.017	0.017	0.024	0.024	0.024
NE _a (MJ/day)	1.39	0.93	0.17	0.90	0.68	0.12
WG (kg/day)	-	-	0.196	-	-	0.160
NE _g (MJ/day)	-	-	1.26	-	-	0.78
Wool (kg/yr)	6.5	3.6	-	-	-	-
NE _{wool} (MJ/day)	0.43	0.23	-	-	-	-
C _{pregnancy}	-	0.075	-	-	0.066	-
NE _p (MJ/day)	-	0.32	-	-	0.20	-

Table 6.8 – Parameters used in determination of Net Energy ingestion lactation for sheep and goats. Weighted averages of individual breed per sub-class animal type.

Specie	Ewe	Doe
Milk Production for suckling (kg/young/day)	0.981	0.802
Weaning age (days)	42	30
Offsprings (nr/female/yr)	0.97	0.85
Average Milk Production for off-spring suckling (kg/day)	0.104	0.056
Milk Production (kg/season)	55	427
Milking period (days/yr)	153	234
Milk Production (kg/day)	0.151	1.169
Total Avg. Milk Production (kg/day)	0.255	1.225
Energy Density of Milk (MJ/kg)	4.60	2.80
NE _l - Milk Production per day (MJ/day)	1.17	3.44

Table 6.9 – Determination of Gross Energy (GE) ingestion, Methane Conversion rate (Y_m) and Emission Factor of CH₄ emissions from Enteric Fermentation for sheep and goats. Weighted averages of individual breeds.

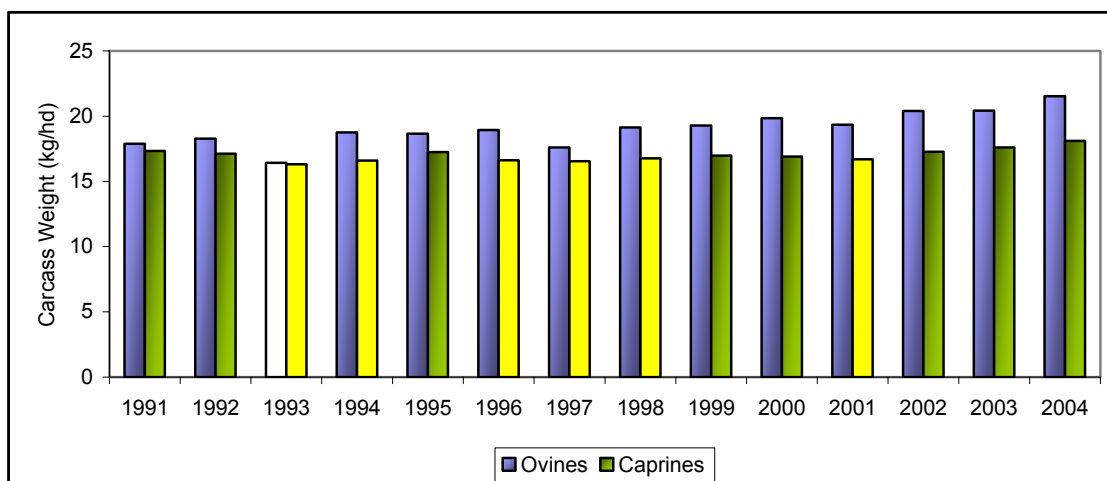
Sub-class	Sheep			Goats		
	Ram	Ewe	Lamb	Buck	Doe	Kid
NE _{ma} /DE	0.495					
NE _{ga} /DE	0.278					
DE (%)	60					
GE (MJ/day)	29.60	24.07	12.67	15.07	24.55	8.19
FI (kg dm/day)	1.60	1.30	0.69	0.82	1.33	0.44
Y _m	0.06			0.05		
FE (g CH ₄ /hd/yr)	11.6	9.5	5.0	4.9	8.1	2.7

Data on the average carcass weight at slaughter, Figure 6.15, is also available for Sheep and Goats. The time series for sheep shows a trend in animal size that was used, in a similar mode

that was already explained for non-dairy cattle, to add a time trend to the estimated quantities, assuming that overall parameters at a given year (Par_x) could be approximately related to carcass weight in the same year ($Cweight_x$), from the values of the parameters and weight at base year (Par_{base} and $Cweight_{base}$) by the power function used for NEm. This procedure resulted that CH₄ emission factors for ovine per animal are in 2004 about 15 per cent higher than the corresponding values in 1990. An equivalent trend in goats is not visible, reflecting probably the lesser interest in improvement of this specie.

$$Par_x = Par_{base} * Cweight_x^{0.75} / Cweight_{base}^{0.75}$$

Figure 6.15 – Average carcass weight at slaughtering. Total sheep and total goats.



Source: INE, Agricultural Statistics (<http://www.ine.pt>)

Swine and Rabbits

The methodology used by the French I.N.R.A. (INRA, 1984) was used to estimate feed intake for each swine sub-class, according to the following formula:

$$GE = Feed_{ED} / (DE / 100)$$

Where,

GE – gross energy, MJ/day;

Feed_{ED} – Recommended feed ingestion, expressed in digestible energy, MJ ED/day;

DE - digestible energy expressed as a percentage of gross energy, per cent.

The characteristics of each animal class as they were used to derive final emission factors for CH₄ emissions from enteric fermentation were obtained from INRA (1984) for each animal sub-class and are presented in Table 6.10.

Table 6.10 – Parameters used in determination of Gross Energy (GE) ingestion and enteric fermentation methane emission factor by swine and rabbits (all values INRA (1984))

sub-class	Weight (kg)	DE (MJ/day)	DE (% GE)	EF (g CH ₄ /h/y)	Ym	Notes
Swine						
Piglets (<20 kg)	10	6.2	79.4	0.31	0.006	Avg. 22 d. to 20 kg
Fattening Pigs (20-50 kg)	35	23.4	72.6	1.27		Regression
Fattening Pigs (50-80 kg)	65	34.5	72.6	1.87		DE = 17.93*Ln(W)-40.13 (r2 - 0.998)
Fattening Pigs (80-110 kg)	95	41.3	72.6	2.24		
Fattening Pigs (> 110 kg)	120	45.5	72.6	2.47		
Boars (>50 kg)	250	32.4	68.0	1.88		
Sows, pregnant	170	31.4	68.0	1.82		Sow in gestation
Sows, non-pregnant	195	64.9	68.0	3.75		Sow in lactation
Rabbits						
Reproductive Female	-	12.6	56.7	3.63	0.025	per female cage. The Ym is the IPCC default for Horses

Poultry⁹⁹

The methodology that was used to derive Gross Energy ingestion is similar to that used for swine and rabbits, albeit Metabolic energy (ME) is used as indicator of feed ingestion, and digestibility is replaced by Metabolisability (McDonald et al,2002; INRA,1985):

$$GE = \text{Feed}_{ME} / (EM/GE / 100)$$

Where,

GE – gross energy, MJ/day;

Feed_{ME} – Recommended metabolic energy ingestion, MJ/day;

EM/GE - Metabolisability, metabolic energy expressed as a percentage of gross energy, per cent.

⁹⁹ CH₄ emissions from Enteric Fermentation are not estimated for Poultry. Nevertheless GE is estimated for these animal types for the estimate of CH₄ emissions from Manure Management. GE is reported here for better comparison to the GE values for other animal types

Table 6.11 – Parameters used in determination of Gross Energy ingestion by Poultry

Animal Type	Energy Intake (MJ EM/day)	Metabolizability (EM/GE)	GE (MJ/day)	Ym
Broiler	1.02	68.3	1.50	NA
Laying hens, eggs production	1.39	63.5	2.20	NA
Laying hens, reproduction	1.36	63.5	2.15	NA
Cocks	1.71	63.5	2.69	NA
Turkeys	3.23	68.0	4.75	NA
Ducks#	1.46	65.8	2.22	NA

used as reference for other fowl

6.3.A.4 ACTIVITY DATA

Explain the available statistics...{to be completed}

Annual livestock numbers were available from the statistical databases of the National Statistics Institute (INE) from 1987 to 2004 for cattle, swine, sheep, goats, horses, mules and donkeys, disaggregated per region¹⁰⁰, age and sex. The number of rabbits, hens, broilers, turkeys, ducks, geese and guinea-fowl, is only available for 1999 – from the national agriculture census that is done every ten years - and extrapolations were done for the other years using surrogate indicators of trend. The following procedures were made to estimate the full time series:

- The number of hens for industrial egg production and for chicks production was available from the Regional Agriculture Statistics (INE) from 1990 to 2000. The census made in 1999 (RGA99 from INE) arrived to a substantially higher number of hens, 95 per cent higher than the values reported in the Regional Agriculture Statistics, reflecting the consideration, in the RGA99 census only, of animal in small farms. The original number of hens was corrected by the ratio of total hens in RGA99 and total hens from Regional Statistics. The values after 2001 are provisional;
- Broilers: two different situations were considered: animals risen in industrial poultry farms and in small agricultural farms. The total number of animals in 1999 was obtained from the agriculture census (RGA99). The number of animals in small farms at that same year was estimated by difference of total numbers from the total number of available broiler places in industrial exploitations (about 24 per cent of total population), which is also statistical information from INE, and assumed constant in the period 1990-2004. The remaining part, industrial broilers, were extrapolated for years other than 1999, using annual slaughtered animals as surrogate driver;
- Also for turkeys, the livestock from the 1999 census (RGA99) was considered to be the most representative of total population, including both animals in industrial units and in small farms. The full time series was constructed by extrapolation, using number of animals slaughtered as the driver;
- Rabbits. Number of breeding females was available for 1999, from the RGA99 census. The number of animals for the full time series was estimated using total tons of slaughtered animals as surrogate driver. This procedure may result in an increasing

¹⁰⁰ A total of 9 regions were available: the 5 regions in Continental Portugal (NUT II level), Norte, Centro, Lisboa e Vale do Tejo, Alentejo and Algarve; subdivision of two of these regions in two sub-regions each (Norte divided in Entre-Douro-e-Minho and Trás-os-Montes, and Centro divided in Beira Litoral e Beira Interior); and the two Autonomous regions of Azores and Madeira.

trend more accentuated than in reality, because animals in small farms are expected to have less tendency to increase in numbers;

- Ducks, geese, guinea-fowl and other poultry. Because the only available information concerns the Statistical census, RGA99, and also because there are no reliable information to establish a surrogate driver, a constant number of animals was assume in the all period.

For all animal types the value that was considered as activity data is the average of the last three years, i.e: the activity data reported for year n (1990 given as example) is the average of livestock numbers for n-2, n-1 and n (1988, 1991 and 1992).

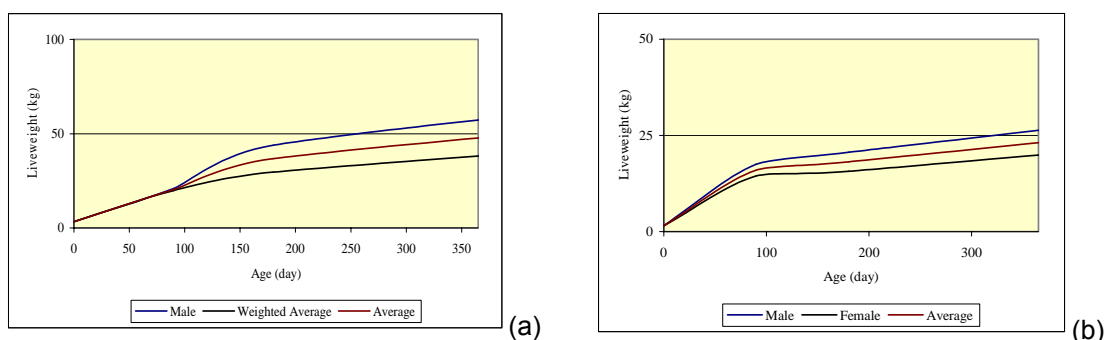
All original figures in statistical database represent stock numbers at a particular time of the year, mostly December and consequently for some species with strong seasonal reproducing periods, such as goats and sheep, these numbers had o be corrected and converted in average annual population. The seasonal correction was found not to be necessary for the other animal types.

The annual number of lambs and kids was set from the number of registered slaughtered animals, as published by the Regional Statistics, for which a correction factor was applied to account for the slaughtering that occurs outside normal market (auto-consumption). GPPAA (2004) reports a doubling factor for both sheep and goats (Correction Factor = 2). The number of lambs and kids reported as activity data represents the equivalent annual average of animals, i.e.:

$$\text{lambs/kids (hd)} = \text{Annual Slaughter (hd/yr)} * \text{CorrectionFactor} * \text{Age_Slaughter (days)} / 365$$

The age at which slaughter occurs (Age_Slaughter) was determined from the inverse function of the growth models¹⁰¹ for both species, Figure 6.16, using the weight at slaughter that was determined from the information in the Regional Statistics (INE), which values are presented in Figure 6.17. Resultant average ages vary from 107 to 113 days for sheep and 73 to 102 days for kids.

Figure 6.16 – Growth Model for Sheep (a) and Goats (b)



For both caprine and ovine animals there is a very appreciable variation of number of slaughtering according to months, as may be seen in Figure 6.18 for two subsequent years (GPPAA,2004). The importance of the periods of Christmas and Easter is evident. From this data, the population of lambs and kids was estimated for the beginning of each month (day 1), considering that at that moment were alive all animals killed in that same month and in the

¹⁰¹ Model set from the information on the breeds existent in Portugal, complemented by information in Jarrige (xpto) concerning growth pattern.

subsequent months according to the average age when young animals are killed. The ratio of population of young animals in the first of December (reference data for RGA99) to the average annual population, estimated to be 117 for sheep and 189 for goats, was used to estimate lamb and kids population in the moment of the RGA. The number of animals remaining from the total ovine and caprine numbers after subtraction of number of females (ewes and does) and the number of youngsters (lambs and kids) is reported as “Other Ovines” and “Other Caprines”. These animals are mostly adult males, but also young animals that are kept to reproductive functions and are not slaughtered.

Figure 6.17 – Average carcass weight at slaughtering. Lambs and Kids.

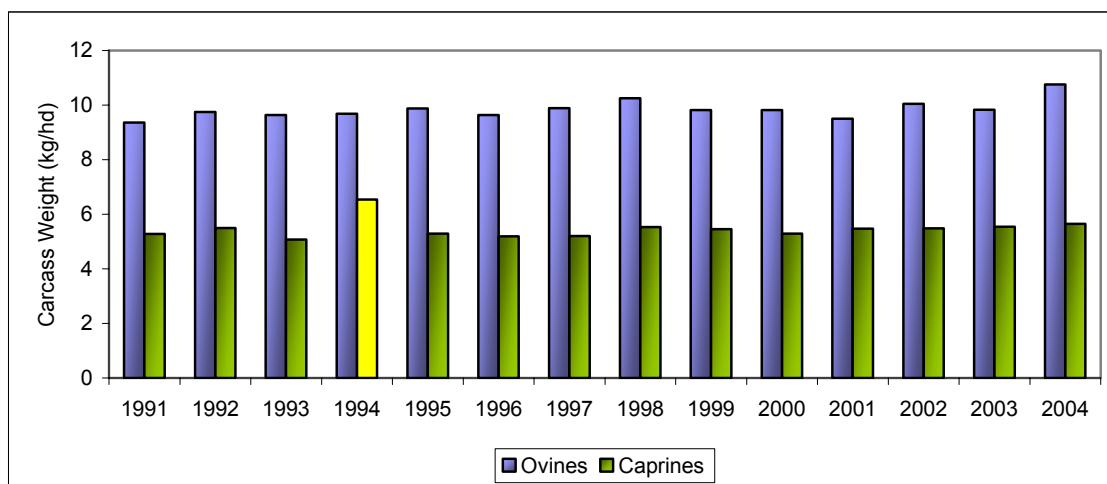


Figure 6.18 – Number of slaughtered young animals in each month for the years 2001 and 2002

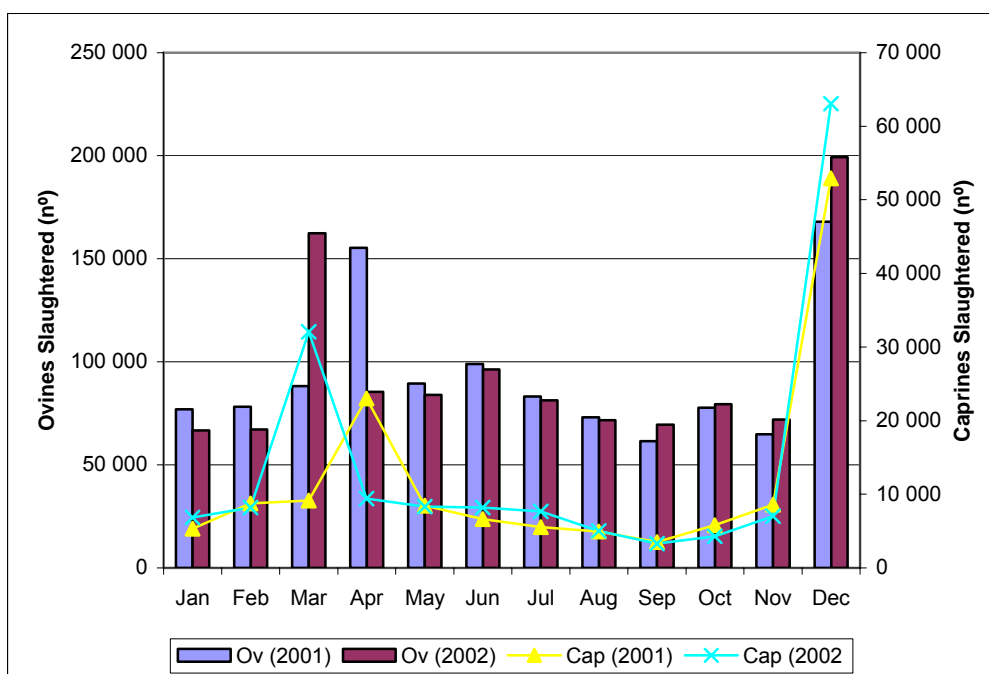


Table 6.12 - Livestock Numbers (Thousands): 1990-1996

Animal	sub-class	1990	1991	1992	1993	1994	1995	1996
Dairy-Cattle	Dairy cows	394	388	381	383	382	383	380
non-dairy cattle	Beef calves (<1 yr)	46	52	53	53	58	60	64
	Calves M.Rep. (<1 yr)	186	185	182	176	167	162	155
	Calves F Rep. (<1 yr)	177	178	178	174	164	158	152
	Males 1-2 yrs	112	114	114	108	103	103	105
	Beef Fem. 1-2 yrs	18	19	20	22	22	22	24
	Females rep. 1-2 yrs	111	115	112	109	106	109	112
	Steers (>2 yrs)	38	38	36	37	35	33	33
	Heifers Beef (>2 yrs)	4	5	7	9	10	10	9
	Heifers rep. (>2 yrs)	45	46	45	48	50	52	51
	non-dairy cows	242	245	238	241	252	273	296
Swine	Piglets (<20 kg)	727	756	756	750	735	726	703
	Fatt. Pigs (20-50 kg)	662	675	660	671	668	660	633
	Fatt. Pigs (50-80 kg)	537	558	557	553	542	530	505
	Fatt. Pigs (80-110 kg)	209	217	216	214	203	194	179
	Fatt. Pigs (> 110 kg)	42	43	44	44	43	43	40
	Boars (>50 kg)	26	28	27	28	28	26	24
	Sows, pregnant	210	219	218	220	216	211	204
	Sows, non-pregnant	124	131	135	136	134	132	127
Ovines	Ewes	2 211	2 251	2 257	2 268	2 303	2 339	2 376
	Other Ovines	395	398	402	420	430	433	414
	Lambs	592	610	606	578	565	568	592
Caprines	Does	600	581	556	538	528	517	509
	Other Caprines	44	42	41	39	39	38	37
	kids	102	102	96	92	89	82	77
Equides	Horses	33	38	40	42	44	48	52
	Asses and Mules.	118	116	114	114	109	103	96
Poultry	Hens, reproductive	1 876	1 953	1 935	2 061	2 179	2 712	2 978
	Hens eggs	4 133	4 598	4 966	5 715	6 000	6 347	6 290
	Broilers	20 095	20 437	190	972	840	179	769
	Turkeys	603	623	643	693	757	827	886
	Ducks, Geese and Guinea Fowl	804	804	804	804	804	804	804
Other	Rabbits	274	275	276	286	307	328	344

Table 6.13 - Livestock Numbers (Thousands): 1997-2004

Animal	sub-class	1997	1998	1999	2000	2001	2002	2003	2004
Dairy-Cattle	Dairy cows	379	375	369	361	350	344	336	336
non-dairy cattle	Beef calves (<1 yr)	64	65	66	67	72	72	70	73
	Calves M.Rep. (<1 yr)	151	149	149	149	149	150	155	153
	Calves F Rep. (<1 yr)	152	155	165	171	173	172	169	168
	Males 1-2 yrs	101	95	86	82	80	78	79	78
	Beef Fem. 1-2 yrs	24	24	20	17	15	15	15	16
	Females rep. 1-2 yrs	109	108	116	126	133	133	130	132
	Steers (>2 yrs)	31	31	29	27	25	23	22	22
	Heifers Beef (>2 yrs)	9	9	7	5	4	5	5	5
	Heifers rep. (>2 yrs)	50	52	60	67	67	60	55	57
	non-dairy cows	316	332	338	342	345	351	360	371
Swine	Piglets (<20 kg)	701	695	691	685	684	686	678	676
	Fatt. Pigs (20-50 kg)	631	633	623	610	596	589	575	567
	Fatt. Pigs (50-80 kg)	496	492	498	501	502	494	483	481
	Fatt. Pigs (80-110 kg)	177	174	176	176	190	205	216	221
	Fatt. Pigs (> 110 kg)	39	38	38	39	43	43	42	39
	Boars (>50 kg)	23	23	22	21	20	20	18	17
	Sows, pregnant	204	202	201	199	206	210	213	209
	Sows, non-pregnant	128	127	127	126	118	111	102	103
Ovines	Ewes	2 368	2 367	2 388	2 417	2 403	2 350	2 304	2 297
	Other Ovines	401	431	430	422	352	303	301	374
	Lambs	598	604	615	639	674	725	702	669
Caprines	Does	498	485	472	461	441	419	393	383
	Other Caprines	36	35	34	34	32	31	29	28
	kids	72	73	73	66	76	83	85	73
Equides	Horses	54	56	57	58	59	59	58	61
	Asses and Mules.	90	82	75	69	63	57	51	47
Poultry	Hens, reproductive	3 069	2 919	2 733	2 806	2 824	3 026	3 099	3 175
	Hens eggs	6 678	7 866	8 960	9 591	9 532	9 670	9 904	10 145
	Broilers	24 519	25 902	26 636	26 999	26 511	26 056	24 603	23 934
	Turkeys	937	1 069	1 180	1 283	1 288	1 285	1 150	1 068
	Ducks, Geese and Guinea Fowl	804	804	804	804	804	804	804	804
		804	804	804	804	804	804	804	804
Other	Rabbits	342	346	346	356	359	363	363	363

6.3.A.5 UNCERTAINTY ASSESSMENT

The uncertainty of livestock numbers for cattle is expected to be lower than for other animal types, due to the longer growing period for this specie and also due to the strong control (tagging) that is made on this animals. An almost similar situation may be assumed to the swine population. Herd numbers of sheep and goats are probably less known, mostly because of the strong seasonal character of breeding, because of the younger age at which animals are sacrificed and finally due to the significant importance of auto-consumption. The absence of statistic numbers for poultry, the need to estimate a time-series based on surrogate drivers, and the prevalence of dispersed animals in small farms, naturally causes higher uncertainty values for these animals. Finally, animals that are usually not considered as meat, such as equines, are less controlled and numbers tend to be known with less rigour.

A consistent pattern of values of uncertainty was obtained by making the comparison between values in the national statistics and the time series available from FAO.

National statistics from INE (annual livestock numbers) agree quite well with FAO data on cattle numbers, particularly toward the end of the period. The situation is similar for goats and pigs. However, in what refers to sheep, FAO reports numbers that are from 56 up to 86 per cent higher than those reported by the National statistics. This probably results from the inclusion of temporary animals in stock (lambs) that do not exist in December. The number of horses, mules, asses and turkeys¹⁰² is very different when comparing statistics from FAO and INE, but they have a small importance in the emissions inventory.

The population of laying hens, also from National Statistics, include animals producing eggs for consumption as well as eggs used to obtain broilers and to replace other laying and reproductive animals. Poultry numbers include also animals kept in domestic rural houses and not only animals in farms and agro-industrial places. These two facts may explain the constant higher numbers reported for birds in National Statistics than those reported in FAO database.

The per cent differences between FAO data and INE time-series¹⁰³, which are presented in table Table 6.14, was used as an indicator of the uncertainty of livestock numbers.

Table 6.14 - Uncertainty for livestock population.

Animal Type	U (%)
Dairy - Cattle	6
Non dairy cattle	6
Sheep	84
Goats	19
Pigs	11
Horses	71
Mules and Asses	272
Hens	64
Broilers	41
Turkeys	771
Other	771

The uncertainty of the emission factor was assumed to be 20 per cent for all animals where tier 2 was used and 50 per cent when tier 1 emission factors were used, in accordance with the Good Practice Guidebook (IPCC, 2000).

The reduction in uncertainty since last year's submission (50 per cent for all animal types except for rabbits whereas 100 per cent was considered) reflects the methodological improvement resulting from the passage from a tier 1 to a tier 2.

6.3.A.6 RECALCULATIONS

Substantial changes have resulted in emission estimates of methane from enteric fermentation, since last submission, resulting from:

¹⁰² While poultry numbers do not affect emissions of CH₄ from Enteric Fermentation they are discussed here to simplify NIR presentation.

¹⁰³ The comparison was done without 3 year averages were calculated.

- the enhancement of livestock characterization, using the most detailed disaggregation available from the national statistics. Annual livestock numbers for the most important animal types are now considered separately by age class, sex and region;
- the emission factor determination follow now a tier 2 methodology. The improvement in methodology resulted from the use of a detailed characterization of the population, the use of country-specific information concerning dominant races and the consideration of evolution in time, as function of productivity indicators such as milk yield per cow and weight of carcass;
- the correction of livestock numbers for animals which youngsters populations present strong seasonal variations, sheep and goats;
- efforts were done to add timeliness to some animal populations, such as poultry and rabbits, using surrogate information;
- the 3 year average is no longer centred, but represents the average of the 3 last years. This prevents the existence of provisional values in the end of the commitment period for the Kyoto Protocol.

6.3.A.7 FURTHER IMPROVEMENTS

The use of a tier 2 approach in the present submission represents a major improvement over last year's submission. Nevertheless in some cases, the tier 2 methodology, although considering an enhanced and detailed characterization of livestock still needs the determination of parameters country specific and based on actual feed data. Efforts are to be continued in the following years, although they will probably only affect the emission estimates in the second commitment period.

Estimate of CH₄ emissions from Enteric Fermentation from wild and semi-wild game animals is also foreseen in the near future although this is not a priority action.

6.3.B CH₄ Emissions from Manure Management (CRF 4B)

6.3.B.1 OVERVIEW

Methane emissions from manure occur when the organic material it contains, either solid or dung or liquid as urine, decomposes, during storage or treatment, in anaerobic environments by the action of methanogenic bacteria. The quantity that is emitted depends mostly of the existence of anaerobic conditions during storage of manure that promotes the activity of methanogenic microorganisms. Methane formation is therefore particularly important in highly anaerobic Manure Management Systems (MMS) such as anaerobic lagoons, anaerobic digesters, accumulation in tanks in liquid or slurry state or where manure remains for a long time residence on stall floor. Methane emissions resulting from manure deposited directly in soil during grazing and pasture, although in small quantities, are also included in this source category¹⁰⁴.

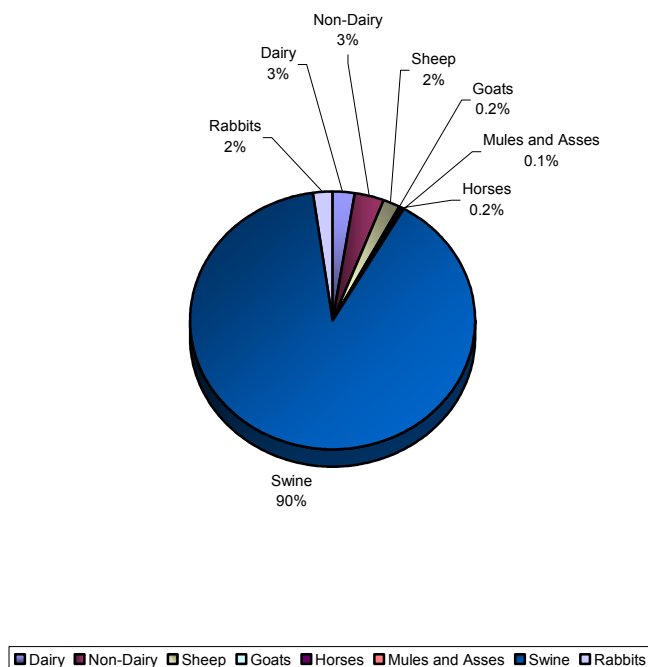
In some systems, such as anaerobic lagoons and digesters, the emitted gas may be collected and burned for energy use or simply flared. In these cases, methane emissions to the atmosphere may be significantly reduced.

Methane emission from Manure Management in Portugal is a key source. According to origin of manure by specie, most emissions result from swine manure, with 90 per cent of emissions in

¹⁰⁴ Nitrous oxide emissions from manure deposited in soil during grazing and pasture are nevertheless included in source category N₂O from agricultural soil: Animal production, in accordance with UNFCCC reporting guidelines.

2004, as may be seen in Figure 6.19, and according to the Good Practice rule of thumb this specie is the only significant source.

Figure 6.19 - Relative Importance of emissions of CH₄ from Enteric Fermentation per each animal specie in 2004



6.3.B.2 METHODOLOGY

Following the 1996 IPCC Revised Guidelines and the Good Practice Handbook, emission estimates are calculated by the following simple equation (following equation 4.15 of GPG) applied for each animal type and considering emission factors dependent on animal type and climatic conditions. By this procedure both the quantity of manure produced per animal and the storage conditions are included in the determination of the emission factor, and will be discussed thereafter.

$$Emi_{CH_4} = \sum_t \sum_c [EF_{(i,k)} * N_{(i,k)}]$$

where, for each specie:

Emi_{CH_4} = methane emissions from manure management, kg CH₄/year;

$EF_{(i,k)}$ = emission factor for the specific population of animal type i, living in climate region k, kg/head/year;

$N_{(i,k)}$ = total number of animals of type i, living in climate region k, head.

6.3.B.3 EMISSION FACTORS

Emissions Factors for each animal type were established according to the tier 2 methodology proposed in GPG (equation 4.17), which considers the use of country specific information concerning the quantity of manure produce per animal and the share of each Manure Management System that is used for each animal type. The equation used for the calculation of the EF for each animal species is therefore:

$$EF_{(i)} = VS_{(i)} * 365 * Bo_{(i)} * 0.67 * \sum_{jk} MCF_{(jk)} * MMS_{(jk)}$$

$EF_{(i)}$ - annual emission factor for a defined livestock animal specie i (kg/year);

$VS_{(i)}$ - Amount of excretion, expressed in Volatile Solids (VS) for an average animal i in the livestock population (kg VS /day);

$Bo_{(i)}$ - Maximum methane production capacity from manure (m³/kg VS) for animal specie i. 0.67 kg/m³ is methane density;

$MCF_{(jk)}$ - methane conversion factor for each Manure Management System j and for each climate region k;

$MMS_{(jk)}$ - fraction of total manure from animal specie i handled with Manure Management System j and for each climate region k.

B_o values were set according to IPCC96 (IPCC,1997). The amount of volatile solids (VS) excretion per animal, was estimated using the same data that was used to calculate Gross Energy (GE) intake for the determination of the emission factors of CH₄ from enteric fermentation, and using equation 4.16 of the Good Practice Guidebook:

$$VS = GE * ED_{feed} * (1-DE/100) * (1-Ash/100)$$

Where

GE – Daily average gross energy feed intake, MJ/day;

ED_{feed} – Energy Density of the feed, assumed constant and equal to 18.45 MJ/kg-dm;

DE – Digestible energy of the feed, per cent;

Ash – mineral content of feed, per cent.

The next table presents the parameters that were used for each animal class: Digestibility of feed (DE; Ash content in manure (Ash) and the maximum methane production capacity from manure (B_o) for each animal type. VS values change along years as consequence of the change in Gross Energy estimates.

Table 6.15 – Parameters used in the estimate of Volatile Excretion per animal

Animal Class	sub-class	DE (MJ/kg)	Ash (%)	Bo (m ³ /kg VS)
Dairy-Cattle	Dairy Cows	60	8	0.24
non-dairy cattle	Calfs (<1 yr)	65	8	0.17
	Other animals	60	8	0.17
Swine	Piglets (<20 kg)	79 [#]	2	0.45
	Fattening Pigs	73 [#]	2	0.45
	Sows and Boars	68 [#]	2	0.45
Ovines	All sub-classes	60	8	0.19
Caprines	All sub-classes	60	8	0.17
Equides	Horses	70	4	0.33
	Asses, Mules and hynies	70	4	0.33
Poultry	Hens Reproductive	63 [#]	5 [#]	0.32
	Hens eggs	63 [#]	5 [#]	0.32
	Broilers	68 ^{\$}	2 [#]	0.32
	Turkeys	68 [#]	3 [#]	0.32
	Ducks, Geese and Guinea Fowl	66 [#]	2 [#]	0.32
Other	Rabbits	57 [#]	3 [#]	0.33 (a)

Note: all values IPCC default, except:

- INRA (1984); \$ McDonald et al (2004); (a) Value assumed equal to horses

However, the significant difference between the Portuguese country-specific emission factors (CS) and the IPCC default emission factors for CH₄ emissions from Manure Management arises mostly, from the use of a different share of Management Systems for Manure, which are presented in Table 6.16 and also in Figure 6.20. Expert guess¹⁰⁵, based on survey data and field knowledge, from technical personnel of the Ministry of Agriculture was used to establish the percent of each Management System in 1990. The same expertise was used to establish a prevailing trend in the period 1990-2010, considering the practices that are becoming more common and some results of legislation and institutional control. Although the exact year at which the situation changes is unknown, a linear evolution between year 1990 and the target year of 2010 was assumed, Table 6.17. The new structure replaces the former expert guess used in the inventory, and also available from the Agriculture Ministry (Seixas et al, 2000), being assumed that it represents better the portuguese situation.

The country-specific percentages used in Portugal differ substantially from those in IPCC default:

- Swine manure in Portugal is usually treated in anaerobic lagoons, which have the highest MCF among MMS;
- the management of wastes from dairy cows kept in stall is split among solid storage and short retention time pits;
- dairy cows in pasture are more common in Portugal than the default assumption in IPCC;

¹⁰⁵ Information received from Dr. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005.

- non dairy cows with milking calves are usually kept on pasture, but fattening animals are usually grown in confined areas. Solid storage is still the prevalent method of treatment for wastes from other cattle;
- Daily spread and usage as fuel are practically unknown in Portugal;
- there is a small percentage of traditional swine and kept outdoors and foraging in pasture range;
- some poultry is kept outside, either in small farms or industrial production of country poultry;
- there are no substantial seasonal variations in the share of management system.

Table 6.16 – Methane emissions from Manure Management: Share of each Manure Management System per animal type in 1990

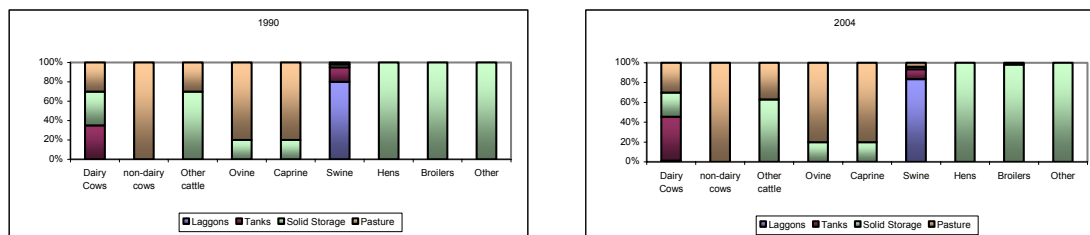
Animal Type	Laggons	Tanks	Solid Storage	Pasture	Total
Dairy Cows		35	35	30	100
non-dairy cows				100	100
Other cattle			70	30	100
Ovine			20	80	100
Caprine			20	80	100
Swine	80	15	3	2	100
Hens			100		100
Broilers			99.9	0.1	100
Turkeys			100		100
Ducks			100		100
Rabbits			100		100

Table 6.17 – Methane emissions from Manure Management: Annual variation of the share of each Manure Management System per animal type.

Animal Type	Laggons	Tanks	Solid Storage	Pasture
Dairy Cows	0.1	0.65	-0.75	
non-dairy cows				
Other cattle			-0.5	0.5
Ovine				
Caprine				
Swine	0.25	-0.35	-0.05	0.15
Hens				
Broilers			-0.12	0.12
Turkeys			-0.005	0.005
Ducks				
Rabbits				

Note: values represent the annual increment in the per cent of MMS use. Positive values represent increment in the per cent of the MMS. Negative values represent decrease in use

Figure 6.20 - Percentage of manure handled by each Manure Management System, by animal type in 1990 and 2004



Two climate regions occur in Portugal, in accordance with IPCC definition (IPCC,1997): temperate (annual average temperature between 15°C and 25°C) and cool (annual average temperature below 15°C). Livestock populations living in each climate region were determined according to the following mode:

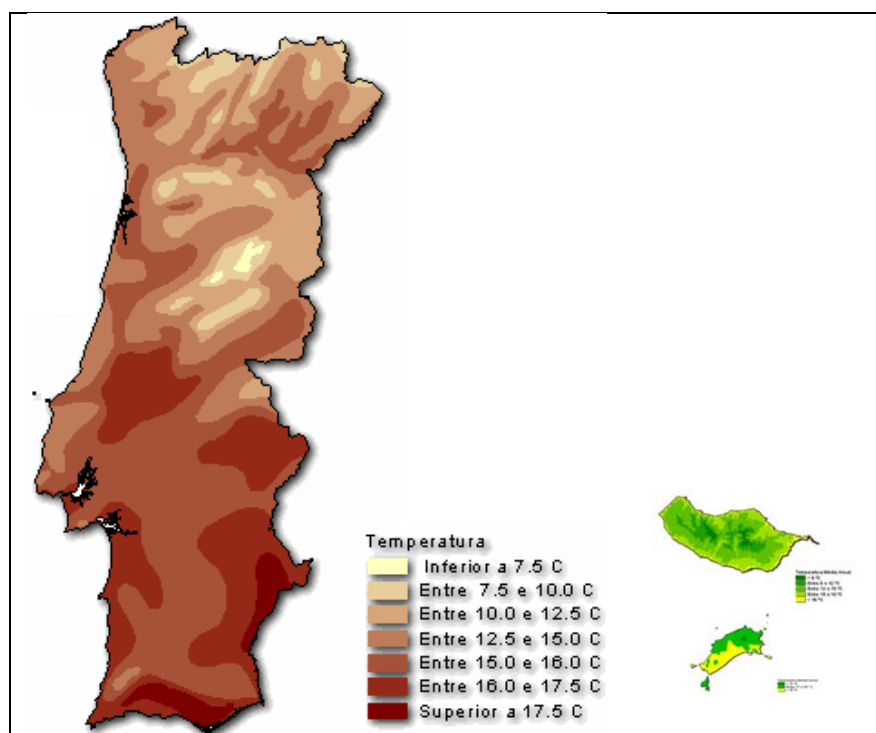
- the percentage of livestock numbers at each climate region was determined for each *concelho* territorial unit¹⁰⁶ and for each animal sub-type (). Within each *concelho* a homogenous distribution of animals was assumed;
- for each *Concelho* in mainland Portugal and Madeira archipelago the percentage of land area above and below 15°C was determined using the annual average air temperature map, which is presented in Figure 6.21. All area in Azores islands were considered to be in temperate region;
- Livestock numbers per animal type were available at *Concelho* level from two detailed agriculture surveys: RGA89 and RGA99¹⁰⁷. Data for 1999 was available for all animal types and for 1989 only for dairy cattle, other cattle, ewes, other sheep, female goats and other goats, sows and other swine;
- Livestock numbers in each *Concelho* area were allocated to each climate region, for year 1999, according to the land are percentage, and always assuming an homogeneous distribution of animals in the *Concelho* territorial area. Number of animals were summed at each Administrative Region (*Região*)¹⁰⁸ for all *Concelhos*, and a per cent of animals in each *Região* was established, and assumed constant in the period;
- Livestock population in each climate region and by *Região* was estimated annually from total livestock population in *Região* and considering the constant share and, finally, the total national livestock population for each region was calculated.

¹⁰⁶ *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 xpto km². A nut III level territorial unit is defined as a set of *Concelhos*.

¹⁰⁷ Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

¹⁰⁸ *Região* in continental Portugal is equivalent to a NUT I level territorial unit. In Azores and Madeira, *Região* is equivalent to the whole autonomous region. There are 7 administrative regions in Portugal.

Figure 6.21 – Isothermal map for continental Portugal and Madeira archipelago (IA,1974)
(Madeira island not to scale with mainland Portugal)



The percentage of livestock population living in cool climate regions for major animal types in 1990 and 2004, obtained in accordance with the above explained procedure, is presented in Table 6.19.

Table 6.18 – Percentage of livestock population living in climate cool regions in Portugal in years 1989 and 1999.

Animal Type	1990	2004
Dairy Cows	48	45
Other Cattle	43	29
Sheep	29	31
Goats	50	51
Horses	34	37
Mules and Asses	58	65
Swine	22	20
Poultry	43	44
Other	65	65

Finally, the Methane Conversion Factors are the defaults for temperate regions of Western Europe and developed countries:

Table 6.19 - Methane Conversion Factors (MCF), per cent, for determination of CH₄ emissions from Manage

MMS	Temperature	cool
Laggon	45	39
Tanks	0	0
Solid Storage	1.5	1
Pasture	1.5	1

6.3.B.4 ACTIVITY DATA

In a consistent manner livestock numbers are the same that were used in previous sub-category: CH₄ from enteric fermentation. Although for this source category more species are considered in the emissions estimates: birds. Livestock data were already presented.

6.3.B.5 UNCERTAINTY ASSESSMENT

Livestock numbers are considered to be the activity data of this source category and the uncertainty values were equal to uncertainty values discussed for CH₄ emissions from Enteric Fermentation, as explained in the previous chapter.

No recommendations exist in the Good Practice Handbook concerning the uncertainty levels associated with emission factors, and they were set in the following mode:

- total uncertainty in the emission factor was determined calculating the propagation of error in accordance with the equation that was used for the determination of the Emission Factors and incorporating an additional factor for the consideration of errors in climate region determination;
- uncertainty for the quantity excreted, VS parameter, was set at 20 per cent, considering the use of an enhanced livestock characterization, similar to that used in the derivation of the emission factor of CH₄ from Enteric Fermentation;
- the uncertainty of the allocation of manure for each Manure Management System (MMS) was determined comparing the share patterns that were used in Seixas et al (1999) with the new revised patterns¹⁰⁹. This error was combined with the error associated with the MCF parameter: the uncertainty was assumed to be 100 per cent for Anaerobic Lagoons, given the possible range in the IPCC defaults (IPCC,2000), and Liquid Storage, in this case considering not only the range of IPCC defaults but also the uncertainty in the time period during which the manure is stored; for solid storage and pasture, the uncertainty values of 50 per cent reflect the variation of this parameter;
- the error associated with the parameters B₀ is specie dependent and was establish from the range of possible values in the IPCC, for developed and developing nations. Uncertainty values vary from 10 per cent for horses up to 22 per cent for dairy cows. The uncertainty of the biogas density was assumed not to be determinant of the overall uncertainty value;
- from observation of the climate maps it is evident that, from the particular conditions that affect Portuguese climate, small annual variations in average air temperatures and also mapping techniques could exert a profound modification in the percentage of

¹⁰⁹ Although these two patterns are not fully independent, they represent information from two different experts, and could be representative of the range of possible values.

livestock numbers that are classified as either cool or temperate. Territorial units under each climate class could easily change as much as 30 per cent in either direction, value that was assumed as representative of uncertainty for this factor.

The individual uncertainty values are presented in next table.

Table 6.20 – Uncertainty Values of the Emission Factors of CH₄ emissions from Manure Management

Specie	Σ MMS*MCF	VS	Bo	Region	EF
Dairy Cows	43	20	22.9	30	61
Mother cows	62	20	20.6	30	74
Other cattle	42	20	20.6	30	59
Sheep	44	20	15.8	30	59
Goats	44	20	11.8	30	58
Swine	82	20	17.8	30	91
Poultry	54	20	12.5	30	66
Rabbits	54	20	12.5	30	66
Equides	48	20	10.6	30	61

The improvements in the methodology made since the submission of last year have resulted in the reduction of the uncertainty in the emission factors from 118 per cent to values that vary from 58 to 91 per cent.

6.3.B.6 RECALCULATIONS

This source sector suffered substantial changes since last submission:

- The time series of livestock numbers were revised in a consistent way to what was done for Enteric Fermentation emissions, that was already discussed in the previous chapter.
- Emission factors were improved, reducing uncertainty, as result of the use of data from the enhanced livestock population characterization and of determination of country specific production, per animal, of manure (VS);
- New expert information concerning the share of each MMS and its evolution in time was used in the improvement of the emission factors;
- The share of the livestock population per climate region was revised, and the trend of population in administrative regions is considered.

6.3.B.7 FURTHER IMPROVEMENTS

No improvements are expected for this source sector in the near future, except the amelioration and better documentation of activity data and parameters.

6.3.C CH₄ Emissions from Rice Cultivation (CRF 4C)

6.3.C.1 OVERVIEW

Methane production is enhanced in rice cultivation areas (rice paddies) due to the prevalence of anaerobic conditions which result from flooding and high levels of organic material in soil surface. The methane that is formed in soil underwater escapes to atmosphere as greenhouse gas emission, as visible bobbles or trough transport inside plant stems.

6.3.C.2 METHODOLOGY

Methane emissions from rice production were estimated following the equation 4.41 of GPG, but simplified because there are no appreciable differentiation in Portugal in what concerns water management regimes or any other conditions that are known to affect emissions from this source sector. Original formula was therefore simplified to:

$$E_{\text{Rice}_{\text{CH}_4(y)}} = EF * \text{Rice}_{\text{Area}(y)} * 10^{-2}$$

where

$E_{\text{Rice}_{\text{CH}_4(y)}}$ - Emission from rice production estimated for year y (ton/yr);

EF - Final emission factor, seasonally integrated and adjusted for management practices ($\text{g}/\text{m}^2/\text{yr}$);

$\text{Rice}_{\text{Area}(y)}$ - Area under rice cultivation in year y (ha).

6.3.C.3 EMISSION FACTORS

According to GPG formulation, the final value for the emission factor results from the multiplication of several factors:

$$EF = E_{fc} * SF_w * SF_o * SF_s$$

where

EF - Final emission factor, seasonally integrated and adjusted for management practices ($\text{g}/\text{m}^2/\text{yr}$);

E_{fc} - Seasonally integrated emission factor for continuously flooded fields without organic amendments ($\text{g}/\text{m}^2/\text{yr}$);

SF_w - Scaling factor for water management regime and ecosystem hydrologic conditions;

SF_o - Scaling factor reflecting organic amendments (rice straw, manure, compost, wastes), because easily decomposable carbon increase methane formation;

SF_s - Scaling factor for soil type.

The default E_{fc} proposed in GPG ($20 \text{ g}/\text{m}^2/\text{yr}$) was not used, but $36 \text{ g}/\text{m}^2/\text{yr}$ was used instead, which is the value proposed by IPCC96 in table 4-13 for Italy. In accordance with opinion expressed by the Portuguese Agriculture Ministry it was considered that this later value, determined for a European country with environmental conditions similar to Portugal was better suited than the use of the GPG default.

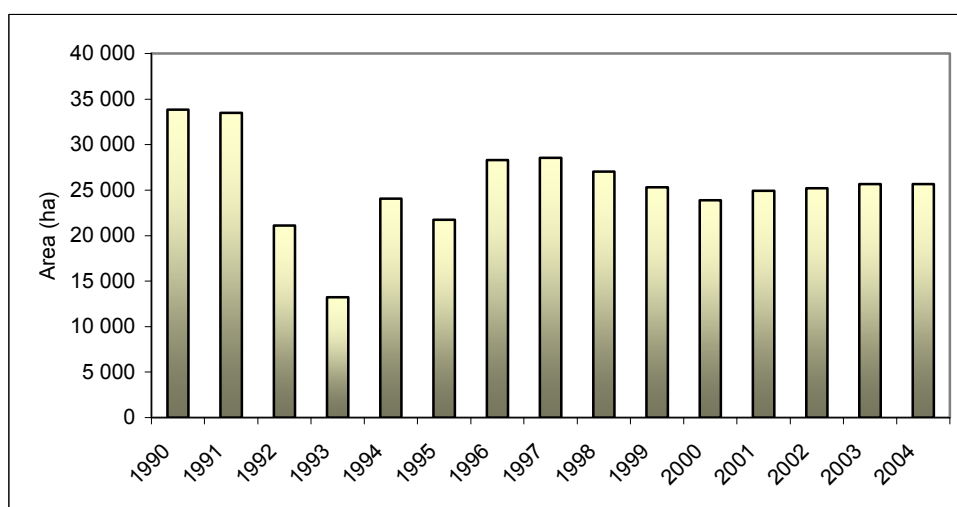
Rice culture in Portugal is almost homogeneous, in what concerns hydrologic management regime and characterized by cultivation being done under irrigated continuous flooded areas, where water regime is controlled by human activity (water diversion, irrigation and dikes). Rice fields are in standing water throughout all rice growing season and are only dried for harvest. All areas under rice cultivation are situated close to river banks almost at sea level. Accordingly the parameter SF_w was set as 1.0.

No statistical information exists concerning the use of organic amendments in rice fields but according to the Ministry of Agriculture these are not representative in Portuguese oriziculture, and the most appropriate value for SF_o is 1. In a similar way no information is available to establish influence of soil type and SFs was also set to one.

6.3.C.4 ACTIVITY DATA

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 6.22. It is noticeable the existence of huge variations in annual rice paddy areas, expressing annual variations in hydrological conditions. There is only one rice crop per year.

Figure 6.22 – Area under rice cultivation in Portugal (1990-2004)



Relevant characteristics of rice cultivated areas, such as water management regime, organic amendments and soil type are included already in emission factor setting.

6.3.C.5 UNCERTAINTY ASSESSMENT

The uncertainty in the adjusted seasonally integrated emission factor was set at 40 per cent, according to the range proposed in table 4.22 of the GPG. For activity data, the standard deviation of inter-annual area under rice cultivation was considered, also 40 per cent.

6.3.C.6 RECALCULATIONS

No changes have occurred since last submission.

6.3.C.7 FURTHER IMPROVEMENTS

No improvements in methodology are expected in near future. The establishing of a national integrated emission factor would be welcomed but there are no current plans or studies to achieve that goal.

6.3.D N₂O Emissions from Manure Management (CRF 4B)

6.3.D.1 OVERVIEW

Part of the Nitrogen that is in manure, either in faeces or urine, is emitted as N₂O during management or during storage of manure, before application to soil, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen.

Emissions of N₂O that occur after manure is deposited in soil, either as a way for disposal or as a fertilizer process, are reported in the category N₂O from agricultural soils and are discussed later. Following the UNFCCC reporting guidelines, emissions of N₂O from dung and urine that are deposited directly into soil during grazing, pasture and in paddocks, are also included in category N₂O from agricultural soils.

In a short description, this is a biological based process where emission of N₂O from manure require the previous oxidation of organic nitrogen in ammonia form, which results from bacterial mineralization of organic nitrogen, into nitrites and nitrates (nitrification, a biological process mediated by bacteria such as Nitrobacter and Nitrosomomas) in an aerobic environment and thereafter the reduction of this compounds in an anaerobic environment (the denitrification process where nitrate is converted to N₂ and nitrous oxide). Although there is no extensive information concerning the factors that affect this process it is believed that N₂O emissions increase with aeration, at least to finalize the process, and hence increase under opposite conditions that determine methane emissions from solid storage or deposition during grazing and dry lot, which means that are lesser emissions in fully anaerobic systems like liquid systems and anaerobic lagoons.

In terms of the importance of each Manure Management System, observable in Figure 6.23, the great majority of emissions result from solid storage and dry-lot, totalizing on average in the 1990-2004 period 97.4 per cent of total N₂O emissions from Manure Management. The rest comprehends 1.3 per cent of emissions from anaerobic lagoons and 1.3 per cent of total emissions from liquid systems. In terms of origin by animal type¹¹⁰, emissions are dominated by poultry, non dairy cattle and dairy cattle, which together comprehend about 80.7 per cent of total emissions, as may be seen in Figure 6.24 **Error! Reference source not found.** for the year 2004. Emissions from poultry is the most significant source with 48.8 per cent of emissions in 2004¹¹¹ while, non-dairy cattle (19 per cent in 2004) and dairy cattle (13 per cent) are also important sources.

¹¹⁰ Division of emissions per animal type or specie is not required according to CRF reporting format, but it is nevertheless relevant to understand the origin of emissions and the relevance of each specie.

¹¹¹ According to the IPCC rule of thumb in figure 4.4 of IPCC (2000), although in strict terms sub-categories for this source category are management systems and not animal species.

Figure 6.23 – Distribution of total N₂O emissions from Manure Management per System in year 2004

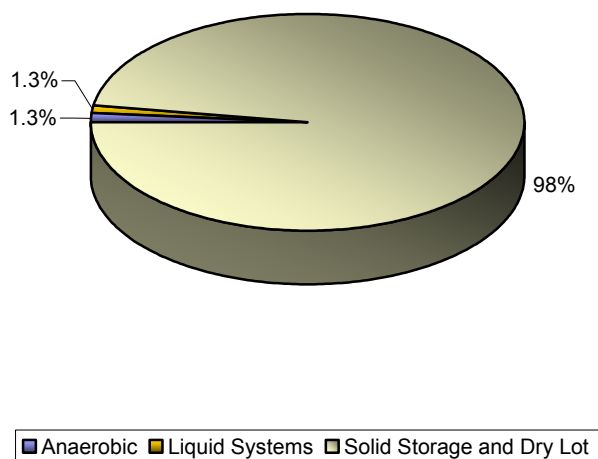
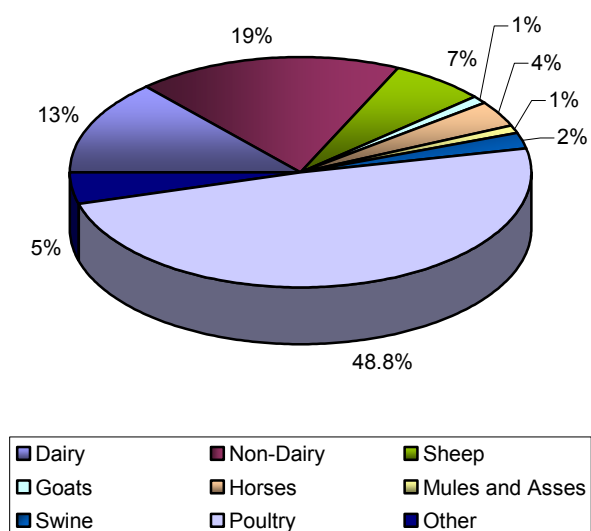


Figure 6.24 – Distribution of total N₂O emissions from Manure Management per animal specie as origin of manure in year 2004



6.3.D.2 METHODOLOGY

Emissions of N₂O from manure for each Manure Management Systems were estimated from the following formula:

$$EN_{2O(s)} = 44/28 * \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)}$$

where,

$EN2O_{(s)}$ - 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).

This formulation follows the one proposed in GPG (equation 4.18).

The following Manure Management Systems were considered for the calculation of total N_2O emissions from manure management, in accordance with the expert information received from the Ministry of Agriculture (MADRAP). The following table presents the original classes from the MADRAP and the correspondent classes in CRF table 4.D.

Table 6.21 – Classification of Manure Management Systems in Portugal, for the

MADRAP	GPG Class (Table 4.12)	CRF classification
Water Treatment Plant: Anaerobic Lagoon	Anaerobic Lagoons	Anaerobic Lagoon
Tank	Liquid/slurry or Open pits below animal confinements	Liquid System
Solid Storage: Composting	Solid Storage	Solid Storage and Dry Lot

This same methodology was used to assess Direct N_2O soil emissions from manure deposited in soil during grazing (Pasture Range and Paddock). However, emissions from this activity are further discussed in the sub-chapter (6.2.5) “Direct Nitrous Oxide Emissions from agricultural soils”.

Parameters $N_{(i)}$, $Nex_{(i)}$ and $MS_{(i,s)}$ will be discussed under “activity data” and $EF3_{(s)}$ will be discussed as “emission factor”.

6.3.D.3 EMISSION FACTORS

N_2O emission factors are presented in next table for all MMS (although the uses of daily spread, use for fuel and other systems are not considered in the Portuguese inventory). These emission factors are the default IPCC96 emission factors (table 4-22 which were maintained in GPG table 4.12) because there are no country-specific emission factors.

Table 6.22 – N_2O from Manure Management: Emission factors per Manure Management System

MMS	EF3 (kg N_2O -N/kg N)
Water Treatment Plant: Anaerobic Lagoon	0.001
Liquid Systems: Tank, Open Pit	0.001
Solid Storage and drylot	0.02
Pasture Range and Paddock	0.02

6.3.D.4 ACTIVITY DATA

Livestock population numbers used to estimate total nitrogen excretion are the same that were also used to estimate emissions of CH₄ from Enteric Fermentation and CH₄ from Manure Management, and which were already presented in the chapter concerning CH₄ emissions from Enteric Fermentation.

The quantity of nitrogen excreted per head results from expert information provided by the Ministry of Agriculture¹¹². The modification in excretion rates that occurred since last submission was necessary to:

- allow the use of different excretion rates for animals according to age and sex, and to use the full possibilities of the enhanced livestock characterization that was used in other source sectors (CH₄ emissions from Enteric Fermentation and Manure Management);
- make consistent and coherent calculations of the nitrogen balance, that is made by the National Statistical Institute (INE), with the technical help of the Ministry of Agriculture, and sent to the OECD/EUROSTAT.

The new nitrogen excretion rates proposed by the Ministry of Agriculture reflect the monitoring results obtained in the Laboratory Rebelo da Silva, complement with international sources such as Ryser et al. (1994) and data submitted by other countries. These rates were considered to be more representative of the national conditions than those that were formerly submitted and which were set (Seixas et al, 2000) from information received from the Agriculture Ministry. For some few animal types, for which excretion rates were not provided by this information source, the rates were estimated from data on animal feed, ingestion of nitrogen (Crude Protein converted in nitrogen) and the use of the retention rates proposed in the GP (IPCC,2000). The nitrogen rates that were used per animal type are presented in next table, together with the default nitrogen excretion rates from IPCC for Western Europe (table 4-20 of IPCC96).

There is an acceptable agreement between country-specific values and IPCC defaults for all species other than sheep, goats and equines. Albeit the nitrogen excretion rate for sheep appearing now too low, when in comparison to IPCC default (7 against 20), it has similarities to those used by other parties.

¹¹² Dr^a Fátima Calouro, director of the Laboratório Químico Agrícola Rebelo da Silva in Lisbon. This lab...

Table 6.23 – N excretion rate per head and by animal species/category (Nex)

Animal Class	Animal type	Nex (kg N/hd/yr)		
		Sub 2006	Sub 2005	IPCC Default
Dairy-cattle	Dairy Cows	87.6	108.07	100
non dairy cattle	Beef calves (<1 yr)	26.3	54.03	70
	Calfs, Males for Rep. (<1 yr)			
	Calfs, Females for Rep. (<1 yr)			
	Males 1-2 yrs	52.6		
	Beef Fem. 1-2 yrs			
	Females for R. 1-2 yrs			
	Steers (>2 yrs)	61.3		
	Heifers for Beef (>2 yrs)	70.1		
	Heifers for Rep. (>2 yrs)	70.1		
	non-dairy cows	61.3		
Swine	Piglets (<20 kg)	2.0	14.89	20
	Fat. Pigs (20-50 kg)	7.0		
	Fat Pigs (50-80 kg)	10.0		
	Fat Pigs (80-110 kg)			
	Fat Pigs (> 110 kg)			
	Boars (>50 kg)	17.5		
	Sows, pregnant			
	Sows, non-pregnant			
Ovine	Ewes	7.0	6.9	20
	Other Ovines			
	Lambs			
Caprine	Does	7.0	4.93	25
	Other Caprines			
	kids			
Equides	Horses	60.0	54.03	25
	Asses, Mules and hynies	22.0		
Poultry	Hens Reproductive	0.6	1.58	0.6
	Hens eggs			
	Broilers	0.8	0.74	
	Turkeys	1.8	3.29	
	Ducks, Geese and Guinea Fowl	0.9	1.58	
Other	Rabbits	7.4	1.5	25

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to year 2004, is presented in Table 6.24 and Table 6.25.

Table 6.24 – Total Nitrogen in Manure produced by livestock in Portugal 1990-1997 (ton N/yr)

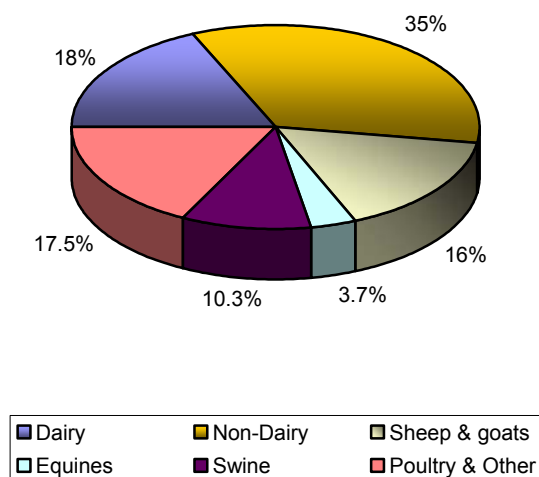
Animal Type	1990	1991	1992	1993	1994	1995	1996	1997
Dairy	30 365	29 878	29 338	29 492	29 415	29 492	29 236	29 184
Non-Dairy	41 751	42 639	42 042	42 008	42 019	43 266	44 571	45 312
Sheep	19 089	19 427	19 490	19 627	19 916	20 184	20 360	20 225
Goats	4 625	4 489	4 288	4 152	4 069	3 975	3 906	3 811
Horses	2 225	2 563	2 692	2 833	3 003	3 221	3 496	3 686
Mules and Asses	2 931	2 888	2 835	2 819	2 699	2 564	2 373	2 221
Swine	15 897	16 512	16 449	16 531	16 220	15 881	15 183	15 079
Poultry	16 325	16 814	17 464	18 414	19 218	19 929	20 470	21 220
Other	1 579	1 584	1 596	1 651	1 772	1 894	1 988	1 977
Total	134 788	136 793	136 194	137 526	138 331	140 407	141 583	142 716

Table 6.25 – Total Nitrogen in Manure produced by livestock in Portugal 1998-2004 (ton N/yr)

Animal Type	1997	1998	1999	2000	2001	2002	2003	2004
Dairy	28 876	28 382	27 810	26 929	26 521	25 848	25 847	28 876
Non-Dairy	46 091	46 831	47 634	47 961	47 775	47 876	48 690	46 091
Sheep	20 441	20 596	20 787	20 282	19 691	19 316	19 701	20 441
Goats	3 718	3 628	3 529	3 402	3 253	3 070	2 968	3 718
Horses	3 822	3 886	3 931	3 962	3 961	3 928	4 106	3 822
Mules and Asses	2 044	1 870	1 707	1 557	1 409	1 259	1 155	2 044
Swine	14 980	14 955	14 854	14 904	14 881	14 692	14 593	14 980
Poultry	22 725	23 747	24 438	24 135	24 016	23 095	22 725	22 725
Other	1 996	1 998	2 054	2 072	2 093	2 093	2 093	1 996
Total	144 693	145 894	146 744	145 203	143 600	141 177	141 878	144 693

The major contributors to total nitrogen from livestock in Portugal in 2004 were cattle, poultry and swine, as may be seen in Figure 6.25.

Figure 6.25 – Origin of nitrogen in manure from livestock production in Portugal in 2004, per animal type



The percentage of manure that is attributed to each Manure Management System was established in a coherent mode with the share considered in CH₄ emissions from Manure Management¹¹³.

According to the national share of MMS, it is larger the percentage of cattle in pasture range than according to what it is recommended by the IPCC (IPCC,1997), particularly for dairy cattle. Also, the percentage of dairy cows in solid storage is also higher than the per cent assumed by IPCC. Non dairy cattle not in pasture in Portugal is managed in dry storage manure systems, whereas IPCC assumes for western Europe a representative share of liquid systems. Therefore N₂O emissions from manure are larger than if the default MMS from IPCC was applied.

For pigs, the fact that IPCC assumes most manure managed is Liquid systems, while national information considers Anaerobic Lagoons is not much relevant because the default EF₃ is the same for both MMS. However IPCC recommends a higher level of solid storage systems than the per cent that it was considered in the national inventory according to the experts of the Portuguese Ministry of Agriculture. There exist a small number of animals kept feeding by grazing in range. Overall emissions estimated using country specific data results in lower values than those that would result from the utilization of IPCC defaults.

For sheep and goats, there is a different percentage of animals in closed systems and in Pasture, but that does not affect significantly total N₂O estimates - because EF₃ has equal default value for both MMS - although emissions are allocated to different emission categories.

At national level it was preferred to classify MMS for poultry as solid storage rather than the ambiguous IPCC classification of other systems. Manure in poultry and small mammals installations use mostly dry manure removal systems. Emissions are therefore higher than those that would result from estimates using IPCC default share of Manure Management Systems.

¹¹³ In the 1996 Revised IPCC Guidelines, however, there is no coherence between the default Manure Management System share proposed to estimate CH₄ from Manure Management and that for N₂O from Manure Management.

6.3.D.5 UNCERTAINTY ASSESSMENT

Uncertainty in activity data is the result of the combined uncertainties in livestock number, nitrogen excretion rates and the distribution by each manure management system. The values for uncertainty in livestock numbers are the same that were for sector CH₄ emissions from enteric fermentation. The uncertainty in N-excretion rate was set at 37.5 per cent, considering an intermediate situation between the uncertainty values recommended by GPG for default N-excretion rates (50 per cent) and the lower uncertainty when country-specific values are based on accurate national statistics (25 per cent). Uncertainty in MMS share was determined as the maximum difference in total excretion for each MMS considering the allocation per MMS used in previous submissions (Seixas et al, 1999) and the new revised share of MMS, and the values vary from about 1 per cent for anaerobic lagoons and liquid systems to around 10 per cent for solid systems and pasture. The overall uncertainty values range from 37.5 per cent to 39 per cent, which is lower than the value considered in last year's submission (52 per cent) and reflects the improvements made in the methodology and determination of parameters.

The uncertainty in N₂O emission factors was set in accordance with the maximum values proposed in table 4.12 of the Good Practice Handbook (IPCC,2000), 100 per cent for all MMS.

6.3.D.6 RECALCULATIONS

Substantial improvements were made in this source category:

- Use of an enhanced livestock population, detailed by sex and age;
- Revision of the share of each Manure Management System (MMS) in a coherent mode to what was done for the N₂O emissions from Manure Management;
- The use of an enhanced population characterization was accompanied by development of new nitrogen excretion rates, based in expert guess from technical experts in the field, and which was considered more representative of the national conditions.

6.3.D.7 FURTHER IMPROVEMENTS

Presently the nitrogen excretion rates are fixed in time. Efforts will be made to add time evolution in accordance to what was done for other source categories.

6.3.E Direct N₂O Emissions from Agricultural Soil (CRF 4D1)

6.3.E.1 OVERVIEW

In agricultural soils, emission of N₂O is enhanced by an increase in available mineral nitrogen which promotes soil biogenic activities of nitrification and denitrification. Increase of available nitrogen in soil may be caused by anthropogenic activities such as the addition of nitrogen to soil as a fertilizer or in crop residues or as consequence of cultivation of organic soils where degradation of organic matter is enhanced liberating fixed nitrogen. N₂O emissions considered in this inventory include therefore only the increase in soil emissions that are due to human management of soils, and not comprehending the Nitrous Oxide emissions that would occur in the same area under unmanaged conditions (background emissions).

Although some scientific references indicate that soils may also be soil sinks of N₂O, there are no available sound estimate techniques and consequently these were not estimated in this inventory.

Direct emissions of N₂O resulting from the increase of nitrogen added to cultivated soils due to agricultural activities include the following sub-categories:

- application of synthetic fertilisers;
- application of animal manure;
- animal manure (droppings) deposited directly by animals on pasture, range and paddock;
- nitrogen fixation by N-fixing crops (leguminous plants);
- nitrogen input from incorporation of crop residues into soils.

Most effort was placed to make estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources: N_2O , CH_4 and NH_3 .

The inventory of N_2O from Direct Soil Emissions from Agricultural Soils is almost complete, except the non inclusion of estimates for N_2O from the application of sewage sludge, due to the unavailability of data. However, this sources is probably minor in importance.

Considering climate conditions and the long period since when soils have been subjected to agriculture in Portugal, histosols represent at most a negligible emission quantity in Portugal, and they may be reported as not occurring for all practical purposes. Emissions due to application of sewage sludge as a soil amendment is also not included in the inventory, as there are no reliable statistics for this activity, which is considered nevertheless negligible.

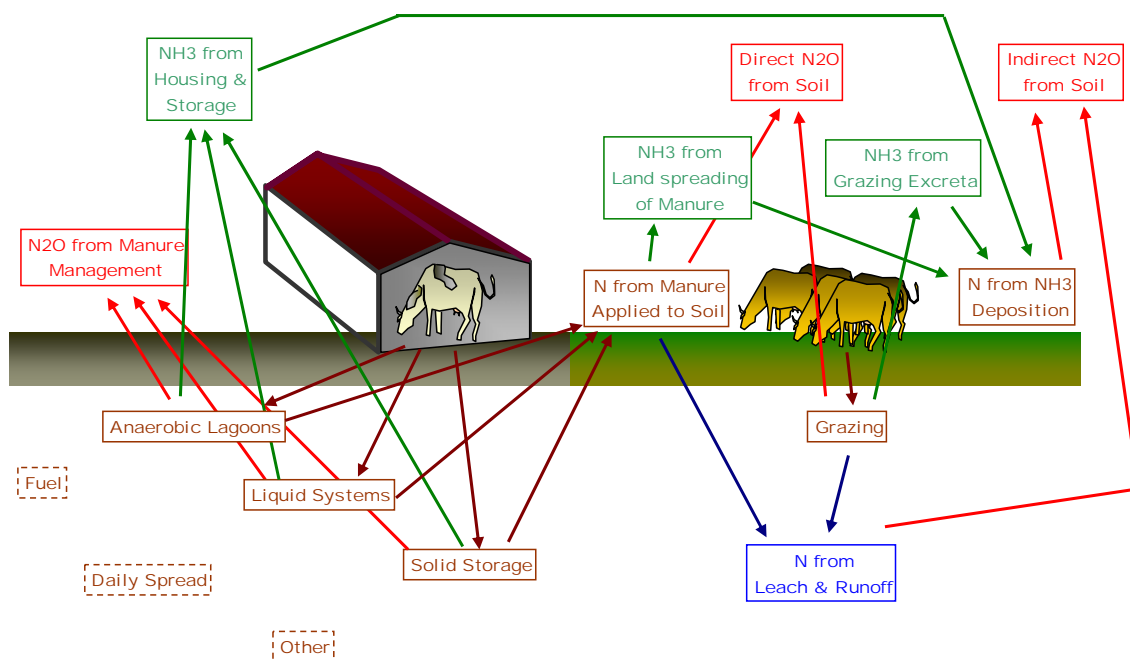
It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

The situation concerning N_2O emissions from manure is somehow complex because nitrogen originally in manure may give origin to N_2O emissions that are considered in different IPCC categories:

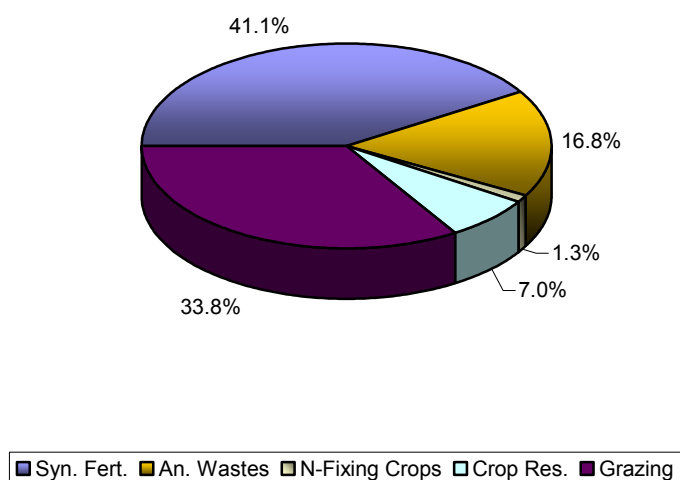
- emissions of N_2O , as well of ammonia, during the period that manure is stored in house or any Manure Managed System were already considered under source category N_2O emissions from Manure Management;
- emissions from nitrogen in manure added to soil as fertilizer is included in source category "direct N_2O from agricultural soils". In Portugal it was assumed that manure managed as liquid systems and solid storage is fully applied to agricultural soil as a fertilizer, irrespective of the animal species considered, whereas only a percentage of manure handled in anaerobic lagoons is placed in soil.

The following figure synthesizes the livestock system in what concerns nitrogen fluxes and direct and indirect N_2O emissions.

Figure 6.26 – Nitrogen fluxes from livestock system



The comparative importance of the several sub-source activities is shown in Figure 6.27, from where it is evident the major contribution from synthetic fertilizers (Syn. Fert with 44.1 per cent), and animal wastes, considering both the contributions from manure used as fertilizer (An. Wastes 16.8 per cent of total emissions) and direct deposition (Grazing 33.8 per cent). This set of emission sources are the significant sources in accordance with the IPCC rule of thumb. N₂O from nitrogen fixing crops contribute with a less representative part of emissions from this source sector, responsible for only 1.3 per cent of emissions from this source sector.

Figure 6.27– Contribution of the various sub-sources to total N₂O emissions from Direct agricultural soil emissions in 2004

6.3.E.2 METHODOLOGY

N₂O EMISSIONS FROM AGRICULTURAL SOILS OTHER THAN ANIMAL PRODUCTION

The approach used to estimate N₂O emissions from agricultural soils other than animal production (emissions of N₂O in Pasture Range and Paddock) may be better classified as Tier 1a, because the same emission factor was used to all nitrogen sources to soil¹¹⁴.

Final N₂O emissions are estimated with a formulation derived from equation 4.20 of GPG:

$$EN_{2O_{Direct}} = 44/28 * (FSN + FAM + FBN + FCR) * EF_1$$

where:

EN_{2O_{Direct}} - Annual emission of N₂O

FSN - Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilises as NH₃

FAM - Annual amount of animal manure nitrogen intentionally applied to soils adjusted to account for the amount that volatilises as NH₃

FBN - Amount of nitrogen fixed by N-fixing crops cultivated annually

FCR - Amount of nitrogen in crop residues returned to soil annually

EF₁ - N₂O emission factor from N input to soil (kg N₂O-N/kg N input)

FSN, the annual amount of synthetic fertilizer nitrogen applied to soil after adjusting to account for the amount that volatilises, is estimated from:

$$FSN = N_{Fert} * (1 - \text{Frac}_{GASF})$$

where,

N_{Fert} - total amount of nitrogen in synthetic fertilizers consumed annually

Frac_{GASF} - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH₃ or NO_x

The amount of nitrogen in animal manure that is used as fertilizer (FAM) was estimated from total nitrogen excreted from livestock that is applied to agricultural soils and after subtraction of nitrogen that was volatilised in housing, manure storage and after deposition in soil as fertilizer. The following equation applies:

$$FAM = \sum_i \{ N_{(i)} * N_{ex(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * (1 - EF_{NH3SD(i)}) \}$$

¹¹⁴ However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

where

FAM - total amount of nitrogen in manure from Manure Management System that is applied to soil as fertilizer;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i ;

$MS_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s , except grazing;

$MSSD_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i,s)}$ - Fraction of nitrogen in Manure Management System s from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$ - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

This equation is equivalent to equation 4.23 of GPG if one considers that $Frac_{GASM}$ equals the sum of $EF_{NH3(i,s)}$ and EF_{NH3SD} and being aware that $Frac_{PRP}$ is partly represented by parameter MSSD. To maintain consistency to the Good Practice methodology, and although emissions of N_2O from manure handled in Anaerobic Lagoons, Liquid Storage and solid storage were already accounted in N_2O emissions from Manure Management, the subtraction of the nitrogen that is lost that way is not made here.

Estimates of nitrogen fixed by crops follows exactly the Tier1b approach of the GPG (Equation 4.26) which means that crop-specific residue to product ratio and dry matter content are used:

$$FBN = \sum_i \{Crop_{BF(i)} * (1 + Res_{BF}/Crop_{BF(i)}) * Frac_{DM(i)} * Frac_{NCRBF(i)}\}$$

where

i - Crop type

$Crop_{BF(i)}$ - Crop production of nitrogen fixing crops (ton/yr)

$Res_{BF}/Crop_{BF(i)}$ - Residue to crop product mass ratio for nitrogen fixing crop i (ton/ton)

$Frac_{DM(i)}$ - Fraction of dry matter in the aboveground biomass of crop type i

$Frac_{NCRBF(i)}$ - nitrogen fraction in crop dry biomass (ton/ton)

Finally FCR, nitrogen input to soil in crop residues returned to soil, is estimated for all crops, whether they are nitrogen fixing crops or not, with the GPG tier 1b approach, which can be represented to the following equation, a similar simplification of equation 4.29 of the GPG:

$$FCR = \sum_i \{ [Crop_{(i)} * Res/Crop_{(i)} * Frac_{DM(i)} * Frac_{NCR(i)}] * [1 - Frac_{BURN(i)} - Frac_{FUEL(i)} - Frac_{CNST(i)} - Frac_{FOD(i)}] \}$$

where

i - Crop type

$Crop_{(i)}$ - Crop production (ton/yr)

$Res/Crop_{(i)}$ - Residue to crop product mass ratio for crop i (ton/ton)

$Frac_{DM(i)}$ - Fraction of dry matter in the aboveground biomass of crop type i (assumed to be equal to the fraction in the all plant)

$Frac_{NCRBF(i)}$ - nitrogen fraction in crop dry biomass (ton/ton)

$Frac_{BURN(i)}$ - fraction of crop residue burned in the field before and after harvest

$Frac_{FUEL(i)}$ - fraction of crop residue burned as fuel outside field

$Frac_{CNST(i)}$ - fraction of crop residue used for construction

$Frac_{FOD(i)}$ - fraction of crop residue used as animal fodder.

EMISSIONS OF N₂O IN PASTURE RANGE AND Paddock

Emissions of N₂O due to the input of nitrogen to soils from pasture, range and paddock were estimated with a methodology similar to that used to estimate emissions of N₂O from Manure Management. Emissions were therefore estimated with the following formula:

$$Emi_{N_2O} = 44/28 * FGR * EF_3$$

where,

Emi_{N_2O} - N₂O emissions from manure in Pasture, range and paddock;

EF_3 - N₂O emission factor (kg N₂O-N/kg N);

FGR - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture. This variable is determined from equation:

$$FGR = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)}]$$

where:

i - Animal/species category of livestock;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock.

6.3.E.3 EMISSION FACTORS

EF₁, the emission factor relating N input to soil with N₂O emissions, was set equal to the IPCC default value of 0.0125 kg N₂O-N/kg N input (table 4.17 of GPG and table 4.18 of IPCC96)¹¹⁵.

The emission factor of N₂O for Pasture, Range and Paddock (EF₃) was set at 0.02 kg N₂O-N/kg N which is the default IPCC96 emission factor (table 4-22) that is also maintained in GPG (table 4.12).

6.3.E.4 ACTIVITY DATA

The estimated quantities of nitrogen added to agricultural soils from each specific source are shown in Table 6.26 and Table 6.27 below and the percent contribution of each one in year 2004 is also represented graphically in Figure 6.28.

In the last reported year (2004) the majority (50.3 per cent) of nitrogen added to soil has resulted from the application of synthetic fertilizers, followed by nitrogen in manure as direct droppings during grazing in Pasture (23 per cent) and as manure applied to agricultural soil as fertilizer (18.1 per cent) and . Smaller quantities came from nitrogen returning to soil as crop residues (7.2 per cent) and from nitrogen fixed by leguminous plants (1.3 per cent). Total nitrogen added to agricultural soils in Portugal has been increasing and was in 2004 about 6.1 per cent higher than what it was applied in 1990.

Table 6.26 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1990-1997¹¹⁶

ton N/yr	1990	1991	1992	1993	1994	1995	1996	1997
Synthetic Fertilizer	139 545	140 732	141 563	144 169	143 931	137 628	158 325	153 963
Animal Manure	55 438	56 287	56 309	57 215	57 488	58 015	57 950	58 092
Pasture Range	63 062	63 870	63 229	63 389	63 890	65 345	66 697	67 647
Fixed by Crops	8 140	7 588	6 872	6 261	5 976	6 036	5 850	5 434
Crop Residues	23 461	22 325	20 925	21 066	22 051	23 698	23 364	24 097
Total	289 646	290 801	288 899	292 100	293 337	290 722	312 186	309 234

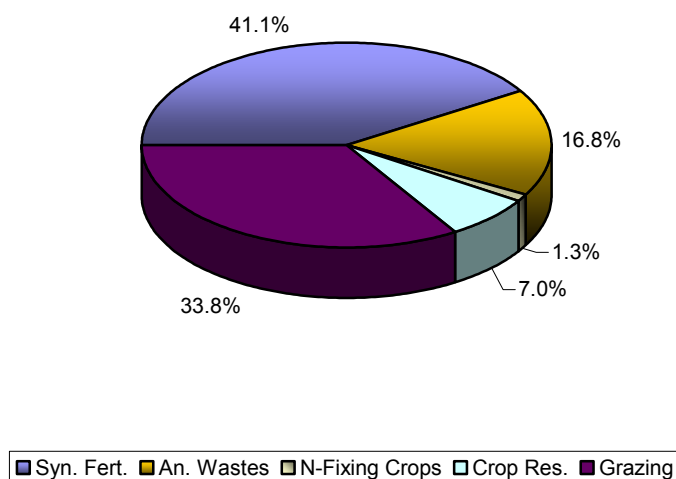
Table 6.27 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1998-2004

ton N/yr	1998	1999	2000	2001	2002	2003	2004
Synthetic Fertilizer	140 850	139 979	160 265	147 938	157 164	110 056	136 102
Animal Manure	58 855	59 269	59 538	58 564	57 697	55 990	55 687
Pasture Range	68 683	69 374	69 909	69 562	69 032	68 768	69 853
Fixed by Crops	4 837	4 502	4 225	4 182	4 124	4 155	4 137
Crop Residues	24 542	24 951	24 275	23 321	22 618	22 447	22 095
Total	297 768	298 074	318 212	303 567	310 635	261 416	287 874

¹¹⁵ Which is the same as stating that 1.25% of nitrogen input to soil is emitted as N₂O

¹¹⁶ To be in accordance with CRF table 4.D nitrogen is expressed after subtraction of ammonia volatilization for synthetic fertilization and animal manure. In the case of Pasture Range/ Animal Production the values refer to nitrogen deposited in soil before NH₃ subtraction

Figure 6.28 – Sources of direct input of Nitrogen to agricultural soil in 2004

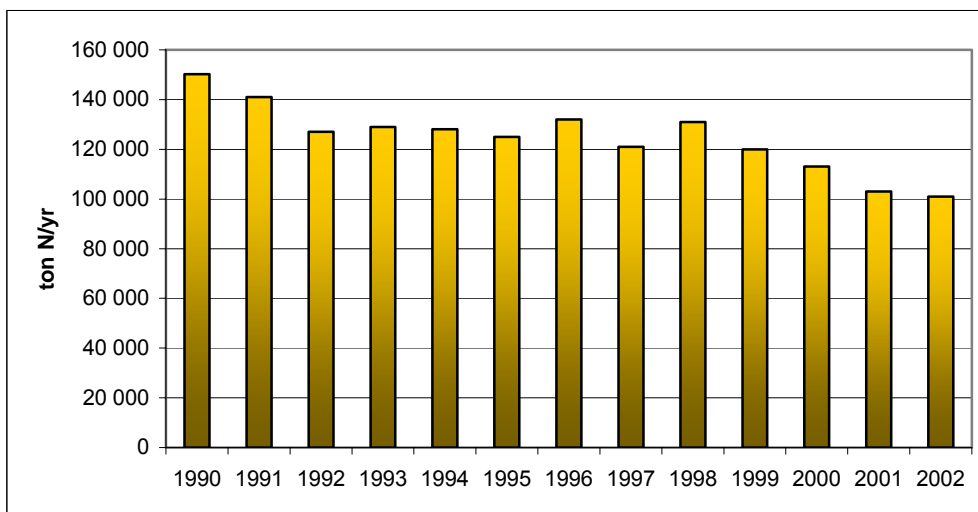


SYNTHETIC FERTILIZERS

There are no available records of statistical information concerning the annual quantity of nitrogen applied to agricultural soils or even available statistical information concerning sales of synthetic fertilizers, for the complete period from 1990 to 2004. Hence, a time series had to be constructed specifically for the Portuguese inventory from the available information.

The more complete time-series available is the FAO's statistical database (<http://faostat.fao.org>), with sales information for "Nitrogenous Fertilizers" from 1961 up to 2002. According to FAO, annual usage of nitrogenous fertilizers have decreased in Portugal from 150 200 ton N in 1990 to 101 000 ton N in 2004, i.e. a overall reduction of about 33 per cent. This series, presented in Figure 6.29, was used as activity data in the Inventory until last year's submission. However, and although its completeness, the Ministry of Agriculture and the National Statistical Institute, shown concerns about the origin of the information behind the final time series, and consider that it did not reflect clearly the situation that existed in Portugal in the period. An alternative source of information had to be pursuit.

Figure 6.29 - Use of Nitrogen Fertilizers in Portugal according to FAO (ton N/yr)



Following the need to respond to other international requests, such as the calculation of the Nitrogen Balance for the OECD/EUROSTAT, the National Statistical Institute, in collaboration with the Laboratório Químico Agrícola Rebelo da Silva¹¹⁷ and ADP¹¹⁸, having found the same lack of available data, produced a methodology (INE,2004) that estimates the Apparent Consumption of Fertilizers in the Agriculture activity (ACFA) by a simple mass balance, from sales and international market information data:

$$ACFA = Prod_{Sales} + Imports - Exports$$

Where $Prod_{Sales}$ is the annual quantity of nitrogen fertilizers produced and sold to market (excluding consumption in industry), and is based on the IAPI census¹¹⁹. Data of Imports and Exports is also from INE. The available time series is presented in Two simplifications were made: (1) Only inorganic fertilizers were considered; (2) The effect of losses and stock variation was not accounted. According to INE (2004) this factors have no significant influence in the outcome.

Figure 6.30.

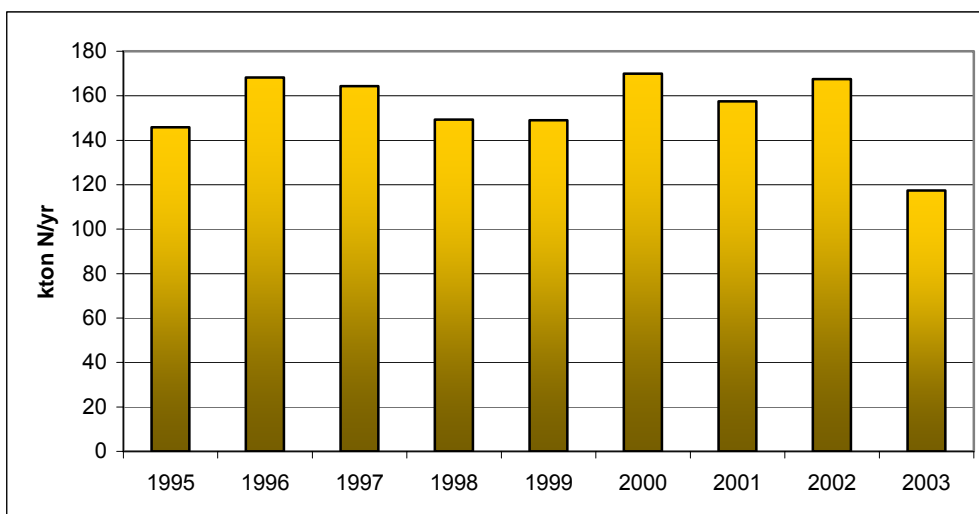
Two simplifications were made: (1) Only inorganic fertilizers were considered; (2) The effect of losses and stock variation was not accounted. According to INE (2004) this factors have no significant influence in the outcome.

¹¹⁷ Laboratório Químico Agrícola Rebelo da Silva is a public laboratory, under the Ministry of Agriculture, and since xpto proceeds to soil, plant and fertilizer analysis.

¹¹⁸ ADP, Adubos de Portugal, S.A., is the main producer of fertilizers in Portugal, and responsible for about 75% of fertilizer sales (INE,2004)

¹¹⁹ Annual census made to the Manufacturing Industry, by INE.

Figure 6.30 - Use of Nitrogen Fertilizers in Portugal according to INE for the period 1995 to 2003 (ton N/yr)



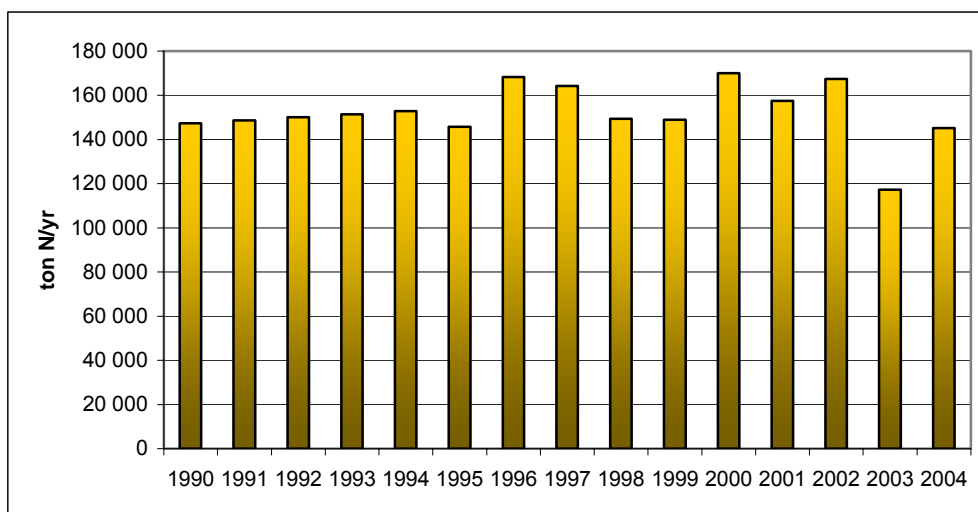
Unfortunately, due to the limited time period requested by the OECD/EUROSTAT survey (1995-2003), and the unavailability of IAPI data prior to 1992, caused the time trend to be limited in time, and not covering the Inventory base year (1990).

To overcome this limitation, and back-cast the time series to the base year, two regression curves between annual fertilizer use in 1995-2003 and estimated nitrogen fertilizer use considering annual crop production per crop and the rate of nitrogen application proposed by (MA,2000). One regression line considered the average application rate and the other assumed that the rate of application evolved in accordance with the average production per ha, also considering the variable rates from MA (2000). Neither regression curves show an adequate correlation, although the figures in the three series show a similar order of magnitude and a similar decreasing trend.

In the end, considering the difficulties in back-casting, a simple regression using time as independent variable was used, but relying only on INE's data from 1995 to 2002, and assuming that the 2003 value from INE reflects already a different situation and is not consistent with the remaining time-series. This results in a conservative approach causing underestimation emissions in the base year. The value for 2004 was also forecast using the same approach.

The line that was obtained, Figure 6.31, shows an increasing trend until 2002, being the value in 2002 less 13.7 per cent higher than the value estimated for 1990, but a decrease thereafter, where the value estimated for 2004 is slightly lower than base year (1.4 per cent). In the period where the time series is available from INE, the annual application of nitrogen fertilizers decreased by 20 per cent, from 1995 till 2003.

Figure 6.31 - Use of Nitrogen Fertilizers in Portugal, estimated from INE data and using a simple regression analysis to base year (ton N/yr)



Losses of nitrogen from volatilisation of NH_3 and NO_x were estimated using a time variable and country-specific fraction $\text{Frac}_{\text{GASF}}$, which varies between 0.053 and 0.063 kg $\text{NH}_3\text{-N/kg N}$, and which are almost half the default value from table 4-19 of IPCC96 (0.1 kg $\text{NH}_3\text{-N/kg N}$). In what concerns acidification emissions it was assumed that these emissions are fully ammonia. A more detailed explanation of the methodology and assumptions used to derive these country-specific volatilization fractions is presented in chapter NH_3 Emissions from Agriculture (Chapter 6.2.8)

ANIMAL MANURE

The quantity of nitrogen in manure that is applied to soil as fertilizer resulting in N_2O emissions was estimated from the same data that was used to estimate nitrogen excreted in N_2O from Manure Management and assuming that all the manure that is treated under Solid Storage or liquid systems is used as soil fertilizer, i.e. $\text{MSSD}_{(\text{i,s})}$ equals 1 only for Solid Storage and Liquid Systems. Concerning the other Manure Management System, Anaerobic Lagoons, 80 per cent of effluent is added to soil as fertilizer¹²⁰, in accordance with a characterization study made in Portugal (Bicudo & Albuquerque, 1995; LNEC, 1996; GPPAA, 2001)¹²¹. As explained before, under CH_4 and N_2O emissions from Manure Management, no other Manure Management Systems exist in Portugal. Quantities applied each year were also presented in Figure 6.29 and Table 6.27 above, where is shown that manure is the third major source of nitrogen applied to soil. Ammonia volatilisation factors, $\text{EF}_{\text{NH}_3(\text{i,s})}$ and $\text{EF}_{\text{NH}_3\text{SD}}$, are presented and discussed in more detail in chapter NH_3 Emissions from Agriculture (Chapter 6.2.8) and they result from EMEP/UNECE Guidebook 3rd ed (table 3A in chapter B1050). These volatilisation fractions depend only on animal class and not on the specific Manure Management System.

¹²⁰ It is not clear if the nitrogen is disposed to soil as fertilizer or only as a final disposal site, and hence better classified as the last step of the treatment process rather than fertilization. For all purposes it was assumed that N_2O emissions would occur in soil according to similar processes, and included in this source category.

¹²¹ According to the same studies the remaining nitrogen is discharge directly to water systems.

Table 6.28 – Emission factors used for calculation of NH₃ volatilisation emissions from land spreading of manure as fertilizer

Animal Type	Losses after land spreading (kg NH ₃ -N/kg N)
Cattle	0.20
Sheep, goats	0.10
Swine	0.24
Equines	0.10
Poultry	0.24
Rabbits	0.24

In the same way, the factors for calculation of ammonia volatilisation from excreta and urine deposited into grasslands during grazing are from EMEP/CORINAIR (chapter B1010 version 4.0 (Sutton, 2003)) and are presented in Table 6.29 and in detail in chapter 6.2.8. The Fraction of livestock nitrogen excreted that is directly deposited onto soil during grazing is constant and equals 28%.

Table 6.29 – Emission factors used for calculation of NH₃ volatilisation from animal droppings during grazing (Pasture Range and Paddock)

Animal Type	Grazing in Pasture
Dairy Cows	0.08
Other Cattle	0.08
Sheep	0.04
Goats	0.04
Swine	0.08
Equines	0.08

The use of emission factors of ammonia volatilisation from EMEP/UNECE results, therefore, in obtaining a value for $Frac_{GASM}$ that is different and slightly higher than the default value for $Frac_{GASM}$ (0.2 kg N-NH₃ + N-NO_x/ kg of N excreted, in table 4-19 of IPCC96). The resultant implied $Frac_{GASM}$ oscillates between 0.22 to 0.23 kg N-NH₃ + N-NO_x/ kg of N excreted¹²².

NITROGEN FIXED BY CROPS AND CROP RESIDUES RETURNED TO SOIL

Quantities of nitrogen added to soil as result of crop fixation (FBN) and in crop residues returned to soil (FCR) were estimated from crop production. The National Institute of Statistics (INE - Instituto Nacional de Estatística) records crop production each year at Regional Area level (RA - Região Agrária) for the most important species. INE also records the area under cultivation of each species allowing the estimate of productivity. For the year 1989 data gathered by the Statistical Institute was collected at a lower level of territorial desagregation: Agricultural Zone (ZA - Zona Agrária) and for 1999 the data was collected at an even thinner desagregation: Concelho. For some crops however the only available information refers to FAO Statistical Database (<http://www.apps.fao.org>) which information was used to complete the dataset.

The data series for crops that was considered in the inventory, at National level, is presented in Table 6.30 and Table 6.31 for leguminous crops and Table 6.32 to Table 6.35 for non leguminous crops. For each year a three year average centered in the reporting year was

¹²² The rates presented in previous tables are expressed in kg N-NH₃ + N-NO_x/ kg of N deposited in soil.

used¹²³. It must be stressed that not only pulses and beans were included in nitrogen fixing crops but all leguminous crops, but also included is a perennial: carob tree (*Ceratonia siliqua*). In a similar way when estimating crop residues not only annual crops were considered but also permanent crops, such as orchards and pastures, were included.

Table 6.30 – Annual (three year average) production of Leguminous Crops (metric tons) (1/2)

Crop	1990	1991	1992	1993	1994	1995	1996
Peanut ^{(1) after 1995}	29	32	29	26	20	17	20
Broad Beans ^{(1) 95-96}	15 486	15 402	15 285	15 182	14 766	15 050	12 776
Broad Beans, green	32 000	30 000	30 000	30 000	30 000	30 000	30 000
Beans	31 243	27 426	21 926	17 070	13 553	12 679	11 722
Chick-Peas	3 563	3 081	2 583	2 101	1 937	1 899	1 815
Lupins	48	43	35	37	34	34	34
Peas Green ⁽¹⁾	5 867	5 867	5 433	5 533	5 867	6 533	7 210
Carobs ⁽¹⁾	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green ⁽¹⁾	25 000	25 000	25 000	25 000	32 200	37 433	40 308
Total	133 236	126 850	120 292	114 949	118 377	123 646	123 886

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.31 - – Annual (three year average) production of Leguminous Crops (metric tons) (2/2)

Crop	1997	1998	1999	2000	2001	2002	2003	2004
Peanut ^{(1) after 1995}	23	27	25	25	25	25	25	25
Broad Beans	10 417	7 390	7 533	6 902	7 108	6 703	7 540	7 540
Broad Beans, green	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000
Beans	10 756	8 951	7 456	6 157	5 883	5 478	5 179	4 943
Chick-Peas	1 810	1 478	1 198	968	1 012	1 167	1 308	1 415
Lupins	34	34	34	34	34	34	34	34
Peas Green ⁽¹⁾	7 417	7 390	6 947	6 974	7 000	7 000	7 000	7 000
Carobs ⁽¹⁾	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green ⁽¹⁾	33 461	26 844	21 002	18 107	16 679	16 833	16 563	16 563
Total	113 917	102 114	94 195	89 166	87 742	87 240	87 649	87 520

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

¹²³ For year n the value reported as production crop is the average of n-1, n and n+1, except for last year of the inventory where only n-1 and n are used.

Table 6.32 - Annual Production of non-leguminous Crops (metric tons) (1/4)

Crop	1990	1991	1992	1993	1994	1995	1996
Wheat	510 519	425 761	467 499	415 445	414 741	409 403	364 982
Triticale	61 983	61 350	67 167	74 463	70 552	63 141	47 680
Maize	666 832	666 596	667 567	685 982	698 177	738 450	789 109
Barley	95 691	88 545	95 201	85 904	82 590	73 074	50 600
Rye	98 612	82 120	72 195	66 673	55 594	51 326	43 625
Oats	91 718	64 436	65 868	66 907	71 084	65 778	54 137
Rice Paddy	156 939	145 418	116 394	103 482	108 432	142 842	153 658
Sunflower	46 954	48 644	43 418	45 355	37 061	34 806	30 466
Hops	194	112	68	45	88	129	131
Tomatoes	714 563	657 940	552 343	612 691	742 308	877 383	848 629
Tobacco	5 072	4 901	4 108	3 855	4 059	5 283	5 665
Tea ⁽¹⁾	170	127	73	43	48	62	57
Chicory ⁽¹⁾	2 203	2 533	2 761	3 035	2 855	2 644	2 391
Potatoes	1 374 093	1 448 989	1 445 498	1 428 786	1 374 603	1 329 139	1 159 229
Sugar Beet	12 225	14 627	21 051	33 769	46 346	46 492	79 635
Yams ⁽¹⁾ after 1994	1 294	1 438	1 369	1 314	1 182	1 176	1 535
Sugar Cane ⁽¹⁾ after 1991	3 760	3 878	3 996	4 000	4 000	4 000	4 000
Sweet Potatoes ⁽¹⁾	27 000	26 667	28 000	27 333	26 333	23 667	22 667
Maize for Forage ⁽¹⁾	3 398 333	3 545 000	3 883 333	4 228 333	4 511 667	4 633 333	4 766 667
Sorghum for Forage ⁽¹⁾	331 667	363 333	361 667	356 667	341 667	346 667	360 000
Roots Fodder ⁽¹⁾	378 333	383 333	388 333	393 333	386 667	395 000	401 667
Forage ⁽¹⁾	6 300 000	6 033 333	5 833 333	6 033 333	6 433 333	6 866 667	6 933 333
Pumpkins ⁽¹⁾	4 200	4 200	4 033	3 867	6 600	9 700	12 600
Lettuce ⁽¹⁾ until 1996	32 000	32 000	34 667	40 000	49 267	56 367	62 761
Garlic ⁽¹⁾	1 667	1 667	1 533	1 467	1 467	1 467	1 433
Eggplants ⁽¹⁾	6 667	6 667	6 100	5 833	5 833	5 833	5 667
Onions ⁽¹⁾ until 1996	57 200	57 200	68 133	82 400	101 933	107 900	109 540
Carrots ⁽¹⁾ until 1996	82 667	83 000	83 000	83 000	97 700	128 133	139 062
Cauliflower ⁽¹⁾ until 1996	19 667	20 000	20 000	20 000	23 300	26 700	29 441
Cabbages ⁽¹⁾ until 1996	166 667	166 667	153 333	146 667	150 000	150 000	195 705
Spinach ⁽¹⁾	16 667	16 667	15 333	14 667	14 667	14 667	14 333
Watermelons ⁽²⁾ until 1996	64 385	43 959	32 427	22 478	24 772	26 355	35 514
Melons ⁽²⁾ until 1996	127 281	109 970	91 754	73 780	80 667	85 122	95 546
Cucumbers ⁽¹⁾	8 333	8 333	7 667	7 333	7 333	7 333	7 167
Chillies ⁽²⁾ until 1996	51 662	48 786	45 088	44 346	49 506	52 461	50 178
Mushrooms ⁽¹⁾	1 000	1 000	1 000	1 000	1 000	1 000	1 000

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>); (2) FAO data used as trend for previous years

Table 6.33 - Annual Production of non-leguminous Crops (metric tons) (2/4)

Crop	1997	1998	1999	2000	2001	2002	2003	2004
Wheat	295 345	277 452	285 933	286 823	307 120	238 743	237 400	149 581
Triticale	37 354	29 787	30 216	29 849	27 295	17 622	15 984	11 275
Maize	877 874	926 044	930 023	905 264	859 531	833 755	797 548	798 021
Barley	41 648	28 096	30 613	26 075	22 982	15 208	15 353	13 022
Rye	42 367	42 930	44 851	42 086	34 980	28 481	29 402	26 955
Oats	44 496	57 578	80 278	83 605	70 852	46 394	46 501	39 019
Rice Paddy	166 064	159 204	152 012	146 731	144 816	146 546	147 170	147 802
Sunflower	34 319	27 399	27 928	23 242	24 443	20 926	19 056	18 015
Hops	107	72	52	51	50	48	42	35
Tomatoes	931 862	963 897	996 516	937 512	889 848	891 044	885 259	894 181
Tobacco	6 310	6 170	6 267	5 895	5 834	5 700	5 691	5 735
Tea ⁽¹⁾	37	25	26	27	27	27	27	27
Chicory ⁽¹⁾	2 290	2 342	2 220	2 633	2 967	3 033	2 767	2 500
Potatoes	996 255	913 913	874 442	795 252	739 309	737 055	750 981	735 828
Sugar Beet	123 188	280 829	384 902	415 982	462 161	469 632	537 386	484 149
Yams ⁽¹⁾ after 1994	1 770	2 091	2 100	2 100	2 100	2 100	2 100	2 100
Sugar Cane ⁽¹⁾ after 1991	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Sweet Potatoes ⁽¹⁾	22 000	22 000	22 000	22 000	22 000	22 000	22 000	22 000
Maize for Forage ⁽¹⁾	4 926 667	4 966 667	5 000 000	5 000 000	5 000 000	5 000 000	5 000 000	5 016 667
Sorghum for Forage ⁽¹⁾	360 000	360 000	360 000	360 000	360 000	360 000	360 000	363 333
Roots Fodder ⁽¹⁾	418 333	420 000	420 000	420 000	420 000	420 000	420 000	423 333
Forage ⁽¹⁾	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 216 667
Pumpkins ⁽¹⁾	12 600	12 167	12 000	12 000	12 000	12 000	12 000	12 000
Lettuce	74 069	84 876	79 469	66 190	54 680	57 424	59 192	59 192
Garlic ⁽¹⁾	1 400	1 400	1 400	1 400	1 400	1 400	1 400	1 400
Eggplants ⁽¹⁾	5 500	5 500	5 500	5 500	5 500	5 500	5 500	5 500
Onions	104 479	108 760	85 286	62 362	34 474	35 335	37 079	37 079
Carrots	144 900	144 646	123 294	90 898	49 775	49 255	50 170	50 170
Cauliflower	29 823	31 140	26 201	20 378	14 715	15 966	17 161	17 161
Cabbages	248 032	316 469	268 789	209 110	153 837	165 642	179 489	179 489
Spinach ⁽¹⁾	14 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000
Watermelons	45 463	55 412	43 959	32 427	22 478	24 772	26 355	26 355
Melons	109 307	127 281	109 970	91 754	73 780	80 667	85 122	85 122
Cucumbers ⁽¹⁾	7 000	7 000	7 000	7 000	7 000	7 000	7 000	7 000
Chillies	50 920	51 662	48 786	45 088	44 346	49 506	52 461	52 461
Mushrooms ⁽¹⁾	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.34 - Annual Production of non-leguminous Crops (metric tons) (3/4)

Crop	1990	1991	1992	1993	1994	1995	1996
Quinces	4 567	4 067	3 560	3 793	3 148	2 647	1 916
Loquat	1 528	1 594	1 527	1 622	1 606	1 666	1 552
Pomegranate	1 803	1 803	1 770	1 737	1 667	1 636	1 422
Pineapples ⁽¹⁾ after 1992	1 476	1 760	1 927	2 093	2 000	2 000	2 000
Bananas ⁽¹⁾ after 1993	43 648	41 156	38 300	37 667	35 000	32 667	31 667
Peach	90 123	94 948	97 090	95 860	90 813	85 731	83 124
Apples	270 551	275 635	269 502	252 390	237 011	234 541	259 108
Kiwi	3 406	5 863	8 403	9 808	9 412	9 554	9 960
Pears	93 580	96 660	97 790	110 070	104 094	108 363	127 956
Sour Cherries	642	682	713	677	630	606	444
Fig	15 100	14 683	13 583	10 809	8 330	6 656	5 548
Kaki	4 650	4 633	4 460	4 393	3 633	2 785	1 582
Apricots	4 543	4 610	4 480	4 695	4 812	4 956	4 904
Cherry	11 795	13 333	13 940	13 291	11 425	10 892	10 841
Plum	16 332	16 639	15 935	16 747	17 162	17 757	17 812
Avocados ⁽¹⁾	20 967	20 333	18 667	16 233	14 100	13 000	13 000
Strawberries ⁽¹⁾	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Raspberries ⁽¹⁾	100	100	100	100	100	100	100
Berries nes ⁽¹⁾	100	133	133	133	100	100	100
Tangerine	25 125	25 623	26 741	29 525	32 194	34 769	34 906
Lemon	10 117	10 438	10 518	10 791	10 906	10 402	9 981
Orange	169 155	174 974	173 802	179 825	190 173	191 883	199 290
Pomelo	4 950	5 267	5 550	5 909	6 320	6 769	6 863
Grapefruit	832	800	760	852	924	996	964
Walnut	5 610	5 283	4 508	3 550	3 105	3 053	3 245
Chestnuts	19 052	17 358	15 266	17 174	19 602	23 316	24 956
Hazelnuts	1 993	1 900	1 690	1 435	1 116	976	865
Almonds	50 377	48 375	47 548	38 783	31 320	26 406	31 049
Olives (Oil)	302 638	246 248	266 260	200 115	256 993	269 537	298 497
Olives (fruit)	21 400	19 900	16 821	12 491	9 823	9 156	9 248
Wine grapes	1 285 581	1 285 582	997 133	826 044	834 841	1 036 179	1 015 820
Grapes ⁽¹⁾	52 752	54 418	52 867	52 112	53 445	55 401	58 131

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.35 - Annual Production of non-leguminous Crops (metric tons) (4/4)

Crop	1997	1998	1999	2000	2001	2002	2003	2004
Quinces	1 819	1 990	2 110	2 203	2 090	2 061	2 068	2 077
Loquat	1 388	1 142	948	888	903	885	869	851
Pomegranate	1 142	743	527	411	411	403	395	387
Pineapples ⁽¹⁾ after 1993	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Bananas ⁽¹⁾ after 1992	31 667	33 333	35 000	35 000	33 333	30 000	30 000	30 000
Peach	71 005	69 346	62 671	53 891	50 153	47 930	57 986	56 927
Apples	234 168	246 816	227 159	261 999	263 940	284 190	291 823	287 493
Kiwi	8 711	8 822	8 315	9 148	9 237	9 774	10 754	10 549
Pears	140 384	147 176	131 057	138 305	136 302	118 911	101 540	89 664
Sour Cherries	268	110	95	91	64	42	42	42
Fig	4 700	3 952	3 840	3 790	3 632	3 634	3 602	3 521
Kaki	994	1 240	1 799	2 591	2 810	3 030	3 162	3 229
Apricots	4 507	4 956	5 148	4 742	4 242	3 907	4 540	4 541
Cherry	9 044	10 786	9 506	12 123	13 201	15 368	16 087	14 135
Plum	16 743	16 975	16 214	15 108	14 478	14 893	16 669	16 781
Avocados ⁽¹⁾	13 000	13 000	13 000	13 000	13 000	13 000	13 000	13 000
Strawberries ⁽¹⁾	2 500	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Raspberries ⁽¹⁾	100	100	100	100	100	100	100	100
Berries nes ⁽¹⁾	100	100	100	100	100	100	100	100
Tangerine	35 814	39 763	42 052	44 924	48 097	53 997	58 489	59 801
Lemon	9 301	9 864	10 516	11 260	11 447	12 019	12 710	13 474
Orange	219 960	231 015	245 725	229 659	251 633	258 756	277 043	276 917
Pomelo	6 868	5 816	4 788	3 774	4 021	4 140	4 249	4 133
Grapefruit	880	657	471	306	287	255	242	228
Walnut	3 331	3 740	3 880	4 322	4 323	4 530	4 563	4 545
Chestnuts	26 981	28 880	31 200	30 135	30 273	30 257	32 640	33 267
Hazelnuts	802	752	668	641	614	596	604	596
Almonds	31 464	33 263	28 821	25 804	24 539	23 470	26 165	23 829
Olives (Oil)	269 950	285 190	237 880	235 516	199 086	221 014	225 822	232 947
Olives (fruit)	9 275	10 160	9 253	10 947	10 952	12 199	11 409	11 291
Wine grapes	818 094	733 423	763 925	940 712	893 026	890 074	875 764	910 998
Grapes ⁽¹⁾	52 392	52 370	49 675	53 888	54 641	54 338	54 315	52 415

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

The Nitrogen fixed by crops was estimated from the ratio of residue to crop product mass ($Res_{BF}/Crop_{BF}$), the fraction of dry matter in product ($Frac_{DM}$) and the fraction of dry biomass in the whole plant that is nitrogen ($Frac_{NCRBF}$). These parameters were established for each leguminous plant using the default IPCC values (table 4.17 of IPCC 1996 Revised Guidelines which was latter replaced by table 4.16 of Good Practice Handbook) when available, and from other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in Table 6.36

Table 6.36 – Parameters considered for determination of N fixed by nitrogen fixing plants

Crop	Res _{BF} /Crop _{BF}	Frac _{DM} (%)	Frac _{NCRBF} (%)
Peanut	1.0	86.0	1.06
Broad Beans	1.5	86.5	2.02
Broad Beans, green	1.5	35.0	2.02
Beans	2.1	85.5	2.62
Chick-Peas	1.5	85.0	2.62
Lupins	1.5	85.0	2.96
Peas Green	1.5	87.0	1.42
Carobs	1.0	85.0	2.62
Beans Green	1.5	20.0	2.62

Nitrogen added to soil in crop residue was also estimated from Res/Crop, Frac_{DM} and Frac_{NCR}. Values for estimation of nitrogen in residues from nitrogen fixing plants are the same that were used in the estimate of nitrogen fixed by crops (Table 6.36). The values for other non-leguminous crops were determined from IPCC defaults (IPCC96 and GP) and other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in next table.

Table 6.37 - Parameters for determination of N added to soil in crop residue from non-leguminous plants

Crop	Res _{BF} /Crop _{BF}	Frac _{DM} (%)	Frac _{NCRO} (%)
Wheat	1.30	85.0	0.28
Triticale	1.45	87.5	0.38
Maize	1.00	78.0	0.81
Barley	1.20	85.0	0.43
Rye	1.60	90.0	0.48
Oats	1.30	92.0	0.70
Rice	1.40	85.0	0.67
Sunflower	1.00	93.3	1.94
Hops	0.10	0.0	0.00
Tomatoes	2.00	27.0	1.50
Tobacco	2.00	15.0	0.67
Tea	2.00	15.0	0.67
Chicory	2.00	15.0	0.67
Potatoes	0.40	22.0	1.10
Sugar Beet	0.20	15.0	1.50
Yams	1.00	15.0	1.50
Sugar Cane	1.00	83.0	0.40
Sugar Potato	0.40	22.0	1.10
Maize for Forage	0.09	17.8	1.58
Sorghum for Forage	0.09	27.6	1.08
Roots Fodder	0.30	10.0	2.28
Forage	0.09	20.0	1.08
Pumpkins	1.00	15.0	1.50
Lettuce	0.10	10.0	1.36
Garlic	0.10	10.0	1.36
Eggplants	1.00	15.0	1.50
Onions	0.10	10.0	1.36
Carrots	0.10	12.5	1.36
Cauliflower	0.10	13.5	2.70
Cabbages	0.10	13.5	2.70
Spinach	0.10	10.0	1.36
Fresh Fruit ^(a)	1.00	15.0	1.50
Dry Fruits ^(b)	1.00	85.0	1.50
Olives	1.00	15.0	1.50
Wine/ Grapes	1.00	15.0	1.50

(a) Fresh fruit: Watermelon, Melons, Cucumbers, Chillies, Mushrooms and fruits from orchards (Apples, pears, etc); (b) dry fruit: Walnut, Chestnuts, Hazelnuts, Almonds and other dry fruits

In estimating the parameter FCR the following assumption was also made: - Frac_{FUEL}, Frac_{CNST} and Frac_{FOD} were set to zero for all crops. Use of crop residues as combustible has negligible expression in Portugal and also there is no tradition of its use as a building material. Although some residues are used as animal feeding, particularly, as result of grazing in after harvesting cereal areas, it is not possible to estimate that fraction quantitatively. Using a conservative approach it was decided not to remove this part of nitrogen added to soil: this approach may result however in some doubling counting of nitrogen added to soil in this sub-category and in nitrogen added to soil from animal production (Pasture Range and Paddock).

In a consistent way, Frac_{BURN} is the same value used in estimate of GHG emissions from field burning of agriculture residues, as presented in previous chapter.

6.3.E.5 UNCERTAINTY ASSESSMENT

The Good Practice Guidebook presents no information concerning the uncertainty in activity data, and therefore, the values were set in the following mode:

Synthetic Fertilizers: Apart from the time series of the total quantity of nitrogen applied in synthetic fertilizers from INE, that was considered as activity data for the period 1995-2000, other estimates are available or were made for the inventory for the same time period: PNAC studies (Seixas et al, 1999), FAO statistical database and the estimates of nitrogen necessity using the Good Practice Use of Fertilizers (MA,2000). Comparing the values of nitrogen in synthetic fertilizers from these independent data sources between 1995 and 2000 a maximum uncertainty value of 17 per cent was obtained. This value represents a good reduction in uncertainty since last submission, when the uncertainty amounted to 66 per cent;

For nitrogen in animal manure applied to soil and animal production the same uncertainty value that was used for activity data in N₂O from Manure Management was used and increased, in the case of animal manure applied to soil, by 100 per cent due to the uncertainty in the percentage of manure that ends up in soil;

An uncertainty error of 25 per cent in crop production was considered in accordance with GPG considerations about overall error for the all source sector;

Errors due to determination of nitrogen volatilization are difficult to access because of the interconnections with indirect emissions, and were quantified only in source category Indirect N₂O emissions from Agricultural Soils.

GPG presents a possible variation from one-fifth to 5 times the default emission factor of 1.25 per cent. From that range an uncertainty of 500 per cent was assumed in uncertainty analysis for nitrogen applied as synthetic fertilizers, manure, crop residues and nitrogen fixed by n-fixing crops. Considering that in the cases of nitrogen added to soil from n-fixing crops and crop residues, an additional 100 per cent uncertainty was added to take into account errors in the determination of nitrogen content of crops and residues from production. In the case of animal production a lower uncertainty of 100 per cent was used, following table 4.12 of the GPG.

6.3.E.6 RECALCULATIONS

The most important direct modification in this source category were:

- the revision of the time series of use of nitrogen fertilizers in agriculture. Although the new time series show similar order of magnitude comparable to previous values from FAO, the trend shows now an increase in nitrogen use (and emissions) in contrasts to the previous situation, where use and emissions were decreasing;
- the inclusion of part of the effluents from the Anaerobic Lagoons (Liquid Systems) as nitrogen added to soil.

Also, the emission estimates for this source category reflect also the changes in livestock numbers and nitrogen excretion rates that were explained in previous chapters.

6.3.E.7 FURTHER IMPROVEMENTS

The share of each nitrogen fertilizer, particularly the importance of urea use, is still under consideration by INE and will be used to improve the preliminary estimate that was made by IA and that is temporarily being used in this year report.

Although the lack of suitable statistical information, efforts will continue to quantify the nitrogen in sewage sludge that is used as soil fertilizer.

6.3.F Indirect N₂O Emissions from Agriculture (CRF 4D2)

6.3.F.1 OVERVIEW

Emissions of N₂O from agriculture are considered indirect emissions from agriculture when they result from nitrogen that was not emitted when was applied the first time into soil but that has first suffered a path through the atmospheric system - after volatilisation as ammonia or nitrogen oxides and intermediate transformation in nitric acid and ammonium salts in particulate or aerosol form- or in the soil-water system - after leaching and/or runoff as ammonia, nitrite, nitrate or light organic compounds.

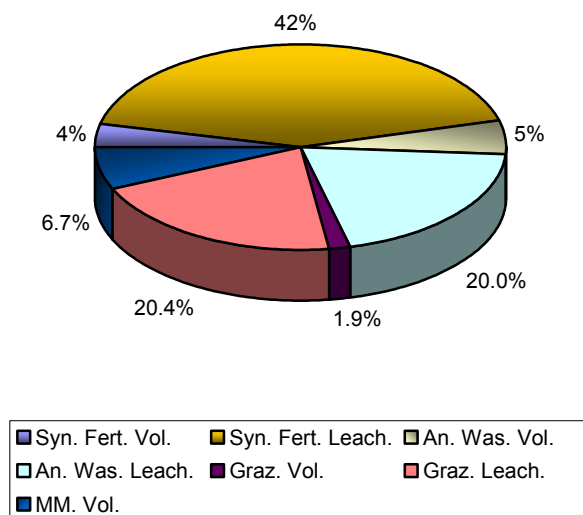
Actually N₂O indirect emissions result from the same microbial process associated to nitrification and denitrification that causes direct emissions. The only difference results from the fact that direct emissions occur solely in agricultural soils whether indirect emissions will occur in whenever conditions are adequate: in agricultural soils, non agricultural soils and even aquatic, Benthic and wetland systems.

Also, all NO_x and NH₃ emissions from other emissions sources may settle in soil and water and result in similar N₂O emissions. However, estimates of indirect emissions from these sources are not included in the portuguese inventory.

Indirect emissions of N₂O from ammonia and NO_x volatilisation were estimated from ammonia volatilised whether actual indirect N₂O emissions occurred in the Portuguese territory or not. In the case of N₂O indirect emissions from leaching and runoff the geographical characteristics of the territory - where there are no water basins discharging to other countries - cause that all indirect emissions will occur still on the national territory or nearby ocean waters¹²⁴.

As may be seen from Figure 6.37, where the percent importance of each sub-source is represented for year 2004, indirect emissions from runoff and leaching from synthetic fertilizers, animal manure applied to soil and direct droppings during grazing are significant sources.

¹²⁴ In fact, part of indirect N₂O emissions from leaching and runoff from agriculture activities in Spain will occur most probably in Portuguese territory. These emissions are not included however in the Portuguese inventory.

Figure 6.32 – Relative importance of Indirect emissions of N₂O from agriculture in year 2003

6.3.F.2 METHODOLOGY

Different methodologies were used to estimate emissions for:

N₂O_(G), Indirect N₂O emissions from atmospheric deposition of nitrogen that has volatilised as NO_x and ammonia from nitrogen used in agriculture as an external input¹²⁵, either synthetic or in animal manure. The following equation, that is similar to GPG Tier1a equation, was utilized for N₂O emissions from volatilisation:

$$N_2O_{(G)} = 44/28 * (SF_NVol + MMS_NVol + AM_NVol + GR_NVol) * EF_4$$

where

SF_NVol - Total volatilisation, as ammonia or nitrogen oxides, of the nitrogen from synthetic fertilizers applied to soil (ton NH₃-N+NO_x-N/yr);

MMS_NVol - Volatilisation of nitrogen from manure in Manure Management Systems (emissions in housing and outside storage) (ton NH₃-N+NO_x-N/yr);

AM_NVol - Volatilisation of nitrogen from manure applied to soil as fertilizer (ton NH₃-N+NO_x-N/yr);

GR_NVol - Volatilisation of nitrogen from animal excreta deposited in soil during grazing in pasture range and paddock (ton NH₃-N+NO_x-N/yr);

EF₄ - Emission factor for N₂O emissions from atmospheric deposition of nitrogen on soil and water surfaces (kg N₂O-N/kg NH₃-N+kg NO_x-N).

¹²⁵ No indirect N₂O emissions are estimated from nitrogen leached or removed in runoff from nitrogen fixation by leguminous plants or from nitrogen in crop residues.

Methodologies for the estimation of ammonia from synthetic fertilizers, manure and animal excreta are explained in chapter NH₃ Emissions from agriculture (6.2.8). It was assumed that volatilisation emissions occurs predominantly in ammonia form.

Indirect N₂O emissions from nitrogen that was removed from agricultural soils after being applied as fertilizer - either as synthetic fertilizer or as manure - and from there removed as consequence of infiltration/percolation and runoff was estimated from next equation, that is proposed in GPG (equation 4.35 or 4.37):

$$N_2O_{(L)} = 44/28 * (N_{Fert} + N_{AM} + N_{GR}) * Frac_{LEACH} * EF_5$$

where,

N_{Fert} - Annual amount of synthetic fertilizer nitrogen applied to soils (ton N/yr);

N_{AM} - Annual amount of animal manure nitrogen intentionally applied to soils (ton N/yr), calculated from:

$$N_{AM} = \sum_i \{N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})]\}$$

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

$MSSD_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i,s)}$ - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

N_{GR} - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture;

$Frac_{LEACH}$ - Fraction of N input that is lost through leaching and runoff

EF_5 - Emission factor for leaching/runoff (Kg N₂O / kg NH₃-N + NO_x-N)

6.3.F.3 EMISSION FACTORS

Default IPCC emission factors were used for EF_4 and EF_5 (table 4-23 of the 1996 IPCC and table 4.18 of the GPG):

Table 6.38 – Emission factors for N₂O indirect emissions from agricultural soil

Emission Factor	Kg N ₂ O / kg NH ₃ -N + NO _x -N
EF4 (Deposited nitrogen from volatilization)	0.010
EF5 (Leaching and Runoff)	0.025

GPG recommends strongly the use of the default IPCC emission factor for deposited nitrogen after volatilisation (EF₄). According to GPG the default value for EF₅ will be probably revised in the near future.

6.3.F.4 ACTIVITY DATA

Emissions of N₂O from atmospheric deposition of nitrogen compounds that were volatilised consider 4 components: SF_NVol; MMS_NVol; AM_NVol and GR_NVol, that are presented in Table 6.39 and Table 6.40 and which contribution of sub-sources in year 2004 is presented in Figure 6.33. Nitrogen from NH₃ volatilisation from Manure Management Systems was the major contributor to indirect emissions with about 39 per cent of total deposition in 2004. The following most important components are nitrogen in manure applied to soil as fertilizer (29 per cent) and nitrogen volatilised from synthetic fertilizers (21 per cent). Nitrogen in droppings during grazing is a less important source with 10.9 per cent of emissions in 2004. Total ammonia emissions and deposition has grown about 6.3 per cent from base year to last year in the inventory.

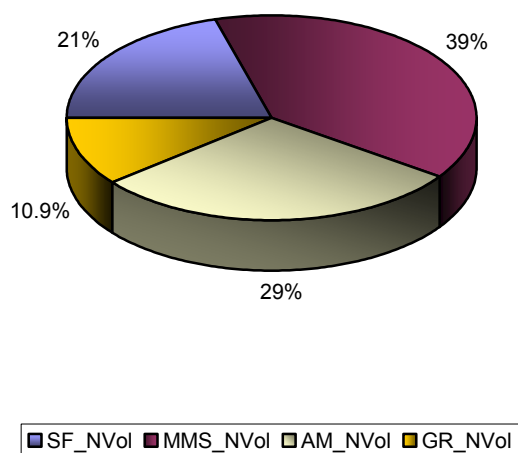
Table 6.39 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1990-1996)

ton NH ₃ /yr	1990	1991	1992	1993	1994	1995	1996
SF_NVol	7 789	7 968	8 503	7 263	8 867	8 187	9 904
MMS_NVol	16 784	17 092	17 144	17 467	17 574	17 738	17 692
AM_NVol	12 844	13 030	13 034	13 252	13 311	13 432	13 407
GR_NVol	4 269	4 326	4 277	4 288	4 320	4 429	4 531
Total	41 686	42 416	42 958	42 270	44 071	43 786	45 535

Table 6.40 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1997-2004)

ton NH ₃ /yr	1997	1998	1999	2000	2001	2002	2003	2004
SF_NVol	10 325	8 453	8 965	9 744	9 573	10 299	7 302	9 141
MMS_NVol	17 782	18 096	18 290	18 415	18 162	17 951	17 436	17 308
AM_NVol	13 446	13 636	13 746	13 819	13 601	13 415	13 017	12 928
GR_NVol	4 612	4 689	4 739	4 777	4 768	4 748	4 745	4 821
Total	46 166	44 873	45 740	46 755	46 105	46 413	42 499	44 199

Figure 6.33 – Percent importance of nitrogen added to soil from volatilization of ammonia applied to agricultural soils, by emission source/component (2004)



The fraction of nitrogen input to soil that is lost through leaching and runoff ($Frac_{LEACH}$) was set as 0.3 kg N/kg N, the default value in IPCC96. The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in tables Table 6.41 and Table 6.42 and in Figure 6.34, for each component that is considered in lixiviation/runoff estimate: FSN, FAM and FGR. Nitrogen added to soil in synthetic fertilizers is the major lixiviation/runoff source. From 1990 to 2003 nitrogen deposited into soil has increased by 1.8 per cent.

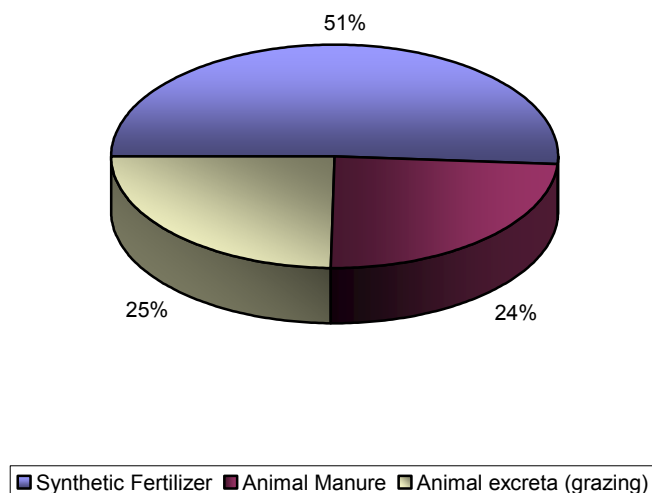
Table 6.41 – Nitrogen Lost from soil from lixiviation and runoff (1990-1996)

ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizer	44 200	44 610	45 020	45 430	45 839	43 745	50 469
Animal Manure	20 485	20 795	20 803	21 140	21 240	21 434	21 407
Animal excreta (grazing)	18 919	19 161	18 969	19 017	19 167	19 604	20 009
Total	83 603	84 566	84 791	85 586	86 246	84 782	91 885

Table 6.42 – Nitrogen Lost from soil from lixiviation and runoff (1990-1996)

ton N/yr	1997	1998	1999	2000	2001	2001	2002	2003	2004
Synthetic Fertilizer	49 286	44 791	44 683	51 003	47 253	50 239	35 207	43 573	49 286
Animal Manure	21 462	21 747	21 904	22 007	21 650	21 334	20 702	20 585	21 462
Animal excreta (grazing)	20 294	20 605	20 812	20 973	20 869	20 710	20 630	20 956	20 294
Total	91 042	87 143	87 400	93 982	89 771	92 282	76 540	85 113	91 042

Figure 6.34 – percent importance of sub-sources of Nitrogen Lost from soil from lixiviation and runoff in 2004



6.3.F.5 UNCERTAINTY ASSESSMENT

The uncertainty in emission factors was set at an order of magnitude, in accordance with the considerations in GPG (IPCC,2000). In what concerns the uncertainty associated with activity data an additional 50% error was applied to the uncertainty in activity data reported in N₂O Direct emissions, in order to incorporate the error of the volatilization and leaching fractions, also in accordance with GPG (IPCC,2000), and the final resultant uncertainty value is 63 per cent.

6.3.F.6 RECALCULATIONS

Changes in emission estimates of N₂O Indirect emissions resulted only indirectly from changes in the quantity of manure that is produced and applied to soil, the quantity of synthetic fertilizers added to soil as fertilizers (discussed in chapter 6.2.3).

6.3.F.7 FURTHER IMPROVEMENTS

No major modifications are expected for this source sector.

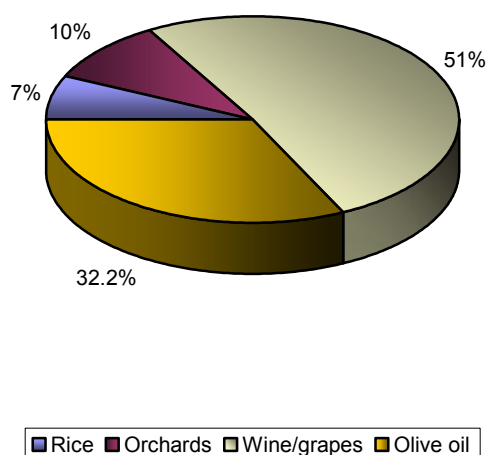
6.3.G Field Burning of Agriculture Residues (CRF 4F)

6.3.G.1 OVERVIEW

In-site burning of agricultural residues is still practiced nowadays in Portugal, being however forbidden by law-decree during the Forest Fire Season from May to September. This burning, results in emissions of trace gases as in other combustion processes, including methane, nitrous oxide, carbon monoxide, nitrous oxides and volatile organic compounds. Carbon dioxide is of course also emitted in this process but because it has biomass origin and it is in principle re-absorbed during next growing season, it is not considered in GHG emission inventory.

Considering equivalent carbon dioxide emissions (Figure 6.35), burning of residues from vineyards and olive oil are the most significant sources of this non-key source.

Figure 6.35 – Importance of GHG emissions from field burning of agriculture residues by crop in 2003



6.3.G.2 METHODOLOGY

Emissions of in-site burning of agriculture residues were estimated from the following equation:

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

where

$\text{Emission}_{(p,crop,y)}$ - Emission estimate of pollutant p from field burning of residues from a specific crop in year y (ton/year);

$\text{Crop}_{\text{BURN}(crop,y)}$ - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{EF}_{(p,crop)}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm).

Other methodology formulations could be used that would result in equal results. However activity data definition in dry matter terms was chosen in order that emission factors would be expressed in the same units that are presented in Implied Emission Factors (IEF) of table 4.F of CRF format. Consequently part of methodology that is in fact used to determine emissions, is included in emission factor determination and part also in activity data determination and they are subsequently described in the appropriate chapters. But for all relevant aspects, the methodology that it is used, follow the same methodology proposed in IPCC96 except for the fact that residue biomass is not estimated from crop production but from residue production quantities by cultivated area.

6.3.G.3 EMISSION FACTORS

Except for NMVOC and Particulate Matter, emission factors for each specific pollutant are estimated from different equations whether they are carbon containing pollutants (CO_2 , CH_4 and

CO) or nitrogen containing pollutants (NO_x and N₂O). This methodology - after IPCC96 - assumes that some fixed part of carbon and nitrogen that are submitted to burning are emitted as specific compounds.

For carbon containing pollutants the equation is:

$$EF_{(pol,crop)} = C_{Fraction (Crop)} * Frac_{RESOXI (crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

For nitrogen containing compounds the equation is:

$$EF_{(pol,crop)} = C_{Fraction (Crop)} * Frac_{RESOXI (crop)} * NC_{Ratio (crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

where

$EF_{(pol,crop)}$ - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$C_{Fraction (Crop)}$ - Ratio of carbon content in dry biomass matter (kg C/kg dm);

$Frac_{RESOXI (crop)}$ - Fraction or ratio of carbon that it is oxidized during the active burning period (kg C/kg C);

$NC_{Ratio (crop)}$ - Ratio of nitrogen to carbon in crop residue (kg N/kg C);

$ER_{(crop,pol)}$ - Emission ratio, the fraction of total carbon/nitrogen content that it is emitted as pollutant pol (kg C/kg C or kg N/kg N);

$MWC_{(Pol)}$ - Stechiometric correction fraction to convert emissions in carbon/nitrogen units to total molecular weight emissions (kg/kg C or kg/kg N respectively for carbon compounds or nitrogen compounds).

The parameters used to establish emission factors for each crop are presented in next table.

Table 6.43 – Parameters used for determination of emission factors for field burning of agricultural residues

Crop	C _{fraction}	Frac _{RESOXI}	NC _{Ratio}
Rice	0.6	0.9	0.04
Orchards	0.6	0.9	0.05
Wine/Grapes	0.6	0.9	0.04
Olive oil	0.6	0.9	0.04

The pollutant specific emission ratios that were used follow the IPCC default emission ratios proposed in table 4-17 of IPCC96 and which were still not updated in GPG (Annex 4.A.2).

Table 6.44 – Pollutant specific emission ratios for determination of emissions from field burning of agricultural residues

Pollutant	Emission Ratio (ER)	Units	MWC Ratio
CH ₄	0.5	% Carbon Released from fuel	16/12
N ₂ O	0.7		44/28
CO	6.0		28/12
NO _x	12.1		46/14

The emission factors for NMVOC and Particulate Matter are those proposed by AP-42 (USEPA,1992), which are reproduced in Table 6.45, together with final emission factors for all other pollutants and all crops.

Table 6.45 – Final emission factors for field burning of agricultural residues by pollutant and crop

Crop	CH ₄	N ₂ O	NO _x	CO	NMVOC	TSP	PM ₁₀ -PM ₁
Rice	2.1	0.14	5	44.2	15.6	15.6	100%
Fresh Fruits	0.4	0.04	1.3	9.1	2.0	2.2	100%
Citrines	0.4	0.04	1.3	9.1	4.0	2.4	100%
Dry fruits	0.4	0.04	1.3	9.1	2.4	2.4	100%
Wine/grapes	1.8	0.12	4.3	37.8	7.5	7.5	100%
Olive oil	0.7	0.04	1.6	14.2	2.6	2.3	100%

6.3.G.4 ACTIVITY DATA

According to expert information from the Ministry of Agriculture (Seixas et al, 2000) only vegetal residues from wine, olive oil cultivation and orchards¹²⁶ are subjected to significant on-site burning.

The basic activity data available from the National Statistical Institute that was used is area cultivated for each relevant crop. Expert opinion from the Agriculture Ministry (Seixas et al,2000) was used to established the quantity of residues that is generated annually by each crop and what percentage is actually burnt in site. Activity data in suitable units is estimated from:

$$\text{Crop}_{\text{BURN (crop,y)}} = \text{Crop}_{\text{AREA(crop,y)}} * \text{Resid}_{\text{PROD (crop)}} * \text{Dm}_{\text{Content(crop)}} * \text{Frac}_{\text{RESBURN (crop)}} * 10^{-7}$$

where

$\text{Crop}_{\text{BURN (crop,y)}}$ - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{Crop}_{\text{AREA (crop,y)}}$ - Cultivated area for each specific crop in year y (ha/yr);

$\text{Resid}_{\text{PROD (crop)}}$ - Quantity of residue generated from each unit cultivation area of crop y expressed in live weight (kg/ha);

$\text{Dm}_{\text{Content(crop)}}$ - Dry matter content of crop residues (% dm/live weight);

¹²⁶ Comprehending fresh fruit, citrines and dry fruits (nuts)

Frac_{RESBURN (crop)} - Fraction of total residues from a specific crop that are burnt in site (%).

Parameters Resid_{PROD}, Dm_{Content} and Frac_{RESBURN} are the same considered in (Seixas et al, 2000) and are presented in Table 6.46. Final activity data expressed in crop area dry matter content may be seen in Table 6.46 and Table 6.47, and in Table 6.48.

Table 6.46 – Parameters used for the estimation of the quantity of burnt crop residues

Crop	Resid _{PROD} kg live weight/ha	Frac _{RESBURN} %	DMContent %
Rice	3 900	50	30
Orchards	800	30	50
Wine/Grapes	2 500	40	50
Olive oil	375	100	50

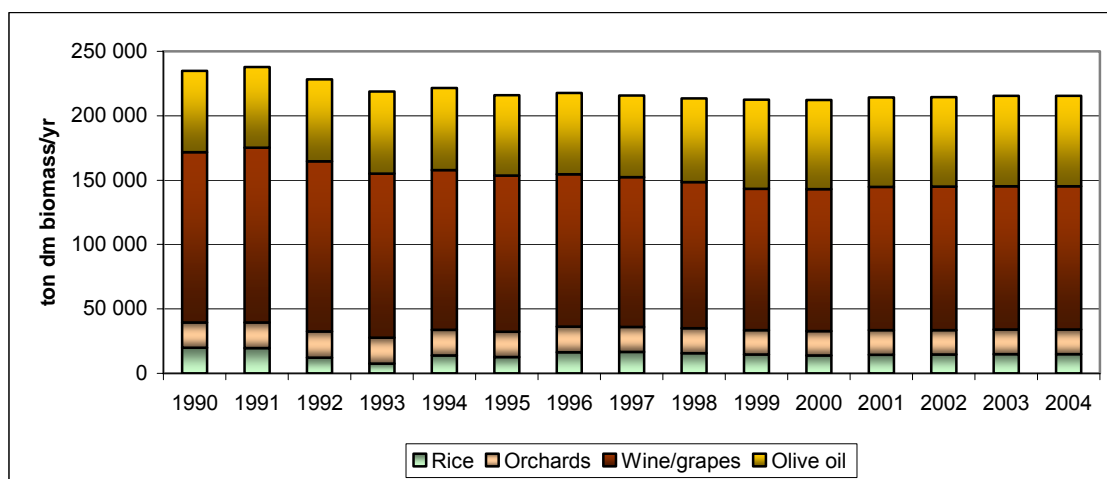
Table 6.47 – Estimated quantities of burnt crop area per crop (ha) (1990-1996)

Crop	1990	1991	1992	1993	1994	1995	1996
Rice	33 824	33 466	21 118	13 200	24 051	21 726	28 278
Orchards	164 147	166 120	168 101	166 838	165 690	164 748	163 842
Wine/grapes	264 359	271 160	264 062	254 528	247 615	241 964	236 654
Olive oil	337 189	333 757	338 947	340 579	340 672	333 144	336 621
Total	799 519	804 503	792 228	775 145	778 028	761 582	765 395

Table 6.48 – Estimated quantities of burnt crop area per crop (ha) (1997-2004)

Crop	1997	1998	1999	2000	2001	2002	2003	2004
Rice	28 540	27 020	25 307	23 859	24 936	25 216	25 657	25 657
Orchards	162 336	161 382	157 122	157 698	157 909	157 985	158 139	158 139
Wine/grapes	232 226	226 497	219 444	220 356	222 569	222 620	222 446	222 446
Olive oil	338 414	347 271	368 974	369 162	369 314	369 858	374 154	374 154
Total	761 516	762 169	770 847	771 075	774 728	775 679	780 396	780 396

Figure 6.36 – Estimated total quantities of burnt crop residues per crop (1990-2004)



6.3.G.5 UNCERTAINTY ASSESSMENT

The uncertainty in activity data is higher than the error associated with crop area determination, because there is a higher uncertainty in the percentage of crop areas that are subjected to burning and in which crops field burning is practiced. An uncertainty value of 100 per cent was therefore considered.

The uncertainty range in emission factors was set at 20 per cent in accordance with recommendations from GPG (IPCC,2000).

6.3.G.6 RECALCULATIONS

The emissions factors for Nitrous Oxide were corrected for a calculation error detected since last submission.

6.3.G.7 FURTHER IMPROVEMENTS

Associated with agriculture activities, the burning of hedge rows and some infestants is still practice in Portugal. There is still no data concerning this activity and a better insight on this subject will have to be developed in next inventories.

The adoption of three year average for crop area and emissions will be discussed under Methodology Development Plan, which is not use yet for consistent with determination of emissions from forest fires.

6.3.H NH₃ Emissions from Volatilization of Fertilizers

6.3.H.1 METHODOLOGY

Although emissions of ammonia from nitrogen was already discussed in several chapters, it is explained again here for inventory clarification.

Ammonia volatilisation from the application of synthetic fertilizers (SN_NH₃) is calculated using the following formula:

$$SN_{NH_3} = N_{Fert} * Frac_{GASF}$$

where,

N_{Fert} - total amount of nitrogen in synthetic fertilizers consumed annually

$Frac_{GASF}$ - fraction of nitrogen in synthetic fertilizers applied ton soil that volatilises as NH₃ or NO_x

Ammonia emission from manure may occur in 4 different places in the life cycle of manure, with differentiated emission factors according to EMEP/CORINAIR Emission Factor Handbook:

- Emission in housing;
- Emission in outside storage;
- Emissions from land spreading of manure collected in each Manure Management Systems;
- Emissions of ammonia volatilised from droppings deposited directly in soil during grazing.

Emissions from manure during housing and storage (MMS_NH₃) are not differentiated and are estimated according to equation:

$$MMS_NH3 = \sum_i [N_{(i)} * Nex_{(i)} * (1 - MS_{GRAZ(i)}) * EF_{NH3(i)}]$$

where

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$EF_{NH3(i)}$ - Fraction of nitrogen from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock;

For the time being the emission factors are only dependent on animal type and not on the manure management system, except in what concerns the differentiation of ammonia volatilisation in grazing.

Emissions from manure collected in Manure Management Systems and that is later deposited in agricultural soil as fertilizer (AM_NH₃) is calculated from:

$$AM_NH3 = \sum_t \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

where

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category T that is managed in Manure Management System s, except grazing;

$MSSD_{(i,s)}$ - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i)}$ - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$ - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

Emissions from volatilisation of nitrogen added to soil during grazing (GZ_NH₃) was estimated by:

$$GZ_NH3 = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * EF_{NH3(i)}]$$

where:

i - Animal/species category of livestock;

$N_{(i)}$ - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$ - Annual country average N excretion per head of animal species/category i ;

$MS_{GRAZ(i)}$ - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock;

$EF_{NH3(i)}$ - Fraction of nitrogen excreted from livestock category i during grazing that is lost to atmosphere as ammonia.

Ammonia emissions from agriculture also result from field burning of residues as it was already presented in chapter 6.2.7.

6.3.H.2 EMISSION FACTORS

AMMONIA VOLATILIZATION FROM SYNTHETIC FERTILIZERS

The volatilization ratio from synthetic fertilizers, $Frac_{GASF}$, was determined from an estimate of the share of nitrogen synthetic fertilizers used in Portugal based on statistical information from INE on import, export and national production of each individual nitrogen fertilizer. Albeit some deficiencies still found in the basic information data, it was considered this volatilization ratio to be more suitable to represent the national conditions than to use the default IPCC approach that is recognized to be too high and not representative of the national conditions of fertilization, particularly when the results of the inventory are being used to discuss capes under the European Emissions Ceiling (NEC). The following approach was used:

- Data information concerning national production of nitrogen synthetic fertilizers was available from INE from 1992 till 2000, from the IAPI industrial survey and using PRODCOM product classification. This statistical information has confidential constraints and may not be published in the present report;
- Statistical information about foreign trade is available also from INE concerning importation and exportation of nitrogen fertilizers. Products are classified according to NC codes. The same confidential constraints apply to this data;
- annual consumption of nitrogen fertilizers per fertilizer type was hence estimated by IA for the years from 1992 to 2000, using the following equation¹²⁷. In Figure 6.37 the share of consumption of each nitrogen fertilizer, as estimated by IA, is presented as an average situation in the 1992-2000 period, where it may be seen that Calcium Ammonium Nitrate is the main fertilizer in use and urea, the fertilizer more prone to nitrogen volatilization, represented about 17 per cent of nitrogen added as fertilizer to soils.

$$\text{Consumption}_{(f)} = \text{Production}_{(f)} + \text{Import}_{(f)} - \text{Export}_{(f)}$$

where,

$\text{Consumption}_{(f)}$ - Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

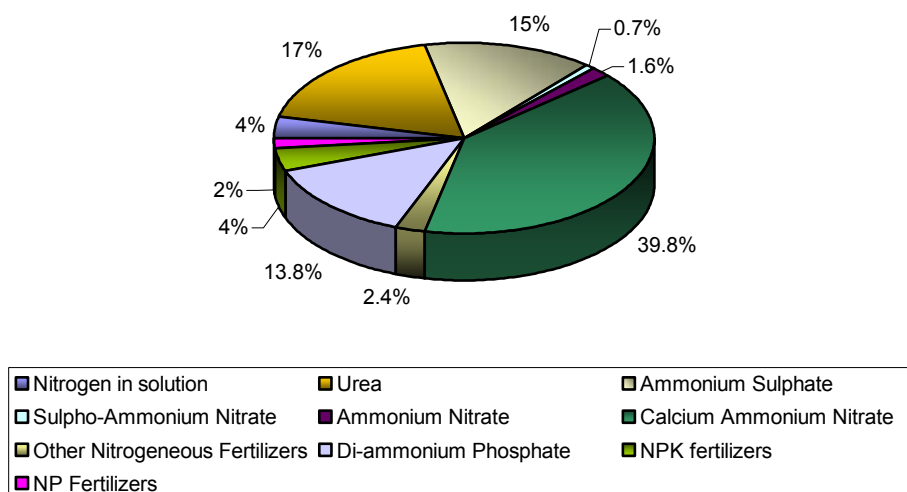
$\text{Production}_{(f)}$ - Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

¹²⁷ This estimates are only preliminary guesses and are being revised together with INE and the Ministry of Agriculture.

Import_(f) – Annual importation in Portugal of nitrogen fertilizer f (ton N/yr);

Export_(f) - Annual exportation in Portugal of nitrogen fertilizer f (ton N/yr);

Figure 6.37 – Relative Importance of the use of various nitrogen fertilizers in Portugal, as estimated by IA form production and foreign trade



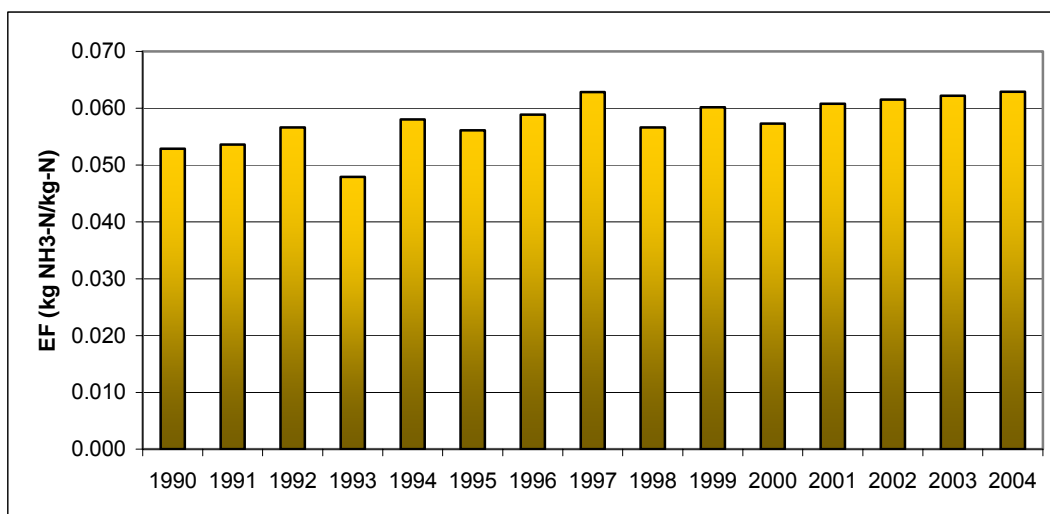
- product specific volatilization rates from EMEP/CORINAIR (EEA,2003) were used for each nitrogen fertilizer type according to Table 6.49.

Table 6.49 – Volatilization rates for each nitrogen fertilizer (Source: EMEP/CORINAIR file B1010vs4 - Revision of 3rd ed in Jan2003)

Acronym	Product	EF (kg NH ₃ /kg N)
UAN	Nitrogen in solution	0.08
UREA	Urea	0.15
AS	Ammonium Sulphate	0.08
SAN	Sulpho-Ammonium Nitrate	0.05
AN	Ammonium Nitrate	0.02
CAN	Calcium Ammonium Nitrate	0.02
N	Other Nitr.Fertilizers	0.053
DAP	Di-ammonium Phosphate	0.05
NPK	NPK fertilizers	0.02
NP	NP Fertilizers	0.02

- finally, the weighted average ammonia volatilization rate was estimated for each year from 1992 to 2000 and back-extrapolated to 1990 and extrapolated to 2004. The final volatilization rates appear in Figure 6.38.

Figure 6.38 – Final volatilization rate of ammonia from the application of synthetic fertilizer in agricultural soils



AMMONIA VOLATILIZATION FROM ANIMAL EXCRETA

The emission factors that were used to estimate ammonia emissions from manure from domestic livestock were already presented in source categories N₂O emissions from Manure Management and Direct nitrous Oxide Emissions from Agricultural Soils and are present again in Table 6.50. These emission factors result from EMEP/UNECE 3rd edition in annex A of chapter B1050 and version 4.0 of chapter B1010 and are not dependent on the Manure Management System that is used. Final emission factors per animal class are presented in next table.

Table 6.50 - Emission factors used for calculation of NH₃ volatilisation from animal housing, land spreading and grazing in pasture (kg N-NH₃/kg N excreted)

Classe	Housing & Outside Storage	Land spreading of Manure	Grazing in Pasture	Total
Dairy Cows	0.17	0.17	0.08	0.42
Other Cattle	0.17	0.17	0.08	0.42
Sheep	0.10	0.07	0.04	0.21
Goats	0.10	0.07	0.04	0.21
Swine	0.22	0.16	0.08	0.38
Equines	0.12	0.07	0.08	0.27
Poultry	0.22	0.16	-	0.38
Hens	0.23	0.15	-	0.39
Rabbits	0.22	0.16	-	0.38

The use of emission factors from EMEP/UNECE results therefore in values for $Frac_{GASM}$ that are different and higher than the default value for $Frac_{GASM}$ (0.2 kg N-NH₃ + N-NO_x/ kg of N excreted, in table 4-19 of IPCC96).

6.3.H.3 ACTIVITY DATA

The quantity of nitrogen that is subjected to volatilisation is presented in Table 6.51 and Table 6.52 and Figure 6.39.

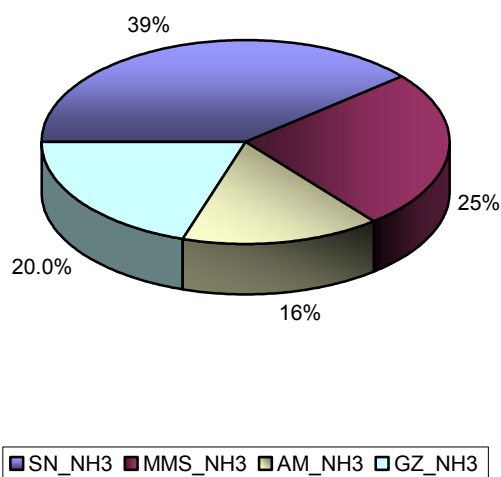
Table 6.51 – Nitrogen subjected to volatilization from each emission source/component (1990-1996)

Source	ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizers	SN_NH3	139 545	140 732	141 563	144 169	143 931	137 628	158 325
M.M.S.	MMS_NH3	87 596	89 049	89 129	90 602	91 003	91 774	91 538
Animal Manure	AM_NH3	55 438	56 287	56 309	57 215	57 488	58 015	57 950
Grazing/ Pasture	GZ_NH3	63 062	63 870	63 229	63 389	63 890	65 345	66 697
Total		345 641	349 938	350 230	355 375	356 312	352 762	374 509

Table 6.52 – Nitrogen subjected to volatilization from each emission source/component (1997-2004)

ton N/yr	1997	1998	1999	2000	2001	2002	2003	2004
SN_NH3	153 963	140 850	139 979	160 265	147 938	157 164	110 056	136 102
MMS_NH3	91 804	93 066	93 790	94 251	92 825	91 567	88 925	88 401
AM_NH3	58 092	58 855	59 269	59 538	58 564	57 697	55 990	55 687
GZ_NH3	67 647	68 683	69 374	69 909	69 562	69 032	68 768	69 853
Total	371 506	361 454	362 411	383 962	368 888	375 461	323 739	350 042

Figure 6.39 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation in 2003



6.3.H.4 RECALCULATIONS

The changes in estimates of emission of ammonia reflect indirectly the changes in nitrogen excreted by livestock, the share of manure and nitrogen that is directed to each specific manure management system, and the quantity of nitrogen in synthetic fertilizers and manure that is added to soil as fertilizer. All these changes were already explained in previous chapters.

6.3.H.5 FURTHER IMPROVEMENTS

The importance of the Manure Management System in ammonia emissions needs to be included in the methodology, but that depends on the existence of appropriate emission factors.

It is expected that efforts will continue to ameliorate the volatilisation rates from the application of synthetic fertilizers, following a future better knowledge of the nitrogen fertilizer types used in Portuguese agricultural soils.

CHAPTER: 7 LAND USE, LAND USE CHANGE AND FORESTRY (LULUCF) (CRF 5)

7.1 Overview

This chapter refers to the estimation of emissions and removals of CO₂ and non-CO₂ for the Land-Use, Land-Use Change and Forestry (LULUCF) sector. The 2003 IPCC Good Practice Guidance for LULUCF (GPG LULUCF) has been applied as far as possible. The estimates include for the first time the quantification of emissions and removals for land-use change (LUC).

The six GPG LULUCF categories are: Forest Land (5A), Cropland (5B), Grassland (5C), Wetlands (5D), Settlements (5E) and Other Land (5F). Although according to the reporting guidelines these categories should be reported individually, it was considered more transparent and consistent to report common considerations under the same chapter – Land Use Conversion. Therefore, only Forest Land Remaining Forest (FF) is reported separately, while for the others only a reference to the Land Use Conversion sub-chapter is made.

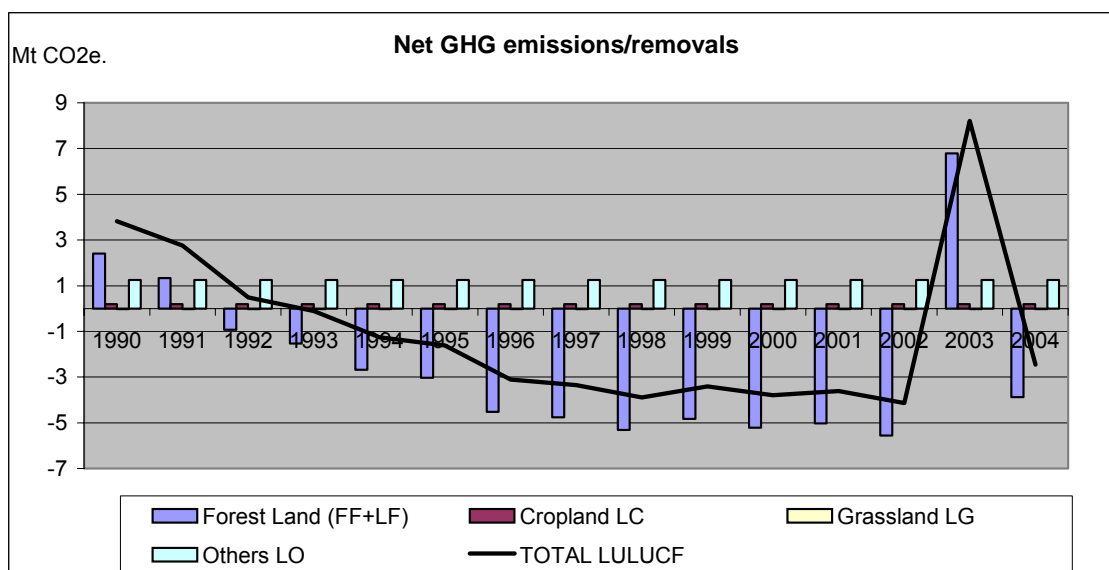
Carbon stock changes in the forest land have been estimated for living biomass (above and below ground). The inventory considers the whole national forest, as all forests are considered to be affected by human intervention, and consequently considered as non-natural/ managed.

N₂O emissions from nitrogen fertilisation of forest soils have not been estimated separately as they are included already in the previous chapter Agriculture, assuming that emission rates are the same for N₂O fertilisation in forest and agricultural areas (Tier 1).

Concerning land-use changes and conversions among the six GPG LULUCF categories, all carbon pools (above and belowground biomass, dead organic matter, and soil organic matter) have been assessed.

The sector shift from a net emitter to a sink in the period 1990-2004, and was responsible for the sequestration of 2.5 Mt of CO₂ in 2004.

Figure 7.1 –Net Annual CO₂ Change from LULUCF (Mt CO₂e.) 1990-2004



7.2 Source categories

7.2.A Forest Land (CRF 5 A)

The estimation of carbon stock changes in Forest Land remaining Forest Land has been estimated for two carbon pools - aboveground and belowground biomass. No estimates have been calculated for dead wood, litter or soil organic matter. The IPCC Guidelines do not require estimate dead wood or litter carbon stocks, considering that the average value of these pools remains constant in time, with inputs to dead matter pools balanced by outputs. Concerning carbon stocks in soils, Tier 1 considers that when forest remains forest the carbon stock in soils does not change, despite e.g. changes in forest management and forest type.

Carbon stock changes in Lands converted to Forest Land has been calculated for all carbon pools (aboveground, belowground biomass, dead organic matter, and soil organic matter).

7.2.A.1 FOREST LAND REMAINING FOREST LAND (FF)

METHODOLOGY

The methodology used is based on the IPCC 1996 Guidelines and GPG LULUCF, and relies on the carbon flux approach. It assesses net CO₂ flux due to changes in forest carbon stocks taking account of emissions caused by biomass carbon loss (e.g. tree fellings and other losses), and carbon uptakes from the atmosphere due to tree growth.

The general equation, which estimates the annual emissions or removals from FF with respect to changes in carbon pools, is given in the following equation:

$$\Delta CFF = (\Delta CFF_{LB} + \Delta CFF_{DOM} + \Delta CFF_{Soils})$$

where:

ΔCFF = annual change in carbon stocks from forest land remaining forest land, t C yr⁻¹

ΔCFF_{LB} = annual change in carbon stocks in living biomass (includes above and belowground biomass) in forest land remaining forest land, t C yr⁻¹

ΔCFF_{DOM} = annual change in carbon stocks in dead organic matter (includes dead wood and litter) in forest land remaining forest land, t C yr⁻¹

ΔCFF_{Soils} = annual change in carbon stocks in soils in forest land remaining forest land, t C yr⁻¹.

As ΔCFF_{DOM} and ΔCFF_{Soils} were assumed as zero, the equation can be summarized as follows:

$$\Delta CFF = \Delta CFF_{LB}$$

CHANGE IN CARBON STOCKS IN LIVING BIOMASS

The methodology that was used follows the method 1 (default method) of GPG LULUCF.

$$\Delta CFF_{LB} = \Delta CFF_G - \Delta CFF_L$$

where:

ΔCFF_G = annual increase in carbon stocks due to biomass growth, t C yr⁻¹

ΔCFF_L = annual decrease in carbon stocks due to biomass loss, t C yr⁻¹

BIOMASS INCREMENT

The **annual increase in carbon stocks** due to biomass increment was calculated as follows:

$$\Delta CFF_G = \sum_i (A_i \cdot G_{TOTALi}) \cdot CF$$

where:

ΔCFF_G = annual increase in carbon stocks due to biomass increment in forest land remaining forest land by forest type (*i*), t C yr⁻¹

A_i = area of forest land remaining forest land, by forest type (*i*), ha

G_{TOTALi} = average annual increment rate in total biomass in units of dry matter, by forest type, t d.m. ha⁻¹ yr⁻¹

CF = carbon fraction of dry matter (default = 0.5), t C (t d.m.)⁻¹

The **average annual increment in total biomass** (above and below ground) was obtained from the annual aboveground biomass increment and the root-shoot ratio (the ratio of belowground biomass to aboveground biomass).

$$GTOTAL = GW \cdot (1 + R)$$

where:

GTOTAL = average annual biomass increment above and below ground, t d.m. ha⁻¹ yr⁻¹

GW = average annual aboveground biomass increment, t d.m. ha⁻¹ yr⁻¹

R = root-to-shoot ratio appropriate to increments

The **average annual aboveground biomass increment** was calculated as follows:

$$GW = I_V \cdot ConvF$$

where:

GW = average annual aboveground biomass increment, t d.m. ha⁻¹ yr⁻¹

I_V = average net annual growth rate, m³ ha⁻¹ yr⁻¹

ConvF = volume stem conversion factor into biomass above ground, t d.m. m⁻³

BIOMASS LOSS

The annual carbon loss in living biomass was estimated as the sum of losses from commercial fellings and carbon losses from fires as follows:

$$\Delta C_{FF_L} = L_{fellings} + L_{Wildfires}$$

where:

ΔC_{FF_L} = annual decrease in carbon stocks due to biomass loss in forest land remaining forest land, t C yr⁻¹

$L_{fellings}$ = annual carbon loss due to commercial fellings, t C yr⁻¹

$L_{Wildfires}$ = annual carbon losses due to wildfires, t C yr⁻¹

The IPCC Guidelines considers also biomass losses from fuelwood gathering. However this part has not been considered in the national estimates, as it has been assumed that forest biomass used in heat production (domestic firewood or industrial) is a forest sub-product resulting from forest management practices, and consequently is not consider as a depletion of carbon sequestration capacity. Non-CO₂ emissions from combustion of this biomass fuel are accounted in other sectors (CRF 1 Energy) on the basis of biomass data from energy balances (DGGE data).

Annual carbon losses due to commercial fellings

The equation used to estimate annual carbon losses due to commercial fellings is:

$$L_{fellings} = H_{adjust} \cdot ConvF \cdot CF$$

where:

$L_{fellings}$ = annual carbon losses due to commercial fellings, t C yr⁻¹

H_{adjust} = adjusted annual volume of commercial fellings, roundwood, m³ yr⁻¹

$ConvF$ = volume stem conversion factor into biomass above ground, t d.m. m⁻³

CF = carbon fraction of dry matter (default = 0.5), t C (t d.m.)⁻¹.

$$H_{adjust} = H \cdot EF$$

H = annual volume of commercial fellings, roundwood, m³ yr⁻¹

EF = expansion factor to account for the whole tree volume (softwood = 1.24; hardwood = 1.2)

For the estimation of biomass loss from commercial fellings the IPCC default was assumed, considering that all carbon in harvested volumes is emitted in the year of removal, and consequently that there is no biomass left to decay in forest (transferred to dead organic matter).

Annual carbon losses due to wildfires

LULUCF GPG recommends to estimate CO₂ emissions resulting from carbon losses due to disturbances as wildfires, when the uptake of carbon by regrowing vegetation is taken into account.

The level of disturbances on a forest varies with the type and severity of the fire, the conditions under which they occur and the ecosystem characteristics. In the event of a disturbance, the generic IPCC proposed method assumes the complete destruction of forest biomass, considering “stand-replacing” disturbances only.

This approach is however far from reality as not all forest biomass is destroyed during a fire. To consider non-stand replacing disturbances, the proportion of pre-disturbance biomass which is not affected by the disturbance was used in the calculs.

The annual carbon loss in living biomass resulting from wildfires was estimated as follows:

$$L_{\text{Wildfires}} = \sum A_{\text{disturbance}} \cdot B_W \cdot (1 - f_{\text{BL}}) \cdot (1 - f_{\text{BB}}) \cdot CF$$

where:

$A_{\text{disturbance}}$ = forest areas affected by wildfires, ha yr⁻¹

B_W = average above ground biomass stock of forest areas, t d.m. ha⁻¹

f_{BL} = fraction of biomass left to decay in forest (transferred to dead organic matter)

f_{BB} = fraction of biomass not affected by the disturbance

CF = carbon fraction of dry matter, t C (t d.m.)⁻¹

The biomass stock (B_W) considered includes the above ground biomass for forest trees, undergrowth cover (only for non-CO₂ emissions), and biomass from litter existing in forest land.

The fraction of biomass left to decay in forest (f_{BL}) was considered to be 0, assuming that all biomass lost is accounted under commercial harvest or that the species regenerate after the disturbance.

To avoid double counting, the calculation of annual carbon loss in tree above ground biomass was estimated, in previous submissions, assuming that all above ground biomass from burnt trees was removed through harvesting as salvaged wood volumes. The most recent UNFCCC review reports raised, however, the issue of the potential underestimation of CO₂ emissions from forest fires. In reality, due to scarcity of information (e.g. the % of salvaged volumes within harvest), it is difficult to determine exactly which part of salvaged wood are considered in the

harvest volumes, or if part of the burnt trees are not removed from the burnt forest, which would generate emissions from dead wood, non-harvested fallen logs, and snags remaining in the forest.

Despite the efforts developed by the inventory team, it was still not possible for this submission to have an assessment of the proportion of the harvested wood coming from burnt areas, or estimates about the fraction of burnt trees that are not removed after a fire. In the absence of this information, the calculation of annual tree carbon loss in above ground biomass considered two situations:

1) For pinus pinaster and eucalyptus, the two representative species in terms of industrial wood consumption, it was assumed that the affected trees are harvested as salvaged wood and used in the industry, and are considered included in the harvest volumes. This approach was based on the premise that these quantities were largely used in industry, and were considered to be fully included in the harvest volumes which refer to wood consumption. However, if the extent of the volumes burnt exceed by large the industrial wood consumption, then the whole amount of the burnt volume are accounted in the estimates, which is the case of the year 2003 for coniferous species.

2) For the other species, the calculation of annual carbon loss in above ground biomass, refer to the fraction of biomass that is affected by the disturbance, based in the assumptions described below, and on the supposition that other species do not have the same economic importance and the trees are left in the burnt areas and that they regenerate in majority after the fire.

The fraction of the tree biomass affected by the wildfires ($1 - f_{BB}$) was estimated based on the following assumptions (PNAC):

50% of the trees in a burnt area are affected;

10% of the total biomass of the affected trees, corresponding to the fine parts of the trees (branches and leaves), is consumed;

80% of the fine materials burn.

In what refers to the undergrowth cover, it was considered that 80% of shrub and bush biomass undercover is combusted in average during a fire (Botelho et al. 1994 e Fernandes et al. 2000).

For the litter part it was assumed that in average 63% of the biomass burns (Botelho et al. 1994 e Fernandes et al. 2000a).

Concerning the forest undergrowth cover it has only been considered non-CO₂ emissions from biomass burning. As previously mentioned, despite the fact that GPG for LULUCF considers good practice to estimate both CO₂ and non-CO₂ emissions, it is also accepted that, if the method applied in the quantification of carbon sequestration (increment) does not consider the removals by re-growth after the disturbances (which has not been estimated), it is not mandatory to report the CO₂ emissions associated with the disturbance events.

CHANGE IN CARBON STOCKS IN DEAD ORGANIC MATTER

Tier 1 IPCC Guidelines do not require estimation on dead organic matter, assuming that inputs balance outputs of these pools. The inventory did not consider these pools in the case of forest remaining forest that was not affected by wildfires. The change in these pools have been considered in LUC and in forest land affected by wildfires.

CHANGE IN CARBON STOCKS IN SOILS

IPCC provides guidance for two types of forest soil carbon pools: 1) the organic fraction of mineral forest soils, and 2) organic soils. In Portugal organic soils are considered negligible and so they have not been considered.

Under Tier 1, it is assumed that when forest remains forest the carbon stock in soil organic matter does not change, regardless of changes in forest management, types, and disturbance regimes, considering that the carbon stock in mineral soils remains constant so long as the land remains forest.

This pool was taken into account using GPG Guidance defaults in the quantification of emissions/removals from LUC.

NON-CO2 GREENHOUSE GAS EMISSIONS

GREENHOUSE GAS EMISSIONS FROM WILDFIRES

The estimates of non-CO2 gas emissions are based on the IPCC 1996 Revised Guidelines (IPCC,1997) methodology, which are based on ratios to carbon released during combustion ($L_{\text{Wildfires}}$).

The carbon trace gas emissions (CH₄, CO and CO₂eq) are calculated using direct ratios to total carbon. To estimate nitrogen trace gas releases (N₂O and NO_x), the total carbon released is first multiplied by the N/C ratio (0.01) to get the total nitrogen released; the emissions of N₂O and NO_x are then calculated multiplying the total N released by the N₂O and NO_x emissions ratios to the total N released.

Emissions ratios:

<p>IPCC 1996 - CH₄: 0.012; CO: 0.06; N₂O: 0.007; NO_x: 0.121</p> <p>AP-42 - CO₂eq: 0.0068</p>
--

Emission estimation:

<p>Emissions CH₄ = $L_{\text{Wildfires}} \times \text{emission ratio} \times 16/12$</p> <p>Emissions CO₂eq (expressed as CH₄) = $L_{\text{Wildfires}} \times \text{emission ratio} \times 16/12$</p> <p>Emissions CO = $L_{\text{Wildfires}} \times \text{emission ratio} \times 28/12$</p> <p>Emissions N₂O = $L_{\text{Wildfires}} \times \text{ratio N/C (0.01)} \times \text{emission ratio} \times 44/28$</p> <p>Emissions NO_x = $L_{\text{Wildfires}} \times \text{ratio N/C (0.01)} \times \text{emission ratio} \times 46/14$</p>

ACTIVITY DATA AND PARAMETERS

AREA OF FOREST LAND

Data for forest area are largely based on data from periodic forest surveys: National Forestry Inventories (NFI) conducted by the General Direction for Forestry Resources/Ministry of

Agriculture, Rural Development and Fisheries (Direcção Geral dos Recursos Florestais (DGRF)/ Ministério da Agricultura, Desenvolvimento Rural e Pescas (MADRP)).

Available inventory surveys for the period analysed (1990-2004) are the NFI 2nd revision (1982) and the NFI 3rd revision (1995¹²⁸). Forest area data for 1990 are estimates from the General Direction for Forestry Resources based on NFIs. Data from 1996 onwards refer to estimates performed by IA as explained below.

Forest definition used by DGRF is based on the UNECE/FAO definition: Forest is defined as vegetation formations constituted by woody trees having crown cover with more than 10%, minimum area of 0.5 ha and 20 m width, and trees having a potential to reach a minimum height of 5 meters. Areas under afforestation and reforestation which will reach in the future a minimum crown density of 10% and a minimum height of 5 meters are also included under this definition.

All forest in Portugal is considered to be affected by human intervention, and consequently considered as non-natural/managed. Bush lands are basically non-managed areas and are not considered in the estimates.

GPG Guidelines require separate estimates and reporting for Forest Land remaining Forest Land from Land converted to Forest Land.

To separate Forest Land remaining Forest Land from Land converted to Forest Land, the information from a cartographic product – CLC Changes – was used. This cartography on land cover changes was developed having as a basis CLC-R (CORINE Land Cover 90 reviewed) referring to information from 1985/86/87, and CLC2000 (Project IMAGE and CORINE Land Cover (I&CLC2000) having the reference year of 2000.

The procedure used for estimation of FF for the years 1990 and 1995 are based on forest area from NFI for each specie subtracted with data from land converted to forest land from CLC Changes weighted by plantations (new forest areas) by forest type in the year, and can be summarized as follows (data from 1991 to 1994 are interpolated):

$$FF_{ni} = A_{F_{ni}} - (LF * plant_{ni} / \sum plant_n)$$

Where:

FF_{ni} = Forest Land remaining Forest Land in year n for forest type i

$A_{F_{ni}}$ = Forest type (i) area from NFI

LF = Land converted to Forest Land in the period 1986/2000

$plant_{ni}$ = plantations (new forest areas) in year n for forest type i

$\sum plant_n$ = total of plantation area in year n

Figures from 1996 to 2004 are estimates based on 1995 NFI data, summed up with CLC Changes data on Land converted to Forest Land (CF, GF, WF, SF, OF) weighted with data on forest type from forestry plans, and discounted with data from Forest Land converted to Other Uses (FC, FG, FW, FS, FO).

¹²⁸ The 3rd Revision was based on the 1995 national aerial photo coverage and on field work developed in 1997/98. The inventory covered 35 attributes of the Portuguese forests for continental Portugal. The results were published in 2001: DGF(2001), Inventário Florestal Nacional – Portugal Continental, 3ª revisão 1995-98.

To estimate the FF from 1996 on the procedure was slightly different to consider either Land converted to Forest and Forest converted to other land:

$$FF_{ni} = FF_{n-1i} + ((LF - FL)/14 \text{ years} * plant_n / \Sigma plant_{ni})$$

Where:

FF_{ni} = Forest Land remaining Forest Land in year n for forest type i

FF_{n-1i} = Forest Land remaining Forest Land in year n-1 for forest type i

LF = Land converted to Forest Land in the period 1986/2000, weighed by the plantations/new forestty areas by forest type in the year n

FL = Forest Land converted to Other Uses in the period 1986/2000, weighed by the plantations/new forestty areas by forest type in the year n

$plant_{ni}$ = plantations (new forest areas) in year n for forest type i

$\Sigma plant_{ni}$ = total of plantation area in year n

The product CLC-Changes are based on data for 1985/86/87 and 2000. For the calculation of the annual cover changes it was considered a period of 14 years (1986 being the intermediate year for the first cartography), assuming a constant land use change during the 14 years.

Table 7.1 – Forest area from National Forest Inventories (1000 ha)

	1982 (NFI 2nd rev.)	1990 (DGF estimates)	1995 (NFI 3rd rev.)
<i>Pinus pinaster</i>	1217	1069	976
<i>other softwood</i>	104	104	105
<i>Eucalyptus</i>	366	554	672
<i>Quercus suber</i>	662	693	713
<i>Quercus ilex</i>	464	462	462
<i>other Quercus</i>	109	123	131
<i>Castanea sativa</i>	30	37	41
<i>other hardwood</i>	89	98	102
Total	3041	3140	3202

Sources:

1982 and 1995: data refer to National Forestry Inventory data, respectively, 2nd and 3rd revision.

1990: estimates from DGRF (Direcção Geral dos Recursos Florestais).

Table 7.2 – Forest Land (1000 ha) used in calculus

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
<i>Pinus pinaster</i>	1037	1023	1008	994	979	965	965	966	966	967	967	968	968	970	971
<i>other softwood</i>	82	81	81	81	81	81	82	83	84	85	86	87	88	89	90
<i>Eucalyptus</i>	515	541	567	593	619	645	646	648	649	650	651	652	654	654	654
<i>Quercus suber</i>	661	660	659	658	657	656	658	661	664	666	669	671	674	677	680
<i>Quercus ilex</i>	458	455	452	449	446	443	444	445	446	446	447	448	449	449	450
<i>other Quercus</i>	123	125	126	128	129	131	131	131	131	131	131	131	131	131	131
<i>Castanea sativa</i>	37	38	38	39	40	41	41	41	41	41	41	41	41	41	41
<i>other hardwood</i>	73	76	78	81	84	86	87	88	88	89	90	91	91	92	93
Total Forest remaining Forest Land	2986	2998	3011	3023	3035	3047	3054	3061	3068	3075	3082	3089	3096	3103	3110
Data CLC Changes (1986-2000)															
Land converted to Forest Land	154														
Forest land converted to other uses	56														
TOTAL FOREST	3140	3152	3164	3177	3189	3201	3208	3215	3222	3229	3236	3243	3250	3257	3264

Sources: IA estimates based on National Forest Inventories (NFI), CLC-Changes cartography and data on plantations.

Data concerning plantations (Table 7.3) refer in majority to public forestry plans. Data sources are: DGRF, IFADAP (PAF, Reg 797, PDF, Reg 2080, Modelo 47, Projecto Florestal Português do Banco Mundial, Fundo Fomento Florestal). For eucalyptus, afforestation refers to the private sector.

Table 7.3 – Area of plantations by forest type (1000 ha)

	1990-94	1995-2004	1990-2004
<i>Pinus pinaster</i>	24	23	47
<i>other softwood</i>	17	38	55
<i>Eucalyptus</i>	30	38	68
<i>Quercus suber</i>	24	93	117
<i>Quercus ilex</i>	3	27	30
<i>other Quercus</i>	0	0	0
<i>Castanea sativa</i>	0	0	0
<i>other hardwood</i>	19	26	45
Total	117	244	361

Sources: DGRF, IFADAP (PAF, Reg 797, PDF, Reg 2080, Modelo 47, Projecto Florestal Português do Banco Mundial, Fundo Fomento Florestal); eucalyptus refer to private afforestation.

Part of the Portuguese forest is characterised by having an undergrowth cover, which could also be considered as a potential sink source. However, as data available for harvest do not include these materials, and to avoid overestimation, the carbon sequester in this pool has not been quantified.

Other wooded land (bushes, shrubs) had not been quantified, as they are generally non-managed areas.

Growth rates refer to m³ of roundwood over bark per ha and per year. This requires the use of coefficients for the conversion of stem volumes into biomass above and below ground. The parameters used results from a study performed by a Portuguese University under a contract with the IA for the development of PNAC. National values for these parameters are presented in the table below.

The IPCC default value for the carbon fraction of dry matter (0.5) was used.

Table 7.4 – Parameters used in the calculations of forest increment

	Growth Rates (m ³ /ha/yr)	Volume stem conversion factor into		Root-shot ratio
		above ground biomass (t ms/m ³)	total biomass	
Pinus pinaster	5.6	0.78	1.03	0.320
Pinus pinea	5.6	0.84	1.11	0.320
other softw ood	5.0	1.44	1.90	0.320
Eucalyptus	9.5	0.7	0.87	0.249
Quercus suber	0.5	0.57	0.82	0.430
Quercus ilex	0.5	0.57	0.82	0.430
other Quercus	0.5	0.57	0.82	0.430
Castanea sativa	5.0	0.56	0.80	0.430
other hardw ood	2.9	0.57	0.82	0.430

Sources:

Growth rates: DGRF.

Above ground biomass: PNAC July 2003 - Santos Pereira et al, "Quantificação dos sumidouros terrestres de carbono em Portugal Continental", Julho 2002, ISA, UTL.

Root-Shoot ratio: LULUCF GPG, Table 3A.1.8; excepting Eucalyptus (Soares and Tomé, 2004).

BIOMASS LOSS

FELLINGS

The amount of biomass lost in forest land due to biomass harvest is quantified on the basis of tree harvesting data. These data is based on annual statistical data of wood consumption and refer mainly to the species - *pinus pinaster* and *eucalyptus*, which was obtained from FAO database. Furthermore, it has been assumed that forest biomass used in heat production (domestic firewood or industrial) is a forest sub-product resulting from forest management practices, and consequently is not consider as a depletion of carbon sequestration capacity. Non-CO₂ emissions from combustion of this biomass fuel are accounted in other sectors (CRF 1 Energy) on the basis of biomass data from energy balances (DGGE data).

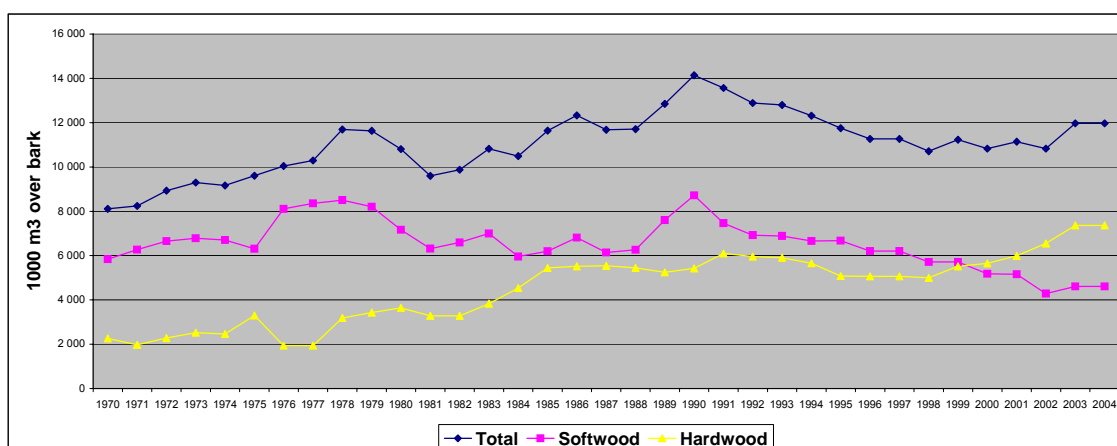
Values for tree feelings refer to roundwood over bark and do not include residues from exploration, i.e. branches, etc. To account for the whole tree volume, the expansion factors used were: for softwood 1.24; hardwood 1.2. The conversion to dry matter was done using the same parameters used for increment growth estimates.

Table 7.5 – Volumes of harvested wood (1000 m³ over bark) (1990-2004)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Pinus pinaster	8 716	7 467	6 925	6 889	6 659	6 672	6 207	6 207	5 717	5 711	5 182	5 161	4 284	4 608	4 608
Eucalyptus	5 423	6 098	5 959	5 907	5 653	5 078	5 060	5 060	4 995	5 516	5 649	5 984	6 546	7 363	7 363
Total	14 139	13 564	12 884	12 796	12 312	11 750	11 267	11 267	10 712	11 227	10 831	11 145	10 830	11 972	11 972

Note: 2004 are provisional figures. Source: FAO, DGRF

The analysis of the last 30 years time series for tree harvesting, shows that 1990 corresponds to a peak driven by a period of steady economic growth and expansion of the paper and pulp industries.

Figure 7.2 – Volumes of harvested wood (1000 m³ over bark) (1970-2004)

Note: 2004 are provisional figures. Source: DGRF; FAO

BIOMASS LOSS

WILDFIRES

Forest wildfires have a substantial impact on Portuguese forest. Yearly fluctuations of burned areas are a consequence of climatic factors. Nevertheless, it is generally acknowledged that adequate forestry and forest management, mainly a consequence of forestland structure (land tenure, size of forest holdings) and socio-demographic factors (private owners old age, low literacy or absenteeism), constitute severe constraints and contribute to the high magnitude of yearly burned areas.

All the forestland in Portugal is considered as non-natural/ managed and was considered in the estimates. Other wooded land ("matos" - bush land, shrubs) is mostly non-managed areas and were not accounted.

IPCC (2000) for LULUCF considers good practice to estimate CO₂ and non-CO₂ emissions from biomass burning on managed forestland.

The estimates consider the the above ground biomass for forest trees, undergrowth cover (only for non-CO₂ emissions), and biomass from litter existing in forest land.

The most recent UNFCCC review reports raised the issue of the potential underestimation of CO₂ emissions from forest fires. In previous submissions, these emissions were quantified assuming that all biomass burnt was removed through harvesting as salvaged wood volumes, based on the premise that these quantities were largely used in industry, and were considered to be fully included in the harvest volumes which refer to wood consumption. However, in reality, due to scarcity of information (e.g. the % of salvaged volumes within harvest), it is difficult to determine exactly which part of salvaged wood are considered in the harvest volumes, or if part of the burnt trees are not removed from the burnt forest, which would generate emissions from dead wood, non-harvested fallen logs, and snags remaining in the forest.

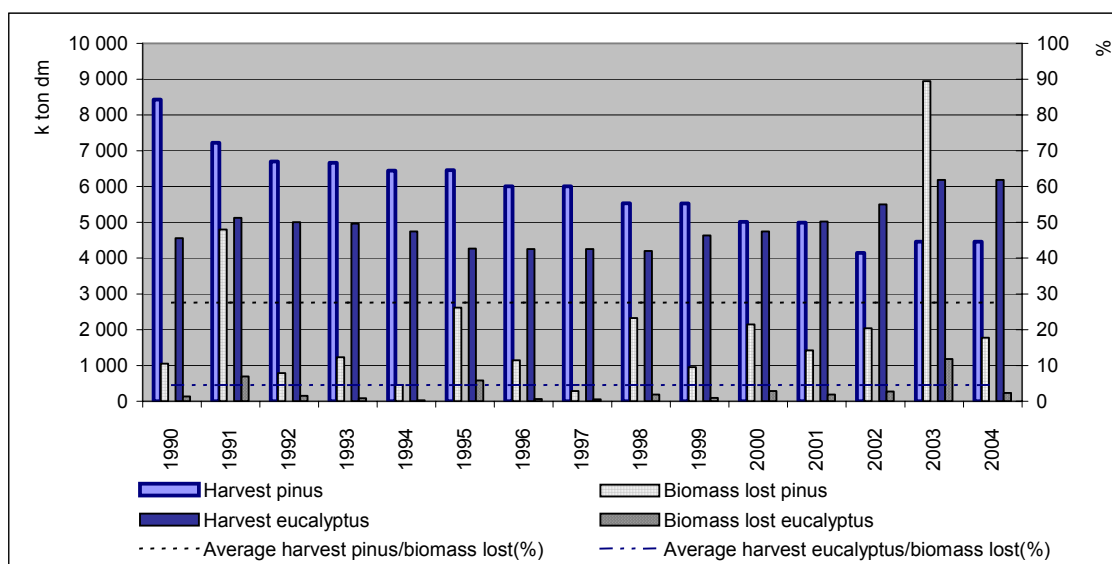
Despite the efforts developed by the inventory team, it was still not possible for this submission to have an assessment of the proportion of the harvested wood coming from burnt areas, or estimates about the fraction of burnt trees that are not removed after a fire. In the absence of this information, the carbon loss in above living biomass of trees resulting from wildfires was estimated as follows:

1) For pinus pinaster and eucalyptus, the two representative species in terms of industrial wood consumption, the same approach as in previous submissions has been used, i.e., it was assumed that the affected trees are harvested as salvaged wood and used in the industry, and are considered to be included in the harvest volumes which refer to wood consumption. However, if the extent of the volumes burnt exceed by large the industrial wood consumption, then the whole amount of the burnt volume are accounted in the estimates, which is the case of the year 2003 for coniferous species.

2) For the other species, the calculation of annual carbon loss in above ground biomass, was based on the estimated fraction of biomass affected by the disturbance. Considering that the other species do not have the same economic importance as pinus pinaster and eucalyptus, it was assumed that the affected trees are left in the forest after a fire and regenerating in majority afterwards.

In order to assess the magnitude of the assumption made concerning the use of burnt biomass from trees in industry, the total of biomass removed in commercial harvest were compared to the estimated loss of biomass in wildfires, converted in quantities of dry matter of carbon. These last were calculated based on the yearly burnt forest surface multiplied by the estimated average biomass above ground for coniferous species and eucalyptus (92.7 t dm/ha and 38.63 t dm/ha respectively, as presented in Table 7.7). The results, presented in next figure, show that for the majority of years the total biomass removed in commercial harvest is significantly higher than the estimated loss of biomass in wildfires, with the exception of 2003 for coniferous species. As the figure shows, the estimated percentual average for the commercial harvest in relation to the estimated loss of biomass is 28% (not taken in account the exceptional year of 2003) for coniferous species, and 4% for eucalyptus. If the period 1990-99 is considered, corresponding to the years for each the information on the species burnt are available (Cardoso Pereira (2003)), the ratio drops to 24% for coniferous species.

Figure 7.3 – Comparison of total biomass removed in commercial harvest and estimated biomass lost in wildfires (1990-2004)



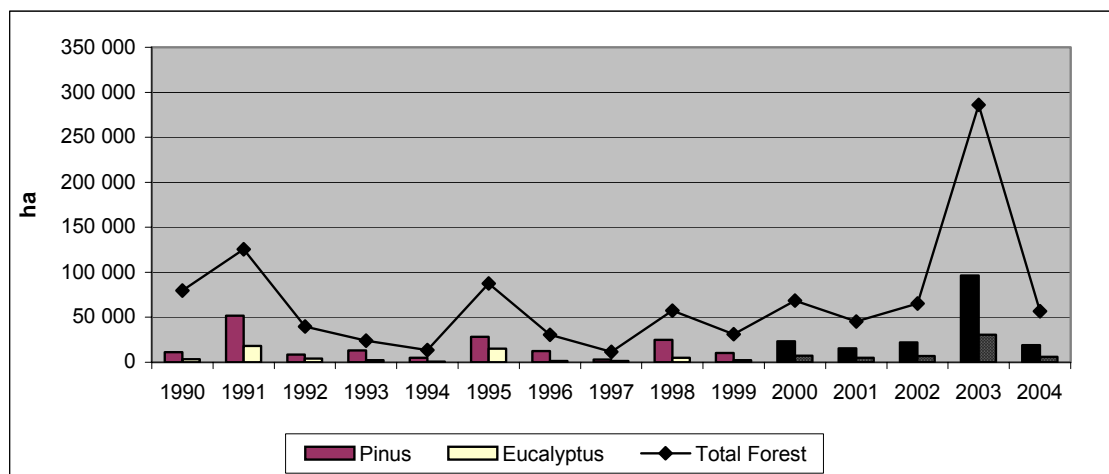
Source: FAO; IA estimates

Yearly data on burnt area are available from DGRF (General Direction for Forest Resources). The information on the share of burnt area by specie (pinus and eucalyptus), was based on data from Cardoso Pereira (2003), "Fire Risk and Burned Area Mapping in Portugal", MADRP, which refer to the period 1990-99. Data for the years 2000-04 refer to estimates from IA based

on the average percentage of the burnt area by specie in relation to the total burnt area in the 1990-99 period.

Bush land (“matos”) was not considered in the inventory, as it is generally non-managed land.

Figure 7.4 – Forest fires: human and natural origin (hectares) (1990-2004)



Notes: Data on burnt species: 2000-04 refer to IA estimates based on the average percentage of the burnt area by specie in relation to the total burnt area in the 1990-99 period from Cardoso Pereira (2003).

Source: DGRF; Cardoso Pereira (2003); IA estimates

Table 7.6 – Forest fires: human and natural origin (hectares) (1990-2004)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total Forest	79 549	125 488	39 701	23 839	13 487	87 554	30 542	11 466	57 393	31 052	68 646	45 327	65 160	286 051	56 733
Pinus	11302	51765	8453	13254	4944	28214	12307	3075	25031	10275	23147	15284	21971	96454	19130
Eucalyptus	3356	17882	3983	2228	743	15110	1460	1433	4817	2353	7325.5	4837.1	6953.5	30526	6054.3

Notes: Data on burnt species: 2000-04 refer to IA estimates based on 1990-99 averages in relation to total area burnt from Cardoso Pereira (2003).

Source: DGRF; Cardoso Pereira (2003); IA estimates

Emissions of air pollutants depend on the fuel type and fuel loading, among other factors. Nevertheless, for the time being, the calculations were done keeping data for the combustible material constant.

For the above ground biomass for forest trees, an average index for dry biomass above ground for forest trees was estimated, considering the same characterisation of the burnt species for all the years considered.

The estimation of this indicator was done on the basis of the relation area/volume for 1995 from INF 3rd rev., and the country volume stem factors used to convert the stem volume into dry biomass above ground, which were applied to the forest area in 1990. The value obtained is 45.6 t dm/ha as shown in the table below.

Table 7.7 – Estimates for biomass above ground in trees

	Volume stem factor into above ground (t dm/m3)	1990			
		Forest area (1000 ha)	Stem Volume a) (1000 m3)	Biomass above ground	
				(1000 t dm)	(t dm/ ha)
<i>Pinus pinaster</i>	0.78	1,069	108,194	84,391	78.96
<i>other softwood</i>	1.44	104	6,727	9,687	92.70
<i>Eucalyptus</i>	0.7	554	30,593	21,415	38.63
<i>Quercus suber</i>	0.57	693	24,276	13,837	19.96
<i>Quercus ilex</i>	0.57	462	9,856	5,618	12.15
<i>other Quercus</i>	1.12	123	4,480	5,018	40.91
<i>Castanea sativa</i>	0.56	37	1,887	1,057	28.83
<i>other hardwood</i>	0.57	97	3,852	2,196	22.61
Total/ Average b)		3,140	189,865	143,219	45.61

Note:

a) Estimated based on the relation area/volume for 1995 (INF 3rd revision).

b) Biomass above ground: weighed average based on forest type area.

Typically, Portuguese forest has undergrowth cover. To take this into account, the estimation of combustible material in forestland also included the quantification of shrub and bush biomass under the forest trees. The area considered in the estimates refers to the forest total area.

Table 7.8 presents the dry biomass data used in the estimates for the undercover and litter parts of forest land.

Table 7.8 – Biomass for undergrowth cover

	Area (1990) ha	Understorey shrubs a) ton/ha	Litter ton/ha
<i>Pinus pinaster</i>	1 068 828	7.811	10
<i>Eucalyptus</i>	554 418	5.589	6
<i>Quercus suber</i>	693 209	4.728	7
<i>Quercus ilex</i>	462 446	3.259	7
<i>Castanea sativa</i>	36 654	7.226	4.5
<i>other Quercus</i>	122 662	7.226	4.5
<i>other softwood</i>	104 498	9.275	7
<i>other hardwood</i>	97 128	7.226	4.5
Total b)	3 139 843	6.069	7.640

Notes:

a) Values correspond to 70% of total shrubs biomass.

b) Understorey and litter: weighted averages based on forest type areas.

Source:

Tiago Pereira da Silva (ISA), et al., "Estimativa de Emissões Atmosféricas Originadas por Fogos Rurais em Portugal".

The fraction of the tree biomass affected by the wildfires ($1 - f_{BB}$) was estimated based on the following assumptions (PNAC):

- 50% of the trees in a burnt area are affected;
- 10% of the total biomass of the affected trees, corresponding to the fine parts of the trees (branches and leaves), is consumed;
- 80% of the fine materials burn.

Concerning the undergrowth cover, it was considered that 80% of shrub and bush biomass undercover is combusted in average during a fire (Botelho et al.1994 e Fernandes et al. 2000).

For the litter part it was assumed that in average 63% of the biomass burns (Botelho et al.1994 e Fernandes et al. 2000a).

Table 7.9 presents the average biomass combusted values used in the calculs of the annual carbon loss from wildfires. The C content of dry matter for above ground and understorey biomass was the IPCC default 0.5; for the litter part the value used (0.37) was taken from LULUCF GPG.

Table 7.9 – Average biomass combusted in wildfires

	Average biomass ton/ ha	Fraction of biomass combusted	Average biomass combusted ton/ ha
Above ground biomass a)	45.61	0.04	1.82
Understorey biomass b)	6.07	0.80	4.85
Litter b)	7.64	0.63	4.81

Notes:

a) Fraction of above ground biomass combusted was estimated based on the following assumptions: 50% of the trees is affected by fire; out of the affected trees, only the thin parts (diameter<0,6cm) are lost (10% of the total biomass); 80% of the thin materials are burnt.

Sources:

a) Fraction of above ground biomass combusted: (PNAC, 2003)¹²⁹.

b) Fraction of above ground biomass combusted: Botelho et al.1994 e Fernandes et al. 2000a.

7.2.A.2 LAND CONVERTED TO FOREST LAND (LF)

Methodologies, activity data and parameters for this category are presented in 7.2.G which refer to Land Use Conversion.

7.2.B Cropland (CRF 5 B)

Methodologies, activity data and parameters for this category are presented in 7.2.G which refer to Land Conversion.

7.2.C Grassland (CRF 5 C)

Methodologies, activity data and parameters for this category are presented in 7.2.G which refer to Land Conversion.

7.2.D Wetlands (CRF 5 D)

Methodologies, activity data and parameters for this category are presented in 7.2.G which refer to Land Use Conversion.

7.2.E Settlements (CRF 5 E)

Methodologies, activity data and parameters for this category are presented in 7.2.G which refer to Land Use Conversion.

¹²⁹ PNAC (Julho 2003), Floresta e Produtos Florestais – Cenário de Referência, Volume 8.

7.2.F Other Land (CRF 5 F)

Methodologies, activity data and parameters for this category are presented in 7.2.G which refer to Land Use Conversion.

7.2.G Land Use Conversion

7.2.G.1 OVERVIEW

The information on methodologies, emission factors, parameters and activity data is presented here concerning several categories that are quantified under Forest Land (5A), Cropland (5B), Grassland (5C), Wetlands (5D), Settlements (5E) and Other Land (5F). Though according to the reporting guidelines should be reported individually it was considered to be more transparent and consistent to report common considerations under the same chapter. Therefore, from all LULUCF categories only Forest Land Remaining Forest (FF) is reported separately, while for the others only a reference to this chapter is made.

Nevertheless, the detail that was used to determine land use conversion is made at a lower level of detail than the major LULUCF categories, and as consequence some emissions reported as Land use remaining the same land use (FF or CC for example) are estimated according to the methodology explained in this chapter. That is to say, for example, that if the forest species planted in a land unit is changed then emissions from removal of former cover and sinks of subsequent grow of the new formation are estimated according to the methodology in this chapter, albeit net emissions/sinks are reported as FF, Forest remaining forest. Care has been taken to avoid double counting in these cases.

In order to shorten explanatory text the abbreviated nomenclature proposed by the LULUCF-GP (IPCC,2003) was extensively used. This procedure follows the rules

- major source land uses are referenced by the first letter (F-Forest; C-Cropland; G-Grassland; W-Wetland; S-Settlements and O-Other land);
- each unit of land is given an unique code composed of two letters XY, where X represents the land use in the beginning of the period and Y the use at the end of the period¹³⁰;
- for each land unit that undergone no change in land use, a double equal letter is used (FF,CC,GG,WW,SS,OO). For example CC refers to Cropland remaining cropland;
- the other cases are listed in the following table.

		To					
		Forest	Cropland	Grassland	Wetland	Settlements	Other
From	Forest	FF	FC	FG	FW	FS	FO
	Cropland	CF	CC	CG	CW	CS	CO
	Grassland	GF	GC	GG	GW	GS	GO
	Wetland	WF	WC	WG	WW	WS	WO
	Settlements	SF	SC	SG	SW	SS	SO
	Other	OF	OC	OG	OW	OS	OO

¹³⁰ Sequences of more than 2 letters could in principle occur. Nevertheless, considering the methodology that was used, the determination of these occurrences could not be detected.

The release and uptake of carbon for the following carbon pools was considered in the estimates made. However, dead wood is not considered separately:

Pool			Definition
Living biomass	above-ground		All living biomass above the soil biomass, including stems, stumps, branches, bark, seeds, and foliage. In the case of forests includes under storey. In case of mixed systems, such as forest with agricultural or grazing below, includes crops or grass together with trees.
Living biomass	below-ground		Living biomass of live roots. The lower limit of root diameter is not explicitly defined.
Dead Organic Matter (DOM)			All non-living biomass above the top layer of soil, in various states of decomposition. Includes the litter, fomic, humic layers, but also dead wood. Verificar
Soil Organic Carbon (SOC)			Includes organic carbon in mineral soils to a the depth of 30 cm.

7.2.G.2 METHODOLOGY

The methodology used can be considered to follow the equations 3.1.1 (default approach, or the Annual Carbon Stock Change in a Given Pool as a Function of Gains and Losses) of the LULUCF-GP (IPCC,2003), where areas are multiplied by rates of carbon loss and gain¹³¹:

$$\Delta C = \sum_{csLL} [A_{csLL} * (C_g - C_L)_{csLL}]$$

Where:

ΔC - carbon stock change in the pool, t C/yr;

A_{csLL} - area of land, for a specific climate type c, for the specific conversion LL, and in soil type s (ha/yr)

C_g - rate of gain of carbon for the area converted, t C/ha/yr

C_L - rate of loss of carbon for the area converted, t C/ha/yr

Considering that, as a general rule, gains in carbon release occur when the previous land use is finalized, while carbon is stored during the development of the new land use, calculation is made individually for land use termination or abandonment and land use formation or initiation¹³². For a specific land conversion LL, net emissions (ΔC_{net}) are determined from removals (ΔC_L) and uptake (ΔC_g):

¹³¹ The use of land use data at two points in time could lead to the impression that the alternative approach (equation 3.1.2 of the LULUCF-GP) was used. Nevertheless, in fact, because the methodology only makes a balance of the areas under a certain use and does not make estimates stock of carbon in the overall system, the methodology should be better defined as equation 3.1.1. Stock changes is used however to estimate annual releases and gains of carbon from unitary land use areas.

¹³² This assumption is not valid for SOC, soil organic carbon, were in fact there is a shift from the previous carbon content to a new carbon content in a period to reach equilibrium. Nevertheless, if one assumes a linear trend between the two values, it may be simulated by a decrease of the initial period to zero and a concomitant increase from zero to

$$\Delta C_{\text{net}} = A_{\text{csLL}} * (\Delta C_L - \Delta C_g)$$

$$\Delta C_{\text{net}} = A * [(\sigma C_{\text{LAB}} + \sigma C_{\text{LBB}} + \sigma C_{\text{DOM}}) - (\delta C_{\text{LAB}} + \delta C_{\text{LBB}} + \delta C_{\text{DOM}}) * T_e + (C_{\text{SOC,t}} - f C_{\text{SOC,i}}) * T_e / T_e]$$

Were:

A_{csLL} - area of land, for a specific climate type c, for the specific conversion LL, and in soil type s (ha/yr);

σC_{LAB} - Carbon stock in Living Aboveground Biomass in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was terminated, t C/ha;

σC_{LBB} - Carbon stock in Living Belowground Biomass (Roots) in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was terminated, t C/ha;

σC_{DOM} - Carbon stock in Dead Organic Matter (DOM) existing in an unitary land area in climate condition c, soil type s and land use L when land use was terminated, t C/ha;

δC_{LAB} - Annual accumulation of carbon in Living Aboveground Biomass in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was initiated, t C/ha/yr;

δC_{LBB} - Annual accumulation of carbon stock in Living Belowground Biomass (Roots) in all vegetation strata existing in an unitary land area in climate condition c, soil type s and land use L when land use was initiated, t C/ha/yr;

δC_{DOM} - Annual accumulation of carbon stock in Dead Organic Matter (DOM) existing in an unitary land area in climate condition c, soil type s and land use L when land use was initiated, t C/ha/yr;

$C_{\text{SOC,t}}$ - Soil Organic Carbon (SOC) at equilibrium for an unitary land area in climate condition c, soil type s and land use L under termination, t C/ha;

$C_{\text{SOC,i}}$ - Soil Organic Carbon (SOC) at equilibrium for an unitary land area in climate condition c, soil type s and land use L resultant from the conversion (initiated), t C/ha;

- T_e - time to carbon stock to reach equilibrium, yr.

Finally, emission and uptake of CO_2 to the atmosphere, are determined from the increase in storage or the release of carbon for each pool:

$$\text{Emi}_{\text{CO}_2} = 44/12 * \Delta C_L$$

$$\text{Sink}_{\text{CO}_2} = 44/12 * \Delta C_g$$

Some assumptions were assumed in the inventory process, which is important to mention:

- When forest is converted to other use, including a different type of forest, all carbon in living biomass and DOM is assumed to be converted to CO_2 ;

the final value, during the equilibrium period. This procedure decouples the land conversion and simplifies calculations with no reflex in results.

- in all cases it was assumed that carbon stock when the land use was terminated is the average value for that specific land use;
- the rate of conversion of areas, either abandonment or creation, occurs at the same rate during the period 1985/86/87 to 2000, with no time variations. The annual area converted (A) was estimated though dividing the total area converted in the period by the time interval from 1986 to 2000, i.e. 14 years;
- It was assumed that the rate of change in land use in the period 1985/86/87 to 2000 is representative of the pattern also in previous years. This is important to assume an equilibrium state in past actions, and not that only actions started in the period under analysis are accounted. Otherwise a variation in rates along years would have to be introduced. Therefore, the increase in carbon gain or release from areas in previous years includes the cumulative effect of all areas converted before until an age equal to the equilibrium state for that specific conversion and pool¹³³;
- the rate of carbon change in soil organic carbon (SOC) occurs in each parcel at a rate $(C_t - C_i)/T_e$, where C_t and C_i are the SOC at equilibrium, respectively for the land use terminated and initiated. However, the consideration of an equilibrium state, implies the consideration of the conversions in past periods until the equilibrium time (T_e) is reached. Assuming variation at constant rate, the annual change in all areas is therefore simply $(C_t - C_i)$;
- the accumulation of DOM is not considered in forest areas and similar land uses, being assumed that this seldom occurs when the vegetation is young. It was considered to occur only in bush lands;
- for the soil pool the IPCC default time to equilibrium (T_e) was considered, 20 years (IPCC,2003) for all land uses. For the living biomass pool, the time to reach equilibrium depends on type of land use being initiated and will be documented under emission factors and other parameters;
- storage of carbon in live biomass pools (aboveground and belowground) in forest trees, either in dense forests, mosaic forest and Montados is only accounted until they are considered new plantations when attaining the age of 15 years. Thereafter, removals and emissions of carbon are estimated according to the methodology explained in chapter "Forest Land Remaining Forest Land";
- the consideration of the case when, in the period 1985/86/87 to 2000, a land use conversion occurs followed by another land conversion, can not be detected from the available data and it is not considered. It causes a slight over-estimation of carbon uptake.

According to the level of detail of the activity data used and the use of country specific carbon rates for some pools, the methodology is better defined to be of second tier level (Box 3.1.1 of the LULUCF-GP). The use of this level is in accordance of the decision tree in the Figure 3.1.1 of the LULUCF-GP.

¹³³ This scheme is valid under the Convention, but must be different for the reporting of emissions and uptakes under article 3.3 of the Kyoto protocol, which only accounts for conversions occurring after 1990.

7.2.G.3 EMISSION FACTORS AND PARAMETERS

LIVING BIOMASS

Living biomass comprehends two pools: above ground living biomass and below ground living biomass. Generally, below ground biomass was established from above ground biomass by the application of shoot-to-root ratios. Two different situations apply, following the explanations given in the description of the methodology, and two set of parameters are given: when a specific land use is being terminated, biomass stock is emitted; when a new land use is initiated and the annual carbon increment in the pool is considered. The values herewith considered were chosen to be in coherence with the values of the parameters considered in "Forest land remaining forest land", presented in chapter 7.2.A.1.

The carbon content in live biomass per unit areas when a given land use is being terminated and converted to other use is presented in Table 7.10, together with a short description of their origin (documentation). Country specific values were considered for the aboveground live biomass of forest (forest species and bush species in undergrowth) and bush land areas and also for the below ground biomass of eucalyptus plantations. For the remaining parameters the lack of suitable information lead to the use of default GP-LULUCF values.

When a given land use is initiated the methodology considers that each year, until equilibrium is reached, an annual increment is added to the soil unit. The individual values for T_e , time to equilibrium, are presented in Table 7.11. In the case of the establishment of forest vegetation, the period is not the time to equilibrium of the forest, but only the time frame of the CLC change period, and the growth of live-biomass after that period is accounted in Forest Land Remaining Forest Land. The set of values that was considered for each land use, for both the aboveground live biomass and the below ground fractions, is presented also in Table 7.11. Again, country specific values, were used for forest species and bushes, in under-growth and in bush-lands, while the remaining values were set from the GP-LULUCF. The same root-to-shoot ratios that apply to biomass stock were used to estimate below ground increment, considering the lack of a differentiation both in national studies and GP-LULUCF.

Table 7.10 - Biomass Carbon Stocks Present on Land Previous to Land Use Change

			Above ground	Below ground	Root-shoot ratio	Documentation
			(tonnes C ha ⁻¹)			
Forest Land	Forest	Pinus pinaster (Maritime Pine)	45.06	14.42	0.32	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002); aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8: Conifer Forest Plantation function of ALB per ha
		Eucalyptus	23.31	5.80	0.25	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002); aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: Soares & Tomé (2004)
		Quercus Suber (Cork Oak)	14.58	6.27	0.43	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002) corrected to include only forest>30% cover; aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8: Temperate BroadLeaf forest function of ALB per ha
		Quercus Rotundifolia (Holm Oak)	9.73	4.19	0.43	
		Forest, mixed or other	28.53	12.27	0.43	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002) average of all species; aboveground undergrowth biomass from Silva (Unpublished) ; Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8: Temperate BroadLeaf forest function of ALB per ha
	Montado	Q. suber: Cold Temp. - Wet	3.92	5.97	1.52	Sum of biomass loss from trees and under canopy grassland; aboveground tree biomass from Pereira et al (2002) corrected to include only forest10-20% cover
		Q. suber: Warm Temp. - Dry	3.52	3.41	0.97	
		Q. rotundifolia: Cold Temp. - Wet	3.26	5.69	1.74	
		Q. rotundifolia: Warm Temp. - Dry	2.86	3.13	1.09	
		Mixed: Cold Temp. - Wet	3.59	5.83	1.62	
		Mixed: Warm Temp. - Dry	3.19	3.27	1.02	
Cropland	Permanent Crops		21.00	IE	NA	GP-LULUCF table 3.3.8: Temperate (all moisture regimes). Assuming 10 year average age (GP-LULUCF table 3.3.2 recommends 30 years, but that time interval appears too large for the dominant permanent crops in Portugal, orchards and vineyards.). Below ground: assumed already included in above ground biomass.
	Annual cropland		5.00	IE	NA	GP-LULUCF table 3.3.8: Annual Cropland. Below ground: assumed already included in above ground biomass.
	Mosaic Agriculture with P. Pinaster		9.42	3.14	NA	Sum of biomass in forest/undercover (10%), according to forest specie, bush land (10%), and annual cropland (80%)
	Mosaic Agriculture with Eucalytus		7.41	2.15	NA	
	Mosaic Agriculture with Q. Suber		6.46	1.76	NA	
	Mosaic Agriculture with Q. Rotundifolia		6.07	1.59	NA	
	Mosaic with all other types		9.56	1.96	NA	
Grassland	Grasslands: Cold Temp. - Wet		1.20	4.80	4.00	Above ground biomass: GP-LULUCF, Table 3.4.2, considering the default carbon fraction of dry matter (0.5); Root-shoot ratio: GP-LULUCF Table 3.4.3 Root-to-Shoot Ratios for the Major Savannah/Rangeland Ecosystems of the World.
	Grasslands: Warm Temp. - Dry		0.80	2.24	2.80	
	Sparse Vegetation: Cold Temp. - Wet		0.60	2.40	4.00	Sparse vegetation assumed half the biomass of grassland
	Sparse Vegetation: Warm Temp. - Dry		0.40	1.12	2.80	
Settlements	Artificial Areas (General)		NO	NO	-	Assumed equal to Mixed Montado
	Gardens, parks, etc: Cold Temp. - Wet		3.59	5.83	1.62	
	Gardens, parks, etc: Warm Temp. - Dry		3.19	3.27	1.02	Intermediate value between Continuous Urban Fabric and Gardens
	Disc. Urban Farbic: Cold Temp - Wet		1.80	2.91	1.62	
	Disc. Urban Farbic: Warm Temp. - Dry		1.60	1.63	1.02	
Other Land	Bushlands		4.63	13.11	2.83	Aboveground: equation $yr = -0.1177 yr^2 + 1.8511 yr + 1.9582$ from Santos Pereira (2002) for full-grow (8 yr); Root-to-Shoot Ratios: GP-LULUCF Table 3A.1.8 Shrubland
Wetlands	-		NO	NO	-	Assuming negligible vegetation. Areas mostly salt pans, salt marshes, etc
Water	-		NO	NO	-	

Table 7.11 - Annual growth of living biomass

			Above ground	Below ground	Root-shoot ratio	Te (yrs)	Documentation
			(t C/ha/yr)				
Forest Land	Forest	Pinus pinaster (Matitime Pine)	1.77	0.57	0.32	15	Includes biomass increase in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002); aboveground undergrowth increase from bush (Mato) but corrected for the adult stock of undergrowth for each specie
		Eucalyptus	3.02	0.75	0.25	15	
		Forest, mixed or other	1.22	0.53	0.43	15	
		Quercus Suber (Cork oak)	0.44	0.19	0.43	15	Includes biomass in trees and undergrowth cover; aboveground tree biomass from Pereira et al (2002) corrected to include only forest>30% cover; ; aboveground undergrowth increase from bush (Mato) but corrected for the adult stock of undergrowth for each specie
		Quercus Rotundifolia (Holm oak)	0.38	0.16	0.43	15	
	Montado	Quercus suber (trees only)	0.05	0.02	0.43	15	Sum of biomass increase from trees and under canopy grassland; aboveground tree biomass from Pereira et al (2002) corrected to include only forest10-20% cover
		Quercus rotundifolia (trees only)	0.06	0.03	0.43	15	
		Mixed Montado (trees only)	0.05	0.02	0.43	15	
		Undercanopy: Cold Temp. - Wet	1.20	4.80	4.00	1	
		Undercanopy: Warm Temp. - Dry	0.80	2.24	2.80	1	
Cropland	Permanent Crops		2.10	IE	NA	10	GP-LULUCF table 3.3.8: Temperate (all moisture regimes). Assuming 10 year average age (GP-LULUCF table 3.3.2 recommends 30 years, but that time interval appears too large for the dominant permanent crops in Portugal, orchards and vineyards.)
	Annual cropland		5.00	IE	NA	1	GP-LULUCF table 3.3.8: Annual Cropland
	Mosaic Agriculture with P. Pinaster		Sum of biomass in forest/undercover (10%), according to forest specie, bush land (10%), and annual cropland (80%). Te in accordance with individual land uses				
	Mosaic Agriculture with Eucalytus						
	Mosaic Agriculture with Q. Suber						
	Mosaic Agriculture with Q. Rotundifolia						
Mosaic with all other types							
Grassland	Grasslands: Cold Temp. - Wet		1.20	4.80	4.00	1	Above ground biomass: GP-LULUCF, Table 3.4.2, considering the default carbon fraction of dry matter (0.5)
	Grasslands: Warm Temp. - Dry		0.80	2.24	2.80	1	
	Sparce Vegetation: Cold Temp. - Wet		0.60	2.40	4.00	1	Sparce vegetation assumed growing at half the rate of grassland
	Sparce Vegetation: Warm Temp. - Dry		0.40	1.12	2.80	1	
Settlements	Artificial Areas (General)		NO	NO	-	-	Assumed equal to Mixed Montado, according to the climate region
	Gardens, parks, etc: Cold Temp. - Wet		Average between Continuous Urban Fabric and Gardens				
	Gardens, parks, etc: Warm Temp. - Dry						
	Disc. Urban Farbic: Cold Temp - Wet						
	Disc. Urban Farbic: Warm Temp. - Dry						
Other Land	Bushlands (Mato)		2.71	7.68	2.83	8	Aboveground: average from equation $yr=-0.1177 \cdot yr^2 + 1.8511 \cdot yr + 1.9582$ from Pereira et al (2002) considering full-grow at 8 yr
Wetlands	-		NO	NO	-	-	Assuming negligible vegetation. Areas mostly salt pans, salt marshes, etc
Water	-		NO	NO	-	-	

DEAD ORGANIC MATTER (DOM)

The estimates refer only to the litter part of DOM, while dead wood was not estimated due to unavailability of information. The following considerations were assumed to establish the quantity of DOM that is removed when land use is terminated and the annual increase in DOM when land use is established, presented in :

- when a given land use is converted to other use all DOM is liberated and converted to CO₂;
- accumulation of DOM in areas converted to forest is usually negligible in the first years and was quantified as zero. However, accumulation of DOM was quantified in areas converted to bushland, in accordance with the faster grow period;

- no DOM is considered in croplands, either annual crops or permanent crops, considering the usual practice of frequent tillage. DOM is also considered to be non-existent in agro-forestry systems (Montados);
- DOM previous to land use conversion is considered to exist in forest areas, excluding Montados, and heterogeneous agriculture mixed with forestry (but only in the proportion of land use that is forest, i.e. 20 per cent of the area);
- no DOM is considered in other land uses such as artificial areas, wetlands and water bodies, including urban areas, urban parks, discontinuous urban areas.

The quantity of litter in stock in mature forest areas was obtained from Silva et al (unpublished) from studies made in Portugal and other Mediterranean places. The original information sources are presented in Table 7.12.

Table 7.12 - Litter biomass stocks by forest type

Forest Type	Litter Stock		Litter Increment		Documentation Source
	(t dm/ha)	(t C/ha)	(t dm/ha/yr)	(t C/ha/yr)	
Pinus Pinaster	10.0	5.0	NO	NO	Botelho et al. 1994, Dimitrakopoulos 2002, Fernandes et al. 2002, Montero et al. 1999.
Eucalyptus	6.0	3.0	NO	NO	Cruz & Viegas 1998, Madeira et al. 2002.
Quercus Suber	7.0	3.5	NO	NO	Fernandes et al. 2000
Q. Rotundifolia	7.0	3.5	NO	NO	Fernandes et al. 2000
Forest, mixed or other	8.0	4.0	NO	NO	Average value for maritime pine and eucalyptus
Bushlands (Matos)	2.8	1.4	0.22	0.11	litter production determined as ratio from biomass stock from Simões et al (2001); leaf biomass from Rambal (2001); total biomass from Pereira et al (2002)

SOIL ORGANIC CARBON

Soil Organic Carbon refers to the carbon in soil at the top 30 cm of soil.

The carbon stock at equilibrium is obtained in accordance with GP-LULUCF (IPCC,2003), from:

$$SOC = SOC_{ref} * F_{LU} * F_{MG} * F_I$$

were:

SOC - soil organic carbon stock at equilibrium, for a given soil type, climatic conditions, land use and management conditions, t C/ha

SOC_{ref} - the reference carbon stock for a given soil, t C/ha;

F_{LU} - stock change factor for land use or land-use change type;

F_{MG} - stock change factor for management regime;

F_I - stock change factor for input of organic matter.

Tillage factors represent the impact of changing management from a conventional tillage system, in which the soil is completely inverted, to conservation practices, including no-till and reduced till. The input factors represent the effect changing carbon input to the soil by planting more productive crops, cropping intensification, or applying amendments; input factors include cropping systems categorised as low, medium, high, and high w/manure amendments. Tillage and input factors represent the effect on carbon stocks after 20 years since the management was changed.

For the time being it was not possible to establish SOC_{ref} values representative of conditions in Portugal. Hence, the default values for warm temperate regions, Table 7.13. The additional parameters for SOC determination (F_{LU} , F_{MG} and F_I) are presented below for agricultural soils (Table 7.14) and for grazing lands (Table 7.15). Soils under dense forest (FOR) and bushlands (BUSH) are considered to have carbon in equilibrium conditions when removed or attain such levels in 20 years. For open forest areas, such as mosaic forest (MOSC) and Montados (MONT), the soil carbon stock and dynamics is mostly influenced by the agricultural and grassland activities made in the under-cover, and parameters were set accordingly. Parks, gardens and low density areas are assumed to have conditions equal to low density forests. Finally it was considered that under dense urban areas (URB), wetlands (WET) and water (H₂O) no soil carbon is stored.

Table 7.13 - Default Reference Soil Organic Carbon Stocks (SOC_{ref}) for Mineral Soils (ton per ha for 0-30 cm depth)

Region	HAC soils	LAC soils	Sandy soils	Spodic soils	Volcanic soils	Wetlands soils
Warm temperate, dry	38	24	19	115	70	88
Warm temperate, moist	88	63	34	115	80	88

Note: (1) All values default IPCC's GPG-LULUCF (table 3.2.3 (IPCC,2003));(2) for Spodic Soils the value of SOC_{ref} for Cold Temperate Moist was considered for all other climate conditions.

Table 7.14 - Relative Stock Change Factors (F_{LU} , F_{MG} and F_I) used for Portuguese cropland and low density forest (MOSC)

Factor	Level	Moisture Regime	GPG revised default	Notes
Land use (F_{LU})	Long-term cultivated	Dry	0.82	
		Wet	0.71	
Land use (F_{LU})	Paddy rice	All	1.10	
Tillage (F_{MG})	Full	All	1.00	Assuming widespread tillage
Input (F_I)	Low	Dry	0.92	Assuming low input in the drier regions in south
Input (F_I)	High - with manure	Wet	1.38	Assuming high input in the wetter regions in the north

Note: (1) All values default IPCC's GPG-LULUCF (table 3.3.4 (IPCC,2003)), for temperate regions

Table 7.15 - Relative Stock Change Factors (F_{LU} , F_{MG} and F_I) used for Portuguese grassland management

Factor	Level	GPG revised default
Land use (F_{LU})	All	1.00
Management (F_{MG})	Natural Grasslands (PRAI)	1.00
	Severely degraded (CHARN)	0.70
	Moderately degraded (MONT)	0.95
	Improved grassland (GRASS)	1.14
Input (F_I)	Nominal	1.00

Note: (1) All values default IPCC's GPG-LULUCF (table 3.4.5 (IPCC,2003)), for temperate regions

7.2.G.4 ACTIVITY DATA

Data on Land Use changes is based on the cartographic product – CLC Changes (Caetano et al 2005). This cartography on land cover changes was developed having as a basis CLC-R (CORINE Land Cover 90 reviewed) referring to information from 1985/86/87, and CLC2000 (Project IMAGE and CORINE Land Cover (I&CLC2000) for the year 2000.

The set of polygons was further divided for consideration of variables originally not considered in the CLC Changes database:

- Soil cartography, using data from the Environment Atlas¹³⁴ (IA,1971);
- Total annual precipitation, using data from the Environment Atlas (IA, 1974);
- Forest land cartography on forest types, from DGRF.

The intersecting of these products resulted in 42 000 polygons which were used to quantify the carbon stocks using some GPG Guidelines defaults and national parameters according to the changes occurred. The final set of polygons in continental Portugal is observable from Figure 7.5.

¹³⁴ Atlas do Ambiente (<http://www.ambiente.pt>)

Figure 7.5 - Total individual polygons identified in continental Portugal



The collection of activity data is classified as a polygon approach 3 of the LULUCF-GP.

CLC CHANGES

Information Data Source

The CORINE program (Co-ordination of Information on the Environment) was created in 1985 by the European Union for the surveillance of the quality of the environment in Europe. The CORINE Land Cover 1990 (CLC90) was one important component of this program, which aim was to obtain the cartography of the land use in Europe for 1990¹³⁵.

Later, the Portuguese project CORINE Land Cover 2000 (CLC2000) was developed under the project: IMAGE and CORINE Land Cover 2000 (I&LC2000), launched by EEA and JRC for the European Commission (EC) (EEA,2002b). The aim was to upgrade the land use cartography for the year 2000. The work was coordinated by the Instituto Superior de Estatística e Gestão de Informação (ISEGI) in collaboration with the Instituto Geográfico Português (IGP). Several additional information sources were used to improve the cartography, which are described in detail in Painho & Caetano (2005), as well as some field work done in 2003 and 2004.

In Portugal both CORINE products (CLC90 and CLC2000) rely on data from the Landsat satellite¹³⁶, follow the Heyford-Gauss system with Lisbon Datum, Heyford Ellipsoid, complemented with data from several other sources (Painho & Caetano, 2005), have a scale of

¹³⁵ The reference year could vary from 1985 to 1995.

¹³⁶ Thematic Mapper (TM) and Multispectral Scanner (MSS) from Landsat-5 (1985-87) and Enhanced Thematic Mapper (ETM+) from Landsat-7 (2000)

1:100 000, minimum areas of 25 ha and inter-line space of 100 m in the military Cartesian coordinate system. The CLC2000 products comprises 3 cartographic products:

- CLC90-R. Geometric and thematic review of the CORINE Land Cover of 1990;
- CLC2000. Land use cartography in the year 2000;
- CLC - Changes¹³⁷. Land use changes between 1985/86/87 and 2000.

Land use data for the CLC90 reflects the land use in the years 1985-1987, while CLC2000 refers only to the year 2000.

The minimum land use area detected by CLC90-R and CLC2000 is 25 ha. However, for the CLC-Changes cartographic product, the minimum size at which areas were detected is 5 ha for the increase or decrease of pre-existent areas and 25 ha for fully new areas not contiguous to others of the same class in CLC90-R¹³⁸.

The CLC information source covers only continental Portugal and not the autonomous regions of Madeira and Azores.

Land use areas in CLC Changes are classified according to a hierarchic nomenclature, with 3 levels and 44 classes¹³⁹ at the lowest (3rd) level, as presented in the next table.

¹³⁷ CLC-alterações in Portuguese.

¹³⁸ The limitation due to this low resolution was corrected to 1 ha, in order to obtain a better consistency with the methodology that is being prepared for the detection of land units covered by article 3.3 of the Kyoto Protocol. This will be explained in more detail in subsequent chapters.

¹³⁹ 42 classes were used in the Portuguese cartography (Painho & Caetano, 2005).

Table 7.16 - Land Use Nomenclature in CLC products

Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Artificial areas	Urban Fabric	Continuous Urban Fabric	Forest and semi-natural areas	Forests	Broadleaved forest
		Discontinuous Urban Fabric			Coniferous forests
	Industrial, commercial and transport units	Industry or commercial units			Mixed forests
		Road and rail networks and associated land		Shrubs and/or herbaceous vegetation associations	Natural grasslands
		Port areas			Moors and heathland
		Airports			Sclerophyllous vegetation
	Mine, dump and construction sites	Mineral extraction sites			Transitional woodland/shrub (Forest areas degraded, recently harvested and new plantations)
		Dump sites		Open spaces with little or no vegetation	Beaches, dunes and sand plains
		Construction sites			Bare rock
	Artificial non-agricultural vegetated areas	Green urban areas			Sparsely vegetated areas
		Sport and leisure facilities			Burnt areas
					Glaciers and perpetual snow
Agricultural areas	Arable land	non irrigated arable land	Wetlands	Inland wetlands	Inland marshes
		Permanently irrigated land			Peatbogs
		Rice fields		Coastal wetlands	Salt marshes
	Permanent crops	Vineyards			Salines
		Fruit trees and berry plantations			Intertidal flats
		Olive groves	Water bodies	Inland waters	Water courses
	Pastures	Pastures			Water bodies
	Heterogeneous Agricultural areas	Annual crops associated with permanent crops		Marine waters	Coastal lagoons
		Complex cultivation patterns			Estuaries
		Agriculture and natural areas			Sea and Ocean
		Agro-Forestry areas			

A more detailed explanation of the definition of each land use can be found in EEA (2002b), Bosard et al (2000) and in Painho & Caetano (2006).

It is important to mention that, following the EEA technical guidelines, the cartographic products were subjected to a quality control and a validation by the technical team of the EEA (Painho & Caetano, 2005).

Analysis of CLC Changes Data

During the period of analysis of the CLC changes project, substantial changes have occurred in the land use pattern in Portugal (Painho & Caetano, 2005). In absolute terms it is noticeable the increase in artificial areas from 1.9 per cent to 2.7 per cent (66 738 ha). Slight increases were

also verified in what concerns Forest areas, 48.1 per cent to 48.2 per cent (11 931 ha), and water bodies, 0.8 per cent to 0.9 per cent (5 390 ha). By the contrary, agricultural areas decreased from 48.9 per cent to 48.1 per cent (84 055 ha). Finally wetland areas remain constant, 0.3 per cent of the continental territory. Nevertheless, at a more detailed level (level 3), about 11 per cent of the territory has suffered changes in land use, which mainly expresses changes in forest and agricultural activities.

The table below summarizes the land-use changes among the six LULUCF categories which have occurred during the period 1986-2000. The meaning of FF (Forest Land remaining Forest Land) or CC (Cropland remaining Cropland) in the table means Forest or Cropland that have suffered changes despite the fact they remained in the same Land Use classification.

Table 7.17 – Matrix for land use change (1000 ha): annual averages 1986-2000

		2000					
		F	C	G	W	S	O
1986	F	1.2	1.5	0.0	0.1	1.5	0.9
	C	3.6	9.2	0.5	0.3	3.0	0.6
	G	0.7	1.5	0.0	0.0	0.1	0.0
	W	0.0	0.0	0.1	0.0	0.0	0.0
	S	0.0	0.0	0.0	0.0	0.3	0.0
	O	5.4	0.7	0.0	0.1	0.2	0.6
Total annual LUC		11.0	12.9	0.6	0.5	5.1	2.2

Source: CLC-Changes cartography.

Quality Control

In accordance with the EEA (2002) technical guidelines, a set of procedures were developed to guarantee the quality of the product. The set of procedures are explained in more detail in Painho & Caetano (2005), basically consisting of:

- thematic and geometric revision of the CLC products at the end of the project, comparing polygons in the final product with classification in the original CLC90 product, auxiliary cartography and field work;
- revision (2003 and 2004) by European Technical Teams

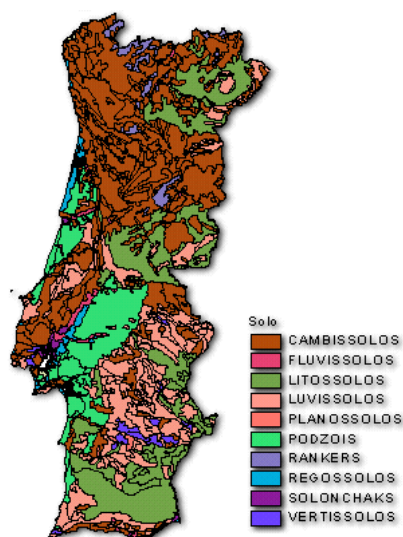
SOIL CLASSES

The soil cartography follows the FAO -UNESCO soil classification system (World Reference Base for Soil Resources - WRB, IUSS,1998). Other classes are available in Portugal (Ferreira, 1965), more detailed in soil types and geographic disaggregation, but do not cover the whole national territory.

Table 7.18 - Soil Types used in calculation of carbon release/uptake from the soil pool

Soil	Qualifiers	Association with	Soil	Qualifiers	Association with
Fluvisols	eutric		Luvisols	orthic	
	eutric	Fluvisols calcareic		rhodo-chormic	
	calcareic			rhodo-chormic calcic	
	dystic			rhodo-chormic calcic vertic	
Regosols	eutric			calcic vertic	
	dystic			vertic	
Litosols	eutric			ferric	
	eutric	ultra-basic rocks		Plinthic	
	eutric	Luvisols		gleyic	
Rankers	-			gleyic albic	
Vertisols	Pellic		Podzols	orthic	
	chromic			orthic	Regosols eutric
	chromic calcareic			orthic	Cambisols dystic
Solonchaks	gleyic			orthic	Cambisols eutric
Cambisols	dystic			orthic	Luvisols gleyic
	dystic	shales and quartzites (Ordovician)		orthic	Cambisols calcareic
	dystic	post-paleozoic sedimentary rocks	Planosols	eutric	
	humic	eruptive rocks			
		Cambisols dystic (eruptive rocks)			
		shales			
		shales, luvisols strong atlantic influence			
		shales, luvisols weak atlantic influence			
		shales, luvisols strong atlantic influence			
		shales and quartzites (Ordovician). Moderate atlantic influence			
		post-paleozoic sedimentary rocks			
	humic chromic				
	eutric	eruptive rocks			
	eutric	shales and quartzites (Ordovician)			
	eutric	post-paleozoic sedimentary rocks			
	calcic				
	chromic				
	chromic calcareic				
	chromic calcareic vertic				

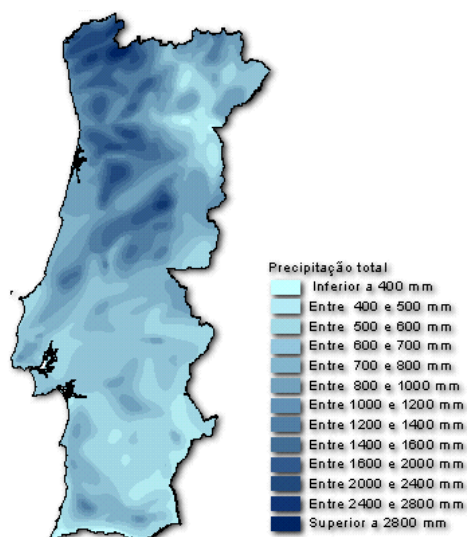
Figure 7.6 - Soil Classes according to the FAO-UNESCO classification scheme in Continental Portugal (IA,1971)



CLIMATIC ZONES

The delimitation of climatic zones is important for the choice of the default parameters for stock and gains in the carbon pools. In terms of average annual temperature, all Portuguese territory was defined as Warm Temperate, following the generic rules set in the LULUCF-GP (Figure 3.1.3 in IPPC,2003): Mean Annual Temperature (MAT) 10-20°C. The differentiation between dry zones from wet zones considers the mean annual total precipitation from the Environment Atlas (<http://www.iambiente.pt>), and presented in Figure 7.7. Wet areas were considered to be those where annual precipitation exceeds 1000mm/yr, whereas areas with lower annual precipitation totals are classified as dry. Therefore, only two climatic zones were considered: Warm Temperate dry and warm temperate wet.

Figure 7.7 - Mean Annual Total Precipitation in Continental Portugal (IA,1974)



FOREST TYPES

The original classes in the CLC changes product were not detailed enough for a full consideration of tree species, making only a distinction between coniferous forests, broadleaved forests and mixed forests. The only possible way to overcome this limitation was to use the data from the last National Forest Inventory for the year 1995 (DGRF,2000). Though this inventory is

made by sampling in geographically located points and not by polygon wall to wall mapping, it represents clearly the geographical distribution of forest species. The most close point to the land unit was used to establish the classification. For the situations where it was not possible to identify a forest type, a mixed forest was assumed.

The following tree species were available from the DGRF mapping in next table.

Table 7.19 - Individual forest type formations

Forest	Specie	Code
Maritime Pine	Pinus pinaster	Pb
Umbrella pine	P. Pinea	Pm
Other coniferous	-	Rd
Cork oak	Quercus suber	Sb
Holm oak	Q. Rotundifolia	Az
Other oaks	Quercus sp.	Qc
Gum tree	Eucalyptus sp.	Ec
Chestnut	Castanea sativa	Ct
Other broadleaved	-	Fd
Other/ mixed woods	-	mx

AGGREGATION OF SOIL USES

All land use areas identified in CLC-changes having suffered a conversion of land use were considered in estimation of carbon release and update¹⁴⁰. Nevertheless the actual calculation was done at a level more aggregated than the one available from the crossing of the CLC-change cartography, with the cartographies of soil type; climate and forest species. These classes represent the adequate level of detail considering the detail of cartography and also the specificities of the parameters that were used in actual calculation. They represent, in fact, the fundamental land use types that actually have different values of carbon stocked or carbon release/ uptake rates, in one or more carbon pools. These intermediate classes are presented in Table 7.20, also showing the rules of conversion from the original cartography classes. All land use types in Table 7.20 were further classified according to soil type, Table 7.18, and, for forestall systems, also in accordance with the dominant tree, Table 7.21. Concerning climate type, the division was only between moist climate and dry climate. Therefore, each land use, corresponding to a land use conversion is codified as the string:

$$USE_i \times USE_f \times CLIM \times SOIL \times TREE$$

Where

USE_i - Land use before the conversion of land use (Table 7.20);

USE_f - Land use resultant from the conversion of land use (Table 7.20);

CLIM - Climate conditions (MOIST/DRY) prevailing in the land use area;

SOIL - Soil type existing in the land use area (Table 7.18);

¹⁴⁰ exception made to some changes in land cover that are only apparent and temporary and are not land use changes, as will be explained later in the chapter Soil Conversion Exclusions.

TREE - Dominant tree species in forest areas or land uses including forest species (Table 7.21).

Table 7.20 - Individual land use types, used in calculation and definition of each class from land use classes of CLC-changes (Level 3)

Code	Land Use	CLC-Changes Level 3	Code	Land Use	CLC-Changes Level 3
CRPPER	Croplands with Perennial/Wooddy Crops	Vineyards	URB	Urban Areas	Continuous Urban Fabric
		Fruit trees and berry plantations			Industry or commercial units
		Olive groves			Road and rail networks and associated land
		Complex cultivation patterns			Port areas
CRPANN	Arable land	non irrigated arable land			Airports
		Permanently irrigated land			Mineral extraction sites
		Annual crops associated with permanent crops			Dump sites
					Construction sites
RICE	Rice Paddies	Rice fields			Sport and leisure facilities
GRASS	Managed Grasslands	Pastures	SURB	Mixed urban areas and parks	Discontinuous Urban Fabric
PRAI	Natural Grasslands	Natural grasslands	WET	Wetlands	Peatbogs
CHARN	Sparse Grassland	Sparsely vegetated areas			Salt marshes
					Salines
			H2O	Water bodies	Inland marshes
					Intertidal flats
					Water courses
FOR	Forest	Broadleaved forest			Water bodies
		Coniferous forests			Coastal lagoons
		Mixed forests			Estuaries
		Transitional woodland/shrub (Forest areas degraded, recently harvested and new plantations)			Sea and Ocean
		Burnt areas	OTH	Other Land Uses	Beaches, dunes and sand plains
MONT	Grasslands with Dispersed trees (Montado)	Agro-Forestry areas			Bare rock
MOSC	Agriculture Areas mixed with forest	Agriculture and natural areas			Glaciers and perpetual snow
BUSH	Bush areas (Matos)	Moors and heathland			unclassified
		Sclerophyllous vegetation			
GAR	Urban gardens & parks	Green urban areas			

Note: "Matos" and "Montado" are the traditional name used for the particular type of vegetation/land use. They are mentioned in brackets due to the lack of an appropriate English term and due to the widespread reference to this terms in statistics and bibliographic references.

Table 7.21 - Forest types considered in calculation

Specie	Forest Structure		
	Forest	Montado	Mosaic
P. Pinaster	FOR-Pb		MOSC-Pb
Eucalyptus	FOR-Ec		MOSC-Ec
Quercus Suber	FOR-Sb	MONT-Sb	MOSC-Sb
Q. Rotundifolia	FOR-Az	MONT-Az	MOSC-Az
mixed or other	FOR-mx	MONT-mx	MOSC-mx

To be reported in the CRF tables the land use areas used in the calculus process had to be aggregated in the final 6 classes to be reported in the GHG inventory: Forest (F); Cropland (C); Grazing Land (G); Wetlands (W); Settlements (S) and Other Land (O). The conversion rules are expressed in the next table.

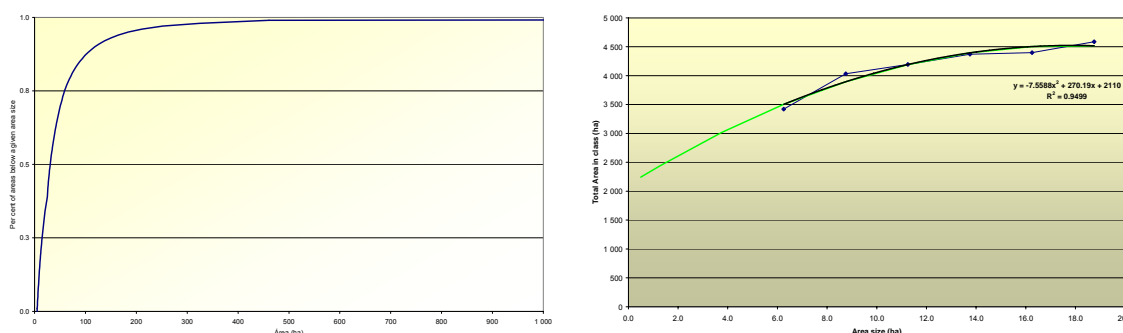
Table 7.22 - Conversion of Land Use Classes in calculus to Land Use Classes under the Inventory

LL Code	CRF class	Code	Class
F	Forest	MONT	Grasslands with Dispersed trees (Montado)
		FOR	Forest Areas
C	Cropland	CRPPER	Croplands with Perennial (Woody) Crops
		CRPANN	Arable land
		RICE	Rice Paddies
		MOSC	Agriculture Areas mixed with forest (<30%)
G	Grazing Land	GRASS	Managed Grasslands
		PRAI	Natural Grasslands
		CHARN	Sparce grassland
S	Settlements	URB	Urban Areas
		GAR	Gardens urban parks
		SURB	Mixed urban areas and parks
W	Wetlands	WET	Wetlands
		H2O	Water
O	Other	BUSH	Bush areas (matos)
		OTH	Other land uses

CORRECTION OF THE MINIMUM DETECTION THRESHOLD

The fact that areas that have changed soil use are not accounted if they size is below 25ha/5 ha might have caused the underestimation of emissions and removals. To overcome this situation a simple procedure was implemented to determine the per cent of area below five ha that could also under come change but was not quantified. The per cent distribution of areas in CLC change under given area limits was plotted in graph (Figure 7.8) and a second order polynomial equation was adjusted to the resultant curve. Calculation of the remaining area, between 5 ha and down to 0.5 ha, indicates that the total area could be about 1.27 per cent of total. This per cent was applied for all estimated of all land use changes.

Figure 7.8 - Distribution of area sizes in CLC changes and adjustment of curve to the lower range of areas



SOIL CONVERSIONS EXCLUSIONS

Some of the soil conversion areas detected in CLC changes are only land cover changes and do not correspond to a definitive change in land use, according to the rules of LULUCF and were not considered. These correspond to the cases when a land unit that was formerly classified as forest is at the end of the period classified as land subjected to fire or forest areas subjected to cuts, new plantations or degradation and vice versa. These changes in CLC class does not result in change in land use, while changes in stock due to these actions (fire, harvesting, degradation, plantations, forest grow, re-grow or recovering) are already considered under category Forest remaining forest and should emissions/removals should not be double counted here.

7.3 Recalculations

In this 2006 submission, the 2003 IPCC Good Practice Guidance for LULUCF (GPG LULUCF) has been applied to the extent of possible. The estimates include for the first time quantification of emissions and removals for land-use change, representing a substantial improvement since last year's submission.

Carbon stock changes in the forest land have been estimated for living biomass (above and below ground). Previously only above ground biomass was considered.

Concerning land-use changes and conversions between the six GPG LULUCF categories, all carbon pools (above and belowground biomass, dead organic matter, and soil organic matter) have been assessed.

Some assumptions concerning the percentual average of the biomass burnt due to forest fires have been revised. Also, further to the above ground biomass stock burnt of trees, and the undergrowth cover (only for non-CO₂ emissions) which were already considered previously, this submission considers also the biomass burnt from litter existing in forest land.

The calculation of annual carbon loss in trees above ground biomass was also revised. In previous submissions, it was assumed that all above ground biomass from burnt trees was removed through harvesting as salvaged wood volumes. This year the calculation of annual tree carbon loss in above ground biomass considered two situations:

- 1) For pinus pinaster and eucalyptus, the two representative species in terms of industrial wood consumption, it was assumed that the affected trees are harvested as salvaged wood and used in the industry, and are consider included in the harvest volumes. This approach was based on the premise that these quantities were largely used in industry, and were considered to be fully included in the harvest volumes which refer to wood consumption. However, if the extent of the volumes burnt exceed by large the industrial wood consumption, then the whole amount of the burnt volume are accounted in the estimates, which is the case of the year 2003 for coniferous species.
- 2) For the other species, the calculation of annual carbon loss in above ground biomass, refer to the fraction of biomass that is affected by the disturbance, based in the assumptions described below, and on the supposition that other species do not have the same economic importance and the trees are left in the burnt areas and that they regenerate in majority after the fire.

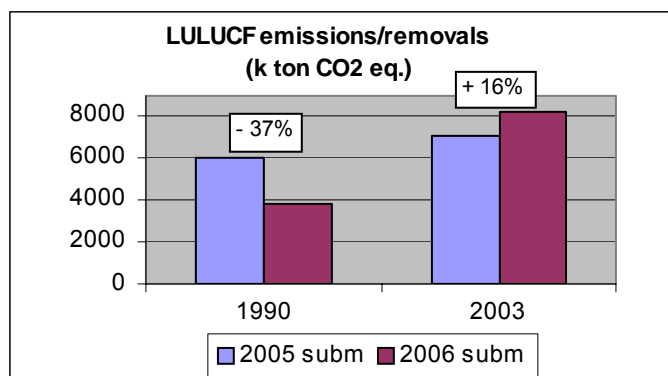
Figure 7.9 – Differences between 2005 and 2006 submissions (CO₂, CH₄ and N₂O)

Table 7.23 – Recalculations (differences between 2005 and 2006 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2005 subm.	2006 subm.	Difference (1)	2005 subm.	2006 subm.	Difference (1)	2005 subm.	2006 subm.	Difference (1)
	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)	CO ₂ equivalent (Gg)	CO ₂ equivalent (Gg)	(%)
1990									
5. Land Use, Land-Use Change and Forestry (net)	5 572.83	3 648.97	-34.52	440.86	153.59	-65.16	44.74	15.59	-65.16
5.A. Forest Land	NA	2 230.69	NA	NA	153.59	NA	NA	15.59	NA
5.B. Cropland	NA	190.60	NA	NA	NO	NA	NA	NE,NO	NA
5.C. Grassland	NA	-24.77	NA	NA	NO	NA	NA	NO	NA
5.D. Wetlands	NA	104.87	NA	NA	NO	NA	NA	NO	NA
5.E. Settlements	NA	1 114.94	NA	NA	NO	NA	NA	NO	NA
5.F. Other Land	NA	32.64	NA	NA	NO	NA	NA	NO	NA
5.G. Other	NA	NO	NA	NA	NO	NA	NA	NO	NA
2003									
5. Land Use, Land-Use Change and Forestry (net)	5 329.99	7 600.48	42.60	1 585.28	552.31	-65.16	160.89	56.05	-65.16
5.A. Forest Land	NA	6 182.20	NA	NA	552.31	NA	NA	56.05	NA
5.B. Cropland	NA	190.60	NA	NA	NO	NA	NA	NE,NO	NA
5.C. Grassland	NA	-24.77	NA	NA	NO	NA	NA	NO	NA
5.D. Wetlands	NA	104.87	NA	NA	NO	NA	NA	NO	NA
5.E. Settlements	NA	1 114.94	NA	NA	NO	NA	NA	NO	NA
5.F. Other Land	NA	32.64	NA	NA	NO	NA	NA	NO	NA
5.G. Other	NA	NO	NA	NA	NO	NA	NA	NO	NA

Notes: (1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission).

7.4 Uncertainty Analysis

For the first time the uncertainty was estimated for emissions for this category sector, in accordance with the values submitted in the inventory report under the convention.

The uncertainty in forest area, for each specific species, is the uncertainty reported in the National Forestry Inventory Report for Forest stands, 0.72 per cent.

Concerning the areas reported as land use conversions, association pairs of the 6 land use classes defined in the GP-LULUCF: Forest (F), Cropland (C), Grazing Land (G), Settlements (S), Wetlands (W) and Other Land uses (O), the overall uncertainty combines the error from Remote Sensing, 12.5 per cent according to GP-LULUCF¹⁴¹, with the biased error of the not consideration of areas below 5 ha, which were determined from extrapolation of the probability of areas under a given area interval in the vicinities of the lower identification limit.

¹⁴¹ According to Painho & Caetano (2005) the global thematic accuracy was estimated to be 82.84 per cent, following the methodology defined in the EEA (2002) Technical Guidance for the I&CLC2000 Project.

The uncertainty of livebiomass (above-ground and below-ground) in Forest remaining Forest (FF) includes the following individual uncertainties propagated in accordance to:

$$U_{\text{Total}} = \sum \{ [A_i * (U_{Ai}^2 + U_{Gi}^2 + U_{BEFi}^2 + U_{RSi}^2 + UC^2)]^{0.5} / \sum A_i$$

Where,

A_i - Total National Area of Forest of specie I;

U_{Ai} - the uncertainty in total national area for the given forest specie I, according to the 3rd National Forestry Inventory (DGF,2002);

U_{Gi} - Uncertainty of the growth rate of specie I, from GP-LULUCF tables 3.A.1.5 to 3.A.1.7;

U_{BEFi} - Composed uncertainty of both density of biomass and BEF, set as 32 per cent from GP-LULUCF;

U_{Ri} - Uncertainty of the root to shoot ratio (GP-LULUCF);

U_{Ci} - Uncertainty in carbon content of biomass. A constant value of 30 per cent was assumed for all species.

The uncertainty in the change in carbon in live-biomass for a given LL pair considers the individual components of uncertainty in carbon in aboveground biomass (U_C) and root to shoot ratio (U_R) in the initial land use under termination (i) and the new land use that results from the conversion (f):

$$U_{LL} = [(U_{Ci}^2 + U_{Ri}^2) + (U_{Cf}^2 + U_{Rf}^2)]^{0.5}$$

The individual uncertainties were established from the default values in GP-LULUCF except the case of land use forest, that was established using the same procedure explained before for Forest land remaining forest land.

For all soil types the same uncertainty error of 95 per cent was set from IPCC. The uncertainty in DOM was calculated from the range of values proposed by the GP-LULUCF, for the land use under termination, and the double of that value for the land use being initiated.

The final uncertainties in activity data and emission factors (Carbon factors) are presented in the table below.

Table 7.24 – Uncertainty Values for Land Use Change and Forestry

LL	U AD	U EF Live	U EF DOM	U EF SOC
Forest	0.7	40	30	95
FF	13.0	27	29	95
CF	15.1	42	26	95
GF	12.9	86	26	95
WF	12.5	20	26	95
SF	20.4	23	26	95
OF	12.7	45	36	95
CC	13.9	53	0	95
FC	30.2	42	13	95
GC	13.4	92	0	95
WC	36.6	38	0	95
SC	53.4	40	0	95
OC	16.0	55	26	95
GG	12.5	119	0	95
FG	21.3	86	13	95
CG	13.4	92	0	95
WG	13.8	84	0	95
SG	21.2	85	0	95
OG	18.4	93	26	95
WW	21.7	7	0	95
FW	20.5	19	13	95
CW	16.2	38	0	95
GW	16.8	84	0	95
SW	45.3	13	0	95
OW	19.1	41	26	95
SS	14.9	18	0	95
FS	26.4	22	13	95
CS	27.0	40	0	95
GS	14.2	85	0	95
WS	35.9	13	0	95
OS	21.1	43	26	95
OO	20.3	58	36	95
FO	12.6	45	29	95
CO	14.4	55	26	95
GO	15.7	93	26	95
WO	32.0	41	26	95
SO	12.5	43	26	95

Uncertainty associated with CH₄ and N₂O emissions from fires was established in the following mode:

- The uncertainty in activity data, according to GP LULUCF, and "Because of increased accuracy and global coverage of area burned by fire, uncertainty is relatively small, in the range of 20-30%." The highest value in the range was considered;
- The uncertainty in CO₂ associated with this class represents the biomass that is not included in harvest. The error is therefore equal to the error in Harvest and determined comparing, in per cent terms, the maximum area subjected to fire that was not included

in harvest (because it was not maritime pine or eucalyptus) from 1990 to 2004. The uncertainty was estimated as 93 per cent;

- The uncertainty in CH₄ and N₂O, both 70 per cent, are those proposed by GP LULUCF, pag 3.50.

7.5 Further Improvements

After finalization of the emission estimates for this sector, efforts have been done to improve the methodology that will be used to report emissions under the Kyoto Protocol. Although the changes aim principally to the Kyoto Protocol, the methodology that will be used under the convention will be revised accordingly, as much as possible, in order to maintain consistency between the two reports. The main actions that are under way and that could affect the estimates under the convention are:

- Revision of the carbon content of soils, with the inclusion of country specific studies and monitoring;
- Development of models of biomass production, for the several components, that will in principle revise the use of the BEF methodology.
- Revision of the methodology used to estimate emission from forest fires, considering the per cents that remain alive after the fire, and avoiding the double counting of harvest and biomass loss during fires;
- Inclusion of emissions and removals from LULUCF in the Madeira and Azores autonomous regions.

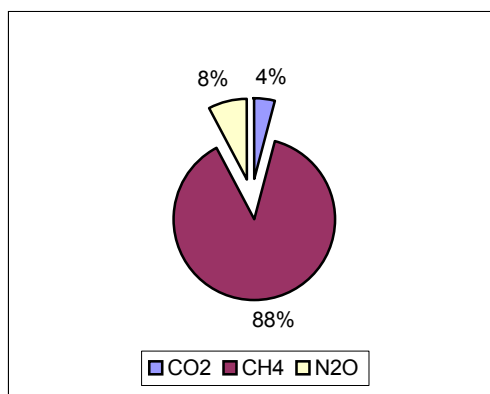
CHAPTER: 8 WASTE (CRF 6)

8.1 Overview

Waste management and treatment of industrial and municipal wastes are sources of GHG emissions. The inventory covers emissions resulting from solid waste disposal on land, treatment of liquid wastes and waste incineration.

The most important gas produced is CH₄, resulting from the anaerobic decomposition of organic waste disposed on land and from handling of wastewater treatment under anaerobic conditions.

Figure 8.1 – Emissions of GHG from waste by gas (2004)



Decomposition of organic waste does not occur instantaneously after disposition on land, but rather over a long period of time, and CH₄ is emitted at a diminishing rate. Different factors affect the generation of CH₄: Waste disposal practices (degree of control of disposal sites – in general, controlled placement of waste favours anaerobic activity and consequently landfill gas formation, but the gas can be recovered and be either flared or used for energy purposes); Waste composition (quantities of degradable materials is one major element influencing biogas production); and Physical factors (e.g. moisture content and temperature).

Solid waste disposal sites (SWDS), which include both managed landfills and open dump sites, can also produce directly significant amounts of CO₂. In fact, the decomposition of organic materials originates landfill gas or biogas consisting of approximately 50 per cent CH₄ and 50 per cent CO₂ by volume. However, this carbon dioxide results in its major part from oxidation of biomass materials and does not contribute hence to ultimate CO₂. Additionally, a much smaller percentage of landfill gas is composed of NMVOC and NH₃.

The biodegradation of soluble organic matter in wastewater can occur under aerobic or anaerobic conditions. CH₄ emissions result from handling of wastewater and the biomass (sludge) produced under anaerobic conditions. The amount of CH₄ produced depends on the extent of biodegradation occurring under anaerobic versus aerobic conditions. CH₄ produced during deliberate anaerobic wastewater treatment processes can be collected and flared or combusted for energy. Untreated wastewater may originate CH₄ if held under anaerobic circumstances.

CH₄ emissions are affected by:

- Wastewater characteristics. Determines how much organic compounds are degraded. Also the degradable organic content of wastewater determines the CH₄ producing potential of wastewater, because it affects the extent to which oxygen is removed from the system. Under anaerobic conditions and all the same conditions, such as temperature, wastewater with higher BOD (Biochemical Oxygen Demand) or COD

(Chemical Oxygen Demand) concentrations will produce more CH₄ than wastewater with lower BOD or COD concentrations);

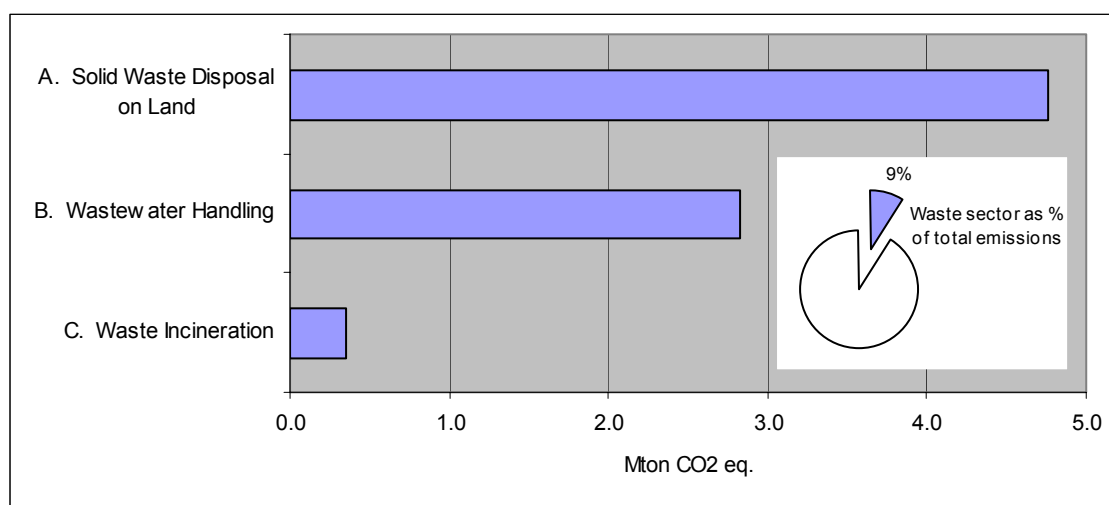
- Handling Systems – anaerobic versus aerobic conditions in system design and operation (the management conditions of collection and wastewater treatment systems determine the potential of CH₄ generation; systems providing anaerobic conditions will generally produce higher CH₄ emissions than systems having aerobic conditions);
- Temperature (CH₄ generation increases with temperature; CH₄ production occurs with temperatures higher than 15°; this factor is specially important in uncontrolled systems and warm climates);
- Systems characteristics (other factors affecting CH₄ production are retention time, degree of wastewater treatment, and other site specific conditions).

Wastewater treatment is also potentially a source of NMVOC and N₂O. Although the available methodologies to estimate these pollutants are far from suitable, N₂O emissions from human sewage were estimated using a basic approach, and rough NMVOC estimates are also presented based on indicative default emission factors from CORINAIR90 Default Emission Handbook.

Incineration of municipal solid wastes (MSW) and hazardous wastes originates emissions of CO₂, CH₄, N₂O, CO, NO_x and NMVOC. Out of the direct GHG, CH₄ emissions are considered to be the less significant due to combustion conditions in incinerators. According to the IPCC Guidelines (IPCC,1997), only CO₂ emissions resulting from the incineration of carbon in waste of fossil origin (e.g. plastics, certain textiles, rubber, liquid solvents, and waste oil) are to be included in emissions estimates, while the carbon fraction that is derived from biomass materials (e.g. paper, food waste, and wooden material) should not be included. Thus, CO₂ emissions from waste combustion depends, on the quantities of waste incinerated, the carbon content of the waste, and the fraction of the carbon that is of fossil origin. The inventory also includes estimates for Particulates and Heavy Metals emissions from the incineration of municipal solid wastes (MSW) and hospital hazardous wastes.

Emissions generated from waste activities represented in 2004 9.4% of total GHG emissions (excluding LULUCF). The biggest sub-category within the sector refers to solid waste disposed on land – 4.76 Mton CO₂ eq. - corresponding to 60% of the sector emissions.

Figure 8.2 – Sources of GHG in waste sector (2004)

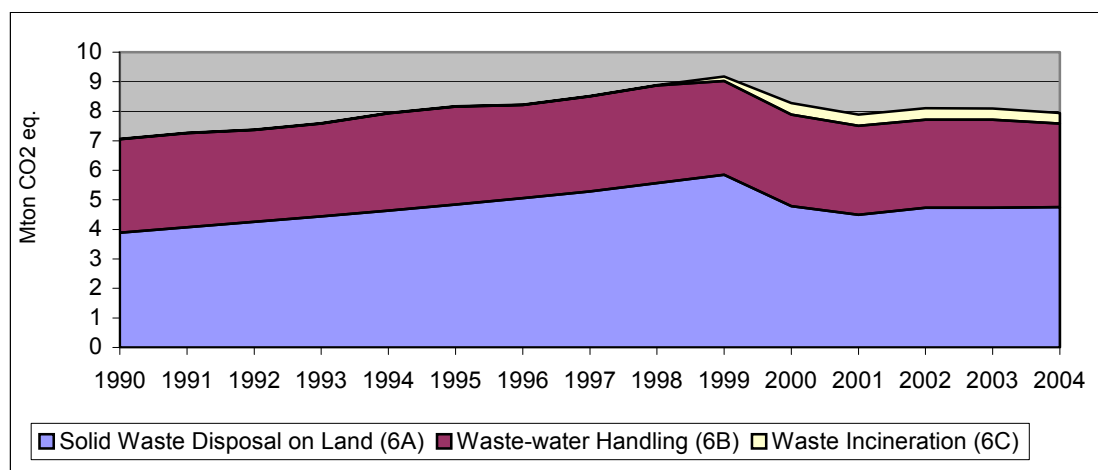


Note: Category 6D (Open burning of industrial waste) is not represented as it represents less than 0.02% of the emissions of the sector in 2004.

In the period 1990-2004 GHG emissions from waste activities have grown 12.5%, having reached a peak in 1999. The increase in the sector is strongly related to the change of consumption patterns registered in Portugal in the last decades, associated with new commercial structures. The opening of the first supermarket occurred in 1961. By the end of that decade/ beginning of the next one, several distribution companies appeared. The late 70s/ beginning of the 80s registered another increase of these commercial units, with the number of supermarkets rising from 196 in 1974 to 375 in 1985. The following years, which recorded a steady economic growth in particular since the Portuguese accession to the EU in 1986, have led to the reduction of customs barriers and the revival of domestic demand, and have definitively changed the consumption habits of the Portuguese population. Since 1985, year of the opening of the first hypermarket in Portugal, until 1997, they were settled 40 hypermarkets and 943 supermarkets in the country (APED)¹⁴².

Another factor related to the emissions growth of this sector refers to the geographical distribution change of the Portuguese population. Since 1960, there was a significant increase of the population living in urban centres. This trend was accompanied by the development of solid waste collection systems: the population served by solid waste collection systems is estimated to have increased from 40% in 1960 to 100% in 2000.

Figure 8.3 – Emission trends of GHG from waste



The emissions from incineration, as presented in Figure 8.3, have grown significantly since 1999, corresponding to the start of operation of the two incineration units dedicated to MSW incineration. This tendency is accompanied by a decrease in the emissions from SWDS reflecting a transfer of MSW final disposal between these two disposal types. Furthermore, the category CRF 6A registers an emission estimates decline since 1999, which is in part due to the flaring of biogas collected in landfills, where have been installed biogas burners.

¹⁴² APED, Anuário da Distribuição Portuguesa 1999.

8.2 Source categories

8.2.A Solid Waste Disposal on Land (CRF 6 A)

8.2.A.1 CH₄ EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

METHODOLOGY

To better take into account to the fact that CH₄ emissions from SWDS occur over a long period of time and not immediately after disposal of waste on land, the methodological approach considered was the First Order Decay Method (Tier 2).

This method can be represented by equations (1) and (2):

$$Q_{T,x} = k R_x L_0 e^{-k(T-x)} \quad (1)$$

where:

$Q_{T,x}$ - methane generated in current year (T) by the waste R_x (Mg CH₄/yr);

k - methane generation rate constant (1/yr);

R_x - quantity of waste disposed in year x (Mg/yr);

L_0 - methane generation potential (Mg CH₄/Mg waste);

x - year of waste input;

T - current year.

$$\text{CH}_4 \text{ emitted in year } T \text{ (Gg/yr)} = [\text{CH}_4 \text{ generated in year } T - R(T)] * (1 - \text{OX}) \quad (2)$$

where:

$R(T)$ - CH₄ recovered in year T (Gg/yr);

OX - oxidation factor (fraction).

CH₄ recovery ($R(T)$) is the amount of CH₄ generated at SWDS that is recovered and combusted (e.g. flared or used for energy) and not emitted as CH₄ but as CO₂¹⁴³. On the other hand, the CH₄ that is recovered but subsequently vented to atmosphere is not subtracted from emissions.

The Oxidation factor (OX) reflects the portion of CH₄ from SWDS that is oxidised to CO₂ in the soil or other material covering the waste. If the OX is zero, no oxidation takes place, and if OX is 1 then 100% of CH₄ is oxidised. Well-managed disposal sites tend to have higher oxidation results than unmanaged dump sites with no cover or where large amounts of CH₄ can escape through cracks in the cover.

The methane generation potential (L_0) depends upon the composition of waste, waste disposal practices and of the physical characteristics of the SWDS. It is estimated by the formula:

¹⁴³ Although not ultimate CO₂.

$$Lo = MCF * DOC * DOC_F * F * 16/12$$

where:

MCF - CH₄ correction factor (fraction);

DOC - degradable organic carbon (fraction) (Mg C/Mg waste);

DOCF - fraction DOC dissimilated;

F - fraction (volume) of CH₄ in landfill gas.

Methane correction factor (MCF) accounts for the effect of management practices on CH₄ generation. Unmanaged disposal sites present lower methane-generating potential, because a larger fraction of waste decomposes aerobically in the top layers.

Degradable organic carbon (DOC) is the organic carbon that is accessible to biochemical decomposition. It is a function of the composition of waste and can be calculated from a weighted average of carbon content of various components of waste.

$$DOC = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)$$

where:

A = fraction of waste that is paper and textiles;

B = fraction of waste that is garden waste, park waste or other non-food organic putrescibles;

C = fraction of waste that is food waste;

D = fraction of waste that is wood or straw.

Fraction of degradable organic carbon dissimilated (DOCF) is an estimate of the fraction of carbon that is ultimately degraded and converted into landfill gas, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS. Theoretically it is assumed that it varies mainly with the temperature (T) in the anaerobic zone of a landfill: $0.014T + 0.28$ (Tabasaran, 1981).

Fraction of CH₄ in landfill gas landfill gas is usually considered to be composed dominantly by half of CO₂ and half of CH₄¹⁴⁴.

ACTIVITY DATA AND PARAMETERS

SWDS include solid municipal or urban waste (household, garden, commercial-services wastes) and industrial wastes.

¹⁴⁴ Other gases exist in lesser quantities however.

Urban wasteQuantities of waste landfilled

In 2004, the management of municipal solid waste (MSW) in Portuguese mainland was under the responsibility of 31 management systems: 12 multi-municipal, 18 inter-municipal and 1 municipal system. In the Autonomous Region of Azores, municipality authorities are the responsible entities for the management of MSW, and in the Autonomous Region of Madeira, this responsibility is shared between municipalities and the Regional Government.

Since 1999, data on MSW is available for the majority of these systems, including production amounts, final disposal and, to a less extent, waste composition.

For previous years, information on urban waste was not collected on a regular basis, and most information was available from:

- PERSU - “Plano Estratégico dos Resíduos Sólidos Urbanos” (Strategic Plan on Municipal Solid Waste), which was approved by the Government in 1997. This plan includes data from annual municipal registries;
- a study performed by Quercus (1995) – “Caracterização dos Resíduos Sólidos Urbanos e Inventariação dos Locais de Deposição em Portugal” (Characterization of Municipal Solid Waste and Survey of Disposal Sites in Portugal). The study of Quercus (1995) considered open dump sites, managed landfills, composting and incineration units, covering aspects as the quantities of waste treated or landfilled and other characteristics (opening and closure year of operation, waste composition, existence of flaring equipment, etc). Data was based on a survey performed in 1994, which enabled the calculation of per capita generation rates for 1994, based on the amounts of waste collected and the population served by waste collection.

The use of the FOD method requires building a data time series for several decades in the past concerning waste quantities, composition and disposal practices. According to IPCC (2000), it is good practice to estimate historical data if such data are not available, when this is a key source category (Annex A). In what concerns the extent of the time series, it was adopted the criteria from USA, based on the emissions model from EPA(1993), and it was considered that landfill waste produces CH₄ for 30 years after disposal.

Before 1994, data on landfill wastes had to be estimated based on expert judgement for waste generation growth rates. For the period 1960-1980 it was considered a per capita waste generation growth rate of 2.5% per year; for the following years (1980-1994) 3% per year. Therefore municipal solid wastes production were estimated for each municipality as follows:

$[\text{Population (inhabitants)} * \text{Annual per capita generation rate (ton/inhabitants/year)}]$

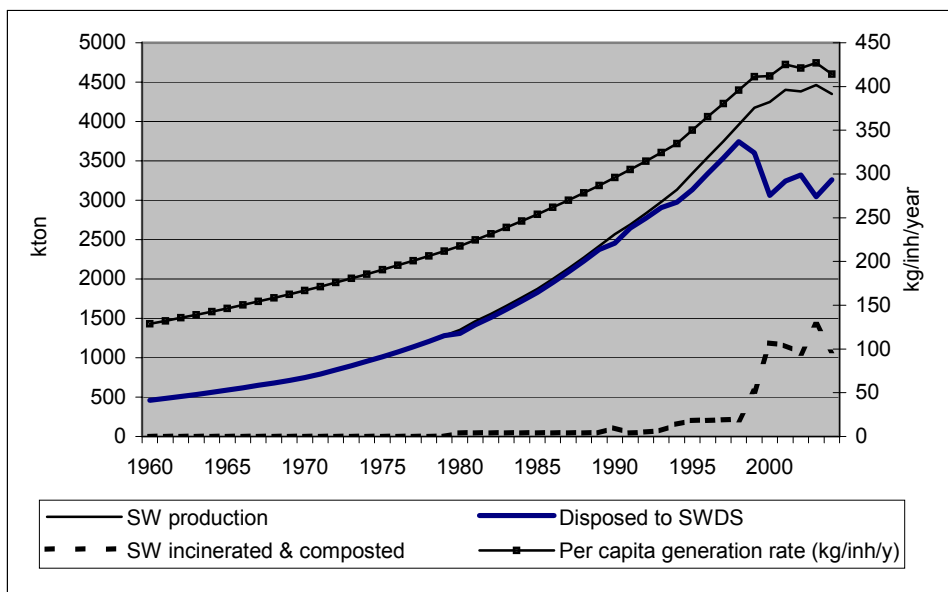
Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991 e 2001. Data for intermediate years were estimated, by interpolation, for each municipality. Figures for 2001 onwards are forecasts.

To take into account the fact that part of the population (rural areas) was not served by an organised waste collection and waste disposal system, values of annual production were multiplied by the percentage of population served by waste collection in each municipality. After 2000, it was assumed that all the population of the country is served by waste collecting systems (100%). The total amount of waste disposed to SWDS was then calculated based on this estimated value minus the amounts of waste incinerated and composted:

$$\text{Waste disposed to SWDS} = [\text{Population} * \text{Annual per capita generation rate} * \\ \text{Percentage of Population served by waste collection}] \\ - \text{Quantity of incinerated waste} - \text{Quantity of composted waste}$$

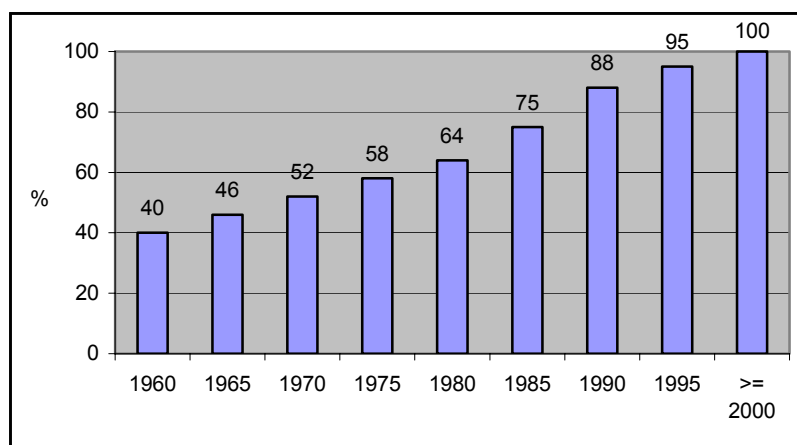
Next figure presents the trends of the per capita generation rates, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series. For the more recent years (for 1994, and since 1999) the information refers to data effectively collected. As presented in the graph, waste disposed to SWDS start reducing in 1999 which corresponds to the beginning of operation of two MSW incineration units.

Figure 8.4 – Urban waste in the period 1960-2004



Source: IA estimates; INR; Quercus study

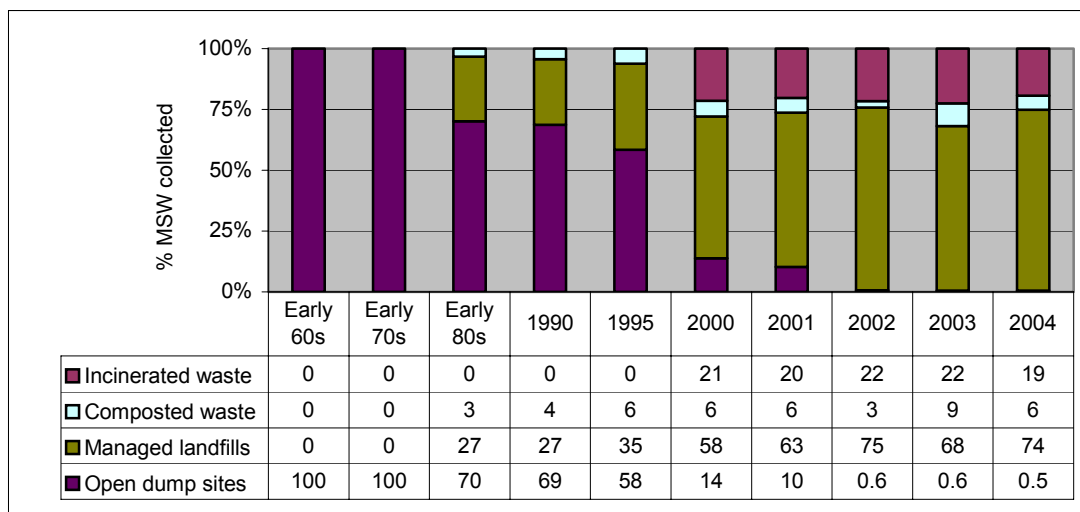
Figure 8.5 - Population served by solid waste collection systems



Source: INR

The share of final disposal destiny for the first years of the time series was calculated having as a basis the Quercus survey. Data for recent years (mainly since 1999) refer to data collected from management systems. As shown in the next figure there was a significant effort at national level to deactivate and closure all uncontrolled dumping sites. This effort was concluded in 2002 when all uncontrolled dumping sites had been closed. Another fact refers to the relatively reduction of final waste disposal on land in favour of incineration. As previously mentioned, in 1999 two MSW incineration units start operating, which was accompanied by a drop of waste disposal in SWDS (in 1998 disposal in SWDS represented 95% of total waste disposal; in 2004 this figure fall to 74%, and the percentage of waste incinerated represents 19%).

Figure 8.6 – Final disposal of waste (% of municipal solid waste collected)



Note: 2002-04 - disposal on open dump sites refer to disposal on controlled dump sites.
Source:IA estimates; Quercus; INR

CH₄ generation potential (Lo)

The parameters used in the calculation are mainly IPCC default values.

Table 8.1 – Parameters used in Lo calculation

Parameter	Explanation	Value considered
MCF	IPCC defaults	Managed landfills = 1.0 Open dump sites = 0.6
DOC	National estimate	Variable on waste composition
DOCF	IPCC default (considering T = 35°)	0.77
F	IPCC default	0.5

The estimation of Degradable Organic Carbon (DOC), presented in the following table, was based on information on the waste composition from several sources.

Table 8.2 - Composition of waste disposed to SWDS (fermentable fractions)

Fermentable fractions	Early 60s	Early 70s	Early 80s	Early 90s	Mid-90s	2000
Percentage of weight						
Paper and textiles (fraction A)	22.5	22.5	22.5	24.9	25.8	27.1
Non-food fermentable materials (fraction B)	0.0	0.0	0.0	13.4	18.7	11.9
Food waste (fraction C)	59.9	59.9	59.9	42.0	34.8	35.9
Wood or straw (fraction D)	0.0	0.0	0.0	0.2	0.3	0.3
DOC	18.0	18.0	18.0	18.6	18.8	18.3

Notes: Early 60s, 70s and 80s data refer to Fernandes, A Pastor (1982), "RSU do Continente - um Guia para Orientação e Inform. Das Autarquias", LNETI. Early 90s: estimates from interpolation. Mid 90s: data refer to 1994; DGA. 2000: INR

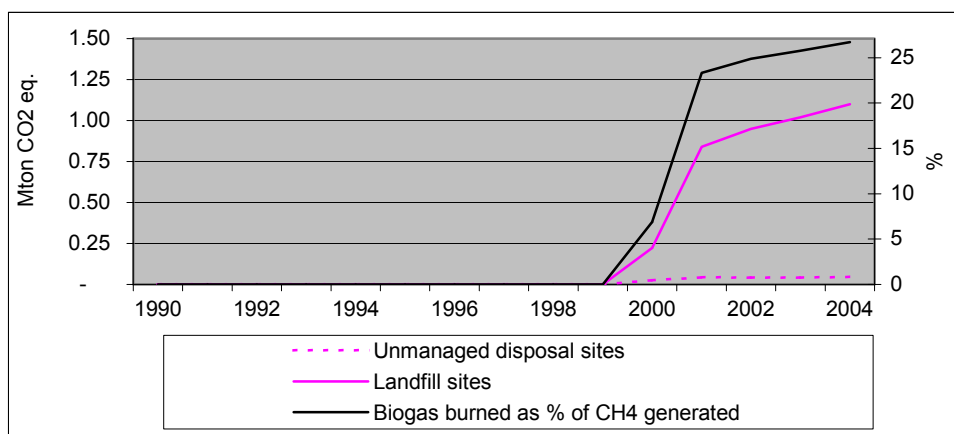
Other parameters

The value of CH₄ generation rate constant (k) depends on several factors as the composition of the waste and the conditions of the SWDS. In the absence of national studies to determine this parameter, and following the recommendations of the in-depth review, the values used in the previous submissions were revised in order to apply the guidance from IPCC 2000.

This parameter is related to the time taken for the DOC in waste to decay to half its initial mass ('half life' or $t_{1/2}$) as follows: $k = \ln 2 / t_{1/2}$. The k value considered was 0.07 (half life of about 10 years), which represents a higher decay rate compared to the k default value proposed by the IPCC 2000 (0.05 - half life of about 14 years).

GPG 2000 proposes to consider an historical time series 3 to 5 half lives in order to achieve an acceptably accurate result. The data series considered are 3 half life periods back in time, i.e. a time trend of 30 years, which is in accordance with the emissions model from EPA(1993) that considers landfilled waste to produce CH₄ for 30 years after disposal.

In the absence of metering landfill gas recovered data, estimates of recovered CH₄ were done based on: the information from INR for each waste management system - existence of burners, and the starting year of landfill operation; and on an average efficiency for the gas capture (75%) and for the burners (97%).

Figure 8.7 – Quantities of CH₄ recovered and combusted (urban waste)

Source: IA estimates.

Concerning uncontrolled dumping sites, it was considered that there is gas burning when a dumping site has been closed and is associated with a managed landfill having recovery of CH₄. It was assumed that gas burning starts typically 2-3 years after the beginning of the landfill operation.

In what concerns the oxidation factor (OX), the IPCC default value – zero - was used for unmanaged SWDS. For landfill sites, which are considered as well-managed SWDS, it was used 0.1 for OX, as recommended in GPG (IPCC,2000). The OX factor was applied after subtraction of CH₄ recovered.

Industrial waste

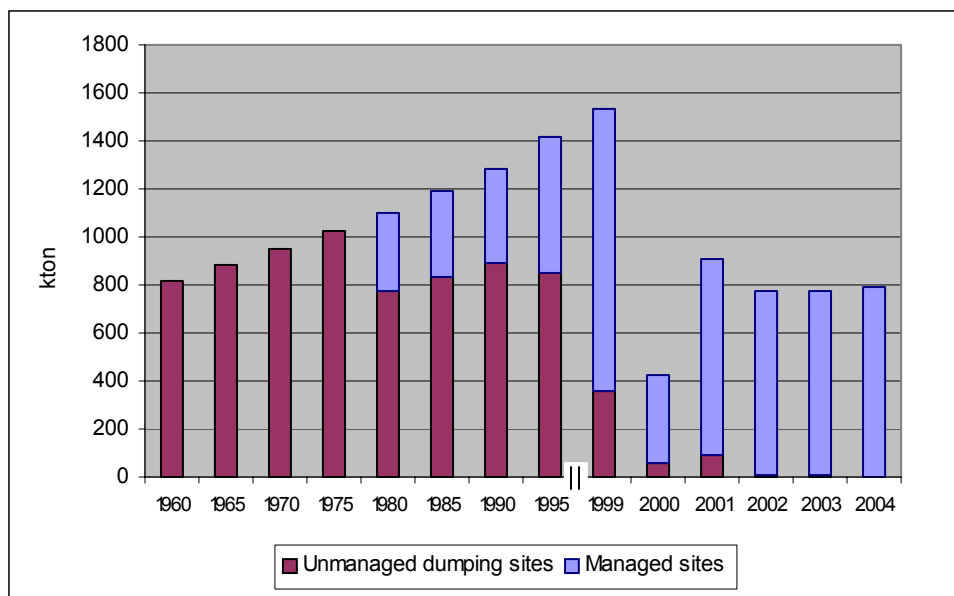
Quantities of waste landfilled

Industrial wastes considered refer only to the fermentable part of industrial waste. Historical time series are based on 1999 data which refer to annual registries relating to industrial units declarations sent to the regional environment directorates (CCDR), and have been estimated based on expert judgement.

For the period 1960-1990 it was considered a growth rate of 1.5% per year; for the following years (1990-1998) 2% per year. Data for the years 2000 and 2002 refer to annual registries. The years 2001, 2003 and 2004 are also estimates based on interpolation (2001) and last available data (2003-04 refer to 2002 data).

All industrial waste generated was consider to be disposed in SWDS together with urban waste. However, as there is no available information concerning final industrial waste disposal, it was assumed that all estimated waste produced have followed the urban disposal pattern between uncontrolled and controlled SWDS.

Figure 8.8 – Quantities of fermentable industrial waste disposed to SWDS



Source:IA estimates; INR

CH₄ generation potential (Lo)

The parameters used in the calculations are basically the same as the ones presented for urban waste, excepted for DOC. Data for this parameter varies according to the available information on industrial waste composition: 0.28 (1960 – 1999), 0.20 for 2000, 0.26 (average of available data) and 0.29 for 2002 to 2004 (2002 data).

Available data on industrial waste production come from INR (Waste Institute) and refer to annual registries from industrial units declarations. These information are classified according to the European Waste Catalogue list (EWC) and are disaggregated by disposal type. From this database the IA selected (by expert judgement) the EWC categories referring to organic origin. Each one of these categories were classified according to a group and were assigned with a DOC value, also defined by expert guess.

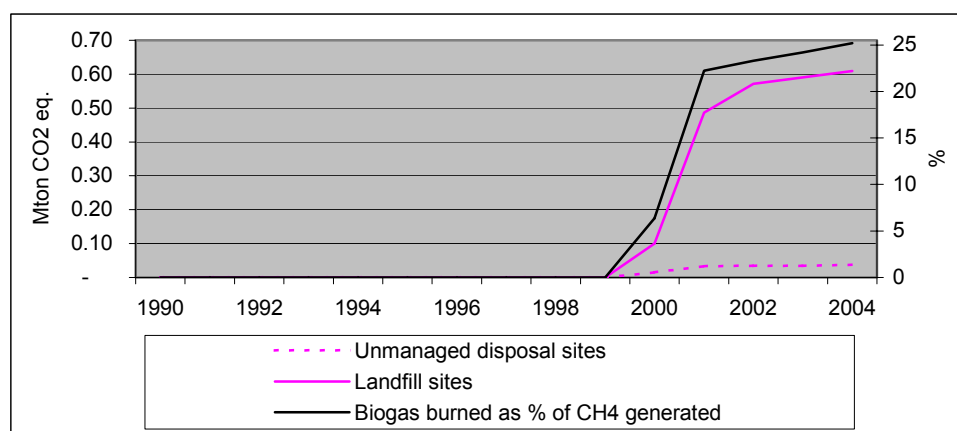
The referred DOC values resulted from weighted averages based on the quantities reported for each EWC category considered and the respective assigned DOC, and refer to disposal on land.

Table 8.3– Base table for industrial waste C content estimation

Groups	C Total (0..1)	DOC (0..1)	% C Biogenic
Paper and textiles	0.40	0.40	100
Garden waste, park waste or other non-food organic putrescibles	0.17	0.17	100
Food waste	0.15	0.15	100
Wood or straw	0.30	0.30	100
Fuels	0.85	0	0
Plastics	0.85	0	0
Sludge from natural origin	0.14	0.14	100
Sludge from non-natural origin or hydrocarbons	0.43	0	0
Synthetic fibres	0.85	0	0
Non-natural organic substances	0.85	0	0

Other parameters

Data on quantities of CH₄ recovered and combusted are estimates based on the assumptions presented for urban waste, considering that they share the same disposal places. Data trends are presented in the following figure.

Figure 8.9 - Quantities of CH₄ recovered and combusted (industrial waste)

Source: IA estimates.

8.2.A.2 COVNM EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

COVNM emissions are calculated using the same methodology as for CH₄, i.e. the FOD method. Activity data and parameters are the ones presented in CH₄ sub-session, with an exception for the COVNM concentration (F) in landfill gas. The AP-42 5th ed. suggests the value 2420 ppmv as hexane for landfills with co-disposal of MSW and non-residential waste. This last value was used to take into account the fact that SWDS have been used for both urban and industrial waste.

8.2.A.3 NH₃ EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

NH₃ emissions are calculated using the same methodology as for CH₄, i.e. the FOD method. Activity data and parameters are the ones presented in CH₄ sub-session, with an exception for F – the fraction of NH₃ by volume in landfill gas is 0.005.

8.2.A.4 NH₃ EMISSIONS FROM COMPOST PRODUCTION

METHODOLOGY

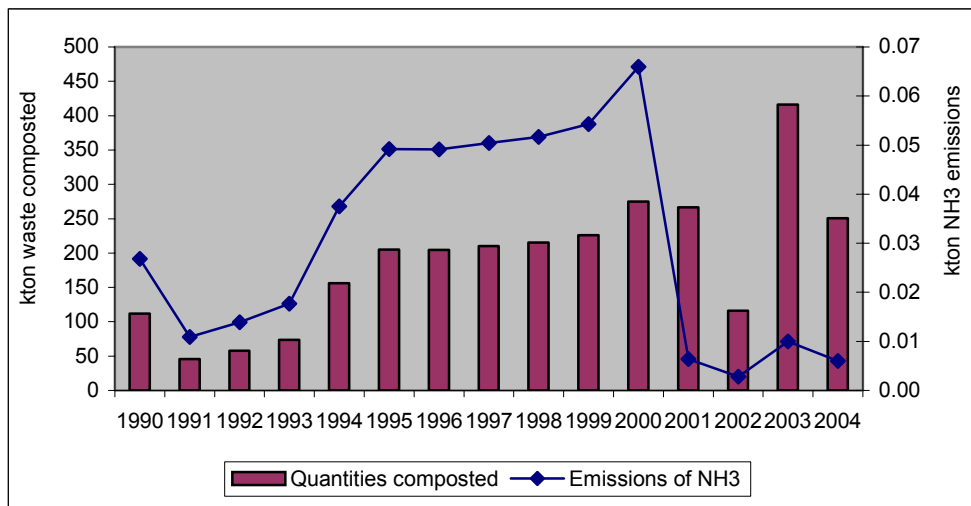
Emission estimates follow a simpler methodology indicated in Corinair 3rd rev., which is based on the quantities of composted waste and the application of an emission factor, as follows:

$$\text{NH}_3 \text{ emitted (ton/y)} = \text{Quantity of composted waste} * \text{EF (g NH}_3\text{/ton RSU)} / 10^6$$

ACTIVITY DATA

The activity level for past years is based on the Quercus survey. Data for recent years refer to data collected from management systems.

Figure 8.10 – Quantities of urban waste composted and related NH₃ emissions



Source: INR; IA

EMISSION FACTORS

Emission factors reflect change in treatment technology. Until 1999 NH₃ emissions from composting domestic organic waste were estimated to be without control; after 2000 it was assumed the existence of emission control with bio-filters.

Table 8.4 – Ammonia emission factors for compost production

	EF g NH ₃ /ton SW	Source
Uncontrolled	240	Corinair 3rd r.
Biofilter	24	Corinair 3rd r.

8.2.B Wastewater Handling (CRF 6 B)

8.2.B.1 DOMESTIC WASTEWATER

This category has been revised in this 2006 submission, to take account of the compilation of data trends on wastewater handling systems performed by INAG (National Institute for Water, the National Focal Point of the National System for this sector).

CH₄ EMISSIONS FROM WASTEWATER HANDLING (WWH)

Methodology

CH₄ emissions from domestic wastewater handling were estimated using a methodology adapted from IPCC 1996 Revised Guidelines (IPCC,1997) and GPG (IPCC,2000), which follows three basic steps:

1 – Determination of the total amount of organic material originated in each wastewater handling system

The main factor determining the CH₄ generation potential of waste is the amount of degradable organic component (DC) of the wastewater stream, which is expressed in terms of either BOD (recommended for domestic wastewater and sludge), or COD (more appropriate for industrial waste streams). Total organic waste (TOW) is a function of human population and the amount of waste generated per person.

$$TOW_{dom} = P * D_{dom}$$

where:

TOW_{dom} - total domestic/commercial organic waste in kg BOD/yr;

P - population in 1000 persons;

D_{dom} - domestic/commercial degradable organic component in kg BOD/1000 persons/yr.

2 – Estimation of emission factors

The emission factor for each wastewater and sludge type depends on the maximum CH₄ producing potential of each waste type (B₀) and a weighted average of CH₄ conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_{0i} \times \sum_x (WS_{ix} \times MCF_x)$$

where:

EF_i - emission factor (kg CH₄ /kg DC) for waste type i (e.g., domestic wastewater or sludge, etc);

B_{oi} - maximum methane producing capacity (kg CH₄/kg DC) for waste type i;

WS_{ix} - fraction of waste type i treated using wastewater handling system x;

MCF_x - methane conversion factors of each wastewater system x.

Maximum CH₄ producing capacity (B_o) is the maximum amount of CH₄ that can be generated from a given quantity of wastewater or sludge.

Methane Conversion Factor (MCF) is an estimate of the fraction of DC that will ultimately degrade anaerobically. The MCF varies between 0 for a completely aerobic system to 1.0 for a completely anaerobic system.

3 – Calculation of emissions

Emissions are a function of total organic waste generated and an emission factor characterising the extent of CH₄ generation for each wastewater handling system. CH₄ that is recovered and flared or used for energy should be subtracted from total emissions, as it is not emitted into the atmosphere.

$$M = \sum_i (TOW_i * EF_i - MR_i)$$

where:

M - Total CH₄ emissions from wastewater and sludge handling in kg CH₄

TOW_i - total organic waste for waste type i in kg DC/yr. (Step 1)

EF_i - emission factor for waste type i in kg CH₄/kg DC (Step 2)

MR_i - total amount of methane recovered or flared from wastewater type i in kg CH₄.

Activity data and parameters

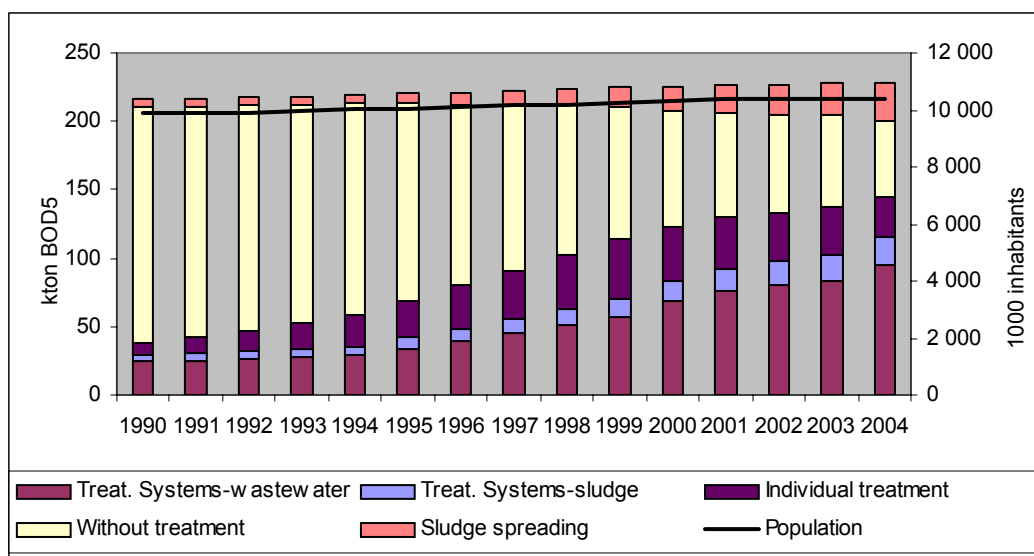
Total organic content of domestic sewage (TOW_{dom}) was determined multiplying the total population for each year by a per capita wastewater BOD₅ production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation. The BOD₅ factor considered was 60 g BOD₅/cap/day, which is the figure considered in the Council Directive 91/271/CEE, 21st Mai, referring to urban waste water treatment.

New background data for wastewater handling systems and types of treatment were based on a compilation study performed by INAG (National Institute for Water, the National Focal Point of the National System for this sector) of all surveys and inventories done in the past concerning sanitation and wastewater treatment infrastructures. Data from this study refer to 1990, 1994 and 1999. From 2000 onwards, data refer to estimates performed by IA which are based in some assumptions, such as the 90% target in 2007 for the % of population served by sewerage and sewage treated from the Water National and Regional Development Plan. The estimates for the % of population served by collective septic tanks, primary treatment, biodisks, laguning, percolation beds and imhoff tanks; were estimated based on the assumption that the respective quantities of organic loads in relation to the total amount of organic material remain constant (assuming that no new treatment systems of this kind were built), making their treated quantities reduce in relative terms. In what refers to the % of population served by activated sludge, oxidation ponds and other treatment the estimates for the years after 2000 were based on the assumption that these treatments accommodate the remaining treatment growth (90% target in 2007 for the % of population served by sewerage and sewage treated). In the future, the 2000

and following years estimates for % of population served by wastewater handling types should be replaced by real data from a new database (INSAAAR – Inventário Nacional de Sistemas de Abastecimento e de Águas Residuais/ National survey on water supply and wastewater systems) which is being implemented by INAG.

Total organic waste (TOW in terms of BOD₅ produced) was divided into different fractions (Figure 8.11), according to the information on wastewater handling types and on assumptions (expert judgment from INAG) concerning the fraction of the organic load treated as a liquid phase (wastewater) and as sludge according to types of wastewater handling systems, and for the % of the organic load retained as non mineralised sludge that is spread in the environment (Table 8.6).

Figure 8.11 – Wastewater BOD produced according to handling systems (ton BOD₅) and national population trends



Source: IA estimates.

Notes: Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Laguning, without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Laguning, with anaerobic pond and Imhoff Tanks (100% of organic load).

Treatment systems – sludge: refer to Biodisks with anaerobic sludge digestion, Activated sludge with anaerobic sludge digestion and Percolation beds with anaerobic sludge digestion (37% of organic load).

Individual treatment: refer to private and collective septic tanks.

Without treatment: refer to discharge into the ocean and inland waters and without sewerage (latrines).

Sludge spreading: refer to the % of the organic load retained as non mineralised sludge in primary treatment (30% of primary organic load generated), and 37% in activated sludge without anaerobic sludge digestion, laguning without anaerobic pond, oxidation ponds and other treatment.

Table 8.5 - Percentage of population by wastewater handling system

Wastewater handling systems		1990	1994	1999	2000	2001	2002	2003	2004
		% population							
1.1-	% de Pop: with discharge into the ocean, without treatment	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
1.2-	% de Pop: with discharge into inland waters, without treatment	36.8	40.8	30.3	25.0	20.9	18.5	16.6	11.3
1.3-	% Pop: without sewerage (latrines)	37.0	23.4	6.4	6.4	6.4	6.4	6.4	6.4
1.4-	% Pop: individual treatment (private septic tanks)	1.5	8.2	14.8	12.2	11.3	10.6	10.1	8.0
2-	% Pop: with greater than preliminary treatment	18.2	21.1	42.0	49.9	54.9	58.0	60.4	67.8
2.1-	% Pop: collective septic tanks	2.2	2.3	5.0	5.0	5.0	4.9	4.9	4.9
2.2-	% Pop: with primary treatment	5.2	5.2	9.0	9.0	8.9	8.9	8.9	8.9
2.3-	% Pop: with secondary and tertiary treatment	10.8	13.6	28.0	36.0	41.0	44.2	46.6	54.0
2.3.1-	Biodisks with anaerobic sludge digestion	1.1	1.4	2.0	2.0	1.9	1.9	1.9	1.9
2.3.2-	Activated sludge without anaerobic sludge digestion	1.4	2.0	4.6	7.6	9.5	10.6	11.5	14.3
2.3.3-	Activated sludge with anaerobic sludge digestion	1.4	2.0	4.6	7.6	9.5	10.6	11.5	14.3
2.3.4-	Laguning, with anaerobic pond	1.7	1.9	3.6	3.6	3.5	3.5	3.5	3.5
2.3.5-	Laguning, without anaerobic pond	0.6	0.6	1.2	1.2	1.2	1.2	1.2	1.2
2.3.6-	Percolation beds with anaerobic sludge digestion	3.6	4.6	8.8	8.8	8.8	8.7	8.7	8.7
2.3.7-	Imhoff Tank	0.6	0.3	0.1	0.1	0.1	0.1	0.1	0.1
2.3.8-	Oxidation ponds	0.3	0.4	1.6	2.7	3.4	3.8	4.1	5.1
2.3.9-	Other treatment	0.0	0.3	1.6	2.6	3.3	3.7	4.0	5.0

Source: INAG, 2005.

Parameters: Bo and MCF - The default IPCC (2000) value for Bo 0.6 kg CH₄/kg BOD was used for wastewater and sludge. Table 8.6 presents MCF factors used for each wastewater treatment system considered.

Table 8.6 - Wastewater handling systems and associated Methane Conversion Factors (MCF), and fraction of organic load treated as liquid and solid phase

Wastewater handling systems		MCF		Share between liquid phase and solid treatment		Sludge spread in the environment
		Wastewater	Sludge	Wastewater	Sludge	e)
				(% of organic load)		
1.1-	% de Pop: with discharge into the ocean, without treatment	0.00	-	-	-	-
1.2-	% de Pop: with discharge into inland waters, without treatment a)	0.30	-	-	-	-
1.3-	% Pop: without sewerage (latrines) b)	0.61	-	-	-	-
1.4-	% Pop: individual treatment (private septic tanks)	0.50	-	-	-	-
2-	% Pop: with greater than preliminary treatment	-	-	-	-	-
2.1-	% Pop: colective septic tanks	0.50	-	-	-	-
2.2-	% Pop: with primary treatment	0.00	0.00	70%	-	30%
2.3-	% Pop: with secondary and tertiary treatment	-	-	-	-	-
2.3.1-	Biodisks w ith anaerobic sludge digestion c)	0.17	0.80	63%	37%	-
2.3.2-	Activated sludge without anaerobic sludge digestion	0.10	0.00	63%	-	37%
2.3.3-	Activated sludge w ith anaerobic sludge digestion c)	0.17	0.80	63%	37%	-
2.3.4-	Laguning, w ith anaerobic pond d)	0.20	0.00	100%	-	-
2.3.5-	Laguning, without anaerobic pond	0.00	0.00	63%	-	37%
2.3.6-	Percolation beds with anaerobic sludge digestion c)	0.17	0.80	63%	37%	-
2.3.7-	Imhoff Tank	0.80	0.00	100%	-	-
2.3.8-	Oxidation ponds	0.00	0.00	63%	-	37%
2.3.9-	Other treatment	0.00	0.00	63%	-	37%

Notes: a) Expert judgment, assuming that half of the situations refer to bad conditions (stagnant sewer MCF=0.5), due to the Summer reduced flow in many sewerage, the high temperatures, and the stagnant conditions and eutrophication of inland waters in many places during that season. The other half of the situations were considered in good drainage and flow conditions of the sewer network (MCF=0.1).

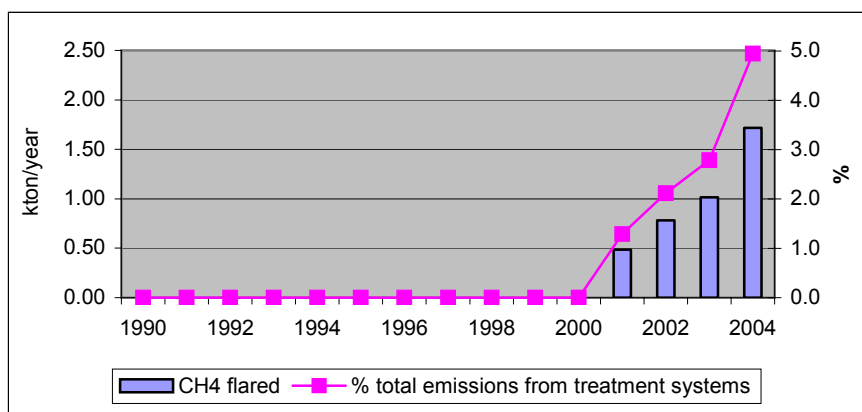
b) Expert judgment, considering 85% of the cases (in majority in the North of the country) as humid conditions (MCF=0.7), and 15% in the better conditions (MCF=0.1).

c) Wastewater: expert judgement, assuming a value between "well management" and "aerobic treatment plant, not well managed".

d) Value corresponding to shallow lagoons (majority of systems).

e) Unknown disposal.

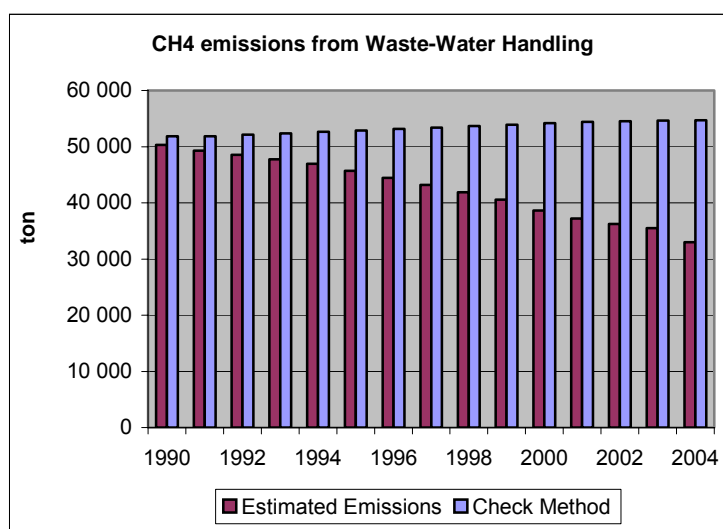
Recovery of CH₄: since 2001 it was assumed that new treatment systems such as, biodisks, activated and percolation beds with anaerobic sludge digestion, recover and burn biogas.

Figure 8.12 - Estimated quantities of CH₄ flared

COMPARISON BETWEEN ESTIMATES FOR CH₄ EMISSIONS FROM WASTE-WATER HANDLING AND IPCC “CHECK METHOD”

Following the in-depth review recommendations, the domestic CH₄ estimated emissions were compared with the “check method” proposed in the IPCC GPG. The comparison shows a big discrepancy between the reported emissions and this method, which represents a rough estimate of global domestic wastewater emissions. The results of the application of the “check method” are for all the period well above the reported emissions. “Check method” figure for 1990 (51.8 kton) was around 35% higher than estimated emissions (33.6 kton); this percentual difference increased to 46% in 2003 (see table W-8 in the attachment).

Also, the 1990-2004 variation of the trend is contradictory. The check method shows a positive variation of 6% between 1990-2004, and the reported emissions show a decrease of about 34% in the same period.

Figure 8.13— Comparison between estimated CH₄ domestic emissions and “check method”

Methodology

IPCC check method is presented in the following to check national estimates. Default parameter values used refer to IPCC GPG.

$$WM = P \times D \times SBF \times EF \times FTA \times 365 \times 10^{-6}$$

where:

WM = Annual CH₄ emission per country, from domestic wastewater (ton)

P = Population of country or urban population for some developing countries (inhab.)

D = Organic load in biochemical oxygen demand per person (g BOD/inhab./day), overall default = 60 g BOD/inhab./day

SBF = Fraction of BOD that readily settles, default = 0.5

EF = Emission factor (g CH₄/g BOD), default = 0.6

FTA = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

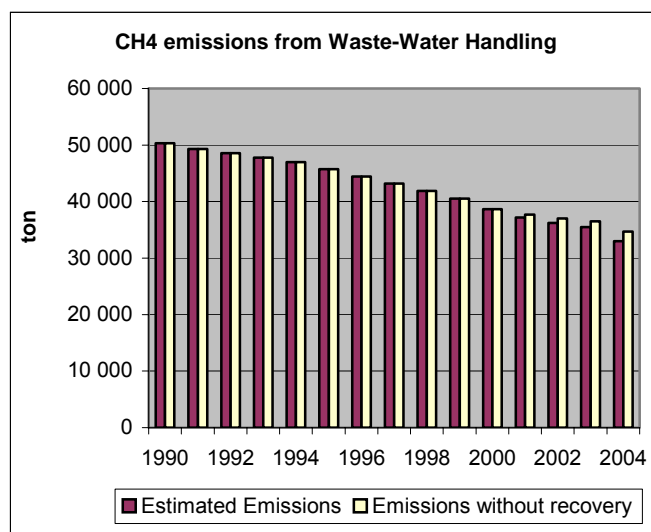
Discussion of the results

As previously mentioned, the results of the application of the “check method” are for the whole period well above the reported emissions. Also the trend variation during the 1990-2004 is contradictory. The 1990-2004 percentage change for the estimated emissions decrease around 34%, while the “check method” accounts for a 6% increase.

The variables Population (P), Organic load in biochemical oxygen demand per person (D), and the EF (g CH₄/g BOD, default = 0.6) are the same in both approaches. Consequently the differences result from other parameters, i.e., the fraction of BOD that degrades anaerobically, and the consideration of CH₄ recovery in the case of the reported emissions.

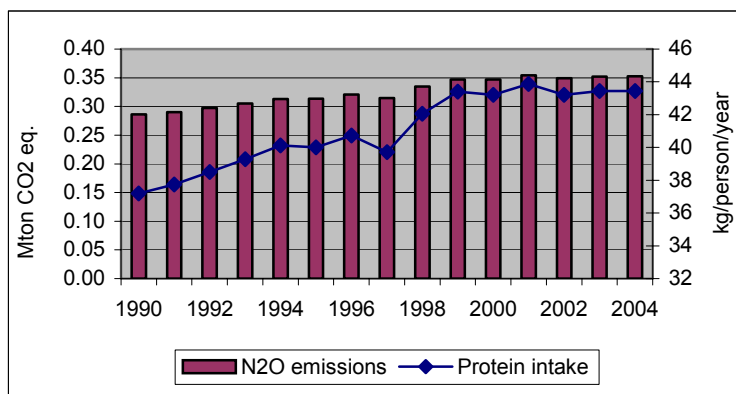
Despite the fact that MCF values considered are based on expert judgement (Table 8.5), it is considered that they represent a better approximation of the real national circumstances than the defaults suggested by the “check method”.

The influence of the CH₄ recovery is not significant as the percentage of the estimated recovery amounts represent only a small part of the total emissions generated in treatment systems (in 2004 they represented around 5% of emissions from treatment systems). Next figure shows that emissions with and without CH₄ recovery are very close and do not explain the difference between the report emissions and the “check method”.

Figure 8.14– Comparison between CH₄ domestic emissions with and without recovery

N₂O EMISSIONS FROM WASTEWATER (HUMAN SEWAGE)

Human sewage can be disposed on land or discharged into aquatic environments (e.g. rivers and estuaries), either directly without treatment or after treatment in septic systems or wastewater treatment facilities. N₂O can be generated during all these stages through nitrification/denitrification of the nitrogen in faeces, urine and other liquid wastes, which are typically in the form of urea and proteins. In general, temperature, pH, BOD, and nitrogen concentration influence N₂O production from human sewage.

Figure 8.15 – N₂O emissions from human sewage and per capita protein intake

Source: Protein intake: FAO database (August 2004); 2003-04 figures: 2002 value.

Methodology

Emissions of N₂O from domestic wastewater were estimated following the proposal of IPCC 1996 Revised Guidelines (IPCC,1997), that considers that the amount of protein consumed by humans determines the quantity of nitrogen contained in sewage.

$$N_2O_{(S)} = \text{Protein} * \text{Frac}_{NPR} * \text{Pop} * \text{EF} * 44/28$$

where:

$N_2O_{(s)}$ - N_2O emissions from human sewage (kg N_2O -N/yr);

Protein - annual per capita protein intake (kg/person/yr);

Frac_{NPR} - fraction of nitrogen in protein (kg N/kg protein);

Pop - number of inhabitants in country;

EF - emissions factor (kg N_2O -N/kg sewage-N produced);

44/28 is the molecular weight ratio of N_2O to N_2 .

Activity data and parameters

Activity data results of protein intake, according to FAO database (Table 8.7), multiplied by total population, from the National Statistical Office (INE) Census for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation.

Other parameters considered for the estimations are based on IPCC (1997) defaults.

Table 8.7 - Data and parameters used calculation of N_2O emissions from wastewater

Parameter	Explanation	Values considered	
		Year	Value (kg/person/year)
Annual per capita protein intake	FAO data (August 2004)	1990	37.2
		1991	37.7
		1992	38.5
		1993	39.3
		1994	40.1
		1995	40.0
		1996	40.7
		1997	39.7
		1998	42.0
		1999	43.4
		2000	43.2
		2001	43.9
		2002	43.2
		2003	43.4
		2004	43.4
Fraction of nitrogen in protein	IPCC96 default	16%	(constant)
Emission factor	IPCC96 default	0.01 kg N_2O -N/kg N	(constant)

Note: 2003-04 figures: 2002 value.

NMCOV EMISSIONS FROM WASTEWATER (HUMAN SEWAGE)

Methodology, activity data and parameters

Total population for each year was multiplied by an emission factor value of 16.425 g COVNM/inhabitant/year, which results from the following emission factor from CORINAIR90 Default Emission Factor:

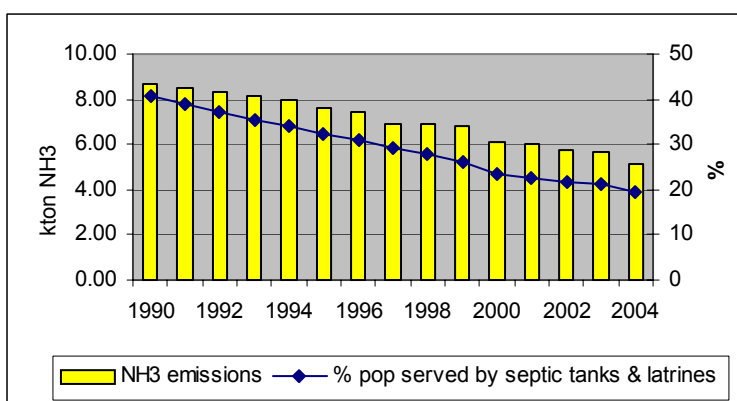
$$EF = 0.36 \text{ kg/106 l wastewater} * 125 \text{ l/inhabitant/year} * 365$$

The daily human sewage production average (125 l/inh.day) was taken from “*Regulamento Geral dos Sistemas Públicos e Prediais de Distribuição de Água e Drenagem de Águas Residuais*”.

NH₃ EMISSIONS FROM WASTEWATER HANDLING (WWH)

NH₃ emissions result mainly from the decomposition of urea and uric acid contained in human excreta. The estimates in the National Inventory considered the population served by individual private treatment facilities (e.g. septic tanks).

Figure 8.16 – NH₃ emissions from individual private treatment and % population served by septic tanks & latrines



Methodology

Emissions were calculated, as follows:

$$\text{NH}_3(\text{S}) = \text{Protein} * \text{Frac}_{\text{NPR}} * \text{EF} * \text{Pop} * \text{Stor} * 17/14$$

where:

NH₃(_s) - NH₃ emissions from human sewage (kg NH₃-N/yr);

Protein - annual per capita protein intake (kg/person/yr);

Frac_{NPR} - fraction of nitrogen in protein (0.16 kg N/kg protein - IPCC default);

EF - emissions factor (0.3 kg NH₃-N/kg sewage-N produced);

Pop - number of inhabitants in country;

Stor - % population served by individual private treatment (septic tanks);

17/14 is the molecular weight ratio of NH₃ to N.

Activity data

Underlying data were already presented in sub-chapter N₂O emissions from wastewater.

Emission factors

The EF proposed by EMEP/CORINAIR (EEA,2002) was used: 0.3 kg NH₃-N/kg sewage-N produced, which is based on the assumption that during storage for one year approximately 30% of nitrogen is emitted as NH₃ in an evaporation process.

8.2.B.2 INDUSTRIAL WASTEWATER**CH₄ EMISSIONS FROM INDUSTRIAL WASTEWATER HANDLING****Methodology**

Methane emissions from industrial wastewater handling also follow the default methodology proposed in the 1996 IPCC Guidelines (IPCC,1997) and the Good Practice Guidebook. The following formula is used, combining equations 5.5 and 5.7 in the GP:

$$Emi_{CH_4} = \sum_i \{TOW_{(j)} * \sum_h [WHS_{(j,h)} * MCF_{(h)}] - Rec_{CH_4(j,h)}\}$$

Where,

Emi_{CH_4} – Total methane emissions from industrial wastewater handling, t CH₄/yr;

$TOW_{(j)}$ – Total Organic wastewater generated from industrial sector j, expressed in COD, t O₂/yr;

$WHS_{(l,h)}$ – Part of the total organic wastewater generated in industrial sector j that is handled by system h, fraction;

$MCF_{(h)}$ – Methane Conversion Factor, fraction;

$Rec_{CH_4(l,h)}$ – Quantity of methane generated from Industrial Wastewater Handling system h and industrial sector j, that is recovered and not released directly or indirectly to atmosphere, t CH₄/yr.

In accordance with the IPCC (2000) methodology, TOW and Rec_{CH_4} will be discussed as activity data and Bo, WHS and MCF are discussed as emission factors.

Activity data

The use of data from specific industrial plants concerning COD concentrations in discharge and its flow could in principle be used to estimate organic wastewater load. Although efforts are being done presently, by the Water Institute in Portugal (INAG) to obtain a reliable survey of industrial discharges, the collected data in the INSAAR system¹⁴⁵ is still not suitable to be used in the inventory of air emissions. Data on sources is scarce, available with difficulty and its representativeness as estimator of load from all units in the sector is undetermined.

After consultation with the experts from INAG, under the works for the Inventory Methodological Development Plan, an alternative approach had to be developed. This approach, which is in line with the recommendations of the IPCC Good Practices, estimates organic wastewater load (TOW) using statistical production data on industries (Ind_{PROD} , ton product/yr) multiplied by pollution coefficients (Pol_{COEF} , kg O₂/ton product).

¹⁴⁵ The INSAAR (Inventário Nacional de Sistemas de Abastecimento de Água e de Águas Residuais) is a database collected data on water supply systems and wastewater treatment implemented by INAG

$$TOW = Ind_{PROD} * Pol_{COEF}$$

The pollution coefficients that were used are not the ones proposed in table 5.4 of the GP, but instead they 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.

The following table shows the pollution coefficients that were used in organic load estimates, based on the coefficients available in Cartaxo et al (1985). The set of available coefficients determined the list of industrial sectors that were considered in the estimation of water pollution discharges. For the estimation of emissions of methane TOW equals CQO load.

Table 8.8 – Pollution Coefficients to estimate Industrial organic wastewater production

Industry	Unit prod (PU)	Discharge (m ³ /PU)	CBO5 (kg/PU)	CQO (kg/PU)	in.eq. (kg yr/PU)
Slaughter House	ton	6	18	27	0.881
Slaughter House, swine	ton	6	18	42	0.900
Slaughter House, Poultry	ton	9	6	13	0.269
Meat Packing	ton	10	20	30	0.978
Milk processing	m ³	1	1	2	0.044
Cheese	m ³ milk	8	13	20	0.651
Other dairy products	m ³ milk	5	7	10	0.347
Fruit and vegetables conservation	ton	15	15	27	0.734
Tomato juice	ton	100	19	32	0.930
Fruit Juices	ton	9	45	77	2.216
Fish processing and canning	ton	35	18	35	0.856
Olive oil production	ton olives	1	15	45	0.734
Olive oil processing	ton	6	1	1	0.044
Edible oils	ton	3	13	19	0.612
Margarine	ton	25	3	8	0.161
Grains milling and processing	ton	3	5	9	0.220
Sugar processing	ton	8	2	4	0.093
Yeast	ton	120	600	1 080	29.354
Ethanol	m ³	17	328	1 192	16.068
Spirits Distillation	m ³	8	95	218	4.628
Wine Cellars	ton grapes	2	5	8	0.220
Beer	m ³	5	4	9	0.215
Mineral water and similars	ton	8	6	10	0.294
Wool production	ton	44	89	366	4.354
Wool processing	ton	537	87	347	4.256
Synthetic fibres processing	ton	155	155	268	7.583
Artificial fibres processing	ton	42	30	52	1.468
Cotton fibres processing	ton	317	155	268	7.583
Leather industry	ton	85	85	213	4.159
Cork processing	ton	1	2	8	0.073
Cork granulation	m ³	1	83	1 104	4.061
Kraft pulping	ton	140	28	158	1.345
Acid sulphite pulping	ton	270	283	1 050	13.845
Kraft paper	ton	14	1	3	0.034
Wafer board and Strand board	ton	1	14	43	0.695
Chlorine and alkalis	ton ClNa	28	0	39	1.336
Inorganic acids	ton	100	0	50	1.712
Cyclic Hydrocarbons	ton	190	285	570	13.943
Aliphatic Hydrocarbons	ton	190	285	570	13.943
Synthetic fertilizers	ton	15	15	38	0.734
Pesticides	ton	4	23	30	1.111
Polymers	ton	15	15	45	0.734
Synthetic rubber	ton	15	15	45	0.734
Artificial fibres production	ton	300	150	450	7.339
Polyester fibres production	ton	348	6	16	0.313
Acrylic fibres production	ton	65	50	121	2.422
Paints, varnishes and lacquers	ton	0	1	9	0.029
Pharmaceutical products	employee	0	0	14	0.462
Soaps	ton	4	6	12	0.294
detergents	ton	3	1	2	0.029
Petroleum refining	ton	2	1	2	0.029

For each industrial sector identified, several statistical information sources - although obtained from the same institution - had to be used to establish the full time series from 1990 to 2004. Nevertheless efforts were made to guarantee that the consistency in time series was not impaired by the use of different origins of information, as will be later explained. Detailed

information on industrial production for each sector can not be delivered in this report, because of confidential restraints existing in certain sectors. Nevertheless, some comments clarify the understanding and documentation of activity data:

- 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 annual surveys on industrial production. Unfortunately the survey that was executed until 1991, the IAIT survey, uses a different methodology, than the one that was used in the IAPI survey, that is being used since 1992.

The IAIT survey was based on an inquiry to each industrial facility, used the Economic Activity Class code rev.1 (CAE rev 1) and a set of specific codes for products and materials. The IAPI survey uses the new revision of the CAE system (CAE rev2), and products and materials use a common code system (PRODCOM) in connection with CAE code. In opposition to the IAIT survey, the IAPI collected data for each company (headquarters). These two surveys were delivered to the Institute of Environment for inventory purposes, but with the compromise that confidential data could not be published;

- Refining of crude oil and petroleum products was established from the DGGE's Energy Balance, which data is available annually from 1990 till 2004;

- Production of paper pulp was available directly from the individual industrial plants, for the all period.

- the remaining data series, for all other source sectors, were constructed from data from IAPI survey, for 1990 and 1991, and from the IAIT survey, for the years from 1992 till 2000. Forecasts for the years from 2001 to 2004, were estimated using a linear extrapolation from the available years. Gaps in middle years were estimated by linear interpolation.

Tables Table 8.9 and Table 8.10 present the building blocks of the activity data time series from the available information. Gaps in mid years were estimated by linear interpolation. In a similar mode, linear extrapolation was used to estimate data for years 1990-1991 and 2001 till 2004, 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 information¹⁴⁶. The checking of the time series was based on graph plotting of the data, and basically the aim was to detect unexpected sudden changes in the magnitude of the time series from 1991 till 1992, when IAIT was changed to IAPI. In some situations the beginning years when IAPI was started had to be discarded, because a sudden and temporary drop from IAIT values was observable and after some years they rise again and continue with a trend compatible with that that existed in IAIT. It was assumed that an adaptation period to the new industrial survey lead to a temporary underestimation of industrial production statistics.

¹⁴⁶ It must be stressed though, that all information sources were produced by the National Statistical Institute (INE). Only methodological procedures for data collection change according to years.

Table 8.9 - Sources of Information used to define the time-series of industrial production (1/2)

Industry	IAIT CAErev1	IAP PRODCOM	Infoline	Note
Slaughter House			1990-2004	Cattle, sheep, goats and horses
Slaughter House, swine			1990-2004	
Slaughter House, Poultry			1990-2004	Broilers, Turkeys, ducks, quails, ostrich, guinea-fowl, geese, pheasants, partridge and pigeons
Meat Packing	311120	15130-1513013-151301190200		
Milk processing	3112		1994-2004	
Cheese	3112	15510		
Other dairy products	3112		1994-2004	Cream, yogurt, powder milk, ice-creams
Fruit and vegetables conservation	3114		1994-2003	
Tomato juice			1994-2003	
Fruit Juices	3131+3132		1994-2003	
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			1993-2003	
Ethanol	313110	159101070; 1592011		
Spirits Distillation	3131+3132	1591010-159101070+1592012		
Wine Cellars	3131+3132	15930; 15950	2001-2003	
Beer	3133	1596010		
Mineral water and similars			1993-2003	

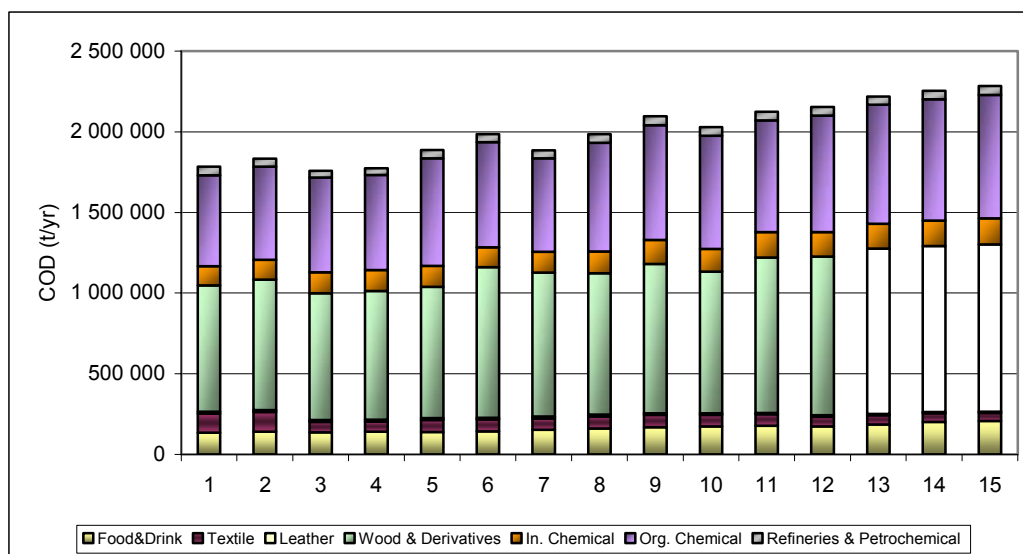
Table 8.10 - Sources of Information used to define the time-series of industrial production (2/2)

Industry	IAIT CAErev1	IAP PRODCOM	Infoline	Note
Wool production		171002021		
Wool processing		171002027;1710042; 1710053		
Synthetic fibres processing	321130	171003031; 171003039;1710052 31/32/33/39/91/92/93 /99;1710055	171003039+17 1005231/32/33/ 39/91/92/93/99 +1710055	
Artificial fibres processing	321130	171003050;1710054/ 55		
Cotton fibres processing	321130	1710043; 171004553; 171004555; 171004557; 1720020; 173001023		
Leather industry		19101; 19102		
Cork processing		2010		AD is cork consumption in all industrial activities
Cork granulation		2052213; 2052214		
Kraft pulping				LPS Data
Acid sulphite pulping				LPS Data
Kraft paper	3412	2112022; 2112023		
Wafer board and Strand board	33 (code 15460)	20202		
Chlorine and alkalis		241301111; 2413015; 2413022		
Inorganic acids		2413014-241301453- 241301475- 241301477		
Cyclic Hydrocarbons		2414312; 2414314		
Aliphatic Hydrocarbons		2414311		
Synthetic fertilizers		2415		Original units is kg N, kg P2O5 and K2O and were converted to ton of fertilizer
Pesticides	3512	242		
Polymers	351312	24160-2416058		
Synthetic rubber		2417		
Artificial fibres production		2470023; 247003070		
Polyester fibres production		247001130; 247001315; 247001350		
Acrylic fibres production		247001150		
Paints, varnishes and lacquers	3521	24301		
Pharmaceutical products			1999-2003	
Soaps		2451131		
detergents		2451120/32		
Petroleum refining				Energy Balance (DGGE): 1990-2004

It was assumed that there was no methane recovery for all Industrial Wastewater Handling Systems, i.e. Rec_{CH_4} is zero for all sectors and wastewater handling systems.

Total wastewater load aggregated per industrial group is presented in Figure 8.17 below, from where it is evident the continuous growth of discharge from 1990 to 2004, and the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry.

Figure 8.17 - Industrial Wastewater load, expressed in CQO, from major groups of industrial activity (1990-2004)



Emission Factors

Wastewater handling systems

As consequence of the fact that there was no available comprehensive information about the existence of each treatment system, the necessary information to determine the per cents for each sector had to be guessed specifically for the inventory using information collected from:

- EPER data. At the time that the inventory was compiled the EPER data was available for 2000 and partially for 2004. Information for the following sectors was available: paper pulp production; crude oil refining; slaughterhouses and meat processing; pig farms; olive oil extraction; fish canning and processing and chemical industry;

- Covenants of Environmental Adaptation. These were voluntary agreements between the Environmental Ministry, other ministries responsible for the permits of specific industrial sectors (Ministry of Economy or the Ministry of Agriculture, Rural Development and Fisheries) and several industrial associations in representation of the industrial units. The agreements were established between March 1997 and February 1998 with the objective to define a time schedule to reach the complete respect of legal constraints concerning the water, air, wastes and noise. The contract involved the elaboration of an *Assessment of the Environmental State*¹⁴⁷ and a *Specific Plan of Elaboration*¹⁴⁸. 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

¹⁴⁷ Caracterização da Situação Ambiental, in the original Portuguese nomenclature.

¹⁴⁸ Plano Específico de Adaptação, in the original Portuguese nomenclature.

For each specific industrial sector the share of use of each specific treatment system was aggregated according to the following classes:

- There is no treatment of wastewater and the effluent is discharged in the water system or in soil;
- Use of individual Septic Tank;
- Primary treatment only;
- Secondary treatment, with deficient management;
- Secondary treatment, well managed;
- Discharge into the sewer system common to the treatment of domestic wastewater system;
- Unknown destiny of effluent, determined as difference to total.

There was also shortage of information concerning the evolution for each sector, that is, the trend in time of the use of each specific wastewater treatment system. The following considerations apply:

- If data from the Covenants of Environmental Adaptation was used, the situation detected in the *Assessment of the Environmental State* was assumed to characterize well the situation before 1997, with no time trend. The plans were assumed to be effective in year 2000 and the situation was considered constant thereafter;
- if only one year was available, for example if data was obtained from EPER, a constant situation was assumed;
- the situation in the activity of refining of crude oil was known annually from 1990 to 2004.

The profiles obtained by this approach albeit suffering from substantial lacks of information, considerable error and inclusion of expert assumptions, represent, nevertheless, the best estimate that can be obtained for the time being. The per cent of total industrial load, expressed in COD, for which the treatment system and final destination of effluents was unknown, varied between 44 and 49 per cent.

Methane Production Potential

The parameter B_0 , representing the maximum Methane Production Potential, was assumed constant and common to all sectors and treatment systems, and set to 0.25 kg CH₄/kg COD, the default value in the Good Practice Guidance from IPCC (2000).

Methane Conversion Factor

The GPG (IPCC,2000) is not very comprehensive in what concerns the choice of default MCF values. The new guidelines from IPCC that were recently published (IPCC,2006) present more detailed values, now specific of treatment systems and management conditions, and they were used to establish the new MCF values, as may be seen in the next table.

Table 8.11 - Methane Conversion Factors (MCF) and assumptions

Treatment System	MCF (%)	Explanatory Note
No treatment	10	IPCC (2006). Table 6.8 Sea, river and lake discharge
Primary	0	Assuming that retention time is insufficient to create anaerobic conditions
Secondary, well managed	0	IPCC (2006) Table 6.8: Aerobic Treatment Plant. Well managed
Secondary, not well managed	30	IPCC (2006) Table 6.8: Aerobic Treatment Plant. Not well managed
Septic Tank	50	IPCC (2006) Table 6.3: Septic system

In the case where the industrial effluent was discharged into the unitary municipal treatment system, the MCF was determined from the average situation in Portugal for the domestic wastewater system when there is any form of treatment, either primary, secondary or tertiary. The values follow the evolution in the urban sector that was explained in previous chapters, have decreased from 18 per cent in 1990 to 13 per cent in 2004. In a similar mode, for the unknown situations the average weighted MCF for all situations of treatment of domestic wastewater was used as a best guess. Values also change over time, from 24 per cent in 1990 to 14 per cent in 2004.

N₂O EMISSIONS FROM INDUSTRIAL WASTEWATER HANDLING

Methodology

The IPCC does not propose any methodology to estimate N₂O emissions from industrial handling. The CORINAIR/EMEP Handbook (EEA,2000) proposes a simple methodology based on the knowledge of total production of wastewater, expressed in equivalent-inhabitants, and the use of a very simple and unspecific emission factor. Although it is recognized that this emission factor does not express the conditions that characterize industrial wastewater – namely, it considers that the nitrogen content of industrial wastewater is similar to that of urban wastewater – it was assumed to be better to have that crude estimate than to under-estimate emissions, in accordance of UNFCCC guidelines. Therefore, emissions are estimated from:

$$Emi_{N_2O} = TLH_{(j)} * EF_{N_2O}$$

Where,

Emi_{N_2O} – Total nitrous oxide emissions from industrial wastewater handling, t N₂O/yr;

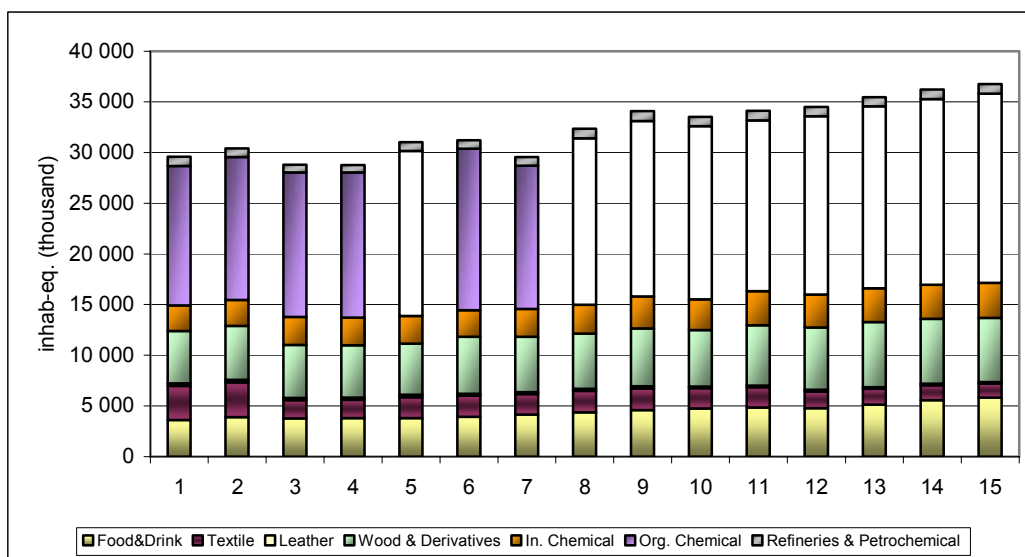
$TLH_{(j)}$ – Total Wastewater Load generated from industrial sector j, expressed in inhabitants-equivalent;

EF_{N_2O} - Emission factor, kg N₂O/inhab-eq/yr.

Activity Data

The total industrial load, in this case expressed in inhabitants-equivalent was also estimated from data on industrial production and multiplication by pollution coefficients. The methodology was already explained under CH₄ emissions from industrial wastewater management. The evolution of total load, and the contribution from major sectors, are presented in Figure 8.18.

Figure 8.18 - Industrial Wastewater load, expressed in inhabitants-equivalent, from major groups of industrial activity (1990-2004)



Emission Factors

The emission factor, 0.02 kg N₂O/kg inhab-eq, is from chapter B9101 from EMEP/CORINAIR (EEA,2002). As stated before this emission factor is not specific for industrial wastewaters.

Recalculations

No change in methodology was made for this sector and emissions estimated were changed since last submission as result in the revision of activity data.

Further Improvements

The emission estimates for this sector needs to be improved by the calculation of the total load of nitrogen in industrial effluents, which would allow the use of the methodology proposed by IPCC for domestic wastewater (IPCC,2000; IPCC,2006). Nevertheless, the lack of pollution coefficients of comprehensive data on wastewater characteristics may postpone improvements in this sector for the near future.

NMVOC EMISSIONS FROM INDUSTRIAL WASTEWATER HANDLING

Methodology

Emissions of non-methane Volatile Organic Compounds are estimated from total wastewater volume discharge, using the following approach:

$$Emi_{NMVOC} = TVW_{(j)} * EF_{NMVOC} * 10^{-6}$$

Where,

Emi_{N_2O} – Total nitrous oxide emissions from industrial wastewater handling, t N_{MVOC}/yr;

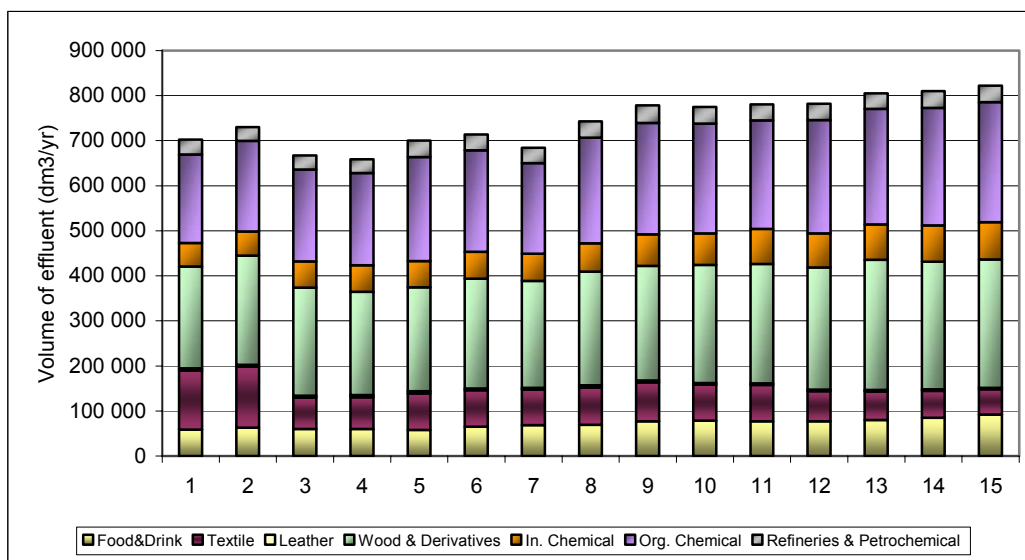
$TLH_{(j)}$ – Total volume of wastewater discharged from industrial sector j, expressed in thousand cubic meters per year;

EF_{NMVOC} - Emission factor, g N_{MVOC}/dm^3 .

Activity Data

Total volume of wastewater discharged in effluents was also estimated using the same production activity and pollution coefficients that were used for calculation of emissions of methane and nitrous oxide. The evolution of discharges is observable in the next figure.

Figure 8.19 - Volume of industrial Wastewater discharge, from the major groups of industrial activity (1990-2004)



Emission Factors

Considering the lack of more recent methodologies, the emission factor in use was set from the CORINAIR Inventory Default Emission Factors Handbook (CEE,1992), 360 g N_{MVOC}/dm^3 of wastewater.

Recalculations

No change in methodology was made for this sector and emissions estimated were changed since last submission as result in the revision of activity data.

8.2.C Waste Incineration (CRF 6 C)

8.2.C.1 CO2 EMISSIONS

METHODOLOGY

IPCC Guidelines (IPCC,1997) proposes the following method for ultimate CO₂ emissions estimation from waste incineration, for each waste type (e.g. municipal solid waste (MSW), hazardous waste, clinical waste, and sewage sludge):

$$CO_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * CCW_i * FCF_i * EF_i * 44 / 12)$$

where:

i - waste type;

IW_i - Amount of incinerated waste of type i (Gg/yr);

CCW_i - Fraction of carbon content in waste of type i ;

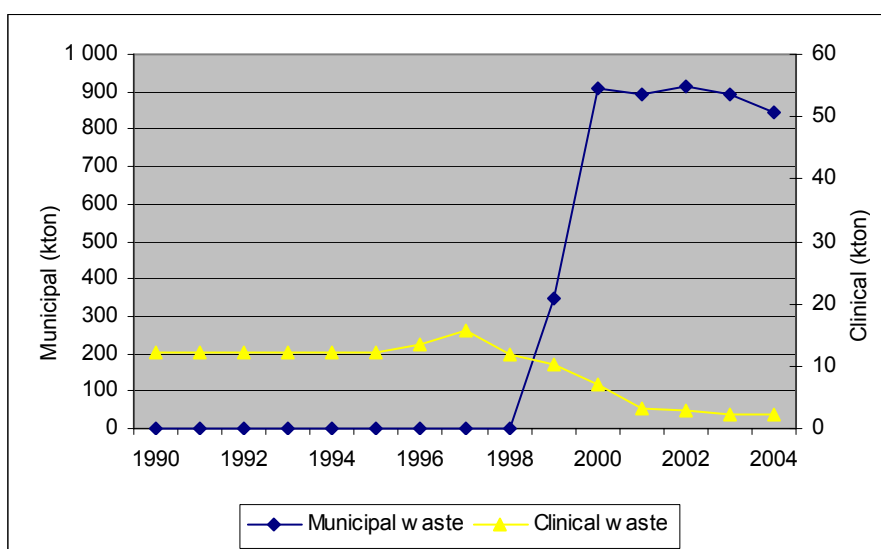
FCF_i - Fraction of fossil carbon in waste of type i ;

EF_i - Burn out efficiency of combustion of incinerators for waste of type i (fraction).

ACTIVITY DATA AND PARAMETERS

Until 1999, incineration of solid wastes refers exclusively to incineration of hospital hazardous wastes. The figure for 1995 was used as an estimated for the former years.

Figure 8.20 – Quantities of municipal and clinical wastes incinerated (1990-2004)



Sources: INR; DGS; IA estimates.

In 1999, two new incineration units, Valorsul and Lipor started to operate in an experimental regime, respectively in April and August 1999. Their industrial exploration started at the end of the same year or early January 2000. These units are exclusively dedicated to the combustion of MSW which is composed of domestic/commercial waste. Most of the organic materials in MSW are of biogenic origin (e.g. food waste, paper), and so they are not accounted for in net emissions calculations, according to the IPCC Guidelines (IPCC, 1997). However, the components of fossil origin – plastics, synthetic fibers, and synthetic rubber – are to be accounted in the estimates.

Data on clinical waste incinerated refers only to Mainland Portugal and correspond to data declared in registry maps of public hospital units (there is no incineration in private units). The quantities of clinical waste incinerated decreased strongly in recent years as shown in previous figure. 25 incinerators were closed in recent years in Mainland Portugal, remaining at present 2 hospital incinerators. Nowadays the other clinical wastes receive alternative treatment or are treated abroad.

The non-biogenic components fractions are considered to be different for MSW, and clinical waste. Data are presented in the following table.

Table 8.12 - Parameters considered

	Unit	MSW	Clinical waste
C content of waste	%	30 a)	60 b)
Fraction of fossil carbon in waste	% total C	37 a)	40 b)
Efficiency of combustion	%	95 b)	

a) National figure; b) IPCC default.

The parameters presented in the previous table for MSW were kept constant and refer to national estimates based on waste composition for 1994. The fossil C content in MSW was calculated from the weighted average of the C content in plastics and textiles (fossil carbon) and the respective fractions of waste weight. The total C content of MSW, which includes the biogenic and non-biogenic (fossil) components, results from the weighted average of the different waste fractions and the respective total C content. The % of fossil carbon in waste was then obtained dividing the fossil C component by the total C content in MSW.

Information used for the calculation are presented in the next table.

Table 8.13– Base table for MSW C content estimation

	% of weight	Non-biogenic C content	Total C content
Paper/ Card	22.7	0	40
Glass	5.1	0	0
Plastics	11.7	85	85
Metals	2.7	0	0
Food waste	34.8	0	15
Textiles	3.1	40	80
Non-food fermentable materials	18.7	0	17
Wood	0.3	0	30
Other	0.8	0	0
C content in Plastics and Textiles (1)		11.2	
Total C of waste (2)		30.0	
% non-biogenic C in waste (1)/(2) * 100		37.3	

8.2.C.2 NON-CO2 EMISSIONS

METHODOLOGY

Emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * EF_i) * 10^{-6}$$

where:

IW_i = Amount of incinerated waste of type i (Gg/yr);

EF_i = Aggregate pollutant emission factor for waste type i (kg pollutant/Gg)

ACTIVITY DATA AND PARAMETERS

Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR (EEA,2002).

Table 8.14 - Emissions factors of GHG and precursors gases from incineration of MSW

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH ₄	g/GJ	6.500	CORINAIR 94
N ₂ O	kg/ton MSW	0.100	Corinair 3rd version. Activity 090201. No NOx abatement
SO _x	kg/ton MSW	0.022	Country measured data
NO _x	kg/ton MSW	0.724	Country measured data
COVNM	kg/ton MSW	0.020	Corinair 3rd version. Activity 090201. Uncontrolled
CO	kg/ton MSW	0.036	Country measured data

Table 8.15- Emissions factors of CLRTAP gases from incineration of MSW

Pollutants	Unit	EF	Source
NH ₃	kg/ton MSW	0.0043	Country measured data
Pb	kg/ton MSW	0.0008	Corinair 3rd version. Activity 090201. Particle and acid gas abatement
PST	kg/ton MSW	0.0070	Country measured data
Cd	kg/ton MSW	0.0001	Corinair 3rd version. Activity 090201. Particle and acid gas abatement
Hg	kg/ton MSW	0.0011	Corinair 3rd version. Activity 090201. Particle and acid gas abatement

Table 8.16 - Emissions factors of GHG and precursors gases from incineration of clinical wastes

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH ₄	g/GJ	6.500	CORINAIR 94
N ₂ O	kg/ton	0.100	Corinair 3rd version. Activity 090201. No NOx abatement
SO _x	kg/ton	1.090	AP-42 Uncontrolled
NO _x	kg/ton	1.780	AP-42 Uncontrolled
COVNM	kg/ton CW	7.400	Corinair 3rd version. Activity 090202. Particle abatement
CO	kg/ton	1.480	AP-42 Uncontrolled

Table 8.17- Emissions factors of CLRTAP gases from incineration of clinical wastes

Pollutants	Unit	EF	Source
NH3	kg/ton MSW	0.0043	Country measured data
Pb	kg/ton MSW	0.0364	AP-42 Uncontrolled
PST	kg/ton MSW	2.3300	AP-42 Uncontrolled
PM10	% PST	65	AP-42 Uncontrolled
Cd	kg/ton MSW	0.0027	AP-42 Uncontrolled
Hg	kg/ton MSW	0.0537	AP-42 Uncontrolled
Ar	kg/ton MSW	0.0001	AP-42 Uncontrolled
Cr	kg/ton MSW	0.0004	AP-42 Uncontrolled
Cu	kg/ton MSW	0.0062	AP-42 Uncontrolled
Ni	kg/ton MSW	0.0003	AP-42 Uncontrolled

8.2.D Other (CRF 6 D)

This category includes emissions from the open burning of industrial solid waste on land which was previously reported in the category 6C. This change relates to the in-depth review recommendation to report these emissions under category 6.A Solid Waste Disposal on Land – Other. These emissions have however been reported under 6.D in order to report more pollutants (SO₂) in CRF tables than was possible in category 6.A.

8.2.D.1 CO₂ EMISSIONS

METHODOLOGY

The same methodology as for category 6.C Waste incineration was used, which refers to IPCC Guidelines (IPCC, 1997). Ultimate CO₂ emissions estimation from open combustion of industrial waste on land were calculated as follows:

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \text{IW} * \text{CCW} * \text{FCF} * \text{EF} * 44 / 12$$

where:

IW - Amount of burned waste (Gg/yr);

CCW - Fraction of carbon content in waste;

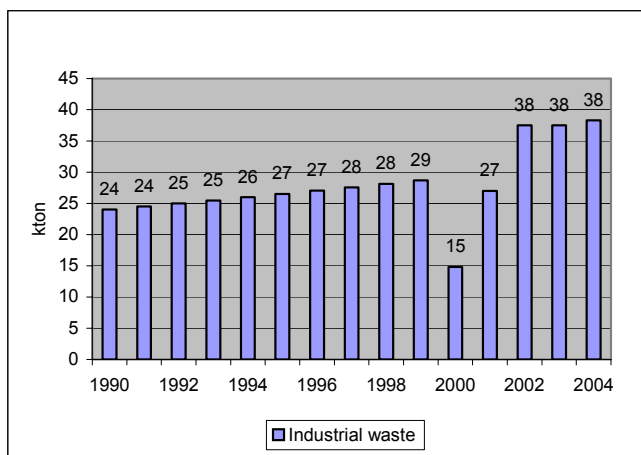
FCF - Fraction of fossil carbon in waste;

EF - Burn out efficiency of combustion of incinerators for waste (fraction).

ACTIVITY DATA AND PARAMETERS

Data refer to uncontrolled combustion of industrial solid waste on land which were collected from INR. Data for the years 2000 and 2002 refer to industrial units declarations. The years 2001 and 2003 are estimates based on interpolation (2001) and on the last available data (2003-04 refer to 2002 data). Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%.

Figure 8.21– Quantities of open combusted industrial waste (1990-2004)



Source: INR; IA estimates.

Table 8.18- Parameters considered

	Unit	Industrial Solid Waste
C content of waste	%	14-18 a)
Fraction of fossil carbon in waste	% total C	20.5-0.3 a) c)
Efficiency of combustion	%	95 b)

- a) C content of waste: until 1999 - 14; 2000 - 18; 2002 - 17.
b) IPCC default.
c) % total C: until 1999 - 20.5; 2000 - 0.3; 2002 - 1.0.

The parameters presented in the previous table (C content and % total C) are national estimates based on the background data on industrial waste production received from INR. As mentioned in the previous sub-section 6.C, these information are classified according to the European Waste Catalogue list (EWC) and are disaggregated by disposal type. Each one of the EWC categories were classified according to a group and were assigned with an estimated fraction of C content and a fraction of fossil carbon in waste, which has been defined by expert judgement (please see Table 8.3). The values considered resulted from weighted averages based on quantities reported for each of the EWC categories and the respective assigned C content and fraction of fossil C, and refer to disposal type "incineration on land".

8.2.D.2 NON-CO₂ EMISSIONS

METHODOLOGY

Emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \text{IW} * \text{EF} * 10^{-6}$$

where:

IW = Amount of combusted waste (Gg/yr);

EF = Pollutant emission factor (kg pollutant/Gg)

ACTIVITY DATA AND PARAMETERS

Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR (EEA,2002).

Table 8.19 - Emissions factors of GHG and precursors gases from open burning of Industrial Solid Wastes

Pollutants	Unit	EF	Source
CH ₄	kg/ton MSW	6.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
N ₂ O	kg/ton MSW	0.1	Corinair 3rd version. Activity 090201. No NO _x abatement
SO _x	kg/ton MSW	0.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
NO _x	kg/ton MSW	3.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
COV	kg/ton MSW	15.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
CO	kg/ton MSW	42.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)

Table 8.20 - Emissions factors of CLRTAP gases from open burning of Industrial Solid Wastes

Pollutants	Unit	EF	Source
PST	kg/ton MSW	8.0000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
PM ₁₀	% PST	100	Conservative EF
Pb	g/ton MSW	0.4580	AP-42. Chp 2.1 (Refuse Combustion) a)
HCl	kg/ton MSW	0.0790	AP-42. Chp 2.1 (Refuse Combustion) a)
As	g/ton MSW	0.0069	AP-42. Chp 2.1 (Refuse Combustion) a)
Cd	g/ton MSW	0.0038	AP-42. Chp 2.1 (Refuse Combustion) a)
Cr	g/ton MSW	0.1300	AP-42. Chp 2.1 (Refuse Combustion) a)
Hg	g/ton MSW	1.6300	AP-42. Chp 2.1 (Refuse Combustion) a)
Ni	g/ton MSW	0.1350	AP-42. Chp 2.1 (Refuse Combustion) a)

Note: a) Mass Burn Waterwall Combustor (MW/WW) with Eletrostatic Prec. And Semi-wet scrubber (same as Spray Dryer) SD/ESP

8.3 Uncertainty Assessment

8.3.A Solid Waste Disposal on Land

8.3.A.1 MUNICIPAL SOLID WASTES

The uncertainty of activity data for Municipal Solid Wastes must be considered high not only because is estimated for each year from population and per capita waste production ratio but mostly because of the low accuracy in the backcast establishment of past solid wastes disposal since 1960. An uncertainty of 25% was therefore considered as representative of the accuracy of the present time series for production of Municipal Solid Wastes.

8.3.A.2 INDUSTRIAL WASTES

The activity data for the calculation of emissions from Industrial Waste Production has an even lower accuracy than Municipal Solid Wastes, because the time trend since 1960 was established with information only collected after 1999. Comparison of the production of industrial solid wastes from 1999 till 2002 show unexpected expressive annual variations, which indicate that annual production could have an uncertainty of about 68%. An uncertainty the double of this value was considered (136%), to incorporate the error in backward forecasts till

1960, which is of the order that IPCC (2000) recommends for countries with low quality data was considered: 100%.

Uncertainty in the determination of the emission factor follows the rules of error propagation and were set from the default values proposed in the GPG for DOC (50%), DOC_F (50%), MCF (10% for Managed systems and 60% for unmanaged) and F (20%) and 300% for k, the methane generation rate constant¹⁴⁹. An overall error of 62 %, for managed systems and 86 % for unmanaged systems, was therefore obtained and used for both urban and industrial wastes.

8.3.B Wastewater Handling

For urban waste water treatment the activity data, expressed in organic load to wastewater systems, was estimated from population and per capita production and the error associated with both variables needs to be incorporated in the determination of the final uncertainty value. Assuming the default uncertainties proposed in GPG, 5 per cent for human population and 30 per cent for BOD per capita, a final 30.4 % error was set for this activity.

In the case of industrial waste-water systems the available information is much more scarce. The uncertainty value was estimated individually for each industry 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);
- the uncertainty of production data is 20 per cent if data was obtained from National Statistics and 50 per cent if was interpolated.

The uncertainty considering all industrial activities, according to their production, varied between 22 and 24 per cent, according to years.

and limited to a few years and, although the consideration of the default GPG uncertainties results in an overall 103% error, a conservative doubling of that value was considered.

Concerning the methane emission factor, the uncertainty of this parameter includes an error in the Maximum Methane Producing Capacity (Bo), for which the GPG default of 30 per cent was used, and the error determination in the fraction of water treated anaerobically. For urban water the uncertainty in this last fraction was estimated as 22 per cent, considering the percentage of individual septic tanks and the lack of knowledge of in which conditions they operate.

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, 30 per cent according to the GP;
- the error of the allocation of each specific treatment system, established from the per cent of unknown situations, augmented by 20 per cent to consider the error for the known cases;

¹⁴⁹ The uncertainty for this variable affects nevertheless when emissions occur and not how much and affects emission estimates exponentially.

- the uncertainty in MCF for each specific treatment system, set from the GP, and varying from 10 per cent for Secondary Treatment, well managed, to 50 per cent, no treatment.

The error was determined for each industry and propagated accordingly. The final uncertainty varies in time from 29 per cent to 35 per cent.

8.3.C Waste Incineration and Other

The uncertainty of the quantity of urban wastes was assumed to be 5%, considering that they are obtained directly from the incineration plants. For hospital wastes an uncertainty of 48% was calculated from comparison of annual variation in the quantities reported as incinerated, and also considering the fact that there is a fair lack of information of the production time series, particularly before 1995. In a way similar to what was done for determination of the uncertainty of production of industrial solid wastes, the comparison of the incineration of industrial solid wastes from 1999 till 2002 and its annual variations, allowed the estimation of an annual uncertainty of about 45%.

The uncertainty of CO₂ emission factors was set as 25% for urban and industrial wastes and 50% for hospital wastes, which expresses the uncertainty in carbon content and the additional uncertainty in the fraction of the incinerated carbon that has fossil origin. For N₂O and CH₄ emission factors a 100% uncertainty was considered.

8.4 Recalculations

The revisions that have been done in the 2006 inventory submission refer mainly to category 6B, either for the domestic and the industrial wastewater handling. Synthesis of changes may be observed in Figure 8.22 and Table 8.21.

Figure 8.22 – Differences between 2005 and 2006 submissions (CO₂ equivalent)

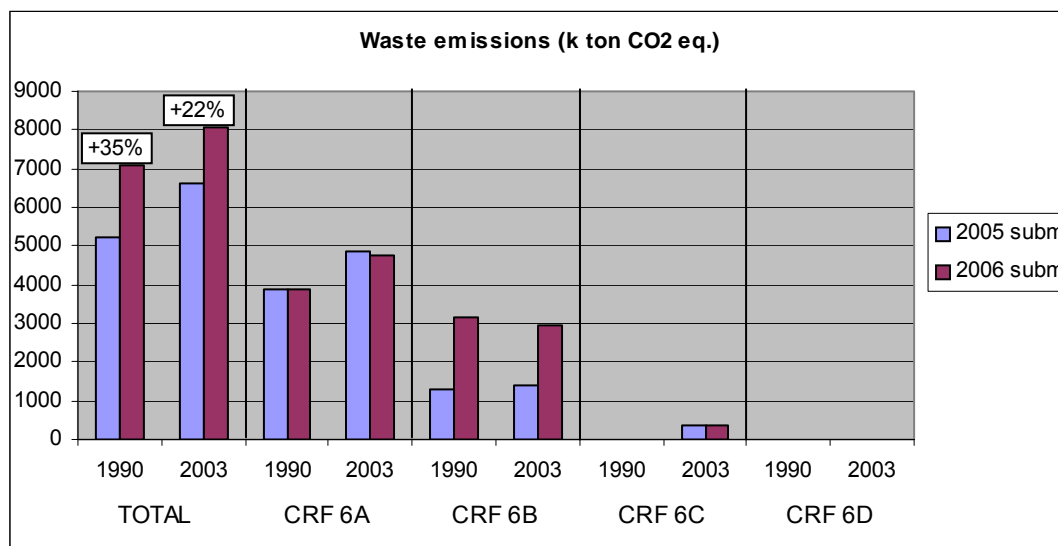


Table 8.21 – Recalculations (differences between 2005 to 2006 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂			CH ₄			N ₂ O		
	2005 subm.	2006 subm.	Difference (1)	2005 subm.	2006 subm.	Difference (1)	2005 subm.	2006 subm.	Difference (1)
	CO ₂ eq (Gg)		(%)	CO ₂ eq (Gg)		(%)	CO ₂ eq (Gg)		(%)
1990									
6. Waste	10.10	10.10	0.00	4 761.38	6 580.46	38.20	448.26	470.52	4.96
6.A. Solid Waste Disposal on Land	0.00	0.00		3 891.80	3 891.80	0.00			
6.B. Wastewater Handling				869.54	2 688.62	209.20	447.15	469.40	4.98
6.C. Waste Incineration	10.08	10.08	0.00	0.01	0.01	0.00	0.37	0.37	0.00
6.D. Other	0.02	0.02	0.00	0.03	0.03	0.00	0.74	0.74	0.00
2003									
6. Waste	350.01	350.01	0.00	5 696.04	7 135.77	25.28	587.44	605.36	3.05
6.A. Solid Waste Disposal on Land	0.00	0.00		4 860.15	4 737.82	-2.52			
6.B. Wastewater Handling				834.89	2 396.95	187.10	558.51	576.43	4.98
6.C. Waste Incineration	350.01	350.01	0.00	0.96	0.96	0.00	27.77	27.77	0.00
6.D. Other	0.00	0.00	0.00	0.04	0.04	0.00	1.16	1.16	0.00

Notes: (1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission).

8.4.A Solid Waste Disposal on Land

Data on MSW were updated until 2004 with information collected by municipal management systems.

8.4.B Wastewater Handling

Concerning the domestic sector, major changes refer to the revision of background data for waste water handling types, coming from a compilation study developed by INAG (the National Institute for Water).

CH₄ emissions estimates for the industrial wastewater were by far one of the sources that were less well characterised and out of date (the most recent data used previously in the calculations refer to 1993). The estimates done last year were based on a very simple methodology relying on a constant quantity of wastewater production, expressed in inhabitants-equivalent, multiplied by a simple emission factor from the CORINAIR guidebook (EEA,2000). The resulting estimates showed a great uncertainty, firstly because of the lack of time-trendness in the activity data, and also because the emission factor in the CORINAIR guidebook reflects the handling situation in a country (the Netherlands) and did not differentiate wastewater management in industry, from wastewater management in industry.

The methodology has changed substantially since last submission. The estimates for this source category have been entirely revised based on a national study referring to specific pollution coefficients for several industrial sectors applied to industrial production data taken from INE. The methodology that is presently used is considered, although all its caveats, to be better documented and representative of conditions existing in Portugal. Also, it is more comparable to the methodology that was used in the estimate of CH₄ emissions from handling of domestic wastewater.

8.4.C Waste Incineration and Other

No changes have been done concerning this source. Data on MSW incinerated were updated for 2004.

8.5 Further improvements

One of the issues that still needs to be improved in the near future is the better quantification of the amount of CH₄ recovered and flared. Data used presently refer to estimates of CH₄ based on the existence of operating flares in the waste management units, and not on metering of gas recovered and flared as proposed in good practice guidance (IPCC,2000).

Considering the limitations in the time trend in load and the share of each treatment system concerning industrial wastewater handling, efforts will continue in order to improve the knowledge of the situation of industrial wastewater. It is expected that the situation will improve soon, after the implementation of a new survey system and data base by the National Water Institute.

CH₄ emissions from CH₄ recovery for the category Industrial Waste-Water Handling should be quantified and reported in the future.

N₂O emissions from human sewage have been estimated according to the IPCC default methodology (IPCC,1997), assuming that all sewage nitrogen is discharged into aquatic environments, and not counting with N₂O emissions related with land disposal and sewage treatment.

The issue of energy recovery in waste incineration has not yet been considered and should be addressed.

8.6 Annex WASTE: Background Data Tables

Table W-1 – National population, per capita generation rates, and urban waste production: 1960-2004

Year	Population	Annual per capita generation rate	Pop. served by waste collection syst.	Urban waste production				
				Total	Open dump sites	Managed landfills	Composted waste	Incinerated waste
	inhabitants	kg/inh/year	% pop.	kton				
1960	8 889 197	128.8	40	457.8	457.8	0.0	0.0	0.0
1961	8 861 388	132.1	41	482.4	482.4	0.0	0.0	0.0
1962	8 833 580	135.6	42	507.8	507.8	0.0	0.0	0.0
1963	8 805 771	139.1	44	534.1	534.1	0.0	0.0	0.0
1964	8 777 962	142.8	45	561.4	561.4	0.0	0.0	0.0
1965	8 750 154	146.5	46	589.6	589.6	0.0	0.0	0.0
1966	8 722 345	150.3	47	618.8	618.8	0.0	0.0	0.0
1967	8 694 536	154.2	48	649.1	649.1	0.0	0.0	0.0
1968	8 666 727	158.3	50	680.4	680.4	0.0	0.0	0.0
1969	8 638 919	162.4	51	712.8	712.8	0.0	0.0	0.0
1970	8 611 110	166.7	52	746.3	746.3	0.0	0.0	0.0
1971	8 722 192	171.2	53	794.5	794.5	0.0	0.0	0.0
1972	8 833 274	175.9	54	845.2	845.2	0.0	0.0	0.0
1973	8 944 357	180.7	56	898.5	898.5	0.0	0.0	0.0
1974	9 055 439	185.6	57	954.5	954.5	0.0	0.0	0.0
1975	9 166 521	190.6	58	1 013.4	1 013.4	0.0	0.0	0.0
1976	9 277 603	195.8	59	1 075.1	1 075.1	0.0	0.0	0.0
1977	9 388 685	201.0	60	1 140.0	1 140.0	0.0	0.0	0.0
1978	9 499 767	206.4	62	1 208.1	1 208.1	0.0	0.0	0.0
1979	9 610 850	212.0	63	1 279.5	1 279.5	0.0	0.0	0.0
1980	9 721 932	217.7	64	1 354.4	949.2	360.5	44.7	0.0
1981	9 833 014	224.6	66	1 462.0	1 021.1	396.2	44.7	0.0
1982	9 836 427	231.6	68	1 558.2	1 088.1	425.4	44.7	0.0
1983	9 839 841	238.8	71	1 658.9	1 158.2	456.0	44.7	0.0
1984	9 843 254	246.2	73	1 764.5	1 231.7	488.1	44.7	0.0
1985	9 846 667	253.9	75	1 875.0	1 308.6	521.7	44.7	0.0
1986	9 850 081	261.8	78	2 001.1	1 396.3	560.1	44.7	0.0
1987	9 853 494	269.9	80	2 133.2	1 488.2	600.3	44.7	0.0
1988	9 856 907	278.3	83	2 271.7	1 584.5	642.5	44.7	0.0
1989	9 860 320	287.0	85	2 416.8	1 685.4	686.7	44.7	0.0
1990	9 863 734	295.9	88	2 568.7	1 764.9	692.1	111.7	0.0
1991	9 867 147	305.1	89	2 690.9	1 731.9	913.5	45.5	0.0
1992	9 916 044	314.7	91	2 831.4	1 821.8	951.7	57.8	0.0
1993	9 964 941	324.5	92	2 978.4	1 915.3	989.4	73.7	0.0
1994	10 013 838	334.6	93	3 132.3	1 839.0	1 137.2	156.2	0.0
1995	10 062 735	350.0	95	3 341.2	1 951.7	1 184.4	205.1	0.0
1996	10 111 632	365.4	96	3 542.8	2 027.8	1 310.3	204.7	0.0
1997	10 160 529	380.7	97	3 748.6	2 007.1	1 531.4	210.1	0.0
1998	10 209 426	395.9	98	3 958.7	1 507.5	2 236.0	215.2	0.0
1999	10 258 323	411.0	99	4 173.3	974.1	2 626.6	226.2	346.4
2000	10 307 220	412.1	100	4 247.9	588.3	2 473.6	274.8	911.1
2001	10 356 117	425.2	100	4 403.1	451.9	2 792.9	266.6	891.7
2002	10 405 014	421.2	100	4 382.7	27.8	3 294.7	116.2	943.9
2003	10 453 911	427.1	100	4 464.6	25.9	3 019.2	416.1	1 003.4
2004	10 502 808	414.3	100	4 351.6	22.3	3 236.3	250.6	842.3

Sources:INE; IA estimates; INR; Quercus Study

Table W - 2 – Fermentable industrial waste disposal: 1960-2004

Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills
kton			kton			ton		
1960	819	0	1975	1 024	0	1990	893	388
1961	832	0	1976	1 040	0	1991	843	463
1962	844	0	1977	1 055	0	1992	860	473
1963	857	0	1978	1 071	0	1993	876	483
1964	870	0	1979	1 087	0	1994	835	551
1965	883	0	1980	773	330	1995	850	565
1966	896	0	1981	782	338	1996	848	594
1967	909	0	1982	794	343	1997	810	661
1968	923	0	1983	806	348	1998	594	907
1969	937	0	1984	818	354	1999	358	1 173
1970	951	0	1985	830	359	2000	59	365
1971	965	0	1986	842	365	2001	94	817
1972	980	0	1987	854	370	2002	5	773
1973	994	0	1988	867	376	2003	5	773
1974	1 009	0	1989	880	382	2004	4	789

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: IA estimates; INR

Table W - 3 – Quantities of CH₄ recovered and combusted (Urban waste): 1990-2004

	Unmanaged disposal sites	Landfill sites	Unmanaged disposal sites	Landfill sites	Biogas burned as % of CH ₄ generated
	kton CH ₄		Mton CO ₂ eq.		%
1990	0.00	0.00	-	-	0
1991	0.00	0.00	-	-	0
1992	0.00	0.00	-	-	0
1993	0.00	0.00	-	-	0
1994	0.00	0.00	-	-	0
1995	0.00	0.00	-	-	0
1996	0.00	0.00	-	-	0
1997	0.00	0.00	-	-	0
1998	0.00	0.00	-	-	0
1999	0.00	0.00	-	-	0
2000	1.17	10.64	0.02	0.22	7
2001	2.08	39.95	0.04	0.84	23
2002	1.93	45.18	0.04	0.95	25
2003	1.98	48.58	0.04	1.02	26
2004	2.15	52.36	0.05	1.10	27

Source: IA estimates

Table W - 4 – Quantities of CH₄ recovered and combusted (Fermentable industrial waste): 1990-2004

	Unmanaged disposal sites	Landfill sites	Unmanaged disposal sites	Landfill sites	Biogas burned as % of CH ₄ generated
	kton CH ₄		Mton CO ₂ eq.		%
1990	0.00	0.00	-	-	0
1991	0.00	0.00	-	-	0
1992	0.00	0.00	-	-	0
1993	0.00	0.00	-	-	0
1994	0.00	0.00	-	-	0
1995	0.00	0.00	-	-	0
1996	0.00	0.00	-	-	0
1997	0.00	0.00	-	-	0
1998	0.00	0.00	-	-	0
1999	0.00	0.00	-	-	0
2000	0.72	4.75	0.02	0.10	6
2001	1.58	23.18	0.03	0.49	22
2002	1.64	27.24	0.03	0.57	23
2003	1.64	28.11	0.03	0.59	24
2004	1.75	29.00	0.04	0.61	25

Source: IA estimates

Table W - 5 – National population and wastewater BOD produced by handling systems: 1990-2004

	Population (1000 inhabitants)	BOD ₅ produced (kton/year)					
		Total	Treatment systems		Individual treatment	Without treatment	Sludge spreading
			wastewater	sludge			
1990	9 864	216	24	5	8	173	5
1991	9 867	216	25	5	12	168	5
1992	9 916	217	26	6	15	164	6
1993	9 965	218	27	6	19	160	6
1994	10 014	219	29	6	23	155	6
1995	10 063	220	34	8	27	144	8
1996	10 112	221	40	9	31	132	9
1997	10 161	223	45	10	36	121	11
1998	10 209	224	51	12	40	109	12
1999	10 258	225	57	13	44	97	14
2000	10 307	226	68	15	39	86	18
2001	10 356	227	76	17	37	77	21
2002	10 375	227	80	18	35	71	22
2003	10 393	228	84	19	34	67	24
2004	10 412	228	95	21	29	55	28

Source: IA estimates

Notes:

Treatment systems – wastewater: refer to primary treatment (70% of organic load), Biodisks with anaerobic sludge digestion, Activated sludge with and without anaerobic sludge digestion, Laguning, without anaerobic pond, Percolation beds with anaerobic sludge digestion, Oxidation ponds and Other treatment (63% of organic load); Laguning, with anaerobic pond and Imhoff Tanks (100% of organic load).

Treatment systems – sludge: refer to Biodisks with anaerobic sludge digestion, Activated sludge with anaerobic sludge digestion and Percolation beds with anaerobic sludge digestion (37% of organic load).

Individual treatment: refer to private and collective septic tanks.

Without treatment: refer to discharge into the ocean and inland waters and without sewerage (latrines).

Sludge spreading: refer to the % of the organic load retained as non mineralised sludge in primary treatment (30% of primary organic load generated), and 37% in activated sludge without anaerobic sludge digestion, laguning without anaerobic pond, oxidation ponds and other treatment.

Table W - 6 – Estimated quantities of CH₄ flared from wastewater handling systems: 1990-2004

Year	Sludge treatment systems	
	kton/year	% emissions of sludge treat.
1990	0.00	0.0
1991	0.00	0.0
1992	0.00	0.0
1993	0.00	0.0
1994	0.00	0.0
1995	0.00	0.0
1996	0.00	0.0
1997	0.00	0.0
1998	0.00	0.0
1999	0.00	0.0
2000	0.00	0.0
2001	0.49	1.3
2002	0.78	2.1
2003	1.02	2.8
2004	1.72	4.9

Source: IA estimates

Table W - 7 – Quantities of waste incinerated: 1990-2004

Year	MSW quantities incinerated	Clinical waste quantities incinerated
	kton	
1990	-	12
1991	-	12
1992	-	12
1993	-	12
1994	-	12
1995	-	12
1996	-	13
1997	-	16
1998	-	12
1999	346	10
2000	911	7
2001	892	3
2002	915	3
2003	893	2
2004	844	2

Note: Estimates in italics

Sources: INR; DGS; IA estimates.

Table W - 7 – Quantities of industrial waste open burned: 1990-2004

Year	Industrial solid waste incinerated
	kton
1990	24
1991	24
1992	25
1993	25
1994	26
1995	27
1996	27
1997	28
1998	28
1999	29
2000	15
2001	27
2002	38
2003	38
2004	38

Note: Estimates in italics

Sources: INR; IA estimates.

Table W - 8 – Comparison between estimates for CH₄ emissions from waste-water handling and IPCC check-method

Year	CH ₄ emissions			National CH ₄ emissions	
	Check method ton	National estimates ton	% difference %	w without recovery ton	recovered ton
1990	51 844	50 305	3.0	50 305	0
1991	51 862	49 312	4.9	49 312	0
1992	52 119	48 540	6.9	48 540	0
1993	52 376	47 759	8.8	47 759	0
1994	52 633	46 968	10.8	46 968	0
1995	52 890	45 714	13.6	45 714	0
1996	53 147	44 445	16.4	44 445	0
1997	53 404	43 163	19.2	43 163	0
1998	53 661	41 865	22.0	41 865	0
1999	53 918	40 554	24.8	40 554	0
2000	54 175	38 649	28.7	38 649	0
2001	54 432	37 209	31.6	37 695	486
2002	54 529	36 225	33.6	37 008	783
2003	54 626	35 493	35.0	36 509	1 016
2004	54 723	32 984	39.7	34 700	1 717
% variation 1990-2004	5.6	-34.4	-	-	-

CHAPTER: 9 NMVOC BIOGENIC EMISSIONS

9.1 Overview

Emissions of Volatile Organic Compounds occur from plant foliage, either in forest or in agricultural lands, and are commonly called biogenic emissions. Usually in emission inventories a distinction is made for emissions of Isoprene, monoterpenes (α -pinene, β -pinene, limonene, etc.) and OVOC (Other Volatile Organic Compounds, mostly oxygenated compounds such as alcohols, aldehydes, etc). This separation pretends to distinguish compounds with different importance in ozone formation, which is apparently higher for isoprene than for terpenes (Simpson et al, 1995)

Biogenic emissions are highly dependent on the vegetation specie and also on climatic conditions. Temperature affects almost all species. Light affects mostly isoprene emissions, but terpene emissions are also affected for a few species.

In Portugal, besides emissions from foliage, the emission inventory considers also monoterpene emissions resulting from resin-tapping. In fact, when coniferous live tissues are damaged, the exposed resin channels result in increased terpene emission. This process is artificially increased by resin-tapping, that is practiced to obtain resin-derivatives. In Portugal resin tapping is common in maritime pine (*Pinus pinaster*) during the spring-autumn period and is done by extraction of part of the bark in the tree trunk. The majority of emissions comprehend α -pinene and β -pinene.

9.2 Methodology

9.2.A Vegetation foliage

Emission of NMVOC from vegetation foliage are estimated separately for isoprenes, monoterpenes and Other Volatile Organic Compounds (OVOC), and using emission factors that are regional specific, at nut 3 level, using the general equation:

$$Emi_NMVOC_{(s,t)} = \sum_n [(EF_Iso_{(s,n)} + EF_Mono_{(s,n)} + EF_OVOC_{(s,n)}) * Veget_{AREA(s,n)}] * 10^{-6}$$

where,

$Emi_NMVOC_{(s,t)}$ - Emissions of NMVOC resulting from crop or tree specie s, added over all national territory, in year t (t/yr);

$EF_Iso_{(s,n)}$ - Isoprene emission factor for specie s at territorial unit n (g/ha/yr);

$EF_Mono_{(s,n)}$ - Total monoterpene emission factor for specie s at territorial unit n (g/ha/yr);

$EF_OVOC_{(s,n)}$ - emission factor of Other Volatile Organic Compounds for specie s at territorial unit n (g/ha/yr);

$Veget_{AREA(s,n,t)}$ - Area occupied by crop or tree specie s in territorial unit n during year t (ha).

The determination of emission factors varies in complexity with VOC compound and specie, as explained next.

9.2.B Resin-tapping

VOC emissions from resin-tapping of maritime pine emissions are estimated using the number of tapped trees as activity data, according to the methodology proposed by (Pio & Valente, 1998):

$$\text{Resin_NMVOC}_{(s)} = \sum_n [(\text{EF_tapping}_{(n)} * N_{\text{tappedtrees}(n)}) * 10^{-3}]$$

where,

$\text{Resin_NMVOC}_{(s)}$ - Emissions of NMVOC resulting from resin tapping in Maritime pine, added over all national territory, in year t (t/yr);

$\text{EF_Tapping}_{(n)}$ - VOC emission factor for resin tapping at territorial unit n (mg/tree/yr);

$N_{\text{tappedtrees}(n)}$ - Number of trees (millions) subjected to resin-tapping in territorial unit n;

9.3 Emission Factors

Two different situations exist in what concern the determination of emission factors.

9.3.A Forest areas and permanent crops

For forest areas, and also for permanent crops such as olive trees, vineyards and orchards, emission factors are fixed from the specie/ecosystem characteristics, foliar density and tacking into account the influence of abiotic factors - light and temperature. This procedure follows the methodology proposed by Guenther (1995) after Tingey et al (1980,1991), and which is reproduced in EMEP/CORINAIR (EEA,2002). Final emission factor is therefore determined from the following adapted equation:

$$\text{EF}_{(s,n,t,c)} = D_{(s)} * \varepsilon_{(s,c)} * \gamma_{(n,t,c)} * 10 / \text{CC}_{(s)}$$

where,

$\text{EF}_{(s,n,t,c)}$ - Emission factor (g/ha/yr) for compound c;

$\text{CC}_{(s)}$ - Carbon content of compound c;

$D_{(s)}$ - Foliar density (kg dm/m²) for each specific species, averaged over the vegetation period;

$\varepsilon_{(s,c)}$ - specie or ecosystem dependent emission factor (µgC/g dm/yr) at standard conditions (PAR flux of 1000 µgmol/m²/s and leaf temperature of 303.15 K). Varies with each specific compound;

$\gamma_{(n,t,c)}$ - non-dimensional adjustment factor accounting for the influence of light (PAR) and leaf temperature. This parameter changes in time, according to meteorological conditions, and it is function of each particular compound;

PAR - Photosynthetically active radiation (400-700 nm), typically about 45-50% of total global radiation (mmol-photons/m²/s).

Values for D and ε where set from available bibliographic references and are presented in next Table 9.1. For deciduous species D is zero during the coldest period, which is also presented in Table 9.1¹⁵⁰:

Carbon content was determined from the chemical formula of Isoprene (C_5H_8) and terpenes ($C_{10}H_{12}$), which value is 88% for both compounds. This same percentage was considered also for OVOC.

Table 9.1 - Meteorological independent parameters used to determine foliage emission factors

Tree Specie		D kd dm/m2		Vegetation Period	ε µgC/g dm/h @standart L,T					
					µgC/g dm/h @standart L,T			Isoprene	Monoterpenes	OVOC
Maritime pine	Pinus pinaster	700	Veldt (1989); Guenther et al (1994); Nunes (1996)	Evergreen	0	-	2.25	Pio et al, 1999	1.5	Guenther et al, 1994
Umbrella pine	P. Pinea	400	same as Other Coniferous	Evergreen	0	-	6	EMEP/CORINAIR-B1101 (EEA,2002)	1.5	
Other coniferous	-	400	(Ortiz and Dory, 1990 in Simpson,1995)	Evergreen	0	-	1.08	Simpson et al 1998. Average for Cupressus, halepensis, Pseudotsuga, P. sylvestris	1.5	
Gum tree	Eucalyptus sp.	300	(Nunes,1996); Nunes & Pio (1999)	Evergreen	32	Nunes & Pio (1999)	1.5	Nunes & Pio (1999)	1.5	
Cork oak	Quercus suber	200	Intermediate value between Forest area Mediterranean Oak (300) Simpson et al (1995) and Monte Hueco (100) from Ortiz and Dory (1990)	Evergreen	0	-	varies along year according to Table 9.2		1.5	
Holm oak	Quercus rotundifolia	200	Intermediate value between Forest area Mediterranean Oak (300) Simpson et al (1995) and Monte Hueco (100) from Ortiz and Dory (1990)	Evergreen	0	-	17	Luchetta, Simon and Torres (Average value)	1.5	
Oaks	Quercus sp.	400	Guenther et al (1994)	Apr-Sept	40	Guenther et al (1994)	0.35	Luchetta et al, 1999(Average Q. robur and Q. petrae)	1.5	
Chetnut	Castanea sativa	375	Guenther et al (1994)	Apr-Sept	0	-	8.71	(Luchetta et al,1999)	1.5	
Other broadleaves	-	418	Guenther et al (1994) in Geron, Guenther et Pierce (1994). Average: Acacia, Betula, Celtis, Fraxinus, Juniperus, Platanus, Populus, Prunus, Salix, Ulmus and Olea)	Mixed Evergreen and Deciduous	12.8	Guenther et al (1994) in Geron, Guenther et Pierce (1994). Average: Acacia, Betula, Celtis, Fraxinus, Juniperus, Platanus, Populus, Prunus, Salix, Ulmus and Olea)	0.6	Guenther et al (1994) in Geron, Guenther et Pierce (1994). Average: Acacia, Betula, Celtis, Fraxinus, Juniperus, Platanus, Populus, Prunus, Salix, Ulmus and Olea)	1.5	
Mixed broadleaves/ coniferous	-	380	Average other species	Mixed Evergreen and Deciduous	-	Average other species	-	Average other species	1.5	
Bush (Matos)	-	200	Ortiz & Dory (1990) in Simpson et al, 1999 (Garrigue)	Evergreen	8	Ortiz & Dory (1990) in Simpson et al, 1999 (Garrigue)	0.65	Ortiz & Dory (1990) in Simpson et al, 1999 (Garrigue)	1.5	
Olive Tree	Olea europaea	200	(Ortiz and Dory, 1990 in Simpson,1995)	Evergreen	0	-	1.6	(Ortiz and Dory, 1990 in Simpson,1995)	1.5	
Orchards/ Vine	-	200		Mixed Evergreen and Deciduous	0	-	1.6		1.5	

¹⁵⁰ During this period emissions from foliage are obviously zero.

Values for γ are estimated according to empirical equations that are functions of both VOC compound and vegetation specie. For Isoprene emissions the general set of equations were used, function of light and temperature, following Guenther et al (1993).

$$\gamma = C_L * C_T$$

C_L , the light dependence factor is determined from:

$$C_T = \frac{0.0027 * 1.066 * Q}{\sqrt{1 + (0.027 * Q)}}$$

where Q is the flux of PAR (mmol/m²/s)

C_T , the temperature dependence is described by:

$$C_T = \frac{\exp \left[\frac{95\,000 * (T - T_s)}{R * T * T_s} \right]}{1 + \exp \left[\frac{230\,000 * (T - 314)}{R * T * T_s} \right]}$$

where T is leaf temperature (K) and T_s is standard temperature (303 K). R is the ideal gas constant (=8.314 J/K/mol)

For monoterpenes Guenther et al (1993) proposed the general formulation:

$$\gamma = \exp [\beta * (T - T_s)]$$

where β is a constant, assumed 0.09 K⁻¹ (Guenther et al, 1993), T is leaf temperature (K) and T_s is standard temperature (303 K)

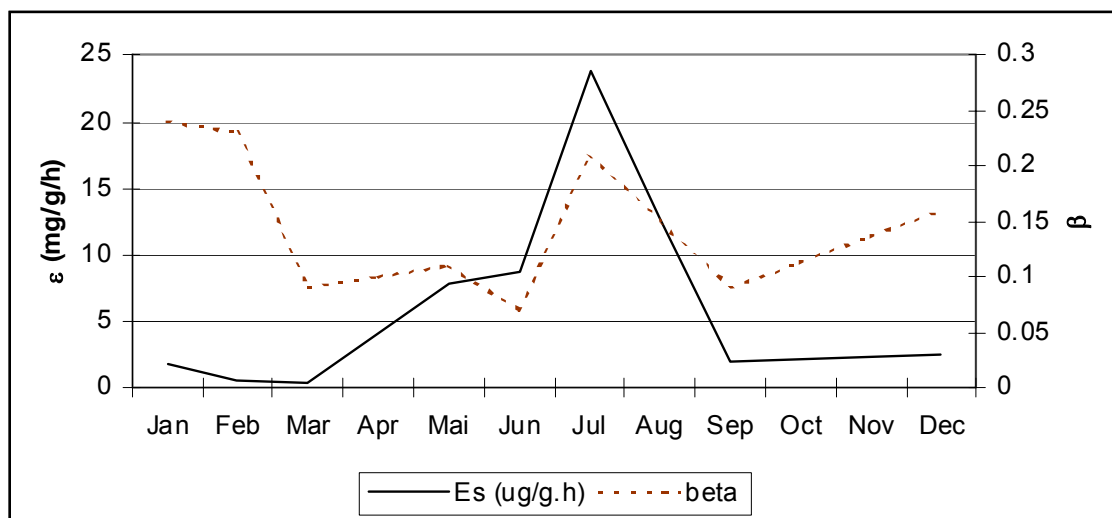
This same equation was used for OVOC following recommendations in Geron et al (1999) and in the EMEP/CORINAIR (Chapter B1101) (EEA,2002).

For some species however, this general formulation was not used but it is replaced by country specific equations. This is particularly the case for cork and Holm oaks, where monoterpene emissions are also function of light¹⁵¹. These equations are summarized in table 9.2.

¹⁵¹ This dependence is however distinct from the emission dependence of isoprenes for oak (*Quercus robur*) and Gum (eucalyptus globulus), for example, because it still occurs during darkness. Hence there is a need for a mixed emission model (Silva et al, 1999)

Table 9.2 – Specie and country specific equations for γ

Specie	Compound	Equation	Reference
P. Pinaster	Monoterpernes	$\gamma = \exp[0.138 * (T-30)]$	Pio et al (1999)
Eucalyptus	Monoterpenes	$\gamma = \exp[0.07 * (T-30)]$	Nunes (1996)
Cork Oak	Isoprene	$\gamma = \{CL*CT + \exp[\beta * (T-T_s)]\}$	Silva et al (1999); CL*CT is Guenther's model. B parameter changes during the year, and the considered variation is in Figure 9.2
Holm Oak	Isoprene	$\gamma = \{CL*CT + \exp[0.09 * (T-T_s)]\}$	

Figure 9.1 - Time variable ε for Cork Oak (adapted from Silva et al (1999))

The γ parameter was determined for each tree specie (s) for each territorial unit, n (nut 3 level) from climatic data for a typical day of 12 hours for each month of the year according to the following equation:

$$\gamma_{(n,s)} = \sum_{m,h} \{\gamma[PAR_{(n,m,h)}, T_{(n,m,h)}, s]\}$$

where,

$\gamma[PAR_{(n,m,h)}, T_{(n,m,h)}, s]$ - γ estimate for a specific hour h of a typical day a particular month m, calculated according to the specific equation for tree specie s;

$PAR_{(n,m,h)}, T_{(n,m,h)}$ - Photosynthetically active radiation of hour h of month m in territorial unit n;

$T_{(n,m,h)}$ - Leaf temperature of hour h of month m in territorial unit n.

9.3.B Other agricultural areas and grasslands

For other agricultural areas and grasslands, the emission factor is simply a constant value, that is not a function of climatic conditions and hence not specific of each territorial area., and that is expressed in mg C/m²h. The considered values in the Portuguese inventory, from (Veldt,1991; Veldt,1998), are presented in table 9.3.

Table 9.3 - Emission Factors of NMVOC for biogenic emissions from agricultural areas, except olives, orchards and vine

Crop	Isoprene	Monoterpene	OVOC	NMVOC
	$\mu\text{gC}/\text{m}^2/\text{h}$			$\mu\text{g}/\text{m}^2/\text{h}$
Arable Land	8	20	12	45
Rice	8	20	12	45
Grassland	8	20	12	45
Market Gardening	8	20	12	45

Source: Veldt, 1991 ; Veldt, 1998

9.3.C Resin-tapping

The emission factor for resin-tapping, per tree in extraction, follows the equation proposed by Pio & Valente (1998), for each particular condition:

$$\log_{10}[\text{EF_tapping}_{(m,h)}] = 0.631 + 0.06 * T$$

where,

$\text{EF_tapping}_{(m,h)}$ - VOC emission rate from resin-tapping (mg VOC/hr/tree) for a specific time;

T - Air temperature ($^{\circ}\text{C}$).

The annual emission factor for each territorial unit was obtained by the addition of the emission factors for each hourly period in a year:

$$\text{EF_tapping}_{(n)} = \sum_{m,h} \{\text{EF_Tapping}_{(m,h)}\}$$

9.4 Activity Data

Basic activity data is the area for each crop or plant species. This information was available from DGRF for years 1990 and 1995 and was interpolated and extrapolated¹⁵² for the remaining time-series. Foliage areas for each tree species were obtained according to the following equation:

$$\text{Foliage_Area}_{(n,s)} = \text{Pure}_{(n,s)} + 0.75 * \text{Dominant}_{(n,s)} + 0.25 * \text{Dominated}_{(n,s)} + \text{Dispersed}_{(n,s)}$$

where,

$\text{Foliage_Area}_{(n,s)}$ - total area covered by foliage of tree specie s in territorial unit n (ha);

$\text{Pure}_{(n,s)}$ - Land area occupied by pure strands of specie s in territorial unit n (ha);

¹⁵² Linear interpolation

Dominant_(n,s) - Land area occupied by mixed strands where specie s is dominant, in territorial unit n (ha);

Dominated_(n,s) - Land area occupied by mixed strands where specie s is non-dominant, in territorial unit n (ha);

Dispersed_(n,s) - Dispersed arboreal areas inter-mixed in non-forest areas forming small woodland areas (Bosquetes) (ha).

Table 9.4 - Forest Area per tree specie (ha) (1990-1996)

Specie	1990	1991	1992	1993	1994	1995	1996
Pinus pinaster	1 037 835	1 050 599	1 062 759	1 074 314	1 085 263	976 069	974 328
P. pinea	35 000	44 607	54 637	65 088	75 962	77 650	78 688
Other coniferous	46 924	44 476	41 760	38 778	35 530	27 358	22 621
Quercus suber	661 835	678 503	695 367	712 428	729 685	712 813	704 109
Quercus rotundifolia	458 104	470 376	482 683	495 026	507 403	461 577	458 748
Other oaks	123 000	131 024	139 212	147 563	156 077	130 899	130 899
Castanea sativa	37 000	39 064	41 179	43 346	45 563	40 579	40 579
Eucalyptus sp.	515 043	565 863	618 913	674 195	731 707	672 149	668 015
Other broadleaves	73 327	82 975	93 189	103 971	115 320	102 037	99 643
Other mixed	0	0	0	0	0	0	0
Bush (Matos)	1 734 822	1 798 772	1 862 722	1 926 671	1 990 621	2 054 571	2 054 571
Olive	322 093	324 236	325 523	321 664	317 805	307 077	303 218
Orchards and Vine	421 501	424 306	425 989	420 940	415 890	401 851	396 801
Arable Land	2 340 754	2 363 534	2 292 882	2 298 800	2 302 868	2 131 628	2 166 240
Rice	33 246	33 466	21 118	13 200	23 132	21 646	22 389
Grassland	858 000	859 000	860 000	862 000	862 000	1 052 798	1 052 798
Market Gardening	32 000	32 000	31 000	31 000	31 000	30 127	29 951
Resin-tapping (M tree)	35	35	35	35	35	35	35

Table 9.5 - Forest Area per tree specie (ha) (1997-2004)

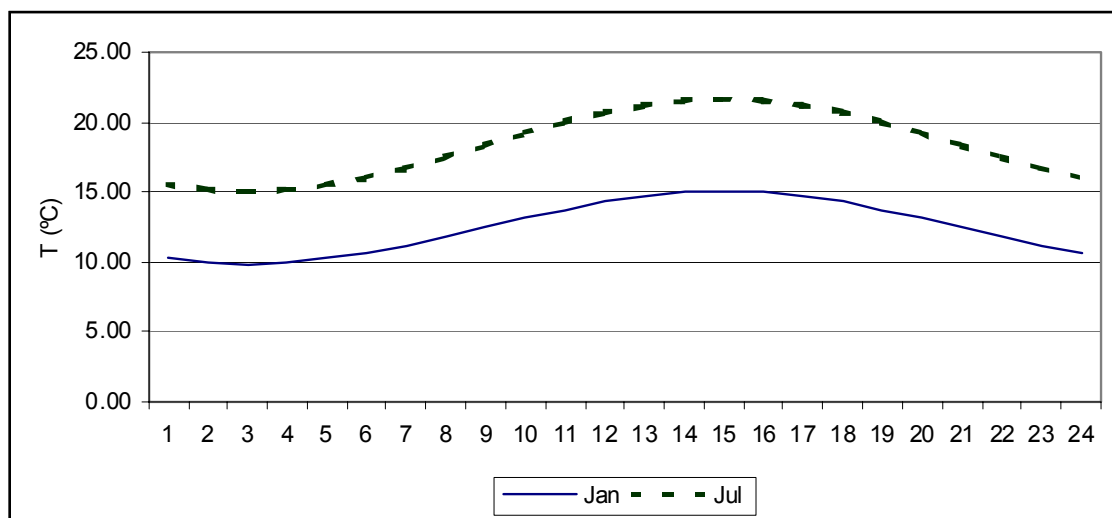
Specie	1997	1998	1999	2000	2001	2002	2003	2004
Pinus pinaster	972 587	970 847	969 106	967 365	967 875	968 385	969 965	971 546
P. pinea	79 726	80 763	81 801	82 839	82 771	82 704	82 442	82 186
Other coniferous	17 884	13 147	8 410	3 673	4 825	5 976	7 107	8 232
Quercus suber	695 405	686 701	677 997	669 293	671 843	674 393	677 605	680 816
Quercus rotundifolia	455 919	453 091	450 262	447 433	448 262	449 091	449 408	449 725
Other oaks	130 899	130 899	130 899	130 899	130 899	130 899	130 899	130 899
Castanea sativa	40 579	40 579	40 579	40 579	40 579	40 579	40 579	40 579
Eucalyptus sp.	663 880	659 746	655 611	651 477	652 688	653 900	653 907	653 915
Other broadleaves	97 250	94 856	92 463	90 069	90 770	91 472	92 371	93 270
Other mixed	0	0	0	0	0	0	0	0
Bush (Matos)	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571
Olive	297 299	291 379	285 460	279 540	279 540	279 540	279 540	279 540
Orchards and Vine	389 055	381 308	373 562	365 815	365 815	365 815	365 815	365 815
Arable Land	2 131 334	2 096 428	2 061 522	2 026 616	2 026 616	2 026 616	2 026 616	2 026 616
Rice	22 389	22 389	22 389	22 389	22 389	22 389	22 389	22 389
Grassland	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798
Market Gardening	29 598	29 245	28 891	28 538	28 538	28 538	28 538	28 538
Resin-tapping (Million Tree)	35	35	35	35	35	35	35	35

For the determination of emissions from resin-tapping the number of pine trees under extraction must be known. Pio & Valente (1998) estimated that this number is about 35 million trees in the 1980-1990 period. After 1990 the same authors believe that there has been a decrease in the number of trees explored, but no statistical information is available

For the calculation of the emission factors it is necessary, as mentioned before, the knowledge of PAR and leaf temperature. These were set for each hour of the day and each month according to the following information.

A time series of 30 years (1951-1980) of average minimum and maximum air temperature, for each month and territorial unit, were used to establish a typical evolution of daily temperature, for each month of the year and each territorial unit. A cosine function was considered with a peak of air temperature occurring at 15.00 (2 PM). In the following figure there is an example for the daily evolution of air temperatures in January and July for Madeira Island.

Figure 9.2 - Cosine modelling of daily evolution of air temperatures in January and July in Madeira Island region. Obtained for average minimum and maximum monthly temperatures in 1951-1980 (INMG)

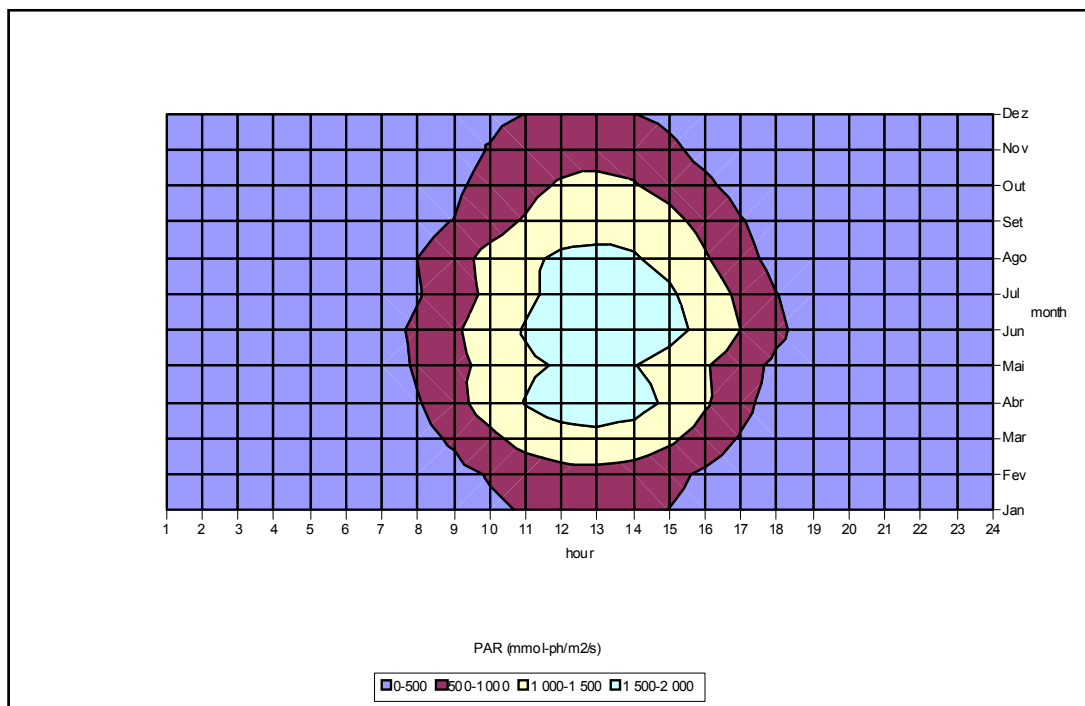


Source: INMG

However the information concerning PAR is scarce and some simplifications and assumptions had to be made. The pattern of monthly and daily variation of PAR was set by UA (Nunes, 1996) in Aveiro region, in central coastal Portugal, from a full year of measurements of total radiation (W/m^2) in the meteorology monitoring station of Cacia. Average hourly total radiation was converted in PAR ($mmol\text{-photons}/m^2/s$) by multiplication of 0.45, the local conversion factor (Pinho, 1995 in Nunes, 1996) and assuming an average wavelength of 550 nm. The annual monthly-hourly pattern of PAR in Cacia is presented in Figure 9.4.

PAR values for Cacia were corrected for each territorial unit proportionally to the relation of insolation in each specific region and in original Cacia station.

Figure 9.3 - Pattern of evolution of PAR (mmol/m²/s) according to month and hour of day (Nunes,1996)



9.5 Recalculations

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

9.6 Further Improvements

The existence and importance of NMVOC emissions from non-tree crops is much subject to debate, as for example in EMEP/CORINAIR (Chapter B1010 and B1104) (EEA,2002). It is expected that further improvements in methodology may lead to changes in emission estimates for this source sector.

It is expected that efforts will be made during next year to revise and improve the methodology and emission factors for the estimate of NMVOC from agriculture and forestry.

The emission factors could be estimated for each specific year using meteorological data.

The possible inclusion emissions of foliage under-canopy or dominated trees should be addressed, at least for some types of ecosystems.

An improvement in information concerning resin extraction may ameliorate the estimates of VOC emissions from resin-tapping in Maritime pine.

CHAPTER: 10 RECALCULATIONS AND IMPROVEMENTS

This section presents an overview of recalculations and improvements made in the 2006 submission. The detailed explanation of the recalculations and the foreseen improvements are included in each sectoral chapter.

In general, changes in methodology, source coverage or scope of the data have been reflected in the recalculation of the entire time series (from 1990 to 2003), in order to make the inventory internally consistent.

10.1 Implications for emissions levels

The implications of recalculations for emission levels by category and for the national totals by gas are presented in the following tables.

In a resumed way, the tables show that: CO₂ emissions recalculations are mostly related to the LULUCF sector, but some changes refer also to the energy sector, in particular energy industries and transport, and to international bunkers; CH₄ emissions changes refer in majority to the waste sector and more specically to the 6.B category (waste water handling), but some changes also were due to the agriculture and wildfires; N₂O emissions revisions are mainly related to Agriculture (Manure Management and Agriculture Soils).

The related explanations are included in the sector specific sections of the report and CRF Tables 8(b).

Table 10.1 – Recalculation difference of CO₂ emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
		kton CO2 eq.													
Total National Emissions and Removals		-2 170	-2 071	-2 837	-3 130	-3 241	-2 720	-3 168	-3 170	-2 731	-2 912	-2 538	-2 495	-2 264	2 577
1. Energy		-257	-254	-221	-215	-136	-65	-43	72	157	102	129	308	383	283
1.A.	Fuel Combustion Activities	-254	-251	-218	-212	-133	-62	-40	74	150	87	115	253	314	200
1.A.1.	Energy Industries	0	0	0	0	0	34	58	91	102	123	162	260	277	321
1.A.2.	Manufacturing Industries and Construction	55	0	0	0	0	13	11	11	12	16	16	13	14	14
1.A.3.	Transport	-309	-251	-218	-212	-133	-108	-109	-29	36	-52	-61	-9	40	-110
1.A.4.	Other Sectors	0	0	0	0	0	0	0	0	0	0	-2	-11	-17	-25
1.A.5.	Other	0	0	0	0	0									
1.B.	Fugitive Emissions from Fuels	-2	-3	-3	-3	-3	-3	-3	-2	7	15	14	55	69	83
1.B.1.	Solid fuel	0		0	0	0									
1.B.2.	Oil and Natural Gas	-2	-3	-3	-3	-3	-3	-3	-2	7	15	14	55	69	83
2. Industrial Processes		11	20	30	18	18	20	21	20	23	25	25	23	23	23
2.A.	Mineral Products	9	19	28	16	16	18	19	18	21	22	22	21	21	21
2.B.	Chemical Industry	2	1	2	2	2	2	2	2	2	3	2	3	3	3
2.C.	Metal Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.D.	Other Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.G.	Other														
3. Solvent and Other Product Use		0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. Agriculture															
4.A.	Enteric Fermentation														
4.B.	Manure Management														
4.C.	Rice Cultivation														
4.D.	Agricultural Soils ⁽²⁾														
4.E.	Prescribed Burning of Savannas														
4.F.	Field Burning of Agricultural Res.														
4.G.	Other														
5. Land Use, Land-Use Change and Forestry (LULUCF)		-1 924	-1 837	-2 645	-2 933	-3 123	-2 675	-3 146	-3 262	-2 911	-3 039	-2 692	-2 826	-2 671	2 270
5.A.	Forest Land														
5.B.	Cropland														
5.C.	Grassland														
5.D.	Wetlands														
5.E.	Settlements														
5.F.	Other Land														
5.G.	Other														
6. Waste		0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.A.	Solid Waste Disposal on Land														
6.B.	Wastewater Handling														
6.C.	Waste Incineration	0	0	0	0	0	0		0	0	0	0	0	0	0
6.D.	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items:															
International Bunkers		353	413	372	0	672	667	786	664	578	184	237	535	600	350
Multilateral Operations															
CO₂ Emissions from Biomass		0	0	0	0	0	0	0	0	0	0	0	-69	-127	-709

Note:

LULUCF: differences not calculated as categories differ from previous reporting.

Table 10.2 - Recalculation difference of CH₄ emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
		kton CO2 eq.													
Total National Emissions and Removals		1 194	1 160	1 362	1 381	1 683	1 606	1 691	1 753	1 765	1 737	1 635	1 845	1 832	1 043
1. Energy		17	17	19	22	24	25	25	59	72	-24	1	274	325	416
1.A.	Fuel Combustion Activities	17	17	19	22	24	25	25	22	18	16	16	15	16	15
1.A.1.	Energy Industries	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.2.	Manufacturing Industries and Construction	3	2	3	3	3	3	3	4	3	4	4	4	5	3
1.A.3.	Transport	15	15	16	19	21	21	22	18	14	12	11	11	11	11
1.A.4.	Other Sectors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.5.	Other	0	0	0	0	0									
1.B.	Fugitive Emissions from Fuels	0	0	0	0	0	0	0	37	54	-40	-15	258	309	401
1.B.1.	Solid fuel		0			0									
1.B.2.	Oil and Natural Gas	0	0	0	0	0	0	0	37	54	-40	-15	258	309	401
2. Industrial Processes		0	0	0	0		0	0	0	0	0	0		0	0
2.A.	Mineral Products		0		0	0	0	0	0	0	0	0	0	0	0
2.B.	Chemical Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.C.	Metal Production														
2.D.	Other Production														
2.G.	Other														
3. Solvent and Other Product Use															
4. Agriculture		-355	-232	-260	-307	-174	-19	2	-102	-7	95	169	208	262	219
4.A.	Enteric Fermentation	28	95	70	-11	109	224	282	178	270	355	429	438	470	419
4.B.	Manure Management	-383	-327	-330	-296	-283	-243	-280	-279	-277	-260	-260	-253	-236	-233
4.C.	Rice Cultivation	0											24	29	35
4.D.	Agricultural Soils ⁽²⁾														
4.E.	Prescribed Burning of Savannas														
4.F.	Field Burning of Agricultural Res.						0				0	0	0	-1	-1
4.G.	Other														
5. Land Use, Land-Use Change and Forestry (LULUCF)		-287	-453	-143	-86	-49	-316	-110	-41	-207	-112	-248	-164	-235	-1 033
5.A.	Forest Land														
5.B.	Cropland														
5.C.	Grassland														
5.D.	Wetlands														
5.E.	Settlements														
5.F.	Other Land														
5.G.	Other														
6. Waste		1 819	1 827	1 746	1 751	1 882	1 917	1 774	1 838	1 907	1 778	1 713	1 526	1 480	1 440
6.A.	Solid Waste Disposal on Land	0	0	0	0	0	0	0	0	0	0	0	-89	-103	-122
6.B.	Wastewater Handling	1 819	1 827	1 746	1 751	1 882	1 917	1 774	1 838	1 907	1 778	1 713	1 615	1 583	1 562
6.C.	Waste Incineration										0	0	0	0	0
6.D.	Other	0	0	0	0	0	0	0	0	0			0	0	0
Memo Items:															
International Bunkers		-2	-2	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-2	-2
Multilateral Operations															
CO₂ Emissions from Biomass															

Note:

LULUCF: differences not calculated as categories differ from previous reporting.

Table 10.3 - Recalculation difference of N2O emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
		kton CO2 eq.													
Total National Emissions and Removals		-687	-554	-391	-350	-293	-343	-160	-86	-356	-229	47	-145	-83	-694
1. Energy		8	9	12	25	42	49	54	56	59	64	61	54	51	42
1.A.	Fuel Combustion Activities	8	9	12	25	42	49	54	56	59	64	61	54	51	42
1.A.1.	Energy Industries	0	0	0	0	0	0	0	0	1	1	1	1	1	2
1.A.2.	Manufacturing Industries and Construction	0	0	0	0	0	0	0	0	0	0	0	0	0	-2
1.A.3.	Transport	8	9	12	25	42	49	53	55	58	63	60	53	50	42
1.A.4.	Other Sectors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.5.	Other	0	0	0	0	0									
1.B.	Fugitive Emissions from Fuels														
1.B.1.	Solid fuel														
1.B.2.	Oil and Natural Gas														
2. Industrial Processes		0	0	0	0	0	0	0	0	0	0	0	0		0
2.A.	Mineral Products														
2.B.	Chemical Industry	0	0	0	0	0	0	0	0	0	0	0	0		0
2.C.	Metal Production														
2.D.	Other Production														
2.G.	Other														
3. Solvent and Other Product Use															
4. Agriculture		-688	-531	-377	-341	-317	-349	-182	-134	-401	-285	5	-192	-124	-648
4.A.	Enteric Fermentation														
4.B.	Manure Management	-380	-366	-363	-349	-349	-354	-351	-368	-394	-386	-387	-410	-429	-449
4.C.	Rice Cultivation														
4.D.	Agricultural Soils ⁽²⁾	-289	-145	5	26	50	22	187	252	11	119	409	236	324	-180
4.E.	Prescribed Burning of Savannas														
4.F.	Field Burning of Agricultural Res.	-19	-19	-19	-18	-18	-18	-18	-18	-18	-17	-17	-18	-19	-19
4.G.	Other														
5. Land Use, Land-Use Change and Forestry (LULUCF)		-29	-46	-15	-9	-5	-32	-11	-4	-21	-11	-25	-17	-24	-105
5.A.	Forest Land														
5.B.	Cropland														
5.C.	Grassland														
5.D.	Wetlands														
5.E.	Settlements														
5.F.	Other Land														
5.G.	Other														
6. Waste		22	13	-12	-26	-12	-11	-21	-4	7	3	7	9	14	18
6.A.	Solid Waste Disposal on Land														
6.B.	Wastewater Handling	22	13	-12	-26	-12	-11	-21	-4	7	3	7	9	14	18
6.C.	Waste Incineration	0	0	0	0	0	0	0	0	0	0		0	0	
6.D.	Other	0	0	0	0	0	0	0	0	0			0	0	0
Memo Items:															
International Bunkers		9	10	10	11	12	12	13	13	12	10	11	13	13	11
Multilateral Operations															
CO₂ Emissions from Biomass															

Note:

LULUCF: differences not calculated as categories differ from previous reporting.

Table 10.4 - Recalculation difference of F-gases emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
		kton CO2 eq.													
Total Actual Emissions							-2	17	-2	45	78	114	133	163	236
HFCs								18	0	47	80	115	135	165	239
PFCs															
SF6							-2	-2	-2	-2	-2	-1	-2	-2	-3

Table 10.5 – Recalculation of total CO₂, CH₄ and N₂O emissions

Year	CO2			CH4			N2O		
	2005 Subm. (kton CO2 eq.)	2006 Subm. (kton CO2 eq.)	Difference (%)	2005 Subm. (kton CO2 eq.)	2006 Subm. (kton CO2 eq.)	Difference (%)	2005 Subm. (kton CO2 eq.)	2006 Subm. (kton CO2 eq.)	Difference (%)
1990	43 612	43 366	-0.6	9 743	11 225	15.2	6 019	5 361	-10.9
1991	45 415	45 181	-0.5	9 878	11 491	16.3	5 896	5 387	-8.6
1992	49 517	49 326	-0.4	9 976	11 481	15.1	5 743	5 367	-6.6
1993	48 122	47 925	-0.4	10 066	11 533	14.6	5 620	5 278	-6.1
1994	49 256	49 138	-0.2	10 330	12 061	16.8	5 839	5 551	-4.9
1995	53 176	53 131	-0.1	10 428	12 351	18.4	6 000	5 689	-5.2
1996	50 280	50 258	0.0	10 670	12 471	16.9	6 146	5 997	-2.4
1997	53 451	53 543	0.2	10 900	12 694	16.5	6 083	6 001	-1.3
1998	58 054	58 234	0.3	11 209	13 182	17.6	6 079	5 744	-5.5
1999	64 767	64 894	0.2	11 599	13 447	15.9	6 385	6 168	-3.4
2000	63 609	63 762	0.2	10 441	12 324	18.0	6 069	6 141	1.2
2001	64 687	65 018	0.5	10 234	12 242	19.6	6 289	6 160	-2.0
2002	68 844	69 250	0.6	10 469	12 537	19.7	6 337	6 279	-0.9
2003	64 293	64 600	0.5	10 477	12 553	19.8	6 317	5 728	-9.3

10.2 Implications for emissions trends

The comparison of total GHG emissions of 2006 with the previous 2005 submission shows a small increase of the national total GHG emissions, with higher estimated levels for both the base year (1990: 1.0%) and 2003: 2.5%. The recalculations resulted in an accentuation of the growing trend from 36.7% (2005 submission without LULUCFs) to 38.8% (2006 submission without LULUCFs) for the 1990-2003 period.

Figure 10.1 – Recalculation of total emissions trends (LULUCFs excl.)

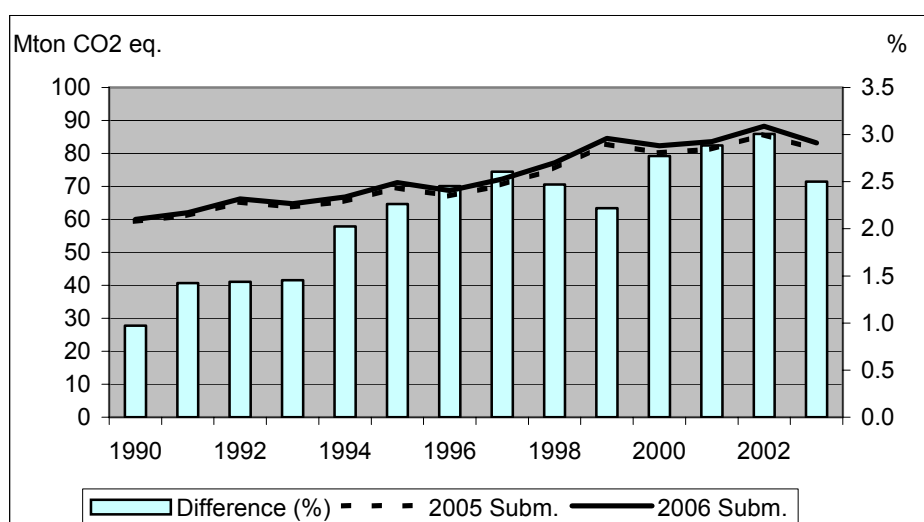


Table 10.6 – Recalculation of total emissions trends (LULUCFs excl.)

Year	2005 Submission (kton CO2 eq.)	2006 Submission (kton CO2 eq.)	Difference (%)
1990	59374	59952	1.0
1991	61189	62059	1.4
1992	65236	66173	1.4
1993	63807	64736	1.5
1994	65425	66750	2.0
1995	69610	71184	2.3
1996	67101	68747	2.5
1997	70440	72275	2.6
1998	75354	77215	2.5
1999	82769	84605	2.2
2000	80148	82371	2.8
2001	81253	83596	2.9
2002	85707	88285	3.0
2003	81157	83187	2.5

10.3 Future improvements

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

Source specific planned improvements are included in the respective sectoral sections or sub sections.

LIST OF ACRONYMS

ABS	Acrylonitrile Butadiene Styrene	Acrilo Nitrilo Butadieno Estireno
AC	Air Conditioning	Ar condicionado
ACAP	Portuguese Association of Automobile Business	Associação do Comércio Automóvel de Portugal
AG	Aviation Gasoline	Gasolina de Aviação
AN	Ammonium Nitrate	Nitrato de Amónio
ANA	Airports and Air Navigation	Aeroportos e Navegação Aérea
ANAM	Madeira Island Airports and Air Navigation	Aeroportos e Navegação Aérea da Madeira
ANECRA	National Association of Companies of Automobile Business and Reparation	Associação Nacional das Empresas do Comércio e da Reparação Automóvel
APED	Portuguese Association of Distribution Companies	Associação Portuguesa de Empresas de Distribuição
APIRAC	National Association of Industry of Refrigeration and Air Conditioning	Associação Portuguesa dos Industriais da Refrigeração e Ar Condicionado
APORBET	Portuguese Association of Bituminous Mixes Producers	Associação Portuguesa de Fabricantes de Misturas Betuminosas
AS	Ammonium Sulphate	Sulfato de Amónia
ASN	Ammonium Sulphate Nitrate	Sulfonitrato de Amónia
BAT	Best Available Technologies	-
BOD	Biochemical Oxygen Demand	Carência Bioquímica de Oxigénio
BOF	Basic Oxygen Furnace	-
CAFE	Clean Air For Europe	-
CAN	Calcium Ammonium Nitrate	Nitrato de Cálcio-amónio
CDDR-LVT	Lisbon and Tagus Valley Coordination and Regional Development Commission	Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
CELPA	Portuguese Paper Industry Association	Associação da Indústria Papeleira
CFC	Chlorofluorocarbons	Clorofluorcarbonetos
CH ₄	Methane	Metano
CITEPA	Interprofessional Technical Center of Studies of Atmospheric Pollution	Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique
CKD	Cement Kiln Dust	-
CMN	Calcium Magnesium Nitrate	-
CN	Calcium Nitrate	Nitrato de Cálcio
CO	Carbon Monoxide	Monóxido de Carbono
CO ₂	Carbon Dioxide	Dióxido de Carbono ou anidrido carbónico
COD	Chemical Oxygen Demand	Carência Química de Oxigénio
CONCAWE	-	-
Concelho	Portuguese territorial unit under the responsibility of a municipal authority	-
CORINAIR	Core Inventory Air Emissions	Inventário de Emissões Atmosféricas
CRF	Common Reporting Format	-
CTCV	Technological Centre for Ceramics and Glass	Centro Tecnológico da Cerâmica e do Vidro
DAP	Di-ammonium phosphate	-
DBH	Diameter at Breast Height	Diâmetro à Altura do Peito (DAP)
DC	Degradable Organic Component	Fracção Orgânica Degradável

DGA	General Directorate of Environment	Direcção Geral do Ambiente
DGF	General Directorate of Forests	Direcção-Geral das Florestas
DGGE (ex DGE)	General Directorate for Geology and Energy	Direcção Geral de Geologia e Energia
DGE (ex DGI)	Enterprises General Directorate	Direcção Geral da das Empresas
DGRF	General Directorate for Forestry Resources	Direcção Geral dos Recursos Florestais
DGTT	General Directorate of Terrestrial Transportation	Direcção Geral dos Transportes Terrestres
DGV	National Entity responsible for road traffic	Direcção Geral de Viação
Distrito	Portuguese territorial unit comprehending several concelhos but not coincident with a region which is NUT II.	-
DOC	Degradable Organic Carbon	Carbono Orgânico Degradável
DOCF	Degradable Organic Carbon Dissimilated	-
DRAOT	Regional Directorate of Environment and Land Use Planning	Direcção Regional do Ambiente e Ordenamento do Território
EAF	Electric Arc Furnace	Forno Arco Eléctrico
EAPA	European Asphalt Pavement Association	-
EF	Emission Factors	Factores de Emissão
EMEP	Cooperative Programme for Monitoring and Evaluation of the Longrange Transmission of Air Pollutants in Europe	-
EPER	European Pollutant Emission Register	Registo Europeu de Emissões Poluentes
E-PRTR	European Pollutant Release and Transfer Register	-
FAEED	Federal Aviation Administration Aircraft Engine Emission Database	-
FAM	Animal Manure Nitrogen Applied to Soils	-
FAO	Food and Agriculture Organization of the United Nations	-
FCC	Fluidized-bed Catalytic Cracking	Cracking catalítico de leito fluidizado
FCR	Fixation in Crop Residues	-
FCT-UNL	Faculty of Science and Technology of New University of Lisbon	Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
FGR	Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that volatilises as 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	-
GWP	Global Warming Potential	-
H₂S	Hydrogen Sulfide	Sulfureto de Hidrogénio
HCFC	Hydrochlorofluorocarbons	-
HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias
HFC	Hydrofluorocarbons	-
IA	Institute for The Environment	Instituto do Ambiente
IAIT	Annual Survey to Manufacturing Industry	Inquérito Anual à Indústria Transformadora
IAP	Annual Survey to Industrial Production	Inquérito Anual à Produção Industrial
ICAO	International Civil Aviation Organization	
IEF	Implied Emission Factors	Factores de Emissão Implícitos
IEP	Portuguese Road Institute	Instituto de Estradas de Portugal
IFADAP	Institute for Financing and Support of Development of Agriculture and Fisheries	Instituto de Financiamento e Apoio ao Desenvolvimento da Agricultura e das Pescas
INAG	National Water Institute	Instituto da Água
INE	National Statistics Institute	Instituto Nacional de Estatística
INR	National Wastes Institute	Instituto Nacional de Resíduos
INRA	National Institute for Agronomic Investigation (France)	Institut National de la Recherche Agronomique (França)
IPCC	Intergovernmental Panel on Climate Change	-
ISP	Portuguese Insurance Institute	Instituto de Seguros de Portugal
IST-UNL	Technical Superior Institute - Lisbon Technical University	Instituto Superior Técnico - Universidade Técnica de Lisboa
JP	Jet Fuel	-
LCP	Large Combustion Plants (the same as GIC)	o mesmo que GIC
LDPE	Low Density Poly Ethylene	Polietileno de Baixa Densidade (PEBD)
LDV	Light Duty Vehicles	Veículos Ligeiros de Mercadorias
LNG	Liquified Natural Gas	Gás Natural Liquefeito
LOSP	Light Organic Solvent-based Preservatives	-
LPS	Large Point Sources (Corinair definition)	Grandes Fontes Poluidoras
LRTAP	Long-range Transboundary Air Pollution	Poluição Atmosférica Transfronteiras a Longa Distância
LTO	Landing and Take-off	Aterragens e Descolagens
LUCF	Land-use Change and Forestry	Alteração do Uso do Solo e Florestas
LULUCF	Land Use, Land-use Change and Forestry	Uso do Solo, Alteração do Uso do Solo e Florestas
MAC	Mobile Air-conditioning systems	-
MADRP	Ministry of Agriculture, Rural Development and Fisheries	Ministério da Agricultura, Desenvolvimento Rural e Pescas
MAOT	Ministry of Environment and Land Use Planning	Ministério do Ambiente e Ordenamento do Território
MCF	Methane Conversion Factor	Factor de Conversão de Metano
MCOTA	Ministry of Urban Affairs, Land Use	Ministério das Cidades,

	Planning and Environment	Ordenamento do Território e Ambiente
MDI	Metered Dose Inhalers	-
MEET	Methodologies For Estimating Air Pollutant Emissions From Transport	-
MMS	Manure Management Systems	Sistema de Gestão de Estrumes
MSW	Municipal Solid Wastes	Resíduos Sólidos Municipais
MTBE	Methyl Tertiary Butyl Ether	Metil-Ter-Butil-Éter
Na ₂ S	Sodium Sulphide	Sulfureto de Sódio
NaOH	Sodium Hydroxide	Hidróxido de Sódio
NATO	North Atlantic Treaty Organisation	Organização do Tratado do Atlântico Norte
NAVE	National Entity responsible for air traffic	Navegação Aérea
NCV	Net Calorific Value	-
NFI	National Forestry Inventories	Inventário Florestal Nacional
NFR	New Format Reporting	-
NH ₃	Ammoniac	Amoníaco
NMVOC	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NO _x	Nitrogen Oxides (NO + NO ₂)	Óxidos de Azoto (NO+NO ₂)
NPK	Nitrogen, Phosphorus and Potassium	Nitrogénio, Fósforo e Potássio
NSS	Normal Super Phosphates	Superfosfatos simples
NUTS (0..III)	Nomenclature of Territorial Units for Statistics	Nomenclatura de Unidades Territoriais para fins estatísticos
OD	Origin - Destiny	Origem - Destino
ODS	Ozone Depleting Substances	-
OECD	Organization for Economic Co-operation and Development	Organização para a Cooperação e Desenvolvimento Económico (OCDE)
OX	Oxidation Factor	Factor de Oxidação
PAF	Florestal Action Program	Programa de Acção Florestal
PAH	Polycyclic Aromatic Hydrocarbons	Hidrocarbonetos Aromáticos Policíclicos
PCI	Low Heating Value (LHV)	Poder Calorífico Inferior
PEN	National Energetic Program	Plano Energético Nacional
PER	Perchloro-ethylene	Percloroetileno
PERSU	Strategic Plan on Municipal Solid Wastes	Plano Estratégico dos Resíduos Sólidos Urbanos
PETROGAL	Portuguese Petroleum Company	Empresa de Petróleos de Portugal
PFC	Perfluorinated Hidrocarbons	-
PM ₁	Particles with Aerodynamic Diameter smaller than 1 micrometer	Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro
PM ₁₀	Particles with Aerodynamic Diameter smaller than 10 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros
PM _{2.5}	Particles with Aerodynamic Diameter smaller than 2.5 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 2.5 micrómetros
PNAC	National Climate Change Program	Programa Nacional para as Alterações Climáticas
PNPA	National Plan for Environmental Policy	Plano Nacional da Política de Ambiente
PP	Poly Propylene	Polipropileno

PS	Poly Styrene	Poliestireno
PTEN	National Emission Ceilings Program	Programa para os Tectos de Emissão Nacional
PVC	Poly Vinyl Chloride	Cloreto de Polivinil
RA	Agricultural Region	Região Agrária
REN	National Electric System	Rede Eléctrica Nacional
RVP	Reid Vapour Pressure	Pressão de Vapor de Reid
SF6	Sulphur Hexafluoride	Hexafluoreto de Enxofre
SNIERPA	National System of Inventories of Emissions and Remotions of Atmospheric Pollutants	Sistema Nacional de Inventários de Emissões e Remoções de Poluentes Atmosféricos
SOx	Sulphur Oxides	Óxidos de Enxofre
SW	Solid Wastes	Resíduos Sólidos
SWDS	Solid Waste Disposal Sites	Locais para Deposição de Resíduos Sólidos
TANKS	Software designed to estimate air emissions from organic liquids in storage tanks (USEPA, September 27, 2001)	Software criado para a estimativa de emissões atmosféricas a partir de líquidos orgânicos em tanques de armazenamento (USEPA, 27 de Setembro de 2001)
TNT	Trinitrotoluene	Trinitrotolueno
TOE	Tons of oil equivalent	Toneladas Equivalentes de Petróleo (TEP)
TOW	Total Organic Waste	Resíduo Orgânico Total
TRANSGÁS	Portuguese Company of Natural Gas	Sociedade Portuguesa de Gás Natural (Empresa)
TSP	Total Suspended Particles	Partículas Totais em Suspensão
TSS	Triple Super Phosphates	Superfosfatos Triplos
UNECE	United Nations Economic Commission for Europe	-
UNFCCC	United Nations Framework Convention on Climate Change	Convenção Quadro das Nações Unidas para as Alterações Climáticas
USEPA	United States Environmental Protection Agency	Agência de Protecção Ambiental dos Estados Unidos da América
VCM	Vinyl Chloride Monomer	Monómero de Cloreto de Vinilo
VOC	Volatile Organic Compounds	Compostos Orgânicos Voláteis
VRF	Vacuum Residual Fuel Oil	Resíduo de Alto Vácuo
WWH	Wastewater Handling	Tratamento de Águas Residuais
ZA	Agricultural Zone	Zona Agrária

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ANNEX A: KEY CATEGORY ANALYSIS

A.1 Introduction

This chapter provides an analysis of key categories following recommendations of the IPCC Good Practice Guidance (IPCC 2000) and IPCC Good Practice Guidance for LULUCF (IPCC 2003). A key category (source or sink) “is one that is prioritised within the national inventory system because its estimate has a significant influence on a country’s total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.” The aim of defining key categories is the improvement of the inventory’s accuracy. As key categories are the most important sources or removals in terms of their contribution to the absolute level of national emissions, the identification of these categories enables the prioritisation of national efforts and a more efficient use of available resources in order to reach an improvement of national estimates. Information on key categories is also important for the development of policies and measures for emissions reduction.

IPCC Good Practice Guidance (IPCC 2000) purposes several methods for performing key source analysis, which are:

- Tier 1 approach (level and trend assessments);
- Tier 2 approach (level and trend assessments with uncertainty analysis);
- Qualitative approach.

A. 2 Methodology for key source identification: Portuguese inventory

Having as a basis the 2006 Portuguese inventory estimates (1990-2004), the determination of key categories was conducted, at a first stage, using the Tier 1 approach. For the first time, the Tier 2 key categories method was also conducted using the results of the uncertainty estimates presented in this document. The Tier 2 analysis is however more sophisticated as it incorporates source category uncertainty estimates. If both analysis have been performed, it is good practice to use the results of the Tier 2 assessment. Both approaches were performed in two steps: excluding an including LULUCF.

Tier 1 - Level assessment

The contribution of each category to the total national inventory was calculated for all years (1990-2004), according to the following equation:

Category Level Assessment = Source or Sink Category estimate / Total contribution

$$L_{x,t}^* = E_{x,t}^* / E_t^*$$

Where,

$L_{x,t}^*$ = level assessment for source or sink category x in year t. The asterisk (*) means that contributions from all categories (including LULUCF categories) are entered as absolute values

$E_{x,t}^* = | E_{x,t} |$ = absolute value of emission or removal estimate of source or sink x for year t

$E_t^* = \sum |E_{x,t}|$ = total contribution, which is the sum of the absolute values of emissions and removals in year t . The asterisk (*) indicates that contributions from all categories (including LULUCF categories) are entered as absolute values.

Key categories are those that, when summed in descending order of magnitude for a given year, add up to 95 percent of the total national inventory for that year.

Tier 1 - Trend assessment

The trend assessment is the product of the category level assessment and the absolute difference between the category trend and the total trend. This analysis enables the identification of categories that have a different trend to the trend of the overall inventory. The category trend assessment will be large if the source category represents a large percentage of the total contribution and/or its trend is significantly different from the overall inventory trend.

The calculation of the contribution of each category's trend to the trend in the total inventory was done upon the following equation:

$$\text{Source or Sink Category Trend Assessment} = (\text{Source or Sink Category Level assessment}) \cdot |(\text{Source Category Trend} - \text{Total trend})|$$

$$T_{x,t}^* = E_{x,t}^* / E_t^* \cdot |[(E_{x,t} - E_{x,0}) / E_{x,t}] - [(E_t - E_0) / E_t]|$$

Where,

$T_{x,t}^*$ = trend assessment for the source or sink category x in year t

$E_{x,t}^* = |E_{x,t}|$ = absolute value of emission or removal estimate of source or sink x for year t

$E_{x,t}$ and $E_{x,0}$ = real values of estimates of source or sink category x in years t and 0, respectively

E_t and $E_0 = \sum E_{x,t}$ and $\sum E_{x,0}$ = total inventory estimates in years t and 0, respectively. E_t and E_0 differ from E_t^* and E_0^* in level assessment equation in that removals are not entered as absolute values.

0 = base year (1990)

Tier 2 - Level assessment

The level assessment is based on the quantified uncertainties presented in the introduction, according to the equation:

$$\text{Level Assessment with Uncertainty} = \text{Tier 1 Level Assessment} \cdot \text{Relative category Uncertainty}$$

$$LU_{x,t} = L_{x,t} \cdot U_{x,t}$$

Where,

$LU_{x,t}$ = Level Assessment with Uncertainty

$L_{x,t}$ = calculated as in Tier 1 equation

$U_{x,t}$ = relative category uncertainty in the year t

Tier 2 - Trend assessment

The trend assessment is based according to the equation:

Trend Assessment with Uncertainty= Tier 1 Trend Assessment • Relative category Uncertainty

$$TU_{x,t} = T_{x,t} \bullet U_{x,t}$$

Where,

$TU_{x,t}$ = Trend Assessment with Uncertainty

$L_{x,t}$ = calculated as in Tier 1 equation

$U_{x,t}$ = relative category uncertainty in the year t

The key categories are those that add up to 90% of the total value of either $LU_{x,t}$ and $TU_{x,t}$.

A.3 Presentation of results

Key category analysis can be very influenced by the definitions of source categories (extent of the split). If a large category is broken into many subcategories, then these subcategories may not have a significant contribution to the total inventory to be considered as a key source. On the opposite, several non-key sources categories may become key source categories if aggregated into a unique source category.

In a general way, the source and removal categories have been split into (sub) categories that have been estimated using the same methodology and emission factors.

Further to Tier 1 method already applied in previous submissions, Tier 2 method was also used. Both approaches have been applied in two steps: without and with the LULUCF sector.

Further to the 41 categories identified using Tier 1 method without LULUCF, the key category analysis with LULUCF resulted in the identification of 6 more key categories: 5E Settlements (CO₂), 1 A 3 d ii National navigation (Liquid fuels, CO₂), 4 C RICE CULTIVATION (CH₄), 5 A Forest Land (CH₄ and CO₂), and 1 A 3 c Railways (Liquid fuels, CO₂). In the case where additional non-LULUCF categories are identified as key when LULUCF is considered in the analysis, GPG recommends not consider the category immediately as key, but to make a more careful analysis using some further qualitative considerations. Two of the additional non-LULUCF categories identified as key in the analysis with LULUCF - 1 A 3 d ii National navigation (Liquid fuels, CO₂) and 1 A 3 c Railways (Liquid fuels, CO₂),- have not been considered as key as they were not identified in the subsequent Tier 2 analysis performed, reflecting the greater confidence on the estimates associated with these sources.

The Tier 2 analysis without LULUCF resulted in the identification of 46 key categories. The Tier 2 assessment increases the importance of relatively uncertain sources. As a result, 14 categories identified in the Tier 1 analysis were not identified as key in the Tier 2 assessment, and 18 others not identified in the Tier 1 analysis, were identified in Tier 2 (Table A-1). The Tier 2 analysis with LULUCF resulted in the identification of 4 LULUCF categories, totalling 50 key categories that are listed in the table A-5, which cover 88.5% of total GHG emissions with LULUCF in 2004.

Table A-1 presents the key source categories identified using the Tier 1 and Tier 2 analysis excluding and including LULUCF, and the criteria used (level and trend) in the identification. Four tables are presented for each of the assessment performed: Tier 1 without LULUCF (Table A-2, a summary of identified key categories for 1990-2004, and Tables A-2.1 to A-2.3 referring to 1990 and 2004 inventory year's level assessment and trend assessment for 1990-2004); Tier 1 with LULUCF (Table A-3, a summary of identified key categories for 1990-2004, and Tables A-3.1 to A-3.3 referring to 1990 and 2004 inventory year's level assessment and trend assessment for 1990-2004); Tier 2 without LULUCF (Table A-4, a summary of identified key categories for 1990-2004, and Tables A-4.1 to A-4.3 for 1990 and 2004 inventory year's level assessment and trend assessment for 1990-2004); Tier 2 with LULUCF (Table A-5, a summary of identified key categories for 1990-2004, and Tables A-5.1 to A-5.3 for 1990 and 2004 inventory year's level assessment and trend assessment for 1990-2004).

As mentioned previously, the Tier 2 analysis changes the importance of relatively uncertain sources. In consequence, the most important sources for all year's level assessment identified by Tier 1, such as: CO₂ emissions from combustion of fossil fuels in Road Transportation (1A3b), Public Electricity and Heat Production (1A1a) (solid fuels – coal and liquid fuels – Oil; combustion in Manufacturing Industries and Construction – Other (1A2f) (liquid fuels – Oil) and Cement production (2A1), do not appear among the top most important sources in the Tier 2 analysis. In this assessment, together with N₂O emissions from Agricultural Soils (4D) already present among the main large contributors identified in Tier 1, the categories that appear in head in the Tier 2 level assessment for each year are: N₂O emissions from Industrial wastewater (6B1); CH₄ emissions from Industrial and Municipal Waste Disposal on Land (6A), and CO₂ emissions/removals from Forest Land (5A), CH₄ emissions from Manure Management (4B) and CO₂ emissions from Road Paving with Asphalt (2A6).

Main key categories identified in Tier 1 analysis, such as CO₂ emissions from Petroleum refining (1A1b) (liquid fuels), combustion in Chemical industry (1A2c) (liquid fuels), Food Processing, Beverages and Tobacco (1A2e) (liquid fuels) and Paper, Pulp and Print industries (1A2d) (liquid fuels), are not consider as key categories in the Tier 2 assessment, due to the greater confidence of these estimates which result from the use of plant specific activity data and FE.

CO₂ emissions from road transports, which is the biggest contributor to the trend 1990-2004, in the Tier 1 analysis, shows the strong increase of transportation during the last decade, in particular road traffic, reflecting the strong investment in the road infrastructure of the country. The analysis changes, however, in the Tier 2 approach as a result of the bigger reliability on the underlying data. In the Tier 2, the emissions that are the most responsible for the overall trend are: CO₂ emissions from Forest Land (5A), N₂O from Agricultural Soils (4D), CH₄ from Industrial Waste Disposal on Land (6A3) and CO₂ emissions from Road Paving with Asphalt (2A6).

The identification of category 5A at the top of the category trend assessment list results from the source/sink shift in the 1990-2004 period in combination with the importance to the total contribution, and some uncertainty of this sector (particularly in what refer to the burnt quantities and salvaged volumes from fires and the soil pool).

N₂O emissions from Agricultural Soils (4D) is another main category identified in the trend analysis, as a result of an increasing tendency in the 1990-2004 period and the associated relative uncertainty, which refer in majority to the synthetic fertilizer, pasture and paddock and animal waste subcategories.

CO₂ emissions from Road Paving is a key category identified in Tier 2 analysis that where not identified during Tier 1, as a result of the high uncertainty of the estimates associated with the lack of information on the types of asphalts used. In any case, the sector was not considered priority in terms of the GHG inventory development, as despite the methodological conservative

approach applied, the sector is a minor source representing a small percentage of the national total.

Other main contributors to the overall inventory trend are: CH₄ from Fugitive emissions from Fuels – Natural Gas (1B2b) (since the introduction of natural gas in 1998 this source is more and more important); and CO₂ emissions from combustion in Agriculture/Forestry/Fishing (1A4c) (liquid fuels), as a reflect of the reduction of the importance of these sectors associated with some uncertainty of the respective underlying data and EF.

Table A-1 – Summary overview of Portuguese key source categories (1990-2004) based on Tier 1 and Tier 2 approaches

Key Categories of Emissions and removals by Gas			Activity		Gas		Tier 1				Tier 2				2004 emissions/r emovals (kton CO2 eq.)
							without LULUCF		with LULUCF		without LULUCF		with LULUCF		
							Level	Trend	Level	Trend	Level	Trend	Level	Trend	
1A 3 b Road Transportation	All Fuels	CO2	X	X	X	X	X	X	X	X	X	X	18708		
1A 1a Public Electricity and Heat Production	Solid Fuels	CO2	X	X	X	X	X		X		X	X	1961		
1A 2 f Other	Liquid Fuels	CO2	X	X	X	X	X		X		X		418		
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO2	X	X	X	X	X	X	X	X	X	X	3776		
2 A 1 Cement Production	Production Quantities	CO2	X	X	X	X	X	X	X	X	X		3538		
4 D AGRICULTURAL SOILS	Input to Soils	N2O	X	X	X	X	X	X	X	X	X	X	3267		
1A 4 a Commercial / Institutional	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	X	X	3162		
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	X	X	3033		
4 A ENTERIC FERMENTATION	Population size	CH4	X	X	X	X	X	X	X	X	X		3012		
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	X	X	X	X	X	X	X	X	X	X	2942		
1A 1b Petroleum refining	Liquid Fuels	CO2	X		X	X							2475		
1A 2 f Other	Caseous Fuels	CO2	X	X	X	X	X		X			X	2035		
1A 4 b Residential	Liquid Fuels	CO2	X	X	X	X	X	X		X		X	1892		
6 A 3 Other	Industrial Waste Disposal on Land	CH4	X	X	X	X	X	X	X	X	X	X	184		
2 B 1 Ammonia Production	Production Quantities	CO2	X	X	X	X	X	X	X	X	X	X	175		
6 B 1 Industrial Wastewater	Wastewater	CH4	X	X	X	X	X	X	X	X	X	X	1566		
1A 2 c Chemicals	Liquid Fuels	CO2	X	X	X	X	X						1343		
4 B MANURE MANAGEMENT	Animal Excretion	CH4	X	X	X	X	X	X	X	X	X	X	1157		
5 E2 Settlements	Emissions/Removals	CO2				X	X				X	X	115		
1A 4 c Agriculture/ Forestry/ Fishing	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	X	X	1054		
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	X	X	X	X	X						695		
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	X	X	X	X	X	X	X	X	X	X	693		
2 B 2 Nitric Acid Production	Production Quantities	N2O	X	X	X	X					X	X	605		
4 B MANURE MANAGEMENT	Animal Excretion	N2O	X	X	X	X	X	X	X	X	X	X	577		
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	X	X	X	X	X						576		
1A 3 b Road Transportation	All Fuels	N2O	X	X	X	X	X	X	X	X	X	X	563		
1A 2 f Other	Solid Fuels	CO2	X	X	X	X	X		X		X	X	539		
1B 2 a Oil	Liquid Fuels	CO2	X	X	X	X	X	X	X	X	X	X	499		
2 A 2 Lime Production	Production Quantities	CO2	X	X	X	X	X	X	X	X	X	X	437		
1A 3 a ii Domestic	Liquid Fuels	CO2	X		X	X	X	X	X	X	X	X	401		
1A 2 c Chemicals	Gaseous Fuels	CO2	X	X	X	X	X						388		
1A 4 b Residential	Gaseous Fuels	CO2	X	X	X	X	X						384		
1B 2 b Natural gas	Gaseous Fuels	CH4	X	X	X	X	X	X	X	X	X	X	373		
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	X		X	X							352		
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	X	X	X	X	X						334		
1A 4 a Commercial / Institutional	Gaseous Fuels	CO2	X	X	X	X	X						332		
6 C WASTE INCINERATION	Waste Incinerated	CO2	X	X	X	X	X	X	X	X	X	X	330		
1A 4 b Residential	Biomass	CH4	X		X		X	X	X	X	X	X	309		
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC		X		X		X	X	X	X	X	283		
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2		X		X							248		
1B 2 d Other (Geothermal)	Energy Production	CO2		X		X							244		
6 B 1 Industrial Wastewater	Wastewater	N2O						X	X	X	X	X	228		
1A 3 d ii National navigation	Liquid Fuels	CO2				X							211		
4 C RICE CULTIVATION	Culture Surface	CH4				X		X	X	X	X	X	194		
5 B Cropland	Emissions/Removals	CO2									X	X	191		
2 A 7 Other	Production Quantities	CO2						X	X	X	X	X	171		
3 C CHEMICAL PRODUCTS, MANUFACTURE	Chemical manufacture and	CO2						X	X	X	X	X	141		
5 LAND USE CHANGE AND FORESTRY	Emissions/Removals	CH4				X					X		110		
3 A PAINT APPLICATION	Paint application	CO2						X	X	X	X	X	95		
1A 3 c Railways	Liquid Fuels	CO2					X						86		
1A 4 c Agriculture/ Forestry/ Fishing	Liquid Fuels	N2O						X	X	X	X	X	81		
3 D OTHER	Other Use of Chemicals	CO2						X	X	X			80		
1A 4 b Residential	Biomass	N2O						X	X	X	X	X	65		
1A 1a Public Electricity and Heat Production	Solid Fuels	N2O						X		X	X	X	57		
2 F 2 Foam Blowing	Consumption	HFC						X	X	X	X	X	56		
1B 2 b Natural gas	Caseous Fuels	CO2							X		X	X	48		
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N2O						X	X	X	X	X	29		
1A 2 f Other	Biomass	N2O						X		X			25		
1A 2 d Pulp, Paper and Print	Biomass	N2O						X		X			17		
1A 2 f Other	Gaseous Fuels	N2O							X			X	15		
1A 4 b Residential	Liquid Fuels	N2O						X		X	X		13		
2 A 6 Road Paving with Asphalt	Production Quantities	CO2						X	X	X	X	X	12		
1A 1a Public Electricity and Heat Production	Liquid Fuels	N2O						X	X	X	X	X	8		
1A 2 a Iron and Steel	Solid Fuels	CO2	X			X	X						0		
5 A Forest Land	Emissions/Removals	CO2				X	X			X	X		-3994		
Sub-total without LULUCF														83355	
% of total without LULUCF														98.8	
TOTAL EMISSIONS WITHOUT LULUCF														84355	
Sub-total with LULUCF														80776	
% of total with LULUCF														98.6	
TOTAL EMISSIONS WITH LULUCF														81900	

Table A-2 – Portuguese key categories (1990-2004) based on Tier 1 without LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identificat	Comments on level assessment	2004 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	8708
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level Trend	All years	1961
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level Trend	All years	418
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	3776
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level Trend	All years	3538
4 D AGRICULTURAL SOILS	Input to Soils	N ₂ O	✓	Level Trend	All years	3267
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level Trend	All years	3162
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	All years	3033
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level Trend	All years	3012
6 A MUNICIPAL SOLID WASTE DISPOSAL ON	SW Disposal on Land	CH ₄	✓	Level Trend	All years	2942
1A 1b Petroleum refining	Liquid Fuels	CO ₂	✓	Level Trend	All years	2475
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	2035
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level Trend	All years	1892
6 A 3 Other	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	All years	1814
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	All years	1715
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level Trend	All years	1556
1A 2 c Chemicals	Liquid Fuels	CO ₂	✓	Level Trend	All years	1343
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1157
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	All years	1054
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	✓	Level Trend	All years	695
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	693
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	✓	Level Trend	All years	605
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	✓	Level Trend	All years	577
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	✓	Level Trend	All years	576
1A 3 b Road Transportation	All Fuels	N ₂ O	✓	Level Trend	1994, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	563
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	All years	539
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	499
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	437
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level	2000, 2001, 2002, 2003, 2004	401
1A 2 c Chemicals	Gaseous Fuels	CO ₂	✓	Level Trend	2003, 2004	388
1A 4 b Residential	Gaseous Fuels	CO ₂	✓	Level Trend	2002, 2003, 2004	384
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	2001, 2002, 2003, 2004	373
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1999, 2000, 2001, 2002, 2003, 2004	352
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	✓	Level Trend	2003, 2004	334
1A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	✓	Level Trend	2004	332
6 C WASTE INCINERATION	Waste Incinerated	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003	330
1A 4 b Residential	Biomass	CH ₄	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1997	309
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Trend		283
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	✓	Trend		248
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Trend		244
1A 2 a Iron and Steel	Solid Fuels	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001	0
Sub-total without LULUCF		All gases				81722
% of total without LULUCF		All gases				96.9
TOTAL EMISSIONS WITHOUT LULUCF		All gases				84355

Table A-2.1 and 2.2 – Tier 1 Level assessment without LULUCF: 1990 and 2004

Tier 1 Level Assessment (1990)

IPCC CATEGORIES	ACTIVITY	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	All Fuels	CO2	9249	9249	0.15	0.15
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	7659	0.13	0.28
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6301	0.11	0.39
1 A 2 f Other	Liquid Fuels	CO2	3368	3368	0.06	0.44
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3226	0.05	0.50
2 A 1 Cement Production	Production Quantities	CO2	3107	3107	0.05	0.55
4 A ENTERIC FERMENTATION	Population size	CH4	2622	2622	0.04	0.59
1 A 2 f Other	Solid Fuels	CO2	2103	2103	0.04	0.63
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2052	0.03	0.66
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1910	0.03	0.69
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	1839	0.03	0.72
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1660	0.03	0.75
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1632	0.03	0.78
1 A 4 b Residential	Liquid Fuels	CO2	1621	1621	0.03	0.81
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1372	0.02	0.83
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1176	0.02	0.85
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	1056	0.02	0.87
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	820	0.01	0.88
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	744	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	743	0.01	0.91
2 B 1 Ammonia Production	Production Quantities	CO2	569	569	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	567	0.01	0.92
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	563	0.01	0.93
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	466	0.01	0.94
1 A 4 b Residential	Biomass	CH4	343	343	0.01	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	286	0.00	0.95
4 C RICE CULTIVATION	Culture Surface	CH4	256	256	0.00	0.96
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	240	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	183	183	0.00	0.96
2 A 2 Lime Production	Production Quantities	CO2	178	178	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	173	0.00	0.97
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	165	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	154	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	151	0.00	0.98
1 A 3 b Road Transportation	All Fuels	N2O	137	137	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	73	0.00	0.98
1 A 3 b Road Transportation	All Fuels	CH4	72	72	0.00	0.98
1 B 1 a Coal Mining	Solid Fuels	CH4	66	66	0.00	0.99
2 B 5 Other	Production Quantities	CO2	65	65	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CO2	65	65	0.00	0.99
2 A 7 Other	Production Quantities	CO2	64	64	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	49	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	49	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	44	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	42	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	35	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	33	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	25	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	19	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	18	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	18	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	12	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	11	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CO2	9	9	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	8	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	4	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	2	0.00	1.00

1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00

Tier 1 Level Assessment (2004)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.22	0.22
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.14	0.36
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.05	0.41
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	0.46
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.04	0.50
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.04	0.54
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.04	0.58
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.04	0.61
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.04	0.65
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.03	0.68
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.03	0.71
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	0.74
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.02	0.76
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.02	0.78
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.02	0.80
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.02	0.82
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.02	0.83
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.01	0.85
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	0.86
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.01	0.87
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	0.88
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.01	0.88
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.01	0.90
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.01	0.90
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.01	0.91
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.01	0.92
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.01	0.92
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	0.93
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	0.94
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	0.94
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.95
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	0.95
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	0.96
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.96
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	0.97
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	171	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	0.98
2 B 5 Other	Production Quantities	CO2	65	122	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	0.99
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	0.99
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	0.99
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	25	0.00	1.00
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	1.00

1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00

Tables A-2.3 – Tier 1 Trend assessment without LULUCF: 1990-2004

Tier 1 Trend Assessment (1990-2004)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Trend Assess.	Contribution to Trend	Cumulative Total
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.05	0.14	0.14
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.05	0.14	0.29
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.03	0.09	0.38
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.02	0.06	0.44
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.02	0.05	0.49
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	0.05	0.54
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	0.03	0.57
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.01	0.03	0.60
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.01	0.03	0.63
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.01	0.03	0.66
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.01	0.02	0.68
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.01	0.02	0.70
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	0.02	0.72
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.01	0.02	0.74
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.01	0.02	0.76
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.01	0.02	0.77
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.00	0.01	0.79
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.00	0.01	0.80
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.00	0.01	0.81
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.00	0.01	0.82
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.00	0.01	0.83
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.00	0.01	0.84
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	0.01	0.85
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	0.01	0.86
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	0.01	0.87
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.00	0.01	0.88
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.00	0.01	0.89
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.01	0.90
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	0.01	0.91
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	0.01	0.91
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	0.01	0.92
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	0.01	0.93
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	0.01	0.93
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.00	0.01	0.94
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.00	0.01	0.94
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.00	0.00	0.95
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.00	0.96
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	0.00	0.96
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	0.00	0.97
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	171	0.00	0.00	0.98
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	0.00	0.98
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	0.00	0.98
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	0.00	0.98
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.00	0.99
2 B 5 Other	Production Quantities	CO2	65	122	0.00	0.00	0.99
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	0.00	0.99
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	0.00	0.99
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	0.00	1.00
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	25	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	0.00	1.00

1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	0.00	1.00
1 A 2 ii National navigation	Liquid Fuels	N2O	2	2	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	0	0	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	0.00	1.00

Table A-3 –Portuguese key categories (1990–2004) based on Tier 1 with LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identificat	Comments on level assessment	2004 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	18708
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level Trend	All years	1961
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level Trend	All years	418
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	3776
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level Trend	All years	3538
4 D AGRICULTURAL SOILS	Input to Soils	N ₂ O	✓	Level Trend	All years	3267
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level Trend	All years	3162
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	All years	3033
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level Trend	All years	3012
6 A MUNICIPAL SOLID WASTE DISPOSAL ON	SW Disposal on Land	CH ₄	✓	Level Trend	All years	2942
1A 1b Petroleum refining	Liquid Fuels	CO ₂	✓	Level	All years	2475
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	2035
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level Trend	All years	1892
6 A 3 Other	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	All years	1814
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	All years	1715
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level Trend	All years	1556
1A 2 c Chemicals	Liquid Fuels	CO ₂	✓	Level Trend	All years	1343
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1157
5 E2 Settlements	Emissions/Removals	CO ₂	✓	Level Trend	All years	1115
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	All years	1054
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO ₂	✓	Level Trend	All years	695
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	693
2 B 2 Nitric Acid Production	Production Quantities	N ₂ O	✓	Level	All years	605
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	✓	Level Trend	All years	577
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO ₂	✓	Level Trend	All years	576
1A 3 b Road Transportation	All Fuels	N ₂ O	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	563
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	All years	539
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	499
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	437
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003, 2004	401
1A 2 c Chemicals	Gaseous Fuels	CO ₂	✓	Level Trend	2003, 2004	388
1A 4 b Residential	Gaseous Fuels	CO ₂	✓	Level Trend	2002, 2003, 2004	384
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	2001, 2002, 2003, 2004	373
6 B 2 Domestic and Commercial wastewater	Wastewater	N ₂ O	✓	Level	All years	352
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO ₂	✓	Level Trend	2003, 2004	334
1A 4 a Commercial / Institutional	Gaseous Fuels	CO ₂	✓	Level Trend	2004	332
6 C WASTE INCINERATION	Waste Incinerated	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003, 2004	330
1A 4 b Residential	Biomass	CH ₄	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 2000, 2001, 2002	309
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Trend		283
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO ₂	✓	Trend		248
1B 2 d Other (Geothermal)	Energy Production	CO ₂	✓	Trend		244
1A 3 d ii National navigation	Liquid Fuels	CO ₂	✓	Level	1990, 1992, 1993	211
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level	1990, 1991	194
5 A Forest Land	Emissions/Removals	CH ₄	✓	Level	1991, 2003	110
1A 3 c Railways	Liquid Fuels	CO ₂	✓	Trend		86
1A 2 a Iron and Steel	Solid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001	0
5 A Forest Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-3994
Sub-total without LULUCF		All gases				82214
% of total without LULUCF		All gases				97.5
TOTAL EMISSIONS WITHOUT LULUCF		All gases				84355
Sub-total with LULUCF		All gases				79444
% of total with LULUCF		All gases				97.0
TOTAL EMISSIONS WITH LULUCF		All gases				81900

Table A-3.1 and 3.2 – Tier 1 Level assessment with LULUCF: 1990 and 2004

Tier 1 Level Assessment (1990)

IPCC CATEGORIES	ACTIVITY	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	All Fuels	CO2	9249	9249	0.14	0.14
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	7659	0.12	0.27
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6301	0.10	0.36
1 A 2 f Other	Liquid Fuels	CO2	3368	3368	0.05	0.42
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3226	0.05	0.47
2 A 1 Cement Production	Production Quantities	CO2	3107	3107	0.05	0.52
4 A ENTERIC FERMENTATION	Population size	CH4	2622	2622	0.04	0.56
5 A Forest Land	Emissions/Removals	CO2	2231	2231	0.03	0.59
1 A 2 f Other	Solid Fuels	CO2	2103	2103	0.03	0.62
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2052	0.03	0.66
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1910	0.03	0.69
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	1839	0.03	0.72
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1660	0.03	0.74
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1632	0.03	0.77
1 A 4 b Residential	Liquid Fuels	CO2	1621	1621	0.03	0.79
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1372	0.02	0.81
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1176	0.02	0.83
5 E2 Settlements	Emissions/Removals	CO2	1115	1115	0.02	0.85
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	1056	0.02	0.87
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	820	0.01	0.88
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	744	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	743	0.01	0.90
2 B 1 Ammonia Production	Production Quantities	CO2	569	569	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	567	0.01	0.92
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	563	0.01	0.93
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	466	0.01	0.94
1 A 4 b Residential	Biomass	CH4	343	343	0.01	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	286	0.00	0.95
4 C RICE CULTIVATION	Culture Surface	CH4	256	256	0.00	0.95
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	240	0.00	0.95
5 B Cropland	Emissions/Removals	CO2	191	191	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	183	183	0.00	0.96
2 A 2 Lime Production	Production Quantities	CO2	178	178	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	173	173	0.00	0.97
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	165	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	154	0.00	0.97
5 A Forest Land	Emissions/Removals	CH4	154	154	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	151	0.00	0.98
1 A 3 b Road Transportation	All Fuels	N2O	137	137	0.00	0.98
5 D Wetlands	Emissions/Removals	CO2	105	105	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	73	0.00	0.98
1 A 3 b Road Transportation	All Fuels	CH4	72	72	0.00	0.98
1 B 1 a Coal Mining	Solid Fuels	CH4	66	66	0.00	0.99
2 B 5 Other	Production Quantities	CO2	65	65	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CO2	65	65	0.00	0.99
2 A 7 Other	Production Quantities	CO2	64	64	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	49	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	49	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	44	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	42	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	35	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	33	0.00	0.99
5 F Other Land	Emissions/Removals	CO2	32	32	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	25	0.00	0.99
5 C Grassland	Emissions/Removals	CO2	-25	-25	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	19	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	18	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	18	0.00	1.00
5 A Forest Land	Emissions/Removals	N2O	16	16	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	12	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	11	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CO2	9	9	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	8	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00

1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	4	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	2	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 1 Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00

Tier 1 Level Assessment (2004)

IPCC CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.21	0.21
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.13	0.34
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.05	0.39
5 A Forest Land	Emissions/Removals	CO2	2231	-3994	0.04	0.43
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	0.47
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.04	0.51
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.04	0.55
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.04	0.58
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.03	0.62
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.03	0.65
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.03	0.68
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.03	0.71
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	0.73
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.02	0.76
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.02	0.78
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.02	0.79
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.02	0.81
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.01	0.83
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.01	0.84
5 E2 Settlements	Emissions/Removals	CO2	1115	1115	0.01	0.85
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	0.86
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.01	0.87
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	0.88
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.01	0.89
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.01	0.90
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.01	0.91
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.01	0.91
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.01	0.92
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	0.92
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	0.93
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	0.93
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	0.94
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.95
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	0.95
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.96
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	0.96
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	0.97
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	0.97
5 B Cropland	Emissions/Removals	CO2	191	191	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	171	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	0.98
2 B 5 Other	Production Quantities	CO2	65	122	0.00	0.98
5 A Forest Land	Emissions/Removals	CH4	154	110	0.00	0.98
5 D Wetlands	Emissions/Removals	CO2	105	105	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	0.99
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	0.99
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	0.99
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	0.99
5 F Other Land	Emissions/Removals	CO2	32	32	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	1.00
5 C Grassland	Emissions/Removals	CO2	-25	-25	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	25	0.00	1.00
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	1.00

5 A Forest Land	Emissions/Removals	N2O	16	11	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00

Tier 1 Level Assessment (2004)

IPCC CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.21	0.21
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.13	0.34
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.05	0.39
5 A Forest Land	Emissions/Removals	CO2	2290	-3935	0.04	0.43
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	0.47
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.04	0.51
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3225	3472	0.04	0.55
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.04	0.59
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.03	0.62
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.03	0.65
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.03	0.69
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.03	0.71
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	0.74
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.02	0.76
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.02	0.78
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.02	0.80
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.02	0.82
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1393	0.02	0.83
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1158	0.01	0.84
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	0.86
5 E2 Settlements	Emissions/Removals	CO2	872	872	0.01	0.87
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.01	0.87
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	0.88
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.01	0.89
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.01	0.90
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.01	0.91
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.01	0.91
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.01	0.92
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	0.92
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	0.93
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	0.94
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	0.94
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.95
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	0.95
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	0.96
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.96
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	280	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	0.96
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	0.97
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	171	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	0.98
2 B 5 Other	Production Quantities	CO2	65	122	0.00	0.98
5 A Forest Land	Emissions/Removals	CH4	154	110	0.00	0.98
5 B Cropland	Emissions/Removals	CO2	109	109	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	0.98
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	0.99
5 D Wetlands	Emissions/Removals	CO2	82	82	0.00	0.99
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	0.99
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	0.99
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	0.99
5 F Other Land	Emissions/Removals	CO2	39	39	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	35	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	25	0.00	1.00
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	25	0.00	1.00
5 C Grassland	Emissions/Removals	CO2	-21	-21	0.00	1.00
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	1.00
5 A Forest Land	Emissions/Removals	N2O	16	11	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1.00

1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	2	3	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Liquid Fuels	CH4	0	0	0.00	1.00
Industries						
1 A 1 c Manufacture of Solid fuels and Other Energy	Solid Fuels	CH4	0	0	0.00	1.00
Industries						
1 A 1 c Manufacture of Solid fuels and Other Energy	Gaseous Fuels	CH4	0	0	0.00	1.00
Industries						
1 A 1 c Manufacture of Solid fuels and Other Energy	Biomass	CH4	0	0	0.00	1.00
Industries						
1 A 1 c Manufacture of Solid fuels and Other Energy	Other Fuels	CH4	0	0	0.00	1.00
Industries						
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00

Tables A-3.3 – Tier 1 Trend assessment with LULUCF: 1990-2004

Tier 1 Trend Assessment (1990-2004)

IPCC CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Trend Assess.	Contribution to Trend	Cumulative Total
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.06	0.16	0.16
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.05	0.12	0.28
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	0.09	0.37
5 A Forest Land	Emissions/Removals	CO2	2231	-3994	0.03	0.07	0.44
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.02	0.05	0.49
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.02	0.05	0.54
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.02	0.05	0.59
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	0.05	0.64
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	0.03	0.66
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.01	0.02	0.68
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.01	0.02	0.70
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.01	0.02	0.72
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	0.02	0.74
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	0	0.01	0.01	0.75
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.01	0.01	0.77
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.01	0.01	0.78
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.00	0.01	0.79
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.00	0.01	0.80
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.00	0.01	0.81
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	0.01	0.82
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.00	0.01	0.83
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	0.01	0.84
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.00	0.01	0.85
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	0.01	0.85
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.00	0.01	0.86
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.00	0.01	0.87
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.00	0.01	0.88
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.01	0.89
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	0.01	0.90
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	0.01	0.90
5 E2 Settlements	Emissions/Removals	CO2	1115	1115	0.00	0.01	0.91
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	0.01	0.92
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	0.01	0.92
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	0.01	0.93
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	0.00	0.93
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.00	0.00	0.94
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.00	0.00	0.94
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	0.00	0.95
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.00	0.00	0.95
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	0.00	0.95
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	0.00	0.96
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.00	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	0.00	0.97
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	171	0.00	0.00	0.97
5 A Forest Land	Emissions/Removals	CH4	154	110	0.00	0.00	0.97
1 B 1 a Coal Mining	Solid Fuels	CH4	66	0	0.00	0.00	0.98
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	0	0.00	0.00	0.98
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	0.00	0.98
5 B Cropland	Emissions/Removals	CO2	191	191	0.00	0.00	0.98
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	0.00	0.99
2 B 5 Other	Production Quantities	CO2	65	122	0.00	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	0	0.00	0.00	0.99
5 C Grassland	Emissions/Removals	CO2	-25	-25	0.00	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	0.00	0.99
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	0.00	0.99
5 D Wetlands	Emissions/Removals	CO2	105	105	0.00	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	0.00	0.99
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.00	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	0.00	0.99
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	0.00	0.99
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	0.00	0.99
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CO2	9	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	0	0.00	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	0.00	1.00
5 F Other Land	Emissions/Removals	CO2	32	32	0.00	0.00	1.00

1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	0.00	1.00
5 A Forest Land	Emissions/Removals	N2O	16	11	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	0.00	1.00
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	25	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	0	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	0.00	1.00

Table A-4 –Portuguese key categories (1990–2004) based on Tier 2 without LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identificat	Comments on level assessment	2004 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	18708
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level	All years	1861
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level	1990, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	418
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1999, 2002, 2004	3776
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level Trend	All years	3538
4 D AGRICULTURAL SOILS	Input to Soils	N ₂ O	✓	Level Trend	All years	3267
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level Trend	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	3162
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003	3033
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level Trend	All years	3012
6 A MUNICIPAL SOLID WASTE DISPOSAL ON	SW Disposal on Land	CH ₄	✓	Level Trend	All years	2942
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Trend		2035
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level	All years	1892
6 A 3 Other	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	1814
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	1990, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	1715
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level Trend	All years	1556
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	1157
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	All years	1054
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	693
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	✓	Level Trend	All years	577
1A 3 b Road Transportation	All Fuels	N ₂ O	✓	Level Trend	2000, 2001, 2003, 2004	563
1A 2 f Other	Solid Fuels	CO ₂	✓	Trend		539
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	499
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	All years	437
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level Trend	All years	401
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	373
6 C WASTE INCINERATION	Waste Incinerated	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003, 2004	330
1A 4 b Residential	Biomass	CH ₄	✓	Level Trend	All years	309
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2002, 2003, 2004	283
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	✓	Level Trend	All years	228
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level Trend	1990, 1991	194
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004	171
3 C CHEMICAL PRODUCTS, MANUFACTURE	Chemical manufacture and	CO ₂	✓	Level Trend	All years	141
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend	1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	95
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	81
3 D OTHER	Other Use of Chemicals	CO ₂	✓	Level Trend	All years	80
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend	All years	65
1A 1a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level	All years	57
2 F 2 Foam Blowing	Consumption	HFC	✓	Level Trend	2003, 2004	56
1B 2 b Natural gas	Gaseous Fuels	CO ₂	✓	Trend		48
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004	29
1A 2 f Other	Biomass	N ₂ O	✓	Level	All years	25
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	✓	Level	1992, 1993, 1994	17
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		15
1A 4 b Residential	Liquid Fuels	N ₂ O	✓	Level	1998, 2000, 2001	13
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level Trend	All years	12
1A 1a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993	8
Sub-total without LULUCF		All gases				75080
% of total without LULUCF		All gases				89.0
TOTAL EMISSIONS WITHOUT LULUCF		All gases				84355

Table A-4.1 and 4.2 – Tier 2 Level assessment without LULUCF: 1990 and 2004

Tier 2 Level Assessment (1990)

IPCC CATEGORIES	ACTIVITY	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
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3226	0.05	173.05	9.31	0.28	0.28
6 B 1 Industrial Wastewater	Wastewater	N2O	183	183	0.00	1000.28	3.06	0.09	0.37
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	1839	0.03	65.98	2.03	0.06	0.43
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1176	0.02	84.77	1.66	0.05	0.48
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1660	0.03	57.50	1.59	0.05	0.52
1 A 4 b Residential	Biomass	N2O	73	73	0.00	1001.80	1.21	0.04	0.56
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1632	0.03	39.15	1.07	0.03	0.59
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	563	0.01	104.44	0.98	0.03	0.62
1 A 4 b Residential	Biomass	CH4	343	343	0.01	161.55	0.93	0.03	0.65
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	1056	0.02	48.28	0.85	0.03	0.67
4 A ENTERIC FERMENTATION	Population size	CH4	2622	2622	0.04	18.94	0.83	0.02	0.70
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	7659	0.13	5.10	0.65	0.02	0.72
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	86	0.00	432.14	0.62	0.02	0.73
1 A 3 b Road Transportation	All Fuels	CO2	9249	9249	0.15	3.97	0.61	0.02	0.75
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	1000.00	0.60	0.02	0.77
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6301	0.11	5.10	0.54	0.02	0.79
2 A 1 Cement Production	Production Quantities	CO2	3107	3107	0.05	10.10	0.52	0.02	0.80
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	165	0.00	165.78	0.46	0.01	0.82
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	10000.05	0.44	0.01	0.83
2 A 2 Lime Production	Production Quantities	CO2	178	178	0.00	105.34	0.31	0.01	0.84
1 A 4 b Residential	Liquid Fuels	CO2	1621	1621	0.03	11.18	0.30	0.01	0.85
2 B 1 Ammonia Production	Production Quantities	CO2	569	569	0.01	31.57	0.30	0.01	0.86
1 A 2 f Other	Biomass	N2O	21	21	0.00	818.23	0.29	0.01	0.86
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	199.49	0.27	0.01	0.87
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	998.52	0.26	0.01	0.88
4 C RICE CULTIVATION	Culture Surface	CH4	256	256	0.00	56.79	0.24	0.01	0.89
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	151	0.00	95.65	0.24	0.01	0.89
1 A 2 f Other	Liquid Fuels	CO2	3368	3368	0.06	3.89	0.22	0.01	0.90
1 A 2 f Other	Solid Fuels	CO2	2103	2103	0.04	5.69	0.20	0.01	0.91
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	11	0.00	1000.00	0.19	0.01	0.91
1 A 4 b Residential	Liquid Fuels	N2O	11	11	0.00	1000.05	0.19	0.01	0.92
3 A PAINT APPLICATION	Paint application	CO2	42	42	0.00	249.58	0.18	0.01	0.92
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1910	0.03	5.10	0.16	0.00	0.93
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	240	0.00	39.74	0.16	0.00	0.93
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	820	0.01	11.18	0.15	0.00	0.94
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1000.00	0.15	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	286	0.00	30.41	0.15	0.00	0.95
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	744	0.01	11.18	0.14	0.00	0.95
2 A 7 Other	Production Quantities	CO2	64	64	0.00	113.66	0.12	0.00	0.95
1 B 1 a Coal Mining	Solid Fuels	CH4	66	66	0.00	98.85	0.11	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1372	0.02	4.50	0.10	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	567	0.01	10.05	0.10	0.00	0.96
2 B 5 Other	Production Quantities	CO2	65	65	0.00	85.07	0.09	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.09	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	809.19	0.09	0.00	0.97
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	420.45	0.08	0.00	0.97
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00	975.73	0.07	0.00	0.97
1 A 3 b Road Transportation	All Fuels	N2O	137	137	0.00	28.01	0.06	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	33	0.00	105.02	0.06	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	743	0.01	4.50	0.06	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	19	0.00	150.03	0.05	0.00	0.98
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	466	0.01	5.83	0.05	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CH4	35	35	0.00	72.92	0.04	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	49	0.00	50.09	0.04	0.00	0.98
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	2	0.00	1000.05	0.04	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.04	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CO2	65	65	0.00	32.36	0.03	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	72	0.00	28.51	0.03	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	18	0.00	93.78	0.03	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	18	0.00	93.94	0.03	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	776.91	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00	1001.80	0.02	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	714.37	0.02	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO2	173	173	0.00	7.07	0.02	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	1	0.00	723.74	0.02	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CO2	9	9	0.00	98.85	0.01	0.00	0.99
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1000.00	0.01	0.00	0.99
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	154	0.00	5.15	0.01	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	278.57	0.01	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	4	0.00	149.09	0.01	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	72.33	0.01	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	7	0.00	86.49	0.01	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	50.25	0.01	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00	50.25	0.01	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	12	0.00	42.08	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	7.07	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1000.01	0.01	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00	793.25	0.01	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Liquid Fuels	CO2	49	49	0.00	6.40	0.01	0.00	1.00

Industries									
1 A 2 c Chemicals	Solid Fuels	CO2	44	44	0.00	7.07	0.01	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	2	0.00	105.96	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	131.71	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	150.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	73.40	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	149.98	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	161.55	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	1	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	1	0.00	112.30	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	25	0.00	5.10	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	5.83	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	8	0.00	11.18	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	186.54	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	100.00	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	100.12	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	30.92	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00	10.00	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	3	0.00	5.83	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	135.81	0.00	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	1	0.00	11.18	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	87.18	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	150.05	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	100.50	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	100.12	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	7.07	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	50.25	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	100.04	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	0	0	0.00	31.62	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00

Tier 2 Level Assessment (2004)

IPCC CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Level Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.04	177.43	6.87	0.20	0.20
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	1000.26	2.70	0.08	0.29
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.02	110.56	2.38	0.07	0.36
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.03	53.93	1.88	0.06	0.41
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	10000.05	1.40	0.04	0.45
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.01	82.08	1.13	0.03	0.49
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	617.47	1.03	0.03	0.52
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.22	3.65	0.81	0.02	0.54
1 A 4 b Residential	Biomass	N2O	73	65	0.00	1001.80	0.78	0.02	0.57
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.14	5.10	0.72	0.02	0.59
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.04	20.21	0.72	0.02	0.61
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.01	104.57	0.72	0.02	0.63
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.02	37.88	0.70	0.02	0.65
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	1000.00	0.67	0.02	0.67
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	150.33	0.66	0.02	0.69
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.02	31.57	0.64	0.02	0.71
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	48.52	0.61	0.02	0.73
1 A 4 b Residential	Biomass	CH4	343	309	0.00	161.55	0.59	0.02	0.75
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.01	105.34	0.55	0.02	0.76
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.04	10.10	0.42	0.01	0.77
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.04	11.18	0.42	0.01	0.79
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	48.28	0.40	0.01	0.80
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	75.75	0.36	0.01	0.81
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1000.00	0.35	0.01	0.82
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	97.42	0.33	0.01	0.83
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	261.75	0.29	0.01	0.84
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.01	46.17	0.27	0.01	0.85
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.02	11.18	0.25	0.01	0.85
1 A 2 f Other	Biomass	N2O	21	25	0.00	788.11	0.23	0.01	0.86
2 A 7 Other	Production Quantities	CO2	64	171	0.00	113.66	0.23	0.01	0.87
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	5.10	0.23	0.01	0.87
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	50.25	0.20	0.01	0.88
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	202.58	0.19	0.01	0.89
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.05	3.90	0.19	0.01	0.89
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.01	27.20	0.18	0.01	0.90
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	245.31	0.16	0.00	0.90
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	813.39	0.16	0.00	0.91
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.04	4.48	0.16	0.00	0.91
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1000.05	0.15	0.00	0.92
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.03	5.10	0.15	0.00	0.92
2 B 5 Other	Production Quantities	CO2	65	122	0.00	90.33	0.13	0.00	0.92
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	56.79	0.13	0.00	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	30.41	0.13	0.00	0.93
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1000.00	0.12	0.00	0.94
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1000.05	0.11	0.00	0.94
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	105.02	0.11	0.00	0.94
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	4.28	0.10	0.00	0.95
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	545.23	0.10	0.00	0.95
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	39.74	0.10	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.01	11.18	0.09	0.00	0.95
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	94.72	0.09	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	150.33	0.09	0.00	0.96
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	801.59	0.08	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.02	4.66	0.07	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.01	10.05	0.07	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	819.81	0.07	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.06	0.00	0.97
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	442.13	0.06	0.00	0.97
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.01	7.98	0.05	0.00	0.97
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	11.18	0.05	0.00	0.97
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	11.18	0.04	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	144.92	0.04	0.00	0.98
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.01	5.83	0.04	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	72.92	0.04	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1000.01	0.04	0.00	0.98
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1000.00	0.03	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	11.18	0.03	0.00	0.98
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	765.90	0.03	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	7.07	0.03	0.00	0.98
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	100.12	0.03	0.00	0.99
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1000.05	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	981.79	0.03	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	10.00	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	6.94	0.03	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	50.09	0.03	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.02	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1000.05	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1001.80	0.02	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1318.21	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	95.14	0.02	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	25.30	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	95.28	0.02	0.00	0.99

1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	776.91	0.02	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	135.27	0.01	0.00	0.99
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	63.51	0.01	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1000.00	0.01	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	73.48	0.01	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	78.70	0.01	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	278.57	0.01	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	150.33	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	7.07	0.01	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	7.07	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1000.01	0.01	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	119.48	0.01	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1000.01	0.01	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	7.07	0.01	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	100.00	0.01	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	7.07	0.01	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	4.71	0.01	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	159.30	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	150.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	150.00	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	50.25	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	150.03	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	712.43	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	127.95	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	161.55	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	5.83	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	120.08	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	150.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	67.34	0.00	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	500.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	150.00	0.00	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	29.18	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	100.12	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	11.18	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	5.10	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	30.92	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	100.00	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	120.07	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	147.35	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	106.14	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	100.50	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	87.18	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	5.83	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	100.04	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	7.07	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	150.00	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	50.25	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	0	0	0.00	31.62	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00

Tables A-4.3 – Tier 2 Trend assessment without LULUCF: 1990-2004

Tier 2 Trend Assessment (1990-2004)

IPCC CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Trend Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.01	177.43	1.90	0.17	0.17
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.01	110.56	1.00	0.09	0.26
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	10000.05	0.69	0.06	0.32
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	48.52	0.52	0.05	0.37
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	150.33	0.47	0.04	0.41
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.00	82.08	0.34	0.03	0.45
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	48.28	0.32	0.03	0.47
1 A 4 b Residential	Biomass	N2O	73	65	0.00	1001.80	0.31	0.03	0.50
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	1000.26	0.25	0.02	0.53
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1000.00	0.25	0.02	0.55
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.01	31.57	0.24	0.02	0.57
1 A 4 b Residential	Biomass	CH4	343	309	0.00	161.55	0.24	0.02	0.59
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.01	37.88	0.24	0.02	0.61
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	97.42	0.23	0.02	0.63
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.05	4.48	0.22	0.02	0.65
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.02	11.18	0.20	0.02	0.67
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.00	104.57	0.19	0.02	0.69
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.05	3.65	0.18	0.02	0.70
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	105.34	0.17	0.02	0.72
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.03	5.10	0.16	0.01	0.73
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.00	53.93	0.16	0.01	0.75
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.00	46.17	0.16	0.01	0.76
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	50.25	0.13	0.01	0.77
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.02	5.83	0.12	0.01	0.79
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	245.31	0.12	0.01	0.80
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.01	20.21	0.12	0.01	0.81
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	75.75	0.11	0.01	0.82
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	617.47	0.11	0.01	0.83
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	94.72	0.10	0.01	0.84
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	801.59	0.09	0.01	0.84
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.00	27.20	0.08	0.01	0.85
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	56.79	0.08	0.01	0.86
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	261.75	0.08	0.01	0.87
2 A 7 Other	Production Quantities	CO2	64	171	0.00	113.66	0.08	0.01	0.87
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	4.28	0.07	0.01	0.88
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.01	10.10	0.07	0.01	0.89
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	545.23	0.07	0.01	0.89
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	150.33	0.06	0.01	0.90
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	202.58	0.06	0.01	0.90
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1000.05	0.05	0.00	0.91
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.01	5.10	0.05	0.00	0.91
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	1000.00	0.05	0.00	0.92
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1000.00	0.04	0.00	0.92
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.00	11.18	0.04	0.00	0.92
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	39.74	0.04	0.00	0.93
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.00	11.18	0.04	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	11.18	0.04	0.00	0.93
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	105.02	0.04	0.00	0.94
1 A 2 f Other	Biomass	N2O	21	25	0.00	788.11	0.03	0.00	0.94
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.00	7.98	0.03	0.00	0.94
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	11.18	0.03	0.00	0.95
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1000.01	0.03	0.00	0.95
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1000.00	0.02	0.00	0.95
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1000.00	0.02	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	11.18	0.02	0.00	0.95
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	7.07	0.02	0.00	0.96
2 B 5 Other	Production Quantities	CO2	65	122	0.00	90.33	0.02	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.00	4.66	0.02	0.00	0.96
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1000.05	0.02	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.02	0.00	0.97
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1000.05	0.02	0.00	0.97
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	100.12	0.02	0.00	0.97
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	981.79	0.02	0.00	0.97
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.01	3.90	0.02	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	10.00	0.02	0.00	0.97
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	6.94	0.02	0.00	0.98
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	442.13	0.02	0.00	0.98
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.00	10.05	0.02	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1000.05	0.02	0.00	0.98
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	819.81	0.02	0.00	0.98
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	30.41	0.01	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1318.21	0.01	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	50.09	0.01	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	135.27	0.01	0.00	0.99
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	63.51	0.01	0.00	0.99
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	100.00	0.01	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	765.90	0.01	0.00	0.99

1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	7.07	0.01	0.00	0.99
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.00	5.10	0.01	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.01	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	25.30	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	95.14	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	95.28	0.01	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	776.91	0.01	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	813.39	0.01	0.00	0.99
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	150.03	0.01	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	4.71	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1000.01	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	50.25	0.00	0.00	1.00
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	72.92	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	7.07	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	150.33	0.00	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	278.57	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	712.43	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	144.92	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	67.34	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	119.48	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	150.00	0.00	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	500.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	150.00	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	161.55	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	100.12	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	120.08	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	11.18	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	159.30	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	78.70	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	5.10	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1001.80	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	127.95	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	73.48	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	120.07	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	147.35	0.00	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	29.18	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	150.00	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	30.92	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	5.83	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	100.00	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	5.83	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	106.14	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	7.07	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1000.01	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	87.18	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	7.07	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	100.50	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	7.07	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	50.25	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	100.04	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	0	0	0.00	31.62	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00

Table A-5 –Portuguese key categories (1990–2004) based on Tier 2 with LULUCF

IPCC CATEGORIES	ACTIVITY	GHG	Key source Category	Criteria for Identification	Comments on level assessment	2004 emissions estimate (kton CO ₂ eq.)
1A 3 b Road Transportation	All Fuels	CO ₂	✓	Level Trend	All years	18708
1A 1a Public Electricity and Heat Production	Solid Fuels	CO ₂	✓	Level Trend	All years	1961
1A 2 f Other	Liquid Fuels	CO ₂	✓	Level	1990, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	418
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO ₂	✓	Level Trend	1999, 2002, 2004	3776
2 A 1 Cement Production	Production Quantities	CO ₂	✓	Level	All years	3538
4 D AGRICULTURAL SOILS	Input to Soils	N ₂ O	✓	Level Trend	All years	3267
1A 4 a Commercial / Institutional	Liquid Fuels	CO ₂	✓	Level Trend	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	3162
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO ₂	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2003	3033
4 A ENTERIC FERMENTATION	Population size	CH ₄	✓	Level	All years	3012
6 A MUNICIPAL SOLID WASTE DISPOSAL ON	SW Disposal on Land	CH ₄	✓	Level Trend	All years	2942
1A 2 f Other	Gaseous Fuels	CO ₂	✓	Trend		2035
1A 4 b Residential	Liquid Fuels	CO ₂	✓	Level	All years	1892
6 A 3 Other	Industrial Waste Disposal on Land	CH ₄	✓	Level Trend	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	1814
2 B 1 Ammonia Production	Production Quantities	CO ₂	✓	Level Trend	1990, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	1715
6 B 1 Industrial Wastewater	Wastewater	CH ₄	✓	Level Trend	All years	1656
4 B MANURE MANAGEMENT	Animal Excretion	CH ₄	✓	Level Trend	All years	167
5 E2 Settlements	Emissions/Removals	CO ₂	✓	Level Trend	All years	116
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO ₂	✓	Level Trend	All years	1054
6 B 2 Domestic and Commercial wastewater	Wastewater	CH ₄	✓	Level Trend	All years	693
4 B MANURE MANAGEMENT	Animal Excretion	N ₂ O	✓	Level Trend	All years	577
1A 3 b Road Transportation	All Fuels	N ₂ O	✓	Level Trend	2001, 2003, 2004	563
1A 2 f Other	Solid Fuels	CO ₂	✓	Level Trend	1990	539
1B 2 a Oil	Liquid Fuels	CO ₂	✓	Level Trend	1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002,	499
2 A 2 Lime Production	Production Quantities	CO ₂	✓	Level Trend	All years	437
1A 3 a ii Domestic	Liquid Fuels	CO ₂	✓	Level Trend	All years	401
1B 2 b Natural gas	Gaseous Fuels	CH ₄	✓	Level Trend	1998, 1999, 2000, 2001, 2002, 2003, 2004	373
6 C WASTE INCINERATION	Waste Incinerated	CO ₂	✓	Level Trend	2000, 2001, 2002, 2003, 2004	330
1A 4 b Residential	Biomass	CH ₄	✓	Level Trend	All years	309
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	✓	Level Trend	2002, 2003, 2004	283
6 B 1 Industrial Wastewater	Wastewater	N ₂ O	✓	Level Trend	All years	228
4 C RICE CULTIVATION	Culture Surface	CH ₄	✓	Level Trend	1990, 1991	184
5 B Cropland	Emissions/Removals	CO ₂	✓	Level Trend	All years	191
2 A 7 Other	Production Quantities	CO ₂	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004	171
3 C CHEMICAL PRODUCTS, MANUFACTURE	Chemical manufacture and	CO ₂	✓	Level Trend	All years	141
5 A Forest Land	Emissions/Removals	CH ₄	✓	Level	1991, 2003	110
3 A PAINT APPLICATION	Paint application	CO ₂	✓	Level Trend	1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004	95
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996	81
3 D OTHER	Other Use of Chemicals	CO ₂	✓	Level	1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998, 2000, 2001, 2002, 2003, 2004	80
1A 4 b Residential	Biomass	N ₂ O	✓	Level Trend	All years	65
1A 1a Public Electricity and Heat Production	Solid Fuels	N ₂ O	✓	Level Trend	All years	57
2 F 2 Foam Blowing	Consumption	HFC	✓	Level Trend	2004	56
1B 2 b Natural gas	Gaseous Fuels	CO ₂	✓	Trend		48
1A 1a Public Electricity and Heat Production	Gaseous Fuels	N ₂ O	✓	Level Trend	1999, 2000, 2001, 2002, 2003, 2004	29
1A 2 f Other	Biomass	N ₂ O	✓	Level	All years	25
1A 2 d Pulp, Paper and Print	Biomass	N ₂ O	✓	Level	1992, 1993, 1994	17
1A 2 f Other	Gaseous Fuels	N ₂ O	✓	Trend		15
1A 4 b Residential	Liquid Fuels	N ₂ O	✓	Level	2000	13
2 A 6 Road Paving with Asphalt	Production Quantities	CO ₂	✓	Level Trend	All years	12
1A 1a Public Electricity and Heat Production	Liquid Fuels	N ₂ O	✓	Level Trend	1990, 1991, 1992, 1993	8
5 A Forest Land	Emissions/Removals	CO ₂	✓	Level Trend	All years	-3994
Sub-total without LULUCF		All gases				75080
% of total without LULUCF		All gases				89.0
TOTAL EMISSIONS WITHOUT LULUCF		All gases				84355
Sub-total with LULUCF		All gases				72501
% of total with LULUCF		All gases				88.5
TOTAL EMISSIONS WITH LULUCF		All gases				81900

Table A-5.1 and 5.2 – Tier 1 Level assessment with LULUCF: 1990 and 2004

Tier 1 Level Assessment (1990)

IPCC SOURCE CATEGORIES	ACTIVITY	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
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3226	0.05	173.05	8.75	0.25	0.25
6 B 1 Industrial Wastewater	Wastewater	N2O	183	183	0.00	1000.28	2.88	0.08	0.33
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	1839	0.03	65.98	1.90	0.05	0.39
5 A Forest Land	Emissions/Removals	CO2	2231	2231	0.03	48.11	1.68	0.05	0.44
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1176	0.02	84.77	1.56	0.04	0.48
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1660	0.03	57.50	1.50	0.04	0.52
1 A 4 b Residential	Biomass	N2O	73	73	0.00	1001.80	1.14	0.03	0.56
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1632	0.03	39.15	1.00	0.03	0.59
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	563	0.01	104.44	0.92	0.03	0.61
1 A 4 b Residential	Biomass	CH4	343	343	0.01	161.55	0.87	0.02	0.64
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	1056	0.02	48.28	0.80	0.02	0.66
4 A ENTERIC FERMENTATION	Population size	CH4	2622	2622	0.04	18.94	0.78	0.02	0.68
5 E2 Settlements	Emissions/Removals	CO2	1115	1115	0.02	39.90	0.70	0.02	0.70
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	7659	0.12	5.10	0.61	0.02	0.72
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	86	0.00	432.14	0.58	0.02	0.74
1 A 3 b Road Transportation	All Fuels	CO2	9249	9249	0.14	3.97	0.58	0.02	0.75
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	1000.00	0.57	0.02	0.77
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6301	0.10	5.10	0.50	0.01	0.78
2 A 1 Cement Production	Production Quantities	CO2	3107	3107	0.05	10.10	0.49	0.01	0.80
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	165	0.00	165.78	0.43	0.01	0.81
5 B Cropland	Emissions/Removals	CO2	191	191	0.00	141.18	0.42	0.01	0.82
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	10000.05	0.41	0.01	0.83
2 A 2 Lime Production	Production Quantities	CO2	178	178	0.00	105.34	0.29	0.01	0.84
1 A 4 b Residential	Liquid Fuels	CO2	1621	1621	0.03	11.18	0.28	0.01	0.85
2 B 1 Ammonia Production	Production Quantities	CO2	569	569	0.01	31.57	0.28	0.01	0.86
1 A 2 f Other	Biomass	N2O	21	21	0.00	818.23	0.27	0.01	0.87
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	199.49	0.25	0.01	0.87
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	998.52	0.24	0.01	0.88
4 C RICE CULTIVATION	Culture Surface	CH4	256	256	0.00	56.79	0.23	0.01	0.89
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	151	0.00	95.65	0.23	0.01	0.89
1 A 2 f Other	Liquid Fuels	CO2	3368	3368	0.05	3.89	0.21	0.01	0.90
1 A 2 f Other	Solid Fuels	CO2	2103	2103	0.03	5.69	0.19	0.01	0.90
5 A Forest Land	Emissions/Removals	CH4	154	154	0.00	76.16	0.18	0.01	0.91
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	11	0.00	1000.00	0.18	0.01	0.91
1 A 4 b Residential	Liquid Fuels	N2O	11	11	0.00	1000.05	0.18	0.01	0.92
3 A PAINT APPLICATION	Paint application	CO2	42	42	0.00	249.58	0.17	0.00	0.92
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1910	0.03	5.10	0.15	0.00	0.93
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	240	0.00	39.74	0.15	0.00	0.93
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	820	0.01	11.18	0.14	0.00	0.94
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1000.00	0.14	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	286	0.00	30.41	0.14	0.00	0.95
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	744	0.01	11.18	0.13	0.00	0.95
2 A 7 Other	Production Quantities	CO2	64	64	0.00	113.66	0.11	0.00	0.95
1 B 1 a Coal Mining	Solid Fuels	CH4	66	66	0.00	98.85	0.10	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1372	0.02	4.50	0.10	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	567	0.01	10.05	0.09	0.00	0.96
2 B 5 Other	Production Quantities	CO2	65	65	0.00	85.07	0.09	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.08	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	809.19	0.08	0.00	0.97
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	420.45	0.07	0.00	0.97
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00	975.73	0.07	0.00	0.97
5 D Wetlands	Emissions/Removals	CO2	105	105	0.00	40.14	0.07	0.00	0.97
1 A 3 b Road Transportation	All Fuels	N2O	137	137	0.00	28.01	0.06	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	33	0.00	105.02	0.05	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	743	0.01	4.50	0.05	0.00	0.98
5 F Other Land	Emissions/Removals	CO2	32	32	0.00	96.59	0.05	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	19	0.00	150.03	0.04	0.00	0.98
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	466	0.01	5.83	0.04	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CH4	35	35	0.00	72.92	0.04	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	49	0.00	50.09	0.04	0.00	0.98
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	2	0.00	1000.05	0.04	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.04	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CO2	65	65	0.00	32.36	0.03	0.00	0.99
5 C Grassland	Emissions/Removals	CO2	-25	-25	0.00	82.90	0.03	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	72	0.00	28.51	0.03	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	18	0.00	93.78	0.03	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	18	0.00	93.94	0.03	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	776.91	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00	1001.80	0.02	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	714.37	0.02	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO2	173	173	0.00	7.07	0.02	0.00	0.99
5 A Forest Land	Emissions/Removals	N2O	16	16	0.00	76.16	0.02	0.00	0.99
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	1	0.00	723.74	0.02	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CO2	9	9	0.00	98.85	0.01	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1000.00	0.01	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	154	0.00	5.15	0.01	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	278.57	0.01	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	4	0.00	149.09	0.01	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	72.33	0.01	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	7	0.00	86.49	0.01	0.00	1.00

1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	50.25	0.01	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00	50.25	0.01	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Cleaning	CO2	12	12	0.00	42.08	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	7.07	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1000.01	0.01	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00	793.25	0.01	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	49	0.00	6.40	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	44	0.00	7.07	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	2	0.00	105.96	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	131.71	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	150.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	73.40	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	149.98	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	161.55	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	1	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	1	0.00	112.30	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	25	0.00	5.10	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	5.83	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	8	0.00	11.18	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	186.54	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	100.00	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	100.12	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	30.92	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00	10.00	0.00	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	3	0.00	5.83	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	135.81	0.00	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	1	0.00	11.18	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	87.18	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	150.05	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	100.50	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	100.12	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	7.07	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	50.25	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	100.04	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	0	0	0.00	31.62	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	0.00	0.00	0.00	1.00

Tier 1 Level Assessment (2004)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Combined	Level	Share	Cumulative
			Estimate	Estimate	Assess.	Uncert.	*	Level *	Total
			(kton CO2 eq.) 1990	(kton CO2 eq.) 2004		%	Uncert. %	Uncert. %	
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.04	177.43	6.45	0.19	0.19
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	1000.26	2.54	0.07	0.26
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.02	110.56	2.23	0.07	0.33
5 A Forest Land	Emissions/Removals	CO2	2231	-3994	0.04	41.14	1.83	0.05	0.38
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.03	53.93	1.76	0.05	0.43
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	10000.05	1.32	0.04	0.47
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.01	82.08	1.06	0.03	0.50
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	617.47	0.97	0.03	0.53
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.21	3.65	0.76	0.02	0.55
1 A 4 b Residential	Biomass	N2O	73	65	0.00	1001.80	0.73	0.02	0.57
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.13	5.10	0.68	0.02	0.59
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.03	20.21	0.68	0.02	0.61
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.01	104.57	0.67	0.02	0.63
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.02	37.88	0.66	0.02	0.65
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	1000.00	0.63	0.02	0.67
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	150.33	0.62	0.02	0.69
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.02	31.57	0.60	0.02	0.70
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	48.52	0.57	0.02	0.72
1 A 4 b Residential	Biomass	CH4	343	309	0.00	161.55	0.56	0.02	0.74
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	105.34	0.51	0.01	0.75
5 E2 Settlements	Emissions/Removals	CO2	1115	1115	0.01	39.90	0.49	0.01	0.77
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.04	10.10	0.40	0.01	0.78
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.04	11.18	0.39	0.01	0.79
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	48.28	0.37	0.01	0.80
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	75.75	0.34	0.01	0.81
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1000.00	0.33	0.01	0.82
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	97.42	0.31	0.01	0.83
5 B Cropland	Emissions/Removals	CO2	191	191	0.00	141.18	0.30	0.01	0.84
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	261.75	0.28	0.01	0.85
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.01	46.17	0.26	0.01	0.85
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.02	11.18	0.24	0.01	0.86
1 A 2 f Other	Biomass	N2O	21	25	0.00	788.11	0.22	0.01	0.87
2 A 7 Other	Production Quantities	CO2	64	171	0.00	113.66	0.22	0.01	0.87
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	5.10	0.21	0.01	0.88
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	50.25	0.18	0.01	0.88
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	202.58	0.18	0.01	0.89
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.05	3.90	0.18	0.01	0.89
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.01	27.20	0.17	0.00	0.90
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	245.31	0.15	0.00	0.90
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	813.39	0.15	0.00	0.91
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.03	4.48	0.15	0.00	0.91
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1000.05	0.15	0.00	0.92
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.03	5.10	0.14	0.00	0.92
2 B 5 Other	Production Quantities	CO2	65	122	0.00	90.33	0.12	0.00	0.92
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	56.79	0.12	0.00	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	30.41	0.12	0.00	0.93
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1000.00	0.11	0.00	0.94
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1000.05	0.11	0.00	0.94
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	105.02	0.10	0.00	0.94
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	4.28	0.10	0.00	0.94
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	545.23	0.09	0.00	0.95
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	39.74	0.09	0.00	0.95
5 A Forest Land	Emissions/Removals	CH4	154	110	0.00	76.16	0.09	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.01	11.18	0.09	0.00	0.95
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	94.72	0.09	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	150.33	0.08	0.00	0.96
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	801.59	0.07	0.00	0.96
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.01	4.66	0.07	0.00	0.96
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.01	10.05	0.07	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	819.81	0.06	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.05	0.00	0.97
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	442.13	0.05	0.00	0.97
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.01	7.98	0.05	0.00	0.97
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	11.18	0.05	0.00	0.97
5 D Wetlands	Emissions/Removals	CO2	105	105	0.00	40.14	0.05	0.00	0.97
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	11.18	0.04	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	144.92	0.04	0.00	0.98
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.01	5.83	0.03	0.00	0.98
5 F Other Land	Emissions/Removals	CO2	32	32	0.00	96.59	0.03	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	72.92	0.03	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1000.01	0.03	0.00	0.98
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1000.00	0.03	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	11.18	0.03	0.00	0.98
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	765.90	0.03	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	7.07	0.03	0.00	0.98
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	100.12	0.03	0.00	0.99
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1000.05	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	981.79	0.03	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	10.00	0.03	0.00	0.99
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	6.94	0.03	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	50.09	0.02	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.02	0.00	0.99

5 C Grassland	Emissions/Removals	CO2	-25	-25	0.00	82.90	0.02	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1000.05	0.02	0.00	0.99
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1001.80	0.02	0.00	0.99
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1318.21	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	95.14	0.02	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	25.30	0.02	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	95.28	0.02	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	776.91	0.01	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	135.27	0.01	0.00	1.00
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	63.51	0.01	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1000.00	0.01	0.00	1.00
5 A Forest Land	Emissions/Removals	N2O	16	11	0.00	76.16	0.01	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	73.48	0.01	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	78.70	0.01	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	278.57	0.01	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	150.33	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	7.07	0.01	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	7.07	0.01	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1000.01	0.01	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	119.48	0.01	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1000.01	0.01	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	7.07	0.01	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	100.00	0.01	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	7.07	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	4.71	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	159.30	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	150.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	150.00	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	50.25	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	150.03	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	712.43	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	127.95	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	161.55	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	5.83	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	120.08	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	150.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	67.34	0.00	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	500.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	150.00	0.00	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	29.18	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	100.12	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	11.18	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	5.10	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	30.92	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	100.00	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	120.07	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	147.35	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	106.14	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	100.50	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	87.18	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	5.83	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	100.04	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	7.07	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	150.00	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	50.25	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00

Tables A-5.3 – Tier 2 Trend assessment with LULUCF: 1990-2004

Tier 1 Trend Assessment (1990-2004)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2004	Trend Assess.	Combined Uncert. %	Level * Uncert. %	Share Level * Uncert. %	Cumulative Total
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3226	3267	0.01	177.43	1.48	0.12	0.12
5 A Forest Land	Emissions/Removals	CO2	2231	-3994	0.03	41.14	1.12	0.09	0.21
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1814	0.01	110.56	0.86	0.07	0.28
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	10000.05	0.80	0.07	0.35
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	373	0.00	150.33	0.53	0.04	0.39
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1054	0.01	48.52	0.50	0.04	0.43
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	1056	693	0.01	48.28	0.30	0.02	0.46
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2942	0.01	53.93	0.30	0.02	0.48
2 B 1 Ammonia Production	Production Quantities	CO2	569	1715	0.01	31.57	0.30	0.02	0.50
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	29	0.00	1000.00	0.28	0.02	0.53
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1176	1157	0.00	82.08	0.28	0.02	0.55
1 A 4 b Residential	Biomass	N2O	73	65	0.00	1001.80	0.27	0.02	0.57
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFC	0	283	0.00	97.42	0.26	0.02	0.59
1 A 3 b Road Transportation	All Fuels	CO2	9249	18708	0.06	3.65	0.24	0.02	0.61
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	3162	0.02	11.18	0.23	0.02	0.63
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3033	0.05	4.48	0.22	0.02	0.65
2 A 2 Lime Production	Production Quantities	CO2	178	437	0.00	105.34	0.21	0.02	0.67
1 A 4 b Residential	Biomass	CH4	343	309	0.00	161.55	0.20	0.02	0.68
6 B 1 Industrial Wastewater	Wastewater	CH4	1632	1556	0.01	37.88	0.19	0.02	0.70
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3776	0.04	5.10	0.18	0.01	0.71
1 B 2 a Oil	Liquid Fuels	CO2	65	499	0.00	46.17	0.18	0.01	0.73
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	141	0.00	617.47	0.18	0.01	0.74
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	330	0.00	50.25	0.15	0.01	0.76
4 B MANURE MANAGEMENT	Animal Excretion	N2O	563	577	0.00	104.57	0.15	0.01	0.77
1 A 3 a ii Domestic	Liquid Fuels	CO2	165	401	0.00	75.75	0.14	0.01	0.78
2 F 2 Foam Blowing	Consumption	HFC	0	56	0.00	245.31	0.13	0.01	0.79
5 E2 Settlements	Emissions/Removals	CO2	1115	1115	0.00	39.90	0.12	0.01	0.80
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.02	5.83	0.12	0.01	0.81
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11961	0.02	5.10	0.10	0.01	0.82
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	81	0.00	94.72	0.10	0.01	0.83
3 A PAINT APPLICATION	Paint application	CO2	42	95	0.00	261.75	0.10	0.01	0.83
1 A 3 b Road Transportation	All Fuels	N2O	137	563	0.00	27.20	0.10	0.01	0.84
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	57	0.00	1000.00	0.10	0.01	0.85
2 A 7 Other	Production Quantities	CO2	64	171	0.00	113.66	0.10	0.01	0.86
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	801.59	0.09	0.01	0.86
1 A 2 f Other	Gaseous Fuels	CO2	0	2035	0.02	4.28	0.08	0.01	0.87
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	545.23	0.08	0.01	0.88
6 B 1 Industrial Wastewater	Wastewater	N2O	183	228	0.00	1000.26	0.07	0.01	0.88
5 B Cropland	Emissions/Removals	CO2	191	191	0.00	141.18	0.07	0.01	0.89
4 C RICE CULTIVATION	Culture Surface	CH4	256	194	0.00	56.79	0.07	0.01	0.90
1 B 2 b Natural gas	Gaseous Fuels	CO2	0	48	0.00	150.33	0.07	0.01	0.90
4 A ENTERIC FERMENTATION	Population size	CH4	2622	3012	0.00	20.21	0.07	0.01	0.91
5 LAND USE CHANGE AND FORESTRY	Emissions/Removals	CH4	154	110	0.00	76.16	0.06	0.01	0.91
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1000.05	0.06	0.01	0.92
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	1000.00	0.05	0.00	0.92
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	33	87	0.00	105.02	0.04	0.00	0.92
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	202.58	0.04	0.00	0.93
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.00	10.10	0.04	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	384	0.00	11.18	0.04	0.00	0.93
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	695	0.00	11.18	0.04	0.00	0.94
1 A 3 d ii National navigation	Liquid Fuels	CO2	240	211	0.00	39.74	0.04	0.00	0.94
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	332	0.00	11.18	0.04	0.00	0.94
2 B 5 Other	Production Quantities	CO2	65	122	0.00	90.33	0.03	0.00	0.95
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	576	0.00	7.98	0.03	0.00	0.95
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1000.01	0.03	0.00	0.95
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	3	0.00	1000.00	0.03	0.00	0.95
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	248	0.00	11.18	0.03	0.00	0.96
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	388	0.00	7.07	0.03	0.00	0.96
5 C Grassland	Emissions/Removals	CO2	-25	-25	0.00	82.90	0.03	0.00	0.96
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1000.05	0.02	0.00	0.96
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	26	0.00	100.12	0.02	0.00	0.96
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	981.79	0.02	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	244	0.00	10.00	0.02	0.00	0.97
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	6.94	0.02	0.00	0.97
1 A 4 b Residential	Liquid Fuels	CO2	1621	1892	0.00	11.18	0.02	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1001.80	0.02	0.00	0.97
1 A 2 c Chemicals	Liquid Fuels	CO2	1372	1343	0.00	4.66	0.02	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1000.05	0.02	0.00	0.98
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	813.39	0.02	0.00	0.98
1 A 2 f Other	Biomass	N2O	21	25	0.00	788.11	0.02	0.00	0.98
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1000.00	0.02	0.00	0.98
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	442.13	0.01	0.00	0.98
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1000.05	0.01	0.00	0.98
1 A 3 a ii Domestic	Liquid Fuels	N2O	1	4	0.00	765.90	0.01	0.00	0.98
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	605	0.00	10.05	0.01	0.00	0.98
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	1	0.00	1318.21	0.01	0.00	0.98
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	135.27	0.01	0.00	0.99

5 D Wetlands	Emissions/Removals	CO2	105	105	0.00	40.14	0.01	0.00	0.99
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	819.81	0.01	0.00	0.99
2 F 3 Fire Extinguishers	Consumption	HFC	0	19	0.00	63.51	0.01	0.00	0.99
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	5	0.00	100.00	0.01	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	50.09	0.01	0.00	0.99
1 A 3 c Railways	Liquid Fuels	CO2	173	86	0.00	7.07	0.01	0.00	0.99
5 F Other Land	Emissions/Removals	CO2	32	32	0.00	96.59	0.01	0.00	0.99
1 A 2 f Other	Liquid Fuels	CO2	3368	4118	0.00	3.90	0.01	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1000.05	0.01	0.00	0.99
1 A 3 b Road Transportation	All Fuels	CH4	72	61	0.00	25.30	0.01	0.00	0.99
5 LAND USE CHANGE AND FORESTRY	Emissions/Removals	N2O	16	11	0.00	76.16	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	95.14	0.01	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	18	16	0.00	95.28	0.01	0.00	0.99
1 A 3 d ii National navigation	Liquid Fuels	N2O	2	2	0.00	776.91	0.01	0.00	0.99
1 A 2 f Other	Solid Fuels	CH4	4	2	0.00	150.03	0.01	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1000.01	0.01	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	94	0.00	4.71	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	68	0.00	7.07	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	150.33	0.00	0.00	1.00
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	352	0.00	30.41	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	50.25	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	712.43	0.00	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	278.57	0.00	0.00	1.00
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	72.92	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	119.48	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	67.34	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	1	0.00	150.00	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	7	10	0.00	78.70	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1001.80	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2475	0.00	5.10	0.00	0.00	1.00
2 F 4 Aerosols	Consumption	HFC	0	0	0.00	500.00	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	1	0.00	150.00	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	100.12	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	11.18	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	161.55	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	120.08	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CO2	0	11	0.00	5.10	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	25	0.00	144.92	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1000.05	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	150.00	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CO2	63	87	0.00	7.07	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1001.80	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1000.01	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	63	0.00	7.07	0.00	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	73.48	0.00	0.00	1.00
2 F 8 Electrical Equipment	Consumption	SF6	2	3	0.00	29.18	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	5.83	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	147.35	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	159.30	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	30.92	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	127.95	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	0	0	0.00	120.07	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	150.33	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	5.83	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1000.01	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	100.00	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	106.14	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1000.00	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	0	0	0.00	87.18	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	100.50	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	150.00	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	7.07	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	50.25	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	150.33	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	150.08	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	150.03	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	100.04	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	150.00	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	161.55	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	40.31	0.00	0.00	1.00

ANNEX B: UNCERTAINTY ANALYSIS METHODOLOGY

B.1 Introduction

Uncertainty in results of the GHG inventory of emissions results from natural variability of emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameter due to errors in original monitoring data, reference studies and expert judgement.

Uncertainty values were defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

The uncertainty analysis was performed only for the direct GHG: CO₂, CH₄, N₂O, HFC and SF₆, considering all emissions in CO₂ equivalent (CO₂e). The uncertainty of all source activities was considered to overall uncertainty including, for the first time, the uncertainty of LULUCF category.

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

The uncertainty is estimated for individual years, from emission estimates in specific years and uncertainty values for both activity data and implied emission factors, but also for the trend of emissions for each individual category. In the last case, the sensitivity factor of the emissions is also calculated.

B. 2 Methodology Issues

Level of Analysis

The level at which uncertainties are estimated was determined at the level at which different uncertainty values must be attributed. Therefore the following factors were considered:

- Origin of activity data. A different level was defined whenever activity data resulted from a different origin, including different classes in Energy Balance. In the case when Large Point Source (LPS) was used to estimate part of emissions from a given source sector the uncertainty analysis had to be done independently for that fraction, because error is different, and uncertainty level was independently made for emissions from LPS and from the remaining Area sources. This separation is also very important in agriculture where different animal types have very different levels of error in activity data;
- Emission Factor. A different class is used for sub-sources whenever different emission factors were used. For example, that has caused the detailed consideration of emissions for each product from organic chemical industry (PVC, Polypropylene, etc) because emission factors have different origins. In the same way fuels (e.g. biomass) were analyzed independently in situations where uncertainty values are different;

- For certain processes, if the emission estimate depends of different parts of the product life-time, uncertainty analysis was done at the lowest level also. That is the case of aviation, where separation is done for LTO and cruise emissions, and fluorine gas emissions from refrigeration equipment, where uncertainty analysis was performed independently for assembly, operation and disposal.

Uncertainty Values

The uncertainty values that were used were set from:

- Good Practice Guidebook (IPCC,2000);
- references to emission factors, such as AP42¹⁵³;
- comparison of several sources of information. For example, comparison to international sources such as FAO, IEA;
- inter-annual un expected variations of activity data;
- statistical variation in the determination of country-specific emission factors, for different units or different years.

The actual uncertainty values that were used for each activity source are reported in the main text under methodological considerations for each source.

To avoid an excessive influence of expert judgement from the team that performs the inventory in uncertainty levels definition an exterior technician, not involved in inventory preparation, has helped the choice of uncertainty levels. Nevertheless insight into the inventory is only possible to be assessed from the inventory team for more complex sources (agriculture and wastes for example) and the desired independence was partly affected.

Error propagation

Two different rules were used in error propagation (IPCC,2000):

Rule A: For the case when the quantities are to be combined by addition, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms;

$$U_{Total} = \frac{\{\sum_i [U_i * x_i]^2\}^{0.5}}{\sum_i [x_i]}$$

Where:

¹⁵³ In this reference source quality codes are usually reported from A (good quality) to E (poor quality). The following conversion rules was used in uncertainty assessment:

A	5 %
B	10 %
C	50 %
D	100 %
E	1 000 %

U_{total} is the percentage uncertainty in the sum of the quantities expressed as a percentage;

x_i and U_i are the uncertain quantities and the percentage uncertainties associated with them, respectively;

Rule B: quantities are to be combined by multiplication, a simpler rule applies:

$$U_{\text{Total}} = [\sum_i U_i^2]^{0.5}$$

- U_{total} is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

- U_i are the percentage uncertainties associated with each of the quantities.

B.3 Table of Results

Explanation of tables

A single table is presented including the most basic information used in uncertainty determination. The uncertainty was estimated in a consistent way for all years from 1990 to 2004. However, tables present only information for 2004.

All tables are equal and include the following columns:

- Sector;
- Category: second level of source category according to the IPCC;
- Individual category: the more detailed level at which uncertainties are determined;
- Fuel: type of fuel used in the category, when relevant;
- Source type: uncertainties are estimated with different uncertainty values when emissions are estimated using data from Large Point Sources (LPS) or from national statistics (AREA) ;
- IPCC code: the IPCC code defined for the individual category under calculus (Column A of table 6.1 in GP (IPCC,2000));
- Gas: GHG under consideration : CO₂ ; CH₄ ; N₂O and F G (Fuel gas). Emissions are reported for F gases (HFC, PFC and SF₆) after conversion to CO₂eq using the appropriate GWP factor. Removals and emissions of the LULUCF sector, except fires, are reported as CO₂, by conversion of all carbon fluxes (Column B of table 6.1 in GP (IPCC,2000));
- Base Year emissions : Emissions and removals per category in 1990. Emissions are reported as positive values and removals as negative values¹⁵⁴. All emissions, irrespective of the gas, are reported as CO₂ equivalent (Column C of table 6.1 in GP (IPCC,2000));

¹⁵⁴ Note: all calculation is done with absolute values.

- Current Year emissions : Emissions and removals per category in the last year of the inventory. (Column D of table 6.1 in GP (IPCC,2000));
- AD Uncertainty: uncertainty value attributed to the activity data, half the 95 per cent net confidence interval divided by the mean and expressed as percentage. Detailed presentation of the assumptions and determination of individual values are discussed in main text (Column E of table 6.1 in GP (IPCC,2000));
- EF Uncertainty: the uncertainty value attributed to the implied emission factor, per cent. The determination of this value from basic parameters is discussed in main text. (Column F of table 6.1 in GP (IPCC,2000));
- Combined Uncertainty: derived from the uncertainties of AD and EF and using propagation rule B. (Column G of table 6.1 in GP (IPCC,2000));
- Combined uncertainty as per cent of total national emissions in current year: represents the importance of the uncertainty of each specific individual category to the overall uncertainty in the current year. The addition of the squares of all the entries in column H and after taking the square root (Rule A) is an estimate of the percentage uncertainty in total national emissions in the current year. (Column H of table 6.1 in GP (IPCC,2000));
- type A sensitivity: The per cent difference in emissions for this individual category following a 1 per cent increase in both the base year and current year, expressing the sensitivity in trend to a uncertainty systematic in nature (Column I of table 6.1 in GP (IPCC,2000));
- type B sensitivity: The per cent difference in emissions for this individual category following a 1 per cent increase in the current year only, expressing the sensitivity in trend to a uncertainty due to random error in emission estimate (i.e. error not correlated between years). (Column J of table 6.1 in GP (IPCC,2000));
- Uncertainty in trend from the uncertainty in EF: In all cases type A sensitivity (correlation) was used to estimate uncertainty in EF. (Column K of table 6.1 in GP (IPCC,2000));
- Uncertainty in trend from the uncertainty in AD: In all cases type B sensitivity (no correlation) was used to estimate uncertainty in AD. (Column L of table 6.1 in GP (IPCC,2000));
- Uncertainty into the trend in total national emissions. is an estimate of the uncertainty introduced into the trend in national emissions by the source category in question, derived from the data in columns K and L using Rule B. Total uncertainty in trend is calculated from the entries above using the error propagation equation, summing the squares of all the entries in column M and taking the square root.(Column M of table 6.1 in GP (IPCC,2000)).

Finally, because there are confidentiality issues, for some categories the activity data and combined uncertainty are reported as “C”. Nevertheless, the importance of the uncertainty for each source may still be assessed from the tables.

Table

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq	Current Year Emissions Gg CO2 eq	AD Unc. %	EF Unc. %	Comb. Unc. %	as % of total national emissions in year t %	Type A sens. %	Type B sens. %	Unc. in trend from EF unc. %	Unc. in trend from AD unc. %	Unc. in trend %
					A	B	C	D	E	F	G	H	I	J	K	L	M
Energy	Fuel Combustion Activities	Public Electricity Generation	L	LPS	1A1a	CO2	6 298.5	2 608.1	1.00	5.0	5.1	0.16	-0.09	0.04	-0.43	0.29	0.52
Energy	Fuel Combustion Activities	Public Electricity Generation	S	LPS	1A1a	CO2	7 659.4	11 961.0	1.00	5.0	5.1	0.75	0.03	0.19	0.16	1.33	1.34
Energy	Fuel Combustion Activities	Public Electricity Generation	G	LPS	1A1a	CO2	0.0	3 775.9	1.00	5.0	5.1	0.24	0.06	0.06	0.30	0.42	0.52
Energy	Fuel Combustion Activities	Public Electricity Generation	L	AREA	1A1a	CO2	2.1	424.6	4.00	5.0	6.4	0.03	0.01	0.01	0.03	0.05	0.06
Energy	Fuel Combustion Activities	Petroleum Refining	L	LPS	1A1b	CO2	1 909.5	2 475.5	1.00	5.0	5.1	0.15	0.00	0.04	0.00	0.28	0.28
Energy	Fuel Combustion Activities	Petroleum Refining	G	LPS	1A1b	CO2	0.0	10.9	1.00	5.0	5.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Manufacture Of Solid Fuels	S	LPS	1A1c	CO2	25.4	0.0	1.00	5.0	5.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other Energy Industries	L	AREA	1A1cii	CO2	49.5	0.0	4.00	5.0	6.4	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Iron And Steel	L	LPS	1A2a	CO2	134.0	41.5	3.00	5.0	5.8	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Iron And Steel	S	LPS	1A2a	CO2	466.0	0.0	3.00	5.0	5.8	0.00	-0.01	0.00	-0.05	0.00	0.05
Energy	Fuel Combustion Activities	Iron And Steel	O	LPS	1A2a	CO2	3.1	0.8	3.00	5.0	5.8	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	L	AREA	1A2a	CO2	20.1	52.2	5.00	5.0	7.1	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Iron And Steel	G	AREA	1A2a	CO2	0.0	68.0	5.00	5.0	7.1	0.01	0.00	0.00	0.01	0.01	0.01
Energy	Fuel Combustion Activities	Chemicals	L	LPS	1A2c	CO2	808.0	1 012.1	3.00	5.0	5.8	0.07	0.00	0.02	0.00	0.11	0.11
Energy	Fuel Combustion Activities	Chemicals	L	AREA	1A2c	CO2	563.7	381.3	5.00	5.0	7.1	0.03	-0.01	0.01	-0.03	0.04	0.05
Energy	Fuel Combustion Activities	Chemicals	S	AREA	1A2c	CO2	44.2	62.7	5.00	5.0	7.1	0.01	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Chemicals	G	AREA	1A2c	CO2	0.0	388.1	5.00	5.0	7.1	0.03	0.01	0.01	0.03	0.04	0.05
Energy	Fuel Combustion Activities	Chemicals	O	AREA	1A2c	CO2	62.7	86.8	5.00	5.0	7.1	0.01	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Pulp, Paper And Print	L	LPS	1A2d	CO2	432.3	757.2	3.00	5.0	5.8	0.05	0.00	0.01	0.02	0.08	0.09
Energy	Fuel Combustion Activities	Pulp, Paper And Print	G	LPS	1A2d	CO2	0.0	6.1	3.00	5.0	5.8	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Pulp, Paper And Print	L	AREA	1A2d	CO2	311.1	-181.1	5.00	5.0	7.1	-0.02	-0.01	0.00	-0.05	-0.02	0.05
Energy	Fuel Combustion Activities	Pulp, Paper And Print	G	AREA	1A2d	CO2	0.0	327.5	5.00	5.0	7.1	0.03	0.01	0.01	0.03	0.04	0.04
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	L	AREA	1A2e	CO2	820.4	695.5	10.00	5.0	11.2	0.10	-0.01	0.01	-0.03	0.08	0.08
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	S	AREA	1A2e	CO2	1.2	0.0	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	G	AREA	1A2e	CO2	0.0	247.9	10.00	5.0	11.2	0.03	0.00	0.00	0.02	0.03	0.03

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Other- Textile	L	AREA	1A2fi	CO2	814.0	591.0	10.00	5.0	11.2	0.08	-0.01	0.01	-0.04	0.07	0.08
Energy	Fuel Combustion Activities	Other- Textile	G	AREA	1A2fi	CO2	0.0	434.6	10.00	5.0	11.2	0.06	0.01	0.01	0.03	0.05	0.06
Energy	Fuel Combustion Activities	Other- Ceramic	L	AREA	1A2fii	CO2	659.9	186.2	5.00	5.0	7.1	0.02	-0.01	0.00	-0.05	0.02	0.06
Energy	Fuel Combustion Activities	Other- Ceramic	S	AREA	1A2fii	CO2	0.6	0.0	5.00	5.0	7.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Ceramic	G	AREA	1A2fii	CO2	0.0	883.1	5.00	5.0	7.1	0.08	0.01	0.01	0.07	0.10	0.12
Energy	Fuel Combustion Activities	Other- Glass	L	AREA	1A2fiii	CO2	413.9	149.1	5.00	5.0	7.1	0.01	-0.01	0.00	-0.03	0.02	0.03
Energy	Fuel Combustion Activities	Other- Glass	G	AREA	1A2fiii	CO2	0.0	387.5	5.00	5.0	7.1	0.03	0.01	0.01	0.03	0.04	0.05
Energy	Fuel Combustion Activities	Other- Cement	L	LPS	1A2fiv	CO2	102.7	1 532.0	3.00	5.0	5.8	0.11	0.02	0.02	0.11	0.17	0.20
Energy	Fuel Combustion Activities	Other- Cement	S	LPS	1A2fiv	CO2	2 051.8	538.7	3.00	5.0	5.8	0.04	-0.03	0.01	-0.17	0.06	0.18
Energy	Fuel Combustion Activities	Other- Cement	O	LPS	1A2fiv	CO2	19.7	29.9	3.00	5.0	5.8	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cloth	L	AREA	1A2fv	CO2	66.4	41.7	10.00	5.0	11.2	0.01	0.00	0.00	0.00	0.00	0.01
Energy	Fuel Combustion Activities	Other- Cloth	G	AREA	1A2fv	CO2	0.0	27.2	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Wood	L	AREA	1A2fvi	CO2	145.2	225.1	10.00	5.0	11.2	0.03	0.00	0.00	0.00	0.03	0.03
Energy	Fuel Combustion Activities	Other- Wood	G	AREA	1A2fvi	CO2	0.0	30.2	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	L	AREA	1A2fvii	CO2	46.3	11.9	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	G	AREA	1A2fvii	CO2	0.0	23.1	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	L	AREA	1A2fviii	CO2	311.6	160.0	10.00	5.0	11.2	0.02	0.00	0.00	-0.02	0.02	0.03
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	S	AREA	1A2fviii	CO2	50.6	0.0	10.00	5.0	11.2	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	G	AREA	1A2fviii	CO2	0.0	150.9	10.00	5.0	11.2	0.02	0.00	0.00	0.01	0.02	0.02
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	L	AREA	1A2fc	CO2	145.7	4.0	10.00	5.0	11.2	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	S	AREA	1A2fc	CO2	0.0	0.0	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	G	AREA	1A2fc	CO2	0.0	11.1	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Extractive Industry	L	AREA	1A2fix	CO2	83.3	188.4	10.00	5.0	11.2	0.03	0.00	0.00	0.01	0.02	0.02
Energy	Fuel Combustion Activities	Other- Extractive Industry	S	AREA	1A2fix	CO2	0.2	0.0	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Extractive Industry	G	AREA	1A2fix	CO2	0.0	43.5	10.00	5.0	11.2	0.01	0.00	0.00	0.00	0.00	0.01
Energy	Fuel Combustion Activities	Other- Cop	L	AREA	1A2fx	CO2	505.6	902.7	10.00	5.0	11.2	0.12	0.00	0.01	0.02	0.10	0.10

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Other- Cop	G	AREA	1A2fx	CO2	0.0	14.3	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Lto	L AvG	AREA	1A3ai	CO2	0.1	0.0	48.88	5.0	49.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Lto	L JeK	AREA	1A3ai	CO2	138.4	242.2	97.76	5.0	97.9	0.29	0.00	0.00	0.01	0.03	0.03
Energy	Fuel Combustion Activities	International (C)- Cruise	L AvG	AREA	1A3ai	CO2	3.6	3.9	49.72	5.0	50.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Cruise	L JeK	AREA	1A3ai	CO2	1 248.7	2 128.2	99.43	5.0	99.6	2.59	0.01	0.03	0.04	0.24	0.24
Energy	Fuel Combustion Activities	Domestic- Lto	L AvG	AREA	1A3aii	CO2	0.2	0.3	48.88	5.0	49.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Lto	L JeK	AREA	1A3aii	CO2	75.7	114.0	97.76	5.0	97.9	0.14	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Domestic- Cruise	L AvG	AREA	1A3aii	CO2	0.8	2.9	49.72	5.0	50.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Cruise	L JeK	AREA	1A3aii	CO2	88.0	283.8	99.43	5.0	99.6	0.35	0.00	0.00	0.01	0.03	0.03
Energy	Fuel Combustion Activities	Cars	L Gas	AREA	1A3bi	CO2	3 954.6	5 713.0	5.00	5.0	7.1	0.49	0.01	0.09	0.05	0.64	0.64
Energy	Fuel Combustion Activities	Cars	L DiesO	AREA	1A3bi	CO2	264.0	2 225.6	5.00	5.0	7.1	0.19	0.03	0.04	0.15	0.25	0.29
Energy	Fuel Combustion Activities	Light Duty Trucks	L DiesO	AREA	1A3bii	CO2	2 615.3	4 930.4	5.00	5.0	7.1	0.43	0.02	0.08	0.12	0.55	0.56
Energy	Fuel Combustion Activities	Light Duty Trucks	L DiesO	AREA	1A3bii	CO2	0.0	12.3	5.00	5.0	7.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Heavy Duty Trucks And Buses	L DiesO	AREA	1A3biii	CO2	2 067.2	5 558.3	5.00	5.0	7.1	0.48	0.05	0.09	0.23	0.62	0.66
Energy	Fuel Combustion Activities	Heavy Duty Trucks And Buses	G LPG	AREA	1A3biii	CO2	0.0	33.2	5.00	5.0	7.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Motorcycles	L Gas	AREA	1A3biv	CO2	348.2	195.2	5.00	5.0	7.1	0.02	0.00	0.00	-0.02	0.02	0.03
Energy	Fuel Combustion Activities	Railways	S	AREA	1A3c	CO2	0.1	0.0	5.00	5.0	7.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Railways	L	AREA	1A3c	CO2	173.0	86.4	5.00	5.0	7.1	0.01	0.00	0.00	-0.01	0.01	0.01
Energy	Fuel Combustion Activities	International Marine (C)	L ResO	AREA	1A3di	CO2	1 280.6	1 323.5	51.22	5.0	51.5	0.83	-0.01	0.02	-0.03	0.15	0.15
Energy	Fuel Combustion Activities	International Marine (C)	L GasD	AREA	1A3di	CO2	499.3	516.0	51.22	5.0	51.5	0.32	0.00	0.01	-0.01	0.06	0.06
Energy	Fuel Combustion Activities	National Navigation	L ResO	AREA	1A3dii	CO2	173.0	152.1	51.22	5.0	51.5	0.10	0.00	0.00	-0.01	0.02	0.02
Energy	Fuel Combustion Activities	National Navigation	L GasD	AREA	1A3dii	CO2	67.5	59.3	51.22	5.0	51.5	0.04	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Commercial / Institutional	L	AREA	1A4a	CO2	743.7	3 161.6	10.00	5.0	11.2	0.43	0.03	0.05	0.17	0.35	0.39
Energy	Fuel Combustion Activities	Commercial / Institutional	G	AREA	1A4a	CO2	0.0	332.4	10.00	5.0	11.2	0.05	0.01	0.01	0.03	0.04	0.05
Energy	Fuel Combustion Activities	Commercial / Institutional	B	AREA	1A4a	CO2	0.0	5.2	60.00	5.0	60.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Residential	L	AREA	1A4b	CO2	1 621.3	1 892.3	10.00	5.0	11.2	0.26	0.00	0.03	-0.02	0.21	0.21

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Residential	G	AREA	1A4b	CO2	0.0	384.1	10.00	5.0	11.2	0.05	0.01	0.01	0.03	0.04	0.05
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	L	AREA	1A4ci	CO2	88.1	119.7	10.00	5.0	11.2	0.02	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	G	AREA	1A4ci	CO2	0.0	7.0	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	B	AREA	1A4ci	CO2	0.0	0.6	60.00	5.0	60.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Off-Road Vehicles And Other Machinery- Agriculture/ Forestry	L	AREA	1A4cii	CO2	1 169.2	626.5	81.40	5.0	81.5	0.62	-0.01	0.01	-0.07	0.07	0.10
Energy	Fuel Combustion Activities	Fishing- Stationary	L	AREA	1A4ciii	CO2	1.0	126.1	10.00	5.0	11.2	0.02	0.00	0.00	0.01	0.01	0.02
Energy	Fuel Combustion Activities	Fishing- Mobile	L	AREA	1A4ciii	CO2	401.9	182.2	10.00	5.0	11.2	0.02	-0.01	0.00	-0.03	0.02	0.03
Energy	Fuel Combustion Activities	Stationary- (Other)	S	AREA	1A5	CO2	8.1	0.0	10.00	5.0	11.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fugitive Emissions From Fuels	Underground Mines- Solid Fuels	-	LPS	1B1ai	CO2	8.5	0.0	5.00	100.0	100.1	0.00	0.00	0.00	-0.02	0.00	0.02
Energy	Fugitive Emissions From Fuels	Surface Mines- Solid Fuels	-	LPS	1B1aii	CO2	0.1	0.0	5.00	200.0	200.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fugitive Emissions From Fuels	Transport- Oil	-	AREA	1B2aiii	CO2	11.5	14.0	3.00	50.0	50.1	0.01	0.00	0.00	0.00	0.02	0.02
Energy	Fugitive Emissions From Fuels	Refining/ Storage- Oil	-	AREA	1B2aiv	CO2	36.3	459.1	3.00	50.0	50.1	0.28	0.01	0.01	0.32	0.51	0.61
Energy	Fugitive Emissions From Fuels	Distribution Of Oil Products- Oil	-	AREA	1B2av	CO2	16.8	26.0	10.00	50.0	51.0	0.02	0.00	0.00	0.00	0.03	0.03
Energy	Fugitive Emissions From Fuels	Transmission/ Distribution- Natural Gas	G	AREA	1B2bii	CO2	0.0	48.4	10.00	150.0	150.3	0.09	0.00	0.00	0.11	0.16	0.20
Energy	Fugitive Emissions From Fuels	Oil- Oil & Ng	-	AREA	1B2ci	CO2	48.5	42.3	3.00	50.0	50.1	0.03	0.00	0.00	-0.02	0.05	0.05
Energy	Fugitive Emissions From Fuels	Other (Geothermal)- Oil & Ng	O	AREA	1B2d	CO2	2.0	243.6	10.00	0.0	10.0	0.03	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Mineral Products	Cement Production	-	LPS	2A1	CO2	3 106.5	3 538.4	2.00	9.9	10.1	0.44	-0.01	0.06	-0.07	0.78	0.78
Industrial Processes	Mineral Products	Lime Production	-	AREA	2A2	CO2	168.0	437.2	105.00	8.5	105.3	0.56	0.00	0.01	0.03	0.08	0.09
Industrial Processes	Mineral Products	Limestone And Dolomite Use	-	AREA	2A3	CO2	24.1	3.8	105.00	2.0	105.0	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Mineral Products	Road Paving With Asphalt	-	AREA	2A6	CO2	2.6	11.8	30.92	10	10	1.45	0.00	0.00	1.33	2.63	2.95
Industrial Processes	Mineral Products	Other (Glass)	-	AREA	2A7	CO2	64.3	170.5	100.00	54.0	113.7	0.24	0.00	0.00	0.07	0.21	0.22
Industrial Processes	Chemical Industry	Ammonia Production	-	LPS	2B1	CO2	C	C	31.17	5.0	C	0.66	0.02	0.03	0.08	0.19	0.21
Industrial Processes	Chemical Industry	Nitric Acid Production	-	LPS	2B2	CO2	C	C	1.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Adipic Acid Production	-	AREA	2B3	CO2	C	C	0.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Carbide Production	-	AREA	2B4	CO2	C	C	0.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Industrial Processes	Chemical Industry	Other- * Ethylene	-	LPS	2B5bi	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Butadiene	-	LPS	2B5bii	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene High Density	-	LPS	2B5bv	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene Low Density	-	LPS	2B5bvi	CO2	C	C	10.00	100.0	C	0.01	0.00	0.00	0.00	0.01	0.01
Industrial Processes	Chemical Industry	Other- * Polypropylene	-	LPS	2B5bvii	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Carbon Black	-	LPS	2B5bx	CO2	C	C	10.00	100.0	C	0.13	0.00	0.00	0.06	0.24	0.24
Industrial Processes	Chemical Industry	Other- * Sulphuric Acid	-	LPS	2B5ai	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Flaring In Chemical Industry	-	AREA	2B5bc	CO2	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ammonium Sulphate	-	LPS	2B5aii	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ammonium Nitrate	-	LPS	2B5aiii	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Npk Fertilizers	-	LPS	2B5aiv	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Urea	-	LPS	2B5av	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Vinylchloride (Except 04.05.05)	-	AREA	2B5biv	CO2	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene Low Density	-	AREA	2B5bvi	CO2	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.01	0.01
Industrial Processes	Chemical Industry	Other- * Polyvinylchloride	-	AREA	2B5bviii	CO2	C	C	100.00	1 000.0	C	0.03	0.00	0.00	0.02	0.05	0.05
Industrial Processes	Chemical Industry	Other- * Polypropylene	-	AREA	2B5bvii	CO2	C	C	100.00	1 000.0	C	0.02	0.00	0.00	-0.01	0.03	0.03
Industrial Processes	Chemical Industry	Other- * Polystyrene	-	AREA	2B5bix	CO2	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Formaldehyde	-	AREA	2B5bi	CO2	C	C	100.00	1 000.0	C	0.01	0.00	0.00	0.00	0.02	0.02
Industrial Processes	Chemical Industry	Other- * Phthalic Anhydride	-	LPS	2B5bxi	CO2	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.01	0.01
Industrial Processes	Chemical Industry	Other- * Explosives	-	AREA	2B5bxii	CO2	C	C	48.61	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Metal Production	Iron And Steel Production	-	LPS	2C1	CO2	26.8	35.4	10.00	30.0	31.6	0.01	0.00	0.00	0.00	0.02	0.02
Industrial Processes	Metal Production	Ferroalloys Production	-	AREA	2C2	CO2	2.7	2.7	100.00	260.0	278.6	0.01	0.00	0.00	0.00	0.02	0.02
Industrial Processes	Other Production	Food And Drink- General	-	AREA	2D2	CO2	0.4	0.4	100.00	0.0	100.0	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Paint Application	- * Construction And Building And Domestic Use	-	AREA	3Aiii	CO2	40.1	94.4	25.00	261.2	262.4	0.30	0.00	0.00	0.18	0.55	0.58

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Solvent And Other Product Use	Paint Application	- * Wood	-	AREA	3Avi	CO2	0.0	0.1	25.00	261.2	262.4	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Paint Application	- * Other Industrial Paint Application	-	AREA	3Avii	CO2	2.1	0.2	25.00	261.2	262.4	0.00	0.00	0.00	-0.01	0.00	0.01
Solvent And Other Product Use	Degreasing And Dry Cleaning	- * Metal Degreasing	-	AREA	3Bi	CO2	4.8	4.6	100.00	0.0	100.0	0.01	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Degreasing And Dry Cleaning	- * Dry Cleaning	-	AREA	3Bii	CO2	6.8	0.0	10.00	0.0	10.0	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Rubber Processing	-	AREA	3Cia	CO2	36.7	86.7	10.00	1 000.0	000.0	1.06	0.00	0.00	0.62	1.93	2.03
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Polyester Processing	-	AREA	3Cib	CO2	0.1	0.1	100.00	100.0	141.4	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Polyvinylchloride Processing	-	AREA	3Cic	CO2	1.6	1.6	100.00	100.0	141.4	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Polyurethane Processing	-	AREA	3Cid	CO2	0.0	0.3	100.00	100.0	141.4	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Polystyrene Foam Processing (C)	-	AREA	3Cie	CO2	1.0	1.0	100.00	100.0	141.4	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Paints Manufacturing	-	AREA	3Ciaa	CO2	5.5	8.2	10.00	50.0	51.0	0.01	0.00	0.00	0.00	0.01	0.01
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Inks Manufacturing	-	AREA	3Ciib	CO2	0.2	0.2	10.00	1 000.0	000.0	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Glues Manufacturing	-	AREA	3Ciic	CO2	2.3	2.2	100.00	1 000.0	005.0	0.03	0.00	0.00	-0.01	0.05	0.05
Solvent And Other Product	Chemical Products, Manufacture And Processing	- * Other. Use Of Solvents In Plastic Products Manufacturing	-	AREA	3Cif	CO2	28.0	30.0	100.00	100.0	141.4	0.05	0.00	0.00	-0.01	0.07	0.07

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq	Current Year Emissions Gg CO2 eq	AD Unc. %	EF Unc. %	Comb. Unc. %	as % of total national emissions in year t %	Type A sens. %	Type B sens. %	Unc. in trend from EF unc. %	Unc. in trend from AD unc. %	Unc. in trend %
					A	B	C	D	E	F	G	H	I	J	K	L	M
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Rayon	-	AREA	3Ciia	CO2	C	C	100.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyamides	-	AREA	3Ciib	CO2	C	C	100.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyester	-	AREA	3Ciic	CO2	C	C	100.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyethylene	-	AREA	3Ciid	CO2	C	C	100.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polypropylene	-	AREA	3Ciie	CO2	C	C	100.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Pvc	-	AREA	3Ciif	CO2	C	C	100.00	100.0	C	0.01	0.00	0.00	0.00	0.01	0.01
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Acrylics	-	AREA	3Ciig	CO2	C	C	100.00	100.0	C	0.01	0.00	0.00	0.00	0.01	0.01
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Acrylonitrile	-	AREA	3Ciih	CO2	C	C	100.00	100.0	C	0.01	0.00	0.00	0.00	0.01	0.01
Solvent And Other Product Use	Other	- * Printing Industry	-	AREA	3Di	CO2	1.6	3.8	25.00	50.0	55.9	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Other	- * Fat, Edible And Not Edible Oil Extraction	-	AREA	3Dii	CO2	11.6	7.0	10.00	26.0	27.9	0.00	0.00	0.00	0.00	0.00	0.01
Solvent And Other Product Use	Other	- * Application Of Glues And Adhesives	-	AREA	3Diii	CO2	20.1	20.6	100.00	100.0	141.4	0.04	0.00	0.00	-0.01	0.05	0.05
Solvent And Other Product Use	Other	- * Preservation Of Wood	-	AREA	3Div	CO2	0.6	0.8	100.00	100.0	141.4	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product	Other	- * Use Of Solvents	-	AREA	3Dv	CO2	15.5	15.7	1 000.00	0.0	1 000.0	0.19	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Solvent And Other Product Use	Other	- * Use Of Parfums	-	AREA	3Dvi	CO2	15.1	16.3	100.00	100.0	141.4	0.03	0.00	0.00	-0.01	0.04	0.04
Solvent And Other Product Use	Other	- * Use Of Waxes, Polishing Materials	-	AREA	3Dvii	CO2	14.3	14.5	100.00	100.0	141.4	0.03	0.00	0.00	-0.01	0.03	0.03
Solvent And Other Product Use	Other	- * Soap And Detergent Use	-	AREA	3Dviii	CO2	1.5	1.5	100.00	100.0	141.4	0.00	0.00	0.00	0.00	0.00	0.00
Waste	Waste Incineration	- Domestic	-	AREA	6C1	CO2	10.1	330.1	5.00	50.0	50.2	0.20	0.00	0.01	0.25	0.37	0.44
Waste	Other Waste		-	AREA	6D	CO2	0.0	0.0	0.00	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Public Electricity Generation	L	LPS	1A1a	CH4	1.4	0.9	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Public Electricity Generation	S	LPS	1A1a	CH4	1.3	1.9	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Public Electricity Generation	G	LPS	1A1a	CH4	0.0	0.8	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Public Electricity Generation	B	LPS	1A1a	CH4	0.0	0.7	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Public Electricity Generation	L	AREA	1A1a	CH4	0.0	0.3	4.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Petroleum Refining	L	LPS	1A1b	CH4	1.6	2.0	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Petroleum Refining	G	LPS	1A1b	CH4	0.0	0.0	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Manufacture Of Solid Fuels	S	LPS	1A1c	CH4	0.0	0.0	1.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other Energy Industries	L	AREA	1A1cii	CH4	0.0	0.0	4.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	L	LPS	1A2a	CH4	0.1	0.0	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	S	LPS	1A2a	CH4	0.1	0.0	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	O	LPS	1A2a	CH4	0.0	0.0	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	L	AREA	1A2a	CH4	0.0	0.0	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	G	AREA	1A2a	CH4	0.0	0.0	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Chemicals	L	LPS	1A2c	CH4	0.9	1.4	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Chemicals	L	AREA	1A2c	CH4	0.5	0.3	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Chemicals	S	AREA	1A2c	CH4	0.0	0.0	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Chemicals	G	AREA	1A2c	CH4	0.0	0.2	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Chemicals	B	AREA	1A2c	CH4	0.3	0.5	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Chemicals	O	AREA	1A2c	CH4	0.0	0.0	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Pulp, Paper And Print	L	LPS	1A2d	CH4	1.7	2.4	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Pulp, Paper And Print	G	LPS	1A2d	CH4	0.0	0.0	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Pulp, Paper And Print	B	LPS	1A2d	CH4	18.9	23.8	3.00	150.0	150.0	0.04	0.00	0.00	0.00	0.08	0.08
Energy	Fuel Combustion Activities	Pulp, Paper And Print	L	AREA	1A2d	CH4	0.3	-0.1	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Pulp, Paper And Print	G	AREA	1A2d	CH4	0.0	0.2	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Pulp, Paper And Print	B	AREA	1A2d	CH4	0.0	0.9	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	L	AREA	1A2e	CH4	0.7	0.6	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	S	AREA	1A2e	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	G	AREA	1A2e	CH4	0.0	0.1	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	B	AREA	1A2e	CH4	1.3	1.1	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Textile	L	AREA	1A2fi	CH4	0.6	0.5	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Textile	G	AREA	1A2fi	CH4	0.0	0.2	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Textile	B	AREA	1A2fi	CH4	0.4	0.7	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Ceramic	L	AREA	1A2fii	CH4	0.2	0.1	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Ceramic	G	AREA	1A2fii	CH4	0.0	0.5	5.00	150.0	150.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Ceramic	B	AREA	1A2fii	CH4	1.5	3.3	60.00	150.0	161.6	0.01	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Other- Glass	L	AREA	1A2fiii	CH4	3.5	2.3	5.00	150.0	150.1	0.00	0.00	0.00	-0.01	0.01	0.01
Energy	Fuel Combustion Activities	Other- Glass	G	AREA	1A2fiii	CH4	0.0	8.0	5.00	150.0	150.1	0.01	0.00	0.00	0.02	0.03	0.03
Energy	Fuel Combustion Activities	Other- Glass	B	AREA	1A2fiii	CH4	0.0	0.0	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cement	L	LPS	1A2fiv	CH4	0.2	4.3	3.00	150.0	150.0	0.01	0.00	0.00	0.01	0.01	0.02
Energy	Fuel Combustion Activities	Other- Cement	S	LPS	1A2fiv	CH4	4.1	1.5	3.00	150.0	150.0	0.00	0.00	0.00	-0.01	0.01	0.01
Energy	Fuel Combustion Activities	Other- Cement	O	LPS	1A2fiv	CH4	0.0	0.1	3.00	150.0	150.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cloth	L	AREA	1A2fv	CH4	0.1	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cloth	G	AREA	1A2fv	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Other- Cloth	B	AREA	1A2fv	CH4	0.1	0.0	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Wood	L	AREA	1A2fvi	CH4	0.1	0.2	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Wood	G	AREA	1A2fvi	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Wood	B	AREA	1A2fvi	CH4	0.4	0.5	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	L	AREA	1A2fvii	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	G	AREA	1A2fvii	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	B	AREA	1A2fvii	CH4	0.0	0.0	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	L	AREA	1A2fviii	CH4	0.2	0.1	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	S	AREA	1A2fviii	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	G	AREA	1A2fviii	CH4	0.0	0.1	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	B	AREA	1A2fviii	CH4	0.1	0.1	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	L	AREA	1A2fc	CH4	0.1	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	S	AREA	1A2fc	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	G	AREA	1A2fc	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	B	AREA	1A2fc	CH4	0.0	0.0	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Extractive Industry	L	AREA	1A2fix	CH4	0.6	1.2	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Extractive Industry	G	AREA	1A2fix	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cop	L	AREA	1A2fx	CH4	0.7	1.1	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cop	G	AREA	1A2fx	CH4	0.0	0.1	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Lto	L AvG	AREA	1A3ai	CH4	0.0	0.0	48.88	100.0	111.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Lto	L JeK	AREA	1A3ai	CH4	0.2	0.4	97.76	100.0	139.8	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Cruise	L AvG	AREA	1A3ai	CH4	0.0	0.0	49.72	100.0	111.7	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Cruise	L JeK	AREA	1A3ai	CH4	0.8	0.7	99.43	100.0	141.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Lto	L AvG	AREA	1A3aii	CH4	0.0	0.0	48.88	100.0	111.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Lto	L JeK	AREA	1A3aii	CH4	0.1	0.2	97.76	100.0	139.8	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Cruise	L AvG	AREA	1A3aii	CH4	0.0	0.0	49.72	100.0	111.7	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Domestic- Cruise	L JeK	AREA	1A3aii	CH4	0.2	0.0	99.43	100.0	141.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Cars	L Gas	AREA	1A3bi	CH4	46.5	35.1	5.00	40.0	40.3	0.02	0.00	0.00	-0.02	0.03	0.03
Energy	Fuel Combustion Activities	Cars	L DiesO	AREA	1A3bi	CH4	0.2	1.7	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Light Duty Trucks	L DiesO	AREA	1A3bii	CH4	1.4	2.8	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Light Duty Trucks	L DiesO	AREA	1A3bii	CH4	0.0	0.1	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Heavy Duty Trucks And Buses	L DiesO	AREA	1A3biii	CH4	3.8	9.4	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Heavy Duty Trucks And Buses	G LPG	AREA	1A3biii	CH4	0.0	0.5	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Motorcycles	L Gas	AREA	1A3biv	CH4	20.0	11.4	5.00	40.0	40.3	0.01	0.00	0.00	-0.01	0.01	0.01
Energy	Fuel Combustion Activities	Railways	S	AREA	1A3c	CH4	0.0	0.0	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Railways	L	AREA	1A3c	CH4	0.2	0.1	5.00	40.0	40.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International Marine (C)	L ResO	AREA	1A3di	CH4	0.4	0.4	51.22	100.0	112.4	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International Marine (C)	L GasD	AREA	1A3di	CH4	0.2	0.2	51.22	100.0	112.4	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	National Navigation	L ResO	AREA	1A3dii	CH4	0.1	0.1	51.22	100.0	112.4	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	National Navigation	L GasD	AREA	1A3dii	CH4	0.0	0.0	51.22	100.0	112.4	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Commercial / Institutional	L	AREA	1A4a	CH4	0.9	4.2	10.00	150.0	150.3	0.01	0.00	0.00	0.01	0.01	0.02
Energy	Fuel Combustion Activities	Commercial / Institutional	G	AREA	1A4a	CH4	0.0	0.2	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Commercial / Institutional	B	AREA	1A4a	CH4	0.0	0.0	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Residential	L	AREA	1A4b	CH4	0.9	1.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Residential	G	AREA	1A4b	CH4	0.0	0.4	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Residential	B	AREA	1A4b	CH4	343.5	309.2	60.00	150.0	161.6	0.61	0.00	0.00	-0.32	1.03	1.08
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	L	AREA	1A4ci	CH4	0.1	0.1	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	G	AREA	1A4ci	CH4	0.0	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	B	AREA	1A4ci	CH4	0.0	0.0	60.00	150.0	161.6	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Off-Road Vehicles And Other Machinery- Agriculture/ Forestry	L	AREA	1A4cii	CH4	2.4	1.3	81.40	40.0	90.7	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Fishing- Stationary	L	AREA	1A4ciii	CH4	0.0	0.2	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Fishing- Mobile	L	AREA	1A4ciii	CH4	0.6	0.3	10.00	100.0	100.5	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Stationary- (Other)	S	AREA	1A5	CH4	0.2	0.0	10.00	150.0	150.3	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fugitive Emissions From Fuels	Underground Mines- Solid Fuels	-	LPS	1B1ai	CH4	65.2	0.0	5.00	100.0	100.1	0.00	0.00	0.00	-0.13	0.00	0.13
Energy	Fugitive Emissions From Fuels	Surface Mines- Solid Fuels	-	LPS	1B1aii	CH4	0.9	0.0	5.00	200.0	200.1	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fugitive Emissions From Fuels	Transport- Oil	-	AREA	1B2aiii	CH4	13.2	16.0	3.00	100.0	100.0	0.02	0.00	0.00	0.00	0.04	0.04
Energy	Fugitive Emissions From Fuels	Refining/ Storage- Oil	-	AREA	1B2aiiv	CH4	22.0	26.7	3.00	100.0	100.0	0.03	0.00	0.00	0.00	0.06	0.06
Energy	Fugitive Emissions From Fuels	Transmission/ Distribution- Natural Gas	G	AREA	1B2bii	CH4	0.0	372.9	10.00	150.0	150.3	0.69	0.01	0.01	0.88	1.25	1.53
Energy	Fugitive Emissions From Fuels	Oil- Oil & Ng	-	AREA	1B2ci	CH4	0.0	0.0	3.00	100.0	100.0	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Mineral Products	Road Paving With Asphalt	-	AREA	2A6	CH4	0.8	1.8	30.92	0.0	30.9	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Ammonia Production	-	LPS	2B1	CH4	C	C	31.17	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Nitric Acid Production	-	LPS	2B2	CH4	C	C	1.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Adipic Acid Production	-	AREA	2B3	CH4	C	C	0.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Carbide Production	-	AREA	2B4	CH4	C	C	0.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ethylene	-	LPS	2B5bi	CH4	C	C	10.00	100.0	C	0.01	0.00	0.00	0.00	0.01	0.01
Industrial Processes	Chemical Industry	Other- * Butadiene	-	LPS	2B5bii	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene High Density	-	LPS	2B5bv	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene Low Density	-	LPS	2B5bvi	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polypropilene	-	LPS	2B5bvii	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Carbon Black	-	LPS	2B5bx	CH4	C	C	10.00	100.0	C	0.01	0.00	0.00	0.00	0.02	0.02
Industrial Processes	Chemical Industry	Other- * Sulphuric Acid	-	LPS	2B5ai	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Flaring In Chemical Industry	-	AREA	2B5bc	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ammonium Sulphate	-	LPS	2B5aii	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ammonium Nitrate	-	LPS	2B5aiii	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Npk Fertilizers	-	LPS	2B5aiiv	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Urea	-	LPS	2B5av	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Vinylchloride (Except 04.05.05)	-	AREA	2B5biv	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq	Current Year Emissions Gg CO2 eq	AD Unc. %	EF Unc. %	Comb. Unc. %	as % of total national emissions in year t %	Type A sens. %	Type B sens. %	Unc. in trend from EF unc. %	Unc. in trend from AD unc. %	Unc. in trend %
					A	B	C	D	E	F	G	H	I	J	K	L	M
Industrial Processes	Chemical Industry	Other- * Polyethylene Low Density	-	AREA	2B5bvi	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyvinylchloride	-	AREA	2B5bviii	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polypropylene	-	AREA	2B5bvii	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polystyrene	-	AREA	2B5bix	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Formaldehyde	-	AREA	2B5biii	CH4	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Phthalic Anhydride	-	LPS	2B5bxi	CH4	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Explosives	-	AREA	2B5bxii	CH4	C	C	48.61	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Rayon	-	AREA	3Ciiaa	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyamides	-	AREA	3Ciib	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyester	-	AREA	3Ciic	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyethylene	-	AREA	3Ciid	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polypropylene	-	AREA	3Ciie	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Pvc	-	AREA	3Ciif	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Acrylics	-	AREA	3Ciig	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Acrylonitrile	-	AREA	3Ciih	CH4	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Enteric Fermentation	Dairy	-	AREA	4A1a	CH4	786.2	797.8	6.05	20.0	20.9	0.20	0.00	0.01	-0.07	0.36	0.36
Agriculture	Enteric Fermentation	Non-Dairy	-	AREA	4A1b	CH4	1 028.2	1 313.0	6.49	20.0	21.0	0.34	0.00	0.02	0.00	0.59	0.59

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Agriculture	Enteric Fermentation	Sheep- Ewes	-	AREA	4A3a	CH4	411.4	514.2	83.57	20.0	85.9	0.54	0.00	0.01	-0.01	0.23	0.23
Agriculture	Enteric Fermentation	Sheep- Other Sheep	-	AREA	4A3b	CH4	148.3	181.8	83.57	20.0	85.9	0.19	0.00	0.00	0.00	0.08	0.08
Agriculture	Enteric Fermentation	Goats- Does	-	AREA	4A4a	CH4	104.9	69.9	19.10	20.0	27.7	0.02	0.00	0.00	-0.02	0.03	0.04
Agriculture	Enteric Fermentation	Goats- Other Goats	-	AREA	4A4b	CH4	10.6	7.6	19.10	20.0	27.7	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Enteric Fermentation	Horses	-	AREA	4A6	CH4	12.4	22.9	71.21	50.0	87.0	0.02	0.00	0.00	0.01	0.03	0.03
Agriculture	Enteric Fermentation	Mules And Asses	-	AREA	4A7	CH4	24.8	9.8	271.77	50.0	276.3	0.03	0.00	0.00	-0.02	0.01	0.02
Agriculture	Enteric Fermentation	Swine- Sows	-	AREA	4A8a	CH4	17.7	16.1	10.96	20.0	22.8	0.00	0.00	0.00	0.00	0.01	0.01
Agriculture	Enteric Fermentation	Swine- Other Swine	-	AREA	4A8b	CH4	56.5	51.6	10.96	20.0	22.8	0.01	0.00	0.00	-0.01	0.02	0.02
Agriculture	Enteric Fermentation	Other- Rabbits	-	AREA	4A10e	CH4	20.9	27.6	770.65	20.0	770.9	0.26	0.00	0.00	0.00	0.01	0.01
Agriculture	Manure Management	Dairy	-	AREA	4B1a	CH4	19.2	30.5	6.05	60.6	60.9	0.02	0.00	0.00	0.01	0.04	0.04
Agriculture	Manure Management	Non-Dairy	-	AREA	4B1b	CH4	27.4	37.0	6.49	46.9	47.3	0.02	0.00	0.00	0.00	0.04	0.04
Agriculture	Manure Management	Sheep- Ewes	-	AREA	4B3a	CH4	17.8	22.1	83.57	59.3	102.5	0.03	0.00	0.00	0.00	0.03	0.03
Agriculture	Manure Management	Goats- Does	-	AREA	4B4a	CH4	3.7	2.4	19.10	58.4	61.4	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Manure Management	Horses	-	AREA	4B6	CH4	1.5	2.8	71.21	61.0	93.8	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Manure Management	Mules And Asses	-	AREA	4B7	CH4	2.7	1.0	271.77	61.0	278.5	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Manure Management	Swine- Sows	-	AREA	4B8a	CH4	1 087.0	1 035.1	10.96	91.0	91.7	1.16	-0.01	0.02	-0.52	2.10	2.16
Agriculture	Manure Management	Poultry- Broilers	-	AREA	4B9a	CH4	14.3	22.9	41.14	66.0	77.7	0.02	0.00	0.00	0.00	0.03	0.03
Agriculture	Manure Management	Poultry- Rabbits	-	AREA	4B9e	CH4	2.7	3.6	770.65	66.0	773.5	0.03	0.00	0.00	0.00	0.01	0.01
Agriculture	Rice Cultivation	Continuously Flooded	-	AREA	4C1	CH4	255.7	194.0	40.32	40.0	56.8	0.13	0.00	0.00	-0.09	0.17	0.19
Agriculture	Field Burning Of Agricultural Wastes	Cereals	-	AREA	4F1	CH4	1.5	1.1	100.00	20.0	102.0	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Field Burning Of Agricultural Wastes	Other	-	AREA	4F5	CH4	16.3	15.1	100.00	20.0	102.0	0.02	0.00	0.00	0.00	0.01	0.01
Waste	Solid Waste Disposal On Land	Managed Waste Disposal-Domestic	-	AREA	6A1	CH4	548.7	1 780.1	25.00	62.4	67.3	1.46	0.02	0.03	1.06	2.48	2.69
Waste	Solid Waste Disposal On Land	Unmanaged Waste Disposal-Domestic	-	AREA	6A2	CH4	1 290.6	1 161.4	25.00	86.0	89.6	1.27	-0.01	0.02	-0.68	2.23	2.33
Waste	Solid Waste Disposal On Land	Other (Industrial)- Managed	-	AREA	6A3a	CH4	0.0	880.6	136.19	62.4	149.8	1.61	0.01	0.01	0.87	1.23	1.50
Waste	Solid Waste Disposal On Land	Other (Industrial)- Unmanaged	-	AREA	6A3b	CH4	0.0	977.5	136.19	86.0	161.1	1.92	0.02	0.02	1.32	1.87	2.29
Waste	Wastewater Handling	Industrial Wastewater	-	AREA	6B1	CH4	1 632.2	1 556.3	22.99	30.1	37.9	0.72	-0.01	0.02	-0.26	1.04	1.08

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Waste	Wastewater Handling	Domestic And Commercial Wastewater	-	AREA	6B2	CH4	1 056.4	692.7	30.41	37.5	48.3	0.41	-0.01	0.01	-0.39	0.58	0.70
Waste	Waste Incineration	- Domestic	-	AREA	6C1	CH4	0.0	0.9	5.00	100.0	100.1	0.00	0.00	0.00	0.00	0.00	0.00
Waste	Other Waste		-	AREA	6D	CH4	0.0	0.0	0.00	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Public Electricity Generation	L	LPS	1A1a	N2O	15.3	6.3	1.00	1 000.0	000.0 ¹	0.08	0.00	0.00	-0.21	0.14	0.25
Energy	Fuel Combustion Activities	Public Electricity Generation	S	LPS	1A1a	N2O	36.2	56.7	1.00	1 000.0	000.0 ¹	0.69	0.00	0.00	0.16	1.26	1.27
Energy	Fuel Combustion Activities	Public Electricity Generation	G	LPS	1A1a	N2O	0.0	29.4	1.00	1 000.0	000.0 ¹	0.36	0.00	0.00	0.46	0.65	0.80
Energy	Fuel Combustion Activities	Public Electricity Generation	B	LPS	1A1a	N2O	0.0	2.8	1.00	1 000.0	000.0 ¹	0.03	0.00	0.00	0.04	0.06	0.08
Energy	Fuel Combustion Activities	Public Electricity Generation	L	AREA	1A1a	N2O	0.0	1.9	4.00	1 000.0	000.0 ¹	0.02	0.00	0.00	0.03	0.04	0.05
Energy	Fuel Combustion Activities	Petroleum Refining	L	LPS	1A1b	N2O	9.1	10.0	1.00	1 000.0	000.0 ¹	0.12	0.00	0.00	-0.03	0.22	0.22
Energy	Fuel Combustion Activities	Petroleum Refining	G	LPS	1A1b	N2O	0.0	0.1	1.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Manufacture Of Solid Fuels	S	LPS	1A1c	N2O	0.3	0.0	1.00	1 000.0	000.0 ¹	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Other Energy Industries	L	AREA	1A1cii	N2O	0.1	0.0	4.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	L	LPS	1A2a	N2O	0.4	0.2	3.00	1 000.0	000.0 ¹	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Iron And Steel	S	LPS	1A2a	N2O	0.8	0.0	3.00	1 000.0	000.0 ¹	0.00	0.00	0.00	-0.02	0.00	0.02
Energy	Fuel Combustion Activities	Iron And Steel	O	LPS	1A2a	N2O	0.0	0.0	3.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	L	AREA	1A2a	N2O	0.1	0.1	5.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Iron And Steel	G	AREA	1A2a	N2O	0.0	0.5	5.00	1 000.0	000.0 ¹	0.01	0.00	0.00	0.01	0.01	0.01
Energy	Fuel Combustion Activities	Chemicals	L	LPS	1A2c	N2O	5.0	5.8	3.00	1 000.0	000.0 ¹	0.07	0.00	0.00	-0.01	0.13	0.13
Energy	Fuel Combustion Activities	Chemicals	L	AREA	1A2c	N2O	1.4	1.5	5.00	1 000.0	000.0 ¹	0.02	0.00	0.00	-0.01	0.03	0.03
Energy	Fuel Combustion Activities	Chemicals	S	AREA	1A2c	N2O	0.1	0.1	5.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Chemicals	G	AREA	1A2c	N2O	0.0	3.0	5.00	1 000.0	000.0 ¹	0.04	0.00	0.00	0.05	0.07	0.08
Energy	Fuel Combustion Activities	Chemicals	B	AREA	1A2c	N2O	1.4	1.9	60.00	1 000.0	001.8 ¹	0.02	0.00	0.00	0.00	0.04	0.04
Energy	Fuel Combustion Activities	Chemicals	O	AREA	1A2c	N2O	0.4	0.6	5.00	1 000.0	000.0 ¹	0.01	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Pulp, Paper And Print	L	LPS	1A2d	N2O	1.0	1.8	3.00	1 000.0	000.0 ¹	0.02	0.00	0.00	0.01	0.04	0.04
Energy	Fuel Combustion Activities	Pulp, Paper And Print	G	LPS	1A2d	N2O	0.0	0.0	3.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Pulp, Paper And Print	B	LPS	1A2d	N2O	11.4	13.2	3.00	1 000.0	000.0 ¹	0.16	0.00	0.00	-0.02	0.29	0.30
Energy	Fuel Combustion Activities	Pulp, Paper And Print	L	AREA	1A2d	N2O	0.8	-0.4	5.00	1 000.0	000.0 ¹	-0.01	0.00	0.00	-0.02	-0.01	0.02
Energy	Fuel Combustion Activities	Pulp, Paper And Print	G	AREA	1A2d	N2O	0.0	2.5	5.00	1 000.0	000.0 ¹	0.03	0.00	0.00	0.04	0.06	0.07
Energy	Fuel Combustion Activities	Pulp, Paper And Print	B	AREA	1A2d	N2O	0.0	3.6	60.00	1 000.0	001.8 ¹	0.04	0.00	0.00	0.06	0.08	0.10
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	L	AREA	1A2e	N2O	2.3	2.1	10.00	1 000.0	000.0 ¹	0.03	0.00	0.00	-0.01	0.05	0.05
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	S	AREA	1A2e	N2O	0.0	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	G	AREA	1A2e	N2O	0.0	1.9	10.00	1 000.0	000.0 ¹	0.02	0.00	0.00	0.03	0.04	0.05
Energy	Fuel Combustion Activities	Food Processing, Beverages And Tobacco	B	AREA	1A2e	N2O	5.3	4.9	60.00	1 000.0	001.8 ¹	0.06	0.00	0.00	-0.03	0.11	0.11
Energy	Fuel Combustion Activities	Other- Textile	L	AREA	1A2fi	N2O	2.0	1.6	10.00	1 000.0	000.0 ¹	0.02	0.00	0.00	-0.02	0.03	0.04
Energy	Fuel Combustion Activities	Other- Textile	G	AREA	1A2fi	N2O	0.0	3.4	10.00	1 000.0	000.0 ¹	0.04	0.00	0.00	0.05	0.08	0.09
Energy	Fuel Combustion Activities	Other- Textile	B	AREA	1A2fi	N2O	1.5	2.9	60.00	1 000.0	001.8 ¹	0.04	0.00	0.00	0.02	0.06	0.07
Energy	Fuel Combustion Activities	Other- Ceramic	L	AREA	1A2fii	N2O	3.3	0.6	5.00	1 000.0	000.0 ¹	0.01	0.00	0.00	-0.06	0.01	0.06
Energy	Fuel Combustion Activities	Other- Ceramic	S	AREA	1A2fii	N2O	0.0	0.0	5.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Ceramic	G	AREA	1A2fii	N2O	0.0	6.9	5.00	1 000.0	000.0 ¹	0.08	0.00	0.00	0.11	0.15	0.19
Energy	Fuel Combustion Activities	Other- Ceramic	B	AREA	1A2fii	N2O	16.6	18.7	60.00	1 000.0	001.8 ¹	0.23	0.00	0.00	-0.04	0.42	0.42
Energy	Fuel Combustion Activities	Other- Glass	L	AREA	1A2fiii	N2O	1.3	0.4	5.00	1 000.0	000.0 ¹	0.00	0.00	0.00	-0.02	0.01	0.02
Energy	Fuel Combustion Activities	Other- Glass	G	AREA	1A2fiii	N2O	0.0	3.0	5.00	1 000.0	000.0 ¹	0.04	0.00	0.00	0.05	0.07	0.08
Energy	Fuel Combustion Activities	Other- Glass	B	AREA	1A2fiii	N2O	0.0	0.0	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cement	L	LPS	1A2fiv	N2O	0.2	3.3	3.00	1 000.0	000.0 ¹	0.04	0.00	0.00	0.05	0.07	0.09
Energy	Fuel Combustion Activities	Other- Cement	S	LPS	1A2fiv	N2O	4.5	1.2	3.00	1 000.0	000.0 ¹	0.01	0.00	0.00	-0.07	0.03	0.08
Energy	Fuel Combustion Activities	Other- Cement	O	LPS	1A2fiv	N2O	0.0	0.1	3.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cloth	L	AREA	1A2fv	N2O	0.2	0.2	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cloth	G	AREA	1A2fv	N2O	0.0	0.2	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.01
Energy	Fuel Combustion Activities	Other- Cloth	B	AREA	1A2fv	N2O	0.4	0.0	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Other- Wood	L	AREA	1A2fvi	N2O	0.4	0.6	10.00	1 000.0	000.0 ¹	0.01	0.00	0.00	0.00	0.01	0.01

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Other- Wood	G	AREA	1A2fvi	N2O	0.0	0.2	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Other- Wood	B	AREA	1A2fvi	N2O	1.7	2.3	60.00	1 000.0	001.8 ¹	0.03	0.00	0.00	0.00	0.05	0.05
Energy	Fuel Combustion Activities	Other- Rubber	L	AREA	1A2fvii	N2O	0.1	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	G	AREA	1A2fvii	N2O	0.0	0.2	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Rubber	B	AREA	1A2fvii	N2O	0.1	0.0	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	L	AREA	1A2fviii	N2O	1.3	0.9	10.00	1 000.0	000.0 ¹	0.01	0.00	0.00	-0.01	0.02	0.02
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	S	AREA	1A2fviii	N2O	0.1	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	G	AREA	1A2fviii	N2O	0.0	1.2	10.00	1 000.0	000.0 ¹	0.01	0.00	0.00	0.02	0.03	0.03
Energy	Fuel Combustion Activities	Other- Metal Equipment And Machines	B	AREA	1A2fviii	N2O	0.2	0.3	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	L	AREA	1A2fc	N2O	0.4	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	-0.01	0.00	0.01
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	S	AREA	1A2fc	N2O	0.0	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	G	AREA	1A2fc	N2O	0.0	0.1	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Other Transformation Industries	B	AREA	1A2fc	N2O	0.0	0.0	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Extractive Industry	L	AREA	1A2fix	N2O	0.2	0.4	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Other- Extractive Industry	G	AREA	1A2fix	N2O	0.0	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Other- Cop	L	AREA	1A2fx	N2O	1.3	2.4	10.00	1 000.0	000.0 ¹	0.03	0.00	0.00	0.01	0.05	0.05
Energy	Fuel Combustion Activities	Other- Cop	G	AREA	1A2fx	N2O	0.0	0.1	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Lto	L AvG	AREA	1A3ai	N2O	0.0	0.0	48.88	1 000.0	001.2 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Lto	L JeK	AREA	1A3ai	N2O	1.2	2.2	97.76	1 000.0	004.8 ¹	0.03	0.00	0.00	0.01	0.05	0.05
Energy	Fuel Combustion Activities	International (C)- Cruise	L AvG	AREA	1A3ai	N2O	0.0	0.0	49.72	1 000.0	001.2 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	International (C)- Cruise	L JeK	AREA	1A3ai	N2O	11.2	19.1	99.43	1 000.0	004.9 ¹	0.23	0.00	0.00	0.07	0.42	0.43
Energy	Fuel Combustion Activities	Domestic- Lto	L AvG	AREA	1A3aii	N2O	0.0	0.0	48.88	1 000.0	001.2 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Lto	L JeK	AREA	1A3aii	N2O	0.7	1.0	97.76	1 000.0	004.8 ¹	0.01	0.00	0.00	0.00	0.02	0.02
Energy	Fuel Combustion Activities	Domestic- Cruise	L AvG	AREA	1A3aii	N2O	0.0	0.0	49.72	1 000.0	001.2 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Domestic- Cruise	L JeK	AREA	1A3aii	N2O	0.8	2.5	99.43	1 000.0	004.9 ¹	0.03	0.00	0.00	0.02	0.06	0.06

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Energy	Fuel Combustion Activities	Cars	L Gas	AREA	1A3bi	N2O	30.9	237.8	5.00	50.0	50.2	0.15	0.00	0.00	0.16	0.26	0.31
Energy	Fuel Combustion Activities	Cars	L DiesO	AREA	1A3bi	N2O	11.3	98.3	5.00	50.0	50.2	0.06	0.00	0.00	0.07	0.11	0.13
Energy	Fuel Combustion Activities	Light Duty Trucks	L DiesO	AREA	1A3bii	N2O	60.6	136.1	5.00	50.0	50.2	0.08	0.00	0.00	0.05	0.15	0.16
Energy	Fuel Combustion Activities	Light Duty Trucks	L DiesO	AREA	1A3bii	N2O	0.0	0.3	5.00	50.0	50.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Heavy Duty Trucks And Buses	L DiesO	AREA	1A3biii	N2O	33.2	89.0	5.00	50.0	50.2	0.05	0.00	0.00	0.04	0.10	0.11
Energy	Fuel Combustion Activities	Motorcycles	L Gas	AREA	1A3biv	N2O	1.3	0.8	5.00	50.0	50.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Railways	S	AREA	1A3c	N2O	0.0	0.0	5.00	50.0	50.2	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Railways	L	AREA	1A3c	N2O	11.3	5.6	5.00	50.0	50.2	0.00	0.00	0.00	-0.01	0.01	0.01
Energy	Fuel Combustion Activities	International Marine (C)	L ResO	AREA	1A3di	N2O	10.2	10.6	51.22	1 000.0	001.3 ¹	0.13	0.00	0.00	-0.04	0.24	0.24
Energy	Fuel Combustion Activities	International Marine (C)	L GasD	AREA	1A3di	N2O	3.9	4.0	51.22	1 000.0	001.3 ¹	0.05	0.00	0.00	-0.02	0.09	0.09
Energy	Fuel Combustion Activities	National Navigation	L ResO	AREA	1A3dii	N2O	1.4	1.2	51.22	1 000.0	001.3 ¹	0.01	0.00	0.00	-0.01	0.03	0.03
Energy	Fuel Combustion Activities	National Navigation	L GasD	AREA	1A3dii	N2O	0.5	0.5	51.22	1 000.0	001.3 ¹	0.01	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Commercial / Institutional	L	AREA	1A4a	N2O	2.3	9.5	10.00	1 000.0	000.0 ¹	0.12	0.00	0.00	0.10	0.21	0.23
Energy	Fuel Combustion Activities	Commercial / Institutional	G	AREA	1A4a	N2O	0.0	2.6	10.00	1 000.0	000.0 ¹	0.03	0.00	0.00	0.04	0.06	0.07
Energy	Fuel Combustion Activities	Commercial / Institutional	B	AREA	1A4a	N2O	0.0	0.0	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Residential	L	AREA	1A4b	N2O	11.2	13.1	10.00	1 000.0	000.0 ¹	0.16	0.00	0.00	-0.02	0.29	0.29
Energy	Fuel Combustion Activities	Residential	B	AREA	1A4b	N2O	72.7	65.4	60.00	1 000.0	001.8 ¹	0.80	0.00	0.00	-0.44	1.46	1.52
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	L	AREA	1A4ci	N2O	0.3	0.4	10.00	1 000.0	000.0 ¹	0.01	0.00	0.00	0.00	0.01	0.01
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	G	AREA	1A4ci	N2O	0.0	0.1	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Stationary- Agriculture/ Forestry	B	AREA	1A4ci	N2O	0.0	0.1	60.00	1 000.0	001.8 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Off-Road Vehicles And Other Machinery- Agriculture/ Forestry	L	AREA	1A4cii	N2O	147.2	78.9	81.40	50.0	95.5	0.09	0.00	0.00	-0.09	0.09	0.12
Energy	Fuel Combustion Activities	Fishing- Stationary	L	AREA	1A4ciii	N2O	0.0	0.3	10.00	50.0	51.0	0.00	0.00	0.00	0.00	0.00	0.00
Energy	Fuel Combustion Activities	Fishing- Mobile	L	AREA	1A4ciii	N2O	3.1	1.4	10.00	1 000.0	000.0 ¹	0.02	0.00	0.00	-0.04	0.03	0.05
Energy	Fuel Combustion Activities	Stationary- (Other)	S	AREA	1A5	N2O	0.0	0.0	10.00	1 000.0	000.0 ¹	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Ammonia Production	-	LPS	2B1	N2O	C	C	31.17	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq	Current Year Emissions Gg CO2 eq	AD Unc. %	EF Unc. %	Comb. Unc. %	as % of total national emissions in year t %	Type A sens. %	Type B sens. %	Unc. in trend from EF unc. %	Unc. in trend from AD unc. %	Unc. in trend %
					A	B	C	D	E	F	G	H	I	J	K	L	M
Industrial Processes	Chemical Industry	Nitric Acid Production	-	LPS	2B2	N2O	C	C	1.00	10.0	C	0.07	0.00	0.01	-0.02	0.13	0.14
Industrial Processes	Chemical Industry	Adipic Acid Production	-	AREA	2B3	N2O	C	C	0.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Carbide Production	-	AREA	2B4	N2O	C	C	0.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ethylene	-	LPS	2B5bi	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Butadiene	-	LPS	2B5bii	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene High Density	-	LPS	2B5bv	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene Low Density	-	LPS	2B5bvi	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polypropilene	-	LPS	2B5bvii	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Carbon Black	-	LPS	2B5bx	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Sulphuric Acid	-	LPS	2B5ai	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Flaring In Chemical Industry	-	AREA	2B5bc	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ammonium Sulphate	-	LPS	2B5aii	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Ammonium Nitrate	-	LPS	2B5aiii	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Npk Fertilizers	-	LPS	2B5aiv	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Urea	-	LPS	2B5av	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Vinylchloride (Except 04.05.05)	-	AREA	2B5biv	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyethylene Low Density	-	AREA	2B5bvi	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polyvinylchloride	-	AREA	2B5bviii	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polypropylene	-	AREA	2B5bvii	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Polystyrene	-	AREA	2B5bix	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Formaldehyde	-	AREA	2B5biii	N2O	C	C	100.00	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Phthalic Anhydride	-	LPS	2B5bxi	N2O	C	C	10.00	100.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Chemical Industry	Other- * Explosives	-	AREA	2B5bxii	N2O	C	C	48.61	1 000.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Rayon	-	AREA	3Ciia	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq	Current Year Emissions Gg CO2 eq	AD Unc. %	EF Unc. %	Comb. Unc. %	as % of total national emissions in year t %	Type A sens. %	Type B sens. %	Unc. in trend from EF unc. %	Unc. in trend from AD unc. %	Unc. in trend %
					A	B	C	D	E	F	G	H	I	J	K	L	M
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyamides	-	AREA	3Ciib	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyester	-	AREA	3Ciic	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polyethylene	-	AREA	3Ciid	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Polypropylene	-	AREA	3Ciie	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Pvc	-	AREA	3Ciif	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Acrylics	-	AREA	3Ciig	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Solvent And Other Product Use	Chemical Products, Manufacture And Processing	- * Fibers: Acrylonitrile	-	AREA	3Ciih	N2O	C	C	100.00	0.0	C	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Manure Management	Anaerobic- Direct Emissions	-	AREA	4B10	N2O	7.9	7.7	37.52	100.0	106.8	0.01	0.00	0.00	0.00	0.02	0.02
Agriculture	Manure Management	Liquid Systems- Direct Emissions	-	AREA	4B11	N2O	7.4	7.2	37.51	100.0	106.8	0.01	0.00	0.00	0.00	0.02	0.02
Agriculture	Manure Management	Solid Storage And Dry Lot- Direct Emissions	-	AREA	4B12	N2O	548.1	562.3	38.98	100.0	107.3	0.74	0.00	0.01	-0.23	1.25	1.27
Agriculture	Agricultural Soils	- Synthetic Fertilizers. Direct Emissions	-	AREA	4D1a	N2O	841.8	942.0	14.04	500.0	500.2	5.76	0.00	0.01	-1.12	10.49	10.55
Agriculture	Agricultural Soils	- Synthetic Fertilizers. Indirect Emissions. Volatilization	-	AREA	4D1b	N2O	37.6	50.6	51.93	100.0	112.7	0.07	0.00	0.00	0.00	0.11	0.11
Agriculture	Agricultural Soils	- Synthetic Fertilizers. Indirect Emissions. Leaching And Runoff	-	AREA	4D1c	N2O	533.3	603.2	51.93	100.0	112.7	0.83	0.00	0.01	-0.13	1.34	1.35
Agriculture	Agricultural Soils	- Animal Wastes Applied To Soil. Direct Emissions	-	AREA	4D2a	N2O	337.6	339.1	107.32	500.0	511.4	2.12	0.00	0.01	-0.76	3.78	3.85
Agriculture	Agricultural Soils	- Animal Wastes Applied To Soil. Indirect Emissions. Volatilization	-	AREA	4D2b	N2O	62.6	63.0	118.39	100.0	155.0	0.12	0.00	0.00	-0.03	0.14	0.14
Agriculture	Agricultural Soils	- Animal Wastes Applied To Soil. Indirect Emissions. Leaching And Runoff	-	AREA	4D2c	N2O	249.5	250.7	118.39	100.0	155.0	0.47	0.00	0.00	-0.11	0.56	0.57
Agriculture	Agricultural Soils	- N-Fixing Crops	-	AREA	4D3a	N2O	49.6	25.2	25.00	141.4	143.6	0.04	0.00	0.00	-0.09	0.08	0.12

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Agriculture	Agricultural Soils	- Crop Residues	-	AREA	4D3b	N2O	153.0	141.6	25.00	141.4	143.6	0.25	0.00	0.00	-0.12	0.45	0.46
Agriculture	Agricultural Soils	- Pasture Range And Paddock. Direct Emissions	-	AREA	4D4a	N2O	623.3	689.7	38.98	500.0	501.5	4.23	0.00	0.01	-0.89	7.68	7.73
Agriculture	Agricultural Soils	- Pasture Range And Paddock. Indirect Emissions. Volatilization	-	AREA	4D4b	N2O	21.2	23.9	63.40	100.0	118.4	0.03	0.00	0.00	-0.01	0.05	0.05
Agriculture	Agricultural Soils	- Pasture Range And Paddock. Indirect Emissions. Leaching And Runoff	-	AREA	4D4c	N2O	233.7	258.6	63.40	100.0	118.4	0.37	0.00	0.00	-0.07	0.58	0.58
Agriculture	Agricultural Soils	- Manure Management. Volatilization	-	AREA	4D5a	N2O	81.8	84.3	63.40	100.0	118.4	0.12	0.00	0.00	-0.03	0.19	0.19
Agriculture	Field Burning Of Agricultural Wastes	Cereals	-	AREA	4F1	N2O	1.5	1.1	100.00	20.0	102.0	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	Field Burning Of Agricultural Wastes	Other	-	AREA	4F5	N2O	16.2	15.1	100.00	20.0	102.0	0.02	0.00	0.00	0.00	0.01	0.01
Waste	Wastewater Handling	Industrial Wastewater	-	AREA	6B1	N2O	183.5	227.9	22.99	1 000.0	000.3	2.79	0.00	0.00	-0.13	5.08	5.08
Waste	Wastewater Handling	Domestic And Commercial Wastewater	-	AREA	6B2	N2O	285.9	352.5	30.41	0.0	30.4	0.13	0.00	0.01	0.00	0.00	0.00
Waste	Waste Incineration	- Domestic	-	AREA	6C1	N2O	0.4	26.2	5.00	100.0	100.1	0.03	0.00	0.00	0.04	0.06	0.07
Waste	Other Waste		-	AREA	6D	N2O	0.0	1.2	0.00	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Domestic Refrigeration Assembly	-	AREA	2F1	F G	0.2	0.4	10.00	98.8	99.3	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Commercial Refrigeration Assembly	-	AREA	2F1	F G	0.0	2.4	10.00	217.9	218.1	0.01	0.00	0.00	0.01	0.01	0.01
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Stationary Ac Assembly	-	AREA	2F1	F G	0.0	12.7	20.00	108.2	110.0	0.02	0.00	0.00	0.02	0.03	0.04
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Domestic Refrigeration Operation	-	AREA	2F1	F G	0.2	1.4	15.00	99.4	100.6	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Commercial Refrigeration Operation	-	AREA	2F1	F G	0.0	75.7	30.00	335.5	336.9	0.31	0.00	0.00	0.40	0.57	0.69
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Stationary Ac Operation	-	AREA	2F1	F G	0.1	1.5	30.00	109.8	113.8	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Mac Assembly	-	AREA	2F1	F G	0.2	0.8	20.00	23.8	31.1	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Mac	-	AREA	2F1	F G	4.9	136.9	40.00	43.6	59.2	0.10	0.00	0.00	0.09	0.13	0.16

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Mac Disposal	-	AREA	2F1	F G	0.0	4.0	100.00	52.0	112.7	0.01	0.00	0.00	0.00	0.00	0.01
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Transport Refrigeration Assembly	-	AREA	2F1	F G	0.0	0.1	10.00	119.2	119.6	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Refrigeration And Air Conditioning Equipment * Transport Refrigeration Operation	-	AREA	2F1	F G	0.0	44.0	20.00	113.9	115.7	0.06	0.00	0.00	0.08	0.11	0.14
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Foam Blowing Blowing	-	AREA	2F2	F G	0.0	30.5	50.00	432.6	435.5	0.16	0.00	0.00	0.21	0.29	0.36
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Foam Blowing Leakage	-	AREA	2F2	F G	0.9	25.5	100.00	93.9	137.2	0.04	0.00	0.00	0.04	0.05	0.06
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Fire Extinguishers	-	AREA	2F3	F G	0.0	18.7	20.00	60.3	63.5	0.01	0.00	0.00	0.02	0.03	0.03
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Aerosols *Mdi	-	AREA	2F4	F G	0.0	0.2	500.00	0.0	500.0	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	Consumption Of Halocarbons And Sulphur Hexafluoride	Electric Equipment	-	AREA	2F7	F G	2.8	3.4	25.00	15.0	29.2	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	FF- LIVE Biomass	-	AREA	5A1.1	CO2	2 068.4	-3 895.8	0.72	39.6	39.6	1.88	-0.10	-0.06	-4.09	-3.43	5.34
LULUCF	Forest Land	FF- LIVE Biomass	-	AREA	5A1.2	CO2	4.5	4.5	12.95	27.1	30.0	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	CF- LIVE Biomass	-	AREA	5A2.1	CO2	-231.7	-231.7	15.10	42.4	45.0	0.13	0.00	0.00	0.04	-0.22	0.22
LULUCF	Forest Land	GF- LIVE Biomass	-	AREA	5A2.2	CO2	-49.2	-49.2	12.91	86.2	87.1	0.05	0.00	0.00	0.02	-0.09	0.10
LULUCF	Forest Land	SF- LIVE Biomass	-	AREA	5A2.4	CO2	-2.7	-2.7	20.41	23.4	31.1	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	OF- LIVE Biomass	-	AREA	5A2.5	CO2	-158.3	-158.3	12.67	45.3	47.0	0.09	0.00	0.00	0.03	-0.16	0.16
LULUCF	Cropland	CC- LIVE Biomass	-	AREA	5B1.1	CO2	-181.0	-181.0	13.94	53.0	54.8	0.12	0.00	0.00	0.04	-0.21	0.22
LULUCF	Cropland	FC- LIVE Biomass	-	AREA	5B2.1	CO2	122.5	122.5	30.20	41.8	51.6	0.08	0.00	0.00	-0.02	0.11	0.12
LULUCF	Cropland	GC- LIVE Biomass	-	AREA	5B2.2	CO2	-2.4	-2.4	13.43	91.9	92.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	WC- LIVE Biomass	-	AREA	5B2.3	CO2	-0.4	-0.4	36.60	37.8	52.6	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	SC- LIVE Biomass	-	AREA	5B2.4	CO2	0.0	0.0	53.36	39.5	66.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	OC- LIVE Biomass	-	AREA	5B2.5	CO2	13.4	13.4	16.01	55.3	57.6	0.01	0.00	0.00	0.00	0.02	0.02
LULUCF	Grazing Land	FG- LIVE Biomass	-	AREA	5C2.1	CO2	1.6	1.6	21.29	85.9	88.5	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
LULUCF	Grazing Land	CG- LIVE Biomass	-	AREA	5C2.2	CO2	0.4	0.4	13.38	91.9	92.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	WG- LIVE Biomass	-	AREA	5C2.3	CO2	-1.2	-1.2	13.79	84.0	85.1	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	SG- LIVE Biomass	-	AREA	5C2.4	CO2	-0.1	-0.1	21.22	84.8	87.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	OG- LIVE Biomass	-	AREA	5C2.5	CO2	1.3	1.3	18.45	93.2	95.0	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Wetland	FW- LIVE Biomass	-	AREA	5D2.1	CO2	12.2	12.2	20.51	19.2	28.1	0.00	0.00	0.00	0.00	0.01	0.01
LULUCF	Wetland	CW- LIVE Biomass	-	AREA	5D2.2	CO2	9.0	9.0	16.24	37.8	41.2	0.00	0.00	0.00	0.00	0.01	0.01
LULUCF	Wetland	GW- LIVE Biomass	-	AREA	5D2.3	CO2	0.7	0.7	16.82	84.0	85.7	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Wetland	OW- LIVE Biomass	-	AREA	5D2.5	CO2	3.9	3.9	19.08	41.0	45.2	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Settlements	SS- LIVE Biomass	-	AREA	5E1.1	CO2	2.3	2.3	14.89	17.7	23.1	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Settlements	FS- LIVE Biomass	-	AREA	5E2.1	CO2	226.6	226.6	26.43	22.3	34.6	0.10	0.00	0.00	-0.02	0.11	0.12
LULUCF	Settlements	CS- LIVE Biomass	-	AREA	5E2.2	CO2	89.1	89.1	26.97	39.5	47.9	0.05	0.00	0.00	-0.02	0.08	0.08
LULUCF	Settlements	GS- LIVE Biomass	-	AREA	5E2.3	CO2	3.9	3.9	14.18	84.8	86.0	0.00	0.00	0.00	0.00	0.01	0.01
LULUCF	Settlements	WS- LIVE Biomass	-	AREA	5E2.4	CO2	-0.1	-0.1	35.86	13.5	38.3	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Settlements	OS- LIVE Biomass	-	AREA	5E2.5	CO2	11.8	11.8	21.13	42.6	47.5	0.01	0.00	0.00	0.00	0.01	0.01
LULUCF	Otherland	OO- LIVE Biomass	-	AREA	5F1.1	CO2	-0.1	-0.1	20.34	57.6	61.1	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	FO- LIVE Biomass	-	AREA	5F2.1	CO2	71.1	71.1	12.59	44.7	46.5	0.04	0.00	0.00	-0.01	0.07	0.07
LULUCF	Otherland	CO- LIVE Biomass	-	AREA	5F2.2	CO2	-17.1	-17.1	14.36	55.3	57.2	0.01	0.00	0.00	0.00	-0.02	0.02
LULUCF	Otherland	GO- LIVE Biomass	-	AREA	5F2.3	CO2	-0.7	-0.7	15.72	93.2	94.5	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	WO- LIVE Biomass	-	AREA	5F2.4	CO2	-0.1	-0.1	32.00	41.0	52.0	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	SO- LIVE Biomass	-	AREA	5F2.5	CO2	-0.8	-0.8	12.50	42.6	44.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	FF- DOM (Dead Organic Matter)	-	AREA	5A1.2	CO2	7.9	7.9	12.95	28.5	31.3	0.00	0.00	0.00	0.00	0.01	0.01
LULUCF	Forest Land	CF- DOM (Dead Organic Matter)	-	AREA	5A2.1	CO2	0.1	0.1	15.10	25.5	29.7	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	OF- DOM (Dead Organic Matter)	-	AREA	5A2.5	CO2	28.1	28.1	12.67	36.1	38.3	0.01	0.00	0.00	0.00	0.02	0.02
LULUCF	Cropland	CC- DOM (Dead Organic Matter)	-	AREA	5B1.1	CO2	-14.5	-14.5	13.94	0.0	13.9	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	FC- DOM (Dead Organic Matter)	-	AREA	5B2.1	CO2	14.0	14.0	30.20	12.8	32.8	0.01	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	GC- DOM (Dead Organic Matter)	-	AREA	5B2.2	CO2	-1.1	-1.1	13.43	0.0	13.4	0.00	0.00	0.00	0.00	0.00	0.00

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
LULUCF	Cropland	SC- DOM (Dead Organic Matter)	-	AREA	5B2.4	CO2	0.0	0.0	53.36	0.0	53.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	OC- DOM (Dead Organic Matter)	-	AREA	5B2.5	CO2	-3.5	-3.5	16.01	25.5	30.1	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	FG- DOM (Dead Organic Matter)	-	AREA	5C2.1	CO2	0.2	0.2	21.29	12.8	24.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	CG- DOM (Dead Organic Matter)	-	AREA	5C2.2	CO2	0.0	0.0	13.38	0.0	13.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	OG- DOM (Dead Organic Matter)	-	AREA	5C2.5	CO2	0.2	0.2	18.45	25.5	31.5	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Wetland	FW- DOM (Dead Organic Matter)	-	AREA	5D2.1	CO2	1.1	1.1	20.51	12.8	24.2	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Wetland	CW- DOM (Dead Organic Matter)	-	AREA	5D2.2	CO2	0.0	0.0	16.24	0.0	16.2	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Wetland	OW- DOM (Dead Organic Matter)	-	AREA	5D2.5	CO2	0.3	0.3	19.08	25.5	31.9	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Settlements	FS- DOM (Dead Organic Matter)	-	AREA	5E2.1	CO2	22.1	22.1	26.43	12.8	29.4	0.01	0.00	0.00	0.00	0.01	0.01
LULUCF	Settlements	CS- DOM (Dead Organic Matter)	-	AREA	5E2.2	CO2	0.0	0.0	26.97	0.0	27.0	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Settlements	OS- DOM (Dead Organic Matter)	-	AREA	5E2.5	CO2	1.0	1.0	21.13	25.5	33.1	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	OO- DOM (Dead Organic Matter)	-	AREA	5F1.1	CO2	0.0	0.0	20.34	36.1	41.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	FO- DOM (Dead Organic Matter)	-	AREA	5F2.1	CO2	7.7	7.7	12.59	28.5	31.2	0.00	0.00	0.00	0.00	0.00	0.01
LULUCF	Otherland	CO- DOM (Dead Organic Matter)	-	AREA	5F2.2	CO2	-3.5	-3.5	14.36	25.5	29.3	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	GO- DOM (Dead Organic Matter)	-	AREA	5F2.3	CO2	-0.1	-0.1	15.72	25.5	30.0	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	WO- DOM (Dead Organic Matter)	-	AREA	5F2.4	CO2	0.0	0.0	32.00	25.5	40.9	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	SO- DOM (Dead Organic Matter)	-	AREA	5F2.5	CO2	-0.1	-0.1	12.50	25.5	28.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	FF- SOC (Soil Organic Carbon)	-	AREA	5A1.2	CO2	-3.2	-3.2	12.95	95.0	95.9	0.00	0.00	0.00	0.00	-0.01	0.01
LULUCF	Forest Land	CF- SOC (Soil Organic Carbon)	-	AREA	5A2.1	CO2	-105.0	-105.0	15.10	95.0	96.2	0.12	0.00	0.00	0.05	-0.22	0.23
LULUCF	Forest Land	GF- SOC (Soil Organic Carbon)	-	AREA	5A2.2	CO2	-1.4	-1.4	12.91	95.0	95.9	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	SF- SOC (Soil Organic Carbon)	-	AREA	5A2.4	CO2	-4.5	-4.5	20.41	95.0	97.2	0.01	0.00	0.00	0.00	-0.01	0.01
LULUCF	Forest Land	OF- SOC (Soil Organic Carbon)	-	AREA	5A2.5	CO2	0.0	0.0	12.67	95.0	95.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	CC- SOC (Soil Organic Carbon)	-	AREA	5B1.1	CO2	10.0	10.0	13.94	95.0	96.0	0.01	0.00	0.00	0.00	0.02	0.02
LULUCF	Cropland	FC- SOC (Soil Organic Carbon)	-	AREA	5B2.1	CO2	53.7	53.7	30.20	95.0	99.7	0.07	0.00	0.00	-0.02	0.11	0.12
LULUCF	Cropland	GC- SOC (Soil Organic Carbon)	-	AREA	5B2.2	CO2	82.9	82.9	13.43	95.0	95.9	0.10	0.00	0.00	-0.04	0.18	0.18

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions Gg CO2 eq C	Current Year Emissions Gg CO2 eq D	AD Unc. % E	EF Unc. % F	Comb. Unc. % G	as % of total national emissions in year t % H	Type A sens. % I	Type B sens. % J	Unc. in trend from EF unc. % K	Unc. in trend from AD unc. % L	Unc. in trend % M
LULUCF	Cropland	WC- SOC (Soil Organic Carbon)	-	AREA	5B2.3	CO2	-1.4	-1.4	36.60	95.0	101.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	SC- SOC (Soil Organic Carbon)	-	AREA	5B2.4	CO2	-0.2	-0.2	53.36	95.0	109.0	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Cropland	OC- SOC (Soil Organic Carbon)	-	AREA	5B2.5	CO2	16.6	16.6	16.01	95.0	96.3	0.02	0.00	0.00	-0.01	0.04	0.04
LULUCF	Grazing Land	FG- SOC (Soil Organic Carbon)	-	AREA	5C2.1	CO2	-0.3	-0.3	21.29	95.0	97.4	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	CG- SOC (Soil Organic Carbon)	-	AREA	5C2.2	CO2	-17.6	-17.6	13.38	95.0	95.9	0.02	0.00	0.00	0.01	-0.04	0.04
LULUCF	Grazing Land	WG- SOC (Soil Organic Carbon)	-	AREA	5C2.3	CO2	-5.4	-5.4	13.79	95.0	96.0	0.01	0.00	0.00	0.00	-0.01	0.01
LULUCF	Grazing Land	SG- SOC (Soil Organic Carbon)	-	AREA	5C2.4	CO2	-0.4	-0.4	21.22	95.0	97.3	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Grazing Land	OG- SOC (Soil Organic Carbon)	-	AREA	5C2.5	CO2	-0.1	-0.1	18.45	95.0	96.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Wetland	FW- SOC (Soil Organic Carbon)	-	AREA	5D2.1	CO2	17.7	17.7	20.51	95.0	97.2	0.02	0.00	0.00	-0.01	0.04	0.04
LULUCF	Wetland	CW- SOC (Soil Organic Carbon)	-	AREA	5D2.2	CO2	27.7	27.7	16.24	95.0	96.4	0.03	0.00	0.00	-0.01	0.06	0.06
LULUCF	Wetland	GW- SOC (Soil Organic Carbon)	-	AREA	5D2.3	CO2	3.3	3.3	16.82	95.0	96.5	0.00	0.00	0.00	0.00	0.01	0.01
LULUCF	Wetland	OW- SOC (Soil Organic Carbon)	-	AREA	5D2.5	CO2	6.3	6.3	19.08	95.0	96.9	0.01	0.00	0.00	0.00	0.01	0.01
LULUCF	Settlements	SS- SOC (Soil Organic Carbon)	-	AREA	5E1.1	CO2	2.7	2.7	14.89	95.0	96.2	0.00	0.00	0.00	0.00	0.01	0.01
LULUCF	Settlements	FS- SOC (Soil Organic Carbon)	-	AREA	5E2.1	CO2	270.3	270.3	26.43	95.0	98.6	0.33	0.00	0.00	-0.12	0.57	0.58
LULUCF	Settlements	CS- SOC (Soil Organic Carbon)	-	AREA	5E2.2	CO2	206.1	206.1	26.97	95.0	98.8	0.25	0.00	0.00	-0.09	0.44	0.45
LULUCF	Settlements	GS- SOC (Soil Organic Carbon)	-	AREA	5E2.3	CO2	18.4	18.4	14.18	95.0	96.1	0.02	0.00	0.00	-0.01	0.04	0.04
LULUCF	Settlements	WS- SOC (Soil Organic Carbon)	-	AREA	5E2.4	CO2	-0.4	-0.4	35.86	95.0	101.5	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Settlements	OS- SOC (Soil Organic Carbon)	-	AREA	5E2.5	CO2	18.5	18.5	21.13	95.0	97.3	0.02	0.00	0.00	-0.01	0.04	0.04
LULUCF	Otherland	OO- SOC (Soil Organic Carbon)	-	AREA	5F1.1	CO2	-0.1	-0.1	20.34	95.0	97.2	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	FO- SOC (Soil Organic Carbon)	-	AREA	5F2.1	CO2	0.0	0.0	12.59	95.0	95.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	CO- SOC (Soil Organic Carbon)	-	AREA	5F2.2	CO2	-14.9	-14.9	14.36	95.0	96.1	0.02	0.00	0.00	0.01	-0.03	0.03
LULUCF	Otherland	GO- SOC (Soil Organic Carbon)	-	AREA	5F2.3	CO2	0.0	0.0	15.72	95.0	96.3	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	WO- SOC (Soil Organic Carbon)	-	AREA	5F2.4	CO2	-0.5	-0.5	32.00	95.0	100.2	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Otherland	SO- SOC (Soil Organic Carbon)	-	AREA	5F2.4	CO2	-2.1	-2.1	12.50	95.0	95.8	0.00	0.00	0.00	0.00	0.00	0.00
LULUCF	Forest Land	FIRES- Forest Fires	-	AREA	5A1.3	CO2	736.5	476.0	30.00	92.6	97.4	0.57	-0.01	0.01	-0.69	0.98	1.20
LULUCF	Forest Land	FIRES- Forest Fires	-	AREA	5A1.3	CH4	153.6	109.5	30.00	70.0	76.2	0.10	0.00	0.00	-0.10	0.17	0.20

Sector	Category	Individual category	Fuel	Source Type	IPCC Cat	Gas	Base Year Emissions	Current Year Emissions	AD Unc.	EF Unc.	Comb. Unc.	as % of total national emissions in year t	Type A sens.	Type B sens.	Unc. in trend from EF unc.	Unc. in trend from AD unc.	Unc. in trend
							Gg CO2 eq	Gg CO2 eq	%	%	%	%	%	%	%	%	%
					A	B	C	D	E	F	G	H	I	J	K	L	M
LULUCF	Forest Land	FIRES- Forest Fires	-	AREA	5A1.3	N2O	15.6	11.1	30.00	70.0	76.2	0.01	0.00	0.00	-0.01	0.02	0.02