

**PORTUGUESE NATIONAL INVENTORY REPORT**

**ON GREENHOUSE GASES, 1990 - 2002**

Submitted under the United Nations Framework Convention on  
Climate Change

## **PORTUGUESE NATIONAL INVENTORY REPORT**

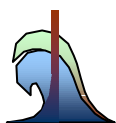
### **ON GREENHOUSE GASES, 1990 - 2002**

Submitted under the United Nations Framework Convention on  
Climate Change



Prepared by:

Vitor Gois Ferreira  
Teresa Costa Pereira  
Pedro Torres  
Tiago Seabra



**InventAr**  
Estudos e Projectos Unip Lda

13th August 2004

## **PREFACE**

The Institute for the Environment (Instituto do Ambiente)/ Ministry for the Environment and Land-Use Planning (Ministério do Ambiente e do Ordenamento do Território), 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 2004 NIR report refers to the 2004 Portuguese Submission on GHG data (CRF tables) sent to the UNFCCC in April 2004, and will serve as a basis for the in-depth review of the Portuguese inventories by the UNFCCC scheduled for the end of September of this year.

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.

Ministry for the Environment and Land-Use Planning  
Rua da Murgueira-Zambujal  
2720-865 Amadora  
PORTUGAL  
tel: +351.21.472.82.00  
fax: +351.21.471.90.74  
<http://www.iambiente.pt>

# TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY .....</b>	<b>i</b>
<b>Chapter: 1 - INTRODUCTION .....</b>	<b>1</b>
<i>1.1 Background Information .....</i>	<i>2</i>
Scope of GHG inventories.....	2
Global warming potentials.....	3
<i>1.2 Institutional arrangements and data sources for inventory preparation.....</i>	<i>4</i>
<i>1.3 Data archiving and documentation system.....</i>	<i>6</i>
<i>1.4 General overview of methodologies .....</i>	<i>7</i>
<i>1.5 Brief description of key source categories.....</i>	<i>7</i>
<i>1.6 Information on QA/QC and uncertainty assessment .....</i>	<i>8</i>
<i>1.7 Overview of the completeness.....</i>	<i>9</i>
<i>1.8 Future developments .....</i>	<i>9</i>
<b>Chapter: 2 TRENDS IN PORTUGUESE GHG EMISSIONS .....</b>	<b>11</b>
<i>2.1 Trends of Total Emissions .....</i>	<i>11</i>
<i>2.2 Trends by Gas.....</i>	<i>11</i>
<i>2.3 Trends by Sector.....</i>	<i>13</i>
<i>2.4 Indirect GHG and SO<sub>x</sub> emissions .....</i>	<i>15</i>
<b>Chapter: 3 Energy (CRF sector 1) .....</b>	<b>16</b>
<i>3.1 Overview.....</i>	<i>16</i>
Fuel Combustion Activities (CRF sector 1A).....	16
Fugitive Emissions from Fuels (CRF sector 1B).....	18
<i>3.2 Category sources .....</i>	<i>19</i>
3.2.A Energy Industries .....	19
3.2.A.1 Public Electricity and Heat Production (CRF 1A1a).....	19
3.2.A.2 Petroleum Refining (CRF 1A1b).....	29
3.2.A.3 Other Energy Industries (CRF 1A1c) .....	33

3.2.A.4 Manufacturing Industries and Construction (CRF 1A2).....	37
3.2.A.5 Transport (CRF 1A3).....	57
3.2.A.6 Other Sectors (CRF 1A4) .....	108
3.2.B Fugitive Emissions from Fossil Fuels (CRF 1B) .....	112
3.2.B.1 Fugitive Emissions from Solid Fuels (CRF 1B1) .....	112
3.2.B.2 Fugitive Emissions from Oil Production and Refining (CRF 1B2a) .....	114
3.2.B.3 Fugitive Emissions from Natural Gas (CRF 1B2b) .....	127
3.3 Recalculations .....	129
3.4 Further Improvements .....	133
<b>Chapter: 4 INDUSTRIAL PROCESSES (CRF sector 2) .....</b>	<b>135</b>
4.1 Overview.....	135
4.2 Category Sources.....	136
4.2.A Mineral Industry (CRF 2A) .....	136
4.2.A.1 Cement Production .....	136
4.2.A.2 Lime Production .....	139
4.2.A.3 Limestone, Dolomite and Carbonate Use .....	142
4.2.A.4 Road Paving with Asphalt .....	145
4.2.A.5 Glass Production .....	150
4.2.B Chemical Industry (CRF 2B) .....	153
4.2.B.1 Inorganic Chemistry and Fertilizers.....	153
4.2.B.2 Organic Chemical Industry .....	161
4.2.C Metal Production (CRF 2C).....	166
4.2.C.1 Iron and Steel Production.....	166
4.2.C.2 Ferroalloys Production.....	170
4.2.C.3 Aluminium Production.....	171
4.2.D Other Production (CRF 2D).....	171
4.2.D.1 Wood Chipboard Production .....	171
4.2.D.2 Food and Beverages.....	172

4.2.D.3 Paper pulp production.....	175
4.2.E Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2F) .....	177
4.2.E.1 Overview .....	177
4.2.E.2 General Methodology.....	178
4.2.E.3 Recalculation.....	179
4.2.E.4 Further Improvement .....	179
4.2.E.5 Domestic Refrigeration .....	180
4.2.E.6 Commercial Refrigeration.....	183
4.2.E.7 Transport Refrigeration.....	187
4.2.E.8 Stationary Air conditioning.....	188
4.2.E.9 Mobile Air Conditioning.....	191
4.2.E.10 Foam Blowing.....	194
4.2.E.11 Electric Equipment.....	196
4.2.E.12 Recalculations .....	198
<b>Chapter: 5 : Solvent and Other Product Use (CRF 3) .....</b>	<b>199</b>
5.1 Overview.....	199
5.2 Category Sectors .....	200
5.2.A Paint Application (CRF 3A) .....	200
5.2.B Degreasing and dry cleaning (CRF 3B).....	206
5.2.C Chemical products, manufacture and processing (CRF 3C) .....	208
5.2.C.1 Overview.....	208
5.2.C.2 Methodology .....	208
5.2.C.3 Polymer processing.....	209
5.2.C.4 Rubber processing.....	210
5.2.C.5 Paints Manufacturing .....	211
5.2.C.6 Inks Manufacturing.....	211
5.2.C.7 Glues Manufacturing .....	213
5.2.D Other use of solvents and related activities (CRF 3D).....	213

5.2.D.1 Overview .....	213
5.2.D.2 Printing .....	213
5.2.D.3 Edible and non edible oil extraction .....	218
5.2.D.4 Glues and adhesives.....	220
5.2.D.5 Wood Preservation.....	222
5.2.D.6 Perfumes and Cosmetics Use.....	222
5.2.D.7 Waxes and polishing products .....	224
5.2.D.8 Soaps and Detergents.....	224
5.2.D.9 Use of solvents from biomass.....	225
5.2.D.10 Other uses of synthetic solvents from fossil fuels.....	226
5.3 Recalculations .....	227
<b>Chapter: 6 Agriculture (CRF 4).....</b>	<b>228</b>
6.1 Overview.....	228
6.2 Source categories .....	231
6.2.A CH <sub>4</sub> Emissions from Enteric Fermentation in Domestic Livestock (CRF 4A).....	231
6.2.A.1 Overview .....	231
6.2.A.2 Methodology.....	231
6.2.A.3 Emission Factors.....	231
6.2.A.4 Activity Data.....	232
6.2.A.5 Recalculations.....	234
6.2.A.6 Further Improvements .....	235
6.2.B CH <sub>4</sub> Emissions from Manure Management (CRF 4B).....	236
6.2.B.1 Overview.....	236
6.2.B.2 Methodology .....	236
6.2.B.3 Emission Factors.....	237
6.2.B.4 Activity Data.....	240
6.2.B.5 Recalculations.....	240
6.2.B.6 Further Improvements.....	241

6.2.C CH <sub>4</sub> Emissions from Rice Cultivation (CRF 4C).....	242
6.2.C.1 Overview.....	242
6.2.C.2 Methodology.....	242
6.2.C.3 Emission Factors.....	243
6.2.C.4 Activity Data.....	244
6.2.C.5 Recalculations.....	244
6.2.C.6 Further Improvements.....	244
6.2.D N <sub>2</sub> O Emissions from Manure Management (CRF 4B) .....	244
6.2.D.1 Overview .....	244
6.2.D.2 Methodology.....	244
6.2.D.3 Emission Factors.....	245
6.2.D.4 Activity Data.....	246
6.2.D.5 Recalculations.....	248
6.2.D.6 Further Improvements .....	249
6.2.E Direct N <sub>2</sub> O Emissions from Agricultural Soil (CRF 4D1) .....	249
6.2.E.1 Overview .....	249
6.2.E.2 Methodology .....	251
6.2.E.3 Emission Factors .....	254
6.2.E.4 Activity Data .....	254
6.2.E.5 Recalculations .....	262
6.2.E.6 Further Improvements .....	262
6.2.F Indirect N <sub>2</sub> O Emissions from Agricultural Soils (CRF 4D2) .....	262
6.2.F.1 Overview .....	262
6.2.F.2 Methodology .....	263
6.2.F.3 Emission Factors .....	264
6.2.F.4 Activity Data .....	264
6.2.F.5 Recalculations .....	266
6.2.F.6 Further Improvements .....	266



6.2.G Field Burning of Agriculture Residues (CRF 4F).....	266
6.2.G.1 Overview .....	266
6.2.G.2 Methodology.....	267
6.2.G.3 Emission Factors.....	267
6.2.G.4 Activity data .....	269
6.2.G.5 Recalculations.....	270
6.2.G.6 Further improvements.....	270
6.2.H NH <sub>3</sub> Emissions from Volatilization of Fertilizers .....	270
6.2.H.1 Methodology.....	270
6.2.H.2 Emission Factors.....	272
6.2.H.3 Activity Data.....	273
6.2.H.4 Recalculations.....	273
6.2.H.5 Further Improvements .....	274
6.3 Recalculations .....	274
<b>Chapter: 7 Land-use Change and Forestry (LUCF) (CRF 5) .....</b>	<b>276</b>
7.1 Overview.....	276
7.2 Source categories .....	277
7.2.A Changes in forest and other woody biomass stocks (CRF 5 A).....	277
7.2.A.1 Methodology.....	277
7.2.A.2 Activity data and parameters .....	277
7.2.B Other: Forest Fires (CRF 5 E).....	281
7.2.B.1 Methodology.....	282
7.2.B.2 Activity data and parameters.....	282
7.3 Recalculations .....	285
7.4 Further improvements .....	287
<b>Chapter: 8 Waste (CRF 6) .....</b>	<b>288</b>
8.1 Overview.....	288
8.2 Source categories .....	291

8.2.A Solid Waste Disposal on Land (CRF 6 A).....	291
8.2.A.1 CH <sub>4</sub> emissions from Solid Waste Disposal Sites (SWDS).....	291
8.2.A.2 CO <sub>2</sub> emissions from Solid Waste Disposal Sites (SWDS) .....	298
8.2.A.3 NH <sub>3</sub> emissions from Solid Waste Disposal Sites (SWDS) .....	298
8.2.A.4 NH <sub>3</sub> emissions from Compost Production .....	298
8.2.B Wastewater Handling (CRF 6 B).....	299
8.2.B.1 Domestic Wastewater .....	299
8.2.B.2 Industrial Wastewater .....	306
8.2.C Waste Incineration (CRF 6 C) .....	306
8.2.C.1 CO <sub>2</sub> emissions .....	306
8.2.C.2 Non-CO <sub>2</sub> emissions .....	308
<i>8.3 Recalculations .....</i>	<i>309</i>
8.3.A Solid Waste Disposal on Land.....	310
8.3.B Wastewater Handling.....	311
8.3.C Waste Incineration .....	311
<i>8.4 Further improvements .....</i>	<i>311</i>
<i>8.5 Annex WASTE: Background Data Tables .....</i>	<i>312</i>
<b>Chapter: 9 NMVOC Biogenic Emissions .....</b>	<b>316</b>
9.1 Overview.....	316
9.2 Methodology.....	316
9.2.A Vegetation foliage.....	316
9.2.B Resin-tapping .....	317
9.3 Emission Factors.....	317
9.3.A Forest areas and permanent crops.....	317
9.3.B Other agricultural areas and grasslands.....	320
9.3.C Resin-tapping .....	321
9.4 Activity Data.....	321
9.5 Recalculations .....	325

<i>9.6 Further Improvements</i> .....	325
<b>List of Acronyms</b> .....	<b>326</b>
<b>Bibliography</b> .....	<b>331</b>
<b>Annex: Key Sources</b>	

## EXECUTIVE SUMMARY

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

By ratifying the United Nations Framework Convention on Climate Change (UNFCCC) on the 31st May of 1994, Portugal is committed 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.

The UNFCCC Guidelines require that Parties prepare a National Inventory Report (NIR) as one part of their annual submissions. The NIR should include references of 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 presents a description of the methods, assumptions and basic data used in the 2004 Portuguese inventory data submission. 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. However there are still many issues that need to be improved, and work is ongoing.

Since last submission, the Portuguese inventory has suffered substantial amendments and improvements, resulting mostly from the use of more detailed methodologies, which were revised to accommodate better country conditions, better underlying activity data, and better database storage and calculation structure. Important issues such as QA/QC procedures and the development of a QA/QC plan have not yet been tackled in this report, but are being developed under the work to establish a National System. Also, information on uncertainties quantification has not yet included, but it is also being developed. It is expected that the next inventory submission will present the first results of these works.

The report presents estimates for the 6 gaseous air pollutants included in Annex A to the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF<sub>6</sub>), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides (SO<sub>x</sub>). The period covered is 1990-2002.

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 (NH<sub>3</sub>) and Particulate Matter (PM, PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1.0</sub>)<sup>1</sup>. 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 these 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 2002, i.e., the inventory is internally consistent.

---

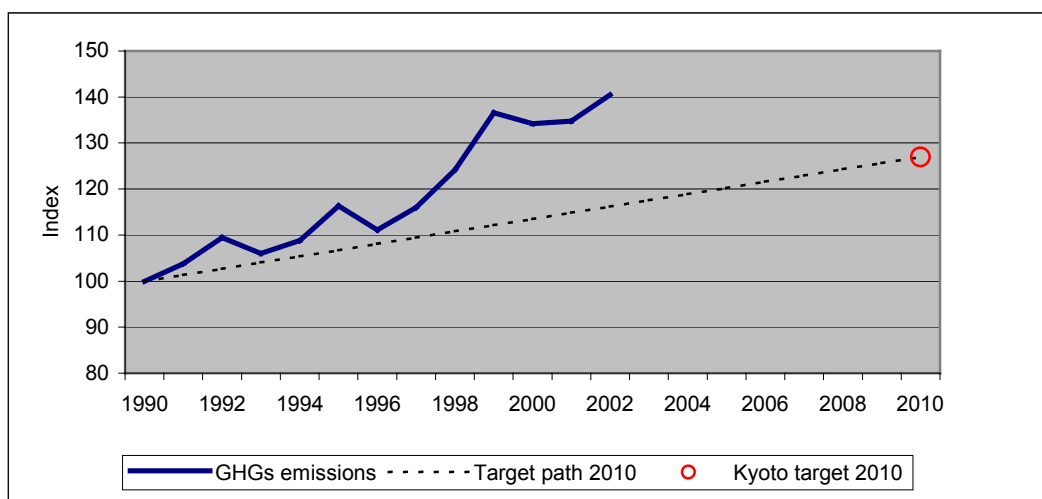
<sup>1</sup> The National Inventory includes, under CLRTAP, emission estimates of Heavy Metals. The methodology and emission factors are not included in the National Inventory Report yet.

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

Portuguese total GHG emissions without CO<sub>2</sub> from land-use change and forestry (LUCF) were estimated about 81.98 Mton CO<sub>2</sub>eq. in 2002, representing an increase of 40.5% compared to 1990 emission levels. Under the EU burden-sharing agreement, Portugal is bind to limit its emissions to +27% compared to the 1990 level. Comparing the 1990-2002 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2002, 24.3 % above this target path (Figure ES. 1).

Figure ES. 1 – GHG emissions 1990-2002 compared with target 2008-2012 (CO<sub>2</sub> from excluding LUCF)



Despite the positive effect in emissions levels of some measures, such as the introduction of natural gas (1998), 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.

The apparent decrease of annual growing rates of latest years (2000 and 2001) has been disrupted in 2002. This situation may reflect the pronounced fluctuations in hydroelectric power generation, which is highly dependent on annual variations in precipitation. The year 2002 corresponded to a dry year, having as a consequence a reduction in the quantities of hydroelectric power generated (hydro power in 2002 was approximately 43% lower than in 2001) and the consequent growth of emissions in 2002. The growth of GHG in the period 1990-2002 is shown in Figure ES. 2.

Figure ES. 2– Increase of emissions by gas over the 1990-2002 period

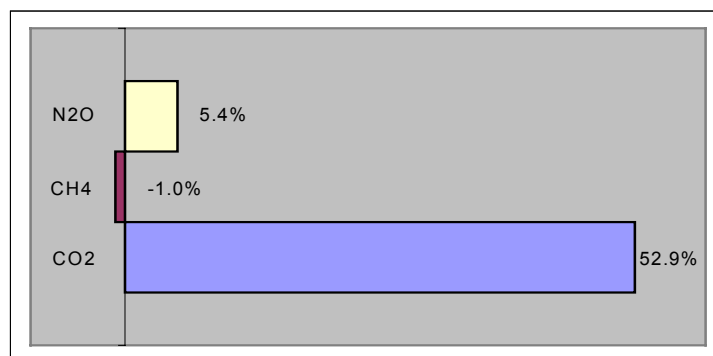
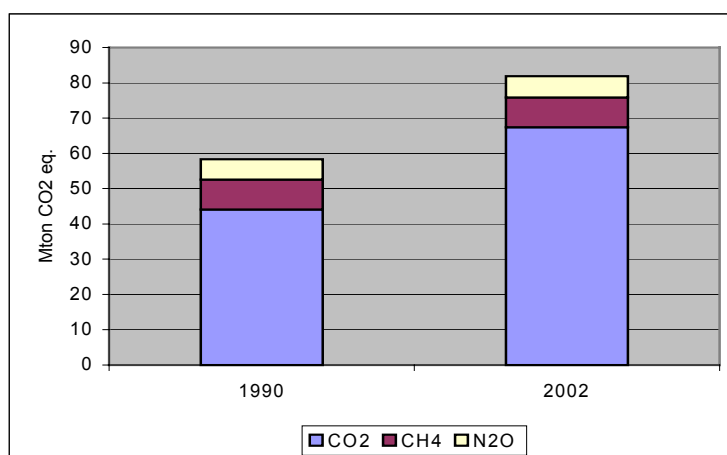


Figure ES. 3 illustrates the absolute contribution of each direct GHG to total national emissions for 1990 and 2002, showing CO<sub>2</sub> as the primary GHG, accounting for about 82.3% of Portuguese emissions on a carbon equivalent basis in 2002 (CO<sub>2</sub> from LUCF excl.). The second most important gas is CH<sub>4</sub>, followed by N<sub>2</sub>O, representing, respectively, about 10.2 % and 7.4 % of total emissions.

Figure ES. 3 – GHG emissions in Portugal by gas: 1990-2002 (F-gases and CO<sub>2</sub> from LUCF excl.)

Portugal has chosen 1995 as the base year for fluorinated gases. In 2002 these gases represented about 0.07% of total GHG emissions.

The overall trend for direct GHG emissions in the 1990-2002 period are presented in Table ES. 1.

Table ES. 1 – GHG emissions and removals in Portugal by gas: 1990-2002

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO <sub>2</sub> equivalent (Gg)												
Net CO <sub>2</sub> emissions/removals	49,703	50,332	53,186	51,313	51,626	54,392	50,545	53,424	56,795	63,999	62,593	63,484	65,858
CO <sub>2</sub> emissions (without LUCF)	44,130	46,009	50,139	48,546	49,792	53,518	50,564	53,531	57,900	64,433	63,843	64,365	67,464
CH <sub>4</sub>	8,450	8,812	8,262	8,005	8,170	8,645	8,420	8,421	8,789	9,016	8,584	8,226	8,365
N <sub>2</sub> O	5,782	5,755	5,469	5,312	5,542	5,727	5,841	5,744	5,782	6,224	5,870	6,012	6,097
HFCs	NE	NE	NE	NE	NE	0	0	1	6	12	24	37	49.05
PFCS	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF <sub>6</sub>	NE	NE	NE	NE	NE	5	5	5	5	6	6	7	7.00
<b>Total (with net CO<sub>2</sub> emis./removals)</b>	<b>63,935</b>	<b>64,899</b>	<b>66,916</b>	<b>64,631</b>	<b>65,338</b>	<b>68,769</b>	<b>64,810</b>	<b>67,595</b>	<b>71,377</b>	<b>79,257</b>	<b>77,076</b>	<b>77,765</b>	<b>80,376</b>
<b>Total (without CO<sub>2</sub> from LUCF)</b>	<b>58,362</b>	<b>60,576</b>	<b>63,870</b>	<b>61,863</b>	<b>63,504</b>	<b>67,895</b>	<b>64,830</b>	<b>67,702</b>	<b>72,483</b>	<b>79,692</b>	<b>78,327</b>	<b>78,646</b>	<b>81,982</b>

Throughout this report, the reference to “total emissions” is meant to refer to “total emissions without CO<sub>2</sub> from LUCF on a carbon equivalent basis”.

### 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. 1 and Figure ES. 5 present direct GHG emissions by sector for 1990 and 2002, respectively. Emissions have risen in almost all these sectors. The exception was agriculture, where the emissions have declined.

Figure ES. 4 – GHG emissions in Portugal by sector: 1990

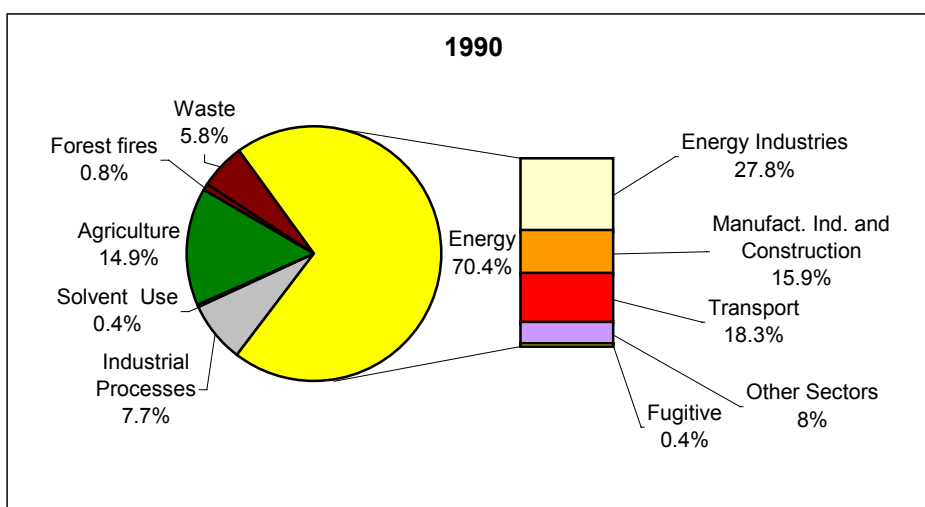
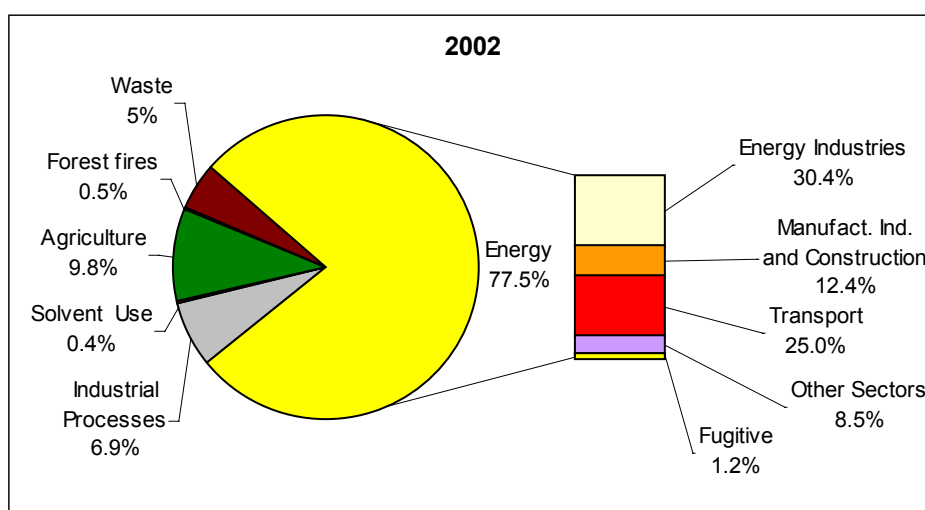


Figure ES. 5 – GHG emissions in Portugal by sector: 2002



Using this aggregated division, Energy was by far the most important sector, accounting for almost 78% of total emissions in 2002, and showing an increase of 55% over the 1990-2002 period. Transport (25% of total emissions in 2002) is, within the energy sector, the second most important source, appearing just after energy industries (30.4% of total emissions in 2002). 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 1990-2002 these emissions increased approximately 92%, 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.

Agriculture is the second most significant source of GHGs emissions (with almost 10% of total emissions) and is the only category showing a negative trend in the analysed period (-7.4%). Industrial processes and Waste represent, respectively, 6.9% and 4.9% of Portuguese emissions in 2002, recording an increase of approximately 26% (industrial processes) and 19% (waste). Use of solvent represents 0.4% of total emissions.

Revised estimates of emissions and sinks from land use change and forestry category, shows now this category as a net emitter in 1990 (6.1 Mt CO<sub>2</sub> eq.) and a carbon sink in 2002: estimated intake of 1.2 Mt CO<sub>2</sub> eq. .

Table ES. 1 presents the overall sectoral trend for direct GHG emissions in the 1990-2002 period.

Table ES. 2 – GHG emissions and removals in Portugal by sector: 1990-2002

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO <sub>2</sub> equivalent (Gg)												
1. Energy	41,093	43,010	47,384	45,773	46,393	49,522	46,878	49,221	53,299	60,589	59,710	59,947	63,549
2. Industrial Processes	4,479	4,427	4,195	4,030	4,838	5,555	5,301	5,951	6,157	5,816	5,619	6,072	5,651
3. Solvent and Other Product Use	222	236	244	236	253	256	276	286	291	286	293	305	313
4. Agriculture	8,711	8,641	8,182	7,919	8,075	8,062	8,116	8,002	8,112	8,300	8,110	8,098	8,068
5. Land-Use Change and Forestry <sup>(7)</sup>	6,058	5,089	3,289	2,913	1,916	1,409	167	-37	-755	-245	-832	-604	-1,208
6. Waste	3,371	3,494	3,622	3,760	3,862	3,965	4,073	4,173	4,273	4,511	4,175	3,948	4,003
7. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

## ES.4 Information on indirect GHG and SOx emissions

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

Table ES. 3 – Indirect GHG and SOx emissions: 1990-2002

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	(Gg)												
CO	1018.3	1135.2	966.2	918.9	882.2	1049.7	905.5	838.4	944.7	867.4	948.4	848.9	878.5
NO <sub>x</sub>	260.1	275.7	289.0	280.4	279.7	293.2	278.8	280.0	293.8	293.7	294.7	287.9	292.7
NM <sub>10</sub> VOC	303.9	333.5	349.1	322.6	328.4	344.3	340.3	340.8	353.3	343.8	343.3	335.2	341.8
SO <sub>2</sub>	322.9	307.7	374.6	320.9	299.3	334.7	273.7	293.7	342.4	343.3	312.3	295.0	295.2

In 2002 NO<sub>x</sub> and NMVOC emissions have increased from 1990 levels: NO<sub>x</sub> 12.6%, NMVOC 12.5%; CO and SO<sub>2</sub> emissions have decreased: CO -13.7% and SO<sub>2</sub> -8.6% (Table ES. 3).

Energy is the major responsible sector for emissions of NO<sub>x</sub>, SO<sub>x</sub>, CO and NMVOC. Industrial processes and Solvent use contribute also significantly for NMVOC emissions.

Within energy, transportation is responsible for the greatest share of CO, NO<sub>x</sub>, and NMVOC emissions, respectively 43%, 39% and 18% of 2002 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<sub>x</sub> emissions from transport



presented a 15% increase over the 1990-2002 period; NMVOC and CO recorded significant reductions, -28% and -18%, respectively.

SOx emissions are mainly generated in the energy industry sector (63% of total emissions in 2002) and combustion in manufacturing industries (23% of total emissions in 2002), 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. However the emissions variation in the period 1990-2002 shows a decrease in SOx emissions in both sub-categories: energy industries -7% and manufacturing industries -16%. These tendencies reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 of 10<sup>th</sup> November). The introduction of natural gas and the increase of its importance as energy source, since 1988, is also another positive factor.

## CHAPTER: 1 - INTRODUCTION

This report was prepared in order to comply with international commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the European Commission (EC). It presents a description of methods, assumptions and background data used in the preparation of the 2004 national inventory submission of GHG. Inventory data in CRF format were already sent previously (April 2004) to the EC and UNFCCC.

It was also envisaged that this report should serve the reporting requirements under the UNECE/CLRTAP in the near future. In this way it already includes data on other pollutants beyond GHGs.

Air emission inventories in Portugal were only initiated in the late ninety-eighties/ early nineties when the first estimates of NO<sub>x</sub>, SO<sub>x</sub> and VOC emissions from combustion were made under the development of the National Energetic Plan (PEN - Plano Energético Nacional), and emissions from combustion and industrial processes were made under OECD inventory and under CORINAIR85 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<sub>x</sub>, NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, CO, CO<sub>2</sub>, N<sub>2</sub>O and NH<sub>3</sub>) and emission sources covered, including not only combustion activities but also storage and distribution of fossil fuels, production processes, use of solvents, agriculture, urban and industrial wastes and nature (forest fires and NMVOC from forest). Information received under the Large Combustion Plant (LCP) directive was also much helpful to improve inventory quality and the individualization of Large Point Sources, as well as statistical information received from the National Statistical Institute (INE) allowing the full coverage of activity data for most emission sources. The CORINAIR90 Default Emission Factors Handbook (second edition), updating the first edition from Corinair85 was used extensively in the development of the current inventory and it was also a key point in the amelioration of the inventory.

The fulfilment of international compromises under conventions UNFCCC and CLRTAP, together with the publication of the IPCC Draft Guidelines for National Greenhouse Gas Inventories (IPPC, 1995) and latter of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), has result in substantial improvement of the methodologies that are used in the inventory, particularly for agriculture and wastes, and that were included at first time in the First National Communication in 1994. The inventory that resulted from CORINAIR90 (CEC,1992) and subsequent modifications from IPCC methodology still structures the present day methodology in what concerns activity data and methodology. Under the evaluation of the first communication the inventory was subjected to a review made by an international team. The second 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 of GHG 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 (1990-2002), 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 (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);
- Sectorial Studies and Proposal for a PTEN (National Plan on Emission Ceilings);
- PNALE (National Plan for Allocation of Emissions);
- Bilateral meetings (IA/UE) for the determination of the Baseline Scenario under the CAFE program (IA,2004).

Emission estimates of particulate matter (PM and fractions PM10, PM2.5 and PM1) and heavy metals were presented for the first time in submission 2004, under CLRTAP convention.

The report is structured generally in accordance with the UNFCCC Reporting Guidelines on Annual Inventories (SBSTA 2002). There are however some important issues that have not yet been treated in this report. Issues such as QA/QC procedures and the development of a QA/QC plan have not yet been considered in this report. Also, uncertainty quantification has not yet been totally accomplished. However work is ongoing under these issues and the next inventory submission is expected to present the first results of this work.

## 1.1 Background Information

### Scope of GHG inventories

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

Furthermore other atmospheric pollutants covered by the UNECE/CLRTAP Convention have been considered in the sectoral chapters. These are: NH<sub>3</sub> and Particulate Matter<sup>2</sup>.

Emissions are estimated for each civil year from 1990 to 2002. Emission estimates for 2002 are however preliminary for some source sectors and may suffer changes in next report when better information on activity data will be available.

---

<sup>2</sup> The National Inventory includes, under CLRTAP, emission estimates of Heavy Metals. The methodology and emission factors are not included in the National Inventory Report yet.

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 sinks from forestry.

The inventory comprehends only those emissions and sinks resulting from anthropogenic activity, although this classification may be controversial for some sources:

- NMVOC from all types of vegetation including forests, were estimated but not included in the UNFCCC inventory submission, because it was considered that these emissions would also occur from natural vegetation (although in different quantities because different species would exist), and also because CRF tables do not have any suitable place for these emissions to be reported. These emissions are however considered in the CLRTAP inventory submission;
- CO<sub>2</sub> from geothermal electric production. Emissions from this source were considered anthropogenic in the present inventory, although they had existed, at least partially, before being used in electricity production.

Estimates are grouped into six sector-specific categories, corresponding to the six large IPCC source categories: Energy (IPCC 1), Industrial Processes (IPCC 2), Solvent and Other Product Use (IPCC 3), Agriculture (IPCC 4), Land Use Change and Forestry (IPCC 5), and Waste (IPCC 6).

## Global warming potentials

A Global Warming Potential (GWP) is defined as the cumulative radiative forcing over a specified time horizon resulting from the emission of a unit mass of gas relative to some reference gas (IPCC, 1997). The reference gas used is CO<sub>2</sub>. The mass emission of each gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide (CO<sub>2</sub> equivalents – CO<sub>2</sub> 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 <sub>2</sub>	1
CH <sub>4</sub>	21
N <sub>2</sub> O	310
HFC	
HFC-23	11 700
HFC-32	650
HFC-41	150
HFC-43-10mee	1 300
HFC-125	2 800
HFC-134	1 000
HFC-134 <sup>a</sup>	1 300
HFC-152 <sup>a</sup>	140
HFC-143	300
HFC-143 <sup>a</sup>	3 800
HFC-227ea	2 900
HFC-236fa	6 300
HFC-245ca	560
PFC	
CF <sub>4</sub>	6 500
C <sub>2</sub> F <sub>6</sub>	9 200
SF <sub>6</sub>	23 900

## 1.2 Institutional arrangements and data sources for inventory preparation

The Institute for the Environment (Instituto do Ambiente - IA)/ Ministry for the Environment and Land-Use Planning (Ministério do Ambiente e do Ordenamento do Território), 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.

All emissions calculations have been performed at IA, while INVENTAR provides technical advice concerning all aspects of inventory development: methodologies, sources of information and emission factors. However many other institutions and agencies contributed to the inventory process, providing activity data, sectoral expert judgement, technical support and comments. Table 1.2 gives an overview of the institutions and data sources involved in the compilation of the Portuguese emission inventories.

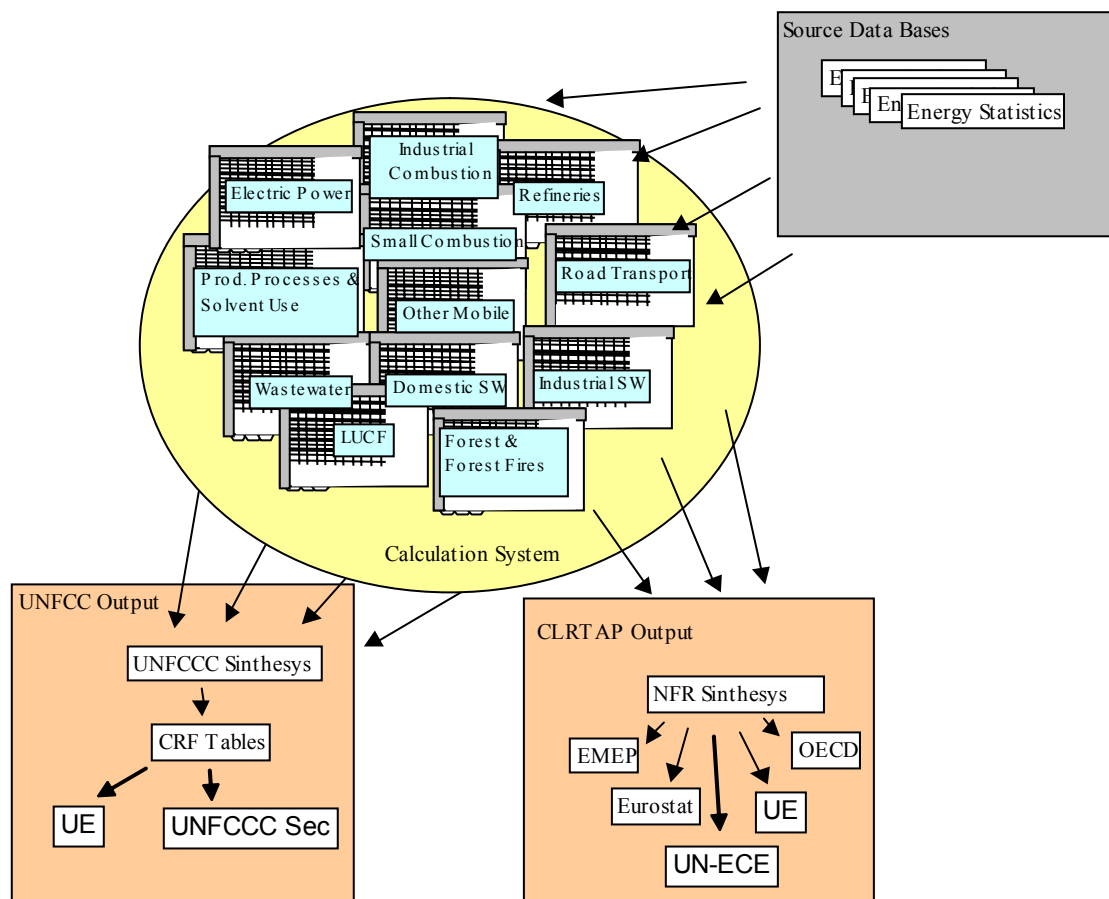
Table 1.2 – Inventory Institutional Arrangements and Data Sources

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

### 1.3 Data archiving and documentation system

All calculation and reporting rely in a set of different Excel spreadsheet workbooks which had been developed in order that all information and calculations occur automatically. The structure of the information system is outlined below.

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



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

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

Backup is done periodically by the system manager in accordance with the outlined procedures for the whole IA. 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

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.

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 <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		HFCs		PFCs		SF <sub>6</sub>	
	Meth.(1)	EF (2)	Meth.(1)	EF (2)	Meth.(1)	EF (2)	Meth.(1)	EF (2)	Meth.(1)	EF (2)	Meth.(1)	EF (2)
<b>1. Energy</b>												
A. Fuel Combustion												
1. Energy Industries	T2	D+C	T2	D+C	T2	D+C						
2. Manufacturing Industries and Construction	T2	D+C	T2	D+C	T2	D+C						
3. Transport	M	D+C	M	D+C+CS	M	D+C+CS						
4. Other Sectors	T2	D+C	T2	D+C	T2	D+C						
5. Other	T2	D+C	T2	D+C	T2	D+C						
B. Fugitive Emissions from Fuels												
1. Solid Fuels	MB	C	T2	D+C	T2							
2. Oil and Natural Gas	MB	C+PS	C+T2	D+C	C+T2							
<b>2. Industrial Processes</b>												
A. Mineral Products	D	D+C	D	D+C	D	D+C						
B. Chemical Industry	MB+D	D+C	D	D+C	D	D+C						
C. Metal Production	D	D+C	D	D+C	D	D+C						
D. Other Production	D	D+C										
E. Production of Halocarbons and SF <sub>6</sub>												
F. Consumption of Halocarbons and SF <sub>6</sub>							D	D+CS			D	CS
G. Other												
<b>3. Solvent and Other Product Use</b>	MB											
<b>4. Agriculture</b>												
A. Enteric Fermentation			T1	D+CS								
B. Manure Management			T2	D (CS)	T2	D (CS)						
C. Rice Cultivation			D	D (CS)								
D. Agricultural Soils					D	D						
E. Prescribed Burning of Savannas												
F. Field Burning of Agricultural Residues			D	D+C+CS	D	D+C+CS						
G. Other												
<b>5. Land-Use Change and Forestry</b>												
A. Changes in Forest and Other Woody Biomass Stocks	D	D+CS										
B. Forest and Grassland Conversion												
C. Abandonment of Managed Lands												
D. CO <sub>2</sub> Emissions and Removals from Soil												
E. Other	D	D	D	D	D	D						
<b>6. Waste</b>												
A. Solid Waste Disposal on Land	T2	D+CS	T2	D+CS								
B. Wastewater Handling			D	D+CS	D	D						
C. Waste Incineration	D	D+C	D	D+C	D	D+C						
D. Other												
<b>7. Other (please specify)</b>												

(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.

## 1.5 Brief description of key source categories

Key source analysis to the 2004 Portuguese inventory estimates (1990-2002) was conducted using a Tier 1 approach and a qualitative approach. Guidance from IPCC (2000) was followed, but the source category level adopted for the analysis does not match exactly the original list of source categories proposed by in table 7.1 in the IPCC Good Practice Guidance (IPCC,2000).



The analysis was carried according to the sectoral breakdown defined in the CRF (Common Report Format).

Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2002 period; and a qualitative criteria was applied to identify some additional sources that are recognised to be significantly uncertain and insufficiently covered.

The analysis resulted in the identification of 57 key sources that are listed in Table 1.4. These sources cover 97.5 % of total Portuguese GHG emissions for 2002.

Table 1.4 – Portuguese key source categories (1990-2002) based on Tier 1 approach

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Criteria for Identification	Comments	2002 emissions
					estimate (kton CO <sub>2</sub> eq.)
1A 1a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	Level Trend	All years	2448
1A 3 b Road Transportation	Diesel Oil	CO <sub>2</sub>	Level Trend	All years	2425
1A 3 b Road Transportation	Gasoline	CO <sub>2</sub>	Level Trend	All years	6633
1A 1a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	6565
1A 1a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	Level Trend	1998, 1999, 2000, 2001, 2002	3253
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	Level Trend	All years	3033
1A 2 f Other	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	2985
1A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	2552
1A 1b Petroleum refining	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	257
1A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	Level Trend	1998, 1999, 2000, 2001, 2002	2063
1A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	1959
2 B 1 Ammonia Production	Production Quantities	CO <sub>2</sub>	Level Trend	All years	1528
1A 2 c Chemicals	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	1365
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	1332
4 B 8 Swine	Population size	CH <sub>4</sub>	Level Trend	All years	1315
4 D 1 Direct Soil Emissions	Input to soils	N <sub>2</sub> O	Level Trend	All years	1195
4 D 3 Indirect Emissions	Input to soils	N <sub>2</sub> O	Level Trend	All years	1127
4 A 1b Non-Dairy Cattle	Population size	CH <sub>4</sub>	Level Trend	All years	1062
6 A 3 Other	Industrial Waste Disposal on Land	CH <sub>4</sub>	Level Trend	All years	1046
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N <sub>2</sub> O	Level Trend	All years	1013
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	949
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	Level Trend	All years	920
1A 2 f Other	Solid Fuels	CO <sub>2</sub>	Level Trend	All years	727
4 A 1a Dairy Cattle	Population size	CH <sub>4</sub>	Level Trend	All years	716
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	699
2 B 2 Nitric Acid Production	Production Quantities	N <sub>2</sub> O	Level Trend	All years	590
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	Level Trend	All years	581
4 A 3 Sheep	Population size	CH <sub>4</sub>	Level Trend	All years	581
4 D 2 Animal Production	Input to soils	N <sub>2</sub> O	Level Trend	All years	519
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO <sub>2</sub>	Level Trend	2001, 2002	488
1B 2 a iv Refining / Storage	Liquid Fuels	CO <sub>2</sub>	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002	433
6 C WASTE INCINERATION	Waste Incinerated	CO <sub>2</sub>	Level Trend	2000, 2001, 2002	380
1A 3 a ii Domestic	Jet Kerosene	CO <sub>2</sub>	Level	All years	375
5 E OTHER	Wildfires	CH <sub>4</sub>	Level Trend	1990, 1991, 1992, 1995, 1998, 2000, 2001, 2002	361
6 B 2 Domestic and Commercial wastewater	Wastewater	N <sub>2</sub> O	Level	All years	356
1A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	Level Trend	2000, 2001, 2002	345
1A 3 b Road Transportation	Diesel Oil	N <sub>2</sub> O	Level Trend	1998, 1999, 2000, 2001, 2002	324
1A 4 b Residential	Biomass	CH <sub>4</sub>	Level Trend	All years	302
1A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	Level Trend	2001, 2002	277
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	Level	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002	275
1B 2 b ii Transmission / Distribution	Gaseous Fuels	CH <sub>4</sub>	Level Trend	1999, 2001, 2002	254
2 A 7 Other	Production Quantities	CO <sub>2</sub>	Level	1999, 2000, 2001, 2002	231
1A 3 b Road Transportation	Gasoline	N <sub>2</sub> O	Level Trend	2000	228
1A 2 c Chemicals	Gaseous Fuels	CO <sub>2</sub>	Trend		219
6 B 1 Industrial Wastewater	Wastewater	CH <sub>4</sub>	Level	1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001	208
6 B 1 Industrial Wastewater	Wastewater	N <sub>2</sub> O	Level	1992, 1993, 1994, 1996, 1997, 1998, 1999, 2000	205
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO <sub>2</sub>	Trend		180
1B 2 d Other (Geothermal)	Energy Production	CO <sub>2</sub>	Trend		179
4 C 1 Irrigated	Culture Surface	CH <sub>4</sub>	Level Trend	1990, 1991, 1996, 1997, 1999, 2000	162
1A 3 d ii National navigation	Gas / Diesel Oil	CO <sub>2</sub>	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997	144
1A 3 c Railways	Liquid Fuels	CO <sub>2</sub>	Level Trend	1990, 1991	111
1A 2 a Iron and Steel	Liquid Fuels	CO <sub>2</sub>	Level	1993	108
1A 2 c Chemicals	Solid Fuels	CO <sub>2</sub>	Level	2000	59
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	Qual		31
2 F 2 Foam Blowing	Consumption	HFCs	Qual		19
2 F 7 Electrical Equipment	Consumption	SF <sub>6</sub>	Qual		7
1A 2 a Iron and Steel	Solid Fuels	CO <sub>2</sub>	Level	All years except 2002	0
Sub-Total		All gases			79962
% of Total		All gases			97.5
TOTAL EMISSIONS		All gases			81982

## 1.6 Information on QA/QC and uncertainty assessment

No formal quality assurance and quality control (QA/QC) procedures have been established so far to the National Inventory that could be, in strict terms, in accordance with the IPCC Good

Practice Guidance (IPCC,2000). In particular, a system of review procedures by personnel not directly involved in the inventory preparation that could be regarded as quality assurance has not been set up.

Nonetheless, the inventory compilation process includes a number of technical activities that can be considered as fundamental elements of quality control. Activities such as: accuracy checks on data acquired and estimated, the use of well documented emission estimations methodologies and emission factors, adequate information archiving and reporting with proper backup scheme, and comprehensive documentation of recalculations can be regarded as quality control procedures. These procedures assure calculation and reporting error detection and retrace of former estimates enabling a degree of confidence on final results. Also because results of the inventory are reported in at least two different format reports, CRF and NFR tables, and these tables are collected from original calculation system using different collection procedures, comparison of emissions and activity data attributed to each source leads to detection of reporting errors.

During the development of the Portuguese National Plan on Greenhouse Gas Emissions (PNAC) and the work for the establishment of a National Plan for Emission Ceiling (PTEN) extensive interaction has occurred among the team responsible for those plans, the sectoral institutional organisms (Ministry of Agriculture, DGRF, INR, DGGE) and also the economic sectors representatives (Electric sector, crude oil refineries, cement, paper pulp, inorganic and organic chemical industry, glass industry and ceramics). All these have been informed of basic methodologies, activity data and emission factors, and have been given the opportunity to comment. Some of these comments and additional information were used to improve the quality of the inventory.

Uncertainty quantification is under study and results using tier 1 analysis are expected by the end of the year. The only information available at the moment is qualitative and based on expert judgment. Table 1.5 shows the qualitative information available. It is planned that the next inventory submission already includes quantitative information on uncertainties.

## 1.7 Overview of the completeness

Table 1.5 gives an overview of the level of completeness of the 2004 submitted inventories to the UNFCCC and EC.

## 1.8 Future developments

The work under way for the establishment of the National Inventory System (SNIERPA) and the Methodological Development Plan (MDP), that is being developed under this context, is a fundamental instrument for the improvement of the inventory quality.

The formal start of the SNIERPA activities occurred at the very beginning of year 2004. Each sectoral institution was asked to make a critical analysis of the respective inventory sector. This work is considered to be a quality assurance procedure, in which experts not directly involved in the inventory compilation process will review the inventory, and will identify areas where further improvement is needed and possible. The contribution of each sectoral expert team to the MDP should be formalised by a final report containing the main findings concerning the methodology, activity levels data, and emission factors. These reports are expected by Autumn 2004, and it is planned that suggestions and comments will be included in the next inventory compilation as far as possible.

Work for the formal definition of a QA/QC Plan is at present under way in the framework of the establishment of the National Inventory System (SNIERPA). Therefore, general QC procedures (Tier 1) should already be applied in the next inventory exercise, according for the plan that is being defined. As far as possible, source category-specific QC procedures (Tier 2) will also be applied.

Table 1.5 – Summary of completeness (CRF overview table 7)

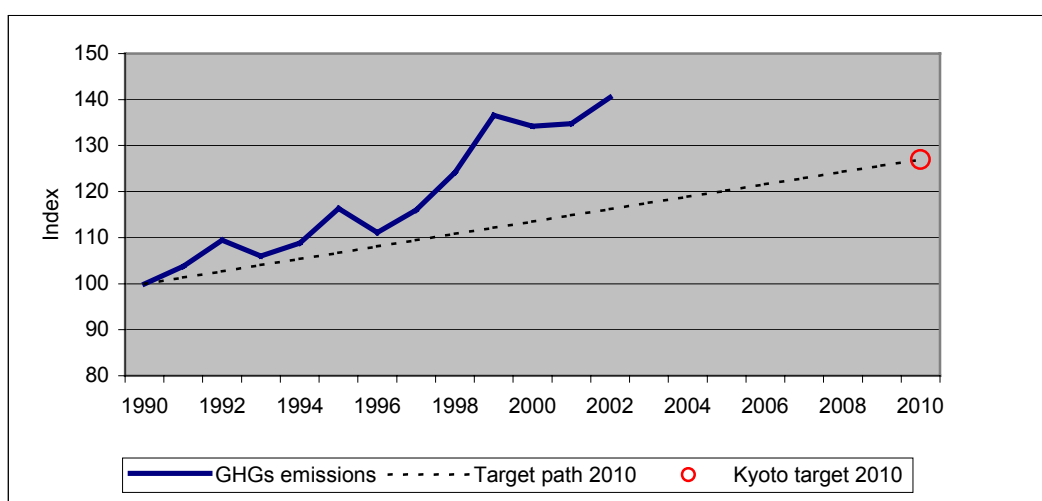
GHG GAS SOURCE AND SINK CATEGORIES	CO2		CH4		N2O		HFCs		PFCs		SF6		NOx		CO		NMVOC		SO2	
	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality
<b>1 Energy</b>																				
A. Fuel Combustion Activities																				
Reference Approach	All	H																		
Sectoral Approach																				
1. Energy Industries	All	H	All	M	All	L							All	H	All	M	All	M	All	H
2. Manufacturing Industries and Construction	All	H	All	M	All	L							All	M	All	M	All	M	All	H
3. Transport	All	H	All	H	All	H							All	H	All	H	All	H	All	H
4. Other Sectors	All	H	All	M	All	L							All	M	All	M	All	M	All	H
5. Other																				
B. Fugitive Emissions from Fuels																				
1. Solid Fuels	All	H	All	M	NE															
2. Oil and Natural Gas	All	H	All	M	NE								NE		NE		NE		NE	
<b>2 Industrial Processes</b>																				
A. Mineral Products	All	H																	All	M
B. Chemical Industry	All	H	All	M	All	M							All	M	Part	M	All	M	All	M
C. Metal Production	All	H	NE		NE				NO		NO		All	M	All	M	All	M	All	M
D. Other Production	All	H											All	H	All	M	All	M	All	H
E. Production of Halocarbons and SF6							NE		NE		NE									
F. Consumption of Halocarbons and SF6																				
Potential							NE				NE									
Actual							Part	L			All	H								
G. Other																				
<b>3 Solvent and Other Product Use</b>	All	M			NE												All	M		
<b>4 Agriculture</b>																				
Enteric Fermentation			All	M																
Manure Management			All	M	All	M											NE			
Rice Cultivation			All	M													NE			
Agricultural Soils	NE		NE		All	M											NE			
Prescribed Burning of Savannas			NO		NO								NO		NO		NO		NO	
Field Burning of Agricultural Residues			Part	M	Part	M							Part	L	Part	L	Part	L	Part	L
Other																				
<b>5 Land-Use Change and Forestry</b>																				
A. Changes in Forest and Other Woody Biomass Stocks	Part	M																		
B. Forest and Grassland Conversion	NE																			
C. Abandonment of Managed Lands	NE																			
D. CO2 Emissions and Removals from Soil	NE																			
E. Other	NE		All	M	All	M							All	M	All	M	All	M		
<b>6 Waste</b>																				
A. Solid Waste Disposal on Land	All	M	All	M											NE		All	L		
B. Wastewater Handling			All	M	All	L							NE		NE		All	L		
C. Waste Incineration	All	H	All	M	All	L							All	M	All	M	All	M	All	M
D. Other	All	M	All	M	All	M														
<b>7 Other (please specify)</b>																				
<b>Memo Items:</b>																				
<b>International Bunkers</b>																				
Aviation	All	H	All	M	All	M							All	M	All	M	All	M	All	H
Marine	All	H	All	M	All	M							All	M	All	M	All	M	All	H
<b>Multilateral Operations</b>																				
<b>CO2 Emissions from Biomass</b>	All	H																		

## CHAPTER: 2 TRENDS IN PORTUGUESE GHG EMISSIONS

### 2.1 Trends of Total Emissions

Portuguese total GHG emissions without CO<sub>2</sub> from land-use change and forestry (LUCF) were estimated about 81.98 Mton CO<sub>2</sub>eq. in 2002, representing an increase of 40.5% 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 1990-2002 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2002, 24.3 % above this target path (Figure 2.1).

Figure 2.1 – GHG emissions 1990-2002 compared with target 2008-2012 (CO<sub>2</sub> from LUCF excl.)



Despite the positive effect in emissions levels of some measures, such as the introduction of natural gas (1998), 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. The apparent decrease of annual growing rates of latest years (2000 and 2001) has been disrupted in 2002.

Apparent inconsistent variations in last years result, in fact, from the very marked fluctuations of hydroelectric power generation, which is highly dependent on annual variations in precipitation and availability of surface water resources. The fact that year 2002 was a dry year, that has caused reduction of the quantities of hydroelectric power generated (hydro power in 2002 was approximately 43% lower than in 2001), may explains the consequent growth of emissions in 2002.

### 2.2 Trends by Gas

Over the 1990-2002 period, all GHG emission levels grew, excepted CH<sub>4</sub> which has registered a slight reduction of -1%. As presented in Figure 2.2, F-gases excluded, CO<sub>2</sub> is the gas having registered the biggest increase (almost 53%).

Figure 2.2 – Increase of GHG emissions by gas over the 1990-2002 period

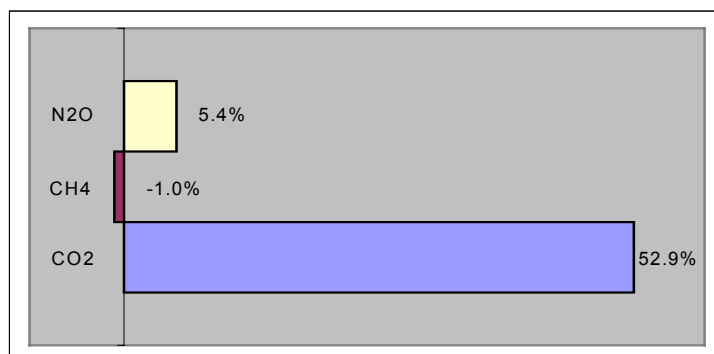


Figure 2.3 illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2002, being evident CO<sub>2</sub> as the primary GHG, accounting for about 82.3% of Portuguese emissions on a carbon equivalent basis in 2002 (CO<sub>2</sub> from LUCF excluded). The second most important gas is CH<sub>4</sub>, followed by N<sub>2</sub>O, representing, respectively, about 10.2 % and 7.4 % of total emissions. Portugal has chosen 1995 as the base year for fluorinated gases. In 2002 these gases represented about 0.07% of total GHG emissions.

Throughout the report, the reference to “total emissions” is meant to refer to “total emissions without CO<sub>2</sub> from LUCF on a carbon equivalent basis”.

Figure 2.3 – GHG emissions by gas: 1990 and 2002

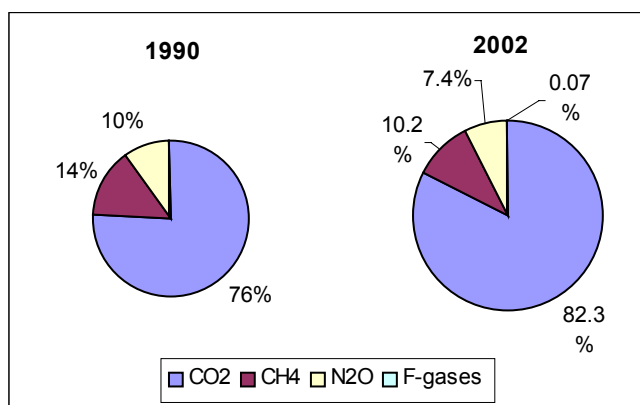


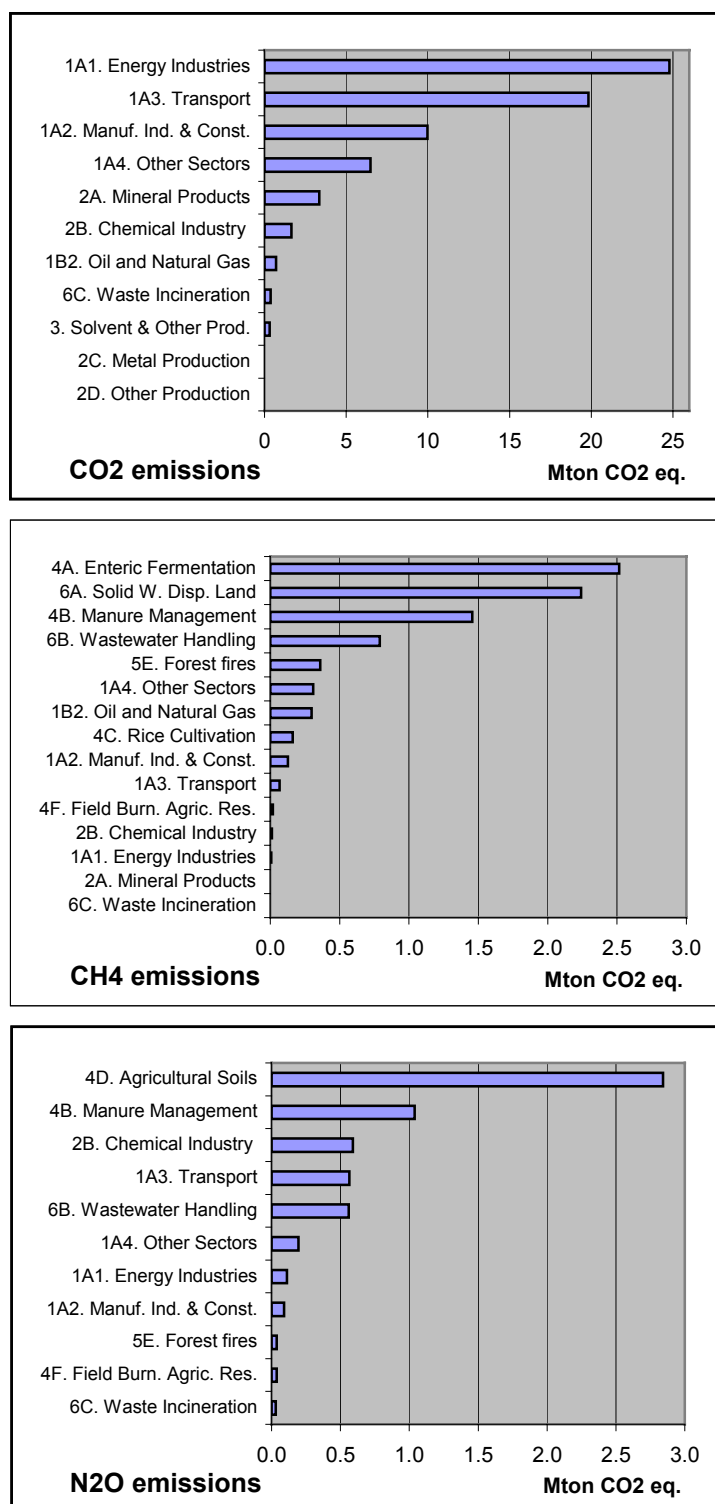
Table 2.1 – GHG emissions and removals in Portugal by gas: 1990-2002

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO <sub>2</sub> equivalent (Gg)													
Net CO <sub>2</sub> emissions/removals	49,703	50,332	53,186	51,313	51,626	54,392	50,545	53,424	56,795	63,999	62,593	63,484	65,858
CO <sub>2</sub> emissions (without LUCF)	44,130	46,009	50,139	48,546	49,792	53,518	50,564	53,531	57,900	64,433	63,843	64,365	67,464
CH <sub>4</sub>	8,450	8,812	8,262	8,005	8,170	8,645	8,420	8,421	8,789	9,016	8,584	8,226	8,365
N <sub>2</sub> O	5,782	5,755	5,469	5,312	5,542	5,727	5,841	5,744	5,782	6,224	5,870	6,012	6,097
HFCs	NE	NE	NE	NE	NE	0	0	1	6	12	24	37	49.05
PFCS	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF <sub>6</sub>	NE	NE	NE	NE	NE	5	5	5	5	6	6	7	7.00
Total (with net CO <sub>2</sub> emis./removals)	63,935	64,899	66,916	64,631	65,338	68,769	64,810	67,595	71,377	79,257	77,076	77,765	80,376
Total (without CO <sub>2</sub> from LUCF)	58,362	60,576	63,870	61,863	63,504	67,895	64,830	67,702	72,483	79,692	78,327	78,646	81,982

NE - not Estimated; NO - not occurring

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

Figure 2.4 – 2002 sources categories of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O



## 2.3 Trends by Sector

According to the UNFCCC Reporting Guidelines, emissions estimates are grouped into six large IPCC categories: Energy, Industrial Processes, Solvent use, Agriculture, Land-Use Change and

Forestry, and Waste. Emissions (Table 2.2) have risen in almost all these sectors. The exception was agriculture, where the emissions have declined.

Table 2.2 – GHG emissions and removals in Portugal by sector: 1990-2002

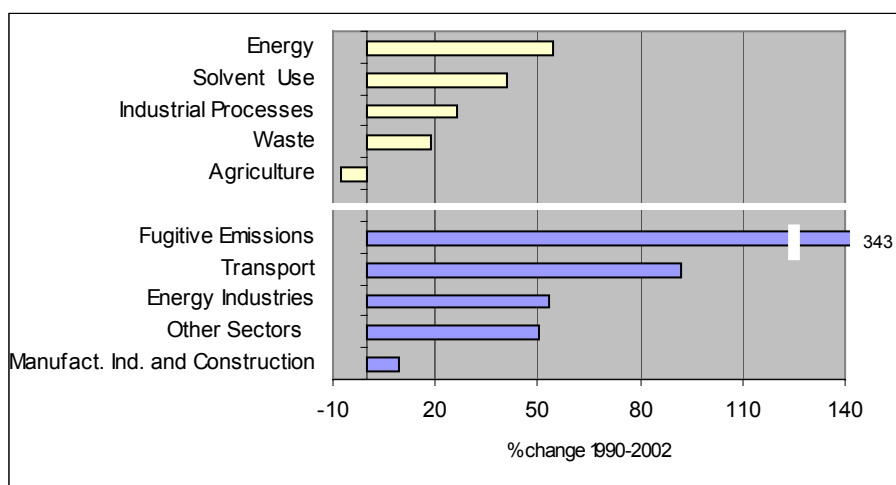
GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	CO <sub>2</sub> equivalent (Gg)												
1. Energy	41,093	43,010	47,384	45,773	46,393	49,522	46,878	49,221	53,299	60,589	59,710	59,947	63,549
2. Industrial Processes	4,479	4,427	4,195	4,030	4,838	5,555	5,301	5,951	6,157	5,816	5,619	6,072	5,651
3. Solvent and Other Product Use	222	236	244	236	253	256	276	286	291	286	293	305	313
4. Agriculture	8,711	8,641	8,182	7,919	8,075	8,062	8,116	8,002	8,112	8,300	8,110	8,098	8,068
5. Land-Use Change and Forestry <sup>(7)</sup>	6,058	5,089	3,289	2,913	1,916	1,409	167	-37	-755	-245	-832	-604	-1,208
6. Waste	3,371	3,494	3,622	3,760	3,862	3,965	4,073	4,173	4,273	4,511	4,175	3,948	4,003
7. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

As previously mentioned, throughout the report, the reference to “total emissions” is meant to refer to “total emissions without CO<sub>2</sub> from LUCF on a carbon equivalent basis”.

Energy is by far the most important sector, accounting for 77.5% of total emissions in 2002, and presenting an increase of almost 55% over the 1990-2002 period. Transport, representing 25% of total emissions is, within the energy sector, the second most important source, seconding only energy industries (30.4% of total emissions). This reflects the country heavy dependence on fossil fuels for electricity generation (which continues to grow due to 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 1990-2002 these emissions increased approximately 92%, due to the steady growth of vehicle fleets 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 augments also the emissions from fossil fuel storage, handling and distribution.

Agriculture is the second most significant source of GHGs emissions (10% of total emissions) and is the only category showing a negative trend or emissions decrease in the period analysed (-7.4% reduction from 1990 to 2002). Industrial processes and Waste represent, respectively, 6.9% and 4.9% of Portuguese emissions in 2002, recording an increase of approximately 26% (industrial processes) and 19% (waste). Solvent use represents less than 1% of total emissions, and is mainly related to NMVOC emissions<sup>3</sup>.

Figure 2.5 – GHGs emissions percentage change (1990-2002) by IPCC category



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

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

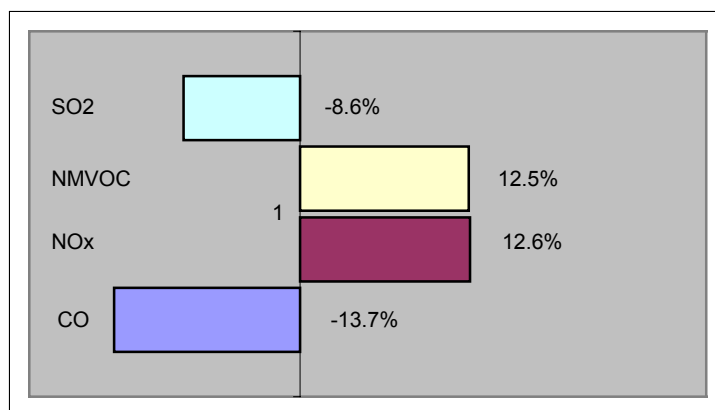
Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO<sub>x</sub>, and NMVOC are precursor substances for ozone which is a GHG. SO<sub>x</sub> produce aerosols, which are extremely small particles or liquid droplets, that can also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

Table 2.3 – Indirect GHG and SO<sub>x</sub> emissions in Portugal: 1990-2002

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	(Gg)												
CO	1018.3	1135.2	966.2	918.9	882.2	1049.7	905.5	838.4	944.7	867.4	948.4	848.9	878.5
NO <sub>x</sub>	260.1	275.7	289.0	280.4	279.7	293.2	278.8	280.0	293.8	293.7	294.7	287.9	292.7
NMVOC	303.9	333.5	349.1	322.6	328.4	344.3	340.3	340.8	353.3	343.8	343.3	335.2	341.8
SO <sub>2</sub>	322.9	307.7	374.6	320.9	299.3	334.7	273.7	293.7	342.4	343.3	312.3	295.0	295.2

In 2002 NO<sub>x</sub> and NMVOC emissions have increased from 1990 levels: NO<sub>x</sub> 12.6%, NMVOC 12.5%; CO and SO<sub>2</sub> emissions have decreased: CO –13.7% and SO<sub>2</sub> –8.6%.

Figure 2.6 – Increase of indirect GHG and SO<sub>x</sub> emissions by gas: 1990-2002 period



Energy is the major responsible sector for emissions of NO<sub>x</sub>, SO<sub>x</sub>, CO and NMVOC. Industrial processes and Solvent use contribute also significantly for NMVOC emissions.

Within energy, transportation is responsible for the greatest share of CO, NO<sub>x</sub>, and NMVOC emissions, respectively 43%, 39% and 18% of 2002 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<sub>x</sub> emissions from transport presented a 15% increase over the 1990-2002 period; NMVOC and CO recorded significant reductions, -28% and -18%, respectively.

SO<sub>x</sub> emissions are mainly generated in the energy industry sector (63% of total emissions in 2002) and combustion in manufacturing industries (23% of total emissions in 2002), 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 1990-2002 shows a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries –7% and manufacturing industries –16%. These tendencies reflect the introduction of new stricter laws regulating the residual fuel oil (Decree-Law 281/2000 of 10<sup>th</sup> November). The introduction of natural gas and its increasing use, since 1998, is also another positive factor that has contributed to control of SO<sub>x</sub> emissions.



## CHAPTER: 3 ENERGY (CRF SECTOR 1)

### 3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting for almost 77.5% of total emissions (CO<sub>2</sub> eq.) in 2002. The most important gas emitted by this sector is CO<sub>2</sub>.

#### Fuel Combustion Activities (CRF sector 1A)

Energy emissions are primarily related to fossil fuel combustion. Due to the heavy dependence on fossil fuels for electricity generation and transportation, energy industries and transport appear as the primary sources of Portuguese GHG emissions, representing respectively 30.4% and 25.0% of total emissions in year 2002. Manufacturing industries and construction is the third larger source within this sector with 12.4% of total emissions. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 8.5% of national emissions. Emissions for each sector in selected years (1990, 1995 and 2002) are presented in figure Figure 3.1, and the full time trend in figure Figure 3.2.

Figure 3.1 – GHG emissions in Fuel Combustion Activities (CRF 1A), by source sub-sector, expressed as CO<sub>2</sub>eq, in 1990, 1995 and 2002

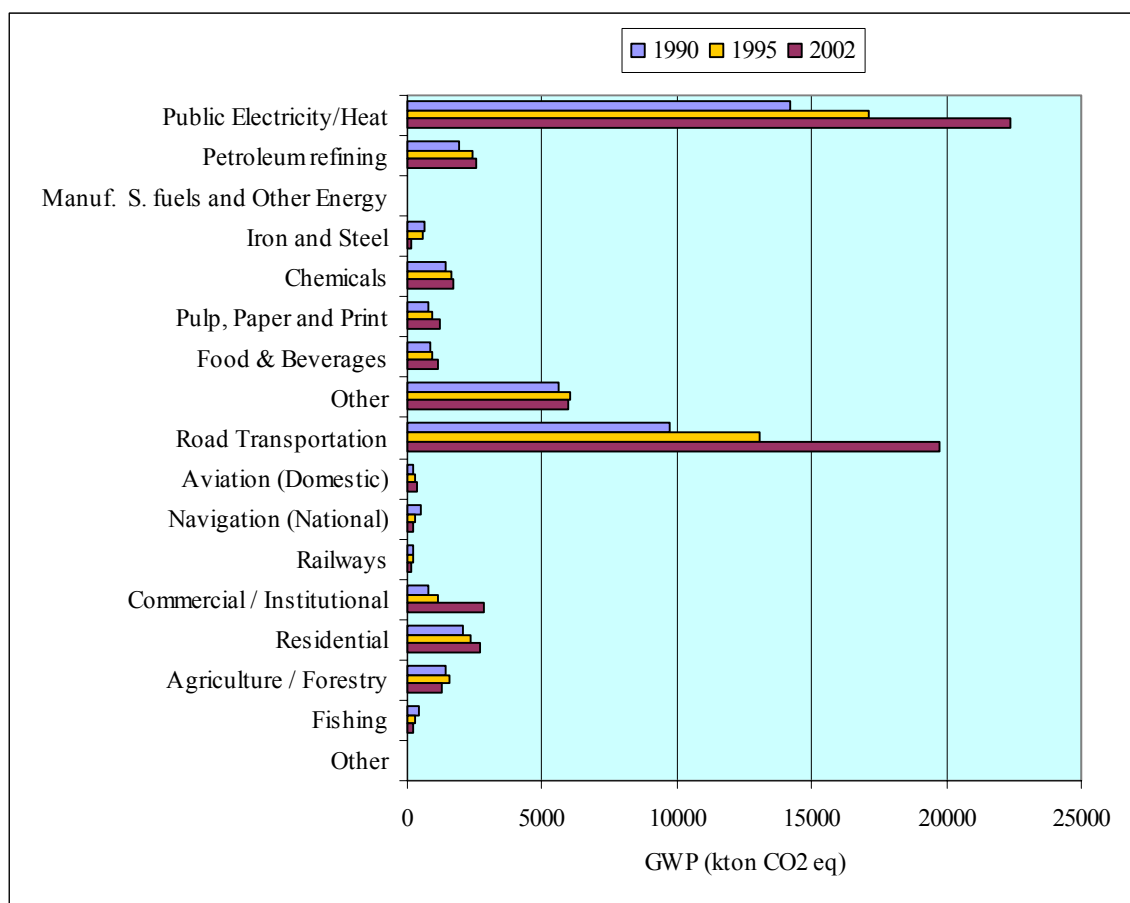
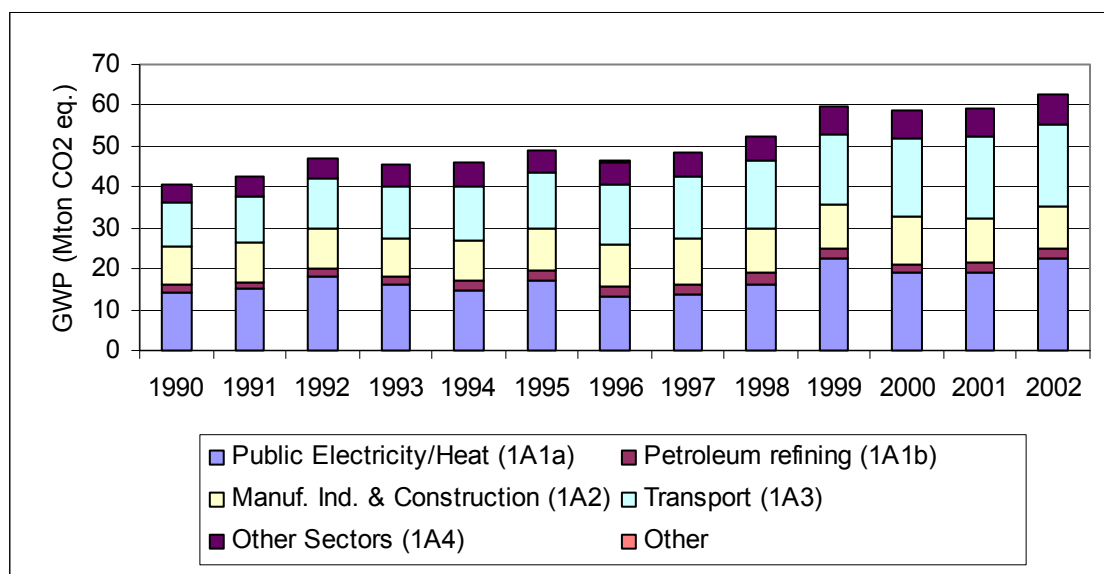


Figure 3.2 – Trend of total GHG emissions in Fuel Combustion Activities (CRF 1A), expressed as CO<sub>2</sub>eq, by sub-sector (1990-2002)



GHG emissions are almost fully dominated by CO<sub>2</sub> emissions, which represents about 96.7 % of total GHG emissions in 2002. CH<sub>4</sub> and N<sub>2</sub>O are minor sources, respectively 0.8 % and 1.5 % of total GHG emissions from 1A sector in 2002.

CO<sub>2</sub> emissions are dependent on the carbon content of the fuel used and, for this reason estimates of CO<sub>2</sub> emissions are more accurate and the methodology is simpler to apply. During the combustion process some carbon is released in smaller amounts in the form of other gases, such as CH<sub>4</sub>, CO and NMVOC and also included in particulate matter. It is presumed that all these other carbon containing substances will oxidise to CO<sub>2</sub> when in the atmosphere and, for this reason, are include in carbon dioxide estimates known as ultimate CO<sub>2</sub><sup>4</sup>.

Emissions from fossil fuel combustion include also individual emission estimates for other GHG, N<sub>2</sub>O and methane, as well as emission estimates for other air pollutants: NO<sub>x</sub>; SO<sub>x</sub>; NMVOC; CO; NH<sub>3</sub> and particulate matter. Unlike CO<sub>2</sub>, calculation of emissions for these air contaminants require more detailed information, such as combustion equipment, operating conditions, combustion and emission control technologies and fuel characteristics. It is usually necessary to use monitoring data or emission factors.

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

Biomass combustion also generates air emissions. CO<sub>2</sub> emissions from this source are estimated, but not included in national emissions totals, being assumed that they do no cause net emissions of CO<sub>2</sub>, because the carbon that was released during biomass combustion had

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

been, in fact, previously fixed from atmosphere by the photosynthetic process and when it is burnt and returns to atmosphere does not increase the atmospheric/biosphere pool. This activity is reported separately in CRF for information purposes. Non-CO<sub>2</sub> emissions from biofuels are nevertheless considered in inventory totals.

### Fugitive Emissions from Fuels (CRF sector 1B)

Apart from fuel combustion emissions, the use of energy is responsible also for emissions occurring during production, transmission, storage and distribution of fossil fuels. The generated gases from these sources are CO<sub>2</sub>, COVNM, SO<sub>x</sub>, CH<sub>4</sub>, NO<sub>x</sub> and CO. Total GHG emissions per sub-sector source are presented in figure Figure 3.3, from where, the major importance of emissions due to oil refining, transport and distribution, may be seen.

GHG emissions realized as CO<sub>2</sub> also dominate in this source sector, with 70 % in 2002, although methane has been increasing its importance, mainly because of the increased use of natural gas. Emissions by gas are represented in figure Figure 3.2.

Figure 3.3 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>eq, by sub-sector (1990-2002)

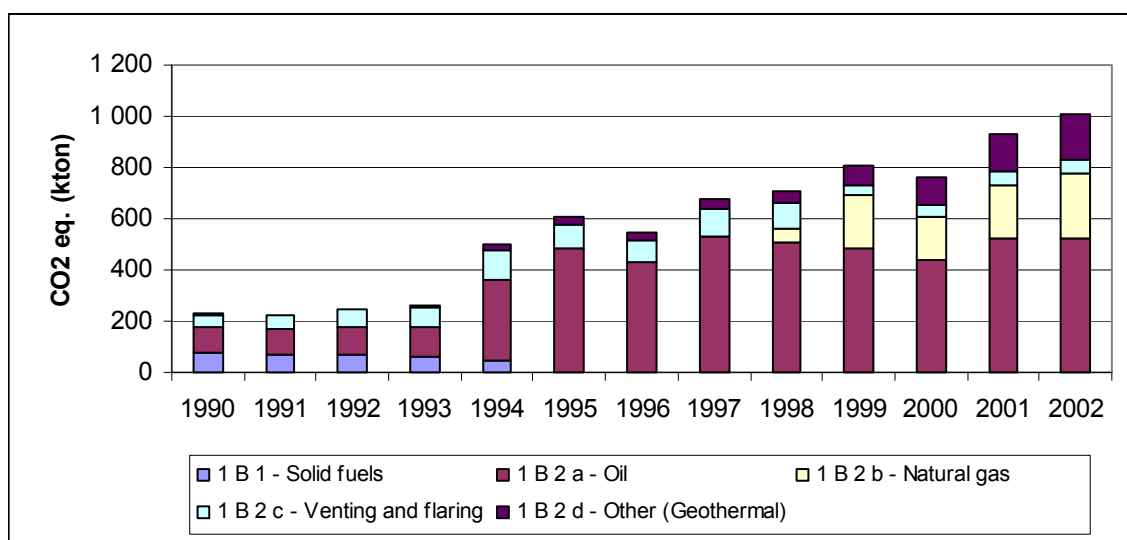
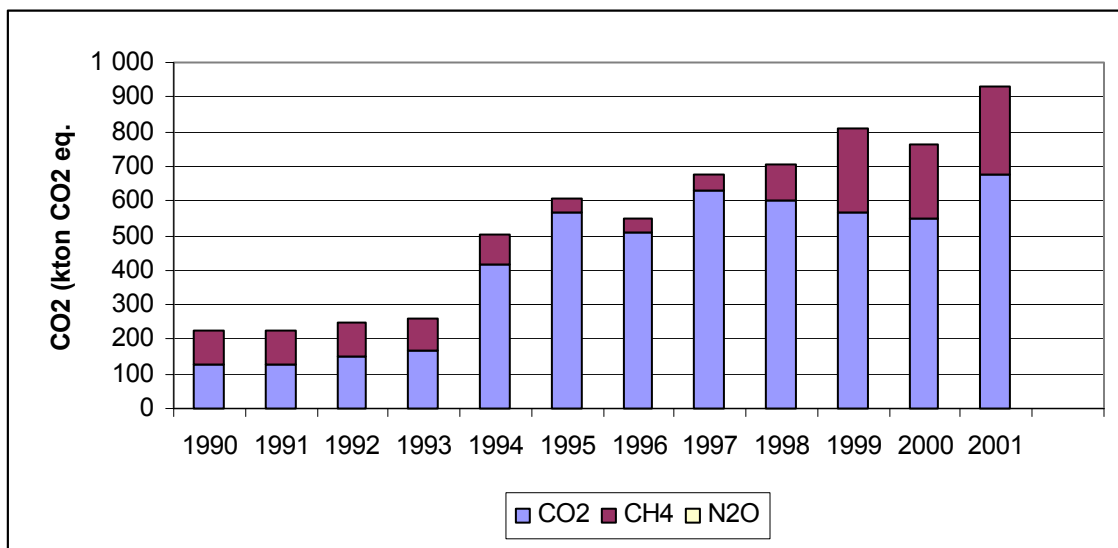


Figure 3.4 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>eq, by GHG (1990-2002)



## 3.2 Category sources

### 3.2.A Energy Industries

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

##### OVERVIEW

Until 1950 electric energy production in Portugal was based in small power plant units using coal as energy source. In the nineteen-fifties increase in the demand from industry consumers caused the increment of medium-sized hydro-electric production units and the construction of *Tapada do Outeiro* power plant using low energy coal (lignite) obtained in 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 *Carregado* unit still in construction phase).

Apart from dedicated electric power plants, auto-producers generate electric energy, generally as co-generation units, for own use or to be sold to the public system. However, not all emissions from these co-generation sources are included here because, according to the Revised 1996 IPCC Guidelines (IPPC,1997), emissions from auto-producers are to be reported under the industrial or commercial branch in which their main economic activity occurs. The present source sector includes only emissions resulting from main power producers<sup>5</sup>.

Several sub categories were individualized in the Inventory of air Emissions from the energy sector and they were dealt differently in the inventory process: Large Point Sources in continental Portugal; Power Plants in Madeira and Azores autonomous regions; Auto-producers and Geothermal energy production.

<sup>5</sup> Main Power Producers generate and sell electricity or heat as their main activity (primary activity) either public or private in nature. In contrast Auto-producers of electricity or heat produce or sell electricity or heat, but as a secondary activity and not as main business.

### Large Point Source Energy Plants

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

Table 3.1 – Main characteristics of the Large Point Sources Energy Plants in continental Portugal

Power Plant	Location	Start	Fuel***	Power MW <sub>e</sub>	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
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

There has been a change in the production structure in large power plants along the 1990-2002 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 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 has shift part of its production groups from residual fuel-oil to natural gas;

- 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;
- *Mortágua* unit in central Portugal initiated production in 1999 using natural gas and wood wastes;
- Finally other new units (*Soporgene* and *Energim*) also in central Portugal have just started recently 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 plants using each type of fuel

Fuel	Number of units		
	1990	1995	2002
Lignite coal/Fuel-oil	1	1	0
Hard coal	1	2	2
Fuel oil	3	3	3
Natural gas	0	0	3
Natural gas/ Fuel-oil	0	0	1
Natural gas/ Wood Wastes	0	0	1

There are two small gas turbine power plants included in the public service: one near Lisbon to sustain peak power demands, and another in Tunes, in the southern province of Algarve, is used to support the increase of demand during touristy seasonal peak demands.

### **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.

### **Non public co-generation Energy Auto-Producers**

Apart from *Barreiro*, *Soporgen* and *Energim* power plants, production of electricity in the co-generation process as auto-producers started in private owned units after 1993. Although some of these units may actually work in close association with other industrial activities they are independent companies which main activity is electric and heat production. Consequently they must be included in this source sector and not in the economic activity of the industrial activity with which they are connected.

### **Geothermic Energy**

A small amount of electricity is produced from two geothermic sources in Azores archipelago: *Pico Vermelho* and *Ribeira Grande* Plants.

Carbon dioxide resulting from gas venting is included in the inventory and discussed here for simplicity although resultant emissions are reported under IPCC source category 1-B2.

## **METHODOLOGY**

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

A bottom-up sectoral Tier 2 approach was used to estimate emissions of CO<sub>2</sub> and other air emissions from this activity.

For all pollutants but sulphur oxides (SO<sub>x</sub>), emission estimates were calculated for each year, power plant and fuel type from the following equation:

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

where:

$\text{Emission}_{(u,f,y,p)}$  - Emission of pollutant p estimated from consumption of fuel f in power plant u in year y (ton except CO<sub>2</sub> in kton);

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

$\text{EF}_{(u,f,y,p)}$  - Emission factor pollutant p, for fuel f consumed in power plant u in year y (g/GJ except CO<sub>2</sub> in kg/GJ).

For emissions of sulphur oxides the following equation was used instead:

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

Where

$\text{SOx}_{(u,f,y)}$  - Sulphur oxide emission estimated from consumption of fuel f in power plant u in year y (ton);

$\text{Fuel}_{\text{Cons}(u,f,y)}$  - Consumption of fuel f in power plant u in year y (any unit in agreement with CF);

$\text{S}_{(u,f,y)}$  - Sulphur content of fuel f, specific of each power plant and year (mass percentage);

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

$\text{AshRet}_{(u,f)}$  - Sulphur retention in ash (mass percentage).

Presently, for most pollutants, the emission factor is independent of year and power plant. The only exception is NO<sub>x</sub> where there are for some units some information concerning annual variations of the emission factors.

For carbon dioxide emissions, the 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<sup>6</sup>. Emissions of ultimate CO<sub>2</sub> from fossil origin was estimated from CO<sub>2</sub> total emissions by:

$$\text{Fossil}_{\text{CO}_2} = \text{U}_{\text{CO}_2} * \text{Fossil}_c * 10^{-2}$$

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

$\text{U}_{\text{CO}_2}$  - Total ultimate carbon dioxide emissions (ton);

<sup>6</sup> "Emission factors for CO<sub>2</sub> from fossil fuel combustion are expressed on a per unit energy basis because the carbon content of fuels is generally less variable when expressed on a per unit energy basis than when expressed on a per unit mass basis" (GPG)

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

However, it is true that 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 CO<sub>2</sub> in the atmosphere or after deposition on soil. Emissions of CO<sub>2</sub> at stack exhaust (End-of-pipe emissions) may be estimated from final CO<sub>2</sub> emissions from:

$$\text{Stack}_{\text{CO}_2} = U_{\text{CO}_2} - 44/12 \cdot (\text{NMVOC} \cdot C_{\text{NMVOC}} + \text{CO} \cdot 12/28 + \text{CH}_4 \cdot 12/16 + \text{TPM} \cdot C_{\text{TPM}}) \cdot 10^{-3}$$

where

Stack<sub>CO<sub>2</sub></sub> - end of pipe emissions of carbon dioxide (kton);

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

CO - carbon monoxide emissions (ton);

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

TPM - Total Particulate Matter emissions (ton);

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

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

### ***Geothermal Energy***

In Azores, since 1994, 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 geothermal units and these were considered in the National Inventory. For the years prior to 1994, when the only available activity data for geothermal electricity production is from General-Directorate of Energy (DGE), emission factors estimated for the post-1994 time series were used.

## **EMISSION FACTORS**

### ***Large Point Source Energy Plants***

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

- IPCC 1996 Revised Guidelines (IPCC,1997);
- IPCC Good Practice Guidance (IPCC,2000);
- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- AP-42.



Table 3.3 – Emission Factors for Large Point Sources in the energy production sector (1/2)

Fuel	U <sub>CO2</sub> kg/GJ	Fossil <sub>c</sub> %	CH <sub>4</sub> G/GJ	N <sub>2</sub> O G/GJ	NO <sub>x</sub> g/GJ	NM VOC G/GJ	CO g/GJ	AshRet <sub>(s)</sub> %
Lignite	101.2	100	1.0	1.4	310	1.5	16	5
Hard Coal	92.0	100	0.7	1.4	260 - 500	1.5	10	5
Fuel-oil	77.4	100	0.7	0.6	210 - 300	3.0	15	0
Orimulsion	80.7	100	0.7	0.6	300	3.0	15	0
Natural Gas	56.1	100	0.1 - 1.4	1.4	85 - 100	5.0	19 - 13	0
Biomass	109.6	0	15	4.3		150	500	0
Diesel (GT)	74.07	100	0.4	2.5	350	4.0	15	0

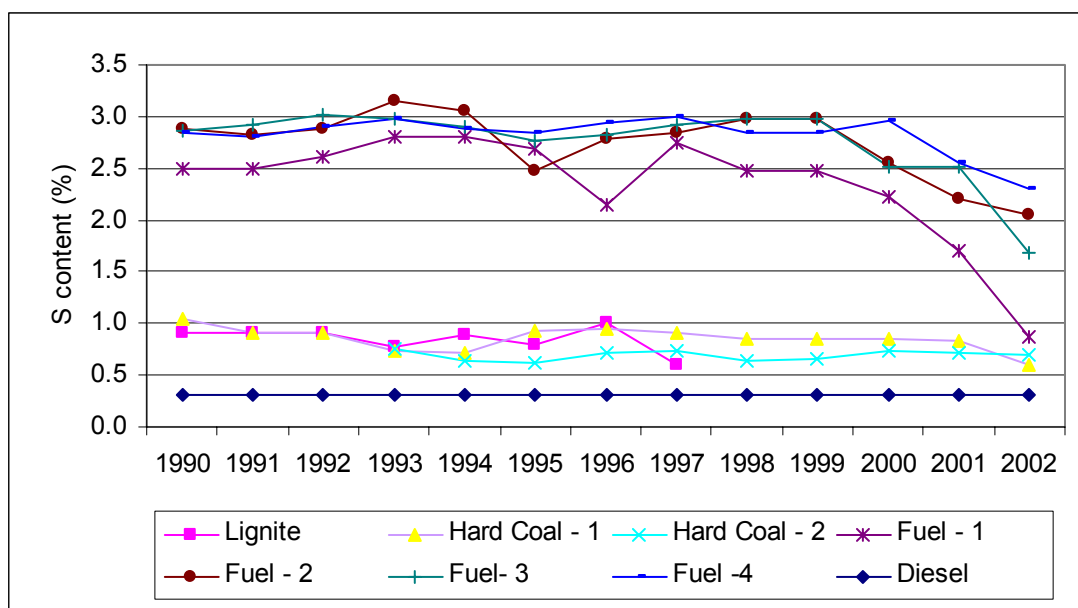
Table 3.4 – Emission Factors for Large Point Sources in the energy production sector (2/2)

Fuel	PM g/GJ	PM10 %	PM2.5 %	PM1.0 %
Lignite	9.3	67	29	14
Hard Coal	6.8	67	67	67
Fuel-oil	0.3 – 0.7 (a)	64	64	64
Orimulsion	0.7	63	63	63
Natural Gas	0.8	100	100	100
Biomass	23.2	74	74	74
Diesel (GT)	1.8	100	100	100

(a) as function of sulphur content (USEPA, 1998b); 56-91 with no ESP

Nitrogen Oxides (NO<sub>x</sub>) emissions 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 Table 3.3. For three units (*Sines*, *Pêgo* and *Turbogas*) emission factors reflect actual monitoring data under *Autocontrolo* program.

Average sulphur content for each fuel type has evolved along the 1990-2002 time series as shown in Figure 3.5 for the most important fuel types and power plants .

Figure 3.5 – Trends of sulphur content by fuel type in Electric Power Plants (LPS)<sup>7</sup>

### Other Thermo-electricity Power Plants

The other smaller power plants are seldom subjected to the *Autocontrolo* program and the scarce available information does not allow the fixation 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 Inventory Guidebook - 3rd edition (EEA,2002);
- AP-42.

Emission factors are present in Table 3.5 and Table 3.6, for the public power plants belonging to the public system in Azores and Madeira, and in Table 3.7 and Table 3.8 for the non public co-generation self producers<sup>8</sup>.

Table 3.5 - Emission Factors for Power Plant Units in Azores and Madeira (1/2)

Region	Fuel	U <sub>CO2</sub> kg/GJ	Fossil <sub>c</sub> %	CH <sub>4</sub> G/GJ	N <sub>2</sub> O g/GJ	NO <sub>x</sub> g/GJ	NM VOC g/GJ	CO g/GJ
Azores	Fuel-oil	77.4	100	2.9	0.6	180	3	15
Azores	Diesel oil	74.1	100	0.14	0.6	1 300	2	15
Madeira	Fuel-oil	77.4	100	2.9	0.6	180	3	15

<sup>7</sup> Power plants are denominated by number and not by name due to confidentiality constraints

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

Table 3.6 - Emission Factors for Power Plant Units in Azores and Madeira (2/2)

Region	Fuel	PM g/GJ	PM10 %	PM2.5 %	PM1.0 %
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 3.7 - Emission Factors for non public co-generation auto-producers (1/2)

Fuel	U <sub>CO2</sub> kg/GJ	Fossil <sub>C</sub> %	CH <sub>4</sub> G/GJ	N <sub>2</sub> O g/GJ	NO <sub>x</sub> g/GJ	NMVOC G/GJ	CO g/GJ	S %
LPG	63.1	100	0.06	1.4	80	2.5	20	0.01
Fuel –oil	77.4	100	2.9	0.6	180	3	15	2.84-2.6
Diesel oil	74.1	100	5	0.6	580	50	15	0.3-0.2
Natural Gas	56.1	100	1.4	1.4	100	5	13	0.0007

Table 3.8 - Emission Factors for non public co-generation auto-producers (2/2)

Fuel	PM g/GJ	PM10 %	PM2.5 %	PM1.0 %
LPG	6.9	100	100	100
Fuel –oil	37-88 <sup>(a)</sup>	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

### Geothermic Energy

Measurements of carbon dioxide emissions are available from one plant after 1994. These results were used to establish an emission factor that was latter used to estimate emissions for *Pico Vermelho* before 1994: 500 ton CO<sub>2</sub>/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 CO<sub>2</sub>/GWh. These emission factors were set from available information from Azores Autonomous Region.

### 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 were 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*)<sup>9</sup> or, when the unit is not obliged to this

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

agreement, from plant activity reports. Activity data for both gas turbine units is from DGGE until 1997 and from industry reports 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<sup>10</sup> for that specific year from where consumption of fuels in energy units are calculated from:

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

or

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

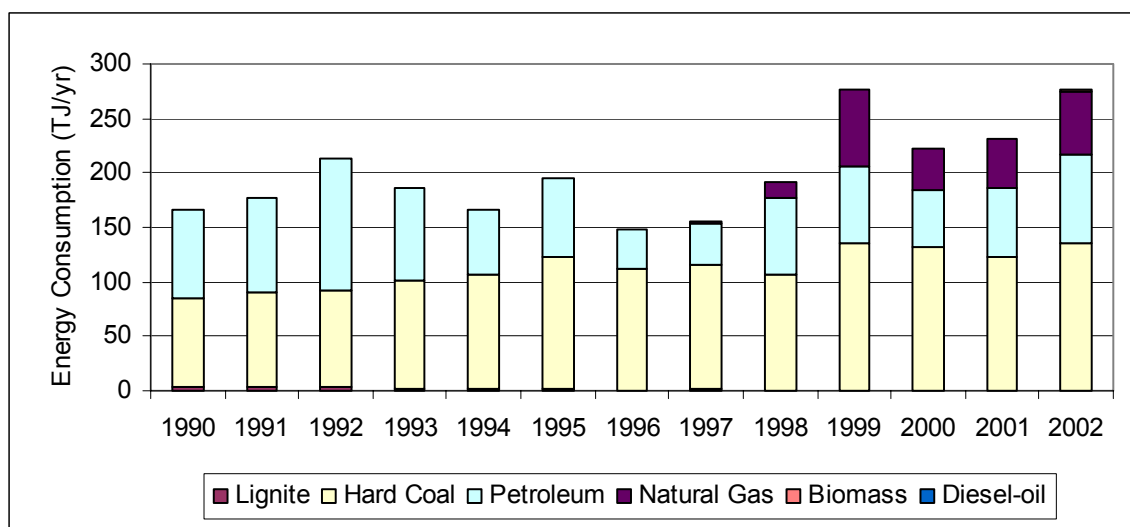
When LHV was not available it was set from interpolation or extrapolation from the remaining available time series. The average value and range of the reported LHV per fuel type is presented in next table (Table 3.9).

Table 3.9 – Low Heating Value (LHV) in Large Power Plants per fuel type

Fuel	LHV
Lignite	16.42 (15.57 - 17.02)MJ/kg
Hard Coal	26.04 (24.78 - 27.23)MJ/kg
Fuel-oil	40.02 (39.42 - 41.15)MJ/kg
Orimulsion	28.00MJ/kg
Diesel oil	43.30MJ/kg
Natural Gas	37.31 (36.02 - 38.01)MJ/N m3
Biomass	7.8MJ/kg

Total consumption per fuel type in comparable energy units (GJ) may be verified in Figure 3.6.

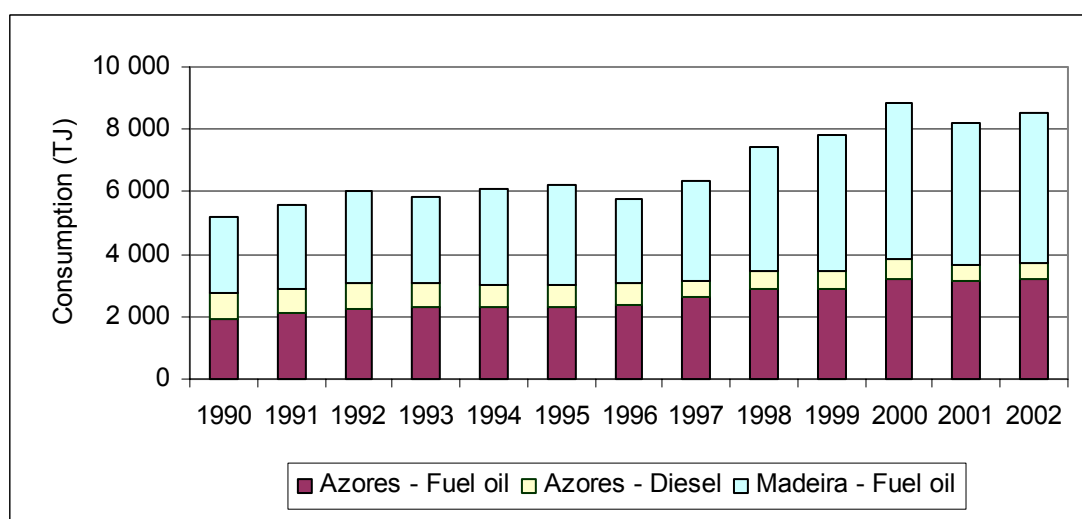
<sup>10</sup> Low Heating Value (LHV) or Net Calorific Values (NCV) measure the quantity of heat liberated by the complete combustion of a unit volume or mass of a fuel, assuming that the water resulting from combustion remains as a vapour and the heat of the vapour is not recovered (GPG). In contrast, Gross Calorific Value (GCV) or Gross Heating Value (GHV) are estimated assuming that this water vapour is completely condensed and the heat is recovered (GPG). The default in IPCC Guidelines is to use the NCV.

Figure 3.6 – Trends of fuel consumption in Large Electric Power Plants per fuel type <sup>11</sup>

### 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 Figure 3.7. Consumption values for 2001 and 2002 are still provisional and result from a forecast based in 1990-2000 data using a linear interpolation.

Figure 3.7 – Trends of fuel consumption in Azores and Madeira Islands



Consumption of fuels expressed in energy units was estimated from the above consumption figures assuming Low Heating Value (LHV) values presented in the following table (Table 3.10).

<sup>11</sup> Time series not visible in the graph: Consumption of diesel oil in gas turbines increased from 29 TJ in 1990 to 784 TJ in 2001. Biomass (wood wastes) consumption was only 86 PJ in 1999, 147 PJ in 2000 and 316 PJ in 2001. Orimulsion and fuel-oil are represented together as Petroleum products.

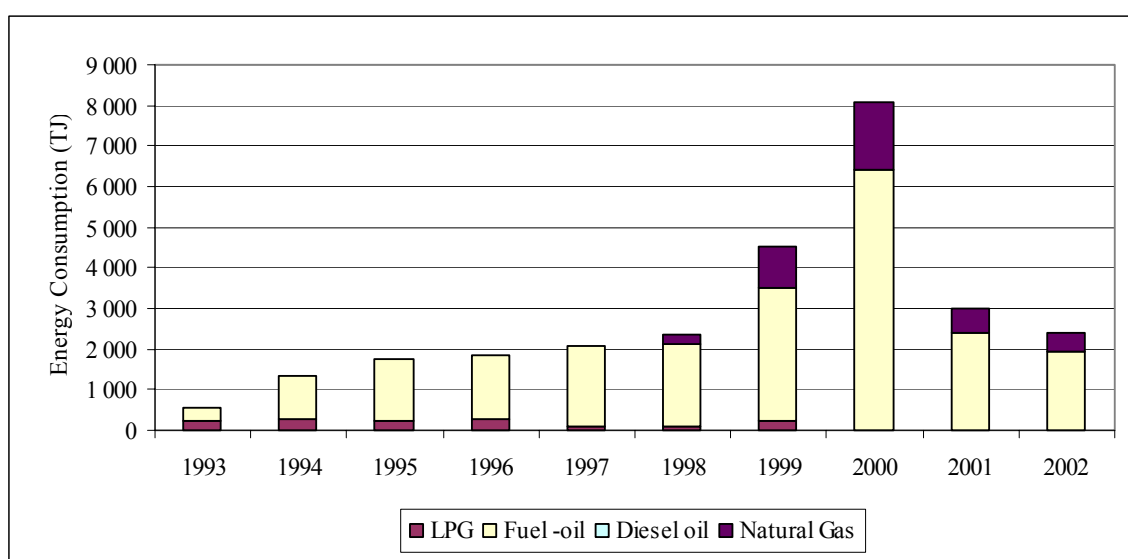
Table 3.10 - LHV per fuel type in electric energy production in Azores and Madeira

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

### Non-public co-generation Energy Producers

Consumption of fuels in co-generation units, except *Barreiro*, *Soporgem* and *Energim* power plants is available in toe units from the revised energy balances from DGGE (DGE,2003), which is presented in next figure.

Figure 3.8 – Trends in consumption of fuels in non-public co-generation plants



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

Table 3.11 - 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

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

#### OVERVIEW

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

Oporto refinery, located in Matosinhos in northern Portugal, 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, lubricant 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: 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 in chapter 3.2.B.2.

Apart from the combustion of fuels as energy sources, SO<sub>x</sub> and NMVOC emissions may also result from sulphur that is removed from final products and that is conveyed to final flux gases (tail gas) where they are lost to atmosphere as diffuse sources or burnt in flares. Sulphur from the refining process is recovered in both Sines and Oporto refineries, in Claus units, resulting also in certain emissions to atmosphere. Emissions from these source are also discussed under Emissions from Flaring and Venting in part 3.2.B.2.

## METHODOLOGY

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

For all pollutants other than sulphur oxides (SO<sub>x</sub>) emission, the following equation was applied:

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

Where

$\text{Emission}_{(e,f,y,p)}$  - Emission of pollutant p estimated from consumption of fuel f in combustion equipment e in year y (ton except CO<sub>2</sub> in ton);

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

$\text{EF}_{(e,f,y,p)}$  - Emission factor pollutant p, for fuel f under burning conditions in combustion equipment e in year y (g/GJ except CO<sub>2</sub> in kg/GJ).

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

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

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);

$\text{S}_{(e,f,y)}$  - Sulphur content of fuel (mass percentage);

It was assumed that there is no ash retention for all fuels and combustion equipments in the refinery process.

### EMISSION FACTORS

The same emission factors were used for all three refineries and were set from international bibliography such as IPCC 1996 Revised Guidelines (IPCC,1997), EMEP/CORINAIR (EEA,2002) and AP-42, and they are presented in Table 3.12.

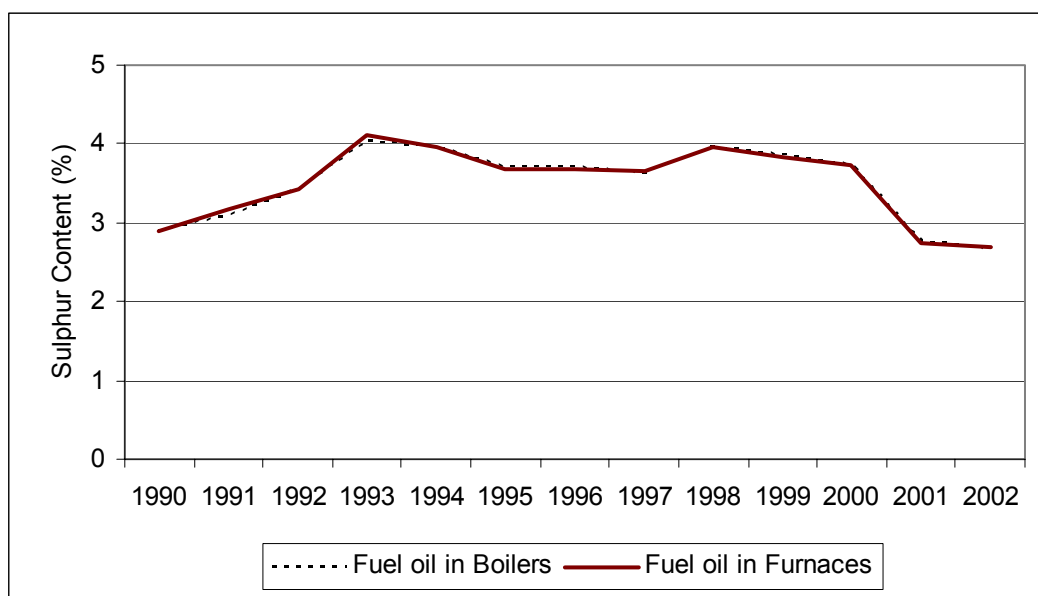
Table 3.12 – Emission Factors for fuel combustion in boilers, furnaces and engines in crude oil refining

Fuel	Equipment	U <sub>CO2</sub> kg/GJ	FossilC %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O g/GJ	NO <sub>x</sub> g/GJ	NMVOC g/GJ	CO g/GJ	PM g/GJ	PM10	PM2.5	PM1.0
										%		
Fuel-oil	Boilers	77.4	100	2.9	0.6	180-190 <sup>(a)</sup>	3	15	66-135 <sup>(b)</sup>	86	56	36
	Furnaces	77.4	100	2.9	0.6	210	3	15	66-135 <sup>(b)</sup>			
Fuel gas	Boilers	60.0	100	2.5	1.4	140	2.5	17	3	100	100	100
	Furnaces	60.0	100	2.5	1.4	150	2.5	17	3			
LPG	Boilers	63.1	100	4	1.4	160	4	17	6.9	100	100	100
	Furnaces	63.1	100	4	1.4	160	4	17	6.9			
Diesel oil	Engines	74.1	100	9.9	0.6	1 100	100	12	6.6	50	12	8

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

Composition of fuels, in what concern sulphur content and LHV/NCV, are reported for each year and for each pollutant directly from refineries under the LCP directive. Weighted average values from 1990 to 2000 are reported in Figure 3.9 for fuel-oil and show a slight increase over years. Fuel gas was reported to have no sulphur.

Figure 3.9 - Trends of sulphur content by fuel type used in crude oil refineries (1990-2002)



### ACTIVITY DATA

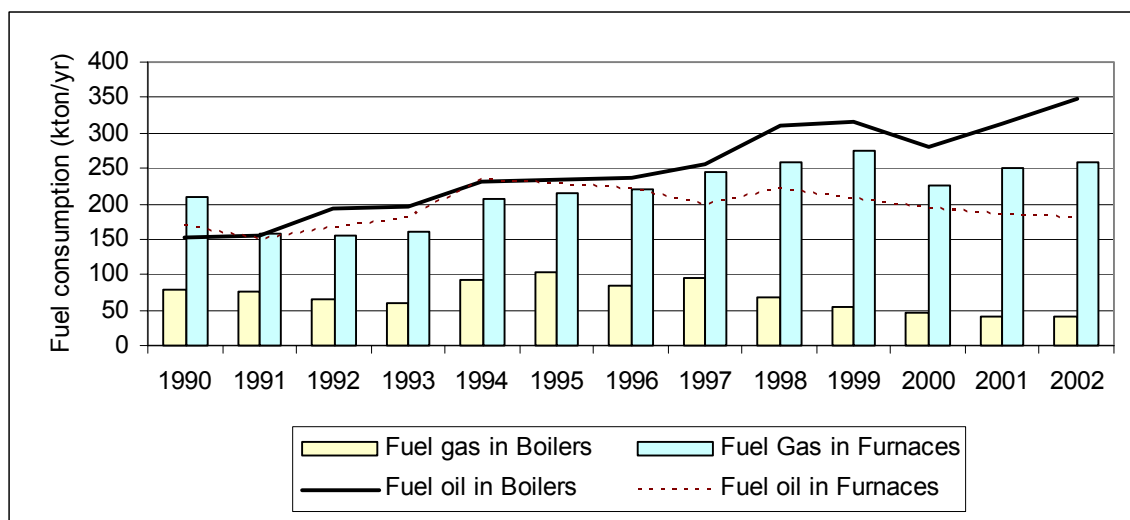
Emissions from this source sector include combustion air pollutants resulting from boilers and furnaces.



The three refinery units consume self produced fuel-oil, fuel-gas, Liquefied Petroleum Gases (LPG) and diesel oil. Sines and Oporto units will start soon to use of natural gas in order to reduce SOx emissions to atmosphere.

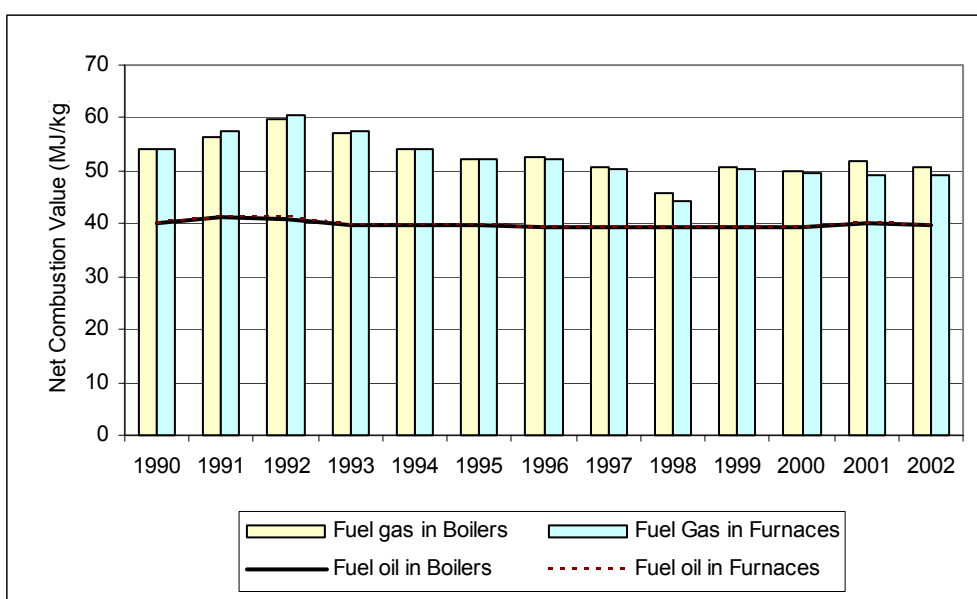
Values of fuel consumption from 1990 to 2002 in boilers and furnaces were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in Figure 3.10 for fuel oil and fuel gas. Use of other fuels such as diesel oil and LPG although included in inventory estimates are not at all significant and do not need to be reported here.

Figure 3.10 – Fuel consumption in boilers and furnaces in crude oil refineries, per year and by type of equipment (1990-2002)



Consumption expressed in energy was calculated with the following time series of LHV/NCV. This time series reflects actual information given by each refinery also under LCP directive and are weighted averages for all three plants (Figure 3.11).

Figure 3.11 – LHV/NCV (MJ/kg) of fuel consumed in crude oil refineries by type of equipment (1990-2002)



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

#### OVERVIEW

The following sub-sources are included in this category:

- External fuel consumption realized in the coquerie unit, that has existed within the single integrated iron and steel plant in Portugal. This coquerie unit was closed in 2001. Coke gas is the only fuel combustion used as energy source in the coquerie unit;
- Combustion emissions done for the production of city gas, that was consumed only in the city of Lisbon. This activity had been progressively substituted as consequence of substitution of this energy source by Natural Gas, and was finally fully deactivated in 2001;
- Combustion emissions for the extraction of coal. Marginal quantities of fuel are still referenced for this economic activity.

#### METHODOLOGY

For all pollutants other than sulphur oxides (SO<sub>x</sub>) emission, the following equation was applied:

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

where

$\text{Emission}_{(y,p)}$  - Emission of pollutant p in year y (ton, except CO<sub>2</sub> in kton);

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

$\text{EF}_{(f,p)}$  - Emission factor pollutant p from coke gas combustion (g/GJ except CO<sub>2</sub> in kg/GJ).

Sulphur oxides emission from combustion are estimated from coke gas consumption quantities and from its sulphur content as:

$$\text{SOx}_{(y)} = 2 * \text{Fuel}_{\text{Cons}(y)} * S$$

where

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

$\text{Fuel}_{\text{Cons}(y)}$  - Consumption of coke gas in the coquerie in year y (M m<sup>3</sup>/yr);

S - Sulphur content of coke gas (g S/Nm<sup>3</sup>).

#### EMISSION FACTORS

Emissions factors for combustion of coke gas in the coquerie unit where set from IPCC 1996 Revised Guidelines (IPCC,1997), EMEP/CORINAIR (EEA,2002) and AP-42. They are reported in Table 3.13.

Table 3.13 – Emission Factors for external combustion at the coquerie (Iron and Steel), city gas production and fuel used in the extraction of coal

Source	Coquerie	City Gas Production			Extraction of Coal					Unit
Fuel	Coke Gas	FO	Naphta	NG	Coal	LPG	Gasoline	GO	FO	
U CO2	41	77	77	56	101	63	69	74	77	kg/GJ
FossilC	100	100	100	100	100	100	100	100	100	%
CH4	2.5	2.9	2.9	1.4	2.40	1.40	10	10	2.90	g/GJ
N2O	1.40	0.60	0.60	1.40	0.70	1.40	0.60	0.60	0.60	g/GJ
SOx	7.05 gS/Nm3	2.6-2.9	0.1	0.0007	0.65	0.0016	0.1-0.015	0.3-0.2	2.6-2.9	% S
NOx	120	160	160	100	200	90	1 300	1 100	160	g/GJ
NMVOc	2.5	3.0	3.0	5.0	190	3	100	100	3.00	
CO	17	15	15	13	160	17	15	12	15	
PST	3	85	6.5	0.8	1 166	3.0	43	133	85	% PST
PM10	95.9	86.0	50.0	100	35.0	100	100	100	86	
PM2.5	93.5	56.0	12.0	100	10.0	100	100	100	56	
PM1	77.4	36.0	8.0	100	6.0	100	100	100	36	

## 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 gas in coquerie was estimated from total consumption of coke gas in the all plant, which information was collected from the energy balances of DGGE. Therefore, except for 1991 to 1994, annual consumption of coke in the integrated iron and steel plant was estimated from:

$$\text{Coquerie}_{\text{CONS (y)}} = \text{Coquerie}_{\text{CONS (91 - 94)}} / \text{Total}_{\text{CONS (91 - 94)}} * \text{Total}_{\text{CONS (y)}}$$

where

$\text{Coquerie}_{\text{CONS (y)}}$  - consumption of coke gas in the coquerie in year y;

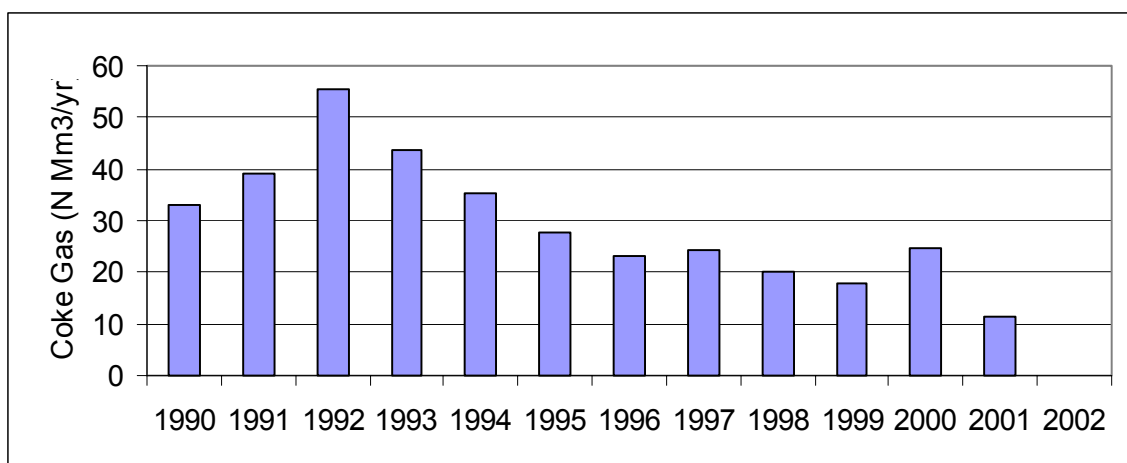
$\text{Coquerie}_{\text{CONS (91-94)}}$  - consumption of coke gas in the coquerie from 1990 till 1994;

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

$\text{TotalPlant}_{\text{CONS (y)}}$  - total consumption of coke gas in year y.

The resultant time series that was used in emission estimates is presented in Figure 3.12. Conversion in energy units was calculated using a LHV/NCV of 18.78 MJ/Nm<sup>3</sup>, the value that is reported under LCP directive.

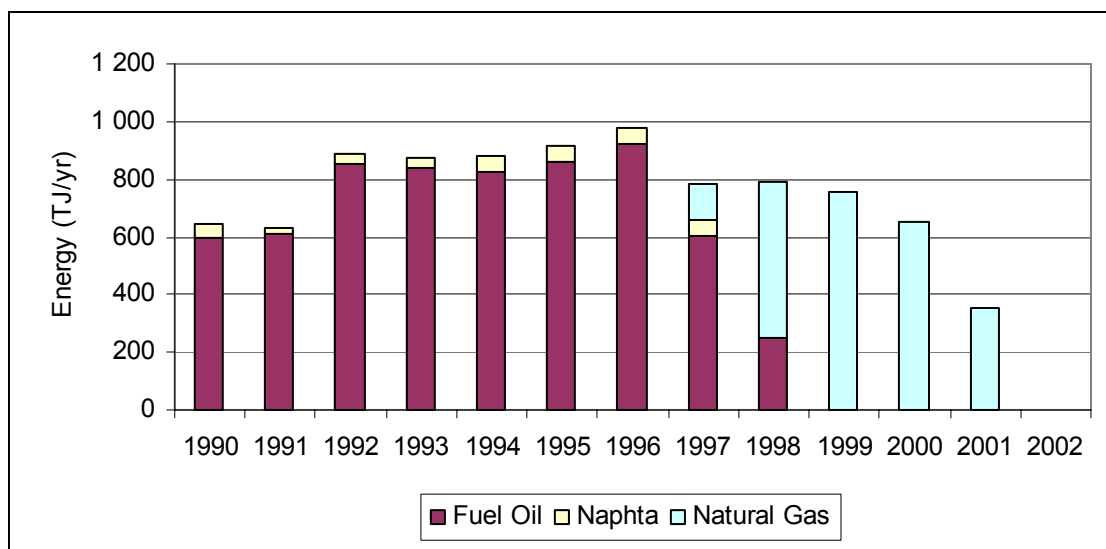
Figure 3.12 – Coke gas consumption in the coquerie as external fuel (1990-2002)



### City Gas Production

According to the energy balances from DGE, this activity has used fuel oil, naphta and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001<sup>12</sup>. The available time series is presented in Figure 3.13

Figure 3.13 – Consumption of fuels in co-generation activity for Lisbon city gas production (1990-2002)



The following Net Calorific Values (NCV) were used.

<sup>12</sup> This activity uses also fuel gas, LPG, fueloil, naphta and natural gas as feedstocks. These quantities, separated in the energy balance, are not included in the inventory at this point but in use of city gas as fuel

Table 3.14 – NCV per fuel type for city gas production

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

### Extraction of Coal

According to data reported by the energy balances from DGE, this activity has very expressive annual changes in the available time series is presented in Figure 3.14<sup>13</sup>. This represents a very small use of energy however.

Figure 3.14 – Consumption of fuels in extraction of coal (1990-2002)

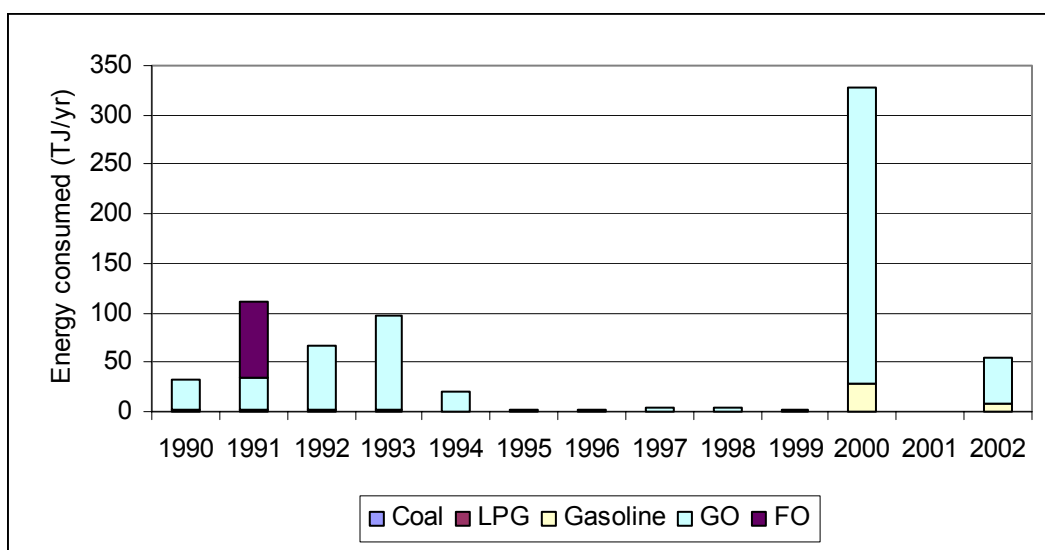


Table 3.15 – NCV per fuel type for extraction of coal

Fuel	NCV (MJ/kg)
Coal	17.15
LPG	47.28
Gasoline	44.77
GO	43.31
FO	40.17

### RECALCULATIONS

Activity data, consumption of coke gas in coquerie, in previous submission, except for years 1991 though 1994 when data was available from the industrial plant, was estimated by IA after

<sup>13</sup> Because coal extraction has not occurred in Portugal since 1994 this activity data may represent activities not directly related with extraction itself and for practical purposes may be removed from this source category.

consumption of coke gas in the associated thermal power plant (LCP directive). In present submission data on total consumption of coke gas from DGGE's energy balances was used.

The CO<sub>2</sub> emission factors for coke gas was revised downward, from 96.3 kg/GJ to 41 kg/GJ, following the recommendations from the centralized review of the Portuguese Inventory 2003, and after revision<sup>14</sup> of calculations of the country-specific emission factor.

Estimates of combustion emissions for the production of city gas and for the extraction of coal are included in the inventory for the first time.

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

Emissions covered in this source category are those resulting from combustion activities in manufacturing industry and building and construction industry, excluding decarbonising emissions of CO<sub>2</sub> 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 emissions of the industry sector, including emissions from process dedicated fuel combustion together with all emissions originated in co-generation units<sup>15</sup>.

### 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 equation:

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

where:

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

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

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

<sup>14</sup> The same composition of gas delivered by the industrial plant was used, but the density that is now used is more consistent with the gas consumed at this particular unit

<sup>15</sup> 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).

In combustion contact process, 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 CO<sub>2</sub> in kton);

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

Production – Production activity rate (ton/yr).

The emissions of SO<sub>x</sub> are directly related to the sulphur content of the fuel<sup>16</sup>. Estimates for SO<sub>x</sub> were calculated assuming that there is no retention of sulphur in ash and no abatement technologies. The following equation applies:

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

where:

$Em_{SOx}$  - Total emissions of SO<sub>x</sub> (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).

The following scheme was therefore used:

- Emissions from the following industries were estimated based only on fuel consumption as activity data (energy approach): Iron and Steel; 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<sub>x</sub>, NO<sub>x</sub>, NMVOC and methane from the recovery boilers and lime kilns in the Kraft and acid sulphide paper pulp plants were estimated using production, 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 were estimated using energy consumption as activity data;

<sup>16</sup> For some activities SO<sub>x</sub> emissions may also be estimated using the production approach

- Clinker production. Emissions from combustion in clinker kilns are 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;

- Emissions of SO<sub>x</sub>, NO<sub>x</sub>, NMVOC, CH<sub>4</sub> 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, CO<sub>2</sub> and N<sub>2</sub>O from furnaces and for all pollutants from other combustion equipments are estimated using energy consumption as activity data indicator. Carbon dioxide emissions from glass production comprehend both oxidation of carbon, that are estimated using the general emission factors based on energy consumption, and decarbonising of materials, which are included in production process;

- air emissions from sintering (SO<sub>x</sub>, NO<sub>x</sub>, NMVOC, CO and PM) and production of lime (SO<sub>x</sub>, NO<sub>x</sub>, CO, CO<sub>2</sub> and PM) in integrated iron and steel production are estimated using production as activity data. The remaining pollutants are estimated using energy consumption. For simplicity activity data and emission factors for this source are discussed in chapter 4.2.C.1 – Industrial Processes: Iron and Steel Production.

## ACTIVITY DATA

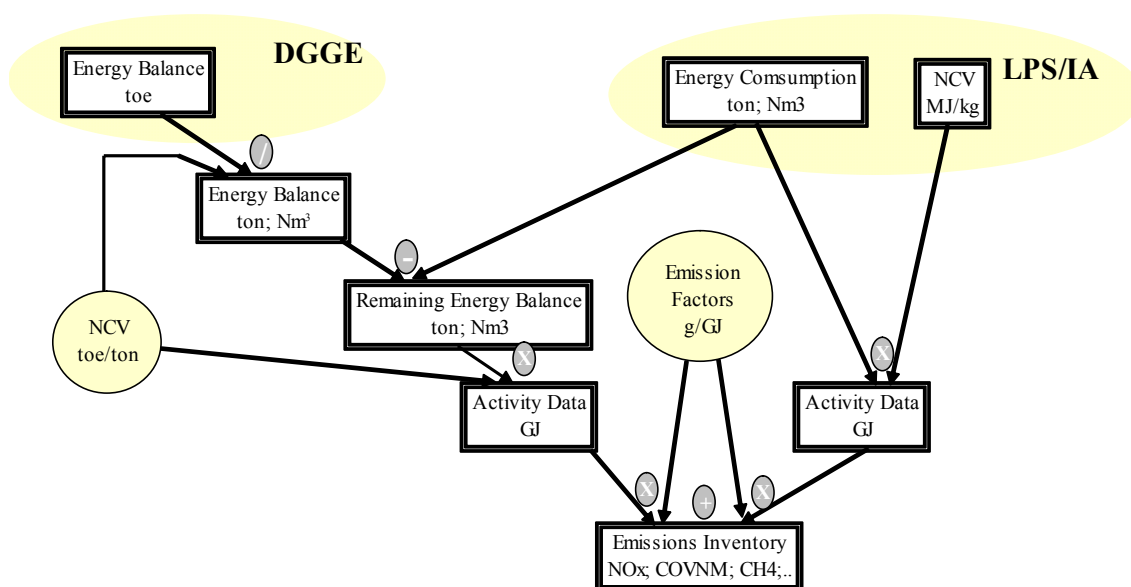
Activity data comprehends consumption of fuels and production rates.

### *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 EPER inventory. The detailed and specific information provided under for this sub-category, refers to the national iron and steel industry, 1 petrochemical unit, 8 paper pulp plants and 6 cement plants. Additional information was available for the only carbon black industrial plant from direct inquiry. The remaining energy consumption data is estimated subtracting LPS consumption data from annual energy balance compiled by DGE for each industrial sector. This procedure is synthesized in Figure 3.15.



Figure 3.15 – General procedure for emissions estimate



Data on 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 where the combustion takes place, apart from division between co-generation and non co-generation, and hence separation of fuel consumption among boilers, furnaces and engines was made by expert judgement according to each economic sector.

Original data of fuel consumption in the DGGE's energy balances is however split between quantities used in co-generation and quantities used without co-generation and emissions could be disaggregated accordingly.

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 desegregation from the other non-LPS sources within the respective sector. Data on paper pulp plants are presented for the 6 LCP units summed together.

Table 3.16 – Fuel consumption in Iron and Steel industry

BOILERS AND FURNACES				1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cod e	Fuel	Unit														
L 203	Residual oil	ton		41 732	8 039	8 406	34 037	28 232	27 277	26 708	27 926	19 292	22 313	26 397	26 924	17 249
L 204	Gas oil	ton		531	345	379	434	375	362	400	131	157	159	180	185	101
L 206	Kerosene	ton		31	37	31	41	66	67	64	75	72	67	13	0	44
L 299	Intermediate products	ton		10 000	10 494	11 386	9 128	6 680	8 002	5 825	8 809	7 364	8 256	9 778	9 778	0
L 299	Intermediate products	ton		10 000	10 494	11 386	9 128	6 680	8 002	5 825	8 809	7 364	8 256	9 778	9 778	0
L 303	LPG	ton		9 867	9 663	11 118	12 781	12 679	12 845	11 888	8 755	6 029	7 008	8 817	8 493	3 298
S 304	Coke oven gas	k m3		32 304	41 894	48 052	49 769	47 895	41 887	45 555	79 009	79 431	85 382	92 630	92 630	0
S 305	Blast furnace gas	k m3		580 000	433 610	724 695	752 091	690 573	557 878	415 705	602 134	513 011	605 933	752 238	752 238	0
G 301	Natural gas	k Nm3		0	0	0	0	0	0	0	5 874	19 227	20 643	26 748	20 968	24 371
O 115	Waste industrial (used oils)	ton		1 000	30	0	0	0	181	139	205	178	208	254	254	0

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	531	345	379	434	375	362	400	131	157	159	180	185	101
L	208	Motor gasoline	ton	37	25	39	23	40	33	50	5	3	4	3	76	24

Table 3.17 – Fuel consumption in Metallurgy

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	28 945	23 853	26 368	17 947	13 800	9 640	11 947	1 965	1 868	1 659	2 020	2 465	0
L	204	Gas oil	ton	334	452	457	468	517	423	744	663	650	1 020	1 013	1 792	1 317
L	206	Kerosene	ton	9	0	0	0	0	0	0	0	12	36	0	0	10
L	303	LPG	ton	11 122	11 007	12 614	10 470	11 127	12 441	13 420	11 607	10 406	7 941	5 113	6 718	7 330
S	102	Steam coal	ton	4 537	4 133	1 054	1 736	211	0	0	0	0	0	0	0	0
S	107	Coke	ton	13 604	8 569	8 567	0	0	0	0	0	0	0	0	0	0
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	31	890	5 086	12 594	13 895	9 670
B	111	Biomass wood	ton	11 367	11 167	10 997	10 777	10 780	10 780	11 433	11 433	11 458	11 500	11 433	11 433	11 501

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	334	452	457	468	517	423	744	663	650	1 020	1 013	1 792	1 317
L	208	Motor gasoline	ton	0	6	15	80	144	159	183	188	157	71	7	245	187

Table 3.18 – Fuel consumption in Chemical and Plastics Industry

## BOILERS

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	245 961	289 084	255 874	191 785	207 444	258 492	251 732	265 561	275 348	278 323	291 782	280 180	298 153
L	204	Gas oil	ton	1 792	2 835	2 475	2 291	3 428	3 853	4 837	3 852	4 901	4 891	2 674	4 009	4 740
L	206	Kerosene	ton	27	12	8	3	2	1	2	223	445	1 041	283	135	494
L	303	LPG	ton	5 480	2 702	2 670	4 541	23 849	34 014	21 859	18 450	10 028	8 873	7 219	12 364	16 282
L	308	Refinery gas	k m3	24 523	18 851	30 003	26 222	13 520	20 484	21 303	25 286	36 994	39 529	40 509	22 968	13 964
L	310	Gas from waste tips	k Nm3	C	C	C	C	C	C	C	C	C	C	C	C	C
L	399	Propylen	ton	21 137	21 004	33 164	30 174	16 110	24 367	25 420	30 077	39 547	45 004	45 926	26 413	40 204
S	102	Steam coal	ton	8 914	6 783	0	0	0	0	0	0	0	0	0	0	0
S	107	Coke	ton	7 017	9 865	16 661	15 251	16 429	17 547	16 749	14 433	18 583	18 583	76 329	20 563	38 179
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	18 603	54 420	67 689	76 758	61 929
B	111	Biomass wood	ton	83 747	82 280	81 040	79 420	79 420	79 420	84 290	84 290	84 468	107 023	108 415	108 413	105 181

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	3 897	6 666	10 324	14 273	4 942	9 191	7 804	8 122	8 688	11 881	11 800	9 414	10 431
L	204	Gas oil	ton	1 849	2 977	2 669	2 441	3 501	3 995	4 957	3 976	5 035	5 074	2 855	4 153	4 900
L	208	Motor gasoline	ton	174	540	1 490	1 506	2 406	3 706	2 940	4 260	4 203	3 608	1 075	1 610	3 514

Data for combustion in paper pulp production is individualized for the 6 industrial units that are covered under LCP directive.

Table 3.19 – Fuel consumption in Paper Pulp Industry in Large Combustion Plants

## FUEL CONSUMPTION

Equipment	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Boilers	L Oil residual + Gas LPG	kton	96.0	97.0	97.0	102.6	133.0	125.7	136.8	136.4	128.8	139.2	136.8	155.5	161.8
Lime kiln	L Oil residual	kton	43.8	37.5	49.0	49.1	53.2	53.2	53.2	53.2	53.2	53.2	53.2	57.3	58.5
Flare	L Gas LPG	kton	C	C	C	C	C	C	C	C	C	C	C	C	C
Biomass boiler	G Gas natural	k m3	C	C	C	C	C	C	C	C	C	C	C	C	C
Boilers	B Black liquor + bark + biomass + bisulfite and sulfite liquor	kton	2 126.4	2 303.4	2 373.2	2 312.4	2 360.5	2 493.3	2 369.7	2 595.6	2 562.6	2 636.8	2 711.2	2 763.3	2 820.9
Lime kiln	B Tall Oil + biomass gasef. + NCG	kton	22.9	26.3	26.3	26.2	26.4	26.4	26.4	26.4	26.4	26.4	26.4	27.1	27.3

C - confidential; NCG – non condensable gases

Table 3.20 – Fuel consumption in Paper and Paper Pulp Industry (non LCP)

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	94 644	119 798	132 426	136 247	144 951	98 149	111 503	118 003	110 414	104 211	122 384	28 355	104 046
L	204	Gas oil	ton	2 081	1 820	1 758	1 638	1 530	1 674	1 656	1 854	1 408	1 376	1 264	1 838	1 418
L	206	Kerosene	ton	0	1	1	0	0	1	0	0	0	0	1	2	1
L	303	LPG	ton	2 186	4 028	4 997	4 217	5 750	5 984	6 378	6 894	7 315	5 608	5 265	5 079	6 821
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	230	9 919	67 879	224 678	96 884
B	111	Biomass wood	ton	0	24 498	62 805	105 689	13 457	54 587	72 966	76 687	89 915	133 227	36 912	61 257	92 993

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	2 081	1 820	1 758	1 638	1 530	1 674	1 656	1 854	1 408	1 376	1 264	1 838	1 418
L	208	Motor gasoline	ton	60	141	197	108	246	137	120	212	199	172	18	543	278
B	309	Biogas	ton	0	0	0	0	0	0	0	0	0	0	280	513	252

Table 3.21 – Fuel consumption in Food processing Beverages and Tobacco Industries

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	221 492	240 269	237 822	224 279	222 569	233 862	233 962	276 772	282 653	263 625	233 494	236 502	259 078
L	204	Gas oil	ton	12 592	13 632	15 769	15 887	16 812	16 983	18 431	17 258	16 619	18 770	15 445	17 047	18 379
L	206	Kerosene	ton	304	154	173	175	142	116	49	105	127	159	40	21	24
L	303	LPG	ton	19 156	22 049	24 258	25 726	28 823	30 919	34 385	41 554	41 095	40 155	35 929	38 301	44 710
S	102	Steam coal	ton	424	227	15	0	0	0	0	0	0	0	0	0	0
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	114	11 541	35 156	52 823	68 337	48 799
B	111	Biomass wood	ton	317 190	311 640	306 947	300 807	300 810	300 810	319 200	319 200	319 875	270 186	273 699	273 667	280 518

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	12 592	12 592	12 592	12 592	12 592	12 592	12 601	12 598	12 592	12 630	12 635	12 637	12 630
L	208	Motor gasoline	ton	393	393	393	393	393	393	393	393	393	393	393	393	393

Table 3.22 – Fuel consumption in Textile Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	258 878	220 824	202 600	183 439	208 016	220 906	283 790	366 226	352 478	291 191	282 069	230 483	309 356
L	204	Gas oil	ton	636	650	717	730	860	862	934	1 174	1 211	1 190	1 739	1 569	1 631
L	206	Kerosene	ton	3	3	2	1	1	0	0	4	4	0	0	0	0
L	303	LPG	ton	4 464	5 500	6 628	6 534	6 915	7 946	9 440	11 730	13 925	15 105	10 738	9 525	13 925
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	462	18 390	123 140	176 953	98 983
B	111	Biomass wood	ton	90 547	88 963	87 623	85 870	85 870	85 870	91 133	91 133	91 326	161 968	164 074	164 073	164 212

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	636	650	717	730	860	862	934	1 174	1 211	1 190	1 739	1 569	1 631
L	208	Motor gasoline	ton	96	105	269	206	416	422	430	487	507	412	1 482	1 342	1 170

Table 3.23 – Fuel consumption in Ceramic Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	82 149	88 093	83 170	79 391	81 824	92 739	97 608	150 207	146 403	111 422	93 418	75 601	114 837
L	204	Gas oil	ton	2 956	3 619	3 632	3 033	3 083	3 007	3 137	4 342	4 608	4 103	4 182	4 967	4 683
L	206	Kerosene	ton	1	5	99	32	2	0	0	0	0	0	8	6	4
L	303	LPG	ton	130 011	142 121	154 888	161 895	173 893	185 839	191 983	172 227	95 131	53 006	29 807	30 845	55 270
S	102	Steam coal	ton	224	77	0	0	0	0	0	0	0	0	0	0	0
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	41 098	188 169	331 730	407 037	432 859	385 174
B	111	Biomass wood	ton	993 940	976 550	961 843	942 610	942 607	942 607	1 000 333	1 000 333	1 002 449	1 062 510	1 076 323	1 076 323	1 067 269

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	2 956	3 619	3 632	3 033	3 083	3 007	3 137	4 342	4 608	4 103	4 182	4 967	4 683
L	208	Motor gasoline	ton	860	926	1 149	1 132	1 185	1 090	780	671	683	462	384	395	380

Table 3.24 – Fuel consumption in Glass Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	109 573	135 444	136 872	149 790	158 017	161 631	168 860	188 310	200 901	139 139	85 792	76 069	132 399
L	204	Gas oil	ton	581	545	576	391	336	492	823	677	624	717	544	810	730
L	303	LPG	ton	24 532	26 394	24 147	23 952	26 748	29 197	32 742	36 649	23 461	11 990	7 269	5 089	12 674
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	831	23 473	83 174	154 951	177 502	128 687
B	111	Biomass wood	ton	110	107	107	103	103	103	110	110	110	110	110	110	110

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	581	545	576	391	336	492	823	677	624	717	544	810	730
L	208	Motor gasoline	ton	89	89	117	125	110	81	85	80	96	60	23	25	38

Table 3.25 – Fuel consumption in Cement Industry in clinker kilns in Large Point Sources

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	17 536	20 053	14 284	11 685	15 596	18 374	14 559	10 123	14 147	9 498	9 914	9 076	4 882
S	102	Steam coal	ton	790 755	778	538	470	917	531	023	521	298	492	465	286	268
S	110	Petcoke	ton	18 096	176	15 791	72 782	33 953	113	114	200	288	408	332	424	449
O	115	Tires	ton	8 365	7 692	2 408	5 514	4 244	3 937	6 759	7 044	6 311	8 025	7 634	7 889	8 569

Table 3.26 – Fuel consumption in Cement Industry (non LPS)

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	8 238	10 556	10 681	12 882	12 756	15 182	20 132	25 307	17 637	19 295	15 280	21 001	22 781
L	204	Gas oil	ton	7 216	8 185	8 391	8 512	8 149	8 518	8 960	9 621	5 507	6 668	7 414	11 645	8 676
L	206	Kerosene	ton	1	0	1	1	0	0	0	0	0	0	0	1 095	365
L	303	LPG	ton	629	853	1 436	1 364	1 314	1 384	1 530	5 640	4 539	2 722	3 725	4 221	4 796
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	2	9	2 193	2 573	1 492
B	111	Biomass wood	ton	20 460	20 103	19 800	19 403	19 403	19 403	20 600	20 600	20 644	20 617	20 633	20 633	20 723

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	7 216	8 185	8 391	8 512	8 149	8 518	8 960	9 621	5 507	6 668	7 414	11 645	8 676
L	208	Motor gasoline	ton	170	140	190	151	179	245	298	259	188	136	67	203	181

Table 3.27 – Fuel consumption in clothing, shoes and leather Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	19 060	21 342	34 637	45 435	33 251	17 536	19 694	19 308	17 787	16 093	8 710	9 219	12 721
L	204	Gas oil	ton	638	632	595	564	585	515	555	460	467	445	348	411	361
L	206	Kerosene	ton	1	1	1	0	0	0	0	0	0	0	0	0	0
L	303	LPG	ton	1 199	2 354	3 428	4 359	4 695	5 055	6 461	6 640	6 979	6 616	4 778	6 662	7 767
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	226	989	4 360	11 219	5 279
B	111	Biomass wood	ton	22 303	21 913	21 583	21 153	21 150	21 150	22 433	22 433	22 481	22 500	22 517	22 517	22 601

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	638	632	595	564	585	515	555	460	467	445	348	411	361
L	208	Motor gasoline	ton	44	61	174	159	210	193	184	178	168	138	86	295	218

Table 3.28 – Fuel consumption in Wood Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	33 498	31 763	17 151	26 757	44 444	75 546	76 827	72 138	70 655	70 776	73 139	43 345	79 365
L	204	Gas oil	ton	5 779	5 687	4 805	4 143	4 272	4 437	4 723	11 075	13 346	11 498	4 760	5 894	9 122
L	206	Kerosene	ton	2	1	0	0	0	0	0	44	66	2	2	2	21
L	303	LPG	ton	1 803	2 118	2 043	2 340	2 450	2 437	2 782	6 982	7 261	8 000	9 890	9 406	10 131
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	0	1 023	6 961	9 007	5 254
B	111	Biomass wood	ton	104 300	102 477	100 933	98 913	98 913	98 913	104 967	104 967	105 189	71 349	72 276	72 000	76 904

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	5 779	5 687	4 805	4 143	4 272	4 437	4 723	11 075	13 346	11 498	4 760	5 894	9 122
L	208	Motor gasoline	ton	18	41	79	81	206	246	267	2 967	3 778	2 894	90	691	2 181

Table 3.29 – Fuel consumption in Rubber Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	14 218	11 507	8 565	7 139	6 534	6 734	6 673	7 001	7 656	8 782	9 453	5 059	5 690
L	204	Gas oil	ton	126	157	314	315	337	311	323	268	274	388	683	770	627
L	206	Kerosene	ton	5	6	5	4	3	3	4	1	1	0	1	0	0
L	303	LPG	ton	585	636	599	590	650	704	829	1 504	592	550	594	748	801
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	11	46	1 022	4 040	1 654
B	111	Biomass wood	ton	3 730	3 663	3 610	3 537	3 537	3 537	3 767	3 767	3 775	3 770	3 767	3 767	3 789

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	126	157	314	315	337	311	323	268	274	388	683	770	627
L	208	Motor gasoline	ton	0	0	37	53	78	106	115	163	156	457	1 282	1 186	946

Table 3.30 – Fuel consumption in Machines manufacturing Industry and other Metal Equipment Industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	22 043	20 284	21 477	13 337	16 123	12 653	25 431	18 122	24 289	16 207	19 173	12 309	16 626
L	204	Gas oil	ton	3 831	3 772	4 066	3 690	3 574	4 867	5 878	5 017	5 779	5 514	2 715	4 045	4 822
L	206	Kerosene	ton	135	62	28	10	2	2	5	5	5	9	7	3	0
L	303	LPG	ton	30 956	31 988	32 450	31 985	34 263	33 957	34 445	50 132	51 946	47 987	37 730	35 419	45 895
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	4 795	12 731	21 084	35 116	45 887	33 750
B	111	Biomass wood	ton	2 260	2 220	2 187	2 143	2 143	2 143	2 267	2 267	2 271	1 274	1 291	1 290	1 428

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	3 831	3 772	4 066	3 690	3 574	4 867	5 878	5 017	5 779	5 514	2 715	4 045	4 822
L	208	Motor gasoline	ton	976	1 126	1 882	1 563	2 124	2 262	3 691	3 638	3 509	3 103	1 020	2 246	3 109

Table 3.31 – Fuel consumption in other transformation industry

## BOILERS AND FURNACES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	36 088	34 508	31 385	23 366	20 195	4 190	4 459	8	0	0	0	0	0
L	204	Gas oil	ton	3 909	5 062	5 508	8 393	6 746	4 169	6 057	462	733	633	412	576	0
L	206	Kerosene	ton	93	91	76	50	23	1	24	0	0	0	0	1	0
L	303	LPG	ton	3 223	4 303	4 961	7 209	8 374	9 111	10 378	2 425	2 044	2 723	1 680	1 057	2 393
L	308	Refinery gas	k m3	5	175	405	4 123	3 565	3 549	3 946	4 648	4 380	3 859	2 833	386	3 957
S	105	Brown coal/lignite	ton	26	12	2	27	41	0	0	0	0	0	0	0	0
G	301	Natural gas	k Nm3	0	0	0	0	0	0	0	0	12	534	3 196	4 249	2 468
B	111	Biomass wood	ton	497	487	480	470	470	470	500	500	501	500	500	500	503

## STATIC ENGINES

	Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	204	Gas oil	ton	3 909	5 062	5 508	8 393	6 746	4 169	6 057	462	733	633	412	576	0
L	208	Motor gasoline	ton	7	108	4 938	20 012	11 246	1 150	1 967	637	732	535	59	317	0

Table 3.32 – Fuel consumption in the extractive industry

Equipment		Code	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Boilers	L	203	Oil residual	ton	2 752	4 440	3 888	2 014	1 241	1 229	1 315	3 088	2 583	2 009	2 378	3 459	2 865
Boilers	L	204	Oil gas	ton	10 482	11 370	12 301	12 242	10 399	11 133	13 407	21 085	18 796	18 955	17 015	22 610	21 753
Boilers	L	206	Kerosene	ton	44	0	29	14	14	14	5	13	12	5	0	0	0
Boilers	L	303	Gas GPL	ton	1 589	1 609	1 582	1 773	2 131	2 190	2 625	3 857	4 205	4 046	3 638	4 432	4 728
Boilers	G	301	Gas natural	ton	0	0	0	0	0	0	0	0	0	299	412	6 103	6 309
Engines	L	204	Oil gas	ton	10 482	11 370	12 301	12 242	10 399	11 133	13 407	21 085	18 796	18 955	17 015	22 610	21 753
Engines	L	208	Gasoline motor	ton	363	353	233	193	143	45	70	128	444	676	462	1 834	1 479

Table 3.33 – Fuel consumption in Construction and Building

	Cod	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	16 713	22 026	21 809	44 214	35 177	43 912	33 705	47 107	49 996	35 578	36 675	40 774	48 081
L	204	Gas oil	ton	137 660	155 909	149 261	152 173	165 203	177 945	183 098	190 628	190 552	187 426	177 193	219 962	211 130
L	206	Kerosene	ton	157	8	48	63	27	15	4	41	253	5	3	9	9
L	208	Motor gasoline	ton	629	1 212	3 754	4 859	8 122	10 175	15 249	8 496	7 941	6 736	1 648	8 848	9 582
L	303	LPG	ton	4 928	4 359	5 593	9 776	14 729	19 297	22 563	13 669	12 142	12 231	11 862	17 838	17 838
G	301	Natural gas	ton	0	0	0	0	0	0	0	0	17	564	1 211	7 256	7 854

### 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 3.34. 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 and 2002 for the same units and the total time series of paper pulp by the acid sulphide process is from CELPA.

Table 3.34 – Total Paper Pulp Production (Kraft and sulphide paper pulp)

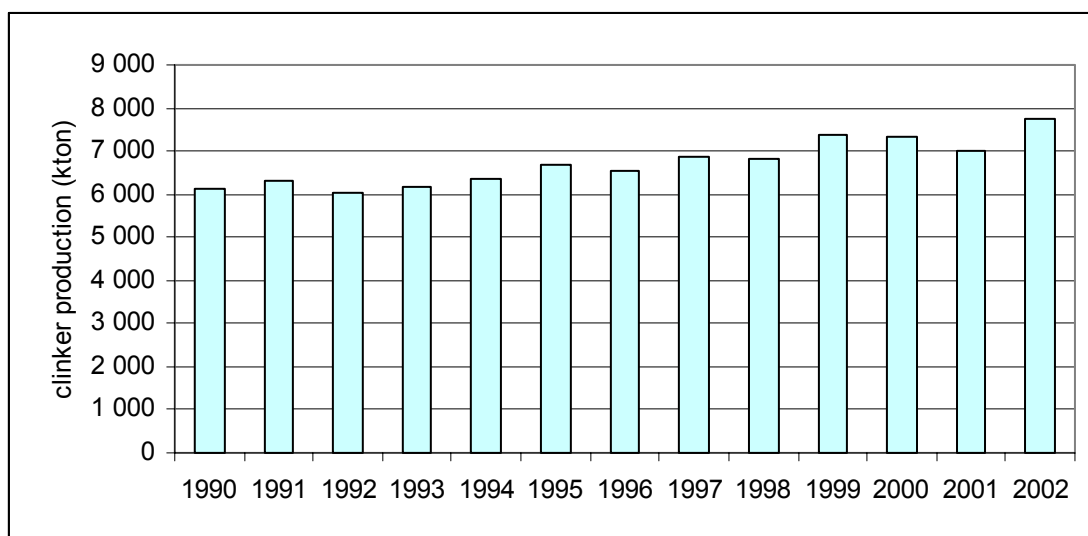
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Paper pulp production	kton of pulp AD	1 471	1 591	1 577	1 511	1 540	1 626	1 577	1 694	1 698	1 752	1 772	1 805	1 929

Production of clinker, presented in Table 3.35 and in Figure 3.16, results from data collected directly from the industrial plants.

Table 3.35 – Total clinker production (1990-2002)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Clinker	kton	6 128	6 311	6 050	6 165	6 352	6 679	6 535	6 870	6 821	7 380	7 343	6 992	7 739

Figure 3.16 – Total clinker production (1990-2002)

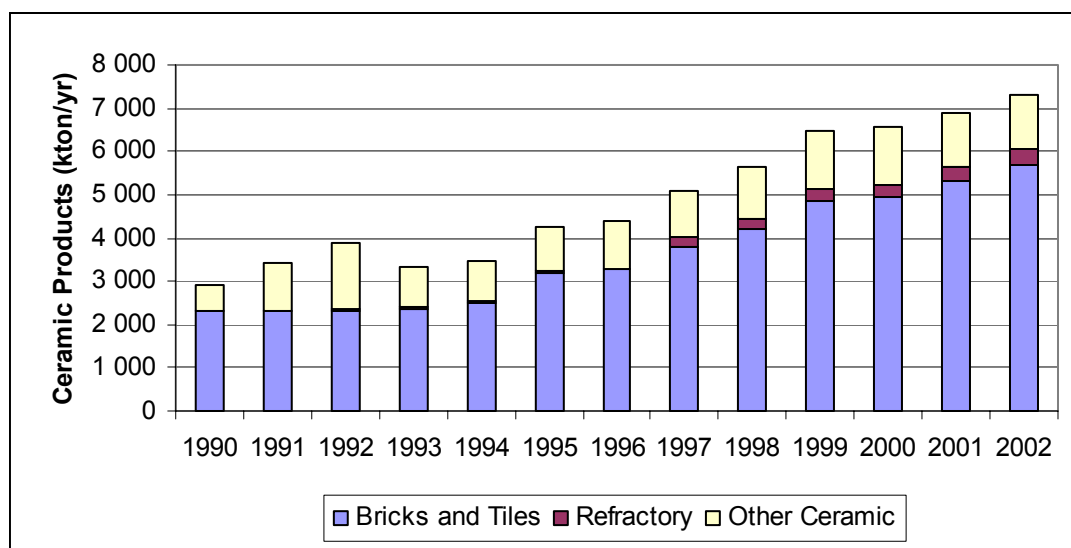


Annual manufacturing of ceramic products is available from 1990 to 2000 from INE statistical database. Values for 2001 and 2002 are provisional forecasts made by IA. Time series for total production may be seen in Table 3.36 and Figure 3.17, according to type of ceramic.

Table 3.36 – Ceramic Production according to type of ceramic

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Bricks and Tiles	kton	2 290	2 290	2 290	2 367	2 513	3 200	3 261	3 786	4 203	4 874	4 932	5 330	5 698
Refractory	kton	31	42	53	40	32	32	37	225	241	275	300	329	368
Other Ceramic	kton	582	1 070	1 558	943	915	1 028	1 097	1 082	1 212	1 310	1 313	1 226	1 239

Figure 3.17 – Ceramic Production according to type of ceramic



Production values for container glass, lead crystal glass and other glass is presented in Figure 3.18 and in Table 3.37, resulting from data in INE statistical databases and information received from Technology Centre for Ceramics and Glass (CTCV). More detailed discussion of origin



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 3.18 - Glass production by glass type (excluding flat glass production)

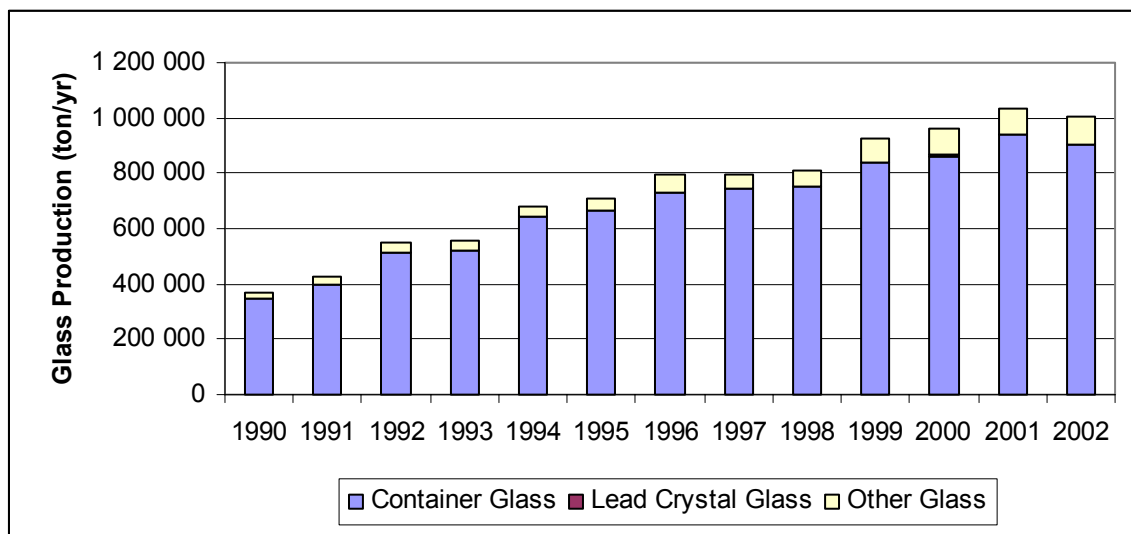


Table 3.37- Glass production by glass type (kton/yr) excluding flat glass production

Type of Glass	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Container Glass	345	400	510	519	640	663	730	741	751	835	864	936	904
Lead Crystal Glass	0.1	0.2	0.5	0.3	0.4	0.5	0.6	0.9	0.8	0.9	1.0	1.1	1.2
Other Glass	26	28	41	40	39	47	61	54	58	90	100	95	102

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

## EMISSION FACTORS

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

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

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

Table 3.38 – Emissions factors for general combustion in boilers and furnaces

Code	Fuel	Unit	NCV	Unit	SOx	NOx	COVNM	CH4	CO	CO2	N2O
						g/GJ	g/GJ	g/GJ	g/GJ	kg/GJ	g/GJ
L 203	Residual oil	GJ/ton	40.17	kg/ton	1.429	160	3.0	2.90	15	77.37	0.6
L 204	Gas oil	GJ/ton	43.31	kg/ton	6.000	60	1.0	0.10	12	74.07	0.6
L 206	Kerosene	GJ/ton	43.72	kg/ton	3.000	60	1.0	0.10	12	71.87	0.6
L 208	Motor gasoline	GJ/ton	44.77	kg/ton	2.000	60	1.0	0.10	12	69.30	0.6
L 299	Intermediate products	GJ/ton	42.74	kg/ton	0.000	160	3.0	2.90	15	77.37	0.6
L 299	Intermediate products	GJ/ton	40.17	kg/ton	12.000	160	3.0	2.90	15	80.67	0.6
L 303	LPG	GJ/ton	47.28	kg/ton	0.032	90	2.5	1.40	17	63.07	1.4
L 308	Refinery gas	GJ/k m3	15.69	kg/ kNm3	0.000	140	25.0	1.40	17	60.00	1.4
L 399	Propylen	GJ/ton	47.28	kg/ton	0.032	90	2.5	1.40	17	63.07	1.4
S 102	Steam coal	GJ/ton	29.29	kg/ton	13.000	170	190.0	2.40	150	96.07	0.7
S 105	Brown coal/lignite	GJ/ton	17.15	kg/ton	13.000	200	190.0	2.40	160	101.20	0.7
S 107	Coke gas	GJ/ton	28.03	kg/ton	20.000	300	12.0	2.40	160	101.95	0.7
S 304	Coke oven gas	GJ/k m3	17.57	kg/ kNm3	0.141	90	2.5	1.40	17	46.50	1.4
S 305	Blast furnace gas	GJ/k m3	3.77	kg/ kNm3	0.001	55	0.0	1.40	17	102.50	1.4
G 301	Natural gas	GJ/k Nm3	37.66	kg/ kNm3	0.001	67	5.0	1.40	13	56.10	1.4
B 111	Biomass wood	GJ/ton	12.55	kg/ton	0.000	70	150.0	15.00	500	109.63	4.3
B 215	Black liquor	GJ/ton	16.74	kg/ton	0.000	70	150.0	15.00	500	73.33	4.3
B 309	Biogas	GJ/ton	34.70	kg/ton	0.032	90	2.5	1.40	17	52.00	1.4
O 313	Hydrogen	GJ/ton	47.28	kg/ton	0.032	90	2.5	1.40	17	63.07	1.4

Table 3.39 – Emissions factors for general combustion in boilers and furnaces: Particulate Matter

Equipment		Code	Fuel	PST	PM10	PM2.5	PM1.0
				g/GJ	% PST	% PST	% PST
Boilers	S	102	Steam Coal	68.3	20	20	20
Boilers	S	105	Brown Coal/Lignite	1165.9	35	10	6
Boilers	S	107	Coke Oven from Hard Coal	68.3	20	20	20
Boilers	L	299	Intermediate Products	53	86	56	36
Boilers	L	303	LPG	3	100	100	100
Boilers	L	206	Kerosene	6.5	50	12	8
Boilers	L	204	Gas Oil	6.5	50	12	8
Boilers	L	203	Residual Oil	53	86	56	36
Boilers	G	301	Natural Gas	0.8	100	100	100
Boilers	G	308	Refinery Gas	0.8	100	100	100
Boilers	S	304	Coke Oven Gas	0.8	100	100	100
Boilers	S	305	Blast Furnace Gas	0.8	100	100	100
Boilers	G	399	Hydrogen	0.8	100	100	100
Boilers	B	111	Biomass Wood	172	90	76	67
Boilers	B	309	Biogas	0.8	100	100	100
Static Engines	L	303	LPG	6.9	100	100	100
Static Engines	L	208	Motor Gasoline	43	100	100	100
Static Engines	L	206	Kerosene	133.3	100	100	100
Static Engines	L	204	Gas Oil	133.3	100	100	100
Static Engines	L	203	Residual Oil	30	82	77	77
Static Engines	G	301	Natural Gas	6.9	100	100	100
Static Engines	B	309	Biogas	6.9	100	100	100

Table 3.40 – Emissions factors for general combustion in engines

	Code	Fuel	NOx g/GJ	COVNM g/GJ	CH4 g/GJ
L	204	Gas oil	1 100	100	9.89
L	206	Kerosene	60	100	9.89
L	208	Motor gasoline	1 300	100	9.89

The emission factors presented in previous Table 3.38 and Table 3.40 were applied in the majority of the sectors considered. Exception to this, are specific emission factors used for some sectors that are presented separately in the following tables.

Table 3.41 –Emission factors for the extractive industry

Equipment		Code	Fuel	PCI MJ/Kg	SOx %	NOx g/GJ	COVNM g/GJ	CH4 g/GJ	CO g/GJ	CO2 g/GJ	N2O g/GJ
Boilers	L	203	Residual Oil	40.17	2.23 - 2.84	160	3	1.4	20	72.6	0.6
Boilers	L	204	Gas Oil	43.30	0.1 - 0.3	60	1	0.6	20	73	0.6
Boilers	L	206	Kerosene	43.72	0.15 - 0.2	60	1	0.6	20	73	0.6
Boilers	L	208	Motor Gasoline	44.77	0.015 - 0.1	0	0	0	0	71	0.6
Boilers	L	303	LPG	47.28	0.0016	65	2.5	1.5	50	64.5	1.4
Boilers	G	301	Natural Gas	37.86	0.0059	67	5	1.4	13	56	1.4
Static engines	L	203	Residual Oil	40.17	2.23 - 2.84	0	0	0	0	72.6	0.6
Static engines	L	204	Gas Oil	43.30	0.2 - 0.3	1100	100	60	20	73	0.6
Static engines	L	206	Kerosene	43.72	0.15 - 0.2	0	0	0	0	73	0.6
Static engines	L	208	Motor Gasoline	44.77	0.1	1300	100	60	20	71	0.6
Static engines	L	303	LPG	47.28	0.0016	0	0	0	0	64.5	0.6
Static engines	G	301	Natural Gas	37.86	0.0059	0	0	0	0	56	1.4

Table 3.42 – Emission factors for Particulate Matter from the extractive industry

Equipment		Code	Fuel	PM		PM10		PM2.5		PM1.0	
				Estimation method	g/GJ	Estimation method	% PST	Estimation method	% PST	Estimation method	% PST
Boilers	L	203	Residual oil	1	53.0	3	86	3	56	3	36
Boilers	L	204	Gas oil	1	6.5	3	50	3	12	3	8
Boilers	L	206	Kerosene	1	6.5	3	50	3	12	3	8
Boilers	L	208	Gasoline motor	1	43.0	3	100	3	100	3	100
Boilers	L	303	GPL gas	1	3.0	3	100	3	100	3	100
Boilers	G	301	Natural gas	1	0.8	3	100	3	100	3	100
Static engines	L	203	Residual oil	1	30.0	3	82.2	3	77.3	3	77.1
Static engines	S	204	Gas oil	1	133.3	3	100	3	100	3	100
Static engines	S	206	Kerosene	1	133.3	3	100	3	100	3	100
Static engines	S	208	Gasoline motor	1	43.0	3	100	3	100	3	100
Static engines	S	303	GPL gas	1	6.9	3	100	3	100	3	100
Static engines	S	301	Natural gas	1	6.9	3	100	3	100	3	100

Note:

NCG - Non Condensable Gases

Estimation method: 1 - g/GJ; 3 - massic % of PST

Table 3.43 –Emission factors for the building and construction industry

## Construction and public works: Emissions Factors

	Code	Fuel	PCI MJ/Kg	SOx %	NOx g/GJ	COVNM g/GJ	CH4 g/GJ	CO g/GJ	CO2 kg/GJ	N2O g/GJ
L	203	Residual oil	40.17	3	160	3	1.6	20	77.4	0.6
L	204	Gas oil	43.31	0.3	1100	50.5	5.0	20	74.1	0.6
L	205	Diesel oil	43.31	0.3	60	1	0.6	20	74.1	0.6
L	206	Kerosene	43.72	0.15	60	50.5	5.0	20	71.9	0.6
L	208	Motor gasoline	44.77	0.1	1300	100	9.9	20	69.3	0.6
L	303	LPG	47.28	0.0016	1200	2.5	1.5	50	63.1	1.4
G	301	Natural gas	42.60	0.0059	1200	100	9.9	20	56.1	1.4

Table 3.44 –Emission factors for Particulate Matter for the building and construction industry

## Construction and public works: Particulate matter Emissions Factors

	Code	Fuel	PM g/GJ	PM10 (% of PST)	PM2.5 (% of PST)	PM1.0 (% of PST)
L	203	Residual oil	53.0	62	23	14
L	204	Gas oil	6.5	55	42	37
L	205	Diesel oil	6.5	55	42	37
L	206	Kerosene	6.5	55	42	37
L	208	Motor gasoline	43.0	100	100	100
L	303	LPG	2.5	100	100	100
G	301	Natural gas	0.8	100	100	100

Other specific emission factors were used for some industrial units, some of them obtained from direct measurements in LPS or are sector specific.

Table 3.45 – Specific emission factors for LPS in Iron and steel (1/3)

## Iron and Steel: Emission Factors (1/3)

Equipment	Code	Fuel	PCI		SOx		NOx		COVNM	
			Unit		Estimation method	EF	Estimation method	EF	Estimation method	EF
Rolling mills	L	203	Residual oil	MJ/kg	40.35	1	3.500	1	190	3.0
Power plant	L	203	Oil residual 3.5%	MJ/kg	40.35	1	3.500	1	190	3.0
Power plant	L	203	Oil residual 1%	MJ/kg	40.35	1	1.000	1	190	3.0
Power plant	L	299	Intermediate products	MJ/kg	34.10	1	0.600	1	300	3.0
Heat power plant	L	303	LPG	MJ/kg	46.04	1	0.005	1	160	4.0
Heat power plant	L	299	Intermediate products	MJ/kg	34.10	1	0.600	1	300	3.0
Lime kiln a)	L	-	-	-	-	4	0.421	4	0.1	0.0
Sintering	S	304	Coke oven gas	MJ/Nm3	18.78	3	1.000	3	0.5	0.1
Blast furnace cowpers	S	304	Coke oven gas	MJ/Nm3	18.78	2	7.050	1	120	2.5
Blast furnace cowpers	S	305	Blast furnace gas	MJ/Nm3	2.87	2	0.045	1	70	2.5
Rolling mills	S	304	Coke oven gas	MJ/Nm3	18.78	2	7.050	1	120	2.5
Power plant	S	304	Coke oven gas	MJ/Nm3	18.78	2	7.050	1	120	2.5
Power plant	S	305	Blast furnace gas	MJ/Nm3	2.87	2	0.045	1	70	2.5
Heat power plant	O	115	Waste industrial (used oils)	MJ/kg	40.35	1	0.000	1	190	3.0

Table 3.46 – Specific emission factors for LPS in Iron and steel (2/3)

## Iron and Steel: Emission Factors (2/3)

Equipment		Code	Fuel	CH4		CO		CO2		N2O	
				Unit	EF	Estimation method	EF	Unit	EF	Unit	EF
Rolling mills	L	203	Residual oil	g/GJ	3.0	1	15	kg/GJ	76.04	g/GJ	0.6
Power plant	L	203	Oil residual 3.5%	g/GJ	3.0	1	15	kg/GJ	76.04	g/GJ	0.6
Power plant	L	203	Oil residual 1%	g/GJ	3.0	1	15	kg/GJ	76.04	g/GJ	0.6
Power plant	L	299	Intermediate products	g/GJ	3.0	1	15	kg/GJ	74.04	g/GJ	0.6
Heat power plant	L	303	LPG	g/GJ	4.0	1	17	kg/GJ	64.55	g/GJ	1.4
Heat power plant	L	299	Intermediate products	g/GJ	3.0	1	15	kg/GJ	74.04	g/GJ	0.6
Lime kiln a)	L	-	-		0.0	4	2	kg/GJ	790.00	g/GJ	0.0
Sintering	S	304	Coke oven gas	g/GJ	2.5	3	30	kg/GJ	96.31	g/GJ	1.4
Blast furnace cowpers	S	304	Coke oven gas	g/GJ	2.5	1	17	kg/GJ	96.30	g/GJ	1.4
Blast furnace cowpers	S	305	Blast furnace gas	g/GJ	2.5	1	17	kg/GJ	241.34	g/GJ	1.4
Rolling mills	S	304	Coke oven gas	g/GJ	2.5	1	17	kg/GJ	96.30	g/GJ	1.4
Power plant	S	304	Coke oven gas	g/GJ	2.5	1	17	kg/GJ	96.30	g/GJ	1.4
Power plant	S	305	Blast furnace gas	g/GJ	2.5	1	17	kg/GJ	241.34	g/GJ	1.4
Heat power plant	O	115	Waste industrial (used oils)	g/GJ	3.0	1	15	kg/GJ	76.04	g/GJ	0.6

a) Emissions estimated based on lime production.

SOx: Estimation method: 1 - from % S; 2- from gS/Nm<sup>3</sup>; 3- from prod sinter unit kg/ton sinter; 4- from lime production: kg/ton lime

NOx: Estimation method : 1 - from g/GJ; 3- from prod sinter: kg/ton sinter; 4- from lime production: kg/ton lime

NMVOC: Estimation method : 1 - from g/GJ; 3- from prod sinter: kg/ton sinter

CO: Estimation method : 1 - from g/GJ; 3- from prod sinter: kg/ton sinter

Table 3.47 – Specific emission factors for LPS in Iron and steel (3/3)

## Iron and Steel: Emission Factors (3/3)

Iron and Steel: Emission Factors (3/3)											
Equipment		Code	Fuel	PM		PM10		PM2.5		PM1.0	
				Estimation method	g/GJ	Estimation method	% PST	Estimation method	% PST	Estimation method	% PST
Rolling mills	L	203	Residual oil	1	0	3	0	3	0	3	0
Power plant	L	203	Residual oil (% S = 3.5)	1	108	3	100	3	100	3	100
Power plant	L	203	Residual oil (% S = 1)	1	37.5	3	100	3	100	3	100
Power plant	L	299	Intermediate products	1	108	3	86	3	56	3	36
Heat power plant	L	303	LPG	1	3	3	100	3	100	3	100
Heat power plant	L	299	Intermediate products	1	108	3	86	3	56	3	36
Lime kiln a)	L	-	-	4	6.8	3	0	3	0	3	0
Sintering	S	204	Coke oven gas	1	3.9	3	15	3	6.5	3	4
Blast furnace cowpers	S	304	Coke oven gas	1	3	3	100	3	100	3	100
Blast furnace cowpers	S	305	Blast furnace gas	1	3	3	100	3	100	3	100
Rolling mills	S	304	Coke oven gas	1	0	3	0	3	0	3	0
Power plant	S	304	Coke oven gas	1	3	3	100	3	100	3	100
Power plant	S	305	Blast furnace gas	1	3	3	100	3	100	3	100
Heat power plant	O	115	Industrial Waste (used oils)	1	108	3	86	3	56	3	36

Note:

NCG - Non Condensable Gases

Estimation method: 1 - g/GJ; 3 - mass % of PST

Table 3.48 – Specific emission factors for LPS in chemical industry (1/5)

**Chemical LPS: Net Calorific Value**

Equipment	Code Fuel	Unit	Range
Boilers	203Residual oil	MJ/kg	39.33 - 41.24
Boilers	308Refinery gas	MJ/kg	47.70 - 52.67
Furnaces	303LPG	MJ/kg	52.67
Furnaces	308Refinery gas	MJ/kg	52.67
Static engines	203Residual oil	MJ/kg	41.24
Static engines	204Gas oil	MJ/kg	43.30
Flares	308Refinery gas	MJ/kg	47.84 - 53.08

Table 3.49 – Specific emission factors for LPS in chemical industry (2/5)

**Chemical LPS: Sulphur content**

Equipment	Code Fuel	Unit	Range
Boilers	203Residual oil	%	0.35 - 3.5
Boilers	308Refinery gas	%	0.0005
Furnaces	303LPG	%	0.0005
Furnaces	308Refinery gas	%	0.0005
Static engines	203Residual oil	%	1.6 - 3.5
Static engines	204Gas oil	%	0.3
Flares	308Refinery gas	%	0

Table 3.50 – Specific emission factors for LPS in chemical industry (3/5)

**Chemical LPS: Emission Factors**

Equipment	Code Fuel	NOx g/GJ	COVNM g/GJ	CH4 g/GJ	CO g/GJ	CO2 (t/t)	N2O g/GJ
Boilers	203Residual oil	140 - 170		3	3	1587.5 - 91.6	0.6
Boilers	308Refinery gas	147		2.5	2.5	1387.9 - 96.8	1.4
Furnaces	303LPG	88		2.5	2.5	13	96.8
Furnaces	308Refinery gas	88		2.5	2.5	13	96.8
Static engines	203Residual oil	900		60	60	15	1753.8
Static engines	204Gas oil	900		60	60	12	1841.1
Flares	308Refinery gas	NE	NE	NE	NE	3.14	NE

NE - Not estimated

CO2 Global or ultimate CO2.

Table 3.51 – Specific emission factors for LPS in chemical industry (4/5)

**Chemical LPS: Emission Factors**

Equipment	Code	Fuel	NCV unit	SOx kg/ ton gas	NOx g/GJ	COVNM g/GJ	CH4 g/GJ	CO g/GJ	CO2 g/GJ	N2O g/GJ
Boiler	L	310 Gas from waste tips	MJ/Nm3	2.02	0.1953	90	2.5	1.4	17	a)
Boiler	L	303LPG	MJ/kg	47.28	0.0320	90	2.5	1.4	17	66.34

a) CO2 emissions estimated based on mass balance from feedstock and fuel consumption, and carbon black produced.

Table 3.52 – Specific emission factors for LPS in chemical industry (5/5)

## Particulate matter Emission Factors

Equipment	Code	Fuel	PM		PM10		PM2.5		PM1.0	
			Estimation method	g/GJ	Estimation method	% PST	Estimation method	% PST	Estimation method	% PST
Boilers	L	203	Residual oil	1	* Formula	86	3	56	3	36
Boilers	L	308	Refinery gas	1	3	100	3	100	3	100
Furnaces	L	303	LPG	1	3	100	3	100	3	100
Furnaces	L	308	Refinery gas	1	3	100	3	100	3	100
Static engines	L	203	Residual Oil	1	30	82	3	77	3	77
Static engines	L	204	Gas Oil	1	133	100	3	100	3	100
Flares	L	308	Refinery gas	1	-	-	3	-	3	-

Note:

\* Formula:  $8.34 \times (1.12 \times \%S + 0.37) \times 0.12 \times 1000 / (0.99 \times \text{LHV})$ 

% S: Ash content

LHV: Low heating value

Estimation method: 1 - g/GJ; 3 - massic % of PST

Table 3.53 – Specific emission factors for LPS in the paper pulp industry (1/5)

## Paper Pulp: Net Calorific Value

Equipment	Code	Fuel	Unit	NCV
Boilers	L 203	Residual oil	kcal/kg	9062-9988
Boilers	L 303	LPG	kcal/kg	11400
Lime kiln	L 203	Residual oil	kcal/kg	9413-9700
Flare	L 303	LPG	kcal/kg	12587
Biomass boiler	G 301	Natural gas	kcal/m3	9058
Recuperation boilers	B 215	Black liquor	kcal/kg	1766-3970
Biomass boiler	B 111	Biomass wood	kcal/kg	2500-7538
Biomass boiler	B 111	Bark	kcal/kg	3680-4898
Boilers	B 215	Bisulfite liquor	kcal/kg	3700
Boilers	B 215	Sulfite liquor	kcal/kg	3769
Lime kiln	B -	Tall oil	kcal/kg	8130-8520
Lime kiln	B -	Gasified biomass	kcal/kg	3500
Lime kiln	B -	NCG	kcal/kg	23312

NCG - Non Condensable Gases

Source: LPS and CEC (1992)

Table 3.54 – Specific emission factors for LPS in the paper pulp industry (2/5)

## Paper Pulp: Emission Factors (1/4)

Equipment	Code	Fuel	SOx				NOx			
			Estimation method	% S	Estimation method	kg/ ton pulp	Estimation method	g/GJ	Estimation method	kg/ ton pulp
Boilers	L 203	Residual oil	1	1.0-3.5			1	180-210		
Boilers	L 303	LPG	1	0.0			1	80		
Lime kiln	L 203	Residual oil			2	0.15			2	0.5
Flare	L 303	LPG	1	0.0			1	80		
Biomass boiler	G 301	Natural gas	1	0.0			1	67		
Recuperation boilers	B 215	Black liquor			2	3.5			2	1.16
Biomass boiler	B 111	Biomass wood	1	0.0			1	200		
Biomass boiler	B 111	Bark	1	0.0			1	200		
Boilers	B 215	Bisulfite liquor			2	12.5			2	1.25
Boilers	B 215	Sulfite liquor			2	12.5			2	1.25
Lime kiln	B -	Tall oil			2	0.0			2	0.5
Lime kiln	B -	Gasified biomass			2	0.15			2	0.5
Lime kiln	B -	NCG			2	3.0			2	0.5

Table 3.55 – Specific emission factors for LPS in the paper pulp industry (3/5)

## Paper Pulp: Emission Factors (2/4)

Equipment	Code	Fuel	COVNM		CH4	
			Estimation method	g/GJ	Estimation method	kg/ ton pulp
Boilers	L 203	Residual oil	1	3	1	3
Boilers	L 303	LPG	1	2.5	1	0.72
Lime kiln	L 203	Residual oil				2 0.065
Flare	L 303	LPG	1	2.5	1	0.72
Biomass boiler	G 301	Natural gas	1	5	1	1.4
Recuperation boilers	B 215	Black liquor				2 0.49
Biomass boiler	B 111	Biomass wood	1	80	1	30
Biomass boiler	B 111	Bark	1	80	1	30
Boilers	B 215	Bisulfite liquor				2 0.625
Boilers	B 215	Sulfite liquor				2 0.625
Lime kiln	B -	Tall oil				2 0.065
Lime kiln	B -	Gasified biomass				2 0.065
Lime kiln	B -	NCG				2 0.065

Table 3.56 – Specific emission factors for LPS in the paper pulp industry (4/5)

## PULP: Emission Factors (3/4)

Equipment	Code	Fuel	CO		CO2		N2O	
			Estimation method	g/GJ	Estimation method	kg/GJ	Estimation method	g/GJ
Boilers	L 203	Oil residual	1	15	1	76	1	0.6
Boilers	L 303	Gas LPG	1	15	1	65	1	1.4
Lime kiln	L 203	Oil residual	1	15	1	76	1	0.6
Flare	L 303	Gas LPG	1	15	1	65	1	1.4
Biomass boiler	G 301	Gas natural	1	13	1	56.1	1	1.4
Recuperation boilers	B 215	Black liquor	1	15	1	106	1	0.6
Biomass boiler	B 111	Biomass wood	1	500	1	100	1	4.3
Biomass boiler	B 111	Bark	1	500	1	100	1	4.3
Boilers	B 215	Bisulfite liquor	1	15	1	106	1	0.6
Boilers	B 215	Sulfite liquor	1	15	1	106	1	0.6
Lime kiln	B -	Tall oil	1	15	1	77-82	1	0.6
Lime kiln	B -	Gasified biomass	1	500	1	101-107	1	4.3
Lime kiln	B -	NCG	1	15	1	65	1	1.4

NCG - Non Condensable Gases

SOx: Estimation method: 1 - from % S; 2 - from paper pulp production: kg/ton pulp

Other pollutants: 1 - g/GJ; 2 - from paper pulp production: kg/ton pulp

Source: LPS and Corinair 90 Inventory Default Emission Factor Handbook 2<sup>nd</sup> ed (CEC,1992)

Table 3.57 – Specific emission factors for LPS in the paper pulp industry (5/5)

## PULP: Emission Factors (4/4)

Equipment	Code	Fuel	PM		PM10		PM2.5		PM1.0	
			Estimation method	g/GJ	Estimation method	% PST	Estimation method	% PST	Estimation method	% PST
Boilers	L 203	Residual oil	1	108	3	86	3	56	3	36
Boilers	L 303	Gas LPG	1	3	3	100	3	100	3	100
Lime kiln	L 203	Residual oil	1	28	3	16.8	3	10.5	3	7.1
Flare	L 303	Gas LPG	1	-	3	-	3	-	3	-
Biomass boiler	G 301	Gas natural	1	0.8	3	100	3	100	3	100
Recuperation boilers	B 215	Black liquor	1	90	3	93.5	3	83.5	3	45.3
Biomass boiler	B 111	Biomass wood	1	172	3	90	3	76	3	67
Biomass boiler	B 111	Bark	1	172	3	90	3	76	3	67
Boilers	B 215	Bisulfite liquor	1	2	3	100	3	100	3	100
Boilers	B 215	Sulfite liquor	1	2	3	100	3	100	3	100
Lime kiln	B -	Tall oil	1	28	3	16.8	3	10.5	3	7.1
Lime kiln	B -	Gasified biomass	1	28	3	16.8	3	10.5	3	7.1



Lime kiln	B	-	NCG	1	28	3	16.8	3	10.5	3	7.1
-----------	---	---	-----	---	----	---	------	---	------	---	-----

Note:

NCG - Non Condensable Gases

Estimation method: 1 - g/GJ; 3 - massic % of PST

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 3.58 and Table 3.59. Most emission factors result from plant specific emission factors developed from monitoring at each installation, as reported to EPER exercise.

Table 3.58 – Emission Factors for cement production (1/2)

Fuel	Code		LHV (MJ/kg)	SOx (kg/ton)	NOx (kg/ton)	NMVOC (kg/ton)	CH4 (kg/ton)	CO (kg/ton)	U CO2 <sup>(a)</sup> (kg/GJ)
Fuel oil	203	L	40.2	0.05-4.10	1.92-3.70	0.01-0.11	0.001-0.030	0.06-2.30	77.4
Coal	102	S	24.3-27.5						101.2
Petro coke	110	L	27						102.0
Tires	115	O	24						99.8

(a) only CO2 from use of fossil fuels, excluding CO2 emissions from limestone and dolomite decarbonizing are included in production processes;

Table 3.59 – Emission Factors for cement production (2/2)

Fuel	Code		N2O (g/GJ)	NH3 (kg/ton)	PM (kg/ton)	PM10 (kg/ton)	PM2.5 (kg/ton)	PM1.0 (kg/ton)
Fuel oil	203	L	0.60	0.01-1.04	0.05-0.31	0.05-0.31	0.05-0.31	0.05-0.31
Coal	102	S	0.70					
Petro coke	110	L	0.70					
Tires	115	O	0.70					

(b) also including non combustion emissions from cement process.

Table 3.60 – Emission Factors for ceramic production

Ceramic Type	Fuel	SOx %	NOx g/GJ	NMVOC g/GJ	CH4 g/GJ	PM g/GJ	PM10 g/GJ	PM2.5 g/GJ	PM1 g/GJ
Bricks and Tiles <sup>(a)</sup>	LPG	1.5	0.4	0.03	0.03	0.143	0.143	0.1	0.1
	FO	1.1	0.5	0.03	0.03	0.140	0.123	0.1	0.1
	NG	1.5	0.4	0.03	0.03	0.143	0.143	0.1	0.1
	Wood	0.4	0.5	0.09	0.03	0.133	0.083	0.1	0.1
Refractory <sup>(b)</sup>	LPG	3.8	0.9	0.03	0.03	67.6	16.6	16.6	16.6
Other Ceramic <sup>(c)</sup>	LPG	0.0	0.3	0.2	0.0	10.9	2.9	2.9	2.9
	FO	62.5	0.3	0.2	0.0	10.9	2.9	2.9	2.9
	NG	0.0	0.3	0.2	0.0	10.9	2.9	2.9	2.9
	Wood	0.0	0.3	0.2	0.0	10.9	2.9	2.9	2.9

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

Table 3.61 – Emission Factors for glass production

Type of Glass	SO <sub>x</sub>	NO <sub>x</sub>	NM VOC	CH <sub>4</sub>	CO	PST	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>1</sub>
	kg/ton								
Flat Glass	1.5	4	0.1	0.01	0.1	1.0	0.95	0.91	0.91
Container Glass	1.7	3.1	4.5	0.45	0.1	0.7	0.67	0.64	0.64
Lead Crystal Glass	2.8	4.3	4.7	0.47	0.1	8.4	7.98	7.64	7.64
Other Glass	2.8	4.3	4.7	0.47	0.1	8.4	7.98	7.64	7.64

Source: USEPA(1986)

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.A.5 TRANSPORT (CRF 1A3)

#### ROAD TRANSPORTATION

##### Overview

Road transportation is one of the most important emitter of greenhouse gases such as carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). It is also a significant emission source of pollutants associated with trans-boundary, regional and local air problems, comprehending sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), non methane volatile organic compounds (NMVOC). 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 desegregated for each of the following vehicle classes<sup>17</sup>:

Table 3.62 - 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 <sup>18</sup>
	Urban Buses
	Coaches

<sup>17</sup> These Classes are those considered in the EMEP/CORINAIR Methodology (3 rd ed)

<sup>18</sup> Heavy duty vehicles with weight greater than 32 t were assumed not representative in national fleet.

Mopeds & Motorcycles < 50cm <sup>3</sup>	
Motorcycles	Two stroke >50 cm <sup>3</sup>
	Four stroke 50 – 250 cm <sup>3</sup>
	Four stroke 250 – 750 cm <sup>3</sup>
	Four stroke >750 cm <sup>3</sup>

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

- Vehicle age or emission abatement technology;
- Fuel type: gasoline/petrol, diesel and liquefied petroleum gases (LPG);
- Driving mode: urban, rural and highway.

The use of petrol/gasoline in road vehicles is also responsible for evaporative emissions which were also included in this source sector. They consist of losses of the most volatile organic components present 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, again the result 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.

### **Methodology**

Exhaust emission estimate follows a country specific integrated methodology developed in 2003/2004 and that it is used in the national submission for the first time. This new methodology was developed with two main objectives:

- Ameliorate emission estimates for those pollutants that are most dependent on vehicle class and abatement technology, such as N<sub>2</sub>O, NO<sub>x</sub> and NMVOC;
- Improve attribution of total emission estimates for each vehicle type and driving mode;
- Allow integration of emission inventory models with projection and management models (Policies and Measures) made under PNAC and PTEN national emission plans.

Two new models or tools were therefore developed for this purpose, comprehending a model for road transport emission calculation – BURNN – together with a module to determine the national vehicle fleet – KAR.

KAR model estimates annual fleet from long-time series of vehicle sales and abatement.

BURNN model is compatible and based extensively in the third edition of the EMEP/CORINAIR Emission Inventory Guidebook (EEA,2002) methodology and emission factors. KAR and BURNN data flow is summarized in Figure 3.19 from where, main following steps may be identified:

- Estimate national fleet per vehicle type<sup>19</sup> (KAR module output);
- First estimate of kilometres driven per vehicle type, driving conditions and vehicle technology, using vehicle fleet and annual kilometres driven per each vehicle type in each driving mode;
- Estimate fuel consumption per vehicle type, driving conditions and vehicle technology (bottom-up approach) from total kilometres driven per each vehicle class;
- 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 driven or fuel consumption.

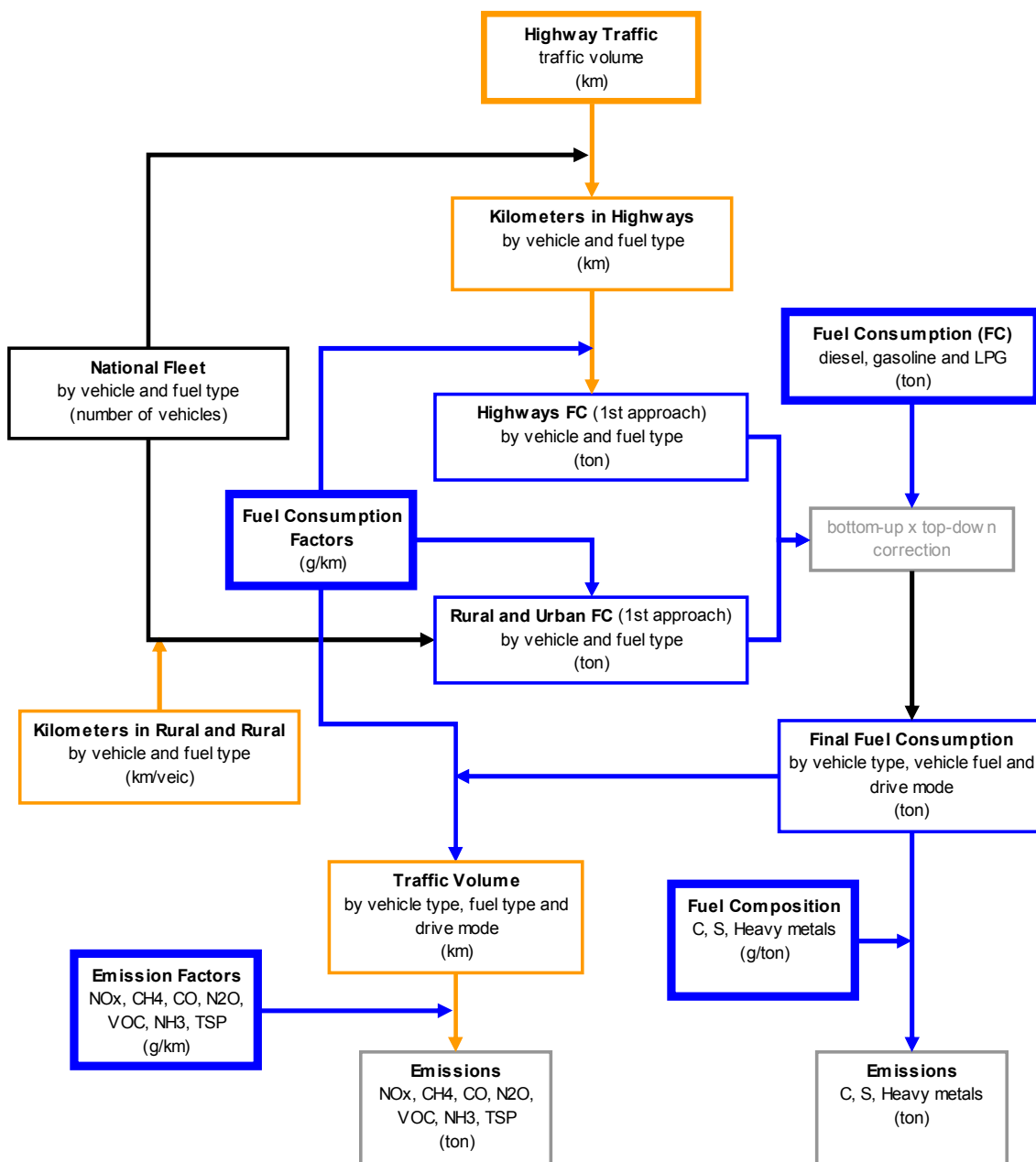
Presently although emissions estimate incorporate a substantial level of spatial disaggregated data, distance driven, fuel consumption and emission estimates are calculated solely at national level for highway, rural and urban driving modes. Exhaust emission factors are corrected for cold-start and for evaporative emissions with meteorological information at nut III.

The following sub-chapters present the methodology in more detail, including also the methodology that was used to derive some activity data such as vehicle fleet, distance driven and emission factors.

---

<sup>19</sup> Vehicle type is disaggregated by vehicle category, age and fuel type. Vehicle technology is function of vehicle age (see Table 3.65).

Figure 3.19 – General scheme of methodology applied for road transport emission estimates



### Vehicle Fleet

#### Light vehicles

A module for estimate national fleet – KAR – based on data provided by the national association of vehicle commerce (ACAP). This module determines active fleet of the following vehicle types:

- Passenger cars;
- Light duty vehicles;
- Two wheelers.

Annual sales for passenger cars and light duty vehicles were available for each car model and engine size since 1975. For passenger cars detailed information allows the distinction of spark engines and compression engines. All light duty vehicles were assumed to be equipped with diesel engines.

A function of fleet abatement based on vehicle age was applied to vehicle sales in order to determine the active fleet by year. This function, from ACAP data, was summarized in the following couple of equations:

$$T_{(c,a,f,y1)} = S_{(c,y2)} \times [1 - (0.0477 \times \exp(0.6003 \times A_{(y1-y2)}))/100], A < 10$$

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

Where,

$T_{(c,a,f,y1)}$  = 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 was estimated from gasoline passenger cars and LPG fuel sales and assuming that they have activity rate, expressed in kilometres per vehicle, similar to that of gasoline passenger cars. Accordingly, the ratio of LPG sales to gasoline sales, together with LPG fuel consumption factors were used to estimate the number of LPG vehicles.

### Heavy Vehicles

The Fleet of heavy duty vehicles was also derived from ACAP data and expressed in number of vehicles in moving fleet per year. Desegregation of vehicle weight was also necessary in order to perform the calculation.

Data of heavy duty vehicles sales in 2001 and 2002 was available from ACAP together with the adequate desegregation per weight class, that was also needed for calculation. The ratio per weight class was therefore adapted and applied to active fleet for all years of the emissions estimation period (1990 to 2002).

Table 3.63 – Percentage of heavy duty vehicles per weight class

Weight Class	Fleet (%)
0 - 7.5 t	0,11
7,5 – 16 t	0,68
16 – 32 t	0,20
> 32 t	0,00

Fleet of heavy duty vehicles desegregation by vehicle age was also performed according with fleet data available from ACAP for the years of 2000 and 2002, which is presented in next table

Table 3.64 – Percentage of heavy duty vehicles by age

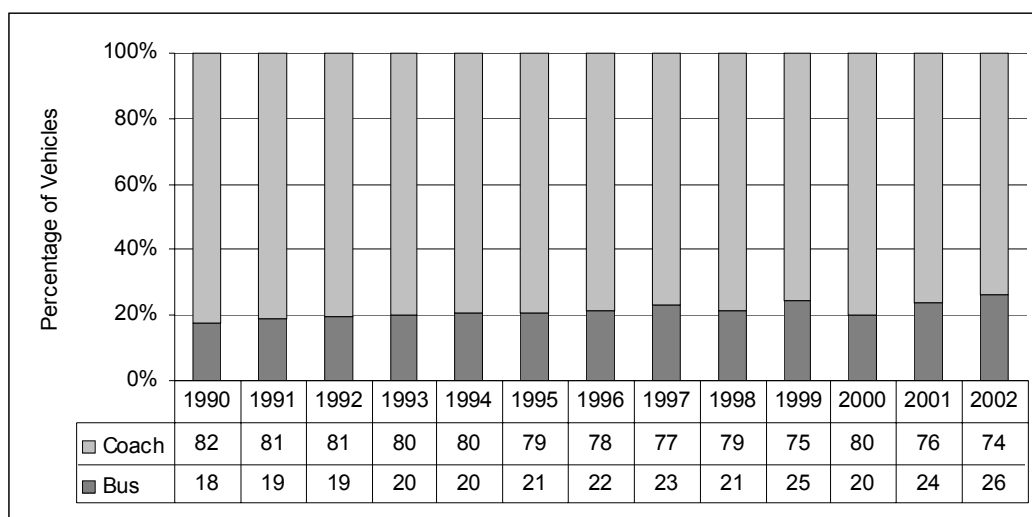
Age		Fleet (%)
From	To	
0	1	4,5
1	2	5,1
2	3	4,9
3	4	4,6
4	5	3,9
5	10	27,6
10	15	30,3
15	19	10,9
	20	8,2

The same age pattern in Table 3.64 was assumed constant for all years in analysis

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

Total number of buses and coaches in active fleet were estimated according with data from the national vehicle authority (DGV) and the Portuguese Insurance Institute (ISP). Data was adapted in order to obtain the necessary desegregation for calculation. Because there were no available distinction made between buses and coaches in data provided by DGV and ISP but only from the available information from the National Statistical Institute (INE), given since 1997. For previous years a trend line was established to estimate the split between buses and coaches - 1990 to 1996.

Figure 3.20 – Estimated percentage of buses and coaches



The same age pattern used for heavy duty vehicles was also assumed for buses and coaches.

#### Distance driven estimate

Total kilometres driven in rural and urban driving modes for each vehicle class is a function of fuel consumption and it is determined from a top-down point of view. This approach requires earlier evaluation of fuel consumption. Vehicle activity under urban and rural driving conditions, expressed in kilometres per vehicle, is later multiplied by the number of vehicles and fuel consumption factors. This constitutes a first approach in the estimation of fuel consumption in

rural and urban driving modes being later corrected to real consumption. Finally, actual fuel consumption is divided by consumption factors to obtain total urban and rural kilometres. This subject is addressed in further sections.

### *Highway traffic*

Distance driven in highway driving conditions was estimated in kilometres. Information about traffic volume is available annually for all Portuguese 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 2002 period was available from National Road Institute (IEP) and the main highway commissioner, BRISA.

The methodology used to determine distance driven in highways implies earlier evaluation of the national fleet which was already described. Kilometres driven in highways were estimated from:

$$Km_{highway(c,t,f,y)} = C_{(c,t,f,y)} \times \sum_{(l,r)} [L_{Length(l,r)} \times L_{Traffic(l,r,y)}]$$

Where,

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

$C_{(c,t,f,y)}$  = national fleet ratio of vehicles of class  $c$  using fuel  $f$  in year  $y$  and with age  $t$  to total vehicle fleet;

$L_{Length(l,r)}$  = 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 age, convertible in vehicle technology: PRE-ECE, ECE, Euro I, Euro II, etc;

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

$y$  = civil year.

### *Urban and Rural Traffic*

Distances driven in urban and rural driving conditions are at this stage estimated in kilometres per vehicle.

#### *Passenger Car*

Distances driven by passenger car in rural and urban modes were determined using a model that was developed according with energy consumption projections from DGGE.



$$Km_{urban(y)} = 15600 / [1 + \exp(-0.014 \times y + 27.624)]$$

$$Km_{total(y)} = 41835 / [1 + \exp(-0.027 \times y + 55.618)]$$

$$Km_{rural(y)} = Km_{total(y)} - Km_{urban(y)}$$

Where,

$Km_{urban(y)}$  = kilometres driven per vehicle in urban mode by passenger cars in year y (km/vehicle/yr);

$Km_{rural(y)}$  = kilometres driven per vehicle in rural mode by passenger cars in year y (km/vehicle/yr);

$Km_{total(y)}$  = kilometres driven per vehicle in all modes by passenger cars in year y (km/vehicle/yr);

y = civil year.

This formulation results in an overestimation of rural distance due to the fact that mileage in rural mode actually includes also the kilometres driven in highway.

#### Light Duty Vehicles

Duty vehicles activity was estimated solely in information from public freight carriers because concerning distance driven by private freight carriers was not available. Therefore, it was assumed the same activity, in kilometres per vehicle, for public and private freight carriers.

Data concerning annual driving distance for duty vehicles was available from INE for year 1996 and 2002. However, data concerning LDV is not clearly separated and it is included, in INE data, as HDV with weight less than 7,5 ton. Distances driven and number of vehicles were assumed to be the same for the two classes of vehicles. Vehicle activity, in kilometres per vehicle, was determined simply by dividing the registered distance by the number of LDV in the correspondent year.

Since data was available only for two years (1996 and 2002), a trend line was established to estimate kilometres per vehicle between 1997 and 2001.

Distinction of urban and rural kilometres driven per LDV were calculated for 1995, using a percentage from INE and assuming the same split for all periods in analysis. Again, rural activity is overestimated because rural includes distance driven in highways.

#### Heavy Duty Vehicles

The number of HDV in moving fleet and the distances driven by this type of vehicles were available from INE for years 1996 and 2002. A trend line was established to estimate HDV activity, in kilometres per vehicle, between 1997 and 2001.

Heavy duty vehicles activity was estimated only from information for public freight carriers because no information was available concerning private freight carriers. Therefore, it was assumed the same activity, in kilometres per vehicle, for public and private freight carriers.

#### Buses and Coaches

Distances driven and number of buses and coaches were available from INE statistical database for the period between 1997 and 2002. Activity, in kilometres per vehicle, was

determined and an average distance for the referred period was established. The same average distance was assumed for the remaining years in analysis.

#### Motorcycles

Motorcycles activity, in kilometres per vehicle, was assumed to be similar to that for passenger cars in all driving modes.

#### Estimate of fuel consumption

##### *Fuel Consumption under Highway mode*

Fuel consumption in highway mode was estimated for each fuel from estimates of distance driven in this driving mode. Therefore:

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

and,

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

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

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

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

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

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

y = civil year.

Individual fuel consumption by each car type was estimated from:

$$\text{Highway}_{FC(c,t,f,y)} = \text{Highway}_{km(c,t,f,y)} \times FC_{(c,t,f,Hway)} \times 10^{-6}$$

##### *Fuel Consumption under Urban and Rural driving modes*

Total fuel consumption under urban and rural driving modes was estimated simply by subtracting fuel consumption estimated in highway mode from total fuel sales, at national level:

$$\text{Urban}_{FC(f,y)} + \text{Rural}_{FC(f,y)} = \text{Total}_{FC(f,y)} - \text{Highway}_{FC(f,y)}$$

Where:,

$\text{Urban}_{FC(f,y)}$ ,  $\text{Rural}_{FC(f,y)}$  = total fuel consumption of fuel type f, under urban and rural driving conditions in year y (t);

Highway<sub>FC(f,y)</sub> = fuel consumption of fuel type f in highway driving condition by vehicles of all classes in year y (t);

Total<sub>FC(f,y)</sub> = total national fuel consumption of fuel type f in year y (t).

Individual fuel use (first approach) under rural and urban driving conditions was determined from the number of vehicles, kilometres driven in urban and rural modes and, fuel consumption factors for all vehicle categories:

$$\begin{aligned}\text{Rural}_{1\text{stFC}(c,t,f,y)} &= T_{\text{class}(c,t,f,y)} \times \text{Km}_{\text{rural}(c,f,y)} \times \text{FC}_{(c,t,f,s)} \times 10^6 \\ \text{Urban}_{1\text{stFC}(c,t,f,y)} &= T_{\text{class}(c,t,f,y)} \times \text{Km}_{\text{urban}(c,f,y)} \times \text{FC}_{(c,t,f,s)} \times 10^6\end{aligned}$$

where,

Rural<sub>1stFC(c,t,f,y)</sub>, Urban<sub>1stFC(c,t,f,y)</sub> = first approach fuel consumption in rural and urban areas made by vehicles of class c, with age/technology t, using fuel f in year y (t);

T<sub>class(c,t,f,y)</sub> = number of vehicles of class c, with age/technology t, using fuel f in year y;

Km<sub>rural(c,f,y)</sub>, Km<sub>urban(c,f,y)</sub> = rural and urban kilometres driven per vehicle of class c, using fuel f in year y (km/vehicle);

FC<sub>(c,t,f,s)</sub> = fuel consumption factor for vehicles of class c, with technology t, using fuel f, at speed s<sup>20</sup> (g/km).

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

A correction must be made to make total fuel consumption equal original fuel sales (DGGE energy balances). Urban and rural fuel use estimates were corrected by the following factor for car type c, technology t, fuel f, driving mode d and year y.

$$\text{Correc}_{\text{Factor}(f,y)} = [\text{Total}_{\text{FC}(f,y)} - \text{Highway}_{\text{FC}(f,y)}] / \sum_c \sum_t [\text{Rural}_{1\text{stFC}(c,t,f,y)} + \text{Urban}_{1\text{stFC}(c,t,f,y)}]$$

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

$$\begin{aligned}\text{Urban}_{\text{FC}(f,y)} &= \text{Correc}_{\text{Factor}(f,y)} \times \sum_c \sum_t [\text{Urban}_{1\text{stFC}(c,t,f,y)}] \\ \text{Rural}_{\text{FC}(f,y)} &= \text{Correc}_{\text{Factor}(f,y)} \times \sum_c \sum_t [\text{Rural}_{1\text{stFC}(c,t,f,y)}]\end{aligned}$$

This correction guarantees that emission estimates are in accordance with good practices. Although emissions were derived from estimate of vehicle driven kilometres and from fuel

<sup>20</sup> Constant speeds were assumed in urban and rural driving modes, respectively, 30 and 70 km/h.

consumption per kilometre (bottom-up approach), they were corrected for total national fuel sales (top-down correction).

### Final Activity Estimate

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

$$\begin{aligned} \text{Km}_{\text{urban}(c,t,f,y)} &= [\text{Urban}_{\text{FC}(c,t,f,y)} \times 10^6] / \text{FC}_{(c,t,f,s)} \\ \text{Km}_{\text{rural}(c,t,f,y)} &= [\text{Rural}_{\text{FC}(c,t,f,y)} \times 10^6] / \text{FC}_{(c,t,f,s)} \\ \text{Km}_{\text{total}(c,t,f,y)} &= \text{Km}_{\text{highway}(c,t,f,y)} + \text{Km}_{\text{urban}(c,t,f,y)} + \text{Km}_{\text{rural}(c,t,f,y)} \end{aligned}$$

Where,

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

$\text{Urban}_{\text{FC}(c,t,f,y)}$ ,  $\text{Rural}_{\text{FC}(c,t,f,y)}$  = 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);

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

### Emission Factor Determination

#### *Emission Functions*

Emissions factors for NO<sub>x</sub>, CO, NMVOC, CH<sub>4</sub>, N<sub>2</sub>O and NH<sub>3</sub> were determined from the available set of algorithms reported in the third edition of the EMEP/CORINAIR Emission Inventory Guidebook (EEA,2002), which results from a compilation for the CORINAIR85 and CORINAIR90 programs and updated with results from the MEET (Methodologies to Estimate Emissions from Transport) project and the COST319 action (Estimation of Emissions from Transport). 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 & Motorcycles with cylinder capacity under 50 cc and; Motorcycles with cylinder capacity greater than 50 cc;
- Fuel type: gasoline, diesel and LPG;
- Technology standard;
- Vehicle dimensions: motor size (cubic centimetres) for light vehicles and two wheelers and vehicle weight for Heavy Vehicles;
- Average vehicle speed under each driving mode.

Technology standards depend on vehicle class and the year when the vehicle was built. The conversion of vehicle age to technology and are those identified in Table 3.65, according to table 1.2 in EMEP/CORINAIR (EEA,2002).

Table 3.65 – Conversion of age of vehicle (year of manufacture) to technology class

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	1992
	Euro I	1993	1996
	Euro II	1997	2000
	Euro III	2001	2004
	Euro IV	2005	...
Light Duty Vehicles	Conv	...	1992
	Euro I	1993	1997
	Euro II	1998	2001
	Euro III	2002	2006
	Euro IV	2006	...
Heavy Duty Vehicles	Conv	...	1992
	Euro I	1993	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	...

Fuel consumption factors 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.

#### *Hot and Cold emission factors*

Final emission factors and fuel consumption factors were estimated in two steps:

- Hot emission factor: 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 temperature<sup>21</sup> increases to normal operation temperature, have generally increased emissions over *normal* hot emissions.

Total emission factor ( $ef^T$ ) is estimated from:

$$ef^T_{(c,t,d,f,p)} = \sum_m \{ ef^{\text{hot}}_{(c,t,d,f,p)} \times [1 + \beta_m \times (cf^{\text{cold/hot}}_{(c,t,d,f,p)} - 1)] \} / 12$$

<sup>21</sup> Cold engines are defined as those with water temperature below 70°C (EMEP/CORINAIR)

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);

$ef_{(c,t,d,f,p)}^{hot}$  - hot emission factor from vehicle type c with technology t and using fuel type f (g/km)

$\beta_m$  - average monthly value for the fraction of mileage driven with cold engines or catalyst operated below the light-off temperature<sup>22</sup>.

$cf_{(c,t,d,f,p)}^{cold/hot}$  - cold to hot ratio of emissions (g/g);

m - Month.

Cold-start corrections were applied for cars using all three fuels: gasoline, diesel and LPG, and for all driving modes<sup>23</sup>. Correction factors  $cf_{(c,t,d,f,p)}^{cold/hot}$ , where set from table 8.7, table 8.8, table 8.11 and table 8.14 in EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002).

### Emission estimate

Two different sets of pollutants are distinguishable:

- Pollutants for which a mass balance may be performed such as CO<sub>2</sub>, SO<sub>x</sub> and heavy metals;
- Pollutants for which emissions are best estimated from kilometres driven: NO<sub>x</sub>, CO, NMVOC, N<sub>2</sub>O and NH<sub>3</sub>.

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<sub>x</sub> 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,

<sup>22</sup>  $\beta_m$  parameter is calculated from average monthly temperature  $T_a$  (°C) and average trip length (km/trip) (Table 8.6 of 3<sup>ed</sup> EMEP/CORINAIR)

<sup>23</sup> Although it may be true that cold-start extra emissions seldom occur in highway mode.

$SO_{x(y)}$  = 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 which emission factors are 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 Emission Inventory Guidebook - 3rd edition (EEA,2002).

Evaporative emissions were determined for powered gasoline vehicles of classes j present in Table 3.66

Table 3.66 – 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 1993 were equipped with canister, year in which EURO I was introduced.

Total evaporative emissions are estimated from:

$$\text{Evap}_{\text{NMVOC}}(y) = [365 \times [(a_j \times e^d) + S^c + S^{fi}] + R] \times 10^{-6}$$

Where,

$\text{Evap}_{\text{NMVOC}}(y)$  = 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,

$$S^c = (1-q) \times (p \times x \times e^{s,\text{hot}} + w \times x \times e^{s,\text{warm}})$$

$$S^{fi} = q \times e^{fi} \times x$$

$$R = m_j \times (p \times e^{r,\text{hot}} + w \times e^{r,\text{warm}})$$

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 temperature<sup>24</sup>;

$x$  = 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 equation in Table 8.1 of EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);

$e^{s,warm}$  = 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 equation in Table 8.1 of EMEP/CORINAIR (EEA,2002);

$e^{fi}$  = mean emission factor for hot and warm soak emission of gasoline powered vehicles equipped with fuel injection. Estimated from equation in Table 8.1 of EMEP/CORINAIR (EEA,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 equation in Table 8.1 of EMEP/CORINAIR (EEA,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 equation in Table 8.1 of EMEP/CORINAIR (EEA,2002);

$m_j$  = total annual mileage of gasoline powered vehicles of category  $j$

Fraction of fuel injection vehicles ( $q$ ) was determined according with percentages in Table 6.1 of EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002), because it was not possible to obtain the percentage of vehicles equipped with fuel injection from national statistics. Therefore, it was assumed the proposed percentages provided in EMEP/CORINAIR for all years of calculation (see Table 3.67). Gasoline light duty vehicles and two-wheelers are treated as non-fuel injected vehicles.

Table 3.67 – Percentage of passenger cars equipped with fuel injection assumed for evaporative emissions calculation

Vehicle Category	Vehicles equipped with fuel injection (%) <sup>25</sup>
< 1.4 l	0.0
1.4 – 2.0 l	10.0
> 2.0 l	30.0

<sup>24</sup> Fraction of trips finished with cold and warm engine,  $w$ , is linked with the parameter  $\beta$  used in calculation of cold start emissions. The assumed relation between  $w$  and  $\beta$  is:  $w \approx \beta$

<sup>25</sup> Obtained from Table 6.1 (Chapter B760) of EMEP/CORINAIR Emission Inventory Guidebook

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 which was made similar to factor  $\beta$ :

$$p = 1 - [0.647 - 0.025 \times l_{\text{trip}} - (0.00974 - 0.000385 \times l_{\text{trip}}) \times t_a]$$

Where,

$p$  = fraction of trips finished with hot engine;

$t_a$  = ambient temperature;

$l_{\text{trip}}$  = average trip length (12 km)<sup>26</sup>.

Distance driven, in kilometres per vehicle, was determined for each vehicle category from Table 3.66 in the following manner:

$$V_{j(c,t,y)} = Km_{(c,t,y)} / N_{(c,t,y)}$$

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:

$$x = v_j / (365 \times l_{\text{trip}})$$

Finally, emission factor for motorcycles is estimated from the light passenger vehicles emission factor but assuming these as only 20% in the case of Motorcycles <50 cm<sup>3</sup> and 40% for other type of two wheelers, as proposed in EMEP/CORINAIR (EEA,2002).

Temperatures used in evaporative emissions estimation were average according with gasoline sales per NUTIII for years 1990, 1996 and 2000 and interpolated for intermediate years.

### **Emission Factors**

#### Carbon Dioxide

Ultimate CO<sub>2</sub> emission factors were established considering the equation in EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002):

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

<sup>26</sup> Obtained from Table 6.3 (Chapter B710) of EMEP/CORINAIR Emission Inventory Guidebook.

Where

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

$R_{H/C}$  = the ratio of hydrogen to carbon atoms in the fuel. Values for this ratio and the resulting  $CO_2$  emission factor are presented in Table 3.68.

Table 3.68 -  $R_{H/C}$  ratio and  $CO_2$  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 1990-2002 period. The following sulphur contents were set as data presented in next table.

Table 3.69 – Legal levels for sulphur content

	1989	1995	1996	2000	2005
Lead gasoline	0.1		0.1	-	
Unleaded Gasoline	0.1		0.05	0.015	0.005
Diesel	0.3	0.2	0.05	0.035	0.005

### Emission Factors Function of driven distance

#### *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 3.65).

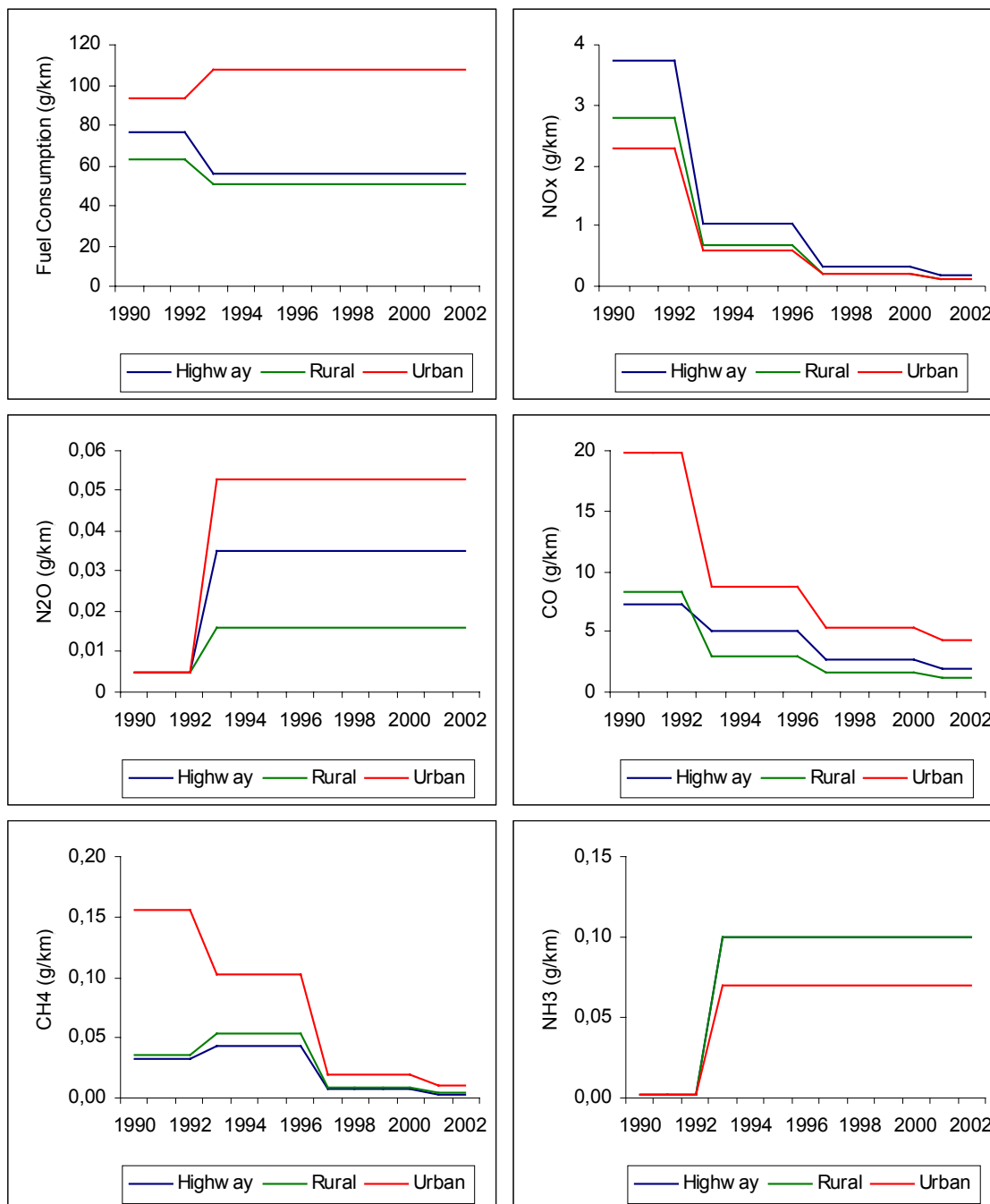
Emission factors were determined for:

- 10 pollutants<sup>27</sup> ( $CO$ ,  $NO_x$ ,  $N_2O$ ,  $SO_2$ ,  $VOC$ ,  $CH_4$ ,  $CO_2$ ,  $NH_3$ , diesel particulates and lead);
- 6 vehicle types (gasoline passenger cars, diesel passenger cars, LPG passenger cars, light duty vehicles, heavy duty vehicles and two wheelers) and each correspondent category (<1.4 l, 1.4 - 2.0 l, etc);
- 3 driving conditions (urban, rural and highways).

<sup>27</sup> For some pollutants ( $SO_2$ ,  $CO_2$ , Heavy Metals) very simply "bulk" emission factors or equations are provided in EMEP/CORINAIR.

Example of time evolution emission factors obtained for new gasoline passenger cars ( $1.4 \text{ l} < \text{CC} < 2.0 \text{ l}$ ) for each year are presented in the next figures.

Figure 3.21 –Fuel consumption and emission factors for new gasoline passenger cars in each year ( $1.4 \text{ l} < \text{CC} < 2.0 \text{ l}$ )



### Evaporative Emissions

Emission factors for evaporative emissions were set in accordance with the methodology proposed in EMEP/CORINAIR Handbook (EEA,2002). Parameters for the algorithms were calculated with the set of equations in Table 8.1 of Chapter B760 of EMEP/CORINAIR Guidebook.

Table 3.70 – Mean evaporative emission factors (values in g/vehicle/day)

Emission Factor	Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
$e^d$	Conventional	5,860	5,860	5,860	5,860	5,860	5,860	5,841	5,841	5,841	5,841	5,258	5,258	5,258
	Canister	1,172	1,172	1,172	1,172	1,172	1,172	1,168	1,168	1,168	1,168	1,052	1,052	1,052
$e^{s,warm}$	Conventional	3,235	3,235	3,235	3,235	3,235	3,235	3,220	3,220	3,220	3,220	2,822	2,822	2,822
	Canister	0,521	0,521	0,521	0,521	0,521	0,521	0,520	0,520	0,520	0,520	0,446	0,446	0,446
$e^{s,hot}$	Conventional	16,897	16,897	16,897	16,897	16,897	16,897	16,584	16,584	16,584	16,584	14,758	14,758	14,758
	Canister	0,782	0,782	0,782	0,782	0,782	0,782	0,780	0,780	0,780	0,780	0,668	0,668	0,668
$e^{fi,hot} \& e^{fi,warm}$	Conventional	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7
	Canister	-	-	-	-	-	-	-	-	-	-	-	-	-
$e^{r,warm}$	Conventional	0,141	0,141	0,141	0,141	0,141	0,141	0,143	0,143	0,143	0,143	0,107	0,107	0,107
	Canister	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,011	0,011	0,011
$e^{r,hot}$	Conventional	0,192	0,192	0,192	0,192	0,192	0,192	0,195	0,195	0,195	0,195	0,146	0,146	0,146
	Canister	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,019	0,015	0,015	0,015

Implied Emission Factors

Implied emission factors are determined simply by dividing the estimated overall emissions for each pollutant by the estimated activity in kilometres, and reflect also the actual fleet composition in each year.

$$EF_{\text{implied}(p,c,t,f,y)} = \text{Emission}_{(p,c,t,f,y)} / \text{Km}_{(c,t,f,y)} \times 10^6$$

Where,

$EF_{\text{implied}}$  = implied emission factor for pollutant p allocated at vehicles of class c with technology t using fuel f in year y (g/km);

$\text{Emission}_{(p,c,t,f,y)}$  = estimated emission of pollutant p allocated at vehicles of class c with technology t using fuel f in year y (t);

$\text{Km}_{(c,t,f,y)}$  = estimated activity for vehicles of class c with technology t using fuel f in year y (km).

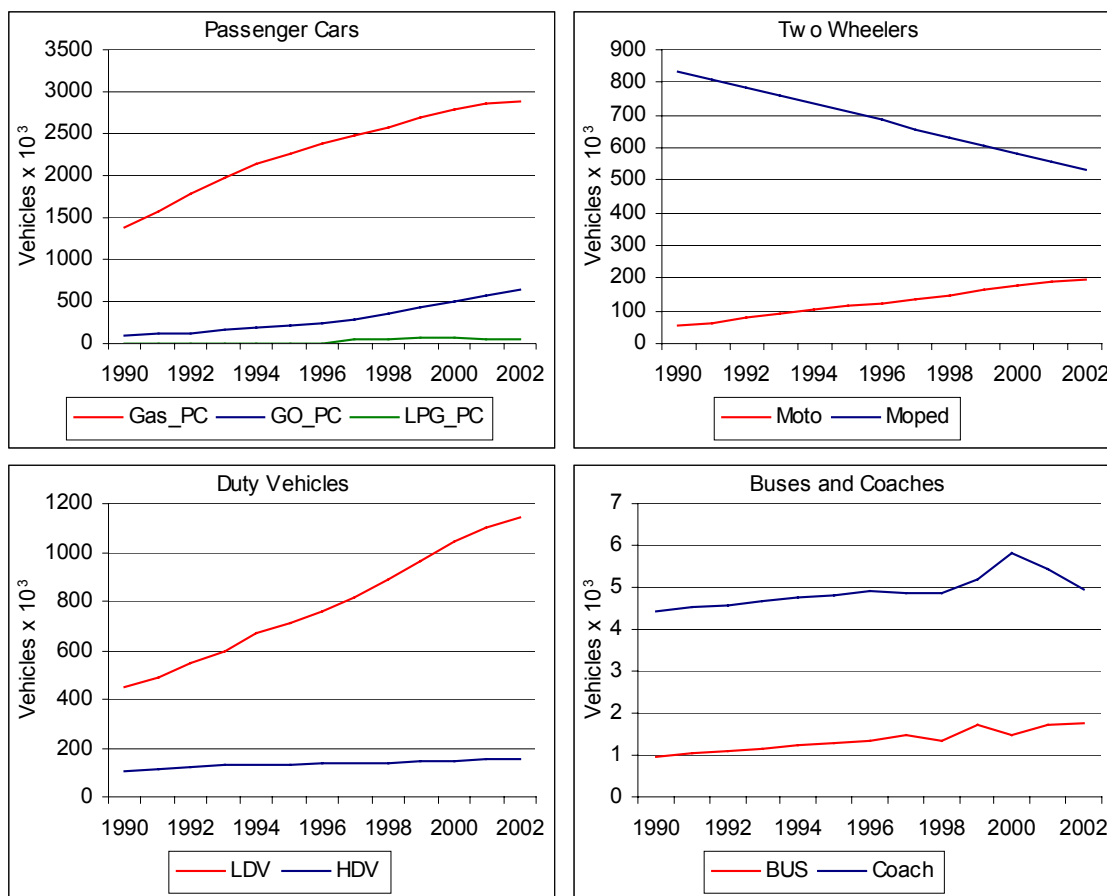
The full set of Implied Emission Factors are included in annexe.

**Activity Data**Vehicle Fleet

The number of vehicles between 1990 and 2002 was based in data available from the National Association of Vehicle Commerce (ACAP), National Insurance Institute (ISP) and National Statistical Institute (INE).

Vehicle data was adapted in accordance with the methodology described before. A national fleet was therefore determined for each year of the calculation period (Figure 3.22)

Figure 3.22 – Vehicle fleet synthesis: 1990-2002



The growth of gasoline passenger cars decreased over the last years while diesel passenger cars has increased. After an initial growth, LPG fuelled vehicles have stabilised as a small percentage of passenger cars. Mopeds had been decreasing according to ISP data for 1990 and 2002.

#### Distance Driven

Total distance driven in highways was estimated by the Institute for the Environment using the methodology already explained. Traffic data was obtained from the National Road Institute (IEP) and BRISA, the main highway commissioner in Portugal and evolution in time of road length (information concerning the data when each link was set open to road traffic circulation) is from the IEP's GIS system. Total national figures have increased steadily between 1990 and 2002 as could be seen in next figure. Traffic in free highways (non toll) for year 2002 is not included because is still not available and was forecasted at IA.

The increase in highway circulation, which has grown 7,2 times from 1990 to 2002, 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 has increased 2,2 and 1,8 times, respectively.

Figure 3.23 - Distance driven for passenger cars, light duty vehicles, heavy duty vehicles, urban buses, coaches and two wheelers

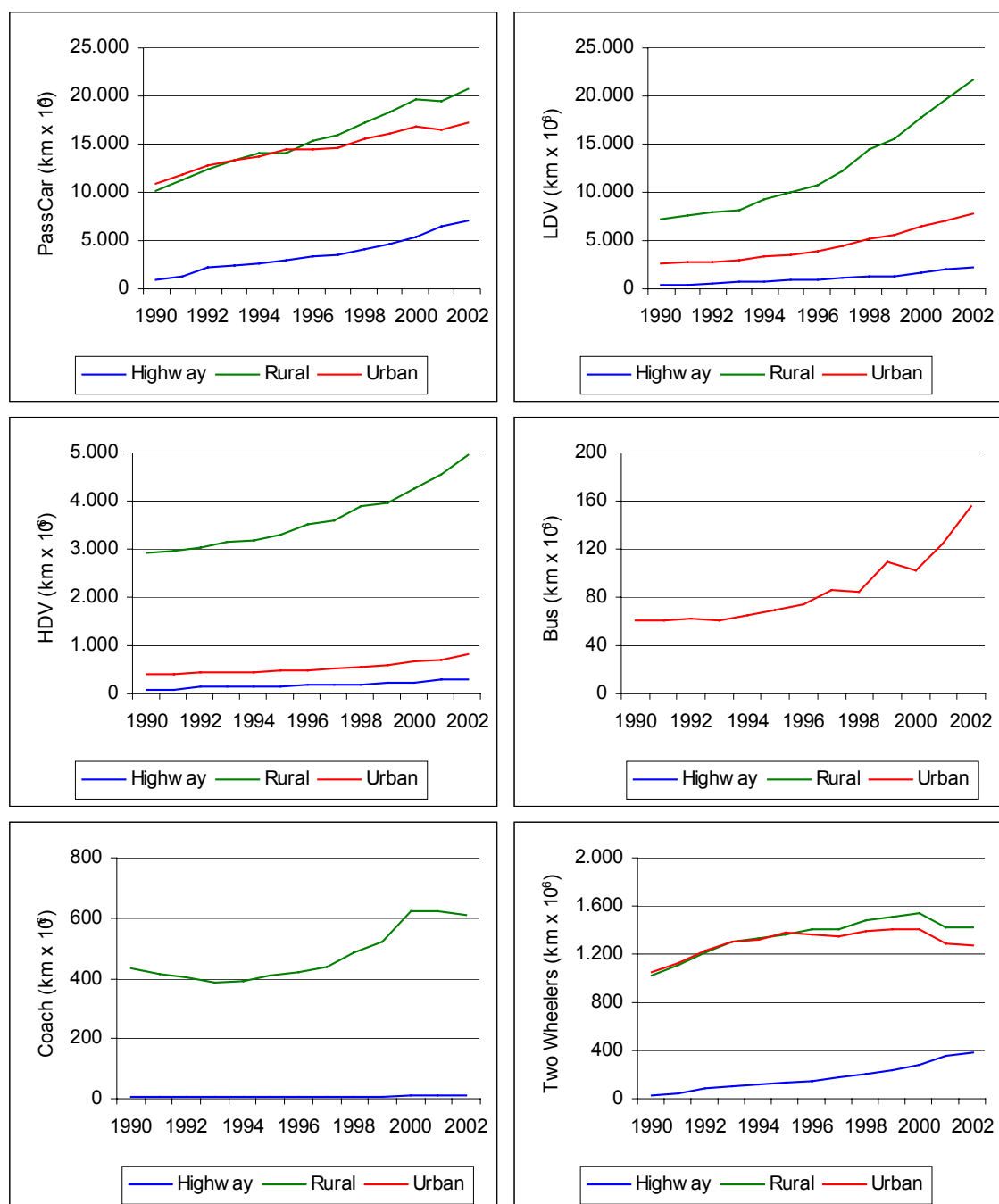


Table 3.71 – Road Transportation: Activity estimated (km×10<sup>6</sup>)

Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	995	1 354	2 163	2 362	2 611	2 948	3 241	3 590	4 120	4 558	5 397	6 538	7 064
PassCar	Rural	10 115	11 218	12 429	13 297	14 002	14 096	15 412	15 964	17 270	18 251	19 602	19 464	20 967
PassCar	Urban	10 873	11 770	12 735	13 312	13 702	14 411	14 430	14 631	15 499	16 045	16 890	16 441	17 371
LDV	Highway	301	396	611	664	753	845	936	1 047	1 229	1 373	1 675	2 071	2 257
LDV	Rural	7 265	7 503	7 939	8 201	9 233	10 060	10 805	12 199	14 470	15 519	17 857	19 707	19 617
LDV	Urban	2 603	2 688	2 844	2 938	3 308	3 604	3 871	4 370	5 184	5 560	6 398	7 060	7 028
HDV	Highway	69	90	134	145	148	159	175	178	193	207	239	289	313
HDV	Rural	2 913	2 981	3 031	3 130	3 174	3 313	3 529	3 582	3 901	3 975	4 272	4 567	4 470
HDV	Urban	409	419	426	440	446	465	496	514	572	596	656	718	720
Bus	Highway	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus	Rural	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus	Urban	60	61	62	61	65	70	74	86	85	109	103	124	141
Coach	Highway	3	4	5	5	5	6	6	6	7	7	9	10	10
Coach	Rural	431	413	402	383	392	410	419	439	487	522	625	620	551
Coach	Urban	-	-	-	-	-	-	-	-	-	-	-	-	-
Moped	Highway	-	-	-	-	-	-	-	-	-	-	-	-	-
Moped	Rural	665	696	708	712	702	719	697	673	668	642	621	546	562
Moped	Urban	665	696	708	712	702	719	697	673	668	642	621	546	562
Moto	Highway	35	50	87	104	118	137	151	171	203	232	282	352	389
Moto	Rural	361	415	502	588	630	648	709	741	809	866	917	874	960
Moto	Urban	388	435	515	589	616	662	663	679	726	761	790	739	795

Driving modes

Three driving modes were individualized in accordance with source categories SNAP97 and EMEP/CORINAIR (EEA,2002) methodology: Urban, Rural and Highway. The following average velocity was assumed for each driving mode which was assumed the same for all vehicle class:

Table 3.72 - Average velocity by driving mode

Mode	Average Velocity (km/hr)
Urban	30
Rural	70
Highway	100

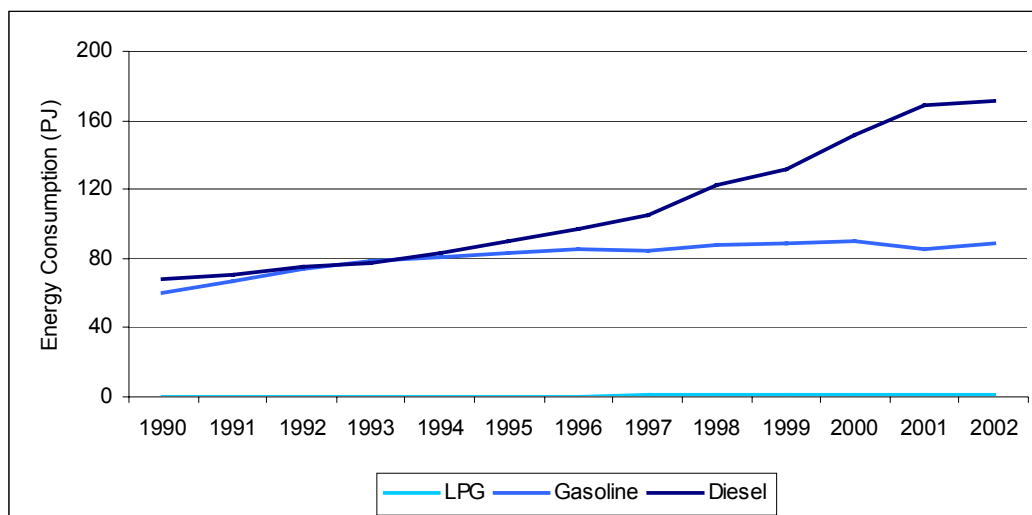
Average speeds in Table 3.72 were assumed for all vehicle classes as well as for all calculation years.



### Fuel Consumption

Consumption of fuel in the road transport sector is available for the years from 1990 to 2002 from the newly revised energy balances of the national directorate-general of energy (DGE). Total consumption of petrol, diesel-oil and LPG is shown in Figure 3.24.

Figure 3.24 – Fuel consumption from road transport sector



Original data in DGE energy balances were in energy units - tonnes oil equivalent and they were converted to mass units by the following Low Heat Values (LHV), also from DGE.

Table 3.73 – Low Heat Values (LHV) in Road Transportation

Fuel	toe/ton	MJ/kg
Diesel oil	1.035	43.31
Petrol	1.070	44.77
LPG	1.130	47.28

### Evaporative Emissions and Cold Start Parameters

#### Evaporative Emissions

The average trip length was set at 12 km ( $L_{trip}$ ), which results in an annual  $\beta$  factor of 0,267. It was considered, according to EMEP/CORINAIR (EEA,2002) recommendations to set  $w$  (fraction of trips finished with cold or warm engine) equal to  $\beta$ .

40% of gasoline vehicles were assumed to be equipped with fuel injection, in accordance with input data used in COPERT 85. From those, 10% are gasoline vehicles with cylinder capacity between 1,4 and 2,0 l and 30% are vehicles with cylinder capacity greater than 2,0 l. These percentages were assumed constant in the period 1990-2002.

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).

Table 3.74 - Legal values for RVP (values in kPa)

Month	Year		
	1989 to 1995	1996 to 1999	≥ 2000 <sup>28</sup>
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

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.

Figure 3.25 – 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

### *Cold star*

Ambient temperature parameter ( $T_a$ ) for cold star emissions was estimated for 1990 and temperature was obtained after weighting each individual NUT III area with fuel consumption realized at that specific territorial area.  $T_a$  was estimated as 15°C for 1990 and this value was used to make cold star emission corrections for other years.

Desegregation of fleet for evaporative emission calculation was derived from KAR output. Evaporative emissions are present in annexe.

<sup>28</sup> 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.

**ANNEXES (Road Transportation)**Table A.1 – NO<sub>x</sub> Implied Emission Factors

<b>1) Implied EF_NOx (g/km)</b>														
<b>Class</b>	<b>Mode</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>
PassCar	Highway	2.969	2.953	2.946	2.737	2.568	2.439	2.311	2.129	1.950	1.775	1.623	1.483	1.359
PassCar	Rural	2.267	2.258	2.253	2.067	1.907	1.788	1.665	1.515	1.359	1.221	1.093	0.967	0.887
PassCar	Urban	1.750	1.752	1.757	1.618	1.502	1.416	1.329	1.227	1.124	1.034	0.957	0.883	0.825
LDV	Highway	1.432	1.432	1.432	1.415	1.398	1.388	1.377	1.365	1.354	1.345	1.336	1.329	1.309
LDV	Rural	0.821	0.821	0.821	0.843	0.865	0.878	0.892	0.907	0.921	0.933	0.945	0.954	0.951
LDV	Urban	2.355	2.355	2.355	2.233	2.110	2.039	1.958	1.874	1.796	1.729	1.663	1.612	1.555
HDV	Highway	4.955	4.955	4.955	4.912	4.863	4.816	4.724	4.634	4.530	4.429	4.336	4.185	4.029
HDV	Rural	5.219	5.219	5.219	5.137	5.046	4.959	4.840	4.732	4.595	4.460	4.331	4.153	3.970
HDV	Urban	8.969	8.969	8.969	8.821	8.656	8.496	8.273	8.065	7.806	7.551	7.308	6.983	6.652
Bus	Urban	15.288	15.288	15.288	15.054	14.793	14.540	14.145	13.770	13.316	12.909	12.529	11.974	11.709
Coach	Highway	8.228	8.228	8.228	8.061	7.874	7.693	7.485	7.300	7.055	6.812	6.576	6.275	5.969
Coach	Rural	7.952	7.952	7.952	7.757	7.539	7.328	7.056	6.807	6.489	6.229	5.980	5.639	5.310
Moped	Rural	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Moped	Urban	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Moto	Highway	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.330	0.335	0.338
Moto	Rural	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.222	0.226	0.229
Moto	Urban	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.097	0.101	0.104

Table A.2 – CH<sub>4</sub> Implied Emission Factors

<b>2) Implied EF_CH4 (g/km)</b>														
<b>Class</b>	<b>Mode</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>
PassCar	Highway	0.031	0.031	0.031	0.040	0.047	0.052	0.057	0.054	0.051	0.048	0.046	0.043	0.041
PassCar	Rural	0.034	0.034	0.034	0.039	0.042	0.045	0.047	0.044	0.040	0.037	0.033	0.030	0.028
PassCar	Urban	0.147	0.147	0.146	0.141	0.136	0.132	0.127	0.115	0.103	0.091	0.080	0.069	0.063
LDV	Highway	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
LDV	Rural	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
LDV	Urban	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
HDV	Highway	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
HDV	Rural	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
HDV	Urban	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110
Bus	Urban	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
Coach	Highway	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
Coach	Rural	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Moped	Rural	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
Moped	Urban	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
Moto	Highway	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
Moto	Rural	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
Moto	Urban	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219

Table A.3 – CO Implied Emission Factors

3) Implied EF_CO (g/km)														
Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	10.560	9.881	9.268	10.545	11.662	12.383	12.827	12.446	12.127	11.861	11.568	11.213	10.877
PassCar	Rural	11.116	10.549	10.014	9.124	8.342	7.746	7.056	6.245	5.471	4.855	4.250	3.630	3.309
PassCar	Urban	24.984	23.917	22.889	20.788	18.921	17.526	16.024	14.281	12.591	11.160	9.778	8.374	7.644
LDV	Highway	1.419	1.419	1.419	1.345	1.270	1.227	1.178	1.126	1.079	1.038	0.998	0.966	0.931
LDV	Rural	1.137	1.137	1.137	1.049	0.960	0.909	0.850	0.789	0.733	0.684	0.637	0.599	0.564
LDV	Urban	1.388	1.388	1.388	1.290	1.191	1.133	1.068	1.000	0.937	0.883	0.830	0.789	0.748
HDV	Highway	1.522	1.522	1.522	1.493	1.460	1.428	1.395	1.366	1.327	1.288	1.250	1.199	1.147
HDV	Rural	1.950	1.950	1.950	1.915	1.875	1.837	1.796	1.759	1.710	1.661	1.613	1.549	1.483
HDV	Urban	3.512	3.512	3.512	3.435	3.349	3.266	3.171	3.087	2.976	2.865	2.757	2.624	2.488
Bus	Urban	4.687	4.687	4.687	4.567	4.433	4.304	4.159	4.029	3.857	3.707	3.560	3.376	3.288
Coach	Highway	1.337	1.337	1.337	1.316	1.292	1.269	1.248	1.230	1.204	1.178	1.152	1.114	1.075
Coach	Rural	1.804	1.804	1.804	1.759	1.710	1.662	1.606	1.556	1.490	1.436	1.385	1.312	1.241
Moped	Rural	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	14.643	14.286	13.929
Moped	Urban	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	14.643	14.286	13.929
Moto	Highway	36.774	36.774	36.774	36.774	36.774	36.774	36.774	36.774	36.774	36.774	34.886	33.300	32.089
Moto	Rural	26.167	26.167	26.167	26.167	26.167	26.167	26.167	26.167	26.167	26.167	24.651	23.379	22.407
Moto	Urban	27.131	27.131	27.131	27.131	27.131	27.131	27.131	27.131	27.131	27.131	25.257	23.685	22.483

Table A.4 – N<sub>2</sub>O Implied Emission Factors

4) Implied EF_N2O (g/km)														
Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	0.006	0.006	0.006	0.010	0.012	0.014	0.016	0.018	0.020	0.021	0.023	0.024	0.025
PassCar	Rural	0.006	0.006	0.006	0.008	0.009	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017
PassCar	Urban	0.006	0.006	0.006	0.012	0.016	0.019	0.022	0.024	0.027	0.029	0.031	0.032	0.033
LDV	Highway	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
LDV	Rural	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
LDV	Urban	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
HDV	Highway	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
HDV	Rural	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
HDV	Urban	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Bus	Urban	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Coach	Highway	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Coach	Rural	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Moped	Rural	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moped	Urban	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moto	Highway	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moto	Rural	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moto	Urban	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table A.5 – VOC Implied Emission Factors

5) Implied EF_VOC (g/km)														
Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	0.771	0.750	0.731	0.654	0.591	0.543	0.494	0.441	0.392	0.346	0.307	0.273	0.243
PassCar	Rural	0.929	0.913	0.897	0.803	0.721	0.660	0.596	0.527	0.457	0.397	0.340	0.285	0.255
PassCar	Urban	1.895	1.861	1.827	1.642	1.482	1.362	1.237	1.100	0.959	0.836	0.719	0.608	0.545
LDV	Highway	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.104
LDV	Rural	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.100
LDV	Urban	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.143
HDV	Highway	0.706	0.706	0.706	0.698	0.689	0.680	0.670	0.661	0.649	0.638	0.626	0.607	0.588
HDV	Rural	0.965	0.965	0.965	0.953	0.939	0.926	0.912	0.899	0.881	0.864	0.848	0.821	0.794
HDV	Urban	2.029	2.029	2.029	2.000	1.967	1.935	1.901	1.870	1.829	1.789	1.749	1.690	1.629
Bus	Urban	1.313	1.313	1.313	1.297	1.278	1.260	1.239	1.221	1.197	1.176	1.155	1.120	1.099
Coach	Highway	0.744	0.744	0.744	0.736	0.726	0.717	0.705	0.694	0.680	0.667	0.653	0.632	0.611
Coach	Rural	1.021	1.021	1.021	0.999	0.974	0.951	0.925	0.903	0.873	0.849	0.825	0.789	0.753
Moped	Rural	9.000	9.000	9.000	9.000	9.000	9.000	9.000	9.000	9.000	9.000	8.764	8.529	8.293
Moped	Urban	9.000	9.000	9.000	9.000	9.000	9.000	9.000	9.000	9.000	9.000	8.764	8.529	8.293
Moto	Highway	2.478	2.478	2.478	2.478	2.478	2.478	2.478	2.478	2.478	2.478	2.350	2.242	2.160
Moto	Rural	2.184	2.184	2.184	2.184	2.184	2.184	2.184	2.184	2.184	2.184	2.103	2.035	1.983
Moto	Urban	3.753	3.753	3.753	3.753	3.753	3.753	3.753	3.753	3.753	3.753	3.556	3.392	3.266

Table A.6 – NMVOC Implied Emission Factors

6) Implied EF_NMVOC (g/km)														
Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	0.924	0.898	0.875	0.829	0.792	0.762	0.729	0.659	0.595	0.535	0.483	0.438	0.398
PassCar	Rural	1.116	1.097	1.077	0.992	0.915	0.858	0.797	0.709	0.621	0.543	0.470	0.397	0.358
PassCar	Urban	2.200	2.158	2.116	1.923	1.755	1.629	1.496	1.331	1.165	1.017	0.878	0.744	0.669
LDV	Highway	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.119
LDV	Rural	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.115
LDV	Urban	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.165
HDV	Highway	0.676	0.676	0.676	0.668	0.659	0.650	0.640	0.631	0.619	0.607	0.596	0.577	0.558
HDV	Rural	0.926	0.926	0.926	0.914	0.900	0.887	0.872	0.860	0.842	0.825	0.808	0.782	0.755
HDV	Urban	1.919	1.919	1.919	1.889	1.857	1.825	1.790	1.760	1.719	1.678	1.638	1.580	1.519
Bus	Urban	1.138	1.138	1.138	1.122	1.103	1.085	1.064	1.046	1.022	1.001	0.980	0.945	0.924
Coach	Highway	0.674	0.674	0.674	0.666	0.656	0.647	0.635	0.624	0.610	0.597	0.583	0.562	0.541
Coach	Rural	0.941	0.941	0.941	0.919	0.894	0.871	0.845	0.823	0.793	0.769	0.745	0.709	0.673
Moped	Rural	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.545	8.310	8.074
Moped	Urban	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.781	8.545	8.310	8.074
Moto	Highway	2.259	2.259	2.259	2.259	2.259	2.259	2.259	2.259	2.259	2.259	2.131	2.023	1.941
Moto	Rural	1.965	1.965	1.965	1.965	1.965	1.965	1.965	1.965	1.965	1.965	1.884	1.816	1.764
Moto	Urban	3.534	3.534	3.534	3.534	3.534	3.534	3.534	3.534	3.534	3.534	3.337	3.173	3.047

Table A.7 – NH<sub>3</sub> Implied Emission Factors

7) Implied EF_NH3 (g/km)														
Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	0.002	0.002	0.002	0.012	0.020	0.026	0.032	0.036	0.040	0.044	0.048	0.051	0.053
PassCar	Rural	0.002	0.002	0.002	0.012	0.020	0.026	0.031	0.035	0.038	0.041	0.043	0.042	0.044
PassCar	Urban	0.002	0.002	0.002	0.009	0.014	0.018	0.022	0.025	0.027	0.029	0.030	0.030	0.031
LDV	Highway	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LDV	Rural	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LDV	Urban	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
HDV	Highway	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
HDV	Rural	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
HDV	Urban	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Bus	Urban	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Coach	Highway	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Coach	Rural	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Moped	Rural	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moped	Urban	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moto	Highway	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moto	Rural	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Moto	Urban	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table A.8 – CO<sub>2pipe</sub> Implied Emission Factors

Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PassCar	Highway	172	173	175	173	171	170	169	168	168	167	166	165	165
PassCar	Rural	149	150	151	150	149	148	148	147	147	146	145	145	144
PassCar	Urban	199	200	201	207	210	214	217	219	221	223	224	224	225
LDV	Highway	312	312	312	308	305	302	300	297	295	292	290	289	287
LDV	Rural	219	219	219	216	213	212	210	208	206	204	203	202	201
LDV	Urban	290	290	290	287	284	282	280	278	276	274	273	271	270
HDV	Highway	647	647	647	647	647	647	647	647	647	647	648	648	648
HDV	Rural	533	533	533	534	534	534	534	534	534	534	534	535	535
HDV	Urban	700	700	700	701	701	701	702	702	702	703	703	704	704
Bus	Urban	981	981	981	981	981	982	982	982	983	983	983	984	984
Coach	Highway	681	681	681	681	681	681	682	682	682	682	682	682	682
Coach	Rural	630	630	630	630	630	630	630	631	631	631	631	632	632
Moped	Rural	29	29	29	29	29	29	29	29	29	29	29	29	29
Moped	Urban	29	29	29	29	29	29	29	29	29	29	29	29	29
Moto	Highway	52	52	52	52	52	52	52	52	52	52	54	56	57
Moto	Rural	44	44	44	44	44	44	44	44	44	44	46	48	50
Moto	Urban	42	42	42	42	42	42	42	42	42	42	46	50	52

Table A.9 – Estimated evaporative emissions from road transportation sector

Vehicle Type	Fuel	Category	Technology	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PC	Gasoline	PC_less1400	Ev_Canister	-	-	-	191	375	515	651	776	930	1 064	1 012	1 053	1 155
PC	Gasoline	PC_1400_2000	Ev_Canister	-	-	-	121	211	293	389	462	556	645	626	669	738
PC	Gasoline	PC_more2000	Ev_Canister	-	-	-	6	10	20	33	38	45	59	63	70	81
PC	Gasoline	PC_less1400	Ev_Conv	22 716	24 690	26 871	25 230	23 506	22 100	20 448	18 562	17 242	15 609	12 440	10 615	9 932
PC	Gasoline	PC_1400_2000	Ev_Conv	5 138	6 238	7 853	7 471	7 059	6 739	6 388	5 956	5 674	5 242	4 253	3 690	3 510
PC	Gasoline	PC_more2000	Ev_Conv	1 004	996	997	916	834	766	691	601	536	468	358	287	246
LDV	Gasoline		Ev_Conv	-	-	-	-	-	-	-	-	-	-	-	-	-
Moped	Gasoline		Ev_Conv	698	704	699	690	674	672	644	622	608	584	497	454	451
Moto_2t	Gasoline	CC_more_50	Ev_Conv	43	50	62	72	77	84	85	90	98	106	100	103	110
Moto_4t	Gasoline	CC_50_250	Ev_Conv	74	85	104	121	130	138	144	151	165	178	166	166	180
Moto_4t	Gasoline	CC_250_750	Ev_Conv	194	223	274	320	342	364	380	399	436	468	438	437	474
Moto_4t	Gasoline	CC_more_750	Ev_Conv	107	122	151	175	188	200	208	219	239	257	240	240	260
			Total NMVOC (t)	29 974	33 107	37 011	35 312	33 405	31 891	30 063	27 875	26 530	24 679	20 193	17 785	17 139

## 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 for all pollutants other than SO<sub>x</sub> are estimated with the following formula:

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

where

Emission<sub>(p,y)</sub> - Emission of pollutant p in year y (ton/yr);

EF<sub>(f,p)</sub> - Quantity of pollutant p emitted from fuel f (kg/ton);

Cons<sub>Fuel(n,f,y)</sub> - consumption of fuel f during in year y (ton/yr).

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

$$\text{SO}_{x(y)} = 2 * \sum_f [\text{FuelCons}_{(f,y)} * S_{(f,y)} * 10^{-2}]$$

where

SO<sub>x(y)</sub> - Sulphur oxide emission in year y (ton/yr);

FuelCons<sub>(f,y)</sub> - Consumption of fuel f in railway sector in year y (ton/yr);

S<sub>(f,y)</sub> - Sulphur content of fuel f (mass percentage).

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

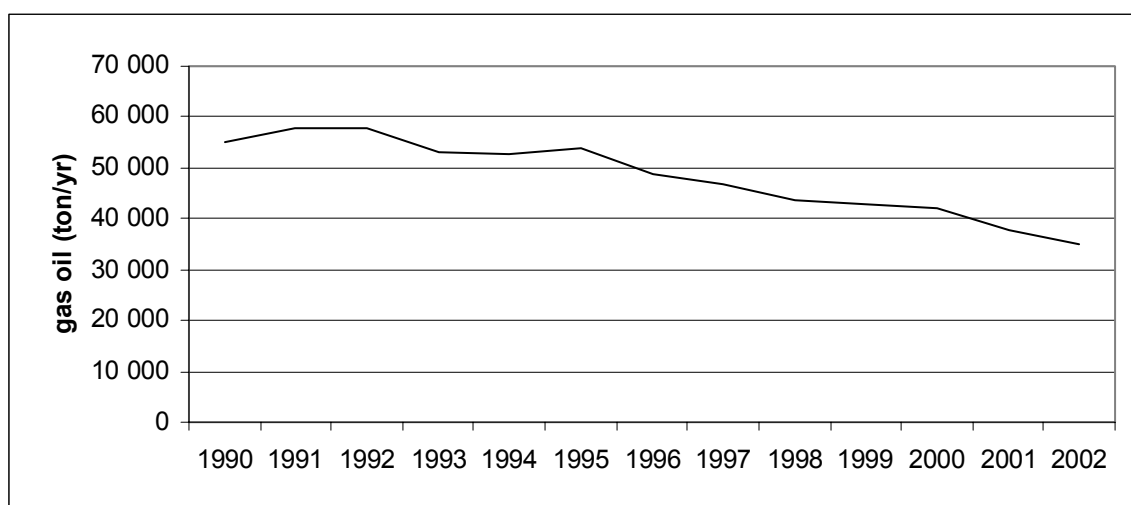
	Coal	Coke	Diesel-oil	Fuel-oil
LHV <sup>(a)</sup>	29.3	28.0	43.3	40.2
NO <sub>x</sub>	55.6			
COVNM	5.1			
CH <sub>4</sub>	0.22			
CO	20			
U <sub>CO2</sub>	3 168			
N <sub>2</sub> O	0.66			
NH <sub>3</sub>	0.01		0.007	0.01
PM	3.79			

(a) LHV/NCV expressed in MJ/kg.

**Activity Data**

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2002 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 oil<sup>29</sup>. The quantities that were consumed have been decreasing steadily since 1992, as can be seen in Figure 3.26.

Figure 3.26 - Consumption of fuel in the railway transport sector: 1990-2002

**3.2.A.5.3 WATER-BORNE NAVIGATION AND FISHING VESSELS****Overview**

This chapter discusses all combustion emissions resulting from fuel used as energy source to propel water-borne vessels, including ships used for transportation and fishing activities, although these emissions are included among several source categories in the inventory. Emissions from navigation for transport purposes is included in source sector 1.A3d - Fuel Combustion Activities in Navigation. 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

<sup>29</sup> Gas oil represents no less than 99.9% of total annual use of combustible energy.

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

The methodology that is used is equals Tier2 approach but is not coherent with Good Practices because separation of domestic and international emissions does not follow the necessary rules.

Four classes of ship are differentiated, from the available activity data information: (1) National (flag) Transport navigation; (2) International Transport Navigation; (3) Coastal Fishing; (4) Deep-ocean fishing (including Cod fishing). Two fuel types are also considered: gas-oil and fuel-oil.

Emissions for all pollutants other than CO<sub>2</sub> and SO<sub>x</sub> are estimated for each ship type using the following formula:

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

where

Emission<sub>(n,p,y)</sub> - Total emission of pollutant p in year y from ships of class n (ton/yr);

EF<sub>(n,f,p)</sub> - Quantity of pollutant p emitted, variable with fuel type f and ship class n (kg/ton);

Cons<sub>Fuel(n,f,y)</sub> - consumption by ships of type n of fuel f during year y (ton/yr).

Emissions of carbon dioxide are estimated from:

$$U_{\text{CO}_2 (n,y)} = \sum_f [\text{Cons}_{\text{Fuel}(n,f,y)} * \text{LHV}_{(f)} * \text{EF}_{\text{CO}_2(f)}] * 10^{-3}$$

where

U<sub>CO<sub>2</sub> (n,y)</sub> - Emission of carbon dioxide in year y from ships of class n(ton/yr);

Cons<sub>Fuel(n,f,y)</sub> - Consumption of fuel f in year y from ship type n (ton/yr);

LHV<sub>(f)</sub> - Low Heating Value (MJ/kg);

EF<sub>CO<sub>2</sub> (f)</sub> - Emission factor pollutant p from fuel f combustion (kg/GJ).

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

$$\text{SO}_x (n,y) = 2 * \sum_f [\text{Fuel}_{\text{Cons}(n,f,y)} * S_{(f,y)} * 10^{-2}]$$

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);

$FuelCons_{(n,f,y)}$  - 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 3.76 – Emission factors for Water Borne Navigation and Fishing Vessels

EF	Units	Coastal Fisheries	Other Fisheries	Navigation	Coastal Fisheries	Other Fisheries	Navigation
		Gas-oil	Gas-oil	Gas-oil	Fuel-oil	Fuel-oil	Fuel-oil
LHV	MJ/kg	43.31	43.31	43.31	40.17	40.17	40.17
SO <sub>x</sub>	%	0.3			3		
NO <sub>x</sub>	g/kg	67.5	87	87	67.5	87	87
NM VOC	g/kg	4.9					
CH <sub>4</sub>	g/kg	0.23					
CO	g/kg	21.3	1.9	1.9	21.3	1.9	1.9
U <sub>CO2</sub>	kg/GJ	74.07	74.07	74.07	77.37	77.37	77.37
N <sub>2</sub> O	g/kg	0.08					
PM	g/kg	1.2			7.6		

### Activity Data

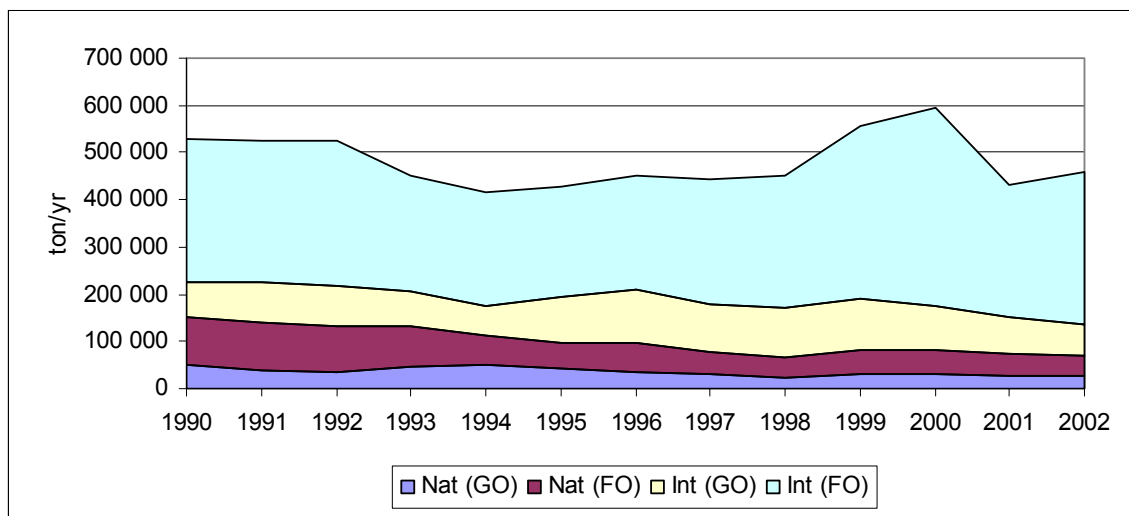
Fuel sales to navigation bunkers and fishing activities were used as basic activity data for both source sectors. This information was collected from the energy balances, produced under the responsibility of the General-Directorate of Geology and Energy (DGGE).

#### Transport Navigation

Information on Fuel consumption expressed in energy units (toe) is available from DGGE, with separate entries for national navigation and international navigation<sup>30</sup>. Desegregated consumption of fuel-oil and diesel-oil is available annually from 1990 to 2002, which time series are represented in Figure 3.27.

<sup>30</sup> Separation is by ship's flag.

Figure 3.27 - Fuel consumption in Transport Navigation by fuel and by national and international navigation: 1990-2002



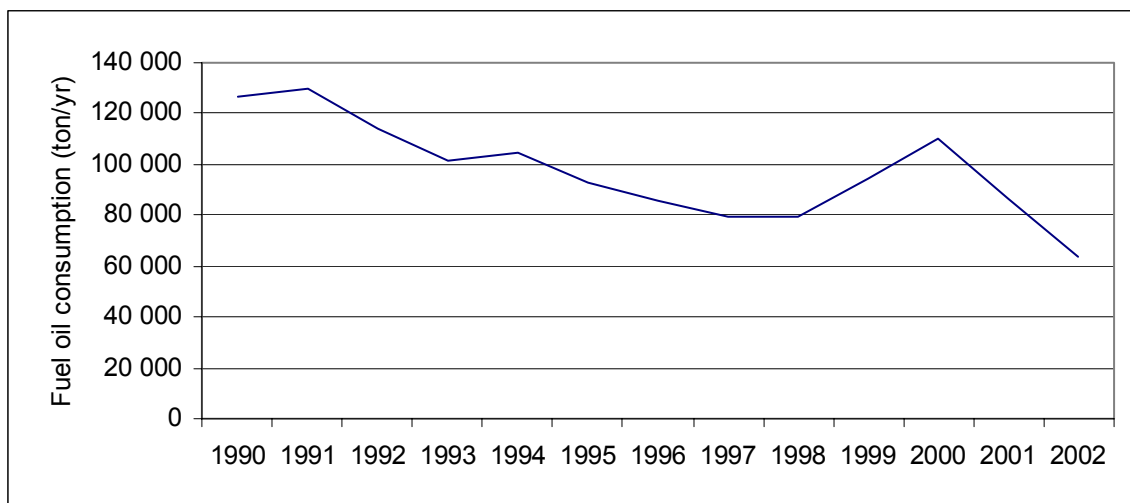
More information was however available from DGGE until 2001, namely it was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha and diesel-oil was further classified in gas-oil and diesel oil. This information was used to construct more desegregated time series for each one of those fuels from 1990 to 2001. For the time being, however, this additional detail has no consequences because emission factors do not distinguish between these particular fuel types.

#### Fishing Vessels

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 Figure 3.28<sup>31</sup>.

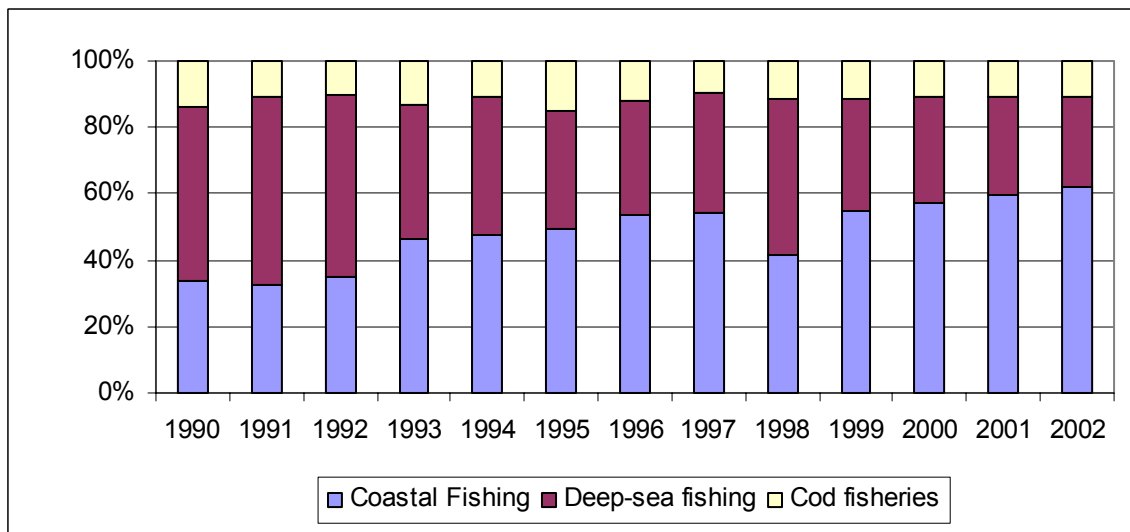
<sup>31</sup> Use of diesel oil and fuel oil is insignificant, always less than 2.5% of gas oil consumption.

Figure 3.28 – Consumption of fuel oil in fishing bunkers (1990-2002)



Additional information in DGGE annual reports, available only until 2001, allow the division<sup>32</sup> of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels<sup>33</sup>. Percentage for each type of fisheries is presented in next figure.

Figure 3.29 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries (1990-2002)



<sup>32</sup> The same situation that was described for transport navigation is true here. It was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha, gas-oil and diesel oil, but available emission factors again do not distinguish these fuel types

<sup>33</sup> All fishing activities were allocated to national total although it is true that some may not be realized in territorial waters or EMEP area. That is clearly the case of cod-fish fishing and it is also partly true for deep-sea fishing.

### 3.2.A.5.4 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. Also, both emissions from civil aviation and military aircraft are included in the inventory in the same source sector, although they may be separated if required.

Emissions from other airborne activities, such as planes used in agriculture for pesticide spreading, helicopters and private airplanes and jets, are also included in this inventory, although it is not possible to individualize their emission from those emissions from large commercial planes.

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 and the LRTAP convention, emissions estimates must differentiate between:

Two different components:

- Landing/Take-off emissions. 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 914 m (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 flights and international flights must be reported separately for UNFCCC, and domestic flights. In order to strictly follow UNFCC good practice the separation is done according to the following table (IPCC,2000).

---

<sup>34</sup> Separation of emissions between national and international transportation it is still not clearly defined in IPCC. COFIRMAR

Table 3.77 – 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

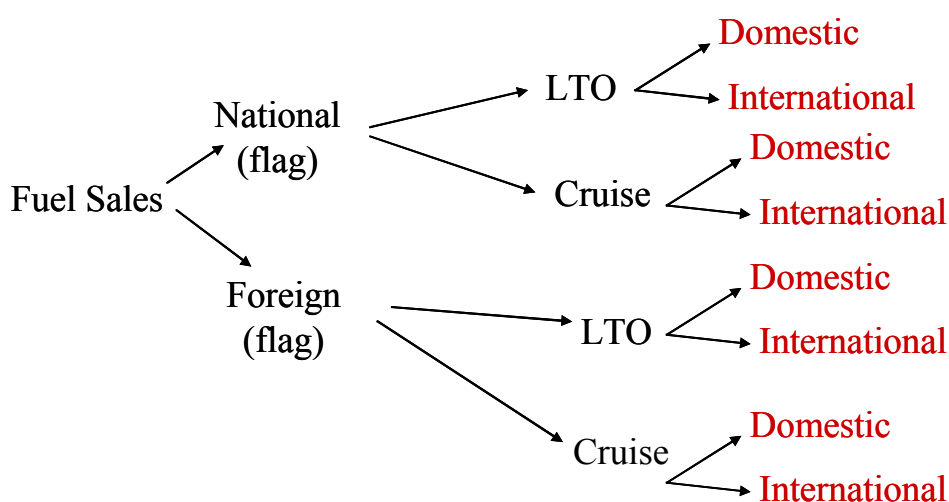
Source: IPCC (2000)

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 where separation was only made according to flag of carrier.

Portuguese territorial area comprehends, in what concerns definition of domestic, mainland continental area and the autonomous regions of Azores and Madeira islands<sup>35</sup>.

Desegregation of emissions is therefore possible according to Figure 3.30 below.

Figure 3.30 – Available Desegregation of total aviation emissions



<sup>35</sup> 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.

### Methodology

The methodology that is used in the inventory is coherent with good practices and is equivalent to the Tier2b approach. Emissions are calculated separately for:

- (1) LTO and cruise;
- (2) Fuel type: Jet Fuel and Aviation Gasoline;
- (3) Nationality of air carrier (flag). National and Foreign company flags are separated;
- (4) Origin-Destiny in relation to territorial space of airport: Domestic and International flights;
- (5) Aircraft type.

Emissions during Landing/Take-off are estimated at major international airports with:

$$\text{Emission}_{\text{LTO}}(p,d,y) = \sum_n [\text{Frac}_{\text{OD}(n,d)} \cdot \sum_a \{ \text{Frac}_{\text{FLAG}(a,n)} \cdot \sum_s [\text{EF}_{\text{LTO}(s,p)} * \text{LTO}_{\text{Number}(s,a,y)}] \}] * 10^{-3}$$

where

$\text{Emission}_{\text{LTO}}(p,y)$  - Emission of pollutant  $p$  in year  $y$  during LTO movements for  $d$  (domestic or international) origin-destiny (OD) (ton/yr);

$\text{EF}_{\text{LTO}(s,p)}$  - Quantity of pollutant  $p$  per aircraft type  $s$  emitted in each LTO movement (kg/LTO);

$\text{LTO}_{\text{Number}(s,a,y)}$  - number of LTO movements realized in year  $y$ , by aircraft  $s$  in airport  $a$ ;

$\text{Frac}_{\text{FLAG}(a,n)}$  - Fraction of LTO movements at airport  $a$  done by planes of air carrier  $n$  (National/Foreign);

$\text{Frac}_{\text{OD}(n,d)}$  - Fraction of planes of flag  $n$  (National/Foreign) and realizing flights of type  $d$ , according to OD (domestic/international).

For the other smaller airports, that represent a smaller fraction of emissions, the methodology is similar but there is no separation per aircraft type and the applied emission factor is an average. In this case methodology is Tier 2a.

Cruise emissions are estimated solely from fuel consumption. Total fuel sales per fuel type ( $\text{FC}_{\text{TOTAL}}(y)$ ) were deduced from fuel consumption during LTO ( $\text{FC}_{\text{LTO}}(y)$ )<sup>36</sup>, and consumption during cruising ( $\text{FC}_{\text{CRUISE}}(y)$ ) is estimated as the remaining:

$$\text{FC}_{\text{CRUISE}}(y) = \text{FS}_{\text{TOTAL}}(y) - \text{FC}_{\text{LTO}}(y)$$

Total fuel consumption in cruise mode is desegregated by fuel type, nationality and, only for JP, type of movement according to origin-destiny  $d$ . The following calculation applies:

<sup>36</sup> Fuel consumption in LTO movements is estimated from LTO movements and using emission factors in a manner similar to calculation of pollutant emissions.



$$FC_{CRUISE(d,f,y)} = \sum_f \{ \text{Frac}_{pkm(f,d,y)} * FS_{(f,n,y)} / [\sum_f \sum_n FS_{(f,n,y)}] * FC_{CRUISE(y)} \}$$

Where:

$FC_{CRUISE(d,f,y)}$  – Fuel consumption in cruise mode, of fuel f, in origin-destiny d (domestic/international) and in year y (ton/yr);

$\text{Frac}_{pkm(f,d,y)}$  – Fraction of fuel f consumption in cruise mode that is done in domestic OD or international OD. It is estimated from passenger-kilometre statistical data;

$FS_{(f,n,y)}$  – Fuel sales of fuel f in year y according to nationality of air-carrier (ton/yr).

Finally, emissions in cruise mode are estimated from:

$$\text{Emission}_{CRUISE(d,p,y)} = \sum_f [EF_{CRUISE(f,p)} * FC_{CRUISE(d,f,y)}] * 10^{-3}$$

where

$\text{Emission}_{CRUISE(n,p,y)}$  - Emission of pollutant p in year y from cruise movement of aircraft, in flights with origin-destiny d (Domestic/ International) (ton/yr);

$EF_{CRUISE(n,f,p)}$  - Quantity of pollutant p emitted during cruise mode variable with fuel type f (kg/ton);

$FC_{CRUISE(n,f,y)}$  - consumption by airplanes in flights with origin-destiny d (Domestic/ International) using fuel f during cruise mode in year y (ton/yr).

### **Emission Factors**

Emissions factors (kg/ton) for LTO were set for each aircraft type according to information in the FAED and EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002)<sup>37</sup> databases.

<sup>37</sup> including information in spreadsheet 2

Table 3.78 - Emissions factors (kg/LTO) for LTO movements per aircraft type (1/2)

Aircraft	FC	NO <sub>x</sub>	NM <sub>VOC</sub>	CH <sub>4</sub>	CO	PST <sup>(b)</sup>
320	1 190	14.6	2.7	0.27	13.2	11.5
737	885	9.8	1.2	0.30	5.5	7.8
EMB	64	1.8	1.0	0.12	1.4	0.4
100 <sup>(a)</sup>	702	8.9	16.9	0.22	17.1	5.7
ATP	570	4.2	0.8	0.20	9.7	14.5
310	1 556	20.9	4.1	0.43	14.9	23.3
757	1 282	15.4	0.7	0.29	6.7	22.2
M80	993	9.4	1.6	0.29	4.2	11.7
767	1 671	22.6	1.7	0.47	5.0	26.6
340	1 965	30.6	10.3	1.16	27.6	30.2
727	1 339	14.1	5.3	0.52	15.6	10.3
AB3	1 693	26.5	5.9	0.76	17.8	26.9
L10 <sup>(b)</sup>	2 394	85.2	50.8	5.64	61.8	36.6
AR1 <sup>(c)</sup>	1 056	21.5	9.9	1.01	16.8	14.5
BEC	87	2.9	1.7	0.19	2.4	0.7
DO8 <sup>(a)</sup>	130	1.3	9.9	1.01	0.7	14.5
F50 <sup>(a)</sup>	130	1.3	9.9	1.01	0.7	14.5
146	574	7.9	1.1	0.17	5.7	4.0
PAG <sup>(b)</sup>	13	12.7	0.2	0.02	0.2	0.0
D28 <sup>(a)</sup>	130	1.3	9.9	1.01	0.7	14.5
DO2 <sup>(a)</sup>	130	1.3	9.9	1.01	0.7	14.5
747	3 472	71.3	26.3	2.62	45.4	56.6
B11 <sup>(b)</sup>	639	18.4	6.0	0.66	7.2	5.3

Emission Factor is average from EMEP/CORINAR (EEA,2002) and FAEED except

(a) EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002)

(b) FAEED Database

(c) Average for all other aircraft types

Table 3.79 - Emissions factors (kg/LTO) for LTO movements per aircraft type (2/2)

Aircraft	FC	NOx	NM VOC	CH <sub>4</sub>	CO	PST <sup>(b)</sup>
AN2	217	0.3	6.4	0.71	10.4	5.4
L15 <sup>(b)</sup>	2 466	90.3	52.4	5.82	63.7	38.5
D9S <sup>(b)</sup>	937	14.4	3.8	0.42	4.6	7.6
DC9	856	9.7	1.8	0.21	4.5	7.2
D10	2 384	51.3	19.9	2.22	42.5	39.3
CVF <sup>(b)</sup>	263	16.4	3.5	0.39	4.3	0.4
BAT <sup>(b)</sup>	639	18.4	6.0	0.66	7.2	5.3
DHT	84	1.9	1.1	0.12	1.7	0.4
BNI <sup>(c)</sup>	1 056	21.5	9.9	1.01	16.8	14.5
F28	664	15.5	26.6	1.30	28.9	5.1
SF3	90	1.2	0.2	0.02	0.4	0.7
CRV <sup>(b)</sup>	866	16.0	4.1	0.45	4.9	6.7
TU5 <sup>(b)</sup>	2 112	123.0	75.4	8.37	91.7	13.6
M11 <sup>(b)</sup>	2 713	27.1	3.4	0.38	4.1	45.6
DFL <sup>(b)</sup>	97	4.5	0.6	0.06	0.7	0.7
TU6 <sup>(b)</sup>	1 807	83.0	50.1	5.57	61.0	15.4
ACD <sup>(b)</sup>	159	18.6	1.6	0.18	2.0	0.3
HS7 <sup>(b)</sup>	76	2.2	0.3	0.04	0.4	0.6
TUPOLEV <sup>(b)</sup>	1 807	83.0	50.1	5.57	61.0	15.4
DC8	1 253	31.3	21.6	2.59	28.6	18.4
707 <sup>(b)</sup>	1 833	60.4	41.8	4.65	50.9	16.9
AB4	1 875	32.5	11.9	1.33	29.4	26.3
Other <sup>(c)</sup>	1 056	21.5	9.9	1.01	16.8	14.5

Emission Factor is average from EMEP/CORINAR (EEA,2002) and FAEED except

(a) EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002)

(b) FAEED Database

(c) Average for all other aircraft types

Therefore, for the major international airports where information was available with detailed aircraft type in LTO movements, emissions emission factors for each aircraft type were applied directly to LTO movements for each aircraft type. For the other airports – which importance is smaller – average emission factors from the former airports was used to estimate emissions: average emission factor from ANA airports was used for ANAM airports and average emission factor for ANA airports in Azores (with detailed LTO movements data) was used for the other Azorean airports. The global average emission factors change along time according to the following tables.

Table 3.80 – Evolution of Average National Emission Factors for LTO movements (1990-1995)

Parameter	Unit	1990	1991	1992	1993	1994	1995
FC	kg/LTO	1 008	1 019	1 005	1 013	1 011	1 023
NOX		18.1	14.8	14.5	14.9	14.4	13.9
NM VOC		7.16	5.82	5.82	6.53	6.06	5.35
CH <sub>4</sub>		0.78	0.59	0.57	0.59	0.54	0.45
CO		12.0	12.0	11.4	11.6	11.2	10.7
PST		11.9	13.5	12.9	12.5	12.2	12.1

Table 3.81 – Evolution of Average National Emission Factors for LTO movements (1996-2002)

Parameter	1996	1997	1998	1999	2000	2001	2002
FC	1 007	971	970	978	961	953	944
NOX	13.0	12.6	12.8	12.6	11.3	10.8	10.2
NM VOC	5.29	4.87	4.57	4.09	4.00	3.69	3.41
CH <sub>4</sub>	0.42	0.41	0.40	0.37	0.30	0.26	0.22
CO	10.8	10.3	10.2	10.5	9.8	9.6	9.4
PST	12.2	11.7	12.1	11.6	11.7	11.6	11.6

The information that was available during development of the inventory did not allow the consideration of different emission factors for domestic and international movements. It must be emphasised however, that the average travel distance in domestic flights in Portugal is not significantly shorter than average distance for international flights – particularly flights to and from UE countries – because they incorporate an important component of travels between mainland and island areas. Table 3.82 shows the average travel distance between several destinies. Therefore, differently from the situation that may occur in other countries, aircraft types may be not significantly different<sup>38</sup>.

Table 3.82 - Average travel distance between several destinies for national air carriers

Origin	Portugal	Mainland	Azores	Madeira
Portugal	759	-	-	-
Mainland	-	358	1 567	998
Azores	-	1 548	205	1 125
Madeira	-	1 000	1 000	59
UE	994	1 062	791	850
Other Countries	3 350	-	-	-

Source: INE

Cruise emission factors were estimated using the default emission factors (kg/ton) from IPCC 1996 Revised Guidelines (IPCC,1997). It is still not possible to differentiate emissions by aircraft type.

Table 3.83 – Emission factors for aviation in cruise mode (kg/ton)

Pollutant	AG	JP
LHV (MJ/kg)	44.77	44.56
SO <sub>x</sub> (%)	0.04	0.04
NO <sub>x</sub>	3.52	12.50
COVNM	24.00	0.78
CH <sub>4</sub>	2.64	0.09
CO	1 034	5
U <sub>CO2</sub>	3 172	3 149
N <sub>2</sub> O	0.04	0.04
PM	#	

Source: IPCC (1997)  
# Equal to LTO

<sup>38</sup> Efforts are under way to confirm this statement however. Otherwise some corrections need to be done.

### Activity Data

#### Fuel Consumption

The determinant activity data for this source activity, particularly for CO<sub>2</sub> emissions, is fuel consumption, which time series were set from fuel sales statistics in the energy balances from General-Directorate of Geology and Energy (DGGE), available from year 1990 to year 2002. The information in energy balances differentiates total fuel consumption in air flight activity for the categories presented in Table 3.84. National and Foreign fuel use which differentiation is based on air carrier's flag; Jet fuel consumption in services refer to sales to military, which were added to National consumption in the inventory.

Table 3.84 – Desegregation of fuel consumption in energy balances (DGGE)

Flag	Fuel
National	Jet Fuel (JP)
	Aviation Gasoline (AG)
Services	Jet Fuel (JP)
Foreign	Jet Fuel (JP)
	Aviation Gasoline (AG)

Fuel consumption for resultant four classes is presented in Figure 3.31 and Figure 3.32 below.

Figure 3.31 – Aviation gasoline consumption in national and foreign aviation according to flag (1990-2002)

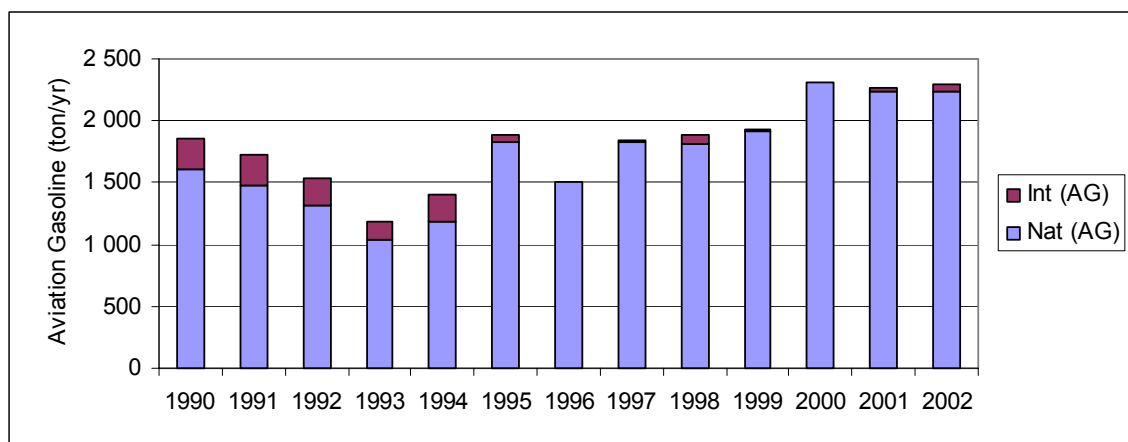
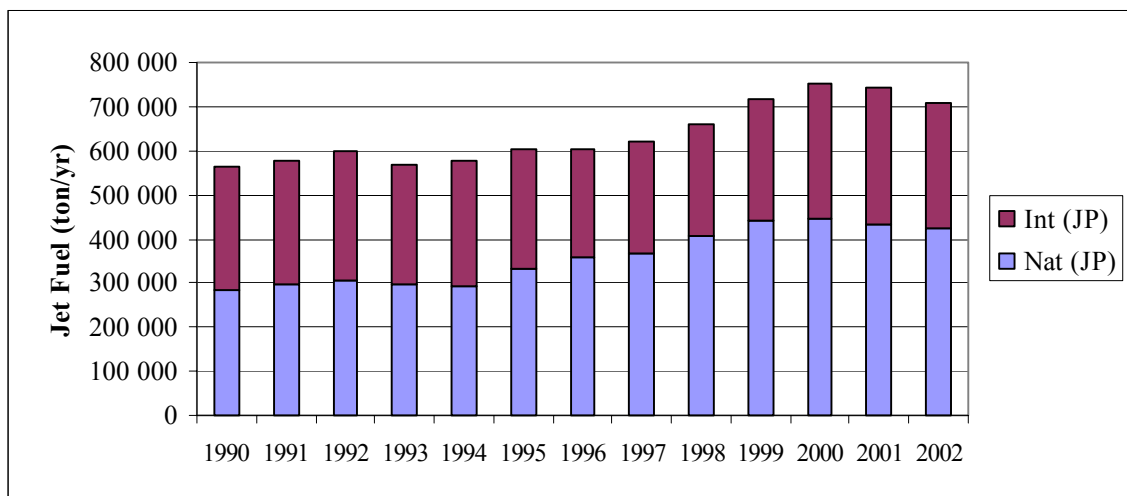


Figure 3.32 – Jet Fuel consumption in national and foreign aviation according to flag (1990-2002)



#### *Flight movements in Airports*

The other necessary piece of activity data is the number of Land/Take-Off movements<sup>39</sup>. LTO movements by aircraft type from 1990 till 1999 were available for the international airports<sup>40</sup> in Portugal from ANA and ANAM<sup>41</sup>.

LTO movements in the other smaller airports<sup>42</sup>, and for ANA/ANAM airports for years 2000 and 2001, result from statistical information published by INE. LTO value for all airports for year 2002 was forecasted at IA. The following Table 3.85 shows the list of codes used by ANA for desegregation of movements by aircraft type, together with the corresponding aircraft type.

<sup>39</sup> A LTO movement is defined as both a single landing together with a single take-off.

<sup>40</sup> Including the airports of Lisbon, Oporto and Faro in continental mainland and Santa Maria, Ponta Delgada, Horta and Flores airports in the Azores archipelago

<sup>41</sup> ANA – Aeroportos de Portugal S.A. is a public company for airport management. ANAM is a regional equivalent company responsible for management of Santa Catarina and Porto Santo airports in Madeira archipelago.

<sup>42</sup> Airports of Graciosa, Pico, S. Jorge and Corvo in Azores archipelago.

Table 3.85 – Aircraft codes as reported in LTO movements (ANA) and corresponding aircraft types

Code	Aircraft	Airship	Aircraft
320	Airbus Industrie A320-111	AN2	Antonov 225 Mriya
737	Boeing 737	L15	Lockheed 1011-500 TRISTAR
EMB	Embraer 110 Bandeirante (EMB-110)	D9S	McDonnell-Douglas DC9 30-50
100	Fokker 100 (F28 Mk0100)	DC9	Boeing (Douglas) C-9A (DC-9-32F)
ATP	BAe ATP	D10	Boeing (Douglas) DC-10
310	Airbus 310	CVF	Convair CV-440/580/600/640 Freighter
757	Boeing 757	BAT	Aerospatiale / BA
M80	Boeing (Douglas) MD-81	DHT	De Havilland DHC-6 Twin Otter 100
767	Boeing 76	BNI	Britten-Norman BN-2A Islander
340	Airbus 340	F28	Fokker F28 Fellowship 1000 (F28 Mk1000)
727	Boeing 727	SF3	S 100B Argus (Saab 340B AEW)
AB3	Airbus A300 Pax	CRV	Aerosp. (Sud) SE210 Caravelle 10B1R
L10	Lockheed 1011 TRISTAR	TU5	Tupolev 154
AR1	Avro RJ100 (Avro 146-RJ100)	M11	Boeing (Douglas) MD-11
BEC	Beech Mentor T-34C	DFL	Dassault (Breguet Mystere) Falcon
DO8	Dornier 228 all series	TU6	Tupolev
F50	Fokker 50 (F27 Mk050)	ACD	Gulfstream/Rockwell Commander/Turbo Commander (Aero)
146	British Aerospace 146		
PAG	AAC (Piper) Aerostar 600A	HS7	BAe (HS) 748-101 Srs 1A
D28	Dornier 228-100	TUPOLEV	Tupolev
DO2	Dornier	DC8	Douglas DC-8 pax
747	Boeing 747	707	Boeing 707-436
B11	British Aerospace (BAC) One Eleven/RomBAC One Eleven	AB4	Airbus A300B2/B4/C4

Total annual LTO per airport are presented in Figure 3.33, and in Table 3.86 for selected years.

Figure 3.33 – Total number of LTO movements per airport (1990-2002)

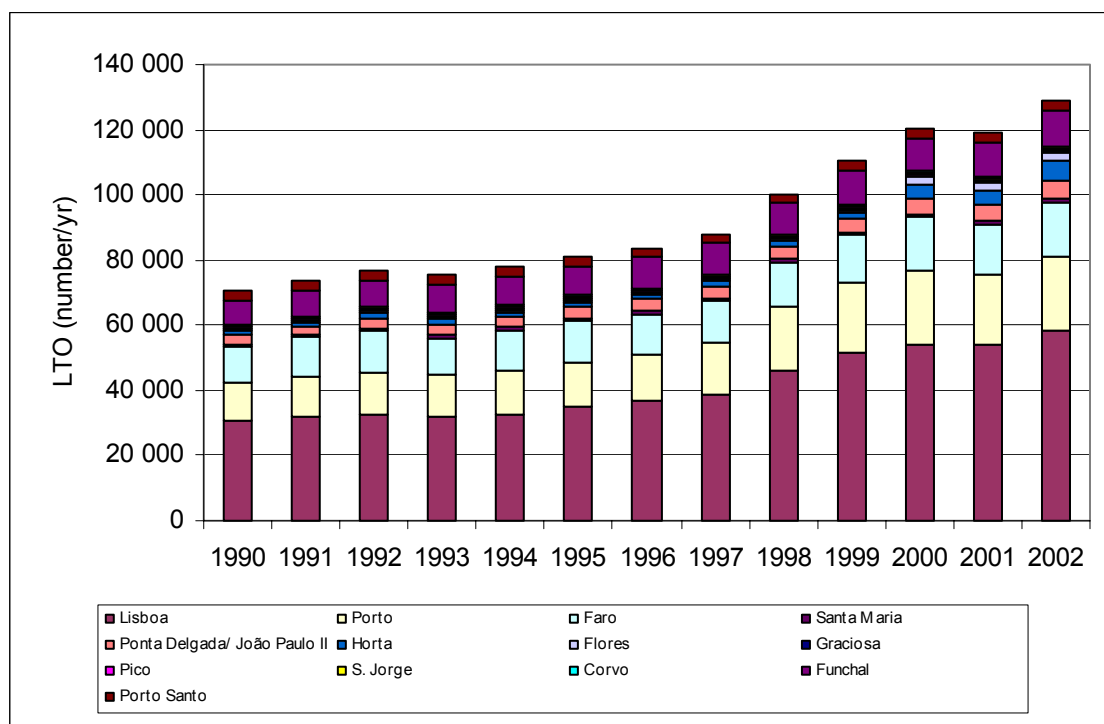


Table 3.86 – LTO movements by airport for selected years

Airport	1990	1995	2000	2002
Lisboa	30 840	34 937	54 260	58 504
Porto	11 565	13 350	22 446	22 638
Faro	11 238	13 067	16 797	16 621
Santa Maria	630	893	682	1 284
Ponta Delgada	2 955	3 381	4 514	5 065
Horta	1 238	1 542	4 676	6 148
Flores	281	357	1 951	2 837
Graciosa	431	423	418	410
Pico	344	509	703	740
S. Jorge	539	547	554	557
Corvo	152	200	253	268
Funchal	7 549	9 024	10 274	11 090
Porto Santo	2 903	2 777	2 570	2 600
			120	128
Total	70 661	81 005	098	760

### Origin-Destiny

Finally, data on movements and miles flown per origin and destiny was necessary to differentiate emissions between domestic and international. For each airport the total number of movements were available from INE according to type of movement: territorial, internal and international, and considering separately air-carriers by nationality. Synthesis of that information is presented in Table 3.87. Calculation in this table shows that for national flag carriers, domestic flights correspond to 60% of LTO while this percentage is only 2.2% for foreign flag air carriers. Unfortunately this information is not further desagregated by aircraft type and airport.



Table 3.87 – Air traffic movements in Portuguese airports by air carrier flag, type of movement and function (2001)

Type of Traffic	Total	Landing	Climbing
<b>Regular Commercial Traffic</b>			
<b>International</b>	121 058	60 288	60 770
National Flag	65 375	32 432	32 943
Foreign	55 683	27 856	27 827
<b>Territorial</b>	28 590	14 253	14 337
National Flag	28 580	14 251	14 329
Foreign	10	2	8
<b>Internal</b>	46 305	23 422	22 883
National Flag	46 133	23 346	22 787
Foreign	172	76	96
<b>non Regular Commercial Traffic</b>			
<b>International</b>	32 229	15 877	15 969
National Flag	4 573	2 092	2 098
Foreign	27 656	13 785	13 871
<b>Territorial</b>	29 376	12 974	12 918
National Flag	28 826	12 670	12 691
Foreign	550	304	227
<b>Internal</b>	2 328	1 061	1 121
National Flag	1 166	516	525
Foreign	1 162	545	596
<b>Other Traffic</b>			
Air taxi	4 108	1 977	2 075
Agriculture	628	313	315
Fire control	7 577	3 281	3 281
Photo survey	2 027	439	443
Training	92 359	56 025	34 227
Private Service	25 134	12 143	12 158
Military	5 671	2 742	2 713
Other	11 474	5 483	5 491

Source: INE

For each airport, total LTO is further separated according to carrier's flag. Information, also from INE, is presented in next table for year 2001.

Table 3.88 – Air traffic movements per airport and nationality of air carrier by Airport (2001)

Nº Planes	Air Carrier Flag		
	Total	National	Foreign
<b>Total</b>	119 385	76 882	42 504
<b>Lisboa</b>	54 264	38 289	15 975
<b>Porto</b>	21 317	12 435	8 882
<b>Faro</b>	15 166	1 942	13 224
<b>Santa Maria</b>	1 311	558	753
<b>João Paulo II</b>	4 808	4 370	438
<b>Lajes</b>	4 629	4 288	342
<b>Horta</b>	2 074	2 002	72
<b>Flores</b>	494	494	0
<b>Graciosa</b>	414	414	0
<b>Pico</b>	680	680	0
<b>São Jorge</b>	548	548	0
<b>Corvo</b>	250	250	0
<b>Funchal</b>	10 816	8 045	2 771
<b>Porto Santo</b>	2 613	2 566	47

Source: INE

Passenger-kilometres driven between continental Portugal, the autonomous islands and foreign destinies were available for some years from INE database, but only for air carriers of national flag. The corresponding origin-destiny table for 2001 was used as indicator to establish the percentage of JP consumed in cruise flights that is allocated to domestic flights and international flights. The original information data is presented in Table 3.89, with separation of regular and non-regular flights. From this table it may be seen that domestic passenger-kilometres correspond to about 17% of total passenger-kilometres, while 83% are international. This percentages were applied to total cruise JP consumption and emissions for air-carriers with Portuguese flag. For foreign air carrier this information is not available and the same percentage used for LTO was also used to desegregate cruise fuel consumption and emissions<sup>43</sup>.

<sup>43</sup> This assumption could be valid if cruise length for foreign flag flights does not vary substantially between domestic and international flights.

Table 3.89 – Passenger-kilometres by origin and destiny that have flew from and into Portugal (2001)

Origin (1E6)	Destiny		Portugal										Lat. Amer.	Car
	Total	UE	Total	Mainland	Açores	Madeira	EFTA	Oth. Europe	Mid East	Africa	Asia and P.	N. Amer.		
<b>TOTAL</b>	<b>12 857</b>	<b>9 850</b>	<b>7 206</b>	<b>5 883</b>	<b>669</b>	<b>654</b>	<b>217</b>	<b>67</b>	-	<b>579</b>	-	<b>667</b>	<b>1 477</b>	
<b>Regular</b>	<b>11 948</b>	<b>9 216</b>	<b>6 739</b>	<b>5 667</b>	<b>535</b>	<b>537</b>	<b>196</b>	-	-	<b>579</b>	-	<b>494</b>	<b>1 463</b>	
UE	9 187	6 465	3 990	2 919	534	537	196	-	-	578	-	486	1 462	
Portugal	7 361	4 641	2 234	1 226	525	483	194	-	-	578	-	486	1 462	
Mainland	6 295	3 577	1 233	330	438	465	194	-	-	578	-	484	1 462	
Açores	533	531	522	434	78	10	-	-	-	-	-	2	-	
Madeira	533	533	479	462	9	8	-	-	-	-	-	-	-	
EFTA	177	177	175	175	-	-	-	-	-	-	-	-	-	
Other European Countries	-	-	-	-	-	-	-	-	-	-	-	-	-	
Middle East	-	-	-	-	-	-	-	-	-	-	-	-	-	
Africa	628	627	627	627	-	-	-	-	-	1	-	-	-	
Asia and Pacific	-	-	-	-	-	-	-	-	-	-	-	-	-	
North America	491	483	483	482	1	-	-	-	-	-	-	8	-	
Latin America and Carab.	1 465	1 464	1 464	1 464	-	-	-	-	-	-	-	-	-	1
<b>Non-Regular</b>	<b>909</b>	<b>634</b>	<b>467</b>	<b>216</b>	<b>134</b>	<b>117</b>	<b>21</b>	<b>67</b>	-	-	-	<b>173</b>	<b>14</b>	
UE	621	414	247	160	-	87	21	o	-	-	-	172	14	
Portugal	454	247	102	97	-	5	21	o	-	-	-	172	14	
Mainland	172	142	69	64	-	5	3	o	-	-	-	24	14	
Açores	135	-	-	-	-	-	-	-	-	-	-	135	-	
Madeira	147	116	33	33	-	-	18	-	-	-	-	13	-	
EFTA	21	21	21	3	-	18	-	-	-	-	-	-	-	
Other European Countries	67	o	o	o	-	-	-	67	-	-	-	-	-	
Middle East	-	-	-	-	-	-	-	-	-	-	-	-	-	
Africa	o	o	o	-	o	-	-	-	-	-	-	-	-	
Asia and Pacific	-	-	-	-	-	-	-	-	-	-	-	-	-	
North America	174	173	173	27	134	12	-	-	-	-	-	1	-	
Latin America and Carab.	26	26	26	26	-	-	-	-	-	-	-	-	-	

Source: INE

### 3.2.A.5.5 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 is the agriculture/forestry sector where it is more or less evident that all gas-oil is used as energy source to vehicles and machines.

Emissions from off-road vehicles and machines from other sectors: industry, residential, institutional and fisheries, 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 for all pollutants other than SO<sub>x</sub> are estimated with the following formula:

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

where

Emission<sub>(p,y)</sub> - Emission of pollutant p in year y (ton/yr);

EF<sub>(p)</sub> - Emission factor for pollutant p (kg/ton);

Cons<sub>Fuel(y)</sub> - consumption of gas oil in agriculture machines and off-road vehicles during in year y (ton/yr).

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<sub>x(y)</sub> - Sulphur oxide emission in year y (ton/yr);

FuelCons<sub>(y)</sub> - Consumption of gas oil in off-road vehicles and machines in agriculture/forestry sector in year y (ton/yr);

S<sub>(y)</sub> - Sulphur content of gas oil (mass percentage).

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).

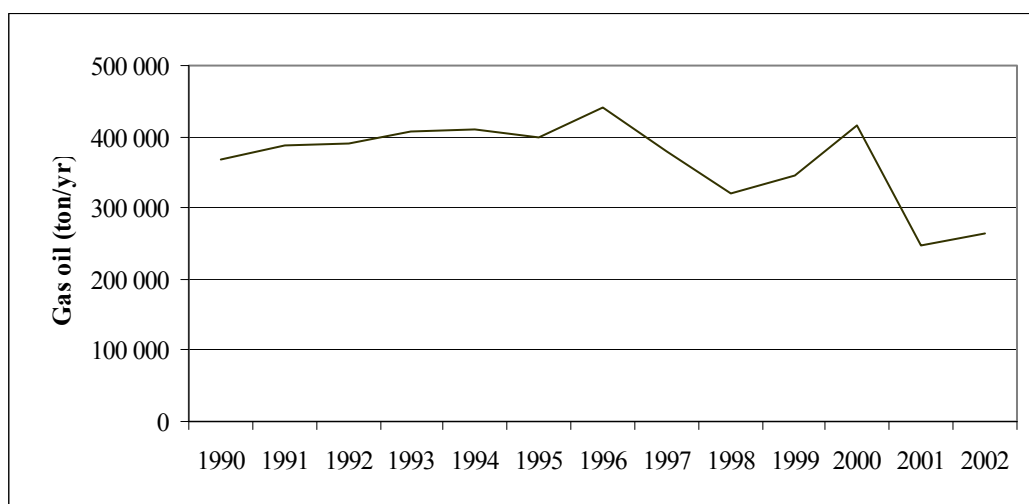
Table 3.90 – Emission factors for gas oil use in agriculture machines and other off-road vehicles

Parameter	EF	Unit
LHV	43.3	MJ/kg
SO <sub>x</sub>	0.3	%
NO <sub>x</sub>	56.9	g/kg
NM VOC	8.4	g/kg
CH <sub>4</sub>	0.3	g/kg
CO	20.7	g/kg
U CO <sub>2</sub>	3 136	g/kg
N <sub>2</sub> O	1.3	g/kg
NH <sub>3</sub>	0.007	g/kg
PM	5.87	g/kg

### Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to 2002 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 3.34.

Figure 3.34 - Consumption of gas-oil in machines and other off-road vehicles (1990-2002)



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

#### OVERVIEW

The sources covered in this chapter refer to emissions resulting from combustion in such activities such as residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) sources. All emissions resulting from combustion equipments, either boilers, co-generation equipment, machines and static engines are included in sector 1A4. However, emissions estimates from fishery bunkers and off-road vehicles in agriculture and forestry, although included in source category 1A4, are nevertheless discussed in chapter 3.2.A.5.

#### METHODOLOGY

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

When emissions are calculated from energy activity rate the following basic formula was used:

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

where:

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

$EF_{(f,s,t)}$  - Emission Factor (g/GJ except CO<sub>2</sub> in kg/GJ);

$Activity_{(f,s,t)}$  - Energy Input (GJ);

f - Fuel type;

s - Sector-activity;

t – Technology or equipment.

Emissions of SO<sub>x</sub> are directly related to the fuel content of the fuel, and are estimated from:

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

where:

Emi<sub>SOx(s)</sub> - Total emissions of SO<sub>x</sub> from sector s (ton/yr);

S<sub>(f,s,t)</sub> - Sulphur content of fuel (%);

Fuel<sub>Cons(f,s,t)</sub> – Fuel consumption for each particular fuel (ton/yr).

## ACTIVITY DATA

Data on fuel consumption were obtained from the annual energy balances compiled by DGGE and are presented in the following tables.

Table 3.91 - Fuels consumption in residential sector

NAPFUE	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L 203	Residual oil	ton	1,582	1,546	1,383	1,281	1,660	1,060	1,078	1,003	272	97	65	0	0
L 204	Gas oil	ton	3,653	4,868	6,593	4,734	4,394	4,640	3,062	2,122	2,447	3,330	2,088	1,903	1,677
L 206	Kerosene	ton	18,145	17,223	14,319	12,133	11,750	8,138	9,511	16,657	17,416	16,130	8,355	4,446	8,868
L 208	Motor gasoline	ton	138	174	132	126	140	214	307	333	328	136	17	2	2
L 303	LPG	ton	483,026	508,837	543,161	575,925	584,924	590,959	638,059	618,453	651,193	689,517	707,191	650,168	721,002
L 308	Refinery gas	k m3	122,615	124,287	126,475	132,125	126,476	123,003	126,011	126,933	134,228	129,977	77,303	9,991	9,991
G 301	Natural gas	ton	0	0	0	0	0	0	0	876	9,918	37,276	78,974	121,900	143,119
B 111	Biomass wood	ton	4,283,750	4,090,420	3,952,383	3,864,901	3,824,057	3,826,667	3,837,778	3,850,000	3,816,667	3,766,667	3,750,000	3,766,667	3,720,000
B 112	Biomass charcoal	ton	29,873	29,429	28,984	28,540	28,095	27,651	27,206	26,762	26,317	25,873	25,428	24,984	24,539

Table 3.92 - Fuels consumed in commercial/institutional sector

NAPFUE	Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L 203	Residual oil	ton	59,161	51,814	49,439	51,447	91,296	106,347	82,222	34,551	64,885	76,581	82,463	85,816	104,892
L 204	Gas oil	ton	130,054	159,539	190,984	194,800	198,172	181,955	201,281	302,345	385,693	423,378	424,325	506,609	489,433
L 205	Diesel oil	ton	98	98	98	98	98	98	98	98	98	98	98	98	98
L 206	Kerosene	ton	1,712	763	1,467	1,686	560	308	290	573	620	393	140	173	173
L 208	Motor gasoline	ton	12,938	14,257	13,788	13,507	23,138	26,226	31,682	57,899	72,826	71,854	49,497	63,724	75,989
L 303	LPG	ton	24,668	28,286	32,540	39,077	38,523	26,111	52,753	78,996	81,070	87,105	90,888	107,210	107,527
L 308	Refinery gas	k m3	32,147	35,485	33,656	41,032	41,291	46,704	50,063	49,576	57,930	66,543	46,668	5,593	5,593
G 301	Natural gas	ton	0	0	0	0	0	0	0	391	13,955	39,423	64,563	93,482	113,400

Table 3.93 - Fuels consumed in agriculture/forestry (excluding mobile sources)

Equipment	NAPFUE		Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Boilers cogeneration	L	203	Residual oil	ton	0	0	0	0	130	6,490	6,297	7,091	6,976	6,904	14,098	17,133	14,955
Boilers non cogener.	L	203	Residual oil	ton	13,053	9,360	7,124	8,551	12,014	4,161	6,459	6,554	4,868	9,996	8,104	2,850	4,669
Boilers	L	206	Kerosene	ton	8,008	7,110	6,221	4,751	4,594	4,369	4,192	9,760	11,292	552	1,015	1,076	2,455
Boilers	L	208	Motor gasoline	ton	751	796	1,058	1,003	3,008	2,894	3,631	4,410	3,893	3,566	954	2,668	3,737
Boilers	L	303	LPG	ton	6,972	8,569	10,124	12,173	12,276	12,100	17,479	11,840	15,089	14,260	10,503	14,231	13,731
Boilers non cogener.	G	301	Natural gas	ton	0	0	0	0	0	0	0	0	1	4	121	4,971	5,031
Boilers cogeneration	G	301	Natural gas	ton	0	0	0	0	0	0	0	0	0	0	0	2,905	2,905
Cogeneration	B	309	Biogas	m3	0	0	0	0	0	0	0	0	0	0	268	224	224

Table 3.94 - Fuels consumed in fisheries (excluding consumption in fishing vessels)

NAPFUE		Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
L	203	Residual oil	ton	100	134	186	227	133	293	124	219	155	1,234	161	449	530
L	204	Gas oil	ton	147	11	23	0	23	392	37	3,485	12,449	17,774	23,099	48,817	37,179
L	206	Kerosene	ton	0	0	0	0	0	0	0	0	61	1,713	230	2	2
L	208	Motor gasoline	ton	31	0	5	2	6	16	22	16	90	1,375	6,231	6,391	9,462
L	303	LPG	ton	60	122	86	32	45	0	2	82	53	178	440	690	705

## EMISSION FACTORS

The emission factors were taken from international sources:

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- 1996 IPCC Revised Guidelines (IPPC,1997);
- US EPAP-42 and EIIP.

Table 3.95- Emissions factors for the domestic sector

NAPFUE		Fuel	PCI		SOx	NOx	COVNM	CH4	CO	CO2	N2O
			unit		%	g/GJ	g/GJ	g/GJ	g/GJ	kg/GJ	g/GJ
L	203	Residual oil	MJ/Kg	40.17	3	160	3	5.1	20	77.4	0.14
L	204	Gas oil	MJ/Kg	43.31	0.3	577.5	51	5.0	40	74.1	1.55
L	205	Diesel oil	MJ/Kg	43.31	0.3	55	2	5.5	40	74.1	0.6
L	206	Kerosene	MJ/Kg	43.72	0.15	55	51	5.0	40	71.9	1.55
L	208	Motor gasoline	MJ/Kg	44.77	0.1	1300	100	9.9	40	69.3	0.6
L	303	LPG	MJ/Kg	47.28	0.0016	65	2.5	1.5	250	63.1	1.4
L	308	Refinery gas	MJ/Nm3	15.69	0	65	2.5	1.5	250	60.0	1.4
S	102	Steam coal	MJ/Kg	29.29	1	150	200	200	4800	94.6	0.7
S	105	Brown coal/lignite	MJ/Kg	17.16	1	150	200	200	4800	96.1	0.7
G	301	Natural gas	MJ/Kg	42.6	0.0059	40	2.5	2.5	14	56.1	
B	111	Biomass wood	MJ/Kg	12.55	0	67	400	300	5000	109.6	4.3
B	112	Biomass charcoal	MJ/Kg	25.10	0	67	400	300	5000	109.6	4.3

Table 3.96– Particulate matter emissions factors for the domestic sector

	NAPFUE	Fuel	PST	PM10	PM2.5	PM1.0
			g/GJ	(% of TSP)	(% of TSP)	(% of TSP)
L	203	Residual oil	53	62	23	14
L	204	Gas oil	7	55	42	37
L	205	Diesel oil	7	55	42	37
L	206	Kerosene	6.5	55	42	37
L	208	Motor gasoline	43	100	100	100
L	303	LPG	2.2	100	100	100
L	308	Refinery gas	2.2	100	100	100
S	102	Steam coal	171	20	7	5
S	105	Brown coal/lignite	1166	35	10	6
G	301	Natural gas	0.807	100	100	100
B	111	Biomass wood	405.1	100	100	100
B	112	Biomass charcoal	405.1	100	100	100

Table 3.97 – Emissions factors: commercial/institutional, agriculture/forestry and fisheries (excluding fuel use in ship vessels)

	NAPFUE	Fuel	PCI		SOx	NOx	COVNM	CH4	CO	CO2	N2O
			unit		%	g/GJ	g/GJ	g/GJ	g/GJ	kg/GJ	g/GJ
L	203	Residual oil	MJ/Kg	40.17	3	160	3	1.6	20	77.4	0.6
L	204	Gas oil	MJ/Kg	43.31	0.3	580	50.5	5.0	20	74.1	0.6
L	205	Diesel oil	MJ/Kg	43.31	0.3	60	1	0.6	20	74.1	0.6
L	206	Kerosene	MJ/Kg	43.72	0.15	60	50.5	5.0	20	71.9	0.6
L	207	Jet Fuel	MJ/Kg	44.56	0.1	1300	100	9.9	20	71.5	0.6
L	208	Motor gasoline	MJ/Kg	44.77	0.1	1300	100	9.9	20	69.3	0.6
L	303	LPG	MJ/Kg	47.28	0.0016	65	2.5	1.5	50	63.1	1.4
L	308	Refinery gas	MJ/Nm3	15.69	0	65	2.5	1.5	50	60.0	1.4
S	102	Steam coal	MJ/Kg	29.29	1	150	200	86	200	94.6	0.7
S	105	Brown coal/lignite	MJ/Kg	17.16	1	150	200	86	200	96.1	0.7
G	301	Natural gas	MJ/Kg	42.6	0.0059	48	10	1.2	20	56.1	1.4
B	111	Biomass wood	MJ/Kg	12.55	0	67	400	15	500	109.6	4.3
B	309	Biogas	MJ/m3	34.7	0	65	2.5	0.72	17	52.0	1.4

Table 3.98 – Particulate matter emissions factors for the commercial/institutional, agriculture/forestry and fisheries (excluding fuel use in ship vessels)

	NAPFUE	Fuel	PST	PM10	PM2.5	PM1.0
			g/GJ	(% of TSP)	(% of TSP)	(% of TSP)
L	203	Residual oil	53	62	23	14
L	204	Gas oil	69.9	77.5	71	68.5
L	205	Diesel oil	69.9	77.5	71	68.5
L	206	Kerosene	69.9	77.5	71	68.5
L	208	Motor gasoline	43	100	100	100
L	303	LPG	2.5	100	100	100
L	308	Refinery gas	2.5	100	100	100
S	102	Steam coal	171	20	7	5
S	105	Brown coal/lignite	1166	35	10	6
G	301	Natural gas	0.807	100	100	100
B	111	Biomass wood	172	90	76	67
B	112	JP	43	100	100	100



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

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

##### COAL MINING AND HANDLING

###### Overview

Coal contains some proportion of methane trapped in its structure that it is usually emitted to atmosphere during and after extraction of coal from mines to open air. Emissions at extraction result from ventilation of mine gas which is done for safety reasons at underground mines. Emissions at open cast mines are usually lower and result from coal mobilization and blasting operations. Post-mining emissions result from the slower liberation of methane still entrapped in coal after it is extracted and stored at surface in piles, or from crushing and drying operations applied to modified and ameliorate coal characteristics. In underground mines, post-mining emissions may occur in fact during extraction if degasification systems are installed but, nevertheless, total emissions remain more or less unaffected.

Since 1990 there was extraction of coal at only two coal mines in Portugal, but both were latter closed down in 1992 and 1994 and did not resume activity since. Both mines - *Peirão* and *S. Pedro da Cova* - are located in northern 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 - *Peirão* - 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 (IPCC,2000). Because no methodology is available to calculate present day flux from abandoned mines - which would require knowledge of all abandoned mines, not only *Peirão* and *S. Pedro da Cova* - no estimates are included in the inventory.

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

###### Methodology

Emission estimates include both emissions occurring during extraction of coal as well as those resulting from processing.

A simple tier 1 approach was used to estimate emissions, which is considered a sufficient approach being present the scarcity of technical information about these mines and because this emission source is no key source and has small relevance. The following equation is similar to the methodology proposed in IPCC 1996 Revised Guidelines (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 IPCC 1996 Revised Guidelines (IPCC,1997) defaults were used for both mines, which are presented in next table. The same emission factor range was maintained in GPG (IPCC,2000).

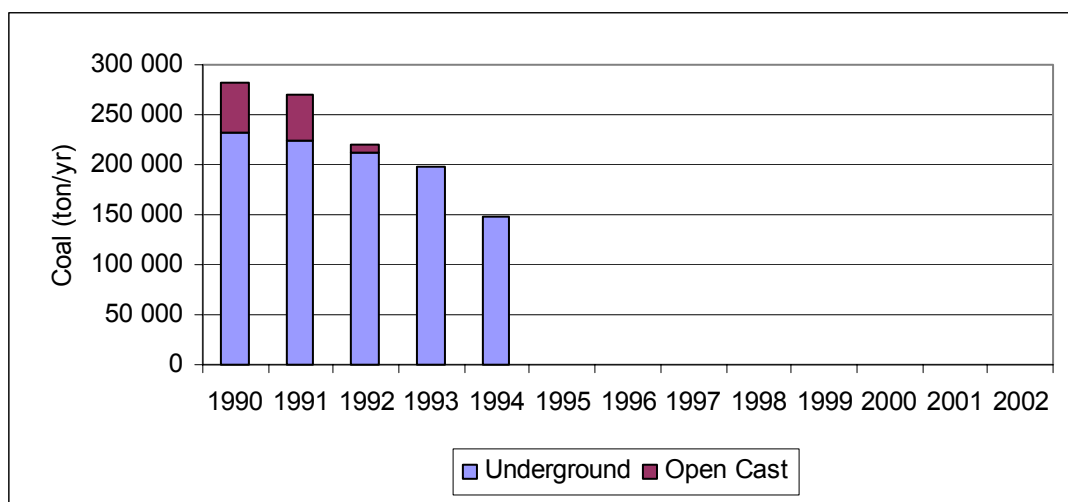
Table 3.99 – Emission Factors for coal extraction and processing

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 3.35 – Quantities of coal extracted from mines in Portugal (1990-2002)



### Recalculations

No recalculations of emissions were made on this source sector.

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

#### Overview

There is no extraction and production of crude oil in the portuguese territory. 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 are mainly 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 were estimated from:

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

where

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

Crude<sub>InFlow</sub> - 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 CH<sub>4</sub>:

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

### Emission Factors

Emission factors for NMVOC and CH<sub>4</sub> are those reported in next table and where set from CONCAWE, USEPA (AP-42) and IPCC 1996 Revised Guidelines (IPCC, 1997).

Table 3.100 – Emission Factors for marine terminals and crude oil transportation

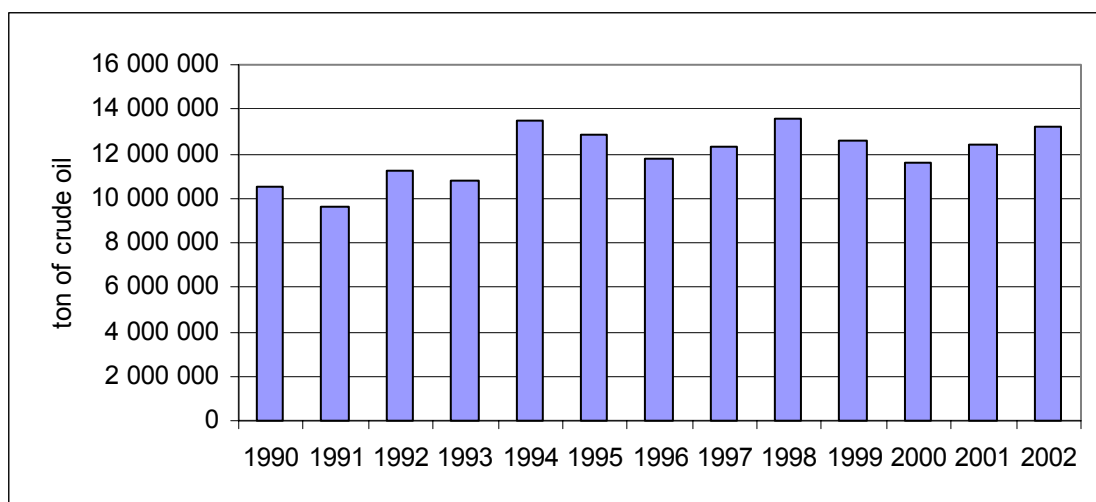
Component	Emission Factor (g/ton crude oil)
NMVOC	300
CH <sub>4</sub>	60 (2500 kg CH <sub>4</sub> /PJ <sup>(a)</sup> )
Ultimate CO <sub>2</sub>	1 100

(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 (DGE), with detailed information on the crude received at each individual refinery, and have increased unsteadily since 1990, as may be seen in next figure.

Figure 3.36 – Total imports of crude oil: 1990-2002



### Recalculations

Small changes were made in the activity data time series for years subsequent to 1997. Values reported in last submission were based in the Energy Balance from DGGE, which were published in toe, while in present submission values were collected directly in the annual publications of DGGE, which are expressed in tons of crude oil delivered at each refinery.

## 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 most activity and only two units remain now operating.

The refining process converts crude oil - which is a complex mixture of hydrocarbon compounds with impurities of sulphur, nitrogen, oxygen and heavy metals - into oil products used as fuels, asphalts, lubricants or feedstock for the organic and inorganic chemical industry. Processes included in Portuguese refineries include:

- Separation process: isolation of individual constituents of crude using differences in boiling-point, using atmospheric and vacuum distillation and recovery of light end gases;
- Conversion process. These may be also classified as: (1) Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular height into smaller ones, including visbreaking; (2) Polymerisation of small molecules combined in bigger molecules with different characteristics. Alkylation has similar objectives and (3) chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing;
- Treatment processes. Operations which include hydrodesulfurization, hydrotreating, chemical sweetening, acid gas removal, deasphaltating and desalting, that are used to remove impurities, the most important is sulphur;
- Blending of individual fractions and intermediate products to obtain final commercial products with characteristics as desired.

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

NM VOC and methane emissions may also result from “normal” leaks<sup>44</sup> 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 chapter xpto.

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 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 SO<sub>2</sub> 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 year 2002 lead to the establishing of plant specific emission factors for NM VOC losses from crude oil and oil products storage. Annual emissions of NM VOC (ton/yr) for the remaining time series are estimated using the emission factor (EF in g/ton) determined for 2002 and relying in the time series of total throughput petroleum materials processed (ton/yr) as an indicator of activity<sup>45</sup>.

$$\text{Emission}_{\text{NM VOC}} = \text{EF} * \text{Throughput} * 10^{-6}$$

### Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations where estimated from:

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

where

<sup>44</sup> Sometimes only these emissions are referred as fugitive emissions from refineries.

<sup>45</sup> This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.

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<sub>x</sub> occurring due to limitations of the sulphur recovery system were estimated annually according to the following procedure:

$$Emi_{SO_x} = 64/32 * [S_{Inc} + S_{Prod} * (100 - Claus_{EFIC}) / Claus_{EFIC}]$$

where

Emi<sub>SO<sub>x</sub></sub> – Emissions of sulphur oxides from sulphur recovery in tail gas (ton S/yr);

S<sub>Inc</sub> - sulphur in tail gas that is incinerated to SO<sub>x</sub> because Claus unit was not operational (ton S/yr);

Claus<sub>EFIC</sub> – percent efficiency of overall Claus unit (%);

S<sub>Prod</sub> - 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 CO<sub>2</sub> (kton/yr) by:

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

### **Emission Factors**

#### Storage/ Tanks

During last year, IA and PETROGAL, 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,1999).

Because it is obviously not possible to present all background information that was used to estimate storage and tank emissions, a short summary is presented here in NIR.

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,1997b).

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

- Site information: meteorological data such as the daily average ambient temperature, the annual average minimum and maximum temperatures, the annual average wind speed, the annual average solar insolation factor, and the atmospheric pressure;
- Liquid characterization: For individual substances the model requires chemical nomenclature, average liquid temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. For mixtures, the information may be as detailed as the mixture name, average, minimum and maximum liquid surface temperatures, bulk temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights;
- tank information is slightly different according to tank type, but in general terms comprehends: shell and roof colour and condition, height, diameter, average and maximum liquid height, working volume, turnover rate and net output, heating conditions and pressure and vacuum settings and the existence and type of seals<sup>46</sup>.

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 next table.

Table 3.101 – 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:

<sup>46</sup> This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

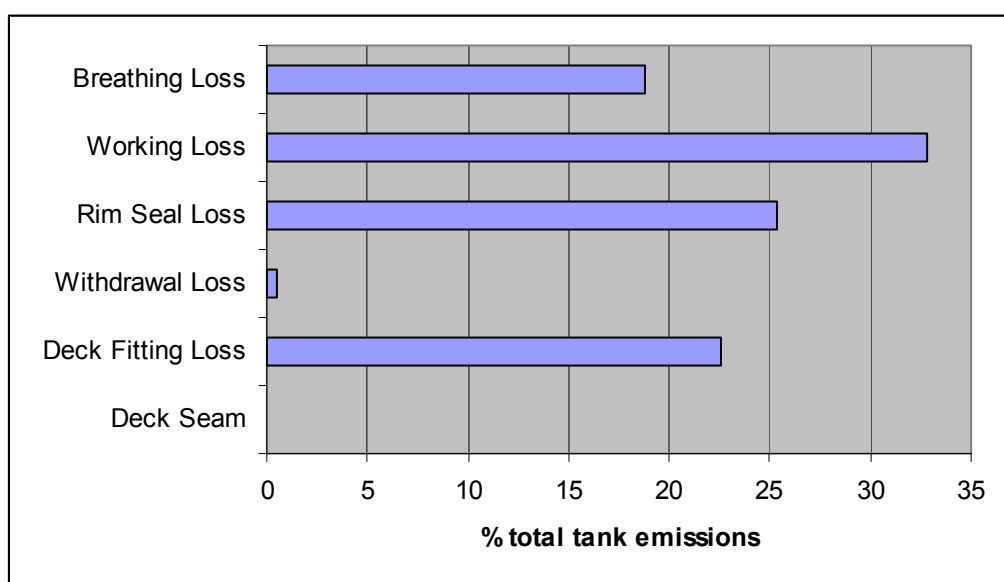


Table 3.102 – Types of losses from tanks for storage of organic compounds and petroleum products

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 3.37.

Figure 3.37 – Percentage of NMVOC emissions per type of emission from storage and tanks of petroleum products



Finally the resultant emission factors, obtained dividing total tank emissions by total throughput<sup>47</sup> in each refinery, are presented in next table.

Table 3.103 – Final emission factor for evaporation of NMVOC from storage and tank in refineries

Refinery	Emission Factor (g NMVOC/ton throughput)
Sines	118
Oporto	204
Lisbon	161 <sup>(a)</sup>

(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 (CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002)).

Table 3.104 – 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<sub>x</sub>, SO<sub>x</sub> and particulate matter) plant specific emission factors were established for this process. For carbon monoxide emission factors from USEPA (1995c) were used, but because original emission in the original reference source are expressed in volume of fresh feed – and this activity rate it is not available from the refinery – the original emission factor was corrected, by multiplication by the ratio of the NO<sub>x</sub> emission factor in both information sources (monitoring data and USEPA (1995c)). Carbon dioxide emission factor was set assuming that coke is 92% carbon. Final emission factors may be verified in Table 3.105.

Table 3.105 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Parameter	Emission Factor kg/ton coke
SO <sub>x</sub>	31.9
NO <sub>x</sub>	3.6
CO	5.8
U CO <sub>2</sub>	3 373
PM	6.8

<sup>47</sup> Crude oil input added to input of other materials.

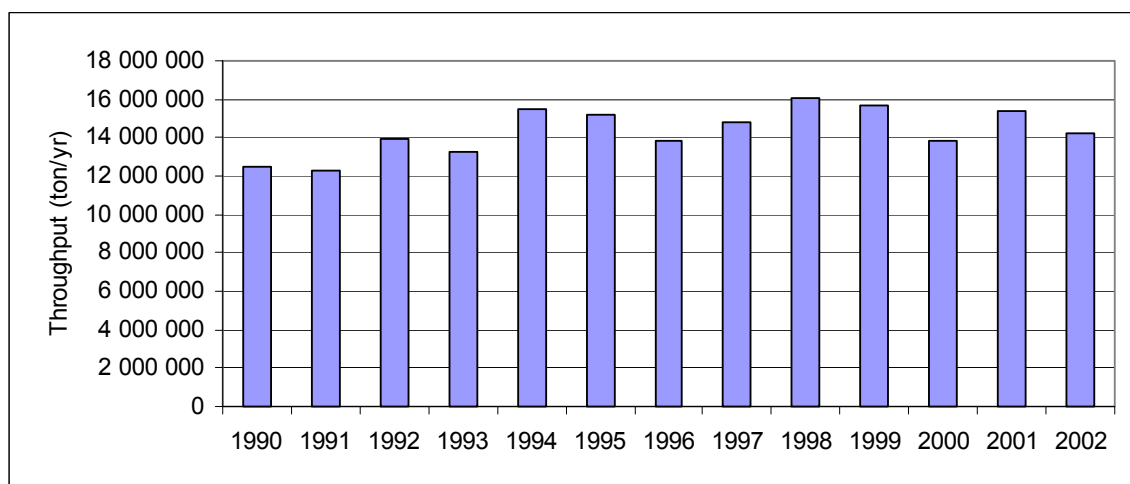
This set of emission factors was also applied to coke burning in the platforming unit, also in Sines refinery, and regeneration of catalysts at Oporto refinery.

### 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 xpto).

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 PETROGAL, is presented in Figure 3.38.

Figure 3.38 – Total throughput entered in Lisbon, Oporto and Sines refineries: 1990-2002



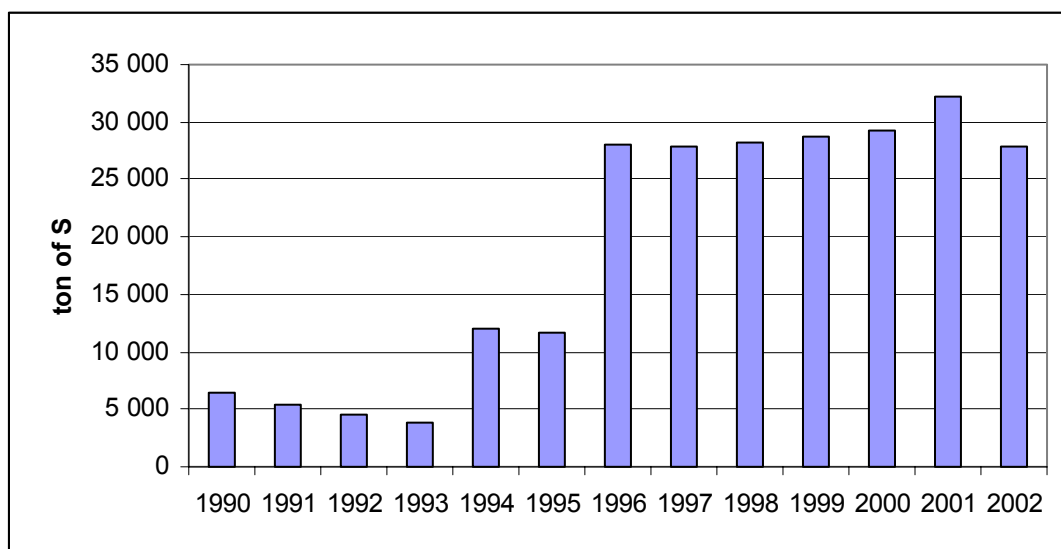
Source: Petrogal

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. Combustion of coke from catalysts in Oporto refinery was only available for 2001-2002, and was assumed constant over the all 1990-2002 period. Total coke burning is confidential data.

Total sulphur recovered in the refineries is available from the balance of petroleum products in annual publications from DGGE, from 1990 to 2001. Production of sulphur has been increasing, particularly after 1996, as could be seen in Figure 3.39, expressing the technology changes set by the auto-oil program. The value for 2002 is a provisional value determined by IA, forecasting activity data for previous years. 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 3.39 – Total sulphur produced in Portuguese refineries recovered in Claus units



## RECALCULATIONS

The improvement of emission estimates resulting from the use of plant specific emission factors for storage and tankering has resulted in substantial reduction of NMVOC emissions from the oil refining process. The emission factor has been reduced an order of magnitude, from 2790 g/ton of crude (USEPA) to 118 to 204 g/ton in present submission. Activity data is now from PETROGAL, the only operator of refineries in Portugal, while previously statistical information was from DGGE. Time series from PETROGAL were preferred because they constitute a complete time series and to achieve consistency for the all period from 1990 to 2002. Nevertheless, because both time series show very small differences, this change has not resulted in appreciable changes in the inventory.

In submission of last year only emissions from regeneration in the FCC unit in Sines were estimated, but using total material feed as activity data, which lead to overestimation of emissions. Improvements in emission estimates from catalyst recovery comprehend also the inclusion of coke burned in platforming and Oporto regeneration processes and the use of emission factors based on monitoring at Sines's FCC unit.

Emissions of sulphur oxides are no longer estimated relying on a mass balance between inputs and outputs, because it was recognized latter that there was a high uncertainty in the establishment of sulphur content in final and intermediate products. Emissions are now estimated only from sulphur production and recovery efficiency of the Claus unit.

## FURTHER IMPROVEMENTS

The efforts that IA has made together with the refineries are expected to continue, in order to ameliorate emission estimates of fugitive emissions, emissions from catalysts regeneration and from sulphur recovery. These estimates should be improved using more detailed methodologies and more detailed information from the refineries.

## DISTRIBUTION OF OIL PRODUCTS

### Overview

This sub-source sector include emissions of volatile organic compounds resulting from distribution of refinery products, mainly gasoline:

(1) Terminal Dispatch Stations in Refineries. Emissions of volatile organic compounds occurring inside refineries during filling of transport equipments - trucks, rail cars - when dispatching products of the refining unit. Most emissions occur when light products with high level of volatile compounds are dispatched;

(2) Transport and Depots, occurring in storage tanks outside the refineries and over the country;

(3) Service Stations, including emissions from tank loading from trucks and when refuelling consumer cars.

Emissions may result from:

- Leakage. Evaporation of liquid products by flaws and seal leakage, pumps and valve systems;
- Displacement emissions, due to displacement of air in tanks by the incoming liquid;
- Breathing emissions in tanks;
- Vapours emitted when filling vehicles in result of displacement of filling air and from splashing and turbulence during filling;
- Unwanted spillage.

### Methodology

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

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

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

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

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

$$\text{Emi}_{\text{CO}_2} = 44 / 12 * 0.85 * \text{Emi}_{\text{NMVOC}}$$

### Emission Factors

Emission Factors for NMVOC, corresponding to those proposed in the simpler methodology of EMEP/CORINAIR (EEA,2002), which result from CONCAWE studies, are reported in next table.

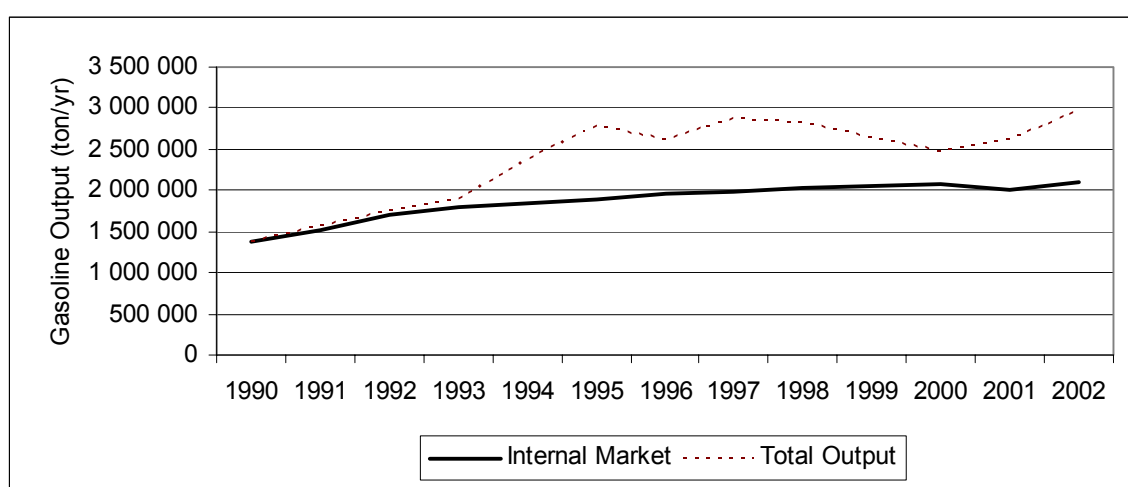
Table 3.106 – Emission Factors

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 2001 is from the annual publications from the General-Directorate of Geology and Energy (DGE). Values for 2002 are preliminary forecasts. Total gasoline output for internal market and exportation is presented in the Figure 3.40.

Figure 3.40 – 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, CH<sub>4</sub> 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);

$EF_{(p)}$  – Emission factor for pollutant p (g/GJ);

$LHV_{GAS(y)}$  – Low Heating Value of flared gas in year y (MJ/kg);

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

SOx emission were calculated according to emission factors based on total feed to refinery (USEPA, 1995), because the sulphur content of flare gas is not known. The following formula was used:

$$Flare_{SOx} = Feed_{InFlow} * den_{FEED} * EF * 10^{-6}$$

where

$Flare_{SOx}$  – total emission of sulphur oxides in flare (ton/yr);

$Feed_{InFlow}$  - is total feed throughput received at all refinery plants for processing (m<sup>3</sup>/yr);

$den_{FEED}$  – Feed density (ton/m<sup>3</sup>);

$EF$  - emission factor (g/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 CO<sub>2</sub> according to:

$$U_{CO2} = EndofPipe_{CO2} + 44/12 * (0.85 * NMVOC + 12/16 * CH_4 + 12/28 * CO) * 10^{-3}$$

### **Emission Factors**

Emission factors for all pollutants except SOx where set from USEPA (1991e). Emission factor for SOx is from (USEPA;1985 in EMEP/CORINAIR 3r ed(EEA,2002)).

Feed density was assumed as of 0.85 kg/L.

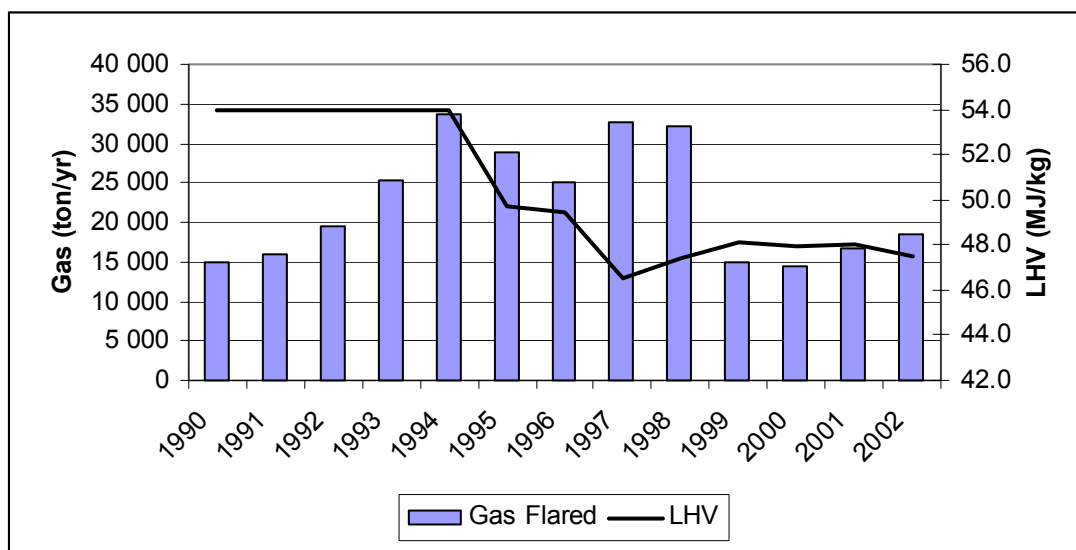
Table 3.107 – Emission Factors for flaring in refineries

Pollutant	EF (g/GJ)
SO <sub>x</sub> (g/m <sup>3</sup> )	65
NO <sub>x</sub>	13
CO <sub>2</sub> (kg/GJ)	60
COVNM	12
CH <sub>4</sub>	15
CO	70

### **Activity data**

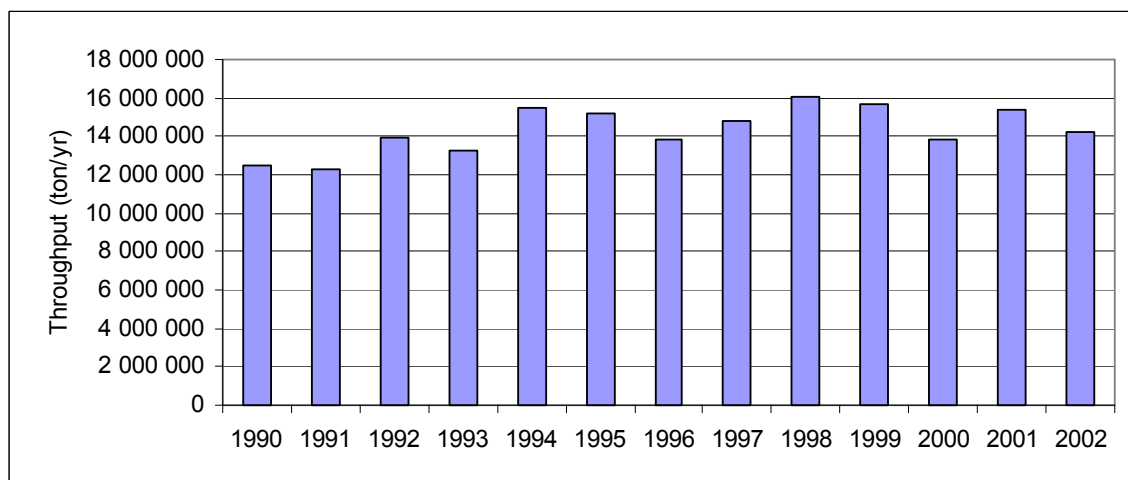
Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL and it is presented in Figure 3.41.

Figure 3.41 – Total consumption of flare gas in Portuguese refineries and Low Heating Value: (1990-2002)



Total throughput (feed) entered in refinery units is available from annual energy publications of (DGGE), and is again presented in Figure 3.42.

Figure 3.42 – Total throughput entered in Lisbon, Oporto and Sines refineries (1990-2002)



### Recalculations

The estimation of emissions from flaring in refineries using the quantity of gas that is burnt in this system represents an improvement from previous submission, when emissions were estimated based on total feed throughput into refineries for all pollutants.

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

#### Overview

The use of natural gas in Portugal was initiated only in 1997 (DGGE) when 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. There is however no production of natural gas in Portugal. All the gas is imported and received though shipping



transport from Algeria 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.

Methane emissions from natural gas result mostly from leaks of unmodified natural gas. Although they 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

Presently emissions of methane from natural gas transport and distribution are estimated from production data using a tier1 approach based on total energy consumed in the country. Emissions are associated to each specific consumer of natural gas:

$$\text{Emission}_{\text{CH}_4 (S)} (\text{ton/yr}) = \text{NG}_{\text{Cons}(S)} * \text{EF} * 10^{-6}$$

where

$\text{NG}_{\text{Cons}(S)}$  - Total quantity of natural gas consumed in a year in economic activity S (GJ);

EF - Emission factor (g/GJ).

## EMISSION FACTORS

The value of 100 g CH<sub>4</sub>/GJ was used in emission estimates for all natural gas consumption in Portugal in all economic sectors. This value was set temporarily from available information from USEPA and from information displayed in IPCC96 (Seixas et al,2000). Actual emission factor does not result from a specific source but reflects the order of dimension of available emission factors, being aware that national inventory only considers transport and distribution. Because no default IPCC emission factors are available and because GPG (IPCC,2000) proposes emission factors based on line length (km) and not gas consumed, and that information was not available for the time being the same emission factor was used.

Table 3.108 – Net Calorific Value and Emission Factor for fugitive emissions from natural gas

Fuel	NCV MJ/Kg	EF CH <sub>4</sub> g/GJ
Natural gas	42.97	100

## ACTIVITY DATA

Emissions were estimated for total natural gas consumed, but specific emissions were attributed for each end-user activity consuming this fuel. Natural gas consumed for each activity is presented in next figure.

Table 3.109 – Natural gas consumption per sector (GJ) 1990-2002

Sectors	1990-96	1997	1998	1999	2000	2001	2002
Energy	0	998	15 137	71 282	40 063	45 270	55 913
Refineries	0	0	0	0	0	0	0
Industry #	0	2 043	10 524	21 961	35 885	46 684	53 286
Services/Commercial	0	16	563	1 592	2 611	3 801	4 946
Domestic	0	35	400	1 505	3 188	4 921	6 157
Agriculture	0	0	0	0	5	201	246
Fisheries	0	0	0	0	0	0	0
Construction and public works	0	0	1	26	55	293	584
TOTAL	0	3 091	26 626	96 365	81 806	101 170	121 133

# excluding building and construction

## RECALCULATIONS

Emissions of methane suffered slight modifications, due to:

- correction of Net Calorific Value, using data from gas importer (TRANSGÁS);
- it was realized that in the energy balances from DGE energy consumption of Natural Gas was expressed in Gross Heating Value and not Net Calorific Value.

## 3.3 Recalculations

Changes in sectoral overall GHG emissions, expressed in CO<sub>2</sub> equivalent, since last submission were not very significant in the energy sector, as may be seen in Figure 3.43, both in what concerns base year (1990) and year 2001. Nevertheless, from Table 3.110, it may be verified that substantial changes have affected emissions of methane, N<sub>2</sub>O and also CO<sub>2</sub> for specific sectors. The more expressive changes are related to:

- Emissions of carbon dioxide from manufacturing industries and construction;
- Methane emissions from energy consumption in manufacturing industries and construction and from transportation;
- Nitrous oxide emissions from road transportation.

Changes in year 2001 are partly explained by the actualization of activity data for that year. Emission estimates for 2001 in submission 2003 were provisional values.

Fugitive emissions from fuels show also substantial changes in base year and 2001, but they have a lesser importance in the modification of total national GHG emissions.

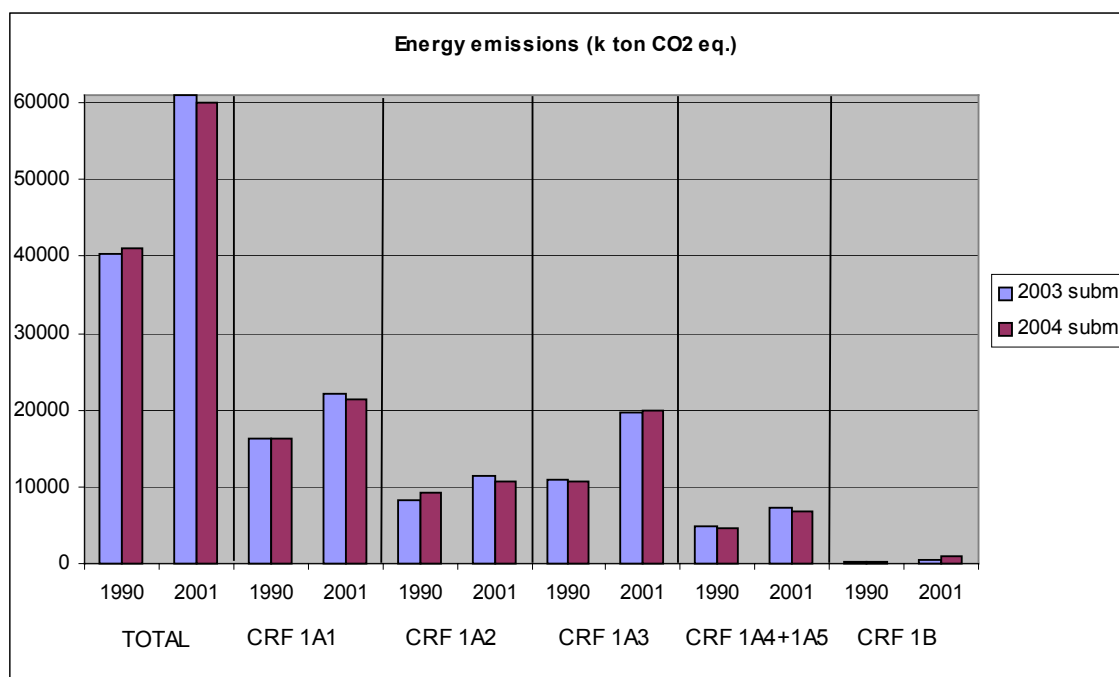
Figure 3.43 – Differences between 2003 and 2004 submissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O)

Table 3.110 – Recalculations (differences between 2003 to 2004 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
			2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)
			CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)
<b>1990</b>											
1.	Energy		39,434.02	39,994.37	1.42	527.91	583.16	10.47	500.25	515.07	2.96
1.A.	Fuel Combustion Activities		39,270.72	39,868.20	1.52	423.74	481.95	13.74	500.25	515.07	2.96
1.A.1.	Energy Industries		16,198.64	16,186.80	-0.07	4.31	4.34	0.69	61.05	61.04	-0.01
1.A.2.	Manufacturing Industries and Construction		8,165.99	9,157.66	12.14	33.47	70.75	111.39	64.84	67.13	3.53
1.A.3.	Transport		10,700.81	10,460.20	-2.25	37.21	58.42	56.97	136.78	149.97	9.64
1.A.4.	Other Sectors		4,196.98	4,055.25	-3.38	348.60	348.30	-0.09	237.56	236.92	-0.27
1.A.5.	Other		8.29	8.29	0.00	0.15	0.15	0.00	0.02	0.02	0.00
1.B.	Fugitive Emissions from Fuels		163.30	126.17	-22.74	104.18	101.21	-2.85	0.00	0.00	0.00
1.B.1.	Solid fuel		8.65	8.65	0.00	66.02	66.02	0.00	0.00	0.00	0.00
1.B.2.	Oil and Natural Gas		154.65	117.53	-24.01	38.16	35.19	-7.77	0.00	0.00	0.00
<b>2001</b>											
1.	Energy		59,338.30	58,275.26	-1.79	603.47	762.40	26.34	992.36	909.03	-8.40
1.A.	Fuel Combustion Activities		58,991.25	57,598.91	-2.36	404.94	508.15	25.49	992.36	909.03	-8.40
1.A.1.	Energy Industries		21,952.95	21,402.78	-2.51	5.84	5.52	-5.49	96.54	95.44	-1.14
1.A.2.	Manufacturing Industries and Construction		11,324.17	10,561.88	-6.73	41.77	126.34	202.50	88.15	90.24	2.37
1.A.3.	Transport		19,076.81	19,380.78	1.59	52.36	67.54	28.98	566.70	534.29	-5.72
1.A.4.	Other Sectors		6,637.32	6,253.47	-5.78	304.97	308.75	1.24	240.97	189.05	-21.55
1.A.5.	Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.	Fugitive Emissions from Fuels		347.05	676.35	94.89	198.53	254.25	28.07	0.00	0.00	0.00
1.B.1.	Solid fuel		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.2.	Oil and Natural Gas		347.05	676.35	94.89	198.53	254.25	28.07	0.00	0.00	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).

### 3.3.A Cross-cutting issues

Apart from update of the time series, with the use of the final energy balance for 2001 and provisional balance for year 2002, both from DGGE, the major changes that were done across all sub-source sectors comprehend:

- The sulphur content of fuels was revised, for the all time series, in order to improve consistency between sub-source sectors. Hence, presently similar fuels have the same sulphur content in all activities, except when there is a legal constraints that determine a different situation: sulphur content in gas oil used in road transport and in boilers have now different legal standards;
- Errors in reporting of SO<sub>x</sub> emissions, detected in submission 2003, were corrected;
- Revision of the LHV/NCV for sub-bituminous coal – except in LPS plants, where plant specific information is available - from 17 MJ/kg to 20 MJ/kg;
- according to DGGE, in the energy balance natural gas is the unique fuel that is reported using High Heating Value instead of Low Heating Value. In submission 2003 this caused error determinations in activity data when original data in the energy balance, in toe units, was converted to ton of gas. In submission 2004 this situation was corrected: values in energy balance are converted into tons using the conversion factor from DGGE (HHV); conversion of natural gas consumption in energy units is thereafter made using the LHV from TRANSGAS, the sole natural gas supplier in Portugal;

### 3.3.B Manufacturing Industries and Construction

Major changes in emission estimates for this source sector are related with:

- Consumption of coke from petroleum coke and recovered tires were added to fuel consumption in the cement industry. Combustion of these fuels was not accounted in submission 2003, leading to under-estimation of emissions;
- Consumption of fuel gas as energy source in furnaces in the organic chemical industry were updated from information collected from major industrial plants. Repartition of fuel use as feedstock or energy source was revised, according to recommendations from DGGE;
- Fuel consumption in paper pulp units was revised, particularly for acide-sulphide plants, using data from the co-generation plants from DGGE;
- Consumption of coke gas and blast furnace gas in iron and steel activity was revised, for year 1990 and 1995-2002, using data from DGGE's energy balance and coquerie balance;
- Consumption of fuels in the energy balance reported as category "metallurgy" was included, in submission 2003, under combustion in non-ferrous metal industry (category 1A2b). Because, in fact, this sector in the energy balance includes fuel use in both ferrous and non-ferrous metal industry, emissions were moved to category 1A2f. This modification did not cause modification in total emissions from sector;
- revision of the equipment (boilers or engines) where diesel oil and gasoline are consumed, with affects substantially the choice of emission factors, specially for NO<sub>x</sub>, NMVOC and CO. The share of each equipment type was revised in a consistent mode for all energy activities;
- The use of the production approach as methodology to estimate combustion emissions was extended to the following industrial activities: ceramic, cement and glass;
- Time series for paper pulp production, production of iron and steel and clinker production were revised after data collected from individual industrial plants, CELPA and DGGE. These changes implied changes in emission estimates for those pollutants where the production approach was used;

- monitoring data registered at individual cement units (EPER) was used to establish plant-specific emission factors (production approach) for this sector.

### 3.3.C Other Energy Industries

Consumption of coke gas in coquerie, the activity rate used to estimate emissions for category 1A1c, was set in previous submission from the consumption of coke gas in the associated thermal power plant (LCP directive). In present submission data on total consumption of coke gas from DGGE's energy balances was used.

The CO<sub>2</sub> emission factors for coke gas was revised downward, from 96.3 kg/GJ to 41 kg/GJ, following recommendations from the centralized review of the Portuguese Inventory 2003, and after revision<sup>48</sup> of calculations of the country-specific emission factor.

Estimates of combustion emissions for the production of city gas and for the extraction of coal are included in the inventory for the first time.

### 3.3.D Road Transport

The methodology for estimation of emissions from road transportation has suffered extensive improvements. The actions that were foreseen as "Further Improvements" in submission 2003 have been almost completely incorporated in the National Inventory, namely:

- Use of detailed fleet composition, estimated from vehicle sales;
- Inclusion of vehicle age classes and determination of age specific emission factors considering evolution of technology and air emission standards;
- Desegregation of emission estimate by detailed vehicle category, including division of Heavy Vehicles in Heavy Duty Vehicles and Buses and Coaches;
- Knowledge of motor volume classes for light vehicles and weight for heavy duty vehicles;
- Revision of the repartition of urban and rural emissions, and better inclusion of highway traffic countings in the calculation of highway emissions.

In fact, the methodology that is now used to estimate road traffic emission, has been totally reviewed from the one that was used in submission 2003.

Emissions from fuel combustion of kerosene, fuel oil and natural gas in the road transportation sector - according to information in the energy balances - are now included as independent emission source. Emissions from the use of this fuel were not accounted in emission inventories in submission 2003.

### 3.3.E Aviation

Also for this sector the objectives of "Further Improvements" in submission 2003 have been fulfilled and extensively improved, and now total bunker emissions are separated from origin-destiny and not by flag or air carrier, as was done in submission 2003. Main changes comprehend:

---

<sup>48</sup> The same composition of gas delivered by the industrial plant was used, but the density that is now used is more consistent with the gas consumed at this particular unit

- Annual LTO movements (1990-1999), desegregated per aircraft type for each major airport, are used now as activity data to estimate emissions during LTO. In previous submission desegregation per aircraft type was only available from 3 major airports (Lisbon, Oporto and Faro) for 1990;
- Data on the movements and passenger-kilometers per origin-destination (OD) permitted the separation of domestic from international emissions in a mode more in accordance to the criteria from IPCC GP (IPCC,2000);
- There is a small quantity of JP attributed to services in the DGGE's energy balance, which corresponds to consumption in military aviation. This fraction was not accounted in the inventory in submission 2003;

### 3.3.F Other Sectors

The following modifications were made:

- Correction of the activity data time series reported in submission for combustion in services, institutional and commerce, for natural gas, biogas and city gas;
- Revision of the activity data for biogas combustion in agriculture sector. In present submission information is solely from energy balances, in order to avoid double counting.

## 3.4 Further Improvements

Because the energy sector is the most prevalent emission source, special efforts must always be made to improve emission estimates. 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, the following preliminary routes may be here identified.

- Better integration between activity data in the Air Inventory and other surveys such as LCP directive, Auto-controlo program, EPER and surveys made annually by DGGE. Contacts are being made to implement it;
- Determination of country-specific emission factors (SO<sub>x</sub>, NO<sub>x</sub> and PM) from monitoring data collected from the *Autocontrolo* program and CO<sub>2</sub> emission factors for information collected under carbon market;

Some particular issues still need a more detailed improvement in the road transportation sector:

- review of average velocities per driving mode;
- 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 emission year;
- incorporation of factors in emission factors calculation such as vehicle aging and maintenance;

- incorporation of regional and local emission estimates.

Water-borne navigation emissions are not disaggregated in adequate categories to answer UNFCCC and LRTAP conventions, and efforts need to be made to separate emissions realized in the EMEP area from international sea traffic for domestic and international flag ships and to separate emissions from international transportation.

Although it is considered that the changes made in the aviation sector have improved the inventory substantially, additional efforts must be done to pursue the following objectives: Emission factors from LTO movements could be improved using actual database records of airport movements, using specific durations for idle, taxi, take-off, for the individual airports considered and being aware of airplane age. An effort is necessary to differentiate between emissions of large commercial flights and local emissions resulting from small airplanes, private jets and helicopters.

## CHAPTER: 4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

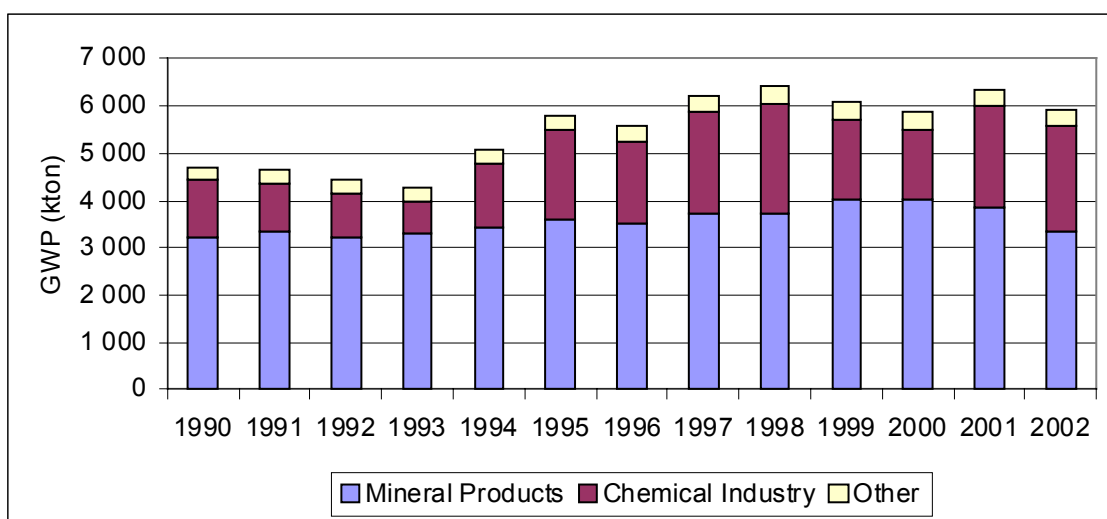
### 4.1 Overview

In industrial transformation processes, where raw materials are chemically or physically transformed, many different GHG can be released, such as CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. Fluorinated compounds (HFC, PFC and SF<sub>6</sub>), on the other hand, are consumed in industrial processes or used in different applications as substitutes to ozone depleting substances (ODS). They have also been considered in the inventory under this sector although some, in fact, occur associated with domestic and services activity.

Industrial processes, either involving combustion or not, result also in the release of other atmospheric pollutants, including acidifying gases and indirect GHG, such as NO<sub>x</sub>, NMVOC and SO<sub>x</sub>. They are relevant sources of particulate matter (PM, PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub>) and local air pollutants as CO and Heavy Metals.

In terms of GHG, emissions from industrial production sector have increased in the period 1990-2002, from about 4.7 Gton in 1990 to 5.9 Gton in 2002, as may be seen from Figure 4.1, particularly after 1993. The biggest emission value occurred in 1998, when 6.4 Gton were emitted. Emissions in 2002 for the overall source sector are about 26% higher than in the base year 1990. The majority of emissions, expressed in CO<sub>2</sub> equivalent (GWP), are associated with mineral industry, varying between 57% and 77% of total emissions from the sector. In second place of importance are the emissions from the chemical industry

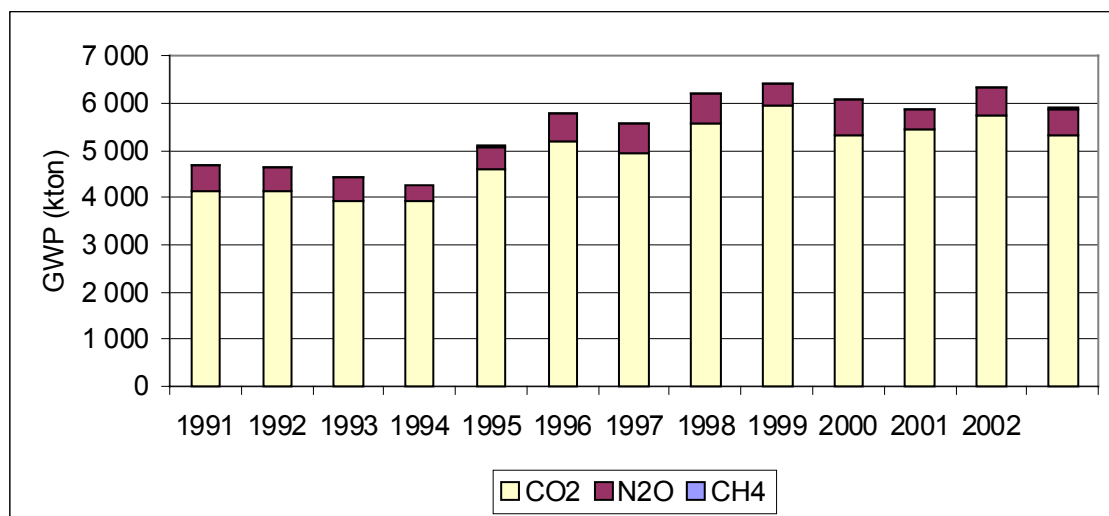
Figure 4.1 – Total GHG emissions from Industrial Processes per source sub-sector (1990-2002)



GHG emissions from industrial production varied between 6.5 and 8.8 % of total national emissions in the period from 1990 to 2002. Great part of green-house gas emissions are realized directly as CO<sub>2</sub>; N<sub>2</sub>O represents a smaller proportion of emissions and methane emissions are a non relevant part, as may be seen in Figure 4.2



Figure 4.2 - GHG emissions from Industrial Processes per green-house gas



Falar das emissões de acifantes

## 4.2 Category Sources

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

#### 4.2.A.1 CEMENT PRODUCTION

##### OVERVIEW

During the 1990-2002 period there were six cement production plants operating in Portugal, almost all installed in the southern half of the country and mostly dedicated to Portland cement production<sup>49</sup>. There were also smaller additional cement plants in Portugal but that do not produce clinker. Five of the clinker producing units are based on the dry process while the remaining one uses both the dry and the semi-wet process - although the dry process is prevalent. All dry process units have short kilns with pre-heaters, and 5 kilns in four units are provided with pre-calciners<sup>50</sup>. Main characteristics of the six plants are presented in table 4.1, from where it is evident that production of clinker and CO<sub>2</sub> decarbonising emissions are dominated by three plant units.

Table 4.1 - Main Characteristics of Cement Production Plants in Portugal

Unit	Nut III	Average % of total Clinker Production
Souzelas	RC122	25.8
Maceira	RC123	12.3
Pataias	RC123	4.6
Alhamdra	RC132	25.3
Outão	RC133	24.2
Loulé	RC150	7.7

<sup>49</sup> There is also some production of white Portland cement, which is characterized by a lower iron and manganese constant, than grey cement, and it is used mainly for decorative purposes (EPA,1995)

<sup>50</sup> One calciner is a false pre-calciner.

Portland cement is broadly a mixture of clinker and gypsum with some minor additives. Cement production is basically 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  $\text{CaCO}_3$  and  $\text{MgCO}_3$ , the main constituents of limestone, to lime ( $\text{CaO}$ ) and  $\text{MgO}$ , while leaving  $\text{CO}_2$  as by product to atmosphere (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  $\text{CO}_2$ , usually most of the  $\text{SO}_x$  that is formed during calcination will be absorbed and long term immobilized in clinker and then in cement.

Only emissions of  $\text{CO}_2$  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.  $\text{CO}_2$  emissions from liberation of carbon in fuel during combustion are reported also in Energy sector 1A2. However, although emissions are estimated separately from carbon originally present in fuel and carbon present in raw materials, they are in fact emitted at same place and are inseparable in concept.

## METHODOLOGY

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to equation 3.1 of GPG (IPCC,2000), 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  $\text{CO}_2$  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 to 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

According to GPG (equation 3.3 in IPCC,2000), the emission factor for  $\text{CO}_2$  is:

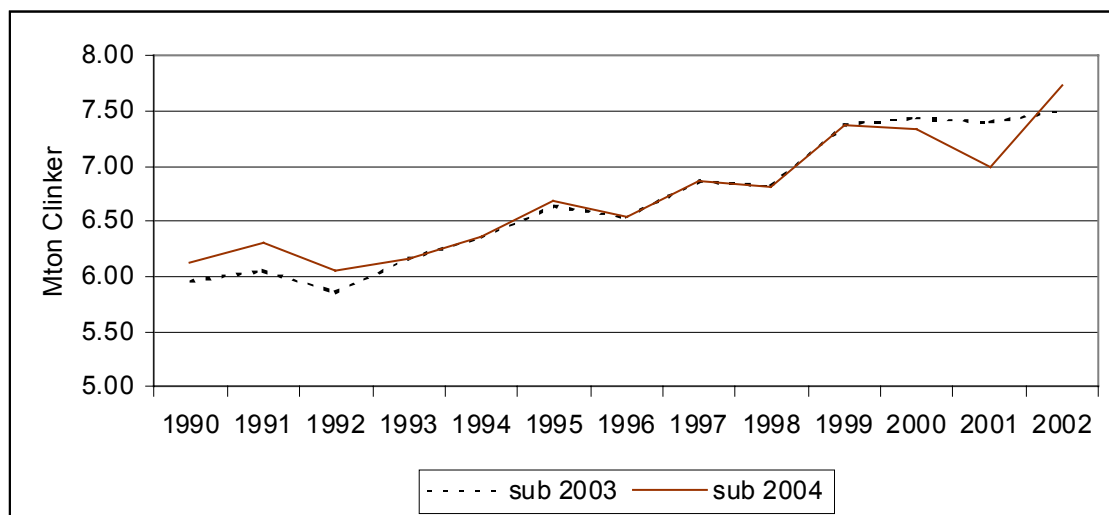
$$\text{EF}_{\text{Clinker}} = 0.785 * \text{Ratio}_{\text{CaO}}$$

where  $\text{Ratio}_{\text{CaO}}$  is the Calcium oxide (lime) content of clinker (kg  $\text{CaO}$ / kg clinker). The default IPCC  $\text{CaO}$  fraction in clinker was considered in the inventory (64.5%). Final emission factor is therefore 0.507 ton  $\text{CO}_2$ / ton clinker.

## ACTIVITY DATA

Clinker production, for all the years from 1990 to 2002, was collected directly for each industrial plant<sup>51</sup>. Production of cement, although not used in emission estimates, is available from the National Statistical Institute INE from 1990 to 2000. Evolution of clinker production may be observed in next figure.

Figure 4.3 – Total Production of clinker (sub 2004) and comparison to time series reported in submission 2003 (sub 2003)



There is no need to consider a CKD correction to clinker production, because in all production lines in portuguese cement plants, dust is returned back to the process and incorporated in final product.

## RECALCULATIONS

The only modification for this sector, since last submission, consists in changes in the origin of activity data. In previous submission total clinker production was collected from National Industry Statistics from INE for 1990-2000<sup>52</sup>. Now, production is available at each plant level for the all period from 1990 to 2002. Changes between these two data sources are very small (maximum of 6% until 2001) but affect overall trend. The former and present time series are presented in Figure 4.3 above. The use of the same data origin for all the time series has improved consistency in the inventory.

In previous NIR, emission factors for SO<sub>x</sub> and NH<sub>3</sub> were discussed in this chapter although emissions were included in source category Energy (1A2). Presentation of emission factors was now moved to chapter 3.2.A.4 - Energy in Manufacturing industries and construction. This modification did not affected inventory totals.

## FURTHER IMPROVEMENTS

According 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:

<sup>51</sup> For one plant the clinker production in 2002 was not available and it was forecasted at IA from the available time series. The value for 2002 should be assumed as provisional.

<sup>52</sup> National Industry Statistics suffered a change in methodology and survey procedures in 1992, from IAIT to IAPI.

$$EF_{\text{Clinker}} = 0.785 * \text{Ratio}_{\text{CaO}} + 1.092 * \text{Ratio}_{\text{MgO}}$$

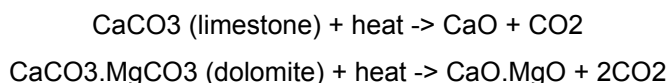
The emission factors would therefore change from 0.507 ton CO<sub>2</sub>/ton clinker to 0.525 ton CO<sub>2</sub>/ton clinker, resulting in an increase of emissions of 3.55 %<sup>53</sup>.

The data that was collected directly from each unit plant did comprehend also the consumption of raw materials. Enough information from this sources could still not be used to derive country-specific CaO contents: CaO fractions are not available for all industrial plants and some raw materials, such as carbonate shales, have a very large range of possible carbonate content. Efforts will be done in order to improve the knowledge of carbon content, or CaO and MgO content, for all plants with the possible outcome of a country-specific emission factor.

#### 4.2.A.2 LIME PRODUCTION<sup>54</sup>

##### OVERVIEW

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200°C) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving calcium oxide (CaO) or magnesium oxide (MgO) as valuable products. The following chemical conversion equation applies, where for each mol of oxide a mol of carbon dioxide is emitted.



Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy CaCO<sub>3</sub> content (at least 50%) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of Na<sub>2</sub>CO<sub>3</sub>, NaOH, steel, refractory material, SO<sub>2</sub> absorption, CaC<sub>2</sub>, glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;
- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45% in content). Dolomite quicklime is a mixture of CaO and MgO;
- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime: Ca(OH)<sub>2</sub> It is produced from CaO and water. When an equivalent quantity of water is used is called slaked lime, when an excess water is used is milk of lime and a clear solution of Ca(OH)<sub>2</sub> in water is limewater. It is used as an industrial alkali and in the preparation of mortar (slaked lime plus sand) which sets to solid by reversion of the hydroxide to CaCO<sub>3</sub> (Sharp, 1981);
- Hydraulic Lime. A mixture of calcium oxide (CaO) and silicates, it is an intermediate product between lime and cement.

<sup>53</sup> Assuming CaO fraction in clinker of 64.5% and MgO 2%, the default value set by GHP Protocol (WBCSD/WRI).

<sup>54</sup> Due to problems in data collection – links in original excel files – emissions from lime production were not reported in CRF tables and were not included in key source analysis. Nevertheless it was opted to include a specific paragraph for this source sector already in NIR 2004

Besides the production of lime to furnish market requirements, lime is also produced and consumed inside industrial sectors, such as paper pulp production or iron and steel production. Emissions of CO<sub>2</sub> from lime production in paper pulp industry are reported in Limestone and Dolomite use (1A3), because it is difficult to separate what part of carbonate/limestone material is used as lime production or as an additive. In the case of iron and steel production, CO<sub>2</sub> emissions are estimated using sector specific activity data and emission factors, and hence for this sub-category, methodologies, activity data and emission factors are discussed and reported in Energy (1A2).

## 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:

$$Emi_{CO_2} = (Prd_{Lime} * EF_{Lime} + Prd_{Slaked} * EF_{Slaked} + Prd_{HLime} * EF_{HLime}) * 10^{-3}$$

Where,

$Emi_{CO_2}$  – CO<sub>2</sub> 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);

$Prd_{Slaked}$  – production of slaked lime as final product (ton/yr);

$Prd_{HLime}$  – Annual production of hydraulic lime (ton/yr);

$EF_{Lime}$ ,  $EF_{Slaked}$ ,  $EF_{HLime}$  – emission factors applied respectively to lime, slaked lime and hydraulic lime (ton CO<sub>2</sub>/ton lime).

## EMISSION FACTORS

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:

$$EF = [(1 - Dol_{Lime}) * SR_{CaO} * Content_{CaO} + Dol_{Lime} * SR_{CaO.MgO} * Content_{CaO.MgO}] * (1 - Content_{H_2O})$$

Where,

$Dol_{Lime}$  – Ratio of total lime produced that is Dolomite Lime (kg/kg);

$SR_{CaO}$  – stoichiometric ratio between CaO and CO<sub>2</sub> during production of pure high calcium quicklime (kg/kg);

$SR_{CaO.MgO}$  - stoichiometric ratio between CaO.MgO (50:50) and CO<sub>2</sub> during production of pure Dolomite lime (kg/kg);

$Content_{CaO}$  – Content of CaO in high calcium lime as in final product (kg/kg)<sup>55</sup>;

<sup>55</sup> This 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.

Content<sub>CaO.MgO</sub> - Content of CaO.MgO in Dolomite lime as final product (kg/kg);

Content<sub>H<sub>2</sub>O</sub> - 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<sub>Lime</sub> 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 4.2 – Parameters used to derive the Emission Factors for Lime Production

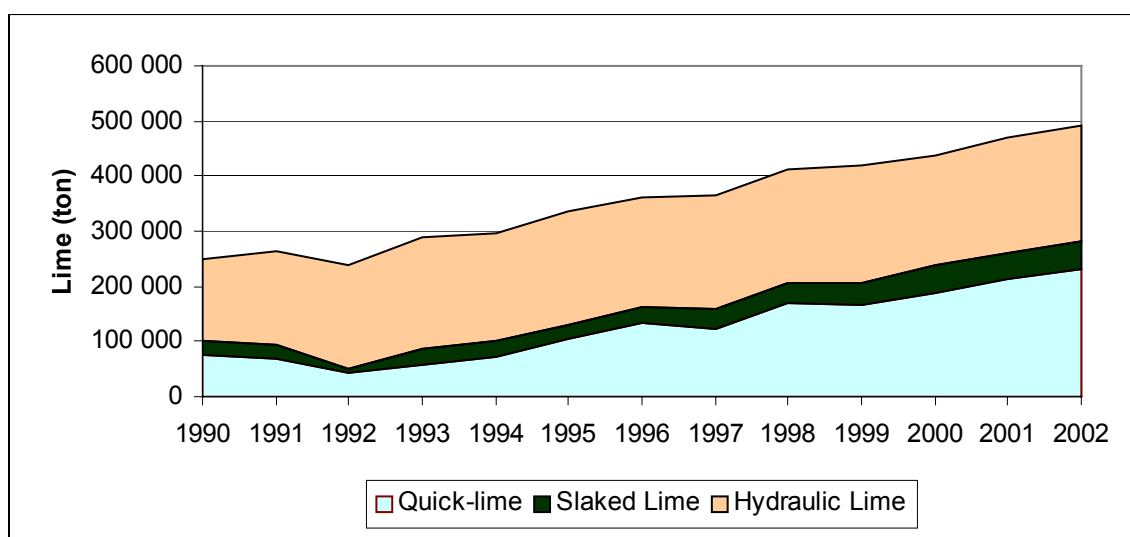
Lime	Dol <sub>Lime</sub> (%)	Content <sub>CaO</sub>	Content <sub>CaO.MgO</sub>	Content <sub>H<sub>2</sub>O</sub> (%)	Emission Factor (kgCO <sub>2</sub> /kg lime)
QuickLime	15	0.95	0.95	0	0.76
Slaked Lime	15	0.95	0.95	27	0.56
Hydraulic Lime	0	0.75	0	-	0.59

Stoichiometric ratios are 0.785 kg CO<sub>2</sub>/kg CaO for high calcium lime (SR<sub>CaO</sub>) and 0.913 kg CO<sub>2</sub>/kg CaO.MgO for Dolomite Lime (SR<sub>CaO.MgO</sub>).

#### ACTIVITY DATA

Production of lime products 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. No distinction could be made between high calcium lime and dolomite lime. Production values for 2001-2002 are simple linear forecasts from the available statistical time series. The considered Lime production per lime type is presented in Figure 4.4, from where it is evident the pattern of production increase, particularly quick-lime, and the minor importance of hydrated lime production.

Figure 4.4 – Production of lime in Portugal per lime type (1990-2002)



## RECALCULATIONS

During the elaboration of submission 2003 activity data on lime production was yet not available from INE statistical database and emissions from this source category included only those emissions resulting from production of lime in paper pulp production and iron and steel production. However, during the process of collection of data for PNALE - the National Plan for Allocation of Emission Trading - 6 units dedicated to the production of lime were detected and their emissions quantified for the first time. More adequate data was hence collected from INE Statistical database and first estimate of emissions for this source category are now available.

Due to a processing error emission estimates for this source category were not, however, incorporated in CRF tables for submission 2004. This situation will be corrected in submission for next year, increasing total emissions consequently.

## FURTHER IMPROVEMENTS

Although only lime produced for sale was quantified there is still the possibility of double count CO<sub>2</sub> emissions from quick-lime production again in slacked lime or hydraulic lime if these last products are produced in a different industrial plant. To correct that effect, emissions estimated from lime production should be cross checked with emission estimates from limestone and dolomite consumption.

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 - allowing this differentiation to be used in activity data and not in emission factor as it was done in this submission.

Part of CO<sub>2</sub> emissions from lime production are reported as energy (1A2) under iron and steel production. Efforts will be made in order that these emissions should be moved to Lime Production source in next submissions.

### 4.2.A.3 LIMESTONE, DOLOMITE AND CARBONATE USE

#### OVERVIEW

Carbon dioxide is liberated to atmosphere in several industrial activities that use limestone (CaCO<sub>3</sub>), dolomite rock (CaCO<sub>3</sub>.MgCO<sub>3</sub>) or other carbonates, but only when original materials are not incorporated as inert components but suffer a chemical removal of carbon, as for example when calcium carbonate is added to nitric acid to form calcium nitrate.

Lime production involves also the consumption and decarbonising of carbonate materials. Emissions from this process when lime is produced to be sold in market were already discussed in chapter 4.2.A.2. However, lime is also produced inside some industrial processes. 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.

Presently only emissions from consumption of carbonates in paper pulp production are discussed here. Use of carbonate in glass industry is covered in sector activity xpto. Use of carbonates in iron and steel industry as flux in blast furnace result in emissions that are included in Energy (A2), because it was assumed that the emission factor of CO<sub>2</sub> from blast furnace consumption<sup>56</sup> already includes carbon in carbon dioxide liberated from flux in the blast furnace. A small emission component of electrode use in machine building industry is also included here.

---

<sup>56</sup> Determined from composition of Blast Furnace Gas given by industry.

Consumption of carbonate materials is reported in National Statistics (INE) for other industrial activities, but it was assumed that they do not correspond to uses where carbon is liberated: ceramic, 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.

## METHODOLOGY

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

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

where

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

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

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

## EMISSION FACTORS

Carbon content of materials consumed in Portugal was set from molecular stoichiometry<sup>57</sup>:

Table 4.3 - Carbon content of carbonate materials

Material	Ccontent
Sodium Carbonate	0.42
Limestone*	0.44
Magnesium Carbonate	0.52
Coal (Electrodes)	3.67

\* assumed pure calcium carbonate

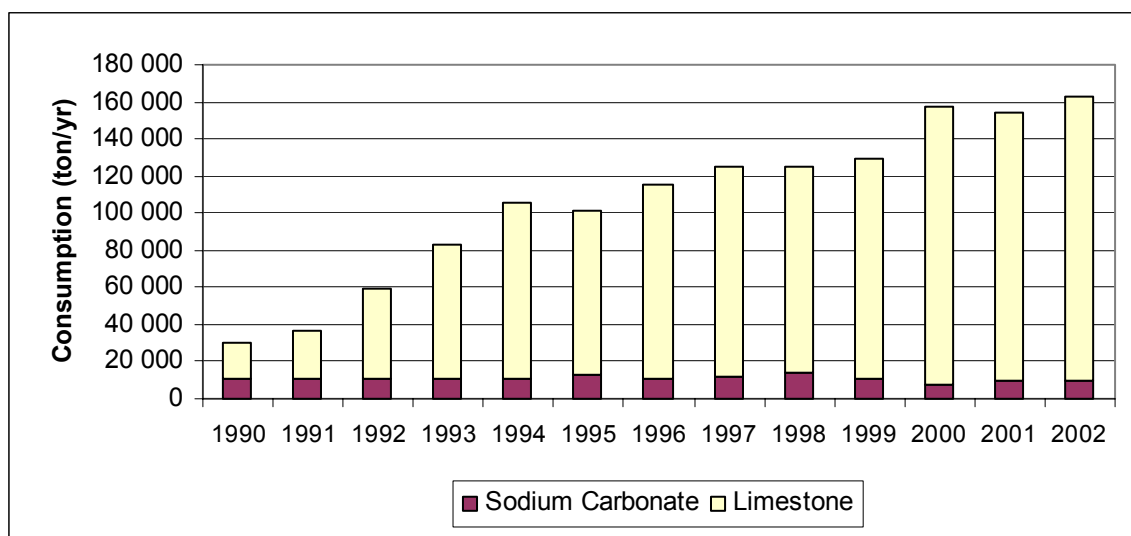
## ACTIVITY DATA

Consumption of mineral carbonaceous materials that may result in CO<sub>2</sub> emissions, except in glass and iron and steel industry, were set from statistical information from INE from 1990 to 2000 and thereafter forecasted. Annual consumption for limestone and sodium carbonate use in paper and pulp industry is presented in Figure 4.5 below.

<sup>57</sup> It was assumed that limestone was totally pure, which causes over-estimated emissions.



Figure 4.5 - Consumption of carbonate materials in industry (1990-2002)\*



\* Consumption of Magnesium Carbonate in paper pulp industry started in 1998 with 740 ton, raised to 823 ton in 2000 and was forecasted as 1164 ton in 2002. Use of coal electrodes lasted only from 1996 to 1998 and the quantities consumed are very small, from 27 ton to 68 ton.

## RECALCULATIONS

Changes in emission estimates for this source sector were made in both activity data and emission factors, while methodology is the same since last submission.

Activity data was updated. While in previous submission the quantity of carbonates that were used was constant since 1992 - and they were average values in 1990 and 1991 - now, in submission 2004, time series of carbonate consumption is updated until 2000 from INE statistical database.

An error in emission factors<sup>58</sup> was detected in previous submission for limestone. This error, which was detected during review by secretariat, was corrected from 0.31 kg CO<sub>2</sub>/kg limestone to the stoichiometric value of 0.42 kg CO<sub>2</sub>/kg limestone.

## FURTHER IMPROVEMENTS

It is foreseen that in next submissions emissions from limestone use in paper pulp plants will be moved to Emissions from Lime Production (xpto) and discussed in chapter 4.2.A.2. Only emissions from the use of sodium carbonate will remain reported in this su-source activity.

Presently included in this source sector are the emissions of consumption of carbon electrodes in mechanical industry. Although this corresponds to a very small quantity a more adequate place should be found for these emissions of carbon dioxide.

Due to the lack of appropriated statistical information emissions from carbonate use in the production of synthetic fertilizers (nitrates of calcium and magnesium and ammonium nitrate with calcium and magnesium) are not quantified, although they may involve consumption of carbonate rocks and liberation of carbon dioxide to atmosphere. More efforts to obtain necessary statistical information or alternative methodologies will be envisaged to estimate emissions from that activity and include them in this source category.

<sup>58</sup> This emission factors are in fact only a mass balance of carbon in carbonates. Nevertheless there was an error in this mass balance.

Detailed calculation and check must be done in what concerns emissions from the use of carbonate as flux in the iron and steel industry (blast furnace), that is presently assumed to be already quantified as CO<sub>2</sub> emissions from combustion of blast furnace gas, but other leaks may nevertheless exist. Although blast furnace was decommissioned after 2002, efforts will be made to estimate emissions for this source using consumption of limestone.

Finally care must be made to avoid double counting of emissions that may be already included in other industrial sectors.

#### 4.2.A.4 ROAD PAVING WITH ASPHALT

##### OVERVIEW

Emission estimates for this source category include emissions occurring from road paving 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 as hotmix or 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°)<sup>59</sup>. 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 emulsifiers<sup>60</sup>. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphtha (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing of 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 height and low vapour pressure (USEPA,2001c – 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 PST 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

---

<sup>59</sup> That are needed to fluidize the asphalt cement.

<sup>60</sup> And also a solvent in several emulsion types.

(A2)<sup>61</sup>. 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 activity<sup>62</sup>.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible<sup>63</sup>.

It was still not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation or asphalt roofing, and therefore all emissions from production of asphalts – except emissions from fuel combustion – are included in this source category.

## 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, 1979; 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).

<sup>61</sup> To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

<sup>62</sup> It is not possible to distinguish fuel combustion in hot mix production activity.

<sup>63</sup> Some emissions do occur in fact during mixing and stockpiling operations. However, because the methodology is based on mass balance, these emissions are in fact quantified under application of asphalt.

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:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

### **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 (EEA,2002) or industrial expert guess.

Table 4.4 - Emission Parameters for road paving with asphalt

Parameter	Cutback	Emulsions
$SLV_{Fac}$	25 %	3 %
$d_{SLV}$	0.85 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 4.5 - Emission Parameters for Hot Mix asphalt production

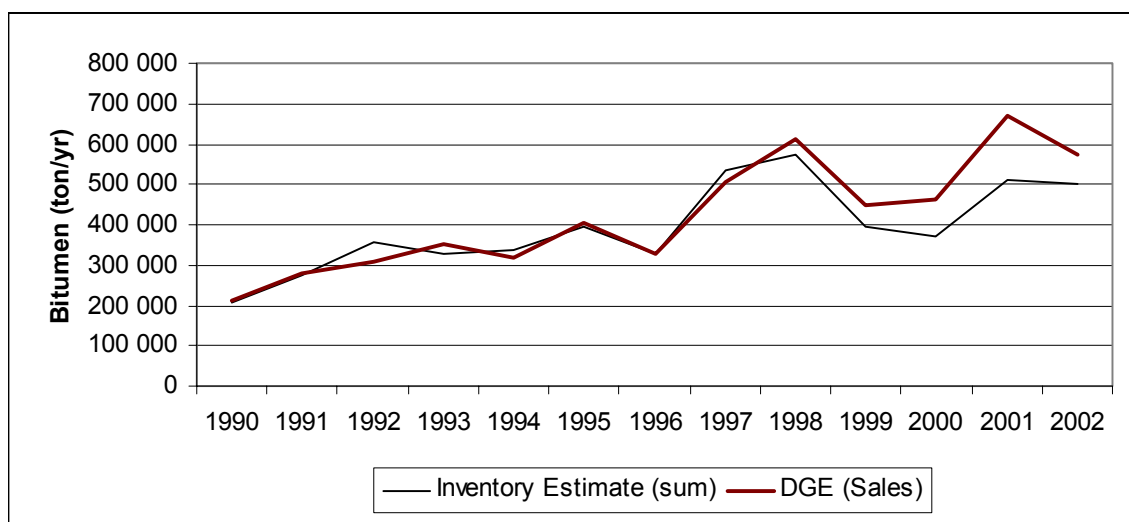
Pollutant	Continuous	Batch	Unit EF
PM	14	16	kg/ton
PM10	23	14	%
PM2.5	5.5	1	%
NMVOC	32.0	22.1	g/ton
CH4	12.0	7.4	g/ton

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 (DGE) based on surveys<sup>64</sup>, and it is presented in Figure 4.6. Although this time series was not used in the inventory, it is nevertheless used for the verification that the estimates made for each asphalt materials, which are subsequently explained, are coherent with total sale statistics.

Figure 4.6 - Total consumption of bitumen in the construction sector according to sales from DGGE and sum of values of asphalt used, according to the inventory (1990-2002)



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 4.6 and Figure 4.7. 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 DGE, match the sum of individual estimates, and both values agree reasonably well as may be seen from Figure 4.6 above.

<sup>64</sup> Original data from DGE is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGE

Total production of Hot mix concrete asphalts is presented in figure xpto.

Table 4.6 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (ton)

Asphalt	1990	1991	1992	1993	1994	1995	1996
Cutback	4 100	3 500	2 700	3 100	2 600	676	407
Emulsified	0	10 567	21 133	36 576	49 852	65 025	100 517

Asphalt	1997	1998	1999	2000	2001	2002
Cutback	1 232	933	162	576	824	501
Emulsified	110 000	130 000	95 000	86 000	107 000	116 000

Figure 4.7 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (1990-2002)

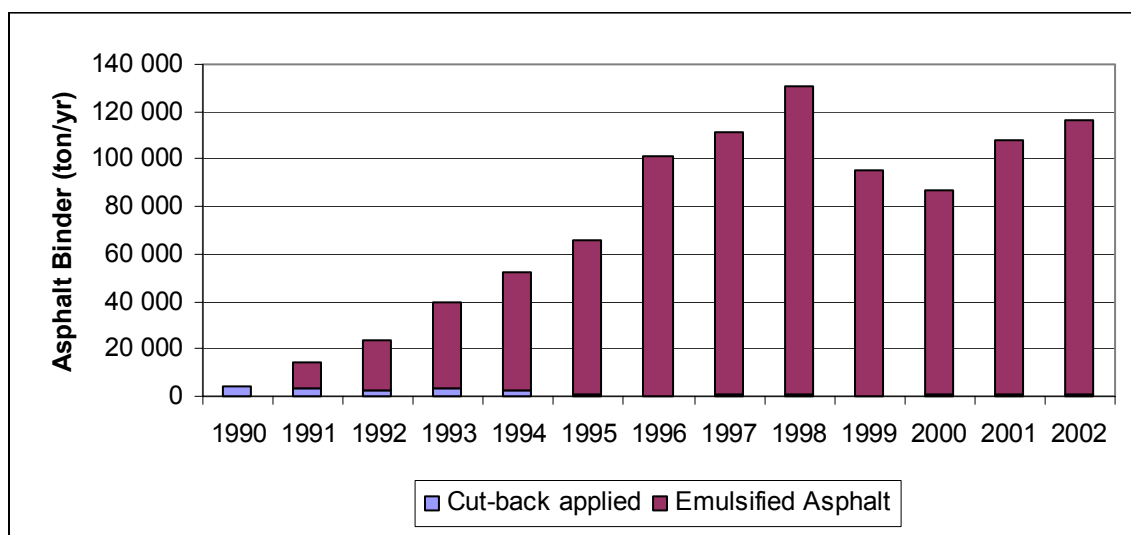
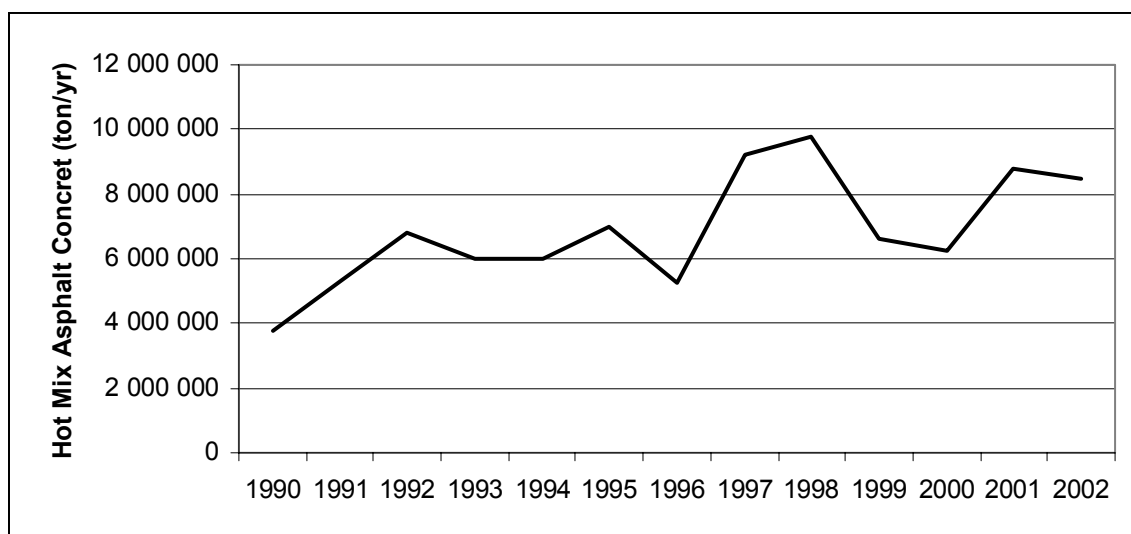


Figure 4.8 – Total Production of Hot Mix Asphalt (1990-2002)



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).

## RECALCULATIONS

This is one of the emission source sectors that have suffered more extensive modifications in emission estimates. Overall emissions from this source were revised downward and it is concluded that this emission source was formerly much over-estimated. These modifications took place in sequence of the development of the first National Plan for Ceilings (PTEN) and under the revision of the Baseline Scenario for CAFE program, both under UE obligations.

The major modification resulted from the revision of the asphalt types that had been used in road paving. In previous submission (NIR 2003) it was assumed that all asphalt that was used in paving was cut-back asphalt. This supposition was not based in country-specific information – which was not available – but on the default asphalt type to be considered if no detailed information is available, according to USEPA<sup>65</sup> (EIIP or AP42). In the present submission the majority of asphalt in pavement is applied as hot mix, emulsified asphalt or cutback,, according to the methodology explained before.

In what concerns cut-back emissions, initial solvent content in asphalt binder was revised downward, because experts from sector consider that most cutback used in Portugal is medium cure (Kerosene). Some modifications were also done for other parameters such as density and cure type.

Emissions from hot mix plants, and during asphalt production, are included in this source sector for the first time.

## FURTHER IMPROVEMENTS

Although emission estimates for this source sector have suffered extensive modifications in last year, it was recognized that some actions could lead to an improvement of emission estimates. They will focus 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, under SNIERPA development.

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 and asphalt roofing. Improvements in this separation are expected in following submissions.

### 4.2.A.5 GLASS PRODUCTION

#### OVERVIEW

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. Combustion emissions from glass production were already considered in source sector 1A2, estimated from fuel consumption data or production data. But glass involves also carbon dioxide emissions, from decarbonising of limestone and carbonate materials, which are considered here.

---

<sup>65</sup> Which results in greater emission estimates and it is hence the conservative approach.

## METHODOLOGY

Carbon dioxide emissions from glass production were estimated from:

$$\text{Emission}_{\text{CO}_2(t,y)} = \text{EF}_{\text{CO}_2(t)} * \text{ActivityRate}_{(t,y)} * 10^{-3}$$

where

$\text{Emission}_{\text{CO}_2(t,y)}$  - annual emission of carbon dioxide from specific glass type t in year y (ton/yr);

$\text{ActivityRate}_{(t,y)}$  - Glass of type t produced in a given year y (ton/yr);

$\text{EF}_{\text{CO}_2(t)}$  - emission factor from production of glass of type t (kg/ton)

## EMISSION FACTORS

The following emission factors were considered, and were set as the average values proposed in EMEP/CORINAIR Handbook (EEA,2002):

Table 4.7 - Carbon Dioxide Emission Factors for Glass Production

Material	EF	Unit EF
Flat Glass	210	kg/ton
Container Glass	200	kg/ton
Lead Crystal Glass	239	kg/ton
Other Glass	239	kg/ton

## 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 (m<sup>2</sup>) 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 (m<sup>2</sup>) but was not used because conversion to weight units would lead to high uncertainties. Production value for 2002 was 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 2001-2002. 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 4.8 – 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 xpto. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 4.9 - Glass production by glass type (excluding flat glass production)

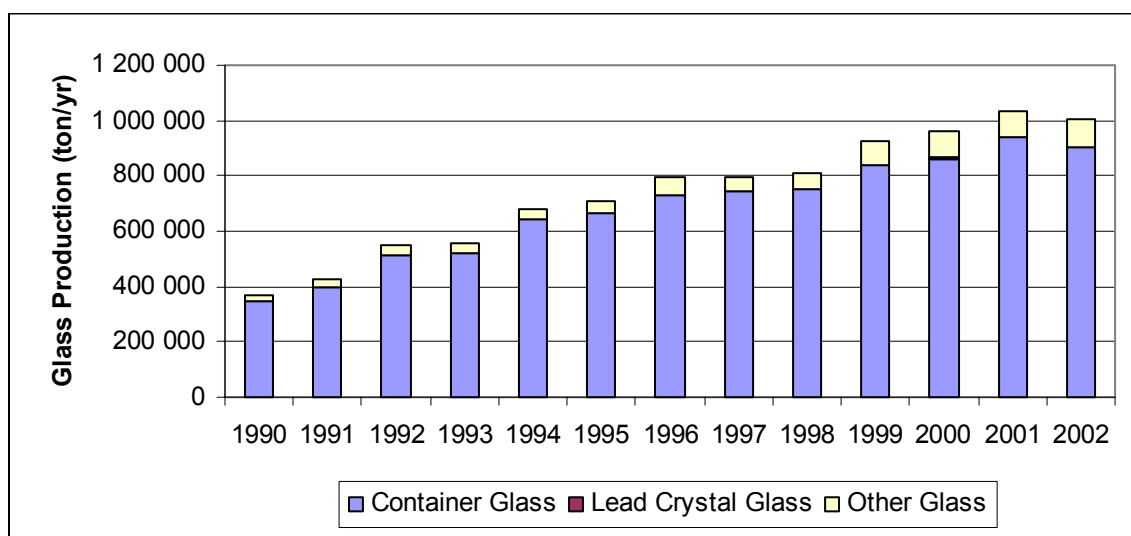


Table 4.9 - Glass production by glass type (excluding flat glass)

Type of Glass	1990	1991	1992	1993	1994	1995	1996
Container Glass	344 967	399 822	509 718	519 111	639 947	663 498	730 342
Lead Crystal Glass	149	234	483	332	387	509	583
Other Glass	26 224	28 311	41 350	39 901	39 411	46 965	61 438

Type of Glass	1997	1998	1999	2000	2001	2002
Container Glass	741 392	751 333	835 451	863 502	936 471	904 433
Lead Crystal Glass	862	837	903	1 009	1 078	1 163
Other Glass	54 183	58 115	90 141	100 059	94 912	102 081

## RECALCULATIONS

The activity data time series was revised for the all period, using statistical information from INE databases. The former value for flat glass production – a constant value was used in the 1990-2001 period – remains similar to the activity rate that is now used for base year (1990), but there are in the new time series, strong oscillations of activity rates in the 1990-2002 time series and a slight increasing trend toward 2002.

In a similar fashion there is now a very sharp increase in production of container glass, from 1990 to 2002, where production in 2002 is 2.6 times the production value for 1990. However, the average value in the 1990-2002 period (680 kton/yr) is not very dissimilar to the constant production value that was considered in previous submission for the all 1990-2001 period (747 kton/yr).

In what concerns other glass, the new time series show also a very accentuated grow pattern, with production in 2002 being 3.9 times the production value in 1990. However, the average value in 1990-2002 (60 kton/yr) is 54% higher than the value that was constant in the 1990-2001 period according to submission 2003 (39 kton/yr). Lead crystal glass, included in the inventory for the first time, represents a very minor contribution to total production and emissions.

The emission factor for “other glass” – covering also production of lead crystal glass – was changed from 210 kg/ton to 239 kg/ton.

## 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.

Finally, if possible, emission estimates obtained from glass production should be checked against emission estimates from consumption of carbonaceous materials.

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

### 4.2.B.1 INORGANIC CHEMISTRY AND FERTILIZERS

#### OVERVIEW

Emissions from the following production processes are included in this sub-source category:

#### *Sulphuric Acid Production*

In 1990 in Portugal there were two industrial units producing sulphuric acid in association with mineral processing and more two additional industrial plants producing H<sub>2</sub>SO<sub>4</sub> 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<sub>x</sub> 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<sub>2</sub> is formed from oxidation of elemental sulphur with air, followed by conversion to SO<sub>3</sub>, 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<sub>2</sub>SO<sub>4</sub>, 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<sub>x</sub> 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.

### ***Nitric Acid Production***

Only three industrial plants produced nitric acid in Portugal between 1990 and 2002, being located in Estarreja, Alverca and Lavradio. Weak nitric acid (60%) is produced from ammonia, involving a catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to NO<sub>2</sub> 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<sub>x</sub> (NO and NO<sub>2</sub>), trace amounts of HNO<sub>3</sub> acid mist, ammonia (NH<sub>3</sub>) and Nitrous Oxide (N<sub>2</sub>O). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of NO<sub>x</sub> are controlled by catalytic reduction.

Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

### ***Ammonia***

Presently only one fertilizer industrial plant manufactures ammonia in Portugal, relying on Vacuum Residual Fuel Oil (VRF) as feedstock and source of hydrogen. Ammonia is formed after reaction of hydrogen with nitrogen from air. There was another unit operating in Portugal, but has stopped activity already in the beginning of year 1990.

### ***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);

$\text{ActivityRate}_{(y)}$  - 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);

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

A specific procedure applies to NMVOC from ammonia production. Methanol emissions were estimated from annual consumption of this compound in the industrial plant and assuming that these quantities are 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.

In the case of sulphur recovery with sulphuric acid production, total SO<sub>x</sub> 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 atmosphere<sup>66</sup>:

$$\text{Emi}_{\text{SOx}(y)} = 2 * \text{Feedstock}_{(y)} * \text{S}_{\text{Feed}(y)} * 10^{-2} - 32/98 * \text{Prod}_{\text{H}_2\text{SO}_4(y)}$$

where

$\text{Emi}_{\text{SOx}(y)}$  - Emission of sulphur oxides<sup>67</sup> (ton/yr);

$\text{FeedStock}_{(y)}$  - Annual consumption of feedstock (ton/yr)

$\text{S}_{\text{Feed}(y)}$  - Sulphur content of feedstock (%);

<sup>66</sup> 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<sub>x</sub>/kg S in VRF) for 1990 and 1993 was used to estimate emissions.

<sup>67</sup> In fact, this emissions include also H<sub>2</sub>S and other sulphur compounds, but it is assumed that they are converted to SO<sub>x</sub> in atmosphere.

$\text{Prod}_{\text{H}_2\text{SO}_4(y)}$  - production of sulphuric acid from sulphur recovery in year y (ton/yr).

Finally, conversion of feedstock to hydrogen results in the liberation of carbon – which was not accounted in fuels - and ultimate CO<sub>2</sub>. Carbon dioxide emissions were estimated from:

$$\text{Emi}_{\text{CO}_2(y)} = 44/12 * \text{Feedstock}_{(y)} * C_{\text{Feed}(y)} * 10^{-5}$$

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 (%).

Actually some part of CO<sub>2</sub> 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 CO<sub>2</sub> may be used in urea manufacturing, the option was not to deduce this CO<sub>2</sub> fixation in feedstock.

## EMISSION FACTORS

The following emissions factors were applied to production data for each substance. They were mostly set from emission factors in CORINAIR/EMEP (EEA,2002) and AP-42.

Table 4.10 - Emission Factors for inorganic chemical industry processes (1/2)

-	Sulphuric Acid	Nitric Acid	Ammonia	Urea	Ammonium Sulphate	Ammonium Nitrate
Pollutant	kg/ton H <sub>2</sub> SO <sub>4</sub>	kg/ton HNO <sub>3</sub>	kg/ton NH <sub>3</sub>	kg/ton Urea	kg/ton (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	kg/ton NH <sub>4</sub> O <sub>3</sub>
U <sub>CO2</sub>			3.20 <sup>(e)</sup>			
N <sub>2</sub> O		7.52 <sup>(b)</sup>				
SO <sub>x</sub>	16.4-30.7 <sup>(a)</sup>					
NO <sub>x</sub>		1.2 – 1.3 <sup>(c)</sup>				
NM VOC			0.60 <sup>(f)(g)</sup>		1.04 <sup>(i)</sup>	
CO			7.9 <sup>(f)</sup>			
NH <sub>3</sub>		NE <sup>(d)</sup>	2.10 <sup>(f)</sup>	9.66 <sup>(h)</sup>		2.0 <sup>(j)</sup> + 1.4 <sup>(b)</sup>
PM				2.01 <sup>(h)</sup>	0.02 <sup>(i)</sup>	2.4 <sup>(k)</sup> + 2.5 <sup>(b+k)</sup>
PM <sub>10</sub>				1.82 <sup>(h)</sup>	0.02	2.4 + 2.0 <sup>(k)</sup>
PM <sub>2.5</sub>				1.61 <sup>(h)</sup>	0.02	2.4 + 2.0 <sup>(k)</sup>
PM <sub>1.0</sub>				1.61	0.02	2.4 + 2.0

Table 4.11 - 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 <sub>3</sub>	1.89 <sup>(c)</sup>	0.1 <sup>(b)</sup>	4.91 <sup>(c)</sup>	0.82 <sup>(f)</sup>	1.0 <sup>(f)</sup>
PM	4.2 <sup>(c+k)</sup>	0.6 <sup>(b)</sup>	4.09 <sup>(c)</sup>	0.73 <sup>(f)</sup>	0.3 <sup>(f)</sup>
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 USEPA (1993b)

(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) Emission Factor not available from bibliography reference or emission monitoring

(e) expressed in ton CO<sub>2</sub>/ ton VFR. Carbon content in feedstock was assumed to be 86%

(f) USEPA (1993)

(g) Not including methanol emissions, estimated by mass balance

(h) USEPA (1993c)

(i) USEPA (1996b). Rotary driers controlled (wet scrubber)

(j) UNEP/UNIDO/IFA (1998)

(k) USEPA (1993d)

(L) USEPA (1993f) Controlled

Sulphur content of feedstock used in the ammonia plant can not be made explicit in NIR due to confidential constraints.

## 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, 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;

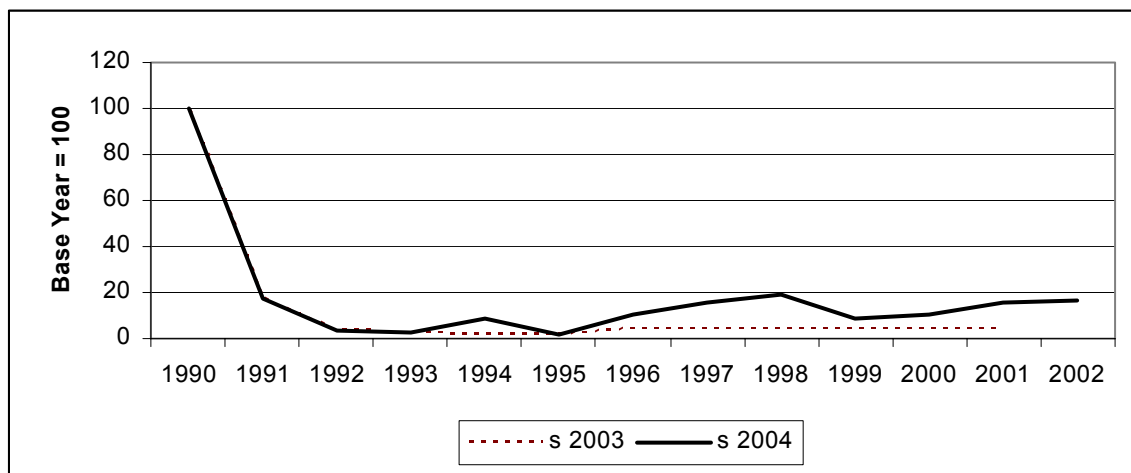
- Quantities of sulphuric acid and nitric acid production for year 1990 are available from a specific questionnaire that had been sent to industrial units by IA under Corinair90 project;

- some information is available for particular years for several industrial plants, and as result of questionnaires made under regional air emission inventory surveys;

- production figures for 2001 and 2002 are estimated from IA, forecasted from previous time series.

**Sulphuric Acid**

Figure 4.10 – Trend in total sulphuric acid production, including sulphur recovery (1990-2002)



Source: Comparison of activity data reported in submission 2003 (s 2003) and present submission (s 2004). Emissions for base year (1990) according to submission 2004 equal 100.

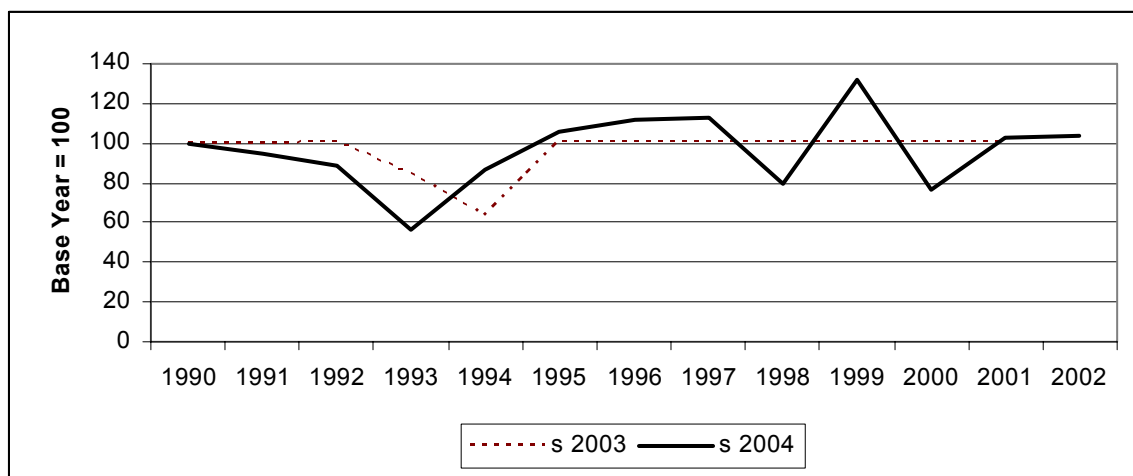
The quantity of sulphur recovered and transformed into sulphuric acid is only available for a limited number of years (1990, 1993 and 1995). The remaining time series was estimated from consumption of VRF and ammonia production in the following mode:

- 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 data<sup>68</sup>;
- 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  $H_2SO_4$  that was recovered.

<sup>68</sup> For confidentiality reasons original data and relation may not be reported in NIR

**Nitric Acid manufacturing**

Figure 4.11 – Trend in Nitric Acid production (1990-2002)



Comparison of activity data reported in submission 2003 (s 2003) and present submission (s 2004). Emissions for base year (1990) according to submission 2004 equal 100.

The time series was set by

- From 1992 to 2000, total national production of Nitric Acid was available from INE statistical database (IAPI survey);
- For 1989-2001 the statistical information is available from IAIT survey.

**Ammonia manufacturing**

Because there is only one industrial plant in operation, it is not possible to present any information concerning activity data for this source activity, either ammonia production and feedstock and methanol consumption.

- total production of ammonia in Portugal is available from INE for the period 1990-2000, resulting from IAIT survey for 1990 and 1991, and from IAPI survey thereafter;
- consumption of VRF feedstock could not be determined from INE statistical database, because differentiation of residual fuel oil for feedstock and energy source was not clarified. Therefore, as explained before, consumption of feedstock VRF was estimated from limited information and relying on linear correlations: the quantity of VRF that was used was set from data collected at the only industrial plant in Portugal for a limited number of years – 1990 till 1994 – and a strong linear relation between feedstock consumption and ammonia production could be established from available data;
- use of methanol was also estimated for the full time period from linear regression from available information for a limited number of years.

**Urea manufacturing**

For the same reason that was explained for ammonia manufacturing, the existence of only one industrial plant producing urea in Portugal, forbids 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.

**RECALCULATIONS**

In general terms, activity data was revised for almost all sub-source activities, as result of the update of time series with data from the IAPI statistical survey for industrial activities (INE). Therefore, time trends were revised for nitric acid, ammonia, urea, ammonium sulphate, ammonium nitrate and NPK fertilizers. Changes in activity data since submission 2003 were already presented during presentation of activity data, whenever possible.

Since last submission some new sub-sources were included, although they result mostly in emissions of ammonia and particulate material and not GHG: calcium nitrate, calcium-magnesium nitrate, super-phosphates and DAP.

Since last submission, no substantial changes in method or parameters were made in estimates of SO<sub>x</sub> emissions from sulphur acid production and sulphur recovery. However, because for some years, production of H<sub>2</sub>SO<sub>4</sub> is estimated using ammonia production as surrogate data, consequently modifications that were made in the time series for ammonia caused indirect changes also in emissions from sulphur recovery.

Emissions of NO<sub>x</sub> and N<sub>2</sub>O from Nitric Acid production were also revised as result of the use of country-specific emission factors for these two pollutants, and following emission studies made during the development of the Regional Air Emission Inventory for the Region of Lisbon and Tagus Valley (CCDR-LVT) in 2003. The emission factor for N<sub>2</sub>O has not suffered substantial changes. By the contrary, the reduction of EF for NO<sub>x</sub> was substantial. The new value is sustained however by comparison with the proposed EF by USEPA (1998e) for similar emission control equipments. Changes in the emission factors are synthesized in the next table.

Table 4.12 – Changes in emission factors for Nitric Acid Manufacturing between submission 2003 and submission 2004 (kg/ton NNO<sub>3</sub>)

Pollutant	Sub. 2003	Reference	Sub. 2004	Reference
N <sub>2</sub> O	8.0	Corinair90 (CEC,1992)	7.52	Monitoring (1 Plant)
NO <sub>x</sub>	7.5	EMEP/CORINAIR (EEA,2002)	1.2 – 1.3	Monitoring (2 plants)

Concerning ammonia, and although activity data can not be reported in NIR, it must be emphasized that the trend in submission 2004 shows a sharp increase whereas in submission from last year, ammonia production remained more or less constant. Emission factors for this activity remained unchanged, except for the inclusion of the emission estimates for CO emission for regeneration of desulphurisation unit, which were not accounted before. The resulting emission factor changed from 1 kg/ton of ammonia to 7.9 kg/ton of ammonia.

Emission factors for NH<sub>3</sub> from fertilizer production were subjected to a detailed revision, under the establishing of the CAFE baseline scenario. In general terms, there was substantial decrease in emission factors for NH<sub>3</sub>, reflecting a better knowledge of the technologies in use in Portugal, and the clarification over double counting of ammonia emissions, that may have been estimated both from ammonia production and then when it is used for producing nitrogen fertilizers (for example, CAN and ASN are mixtures made by granulation of AN with a filler). Major changes may be verified in next table:

Table 4.13 – Changes in Ammonia emission factors between submission 2003 and submission 2004 (kg/ton fertilizer)

Sub-source	Sub 2003	Sub 2004	Comment
Ammonium Sulphate	1.06	-	No reference found for previous EF
Ammonium Nitrate, CAN and ASN	46.30	3.4	Monitoring data. Differentiation of NH <sub>3</sub> emissions from bulk AN and derived solid formulations (AN, CAN, ASN)
NPK Fertilizers	10.69	1.84	Monitoring Data
DAP	-	1.0	First time estimate

Although all these country specific emission factors are still far from being adequately documented it was judged that it was better to use them than to maintain previous emission factors, because the ones that are now used are in more coherence with the equipment for emission reduction that is installed in Portuguese industrial units.

#### 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:

- Revision will be made concerning the different reporting placement for SO<sub>x</sub> emissions from flaring in sulphur recovery, and also about the accounting of the CO<sub>2</sub> that is used to produce urea;
- Estimate of air emissions from Nitric Acid Manufacture should be extended to include also ammonia, preferably using estimates from plant monitoring.

#### 4.2.B.2 ORGANIC CHEMICAL INDUSTRY

##### OVERVIEW

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 only Carbon Black plant in Portugal. It is also situated in the southern part of the country, near Sines. CARBOGAL unit produces Carbon Black by the Oil Furnace Process, a partial combustion process where feedstock with a high content of aromatic material is converted by incomplete combustion, thermal cracking and dehydrogenation to carbon black. Emissions result from Gas Vent, combined dryer vent and fugitive emission in the vacuum system vent.

Finally the last individualized unit (LPS) is an industrial plant located in Lisbon producing Phthalic Anhydride from aromatic compounds.

Apart from those individualized industrial plants other chemical industrial activities were included as area sources in this sub-source sector<sup>69</sup>:

- 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);

$\text{EF}_{(p)}$  - 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:

$$44 / 12 * C_{\text{TailGas}} = C_{\text{Feedstock}} + C_{\text{AuxFuels}} - C_{\text{CarbonBlack}}$$

<sup>69</sup> This list is not extensive to chemical production in Portugal, but comprehends only those products for which there are emission estimate methodologies and emission factors

Where,

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

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

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

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

## EMISSION FACTORS

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994<sup>70</sup>. Emissions estimated for this period were used to determine plant-specific process emission factors that were used to estimate emissions for all time series from 1990 to 2001 and using ethylene production as activity rate indicator<sup>71</sup>. Emissions from flares and flue gas combustor were included in the emission factors.

Table 4.14 – Emission Factors for determination of process emissions in Borealis (kg/ton)

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

In the same way, the carbon black industrial unit was subjected, also for period 1993-94, to a detailed survey and inventory exercise. Consequently mission factors were established for carbon black unit and emission estimates were extended for the rest of the time series using carbon black production as indicator of activity rate. Carbon Gas emissions include also emissions suffering partial combustion.

Table 4.15 – 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 <sup>(a)</sup>	-
COVNM	33.3 <sup>(a)</sup>	2.50 <sup>(b)</sup>	-
CH4	0.80	0.8 + 1.4 <sup>(b)</sup>	-
CO	104	100 + 17 <sup>(b)</sup>	-
N2O	-	1.40 <sup>(b)</sup>	-
PM	0.20 <sup>(c)</sup>	0.12 <sup>(a)</sup>	0.42 <sup>(a)</sup>

(a) kg/ton Carbon Black

(b) g/GJ

(c) g/Nm<sup>3</sup> tail gas

<sup>70</sup> Unpublished.

<sup>71</sup> This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Emission factors for the Phthalic Anhydride Plant are from USEPA (1983) and are presented in table 4.8:

Table 4.16 - 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 4.17 - Emission Factors for Nitrocellulose production (explosives)

FE (Kg/ton)	SOx	NOx
<b>TOTAL</b>	34.7	14
Nitration reactors	0.7	7
Nitric acid concentrator	-	7
Sulphuric acid concentrator	34	-

Source: USEPA (1983b)

- 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 ( $\text{KNO}_3$ ) 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, 1983b):

Table 4.18 - Emission Factors for TNT production (explosives)

kg/ton	SOx	NOx
<b>TNT - Batch process (Total)</b>	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 (USEPA).

Table 4.19 - Emission factors for chemical organic industrial processes

Compound	EF (kgton)	
	NMVOC	PM
VCM	2.5 <sup>(a)</sup>	-
LDPE	10.0 <sup>(b)</sup>	-
PVC	3.0 <sup>(c)</sup>	17.5 <sup>(f)</sup>
PP	8.0 <sup>(b)</sup>	1.5 <sup>(e)</sup>
PS	1.0 <sup>(d)</sup>	-
Formaldehyde	5.0	-

(a) ;(b) (CEC,1992). Old Plants

(c) TNO (1987). Emulsion; (d) USEPA (1991). Controlled (Fabric Filter)

(e) USEPA (1991b); (f) USEPA (1991c)

## 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) and show appreciable limitations. For most of these activities, including Phthalic Anhydride, information is only available for base year (1990) and was kept constant for the following years.

## RECALCULATIONS

No changes have been made on this emission source sector since last submission.

## FURTHER IMPROVEMENTS

The quality of emission estimates from this sub-source sector must be improved in next submissions, namely in what concerns:

- Update of activity data from 1991 to 2003;
- 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.

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, carbon market registry, Regional Air Emission Inventories, cooperation with industry associations or specific inquiries.

## 4.2.C Metal Production (CRF 2C)

### 4.2.C.1 IRON AND STEEL PRODUCTION

#### OVERVIEW

Iron results from reduction of the iron element present in mineral ores by contact with coke - reducing agent - at high temperatures in the blast furnace. The resulting material, pig iron – and also scrap in some steel plants - is transformed into steel into subsequent furnaces which may be a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF). Coke, sinter and lime are intermediate materials necessary for iron and steel production.

Sintering modifies the structure of ore material making it more suitable for iron formation, by converting fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product. Sintering emissions occur from the windbox, discharge and sinter crusher, coolers and screens. Emissions from sintering, which result from a combustion process with contact, are reported under 1.A.2, although the emission factors are reported in this chapter.

Coke is produced by destructive distillation of imported fossil coal in coke ovens, where coal is subjected to heat in an oxygen-free atmosphere until all volatile components in the coal evaporate, forming a fuel used in industry, the Coke Gas. Process heat comes from the combustion of gases between the coke chambers. Excluding emissions associated with coke production resulting from use of fuels in under-fired heating furnaces (which are accounted in Energy source sector 1A1), air emissions from the coquerie result from coal preparation, coal charging, oven leakage during the coking period, coke removal and hot coke quenching. Leaks may also occur from poorly sealed doors, charge lids, off take caps, collecting main and from cracks that may develop in oven brickwork (USEPA, 2001d)

Coke and sinter are added to the Blast Furnace where iron oxides, coke and fluxes react with blast air to form molten reduced iron, carbon monoxide (CO), and slag. Emissions occur during casting and in the blast furnace top. However the gas resulting from process in the blast furnace, which has a high CO content, is normally not emitted to atmosphere but used as fuel in integrated units (Blast Furnace Gas). Emissions from its combustion are also quantified and discussed under chapter 1A2 – Combustion in Manufacturing Industries and Construction. The emissions that are quantified here, in source 2.C, are only those resulting from casting operations and seal leaks at top of furnace.

In Basic Oxygen Furnace original material are re-melted with the addition of substantial source of oxygen which is lanced (injected) and oxidizes part of the carbon associated with iron: This carbon is emitted mostly as CO (contributing nevertheless to ultimate CO<sub>2</sub> emissions). Other emissions from BOF are iron oxides, oxides of other metals and sulphur and particulate matter. In EAF the original material, which is basically scrap, is subjected to an electric discharge that also reduces carbon content.

Steel is finally finished in rolling mills. Emissions from this finishing process are mostly particulate matter besides combustion pollutants which is already included in emissions from the 1.A.2 sector.

Lime is necessary for the blast furnace charging and EAF mixtures. Production of lime from limestone in this unit results in CO<sub>2</sub> emissions from decarbonising.

Emissions of ultimate fossil CO<sub>2</sub> are the result of the oxidation of carbon in coke, anodes and electrodes. Part of the carbon may be sequestered in final product and not emitted to atmosphere as carbon dioxide. Only emissions of carbon that has origin in fossil fuels should be

considered as emissions of final or ultimate CO<sub>2</sub> and not those from the use of biomass origin carbon - charcoal. Emissions of carbon may occur as CO and NMVOC but it is assumed that they are subsequently converted in atmosphere in carbon dioxide. Some carbon may remain in pig iron after initial reducing in blast furnace and partly may be emitted from oxidation in the BOF. Also EAF furnaces may result in carbon emission but from consumption of graphite anodes in the process.

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<sub>x</sub> and heavy metals. But because combustion occurs with contact, emissions are modified - increase or decrease - by contact of combustion gases with products and emissions can not be estimated by mass balance alone.

NO<sub>x</sub> 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);

$\text{Activity}_{\text{Indicator}(p,a,y)}$  - Most suitable indicator for emissions of a particular pollutant p resulting from a specific source activity or equipment a (ton/yr);

$\text{EF}_{(p,a)}$  - Emission factor specific of pollutant and activity/ equipment a (kg/ton).

Emissions from sintering and lime production from limestone at iron and steel unit were also estimated using similar equation and using production of lime as activity data. Emissions for all pollutants for this two emission sources are reported however in source category Energy (1.A.2).

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 CO<sub>2</sub> emissions, nevertheless the carbon dioxide emissions from anodes in EAF is still not contemplated in the inventory.

## EMISSION FACTORS

Emissions factors for production process where set mostly from CORINAIR/EMEP (EEA,2002) also with contributions from IPCC 1996 Revised Guidelines (IPCC,1997) and USEPA (AP42). Emission factors in kg/ton are present in next table.

Table 4.20 - 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)
SO <sub>x</sub>	0.01 <sup>(a)</sup>	1	2	0.01	
NO <sub>x</sub>	0.02 <sup>(a)</sup>	0.5	0.076		
COVNM	2.1 <sup>(a)</sup>	0.1	0.12		
CO <sub>2</sub>				22.5 <sup>(d)</sup>	119 <sup>(e)</sup>
CO	0.635 <sup>(a)</sup>	30	1.412	69 <sup>(c)</sup>	9 <sup>(c)</sup>
NH <sub>3</sub>	0.09 <sup>(a)</sup>				
PM	2.01 <sup>(b)</sup>	3.9 <sup>(c)</sup>	0.45 <sup>(c)</sup>	0.9 <sup>(c)</sup>	25 <sup>(c)</sup>
PM <sub>10</sub> #	39.2 <sup>(b)</sup>	15 <sup>(c)</sup>	51 <sup>(c)</sup>	46.60 <sup>(c)</sup>	58 <sup>(c)</sup>
PM <sub>2.5</sub> #	25.4 <sup>(b)</sup>	6.5 <sup>(c)</sup>	23 <sup>(c)</sup>	32.98 <sup>(c)</sup>	43 <sup>(c)</sup>
PM <sub>1</sub> #	16.3 <sup>(b)</sup>	4 <sup>(c)</sup>	15 <sup>(c)</sup>	13.83 <sup>(c)</sup>	23 <sup>(c)</sup>

# expressed as % of total PM; (a) USEPA (1985) in EMEP/CORINAIR 3rd ed (EEA,2002); (b) USEPA (2001d); (c) USEPA (1986d); (d) carbon reduction from 4.25 to 2%; (e) EMEP/CORINAIR 3<sup>rd</sup> ed (EEA,2002) (average value)

## 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 4.12. 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 ended;
- production time series for sinter, pig iron and steel 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 were estimated from production data in both ovens in 1990 and forecasted thereafter using fuel consumption in the electric power plant<sup>72</sup> as surrogate data<sup>73</sup>, 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.

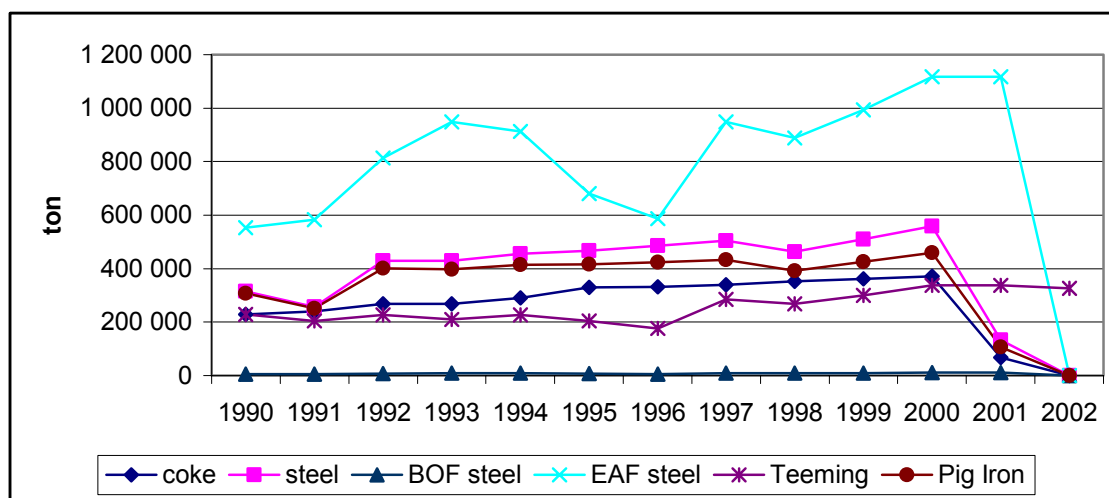
<sup>72</sup> Power plant that is part of the iron and steel plant

<sup>73</sup> They may result not from iron produced at this industrial plant

Before 1994 data information was collected directly from industrial plants and it is mostly probably of good quality. Since then 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 latter period decreased substantially.

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 4.12 - 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 (1990-2002)



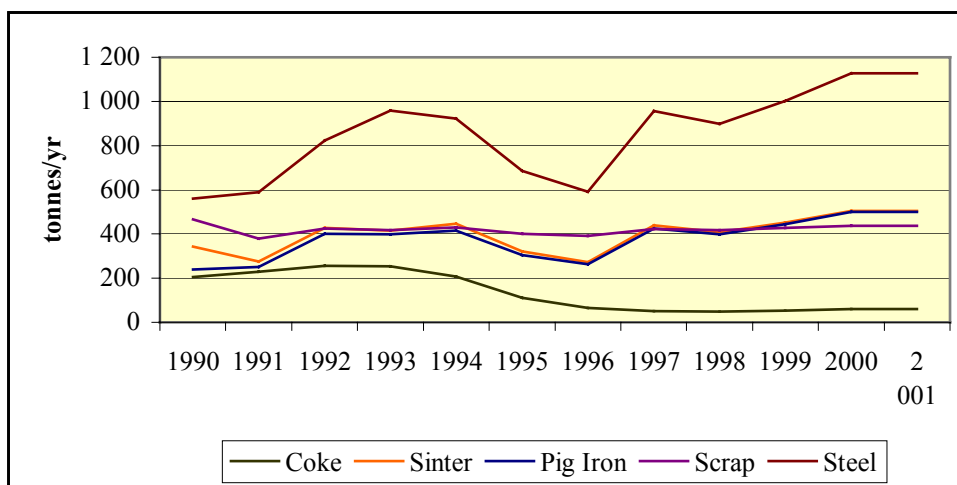
## RECALCULATIONS

Improvements in emission inventory since last submission comprehend mostly changes in activity data. The methodology remained unchanged and only emissions of CO<sub>2</sub> from EAF were added - they were previously unaccounted. Changes in activity data consisted in:

- coke production. Presently time series is from DGGE while in previous submission data was from industrial plant from 1990 to 1994 and thereafter forecasted using fuel consumption in the plant electric power plant (which reports under UE's LCP directive) as surrogate data. There are only small differences between data from plant and DGE data between 1990 and 1994;
- sinter, pig iron and steel. Produced quantities of these products are now estimated from industrial plant data (1990-1994) and extrapolating using coke production as surrogate data thereafter. In previous submission the surrogate data that was used was fuel consumption in the plant electric power plant.

Figure 4.13 presents the activity data considered in previous submission.

Figure 4.13 - Production of iron and steel industry as reported in submission 2003



### FURTHER IMPROVEMENTS

Lack of information concerning activity data and possible double counting in steel production activities substantially lowers quality of activity data since 1994, increases uncertainty and creates inconsistencies in overall time-series. 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.

Possible double counting of emissions of CO, NMVOC and SO<sub>x</sub> will be reviewed, as well as verification that accounting of CO<sub>2</sub> emissions from coke gas and blast furnace gas combustion does in fact include all emissions.

Open dust sources of particulate mater are still not included in the inventory.

CO<sub>2</sub> emissions from lime production, which are placed in combustion sector 1.A.2, should be individualized and reported in industrial production sources, under 2.A.

Because 2002 is a year with substantial changes for this source sector, care must be made to update appropriately the inventory thereafter.

### 4.2.C.2 FERROALLOYS PRODUCTION

#### OVERVIEW

Iron is smelted with other elements, such as silicon, manganese, chromium, molybdenum, vanadium or tungsten, forming alloys that have specific material characteristics requirements.

Usually alloy formation occurs in Electric Arc Furnaces (EAF) and, like the situation described in steel factoring, carbon monoxide and carbon dioxide emissions occur from oxidation of carbon still present in coke - used as raw material - and from consumption of the graphite electrodes.

#### METHODOLOGY

Emissions are estimated by multiplication of emission factors, because no data is available to estimate oxidation of coke and electrodes:

$$\text{Emission}_{\text{CO}_2(y)} = \text{EF}_{\text{CO}_2} * \text{ActivityRate}_{(y)}$$

where

$Emission_{CO_2(y)}$  - annual emission of carbon dioxide in year y (ton/yr);

$ActivityRate_{(y)}$  - Indicator of activity in the production process, the quantity of ferro-alloy produced in a given year y (ton/yr);

$EF_{CO_2}$  – carbon dioxide emission factor (ton/ton)

## EMISSION FACTORS

The emission factor, 2.5 ton/ton, was set from emission factors proposed by IPCC 1996 Revised Guidelines (IPCC,1997) 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.

## 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.

### 4.2.C.3 ALUMINIUM PRODUCTION

#### OVERVIEW AND RECALCULATIONS

Aluminium production will result in carbon dioxide emissions when it is reduced using carbon electrodes in smelting pots and ultimate CO<sub>2</sub> emissions are the result of consumption of electrodes. This situation occurs when aluminium is manufactured from bauxite ore, using the Soderberg process, for example.

In Portugal, according to information received from the General Directorate of Industry (DGI), aluminium is produced from ingots and not from bauxite ore. Consequently emissions of CO<sub>2</sub> for this source sector were removed from emission inventory.

### 4.2.D Other Production (CRF 2D)

#### 4.2.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

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

ActivityRate - Indicator of activity in the production process (ton/yr);

$\text{EF}_{\text{NMVOC}}$  - 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.

### 4.2.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 production<sup>74</sup>;
- Coffee roasting;
- Animal feed production.

## METHODOLOGY

Emissions were estimated by the use of emission factors multiplied by quantity of material produced:

$$\text{Emission}_{\text{NMVOC}}(y) = \sum_a [\text{EF}_{\text{NMVOC}(a)} * \text{ActivityRate}_{(a,y)} * 10^{-3}]$$

where

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

$\text{ActivityRate}_{(a,y)}$  - 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);

$\text{EF}_{\text{NMVOC}(a)}$  - 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 (EEA,2002), IPCC 1996 Revised Guidelines (IPCC,1997) and USEPA (1997c, 1995h, 1997d, 1996e, 1995i, 1997e, 1995j, 1995k):

<sup>74</sup> Emissions of NMVOC from edible oil extractions are included in "Use of Solvents".

Table 4.21 - 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 4.22 – 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 (1998f)

(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 4.23 and Table 4.24 below.

Table 4.23 – Annual production in the Food and Beverage Industry

Product	1990	1991	1992	1993	1994	1995	1996
White wine <sup>(a)</sup>	410	410	410	410	410	410	392
Red Wine <sup>(a)</sup>	592	592	592	592	592	592	478
Beer <sup>(a)</sup>	687	689	690	692	693	694	696
Spirits <sup>(a)</sup>	14	14	14	14	14	14	14
Wheat Bread	302	278	269	261	252	244	235
Other Bread	28	28	27	26	25	23	22
Cakes	38	38	38	38	38	38	38
Fish	238	238	238	238	238	238	238
Sugar	305	282	285	289	293	297	301
Margarine	71	63	67	67	67	67	67
Animal Feed	3 761	3 761	3 761	3 761	3 761	3 761	3 714
Coffee Roasting	28	28	28	28	28	28	28
Milling	4 292	4 345	4 172	4 406	4 611	4 466	5 021

\* (a) Beverages expressed in million liters; food products in kton.

Table 4.24 – Annual production in the Food and Beverage Industry (cont)

Product	1997	1998	1999	2000	2001	2002
White wine <sup>(a)</sup>	392	392	392	392	392	392
Red Wine <sup>(a)</sup>	478	478	478	478	478	478
Beer <sup>(a)</sup>	677	687	687	687	687	687
Spirits <sup>(a)</sup>	14	14	14	14	14	14
Wheat Bread	172	187	172	158	143	129
Other Bread	16	17	16	14	13	11
Cakes	38	38	38	38	38	38
Fish	238	238	238	238	238	238
Sugar	348	323	328	334	339	344
Margarine	67	67	67	67	67	67
Animal Feed	3 809	3 761	3 761	3 761	3 761	3 761
Coffee						
Roasting	27	28	28	28	28	28
Milling	4 741	4 882	4 678	4 645	4 735	4 748

\* (a) Beverages expressed in million liters; food products in kton.

## RECALCULATIONS

No changes have been made since last submission in what concerns GHG emission estimates for this source sector. Emission estimates of Particulate Mater from grain milling is included in national inventory for the first time.

## 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).

### 4.2.D.3 PAPER PULP PRODUCTION

#### OVERVIEW

In Portugal there were in 1990 six paper pulp plants using kraft process and two units using the acid sulphide process. Later, in 1993, one of the smaller of the acid sulphide plants was decommissioned and nowadays only 6 plants remain in operation.

Kraft pulping is essentially a digestion process of wood by a solution of sodium sulphide ( $\text{Na}_2\text{S}$ ) and sodium hydroxide ( $\text{NaOH}$ ) (white liquor) at elevated temperature and pressure that dissolves lignin and leaves cellulose fibers unbind. Apart from digestion other relevant industrial processes include pulp washing, pulp drying, chemical recovery of reactants (sulphur and quicklime) and possibly bleaching. Recovery of sulphur from the spend cooking liquor and washing water (black liquor) includes combustion in the recovery furnace, after concentration in evaporators, and reaction with water and quicklime of the green liquor in a causticizing tank generating white liquor and lime mud. Quicklime is recovered by combustion in a lime kiln.

Emissions of sulphur compounds, including mercaptans, dimethyl sulphide, dimethyl disulphide and  $\text{H}_2\text{S}$ , occur in digester and blow tank relieves, in evaporators, and in the lime kiln. In the recovery furnace sulphur compounds are oxidized to  $\text{SO}_x$ , 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<sub>2</sub> 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 (Pulp<sub>PROD</sub> - ton AD/yr) after applying emission factors (EF - kg/ton AD) specific of each pollutant:

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

## 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 USEPA (1990) 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 4.25 - Emission Factors for paper pulp production (non combustion)

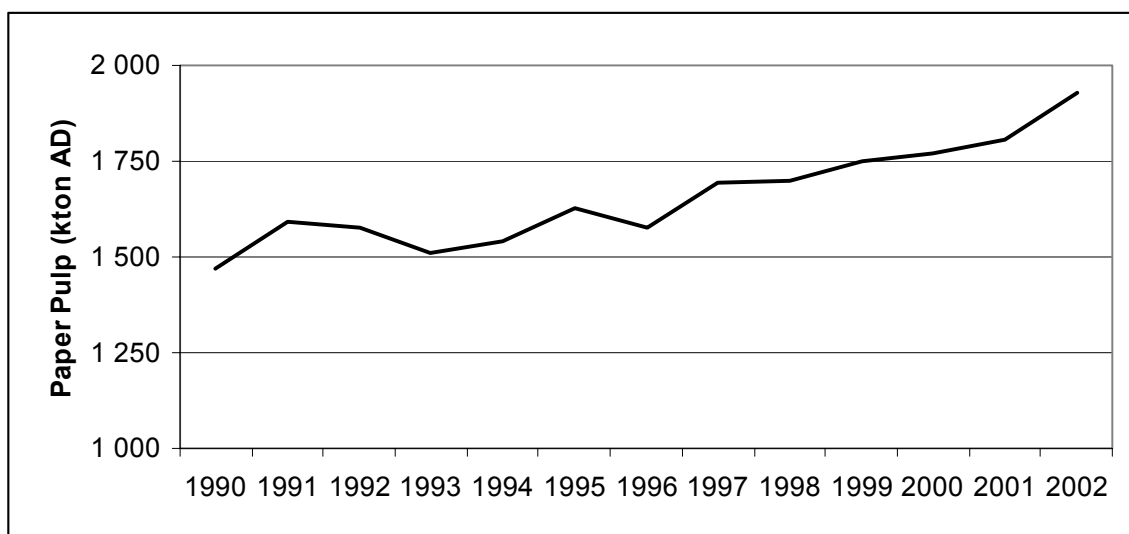
Process	SO <sub>x</sub>	NO <sub>x</sub>	COVNM
Kraft	0.31	1.95	2.74
Sulphide	35.5		

## 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 production<sup>75</sup> 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.

<sup>75</sup> Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

Figure 4.14 - Total production of paper pulp - Kraft and semi-sulphide (1990-2002)



## RECALCULATIONS

The time series for sulphide production has been revised for the all period 1991 to 2002, with information collected from CELPA. Concerning Kraft process, activity data for 1990 to 2000 is still resulting from information collected under LCP directive while values for 2001 and 2002 were delivered also by CELPA.

## FURTHER IMPROVEMENTS

Emission factors for SO<sub>x</sub>, NO<sub>x</sub> 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).

## 4.2.E Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2F)

### 4.2.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 (SF<sub>6</sub>)<sup>76</sup> are the most important among those compounds. CFC and HCFC are already under control and being phased out under the Montreal Protocol, as consequence of their role as Ozone Depleting Substances (ODS). Therefore, under the United Nations Convention on Climate Change it was decided to consider in the GHG inventory those substances not included in the Montreal Protocol: HFC, PFC and SF<sub>6</sub>.

Some emission sources are still not included in the inventory:

<sup>76</sup> Other substances with greenhouse gas potential but less common are NF<sub>3</sub> and some halons. They are not included neither in Montreal Protocol neither in FCCC.

- 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 N<sub>2</sub>O. 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). The use of HFC as a solvent represents probably a minor source in global terms;
- Fire Protection. Fire protection systems using fluorine gases are mostly fixed equipments (acting by flooding) and are used mainly to protect electronic equipment. In Portugal there is no information concerning this type of fire suppressant and emissions from this sub-source must remain unaccounted;
- HFC gases used as aerosols propellants in imported products, including Metered Dose Inhalers (MDI).

Some emissions sources are not completely included 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:

- First-fill emissions of Mobile Air-conditioning (MAC) systems. There is no available information concerning the installation of MAC in new cars or aftermarket MAC system;
- Operation and disposal emissions of MAC systems in heavy-weight vehicles: heavy duty, busses and coaches;
- HFC emissions from closed-cell foams imported and used in Portugal;
- some non-electrical use of SF<sub>6</sub> such as gas tracer in air dispersion and air emission studies.

One source, HFC-23 emissions from HCFC-22 manufacture, did not exist in Portugal during the reporting period and is reported as Not Occurring (NO)

#### 4.2.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 (IPCC,2000). 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 filled<sup>77</sup>;
- operation emissions, occurring during equipment lifetime or usage and resulting mainly from leaks;
- 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.

#### 4.2.E.3 RECALCULATION

No significant changes have been made since last year submission. The only modification, apart from update of time series until emission year 2002, was the revision of number of cars provided with MAC. An error was detected in the submission of last year: the number of cars equipped with a MAC in each year was estimated equal to the percentage of cars sold in that year that were equipped with a MAC. Now, and in a more appropriate way, the number of cars with MAC is estimated from the time series of cars that were sold in previous years and correspondent time series of percentages of cars sold with MAC.

#### 4.2.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:

- Emission of F gases from manufacturing, operation and disposal of certain sources that were not estimated because no reliable activity data was available: Fire extinguishers; Aerosols; Metered Dose Inhalers; solvent use and semiconductors. Although it is probable that these sources are minor and less relevant in Portugal, further work should be developed to obtain activity data for these sources.
- There are still no estimates of HFC emissions from industrial refrigeration units due to the lack of information on basic activity data. This situation will be improved in the future.
- Inclusion of emissions of mobile AC in heavy duty vehicles, buses and coaches. And a better knowledge of the time series of light vehicles with AC should also be followed.
- 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.
- Whenever possible a study of a better characterization of refrigeration equipment in households should be followed.
- The consideration of refilling of refrigeration equipments should be better addressed in the inventory.
- A better knowledge of the fleet of refrigerated vehicles will be followed together with the development of a time series.
- Differentiation as much as possible between foam types: closed cell/open cell and polymer constitution;

---

<sup>77</sup> Assembly emissions could include also emissions during refilling but no data was available to make this distinction

- 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.

#### 4.2.E.5 DOMESTIC REFRIGERATION

##### METHODOLOGY

CFC, HCFC and HFC emissions from operation and disposal of Domestic Refrigeration Equipments were estimated using the bottom-up approach (Tier 2 or actual method) as proposed in chapter 3.7.4 of the GPG (IPCC,2000).

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

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip\%(t,y) \cdot HFC\%(j,y)]$$

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  $t$ ;

$K$  - 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 (IPCC,2000) table 3.22.

Table 4.26 - Emission Factors of HFC gases from Domestic Refrigeration

Emission Factor (percentage of initial charge)	
Charging	Lifetime emission
0.6	0.3

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* (IPCC,1997).

## ACTIVITY DATA SOURCES

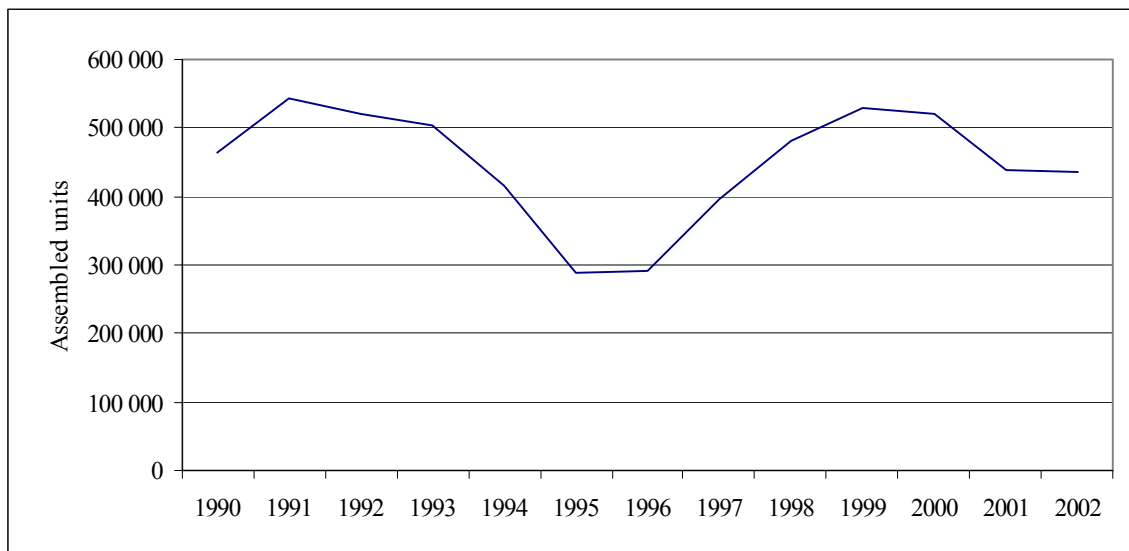
The stock of domestic refrigeration equipments was estimated from the number of households and from the percentage of households with refrigeration equipments, available for years 1990 and 1995 according to an unpublished report from INE. From year 2000 onward the percentage of equipments per household 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 4.27 - Percentage of households in Portugal provided with refrigeration equipments

Equipment	1990	1995	2000 and beyond
Combined (Refrigerator and Freezer)	91.9	96.1	100
Freezers	34.4	50.6	50

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<sup>78</sup>. Values for 2001 and 2002 were forecasted by IA.

Figure 4.15 – Number of assembled refrigeration units (1990-2002)



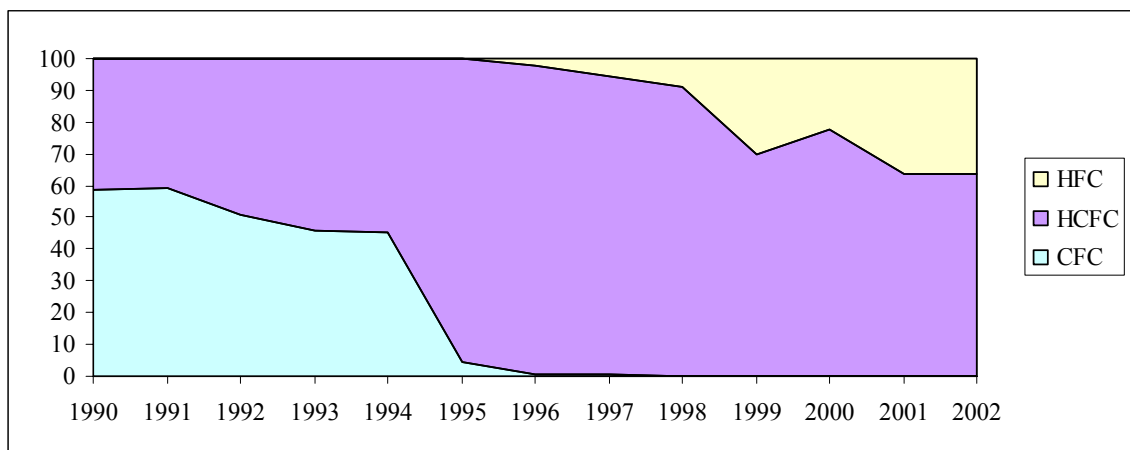
Number of disposed units (scrap rate) is not available in Portugal. It was assumed that 10% of the stock is removed every year.

#### OTHER RELEVANT DATA AND PARAMETERS

The share of each F-gas used in the assemblage of refrigeration equipments was estimated for each year relying on importation data from a relevant national importer and supplier of assemblage units. Although this data does not covers the totality of national market it was considered well representative of the situation. HFC has been imported since 1996 and has been increasingly substituting HCFC import. The share of import of each gas can be seen in the following figure. According to the same data source HFC used in Portugal in refrigeration equipments comprehend HCF 134a, HFC 125 and HFC 143a.

<sup>78</sup> The distinction between assembled domestic units and commercial/institutional units it is not always clear in the statistical results. It was decided to include here all refrigeration units with a opaque door and in commercial/institutional assemblage all units with a showing panel.

Figure 4.16 - Percentage of imported fluorine gases in Portugal by gas type (1990-2002)



The percentage of each gas in the existing stock in each year is estimated using the arithmetic average in the lifetime period of each equipment type. 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 equipment<sup>79</sup>. Prior to 1990 no HFC was used in the assemblage of refrigeration units and it was assumed that there is an equal share of R12 and R 502. Lifetime of domestic equipments was set at 12 years, the lower value in table 3.22 of GPG (IPCC,2000).

The quantity of refrigeration gas charged into the equipment was assumed at an average value of 100 g/equipment unit (Seixas et al, 2000 after information from APIRAC) which is well within the range set in GPG table 3.22 (IPCC,2000).

#### 4.2.E.6 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 2 or actual method) as proposed in chapter 3.7.4 of the GPG (IPCC,2000).

Lifetime and disposal emissions<sup>80</sup> 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

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

<sup>79</sup> In consequence no emissions of HFC from disposal are estimated for the reported period.

<sup>80</sup> Assembly emissions are included in domestic refrigeration because the discrimination of equipment usage it is not feasible for all years



## 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 compound were estimated from total refrigeration gas emissions and considering the percentage of HFC use in total refrigeration gas use in each particular year, according to the following equations:

## Assembly

$$\text{Ass}_{\text{Emi}}(t,j) = \text{Ass}_{\text{Emi}}(t) \cdot \text{HFC}_{\%}(j,t)$$

## Operation/ Lifetime

$$\text{Oper}_{\text{Emi}}(t,j) = \text{Oper}_{\text{Emi}}(t) \sum_{y=t}^{t\text{-Lifetime}} [\text{Equip}_{\%}(t,y) \cdot \text{HFC}_{\%}(j,y)]$$

## 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;

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 (IPCC,2000).

Table 4.28 - Emission Factor for F-gas emissions from commercial, industry and services refrigeration equipments

Emission Factor (percentage of initial charge)	
Charging	Lifetime emission
1.8	5.5

Similarly no recovery of gas was considered at end of product life ( $z=0$ ) and the emitted quantity to the atmosphere is therefore the residual product remaining in equipment (variable  $y$ ) which was set at 90% from 1996 IPCC Revised Guidelines (IPCC,2000).

### ACTIVITY DATA SOURCES

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.

The number of refrigeration equipments was estimated from the following economic activities, for which unit numbers were available from National Statistics Institute (INE):

Table 4.29 - Number of commercial installations in Portugal provided with refrigeration equipments

Activity	number	Period
Hotels	1 753	1995
Restaurant & café	36 453	1995
Food & Beverage stores	49 844	1995
Hypermarkets	88	1997
Total	88 138	-

The following assumptions were made by IA:

- the number of equipments per activity was set with the technical support of APIRAC, according to the following table:

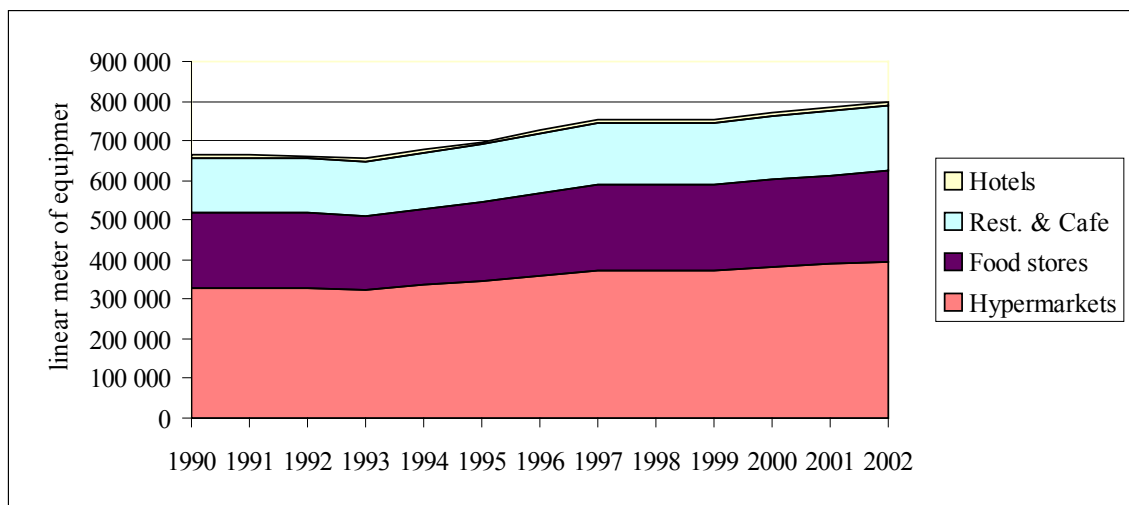
Table 4.30 - Number of refrigeration equipments per commercial unit in Portugal

Activity	Equipments (m/unit) <sup>1</sup>
Hotels	4
Restaurant & Café	4
Food & Beverage stores	4
Hypermarkets	240

<sup>1</sup> linear meter per activity unit

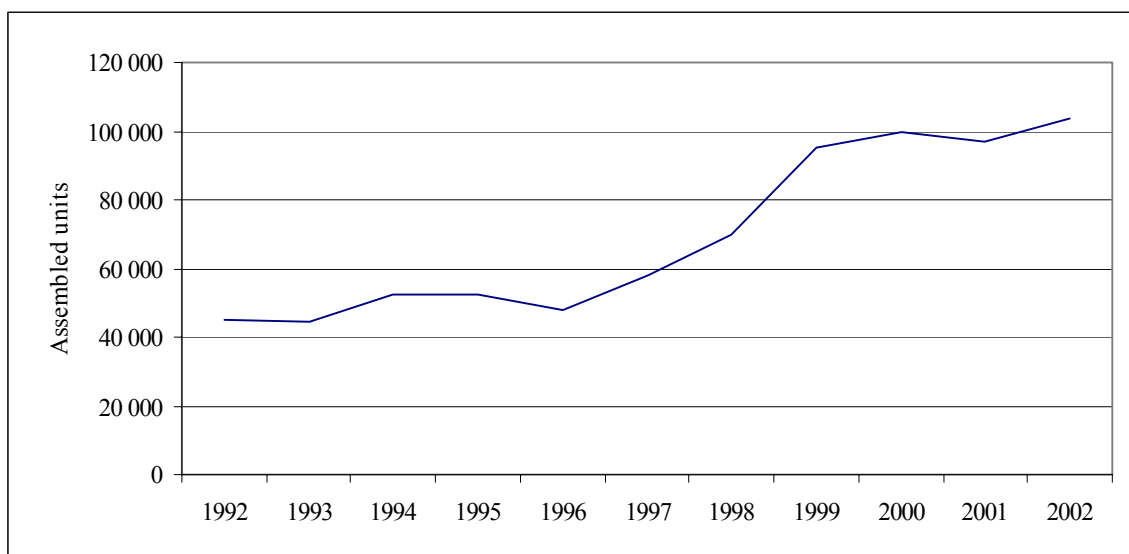
- the activity data time trend was assumed to follow Gross National Product (GNP) in the period 1990-2001.

Figure 4.17 - Refrigeration Equipments in commercial activity in Portugal (1990-2002)



Assemblage of commercial and industrial refrigeration units is only available after 1992 with data collected under the new Industrial Survey (IAP) and refers to refrigeration with a showing panel. Numbers are comparatively smaller than domestic units and are presented in next figure. Values for 2001 and 2002 were forecasted by IA.

Figure 4.18 - Assemblage of commercial and industrial refrigeration units in Portugal (1992-2002)



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.

#### 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 10 years, the average value proposed in GPG table 3.22 for commercial units (IPCC,2000).

IPCC GPG (IPCC,2000) admits a too much wide range for the charge in commercial stand-alone refrigeration equipments. The considered value, 450 g per linear meter of equipment unit,

results from information from an equipment supplier in Portugal. Stand alone equipments were assume to predominate in Portugal.

#### 4.2.E.7 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 2 or actual method) as proposed in chapter 3.7.4 of the GPG (IPCC,2000). Lifetime and disposal emissions<sup>81</sup> were estimated according to the following set of equations after 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 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;

<sup>81</sup> Assembly emissions are not estimated and they are included in assemblage of other refrigeration equipments

$Equip_{\%(t,y)}$  - 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

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 (IPCC,2000). 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* (IPCC,2000) and no recovery is assumed at disposal.

## ACTIVITY DATA SOURCES

A constant fleet of 15 937 vehicles provided with refrigeration equipments for transport was provided by the Portuguese Authority on Vehicles (DGV).

## OTHER RELEVANT DATA AND PARAMETERS

It was assumed that each refrigeration transport vehicle has 5.5 kg of refrigeration gas, the average value recommended by the IPCC GPG in table 3.22 (IPCC,2000). Lifetime was set at 8 years also the average value from table 3.22 of IPCC GPG (IPCC,2000).

### 4.2.E.8 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 2 or actual method) as proposed in chapter 3.7.4 of the GPG (IPCC,2000).

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

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} \cdot HFC_{\% (j,t)}$$

## 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;

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 (IPCC,2000).

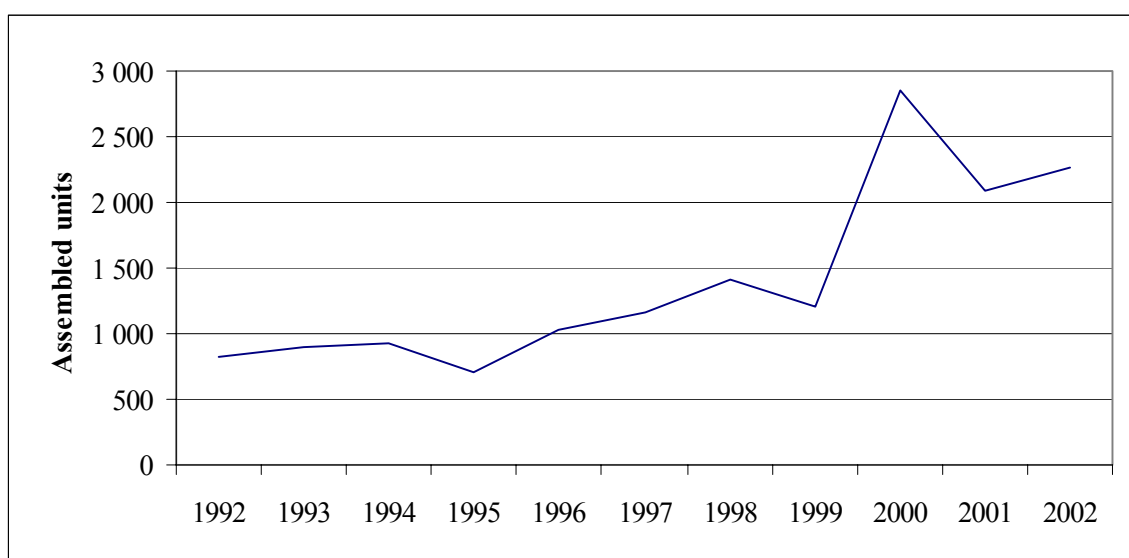
No recovery of gas was considered at end of product life (z=0). The emitted quantity to the atmosphere is therefore the residual product remaining in equipment (variable y) which was set at 90% from IPCC 1996 Revised Guidelines (IPCC,1997).

## ACTIVITY DATA SOURCES

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 INE, the following time series (Figure 4.19), from 1992 to 2002, was assumed in the inventory. Activity data for 2001 was forecasted from 1992-2000 time series. According to IAIT, 50 821 and 63 108 units were assembled respectively, in 1990 and 1991<sup>82</sup>.

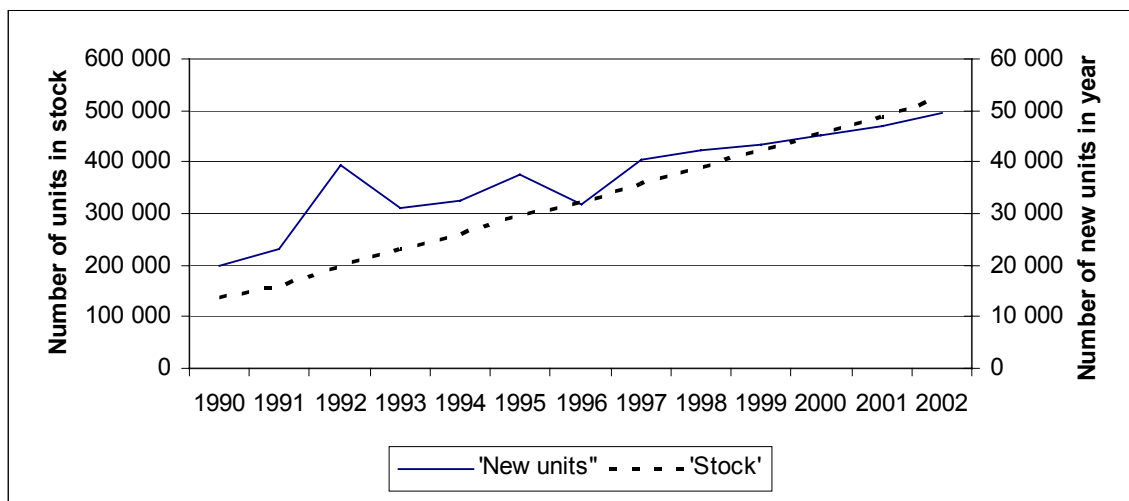
Figure 4.19 - Number of stationary air-conditioning assembled in Portugal in the period 1990-2001



The stock in existence and yearly disposed units is available from unpublished information received from IST-UTL. The time series from 1990 to 2002 is presented in next figure.

<sup>82</sup> Due to difference in magnitude order these values from IAIT are not shown in the graph

Figure 4.20 - Stationary air-conditioning: Annual new equipment units installed and annual stock of equipments in Portugal (1990 to 2002)



#### 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 same F-gas composition that was used to refrigeration equipments is also used for this emission source.

#### 4.2.E.9 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 2 or actual method) as proposed in chapter 3.7.5.1 of the GPG (IPCC,2000). Due to lack of information it was not possible to estimate emissions by vehicle class and age. Emissions refer only to light vehicles<sup>83</sup>. Nevertheless 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:

<sup>83</sup> Although in calculation worksheets space is already available for class desegregation it is still not possible to know the number of vehicles with MAC per class



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

Operation emissions are estimated with an annual rate of 15%, the average of the updated default range (10-20%) in IPCC GPG (table 3.23) (IPCC,2000). Lifetime was set at 12 years also the default value both in IPCC 1996 Revised Guidelines (IPCC,1997) and IPCC GPG (IPCC,2000).

The emitted quantity to the atmosphere equals the residual product remaining in equipment (variable y) and was set at 40 % the new default value in IPCC GPG (IPCC,2000).

## ACTIVITY DATA SOURCES

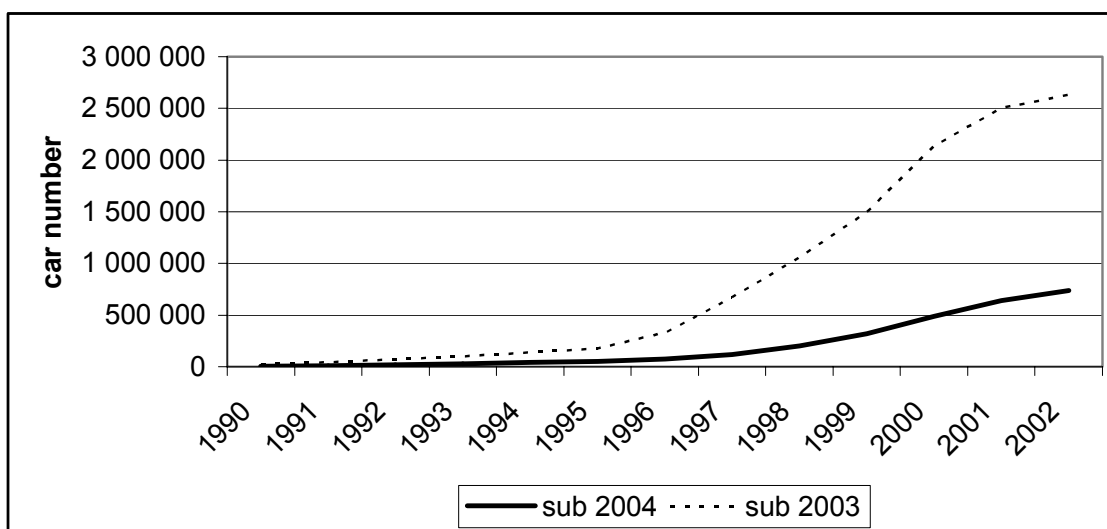
There is scarce information concerning the fleet of road vehicles with air conditioning equipment. The number of light vehicles with MAC were estimated from the total number of light vehicles that are sold each year, using the same information that was used to establish the time series of car sales and fleet in chapter 1A3, and the percentage of new cars sold with MAC in each year in Table 4.31, according to information collected in Seixas et al (2000). Total number of vehicles equipped with MAC is presented in Figure 4.21 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.

Table 4.31 - Number of new light vehicles equipped with Mobile Air Conditioning

Year	Light Vehicles with MAC (%)	Source/ assumptions
1990	1	Top class vehicles only
1995	5	Top class vehicles
2000	50	Figure for most important passenger car

Figure 4.21 - Estimated number of Light Vehicles equipped with MAC systems (1990-2002)



Emissions do not cover air MAC equipments installed on heavy vehicles, buses and coaches.

#### OTHER RELEVANT DATA AND PARAMETERS

The assumed quantity of initial charge is 1.2 kg/MAC unit. IPCC GPG (IPCC,2000) proposes an initial charge of 0.8 kg/MAC for passenger cars and 1.2 kg/unit for light trucks while, however, *1996 IPCC Revised Guidelines* (IPCC,1997) refers 1.2 kg/MAC as adequate for cars<sup>84</sup> and 0.8 kg/MAC is only proposed for new Japanese cars. Because information between these two sources is contradictory it was decided to maintain the previous figures and change it only after complete clarification of the issue.

It was assumed that HFC 134a is the only HFC substituting CFCs and HCFC, which agrees with IPCC GPG (IPCC,2000).

<sup>84</sup> According to UNEP Technical Options Report (UNEP, 1989)

## 4.2.E.10 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.

## METHODOLOGY

It was assumed that all HFC were used in closed-cell foam and that other gases are used in open-cell foams. It was not possible however to distinguish the type of foam where the filling gas is used. Methodology is classified as Tier 2, using national data but with default emission factors. Therefore emissions comprehend:

First year losses from Foam Manufacture and Installation

$$FGas_{Emi(t,j)} = FillGas_{Consumption(t)} * HFC\%(j,t) * (k/100)$$

Annual losses.

$$FGas_{Emi(t)} = FGas_{inFoam(t)} * (x/100)$$

$$FGas_{inFoam(t,j)} = \sum_{y=t}^{t-Lifetime} [FillGas_{Consumption(y)} * HFC\%(j,y)]$$

Where:

$FGas_{Emi(t,j)}$  - gas emission 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 t<sup>85</sup>;

K - first year loss emission factor;

X - annual loss emission factor.

This formulation is similar to equation 3.38 of the GPG (IPCC,2000).

Emissions due to decommissioning of foams was not included in estimates due to the lack of necessary information about foam stock and the expected lifetime of foams. It was assumed that the lifetime period is larger<sup>86</sup> than the time between the first use of HFC and 2002.

## 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 4.32 - Emission Factors to estimate F gas emissions from foam losses

Emission Factor		EF (% Original Charge)
K	First Year Losses	10
x	Annual Losses	4.5

## ACTIVITY DATA SOURCES

Statistical data concerning the use of HFC in foam manufacture is very scarce. According to information in an unpublished article (Carreira, 2002) the foam industry has shifted mainly to cycle-pentane as blowing agent and only a few still produce foams with HCFC or more recently HFC. The share of each blowing agent from 1998 to 2001 is presented in next table (Carreira, 2002).

Table 4.33 – Total quantity of blowing agents used in Foam Blowing in Portugal (ton/yr)

F-gas	1999	2000	2001
HCFC 141b	220	150	120
HCFC 142/22	70	70	60
HFC 134a	20	30	35
HFC 134a/152	-	30	35
Total	310	280	250

It was assumed that no HFC gas was used in foams before 1998.

For closed-cell foams activity data should be corrected from imports and exports. HFC in foams imported result in annual losses emissions while HFC included in foams exported should be deduced from national emissions. Available statistical data at present moment is not detailed enough to differentiate HFC foams from other blowing agent foams neither in imports nor in exports and the option was to consider in the inventory only emissions from foams manufactured in Portugal.

<sup>85</sup> For the time being the stock is restricted to foam filled in Portugal;

<sup>86</sup> Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)

## FURTHER IMPROVEMENT

After CRF tables completion, a mistake was detected in the spreadsheets where calculations are done. This will be corrected in next submission.

### 4.2.E.11 ELECTRIC EQUIPMENT

#### OVERVIEW

In Portugal, Sulphur hexafluoride (SF<sub>6</sub>) 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.

#### METHODOLOGY

Actual emissions of SF<sub>6</sub> from electrical equipment were estimated with a tier 2b method and using a country-specific emission factor. Emissions are determined using the following equation:

$$Emi_{SF_6(t)} = Stock_{SF_6(t)} * (k/100)$$

where:

$Emi_{SF_6(t)}$  - Equipment use emissions, including leakage emissions, servicing and maintenance;

$Stock_{SF_6(t)}$  - total SF<sub>6</sub> gas in existence in year t in all electrical equipments;

k - percentage of SF<sub>6</sub> 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 company responsible for electricity transmission at high voltage (REN). The emission factor was calculated comparing total SF<sub>6</sub> contained in REN equipments with the quantity of SF<sub>6</sub> that is used annually for losses reposition in years 1995 and 1998-2000, in a similar manner to that recommended in GPG (IPCC,2000) for the development of emission factors. It was assumed that reposition quantities equal losses due to equipment failure. The emission factor used for all years is the average value in the period, and it was set as 0.9%. This value is slightly smaller than the default emission factor recommended in the *1996 IPCC Revised Guidelines* (IPCC,1997). The GPG (IPCC,2000) proposes higher values, 5% for equipments installed before 1996 and 2% thereafter. It was assumed that this country-specific emission factor applies also to non-REN users and also to specific uses: insulating gas in electric equipment.

#### ACTIVITY DATA SOURCES

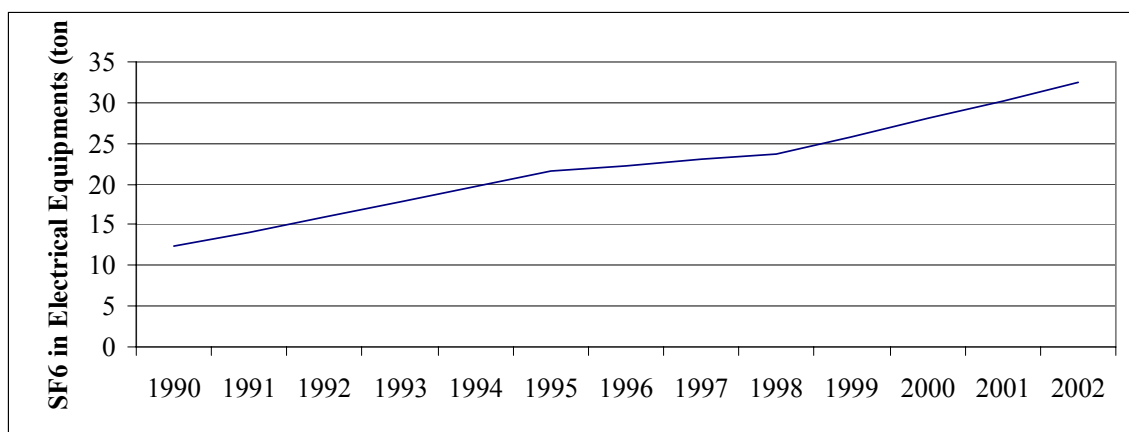
Activity data was available directly from REN, the major national electricity distributor, but only for a restricted number of years (1990, 1995, 1998 and projections for 2020). Information for circuit switch breakers and substations for the available years is presented in next table.

Interpolation was done to estimate SF<sub>6</sub> stock in equipments for intermediate years, and total SF<sub>6</sub> can be seen in Figure 4.22.

Table 4.34 - Quantity of Sulphur hexafluoride stock in Electric Equipments in Portugal

SF <sub>6</sub> (tons)	1900	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 4.22 - Total SF<sub>6</sub> in stock in electric equipments in Portugal (1990-2002)



### 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 SF<sub>6</sub> used to replace leaked gas but only for that part of total stock that is managed by REN. But it is viable to extend that survey to the rest of total country use of SF<sub>6</sub> in electrical equipments.

## 4.2.E.12 RECALCULATIONS

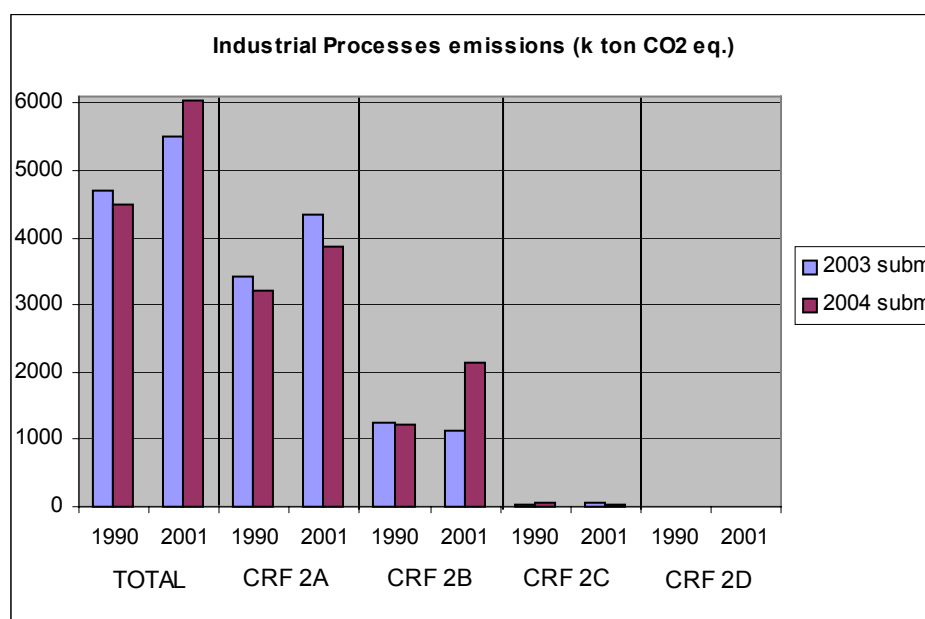
Figure 4.23 - Differences between 2003 and 2004 submissions for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions

Table 4.35 - Recalculations (differences between 2003 and 2004 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
			2003	2004	Difference	2003	2004	Difference	2003	2004	Difference
			subm.	subm.	(1)	subm.	subm.	(1)	subm.	subm.	(1)
			CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)
<b>1990</b>											
<b>2. Industrial Processes</b>			<b>4,093.87</b>	<b>3,903.72</b>	<b>-4.64</b>	<b>8.32</b>	<b>9.08</b>	<b>9.13</b>	<b>602.88</b>	<b>566.68</b>	<b>-6.01</b>
2.A.	Mineral Products		3,425.67	3,219.50	-6.02	0.00	0.76	0.00	0.00	0.00	0.00
2.B.	Chemical Industry		632.82	632.88	0.01	8.32	8.32	0.00	602.88	566.68	-6.01
2.C.	Metal Production		34.94	50.90	45.68	0.00	0.00	0.00	0.00	0.00	0.00
2.D.	Other Production		0.44	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.G.	Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>2001</b>											
<b>2. Industrial Processes</b>			<b>4,899.15</b>	<b>5,434.18</b>	<b>10.92</b>	<b>10.58</b>	<b>12.05</b>	<b>13.86</b>	<b>606.24</b>	<b>582.34</b>	<b>-3.94</b>
2.A.	Mineral Products		4,330.02	3,858.78	-10.88	0.00	1.76	0.00	0.00	0.00	0.00
2.B.	Chemical Industry		506.51	1,540.16	204.07	10.58	10.29	-2.73	606.24	582.34	-3.94
2.C.	Metal Production		62.19	34.81	-44.02	0.00	0.00	0.00	0.00	0.00	0.00
2.D.	Other Production		0.44	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.G.	Other		0.00	0.00	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% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission).

## CHAPTER: 5 : SOLVENT AND OTHER PRODUCT USE (CRF 3)

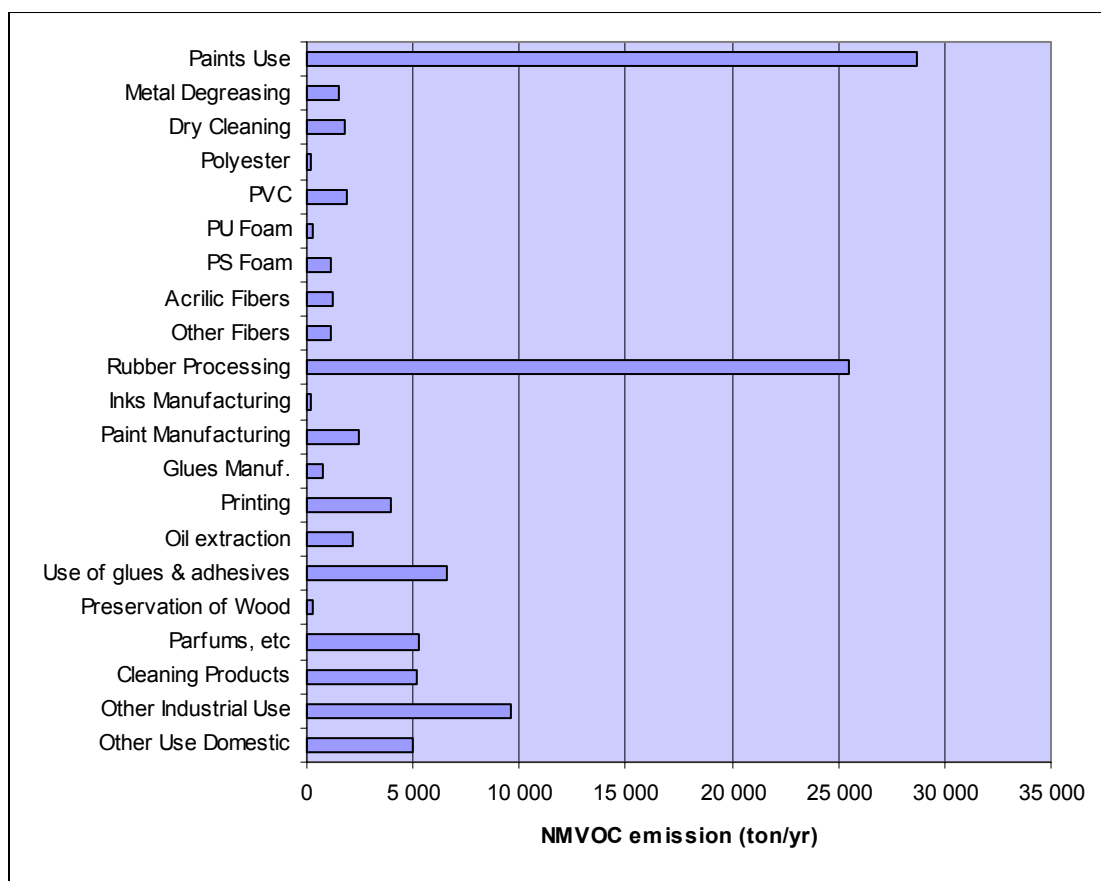
### 5.1 Overview

Solvents and related compounds are a significant source of emissions of non-methane volatile organic compounds (NMVOC). Although emissions of N<sub>2</sub>O could also be included in this source, if resulting from use of this compound as component in specific applications, estimate for these sources is still undone in 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, as some solvents remain in product or are conveyed into wastewater. However, because eventually they are liberated to atmosphere, all solvent losses may be assumed to be air emissions. On the other hand, emissions of solvent in products may occur in three phases: during production, during actual use and during disposal.

Main sources of NMVOC from this sector in Portugal during the period 1990-2002 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 2002. It is evident the prevalence of emissions from paint use, rubber processing and other use of solvent products.

Figure 5.1 - NMVOC emissions from Solvent Use per individual source category in 2002

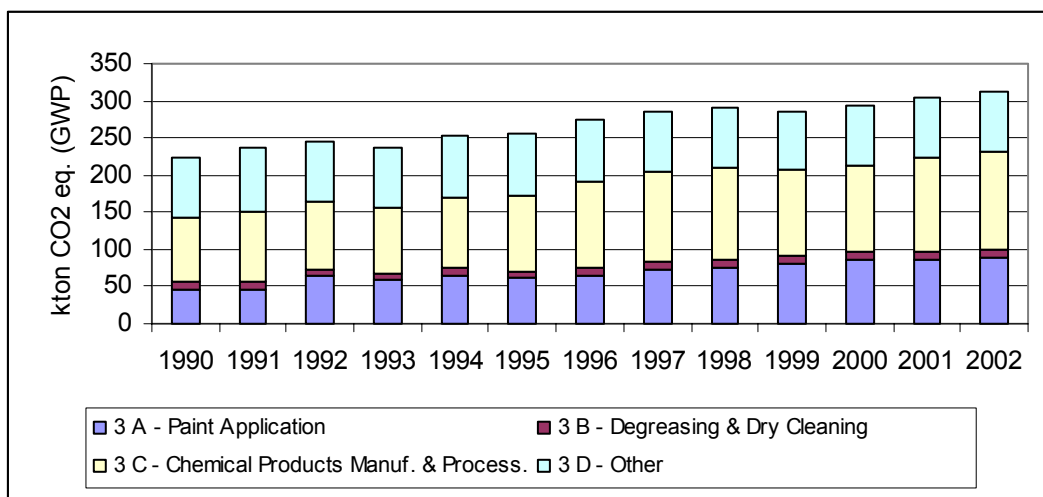


NMVOC emissions estimates should be converted in CO<sub>2</sub> when the carbon that is present in organic compounds has fossil fuel origin (originated from feedstocks from petroleum, coal or natural gas), being assumed that NMVOC compounds are oxidized in air contributing with carbon dioxide to the atmospheric pool.



Total GHG emissions from this source sector have increased steadily in the period from 1990 to 2002, from 222 kton of CO<sub>2</sub> in 1990 (which is only 0.47 % of total CO<sub>2</sub> emissions or 0.37% of total GWP CO<sub>2</sub> eq) to 313 kton CO<sub>2</sub> eq. in 2002. All emissions are quantified as carbon dioxide in Figure 5.2.

Figure 5.2 - GHG emissions from Solvent Use per source sub-sector (1990-2002)



## 5.2 Category Sectors

### 5.2.A Paint Application (CRF 3A)

#### 5.2.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 appearance<sup>87</sup> – such as paints, stains, varnishes, enamels and lacquers, either in buildings or artifacts, and either from professional activities or domestic use. Emissions due to the use of inks and textile coloring are not included here. Emissions from Paint manufacturing are discussed in 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 car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities, domestic use, etc.

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).

<sup>87</sup> Non continuous applications of coatings is printing industry and is included in other sub-source category. Application of continuous layers for gluing materials, by the use of glues or adhesives is also considered elsewhere.

### 5.2.A.2 METHODOLOGY

NMVOC emissions from use of coating materials are simply estimated using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \sum_a \sum_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(y)}$  – NMVOC emissions resulting from use/application of coating substances during year y (ton/yr);

$Coating_{CONS(a,p,y)}$  – Use of coating substance p in economic activity a during year y (ton coater/yr);

$EF_{(p)}$  – NMVOV emission factor (solvent content) resulting from application of substance p (kg/ton).

Ultimate CO<sub>2</sub> emissions were calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO<sub>2</sub> emissions are included in the inventory as CO<sub>2</sub> eq.

$$U_{CO_2} = 44/12 * NMVOC * 0.85$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

### 5.2.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 Portugal<sup>88</sup>.

<sup>88</sup> 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 5.1 - 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 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.

Table 5.2 – 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

#### 5.2.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

type<sup>89</sup>, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 5.3.

Table 5.3 – Paint Production in Portugal by Paint Type in ton/yr (1990-2002)

Type	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Water	Acrylic & Vinyl	#	#	76	64	72			89	103		102		113
	Alkyd & Other	#	#	811	714	375	66 924	80 693	371	585	99 909	718	108 629	530
	Other	78 380	619	211	118	98	102	1 181	1 397	1 639	671	1 883	1 872	2 084
Solvent	Acrylic & Vinyl	#	#	248	48	23	76	134	136	562	535	546	572	635
	Acrylic & Vinyl Low solv.	#	#	0	0	0	63	439	743	2 089	2 476	2 335	2 707	3 068
	Alkydic	#	#	13	10	10			12					
	Celulosic	7 579	7 215	5 663	5 552	5 242	3 679	4 343	4 367	4 401	3 971	3 144	3 167	2 903
	Poliester	#	#	2 155	1 688	1 315	890	1 810	1 849	2 873	3 620	4 247	3 792	4 096
	Other	13 981	13	10					13					
Oil		14 789	13											
Powder		2 069	800	318	364	353	392	430	423	539	556	588	612	647
Other		1 164	1 357	37	2 181	2 133	2 363	2	68	364	310	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 5.4 and Table 5.5, respectively for imports and exports.

Table 5.4 –Import of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint Type	Resin/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 5.5 –Export of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint Type	Resin/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;

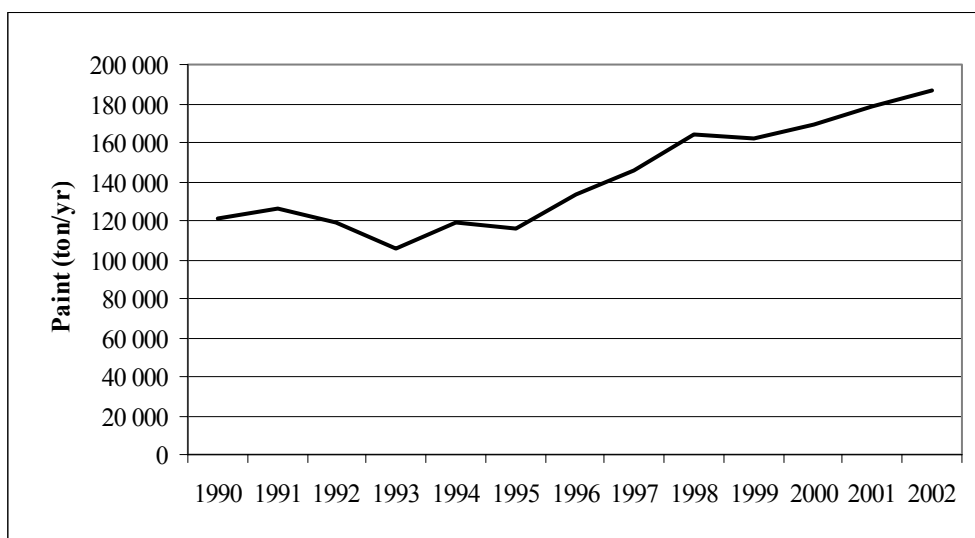
Hence, total consumption of paints was calculated from 1990 and 2000, and the resultant time series is presented in Table 5.6 and in Figure 5.3. Values for 2001 and 2002 result from forecasts made at IA from the available time series of paint consumption.

<sup>89</sup> 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 5.6 –Estimated total consumption of Paints in Portugal by Paint Type (1990-2002)

Type	Polimer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Water	Acrylic & Vinyl	151	438	77 658	65 196	74 616	70 233	83 520	91 575	106 483	101 730	104 198	111 204	116 218
	Alkyd & Other	78 800	82 388	826	1 311	2 036	4 593	7 401	7 514	8 624	6 067	7 337	9 780	10 720
Solvent	Acrylic & Vinyl	78	77	326	149	1 388	514	701	558	918	996	925	1 057	1 124
	Acrylic & Vinyl Low	0	0	0	1 428	2 730	3 853	5 043	4 142	6 821	6 718	7 510	8 781	9 688
	Polyester	0	217	3 090	3 280	1 667	1 222	0	1 646	0	1 624	3 794	1 392	1 307
	Alkyd, celulosic & ot	24 873	25 286	34 473	29 503	31 187	29 138	32 412	35 857	35 871	38 345	38 801	38 948	39 946
Oil	-	14 363	13 601	122	0	33	457	433	547	514	699	554	780	861
Powder	-	2 069	2 542	2 896	2 889	3 269	3 747	3 618	3 843	4 706	5 846	5 759	6 004	6 392
Other	-	1 037	1 436	48	2 164	1 939	2 271	0	39	343	406	576	576	576
Total	-	121 371	984	438	920	866	029	129	145 721	164 281	162 433	169 453	178 521	186 833

Figure 5.3 - Estimated total consumption of Paints in Portugal (1990-2002)



Finally total consumption of paint was desegregated 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 5.7. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction<sup>90</sup>, as well as all use of oil and powder paints.

<sup>90</sup> No further desegregation by this uses is possible from available statistical information

Table 5.7 - Paint and varnish consumption in industrial activities (1990-2002)

Activity	Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Wood	Water	15	13	97	182	266	681	783	887	794	887	1 047	1 205	1 321
Plastic, cables		8	19	1 026	2 033	3 040	2 449	2 881	230	337	597	625	1 180	1 176
Glass and Ceramics		31	33	22	11	0	0	0	0	64	61	161	82	90
Metalic Equipment and furniture		0	0	0	0	0	0	0	0	0	0	0	0	0
Vehicles		0	0	0	0	0	0	0	0	0	0	0	0	0
Other machinery		35	33	22	11	0	2	46	53	84	92	93	89	97
Domestic, Serv. and Construction		78 862	82 728	77 317	64 271	73 347	71 694	87 211	97 920	113 828	106 161	109 609	118 428	124 255
Wood	Solvent	0	0	0	0	0	0	0	0	0	0	0	0	0
Plastic, cables		0	0	0	0	0	0	0	0	0	0	0	0	0
Glass and Ceramics		0	0	0	0	0	0	0	0	0	0	0	0	0
Metalic Equipment and furniture		838	996	664	332	0	0	1	1	3	36	34	34	34
Vehicles		1 581	1 242	836	430	24	28	630	690	735	685	1 874	799	800
Other machinery		476	444	1 936	3 428	4 920	5	12	11	16	16	23	23	23
		22 056	22 898	34 453	30 170	32 029	34 695	37 514	41 501	42 857	46 946	49 099	49 321	51 209
Domestic, Services and Construction	Oil	14 363	13 601	122	0	33	457	433	547	514	699	554	780	861
	Powder	2 069	2 542	2 896	2 889	3 269	3 747	3 618	3 843	4 706	5 846	5 759	6 004	6 392
	Other Paints	1 037	1 436	48	2 164	1 939	2 271	0	39	343	406	576	576	576

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by IA

### 5.2.A.5 RECALCULATIONS

Substantial improvements have been made in emission estimates for this source sector, since last submission. Besides the update of time series, the following main modifications were done:

- the number of classes of paint that are individualized has increased from simple differentiation of paints by solvent type, which was done in last year's submission, to more detailed classification, being now aware of resin polymer type and solvent content;
- National Emission Factors for consumption of National Produced Paint and Varnishes are no longer used, because there is no suitable statistical information in IAPI to determine equivalent emission factors (as could be done before from IAIT statistical database) and also because the ratio of external trade to national production is very high. Average values for this ratio are presented in Table 5.8, showing that the uncertainty in the consumption in Portugal of paints produced internally is very high. However, emission factors are still country specific and reflect expert opinion from major paint and varnish sellers;
- in previous submission, emissions from paint use were established for total use and then desegregation was done for each use according to paint consumption – and weighting for CORINAIR90 emission factors for each use – while in present submission emissions are estimated after allocation of paint use for each end user;
- Emission factor are now only dependent on paint type and not of end use of the paint, as was done in previous submission.

Table 5.8 – Average ratios of external trade (Maximum value between Importation and Exportation) over national production, in the 1990-2002 period

Paint Type	Resin	Ratio
Water Based	Acrilic & Vinyl	0.03
	Alkyd & Other	1.44
Solvent Based	Acrilic & Vinyl	0.62
	Acrylic & Vinyl low solvent content	1.20
	Polyester	2.11
	Alkyd, celulosic & Other	0.22
Oil Paints	-	2.65
Other Paints	-	0.61

### 5.2.A.6 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.

## 5.2.B Degreasing and dry cleaning (CRF 3B)

### 5.2.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, rubber<sup>91</sup>, textiles, glass, paper and fiber-glass, etc. Usually solvents used to achieve degreasing are petroleum distillates, chlorinated hydrocarbons, ketones and alcohols, and the cleaning process is usually done in tanks, which may have some form of emissions control (solvent recovery).

In essence dry-cleaning has the same objective to degreasing, seeking to remove, by the aid of solvents, of contamination or dirt from cloths, textile, furs, leather, down leathers, textiles or other objects made of fibers.

### 5.2.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.

<sup>91</sup> Emissions from degreasing in this industry are included under rubber processing

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several authors (USEPA, 1981; EMEP/CORINAIR (EEA,2002)). However, in Portugal there is no sufficient information to use this other approach.

CO<sub>2</sub> emissions are derived by assuming that 85 percent of the mass emissions of NMVOC is carbon:

$$U_{CO_2} = 44/12 * NMVOC * 0.85$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton);

NMVOC - Global emissions of NMVOC (ton).

### 5.2.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 5.9, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

Table 5.9 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	1992-2002
Metal Degreasing	1 552	1 415	1 484

Source:IAIT industrial survey (INE)

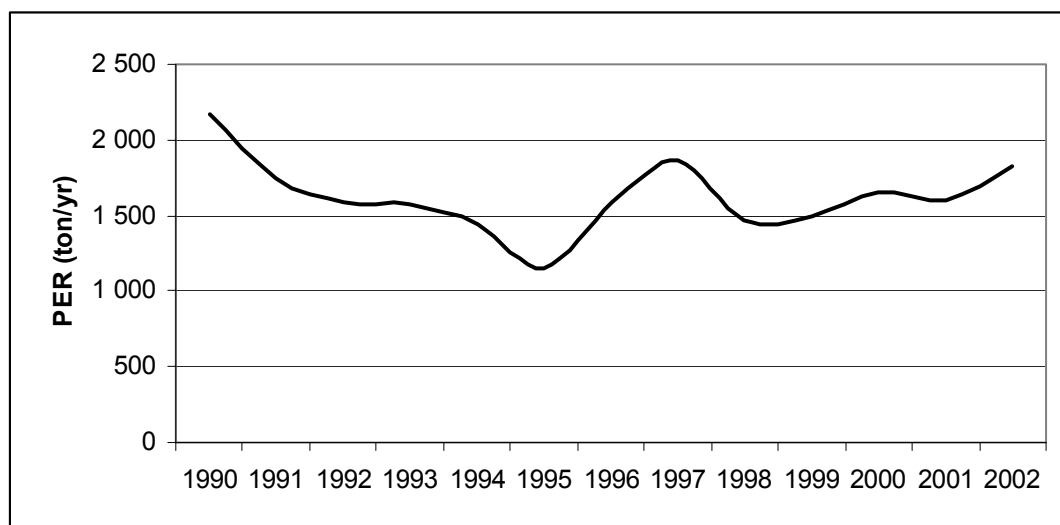
There are no available statistical information concerning consumption of solvents and other materials in dry-cleaning activity, because this activity is not included under IAIT and IAPI industrial surveys. Therefore, it was assumed that all PER (Tetra-chloro-ethylene)<sup>92</sup> imported to Portugal is used in dry-cleaning<sup>93</sup> 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 is presented in Figure 5.4.

<sup>92</sup> Other organic solvents may be also used in dry-cleaning, such as trichloroethylene, 1,1,1-trichloroethane(methyl chloroform), cichloromethane (methylene chloride), R113 (tri-chloro-trifluoroethane) and aliphatic hydrocarbon solvents C10 to C13.

<sup>93</sup> There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.



Figure 5.4 – Annual importation/ consumption of PER (Tetra-chloro-ethylene) in Portugal (ton/yr) 1990-2002



Source: INE;

#### 5.2.B.4 RECALCULATIONS

A new activity data time series was used to establish NMVOC emissions from dry cleaning, resulting in lower emissions for this activity: less 8% at base year (1990) and less 30% for the average value in 1990-2002.

#### 5.2.B.5 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.

### 5.2.C Chemical products, manufacture and processing (CRF 3C)

#### 5.2.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, being 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 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.

#### 5.2.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:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

### 5.2.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 fibbers production emit 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 fibbers 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 fibber production were set from AP42 (USEPA), and from CORINAIR/EMEP (EEA,2002), and are presented in next table:

Table 5.10 – Emission factors of NMVOC from Polymer Processing

Material	Polymer	NMVOC
Synthetic Fibers	Rayon	0.8 <sup>(a)</sup>
	Polyamides	3.93 <sup>(a)</sup>
	Polyester	0.6 <sup>(a)</sup>
	Polyethylene	5 <sup>(a)</sup>
	Polypropylene	5 <sup>(a)</sup>
	PVC	150 <sup>(a)</sup>
	Acrylics	40 <sup>(a)</sup>
Plastics	Polyester	40
	PVC	40
Foam Blowing	Poly-urethane	6.0 <sup>(b)</sup>
	Poly-Styrene	6.0 <sup>(c)</sup>

(a) USPEPA (1990) c02s09; (b) Rentz et al, 1993 in EMEP/CORINAIR 3rd ed-File B633 (EEA,2002); (c) Achermann, 1992 in EMEP/CORINAIR 3rd ed - File B633 (EEA,2002)

## 5.2.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 5.11. From the several materials that were consumed in this activity only Benzene and Gasoline were considered solvents and prone to evaporation.

Table 5.11 – Statistical information used to establish solvent use factors in the rubber processing industry, in Portugal

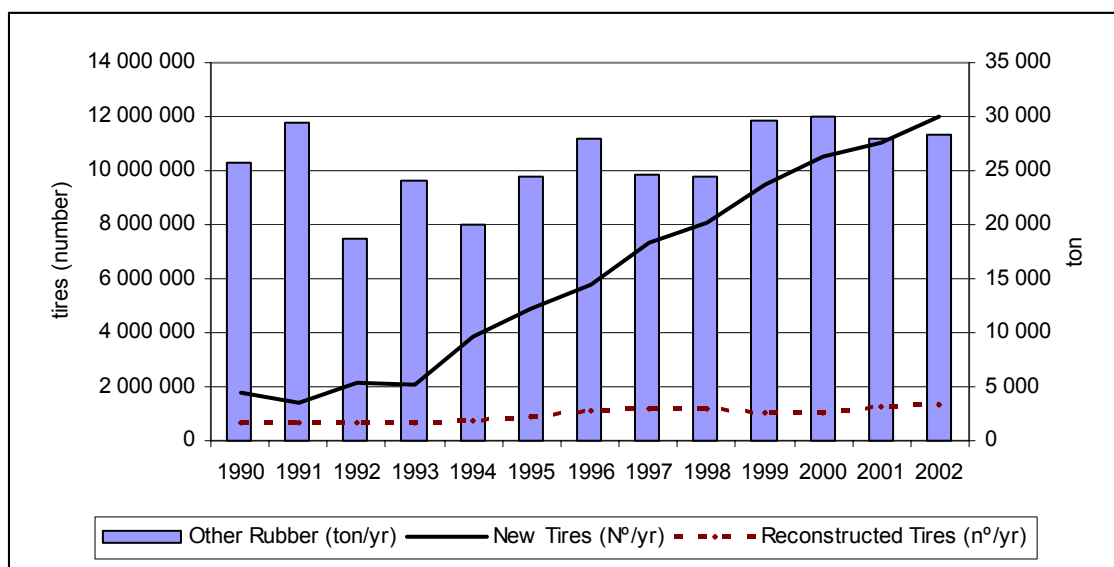
Product	Unit	1989	1990	1991	SFac
New Tires	n°	4 201			
Reconstructed Tires		941	1 796 201	1 378 575	
Other rubber products		969 972	663 772	689 342	
	ton	19 272	25 687	29 502	
New Tires	ton of solvent	615	312	155	
Reconstructed Tires		11 579	11 180	12 851	
Other rubber products		766	285	244	
New Tires	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 5.5.

Figure 5.5 - Processed rubber products in Portugal (1990-2002)



Source: INE (1990-2000); IA's forecasts thereafter

## RECALCULATIONS

Since last submission the activity data time series was revised – part of activity data was formerly confidential and was not fully included in the inventory – and updated until 2002.

Some materials that were assumed as solvents in previous submission were re-evaluated and from the evaluation of vapor pressure and boiling point some were removed from list of solvents> that was the case for instance of estearic acid.

### 5.2.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 (1983c) 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.

### 5.2.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 though 2000. Linear forecast values were considered for subsequent years. Production of inks is presented in Table 5.12 by ink type.

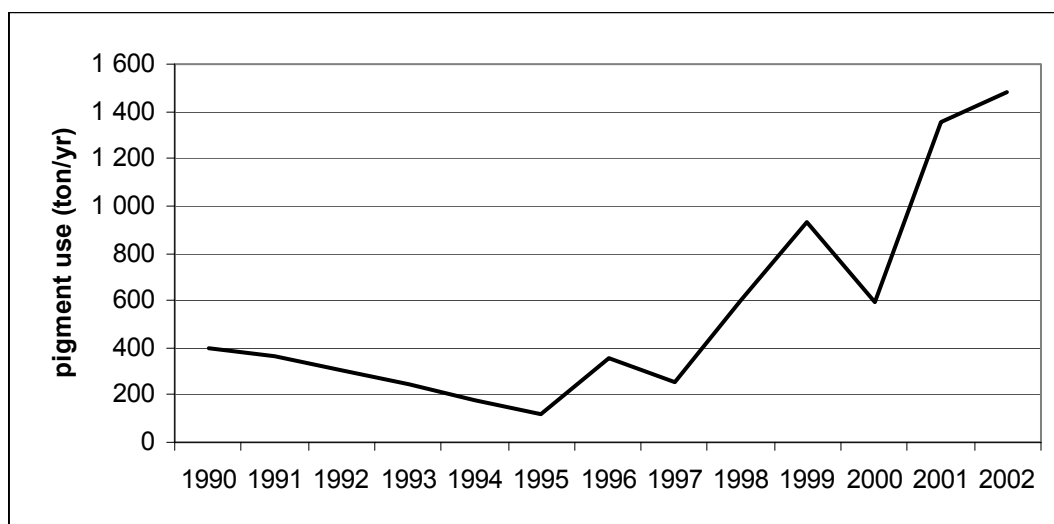
Table 5.12 – Production of inks in Portugal, by type of ink (ton/yr)

Ink	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Lithographic	1 122	1 064	135	45	69	60	448	272	266	213	175	175	175
Newspaper ink	318	185	0	0	0	0	0	0	0	0	0	0	0
Rotogravure	654	406	0	0	0	0	0	0	0	0	0	0	0
Flexography	880	999	119	119	907	1 084	2 025	1 928	2 039	1 663	3 008	2 640	2 857
Serigraphy	31	26	0	0	0	0	0	0	0	0	1	1	1
Drying by physical reaction	482	462	0	0	0	0	0	0	0	0	0	0	0
Other	40	51	99	47	50	22	109	17	11	0	82	82	82
<b>Total</b>	<b>3 528</b>	<b>3 193</b>	<b>353</b>	<b>212</b>	<b>027</b>	<b>1 166</b>	<b>2 582</b>	<b>2 216</b>	<b>2 316</b>	<b>1 875</b>	<b>3 266</b>	<b>2 899</b>	<b>3 115</b>

Source: INE (1990-2000); Forecast by IA (2001-2002)

Use of pigments in ink production was also available in INE's database. Total pigment consumption is presented in Figure 5.6.

Figure 5.6 – Total pigment consumed in ink manufacturing in Portugal from 1990 to 2002



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 (1991d).

Particulate emissions during ink manufacturing were also estimated using an emission factor of 1 kg/ton pigment used (USEPA, 1991d).

## RECALCULATIONS

Activity data time series was revised for 1990 and 1991 and updated from 1992 onward. The emission factor has doubled since last submission.

## 5.2.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.

## 5.2.D Other use of solvents and related activities (CRF 3D)

### 5.2.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.

### 5.2.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

NMVOE 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 CO<sub>2</sub> emissions are calculated assuming that 85 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO<sub>2</sub> emissions are included in the inventory.

$$U_{CO_2} = 44/12 * NMVOC * 0.85$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (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 (1991) and are presented in Table 5.13<sup>94</sup>.

Table 5.13 – 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 (1981b)

## 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 5.14.

Table 5.14 – 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;

<sup>94</sup> 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 5.15, 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 5.15 - Production and External Trade of inks in 1990-1994 (ton)

Year	1990	1991	1992	1993	1994
<b>National Production</b>	3 528	3 193	353	212	1 027
<b>Importation</b>	1 481	1 745	2 705	2 720	3 051
<b>Exportation</b>	65	71	58	34	35
<b>Consumption</b>	4 944	4 868	3 000	2 898	4 044

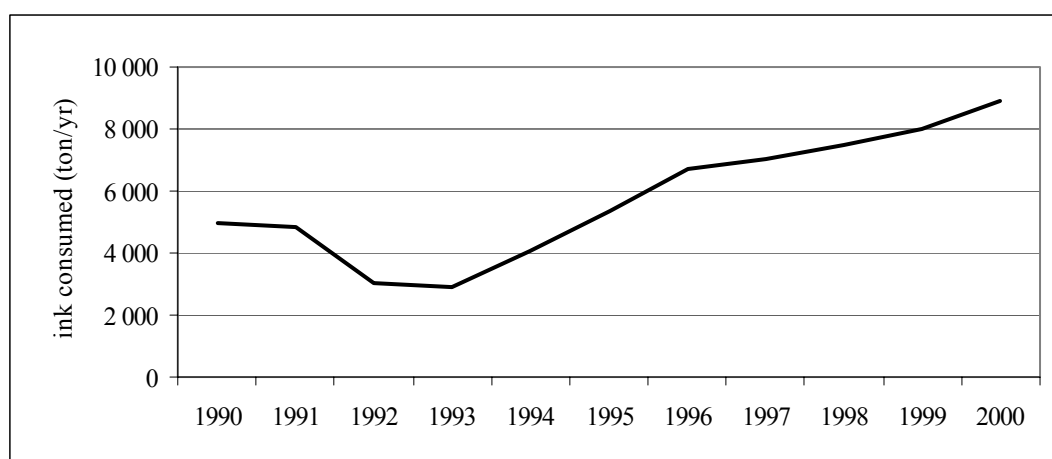
Source: INE

Final consumption of inks per technology type is synthesized in Table 5.16. Values for 2001 and 2002 are forecasts made by IA from the previous time series.

Table 5.16 – Consumption of inks by printing technology and press product (1990-2002)

Technology	Product	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Web Offset Lithography	Newspaper	701	691	426	411	574	762	548	467	422	466	465	430	412
Letterpress		3 <sup>95</sup>	3	2	2	3	4	5	3	11	21	27	20	22
Web Offset Lithography	Books	100	98	60	58	81	108	141	174	259	193	147	211	225
Rotogravure	Publications	18	18	11	11	15	20	24	16	58	110	147	105	115
		1					1	1	1	1	1	1	1	1
Flexography	Packages	008	993	612	591	825	095	250	299	249	364	661	550	627
								1	1	1	1	2	2	2
Flexography	Artifacts	727	716	441	426	595	790	550	710	899	986	351	350	541
Serigraphy	Fabric	0	0	0	0	0	0	0	0	0	0	59	21	24
		4	4	3	2	4	5	6	7	7	8	8	8	9
Total		944	868	000	898	044	372	688	030	486	003	896	839	354

Figure 5.7 – Total inks consumption in Portugal (1990-2002)



## RECALCULATIONS

Specific emission factors for the use of the national produced paint are no longer used in the inventory, because of the high importance of external trade in relation to domestic production of ink. The emission factors reflect now the solvent content of inks for each printing process.

However, some improvements were made in emission estimates for this sector, the most important was the separated consideration of each of the several printing techniques and the use of specific emission factors.

Finally the time series of ink consumption was revised for 1990 and 1991 and updated until 2002.

## 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.

<sup>95</sup> An error was detected in this time series after completion of submission. Actual time series are (ton/yr): 156; 154; 95; 92; 128; 170; 124; 106; 96; 106; 106. This causes emission error which will be corrected in next year's submission.

### 5.2.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 result from mechanical processes or solvent based processes. Mechanical processes, using presses, are used to extract first olive oil from olives<sup>96</sup>. Extraction by solvents, usually using hexane and heat, is presently done in extraction from most oil seeds or secondary extraction of olive oil. Solvent recovery, where the oil is separated from the oil-enriched wash solvent and from the steamed out solvent, is an integral part of the production processes although leakages occur continuously leading to the need of solvent stock replenishment. Losses are either made directly to atmosphere through vents or leaks or indirectly through water and residues.

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 CO<sub>2</sub> emissions are calculated assuming that 85.71 percent of the mass emissions of NMVOC is carbon<sup>97</sup> and is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate CO<sub>2</sub> emissions are included in the inventory.

$$U_{CO_2} = 44/12 * NMVOC * 0.8571$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

Particulate matter emissions are estimated from consumption of grain:

<sup>96</sup> Classified as virgin olive oil

<sup>97</sup> Hexane chemical formula

$$Emi_{PM}(y) = EF * Cons_{GRAIN}(y) * 10^{-3}$$

where:

$Emi_{PM}(y)$  - Emissions of PM (ton/yr);

$Cons_{GRAIN}(y)$  - annual consumption of grain in the production of edible and non-edible oil industry (ton/yr);

EF – Emission factor (g/ton).

## EMISSION FACTORS

The national emission factor for NMVOC was calculated as the ratio of the amount of solvents consumed during manufacture processes to the quantities of edible and non edible oil manufactured. However, from the available data from INE, this emission factor could be only estimated from IAIT industrial survey, i.e. from 1989 to 1991, because solvent consumption is not available from IAPI survey. Statistical information used in actual calculations of annual emission factor are presented in Table 5.17, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole 1990-2002 time period. Because in IAPI survey (1992-2000) it was not possible to distinguish production of edible oils from production of non-edible soils, it was decided just to use a global emission factor.

Table 5.17 – Calculation of the National emission factor for edible and non-edible oils extraction (kg/ton).

Oil	Parâmetro	1989	1990	1991	Average
Edible	Oil refined (ton)	93 401	90 686	107 163	
non-edible		113	110	113	
		749	883	509	
		207	201	220	
sum		150	569	672	
Edible	Solvent Use (ton)	2 328	1 763	1 697	
non-edible		1 394	1 257	1 408	
sum		3 722	3 020	3 106	
Edible	Emission Factor NMVOC (kg/ton)	24.9	19.4	15.8	20.1
non-edible		12.3	11.3	12.4	12.0
sum		18.0	15.0	14.1	<b>15.7</b>

The emission factor for Particulate Material, 1.34 g/kg grain handled is from USEPA (1995g).

## ACTIVITY DATA

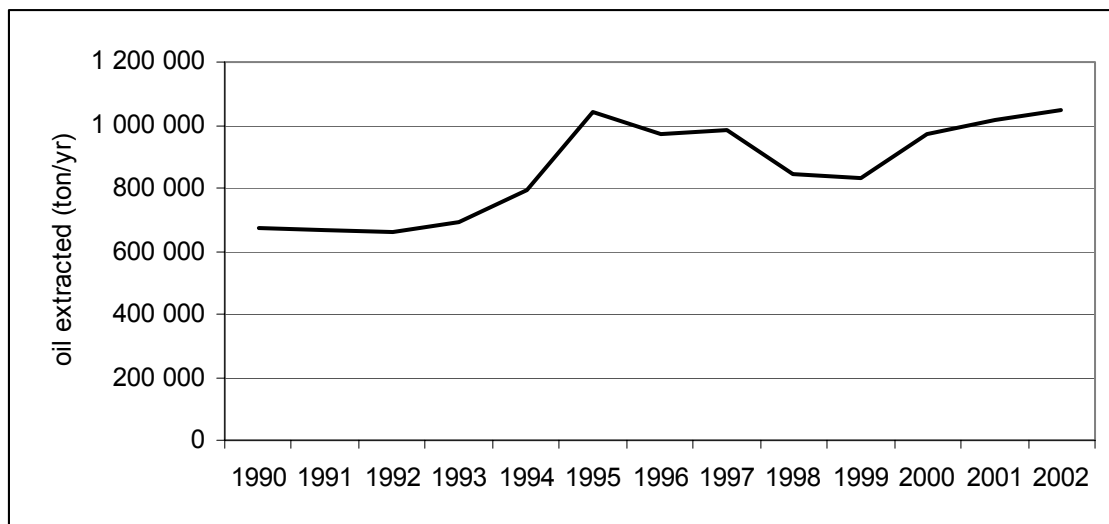
Oil production data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2000. Production data for 2001 and 2002 was forecasted at IA from previous years. All annual values are reported in Table 5.18, together with olive oil production, although that product does not cause NMVOC emissions. Total grain processed is also reported in Table 5.18. Total extraction of edible and non-edible oil is also shown in Figure 5.8.

Table 5.18 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton)

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Olive Oil													
Production	10 253	9 883	8 368	16 948	25 269	27 691	36 404	31 839	41 190	46 673	41 912	38 796	-
	201	220	184		222		208	174		122	136		
Oil refining	569	672	406	161 998	430	223 330	116	686	168 580	263	230	142 748	135 869
	672	668	662		791	1 042	969	982		829	968		
Grain processed	382	734	759	691 625	687	605	983	574	846 161	526	898	1 017 147	1 048 385

Source: National Statistics Institute (INE)

Figure 5.8 – Total edible and non-edible oil extraction in Portugal (ton/yr)



## RECALCULATIONS

The full time series was revised for the 1990 to 2001 period.

Country specific emission factors were estimated again and the average value in 1989/1991 remains approximately equal, having slightly changed from 15 kg/ton oil to 15.7 kg/ton.

### 5.2.D.4 GLUES AND ADHESIVES

#### METHODOLOGY

$$NMVOC = Cons_{Nat} \times FE_{Nat} + Imp \times FE_{imp}$$

where:

NMVOC = Global emissions of NMVOC (ton)

Cons<sub>Nat</sub> = Consumption of Glues and Adhesives produced in Portugal (ton)

FE<sub>Nat</sub> = Emission factor for Glues and Adhesives produced in Portugal (kg NMVOC/ton Ink)

Imp = Importation of Glues and Adhesives (ton)

FE<sub>imp</sub> = Emission factor associated to the use of imported Glues and Adhesives.

$$\text{Cons}_{\text{Nat}} = \text{Prod}_{\text{Nat}} - \text{Exp}$$

where:

$\text{Cons}_{\text{Nat}}$  = Consumed Glues and Adhesives produced in Portugal (ton)

$\text{Prod}_{\text{Nat}}$  = 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 5.19 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5.20). 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 5.19 - 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
<b>Total</b>	<b>6 408</b>	<b>6 224</b>	<b>6 240</b>

Table 5.20 - 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 5.21 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	1992 - 2002
<b>National Production (ton)</b>	36 297	35 769	35 473
<b>Importation (ton)</b>	2 192	2 328	2 260
<b>Exportation (ton)</b>	707	532	620

Source: National Statistics Institute (INE)

### 5.2.D.5 WOOD PRESERVATION

#### OVERVIEW

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts an building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

#### 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 5.22 - Wood preservation products consumption (ton)

Year	1990	1991	1992 - 2002
Wood Preservation products Consumption (ton)	2083	2900	2491

Source: National Statistics Institute (INE)

### 5.2.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:

$$NMVOC = Use * FE_{Prod+use}$$

where:

NMVOC - Emissions of NMVOC associated to the production and use of perfumes (ton)

Use - Use of perfumes (ton);

$FE_{Prod+use}$  - 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.

$$FE_{Prod+use} = \text{Solvents} / \text{National Production}$$

where:

$FE_{Prod+use}$  = 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 5.23 - Calculated emission factor (kg/ton).

1989	1990	1991	Average
162	170	184	172

## ACTIVITY DATA

Table 5.24 - Activity data associated to Perfumes Use (ton)

Year	1990	1991	1992-2002
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)



**5.2.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 5.25 – Emission factors

1989	1990	1991	Average
525	299	293	372

**ACTIVITY DATA**

Table 5.26- Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2002
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)

**5.2.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 5.27 – Emission factors

1990	1991	Average
2	2	2

## ACTIVITY DATA

Table 5.28 - Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2002
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)

## 5.2.D.9 USE 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<sub>NONEMI</sub> – 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 5.29, which may be considered, neglecting foreign trades, equal to the consumption of alcohol. Industrial consumption of alcohol in 1989 is shown in Table 5.30 by use. Statistical data is from INE in both cases.

Table 5.29 - Industrial production of ethanol (ton).

1989	1990	1991
7 754	9 941	8 027

Table 5.30 - 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
<b>Total</b>	<b>4 333</b>

Rosin derivatives include turpentine oil,  $\alpha$ -pinene, etc. The annual production of rosin derivatives is presented in Table 5.31 and foreign trades values in Table 5.32. Statistical information is from the National Statistical Institute (INE).

Table 5.31- Rosin derivatives production (ton).

1989	1990	1991
13 362	12 145	11 299

Table 5.32 - Foreign trades of rosin derivatives (ton).

<i>Imports (ton)</i>		<i>Exports (ton)</i>	
1990	1991	1990	1991
722	700	11 558	13 692

#### 5.2.D.10 OTHER USES OF SYNTHETIC SOLVENTS FROM FOSSIL FUELS

##### METHODOLOGY

NMVOC = Produced Solvents

where:

NMVOC = Emissions of NMVOC (ton)

Consumed Solvents = quantity of produced solvents(ton)

The calculation of Global CO<sub>2</sub> emissions is made according to:

$$U_{CO_2} = 44/12 * NMVOC * 0.85$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

## ACTIVITY DATA

Table 5.33 - Synthetic solvents consumption in other industries (ton)

Year	1990	1991	1992 - 2002
Solvents (ton)	3 885	4 014	3 950

Source: General Directorate of Energy (DGE)

## 5.3 Recalculations

Recalculation of NMVOC emissions for this sector, which causes similar changes in emissions of ultimate fossil carbon dioxide, may be analysed from data in Figure 5.9 and in Table 5.34. Changes had different directions according to year: emissions were reduced in base year (less 18% than in previous submission); while resulting in an increase of emissions for year 2001 (more 9% in comparison to submission 2003). This source sector has suffered extensive improvements as result of the availability, this year, of statistical information from IAPI statistical survey from INE.

This change in pattern, showing now a more step increase in emissions in the 1990-2002 period, reflects mostly the update that was done in the activity data time trends.

Detailed information about each sector will be presented for each sub-category source.

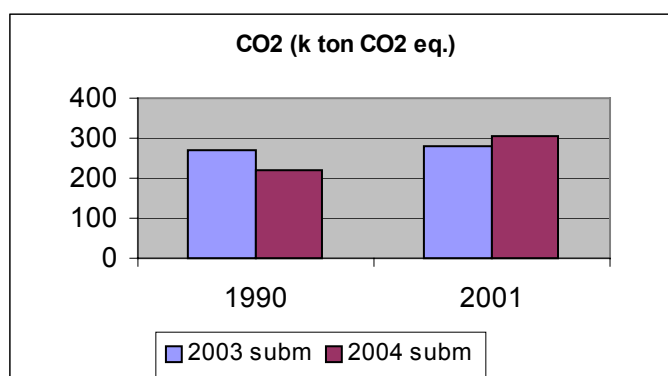
Figure 5.9 - Differences between 2003 and 2004 submissions for CO<sub>2</sub> emissions from solvent use

Table 5.34 - Recalculations of emissions from solvent use: differences between 2003 and 2004 submissions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)
	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)
1990									
3. Solvent and Other Product Use	271.42	222.26	-18.11		0.00		0.00	0.00	0.00
2001									
3. Solvent and Other Product Use	278.88	305.08	9.39		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% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

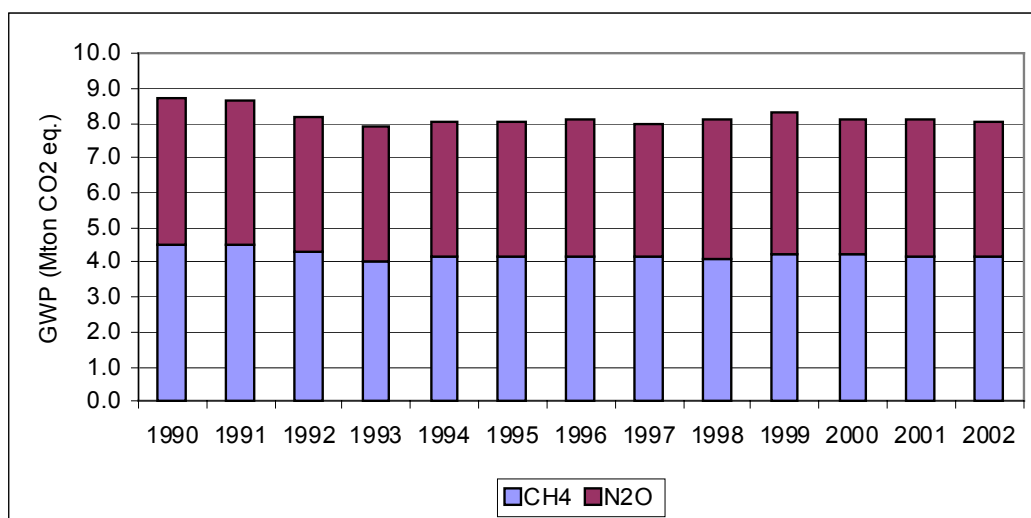
## CHAPTER: 6 AGRICULTURE (CRF 4)

### 6.1 Overview

Agriculture activities generate emissions of GHG from a variety of different sources. This section includes the quantification of: CH<sub>4</sub> emissions from enteric fermentation and rice cultivation; CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management; direct and indirect N<sub>2</sub>O emissions from agriculture soils; and all air emissions from field burning of agriculture residues. Also dealt here are the NH<sub>3</sub> emissions from agriculture, which are used as an intermediate step in the quantification of N<sub>2</sub>O indirect emissions from soil. 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 chapter 32.A.6 Energy: Other Sectors. Presently there are no estimates for CO<sub>2</sub> release or uptake from soil due to cultivation.

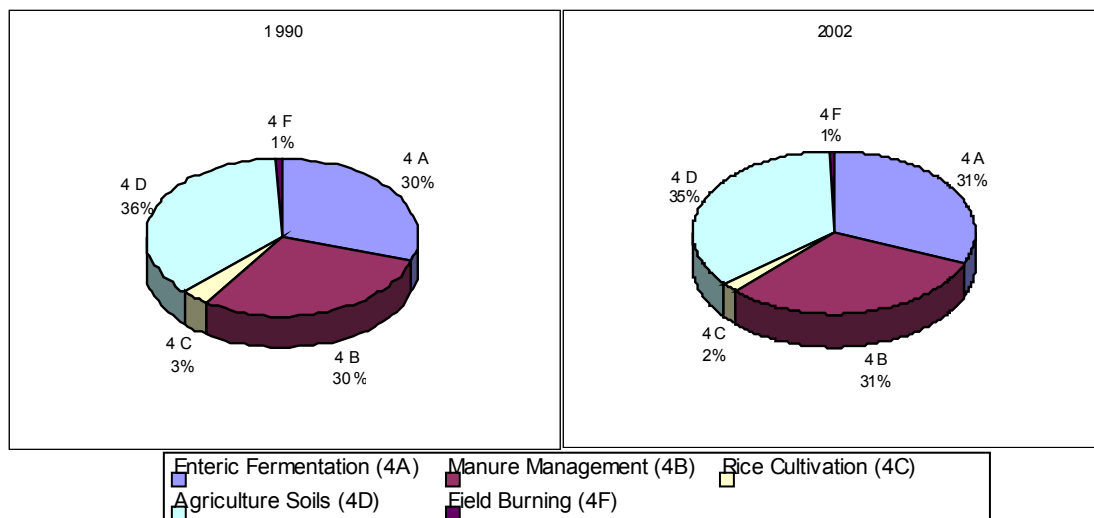
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 15% in 1990 to 10 % in 2002. This trend reflects not only a relative decrease but also the occurrence of an absolute reduction in emissions such that emissions from agriculture in 2002 are 7 % lower than emissions from agriculture in 1990: 8.7 Mton of CO<sub>2</sub> eq in 1990 and 8.1 Mton CO<sub>2</sub> eq in 2002 (Figure 6.1). N<sub>2</sub>O emissions, are slightly higher than those for methane, when expressed in common CO<sub>2</sub> eq, totalizing from 64 to 73% of the total GHG emissions of this sector.

Figure 6.1 – Total Greenhouse Gas Emissions from Agriculture. Trends by GHG



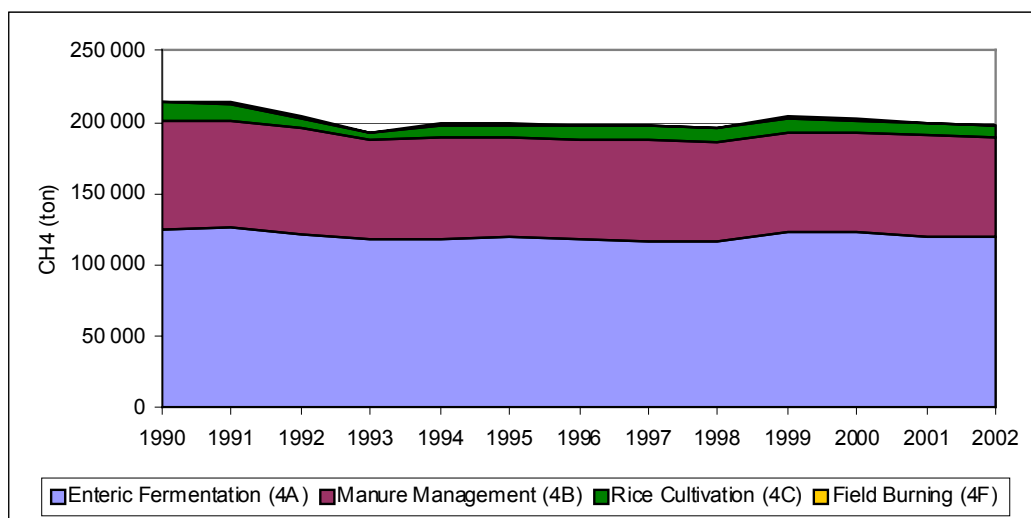
The major part of emissions from agriculture result only from 3 sub-source sectors, approximately with a similar share: Agriculture Soils, Enteric Fermentation and Manure Management (Figure 6.2).

Figure 6.2 - Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2002



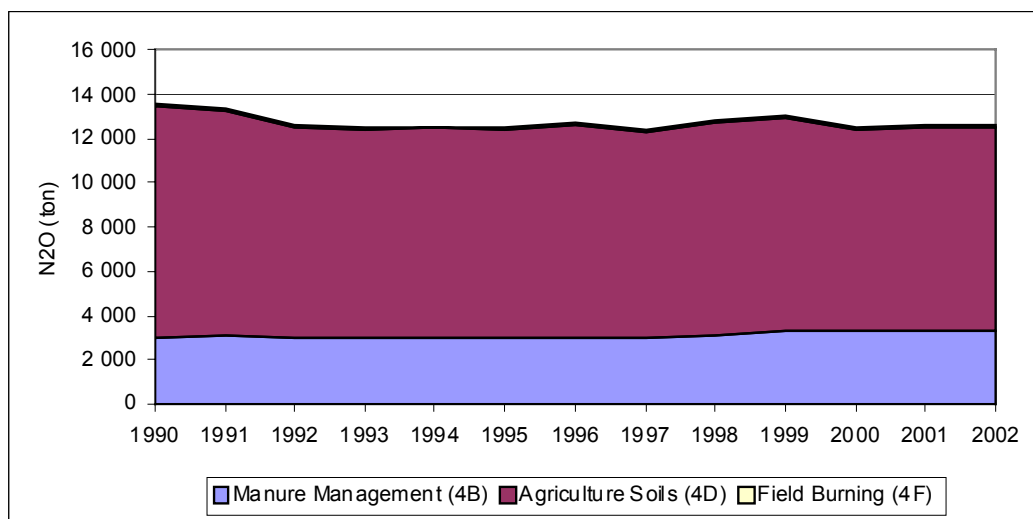
Emissions of CH<sub>4</sub> from agriculture have slightly decreased (7.8 %) from 1990 to 2002 (Figure 6.3). Enteric Fermentation represents, on average in the 1990-2002 period, 59.8 % of the sectoral emissions and Manure Management accounts on average for 35.3 % of the sectoral emissions in the same period. The remaining 4.9 % of emissions result from rice cultivation, with a very small contribution from field burning of residues, which represents only 0.4% of total emissions (average value in the period 1990 to 2002).

Figure 6.3 - Methane emissions from agriculture



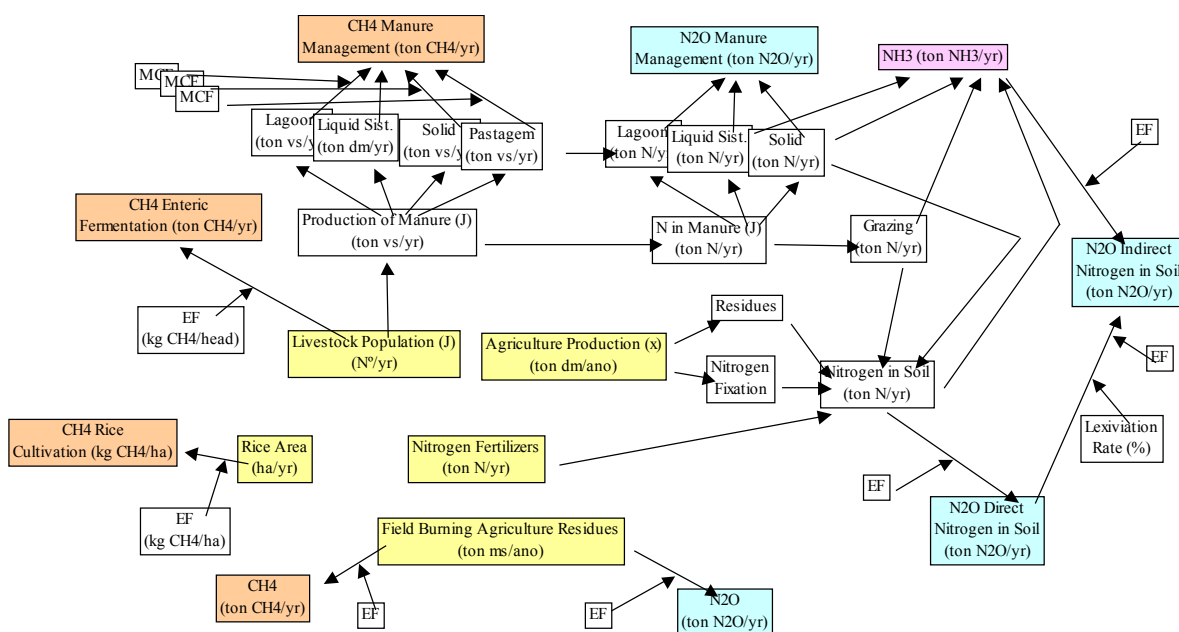
N<sub>2</sub>O emissions were also affected by a similar decrease (6.9%) during the 1990-2002 period (Figure 6.4). The great majority of emissions are associated with direct and indirect emissions from agricultural soils (74.7%), manure management is responsible for 24.4% of emissions, while the small remaining fraction results from field burning of agricultural residues (0.9%).

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 (IPCC,1997) and Good Practice Guidebook (IPCC,2000)) 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 2003 to submission 2004 were done also in a consistent and coherent way among the several source sectors.

## 6.2 Source categories

### 6.2.A CH<sub>4</sub> Emissions from Enteric Fermentation in Domestic Livestock (CRF 4A)

#### 6.2.A.1 OVERVIEW

CH<sub>4</sub> emissions from enteric fermentation in animals result from methane 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 presence of specific micro-organisms in their upper digestive tracts, but also in smaller quantities in monogastric animals (swine, equines, birds and rabbits). The estimates in this inventory include only emissions in domestic animals. Emissions from wild animals and semi-domesticated game are not quantified neither there is quantification of emissions from humans or pet animals.

CH<sub>4</sub> emissions from enteric fermentation is a key source, both by level and trend assessment. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents 32% to 28% of total CH<sub>4</sub> emissions from Enteric Fermentation, while non-dairy cattle represents about 38% to 42% of total CH<sub>4</sub> from enteric fermentation. Altogether cattle is responsible for about 70% of total CH<sub>4</sub> emissions from enteric fermentation.

Sheep are also an important source of methane, for which emissions have oscillated between 21% and 23% of total CH<sub>4</sub> from Enteric Fermentation. Emissions from goats were 2.2-3.5% of total enteric fermentation and swine represented 2.9-3.2% of emissions. Total emissions of methane for all other species decreased from 1.6% to 1.1% along 1990 to 2002 and are therefore less important.

#### 6.2.A.2 METHODOLOGY

Emissions were estimated for each animal type by multiplication of the number of animals by the respective emission factor, in accordance to equation 4.12 of the Good Practice Handbook (Tier 1 method).

$$Emi_{CH_4} = \sum_i [EF_{(i)} * N_{(i)}]$$

where, for each specie:

$Emi_{CH_4}$  - methane emissions from enteric fermentation, kg CH<sub>4</sub>/year;

EF - emission factor for the specific population of animal type i, kg/head/year;

N - the number of animals of type i, head.

#### 6.2.A.3 EMISSION FACTORS

Emission factors may be seen in Table 6.1. For most species they are the default emission factors proposed by IPCC 1996 Revised Guidelines (IPCC,1997) for West Europe (tables 4-3 and 4-4 in IPCC(1997)). For rabbits the emission factor was set approximately from the IPCC default emission factor for horses, assuming that horse is the most similar animal to rabbits – in what concerns digestive processes – from the set of animals for which there are default emission factor in IPCC. The original emission factor for horses was scaled to rabbit size, according to the scaling equation proposed by GPG (IPCC,2000):

$$EF_{Rabbit} = [(rabbit\ weight)^{0.75} / (horse\ weight)^{0.75}] * EF_{Horse}$$



Table 6.1 - Emission Factors for Enteric Fermentation (kg CH<sub>4</sub>/head/year)

Class	EF (kg CH <sub>4</sub> /head/year)
Dairy Cows	100
Other Cattle	48
Ewes (Breeders)	8
Other sheep	8
Female goats (Breeders)	5
Other Goats	5
Female Pigs (breeders)	1.5
Other swine	1.5
Horses	18
Mules and Asses	10
Rabbits (Female breeders)	0.5

In accordance with the unavailability of emissions factors in IPCC 1996 Revised Guidelines (IPCC,1997) 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.

#### 6.2.A.4 ACTIVITY DATA

Livestock numbers, presented in Table 6.2 and Table 6.3, were collected from statistical databases of the National Statistics Institute (INE). However not all statistical information is available for all years and interpolations were done for the missing years. The number of rabbits, turkeys, ducks, geese and guinea-fowl, is only available for 1999 and extrapolations were done for the other years using the available time series from FAO database as surrogate indicator of trend. All figures represent stock numbers at a particular time of the year, mostly December and consequently for some species with seasonal reproducing periods, such as goats and sheep, these numbers could be significantly different than annual averages.

Table 6.2 - Livestock Numbers (Thousands): 1990-1996

k head	1990	1991	1992	1993	1994	1995	1996
Dairy Cows **	403	404	381	375	356	364	362
Other Cattle	972	1 012	964	948	961	960	949
Ewes	2 227	2 240	2 219	2 191	2 264	2 301	2 265
Other sheep	1 133	1 140	1 129	1 114	1 152	1 127	1 115
Female goats	616	634	617	601	588	581	569
Other goats	241	248	241	235	230	218	212
Sows	346	333	331	363	330	333	330
Other swine	2 318	2 231	2 216	1 901	2 086	2 069	2 014
Horses	36	36 *	35 *	35 *	35 *	35 *	36 *
Mules & asses	114	106 *	98 *	90 *	82 *	74 *	69 *
Rabbits	338 *	338 *	338 *	338 *	338 *	338 *	338 *
Broilers & male breeders	22 271	22 677 *	23 084 *	23 490 *	23 896 *	24 303 *	24 709 *
Hens	8 883 *	8 883 *	8 883 *	8 883 *	8 883	9 549	9 257
Turkeys	1 263 *	1 263 *	1 263 *	1 263 *	1 263 *	1 263 *	1 263 *
Ducks, geese, Guinea-fowl, etc	539 #	539 #	539 #	555 #	555 #	555 #	668 #
Total	41 700	42 085	42 339	42 382	43 019	44 070	44 157

Table 6.3 - Livestock Numbers (Thousands): 1997-2002

k head	1997	1998	1999	2000	2001	2002
Dairy Cows **	362	355	357	355	338	341
Other Cattle	923	912	1 064	1 059	1 066	1 054
Ewes	2 288	2 266	2 439	2 436	2 334	2 279
Other sheep	1 126	1 254	1 145	1 143	1 125	1 178
Female goats	572	561	457	453	412	391
Other goats	213	235	172	169	149	148
Sows	334	325	326	323	323	316
Other swine	2 031	2 016	2 024	2 015	2 066	2 028
Horses	38 *	40 *	41	40 *	40 *	41 *
Mules & asses	65 *	60 *	55	45 *	38 *	32 *
Rabbits	338 *	338 *	338	338 *	338 *	338 *
Broilers & male breeders	25 115 *	25 522 *	25 928	26 770	26 741 *	27 147 *
Hens	10 192	12 321	11 980	12 392	13 544 *	14 251 *
Turkeys	1 263 *	1 263 *	1 263	1 263 *	1 263 *	1 263 *
Ducks, geese, Guinea-fowl, etc	719 #	719 #	771	771 #	719 #	719 #
Total	45 580	48 186	48 361	49 571	50 498	51 527

\* estimated/interpolated/extrapolated from time series

\*\* adult animals only.

# INE Figure for 1999, extrapolated for the all period from FAO's time series

National statistics from INE agree quite well with FAO data on cattle numbers, particularly toward the end of the period, as may be seen from Table 6.4. The situation is similar for goats and pigs. However, in what refers to sheep, FAO reports numbers that are from 56% up to 86 % higher than those reported by the National statistics. This probably results from the inclusion of temporary animals in stock (lambs) that did not exist in December. A correction for this number was not made because it is not clear if the default emission factor from IPCC (IPCC,1997) includes or does not include this situation<sup>98</sup>, and also because emissions from lambs are probably less important due to their smaller size and different feeding conditions - ingestion of milk during part of the growing period. Nevertheless, the use of FAO's sheep numbers would not make sheep a significant source of CH<sub>4</sub> for this source category.

<sup>98</sup> Seasonal variation of sheep numbers.

Table 6.4 – Comparison of Livestock numbers in the National Inventory with equivalent values in FAO database and percent of difference (1990-2002)

Class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cattle	1 335 (-2.9%)	1 375 (-2.9%)	1 398 (3.9%)	1 336 (1.0%)	1 348 (2.4%)	1 363 (2.9%)	1 386 (5.7%)	1 389 (8.1%)	1 386 (9.4%)	1 409 (-0.8%)	1 421 (0.5%)	1 414 (0.7%)	1 399 (0.3%)
Sheep	5 567 (65.7%)	5 673 (67.8%)	5 640 (68.5%)	6 125 (85.3%)	5 991 (75.4%)	5 900 (72.1%)	5 800 (71.6%)	6 300 (84.5%)	5 800 (64.8%)	5 850 (63.2%)	5 584 (56.0%)	5 578 (61.3%)	5 478 (58.5%)
Goats	857 (0.0%)	857 (-2.8%)	862 (0.5%)	858 (2.6%)	836 (2.2%)	819 (2.5%)	799 (2.3%)	781 (-0.5%)	785 (-1.4%)	750 (19.2%)	630 (1.3%)	623 (11.1%)	565 (4.8%)
Pigs	2 598 (-2.5%)	2 664 (3.9%)	2 574 (1.1%)	2 690 (18.8%)	2 444 (1.2%)	2 430 (1.2%)	2 375 (1.3%)	2 394 (1.2%)	2 385 (1.9%)	2 350 (0.0%)	2 338 (0.0%)	2 338 (-2.1%)	2 389 (1.9%)
Horses	26 (-27.8%)	26 (-27.3%)	25 (-29.5%)	25 (-29.0%)	25 (-28.5%)	23 (-33.7%)	25 (-31.3%)	22 (-42.2%)	24 (-39.7%)	19 (-54.2%)	17 (-57.4%)	17 (-58.0%)	17 (-58.6%)
Mulas, Asses	250 (119.3%)	250 (135.8%)	250 (155.0%)	230 (155.4%)	230 (180.2%)	230 (210.4%)	210 (202.9%)	210 (225.3%)	190 (217.9%)	185 (236.4%)	180 (301.0%)	175 (357.3%)	175 (453.0%)
Chickens	20 000 (-35.8%)	21 000 (-33.5%)	22 000 (-31.2%)	25 000 (-22.8%)	26 000 (-20.7%)	26 000 (-23.2%)	27 000 (-20.5%)	34 000 (-3.7%)	36 000 (-4.9%)	34 000 (-10.3%)	35 000 (-10.6%)	35 000 (-13.1%)	35 000 (-15.5%)
Turkeys	5 250 (315.7%)	5 250 (315.7%)	5 250 (315.7%)	5 400 (327.5%)	5 400 (327.5%)	5 400 (327.5%)	6 500 (414.6%)	7 000 (454.2%)	7 000 (454.2%)	7 500 (493.8%)	7 500 (493.8%)	7 000 (454.2%)	7 000 (454.2%)
Total	35 883 (-12.1%)	37 095 (-10.0%)	37 999 (-8.3%)	40 329 (-2.8%)	42 274 (0.4%)	42 165 (-2.3%)	44 095 (2.2%)	52 096 (17.0%)	53 570 (13.7%)	52 063 (10.2%)	52 670 (8.7%)	52 145 (5.5%)	52 023 (3.1%)

The number of horses, mules, asses and turkeys<sup>99</sup> is very different when comparing statistics from FAO and INE, but they have a small importance in the emissions inventory.

The number 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.

#### 6.2.A.5 RECALCULATIONS

No modifications in methodology occurred since submission 2003. Livestock numbers for 2001 for all animal types were updated from preliminary values used in last year submission.

More substantial modifications in the time trend of livestock numbers were made in what concerns poultry. Although there are no estimates of emissions from enteric fermentation from poultry<sup>100</sup>, differences in livestock numbers are reported here for report simplicity. Changes concern: an increase in the number of Laying hens to include also animals kept in domestic rural houses, but which are not included in agro-industrial units; a revision of data for broilers after 1999, because former time series showed some inconsistencies in trend; and a revision of the number of turkeys and other poultry using FAO database to extrapolate numbers prior to 1999.

<sup>99</sup> While poultry numbers do not affect emissions of CH<sub>4</sub> from Enteric Fermentation they are discussed here to simplify NIR presentation.

<sup>100</sup> In fact poultry numbers only directly or indirectly affect emissions for CH<sub>4</sub> and N<sub>2</sub>O from Manure Management and N<sub>2</sub>O from agricultural soils.

### 6.2.A.6 FURTHER IMPROVEMENTS

Because CH<sub>4</sub> from enteric fermentation is a key source<sup>101</sup>, for a strict application of Good Practices a tier 2 approach with an enhanced livestock characterization should be used at least for the most significant sources: dairy cattle and non-dairy cattle, which together sum about 70% of total CH<sub>4</sub> emissions from enteric fermentation. For the time being the methodology can not be improved beyond tier 1 as consequence of lack of appropriate country -specific data about energy requirements, feed intake and methane conversion rate. Any calculation done with data available at this moment would result in emission factors different from IPCC defaults (IPCC, 1997; IPCC,2000) but that would not be actually representative of country-specific circumstances . However, it is expected that on-going contacts with the Agriculture Ministry, under the program for the development of National System, will allow improvements in the knowledge of basic data concerning feed intake, digestibility and methane conversion and that a tier 2 could be applied in future inventory reports.

Also, statistical information that is available only for more recent years, will allow a better desegregation per age and sex classes at least for cattle, sheep and swine. An improvement must be made for sheep livestock numbers although in this case it is also necessary to clarify if the default IPCC emission factor (IPCC,1997) is to be applied with or without correction for temporary lambs. This information will be used to enhance livestock characterisation and determine tier 2 emission factors in the near future, using for instance the feed intake energetic model proposed in the Good Practice. It is expected that this update will be available in the next year report for cattle, sheep and swine, following the efforts that are being made to implement a National System.

Efforts are being made, together with the Ministry of Agriculture and the National Statistical Institute, to detect the causes of the differences between FAO statistical data and national statistics at least for sheep and goats.

Livestock numbers for broilers and hens for 2001 and 2002 are still provisional and will be updated with official values in the next submission.

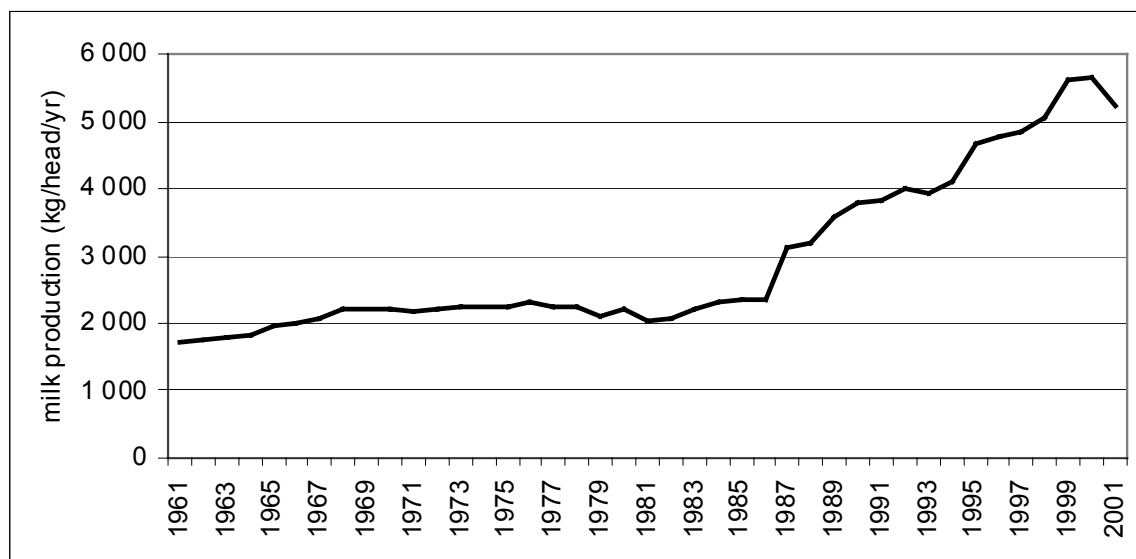
Estimate of CH<sub>4</sub> emissions from Enteric Fermentation from wild and semi-wild game animals is also foreseen in the near future although this is not a priority action.

The average milk production per cow in Portugal since 1990 until 2001 is presented in Figure 6.6. It can be seen that milk production has increased sharply, particularly since the entrance of Portugal in the EEC/UE in 1986. In the period 1990 to 2001 the average milk production per head was about 4633 Kg milk/head/year which is slightly larger than the value assumed in IPCC (1997) when default emission factors for Western Europe were derived (4 200 kg/head/yr in IPCC (1997) table 4-4). No attempt was made to incorporate the effect of increased milk production in the emission factor determination, and plans are to include this trend factor only when methodology could improve to Tier 2.

---

<sup>101</sup> According to the rule of thumb in note 2 of page 4.24 of GPG

Figure 6.6 - Milk production per cow (kg milk/head/year): 1961 to 2001



Source: FAO Statistical Database

## 6.2.B CH<sub>4</sub> Emissions from Manure Management (CRF 4B)

### 6.2.B.1 OVERVIEW

Methane emissions from manure occur when the organic material it contains decomposes in an anaerobic environment 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 long time residence on stall floor.

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.

### 6.2.B.2 METHODOLOGY

Following the 1996 IPCC Revised Guidelines (IPCC,1997) and the Good Practice Handbook (IPCC,2000), emission estimates are calculated by the following simple equation (equation 4.15 of GPG) applied for each animal type. 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.

$$Emi_{CH_4} = \sum_t [EF_{(t)} * N_{(t)}]$$

where, for each specie:

$Emi_{CH_4}$  = methane emissions from manure management, kg CH<sub>4</sub>/year;

EF = emission factor for the specific population of animal type i, kg/head/year;

N = the number of animals of type i, head.

### 6.2.B.3 EMISSION FACTORS

Emissions Factors for each animal type were established according to the tier 2 methodology proposed in GPG (equation 4.17 in IPCC,2000), 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<sub>(i)</sub> - annual emission factor for a defined livestock animal specie i (kg/year);

VS<sub>(i)</sub> - Amount of excretion, expressed in Volatile Solids (VS) for an average animal i in the livestock population (kg VS /day);

Bo<sub>(i)</sub> - Maximum methane production capacity from manure (m<sup>3</sup>/kg VS) for animal specie i. 0.67 kg/m<sup>3</sup> is methane density;

MCF<sub>(jk)</sub> - methane conversion factor for each Manure Management System j and for each climate region k;

MMS<sub>(jk)</sub> - fraction of total manure from animal specie i handled with Manure Management System j and for each climate region k.

Except for ovine and caprine livestock, the amount of manure produced per capita and the dry matter content of manure are from (Seixas et al, 2000) and were established, in that study, from unpublished information received from the Ministry of Agriculture and some assumptions concerning indoor and outdoor dejections. The quantity of manure produced annually for sheep and goats was revised downward during the preparation of the 2004 submission because the original values were found to be too high when comparing them to the respective figure for other Parties or even when in comparison to the values that were considered in the Portuguese inventory for the other livestock animals.

The values for parameter Bo were set according to IPCC 1996 Revised Guidelines (IPCC,1997). Next table presents total annual production of fresh manure per individual, dry matter content and maximum methane production capacity from manure (Bo) for each animal type. It also compares the values set for daily manure produced, expressed as dry matter, against the default values proposed in IPCC (1997) for Western Europe or developed countries.

Table 6.5 – Production of Manure per animal type and manure characterization: dry mater content (dm) and maximum methane production capacity (Bo)

Class	Manure Production per Capita			IPCC (1997)	dm content	Bo	
	kg wt/hd/yr	kg dm/hd/yr	kg dm/hd/day	kg dm/hd/day	%	m3/kg dm	kg CH4/kg dm
Dairy Cows	19 167	2 391	6.55	5.52	12.47	0.24	0.16
Other Cattle	9 583	1 195	3.27	2.88	12.47	0.17	0.11
Ewes	613	153	0.42	0.4	25.00	0.19	0.13
Other sheep	613	153	0.42	0.4	25.00	0.19	0.13
Female goats	438	110	0.30	0.28	25.00	0.17	0.11
Other goats	438	110	0.30	0.28	25.00	0.17	0.11
Sows	4 579	397	1.09	0.5	8.67	0.45	0.30
Other swine	2 289	199	0.54	0.5	8.67	0.45	0.30
Horses	9 583	1 195	3.27	1.72	12.47	0.33	0.22
Mules & asses	9 583	1 195	3.27	0.94	12.47	0.33	0.22
Rabbits	266	33	0.09		12.47	0.32	0.21
Broilers & male breeders	47	12	0.03	0.1	25.20	0.32	0.21
Hens	99	25	0.07	0.1	25.20	0.32	0.21
Turkeys	207	52	0.14	0.1	25.20	0.32	0.21
Ducks, geese, Guinea-fowl, etc	99	25	0.07	0.1	25.20	0.32	0.21

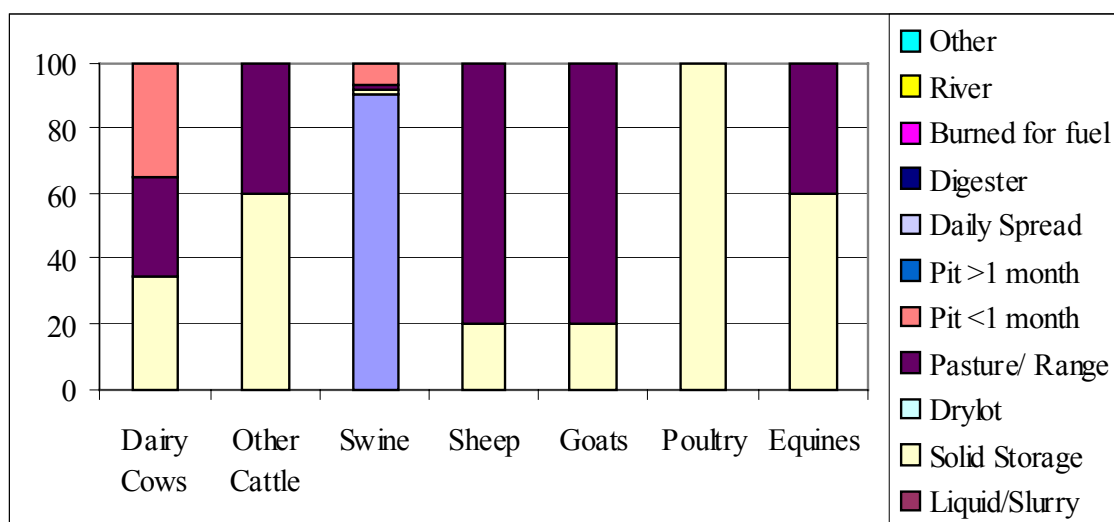
The major difference between the Portuguese country-specific emission factors (CS) and IPCC defaults (IPCC, 1997) arises mostly, however, from the use of a different share of Management Systems for Manure, which are presented in Table 6.6 and also in Figure 6.7. The country-specific percentages used in Portugal differ substantially from those in IPCC default and were set from the Agriculture Ministry (Seixas et al, 2000):

- Swine manure in Portugal is usually treated with 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;
- Solid storage is still the prevalent method of treatment for wastes from other cattle;
- Daily spread and usage as fuel are almost unknown in Portugal;
- there is a small percentage of traditional swine kept outdoors and feed pasture in range;
- there is no substantial seasonal variations in the share of management system.

Table 6.6 – Methane emissions from Manure Management: Share of each Manure Management System per animal type and determination of global MCF

MMS	MCF	Dairy Cows		Other Cattle		Swine		Sheep	Goats	Poultry	Equines
		CS	IPCC	CS	IPCC	CS	IPCC	CS (Country Specific)			
Lagoon	45					90					
Liquid/Slurry	45		40		50						
Solid Storage	1.5	35	18	60		2	21	20	20	100	60
Drylot	1.5				2		2				
Pasture/ Range	1.5	30	19	40	38	1		80	80		40
Pit <1 month	0	35				8	3				
Pit >1 month	45						73				
Daily Spread	0.5		20								
Digester	10										
Burned for fuel	10		2		2						
River	1.5										
Other	1		1		8		1				
Total	-	100	100	100	100	101	100	100	100	100	100
MCF	-	0.975	18.865	1.5	23.38	40.144	33.205	1.5	1.5	1.5	1.5

Figure 6.7 - Percentage of manure handled by each Manure Management System, by animal type



For the sake of MCF determination, it was assumed that Portugal is a temperate climatic region, although this classification does not follow strictly the rule in IPCC (1997), as is discussed in Further Improvements.

Final emissions factors are therefore those presented in next table, where is also done a comparison with the IPCC (1997) defaults for temperate regions of Western Europe and developed countries:



Table 6.7 - Final emission factors for determination of CH<sub>4</sub> emissions from Manure Management

Animal	EF (kg CH <sub>4</sub> /hd/yr)	
	National Inventory	IPCC Default
Dairy Cows	3.4	44
Other Cattle	1.9	20
Ewes	0.3	0.28
Other sheep	0.3	0.28
Female goats	0.2	0.18
Other goats	0.2	0.18
Sows	47.1	10
Other swine	23.5	10
Horses	3.8	2.1
Mules & asses	3.8	1.14
Rabbits	0.102	-
Broilers & male breeders	0.035	0.117
Hens	0.074	0.117
Turkeys	0.154	0.117
Ducks, geese, Guinea-fowl, etc	0.074	0.117

Emission factors were kept constant from 1990 to 2002 because the values that were used for parameters Vs and MMS, are best estimates for the all period considered – and not for a particular year - and because there is no further information or statistical data that could allow the setting of an evolution in time.

#### 6.2.B.4 ACTIVITY DATA

In a consistent manner livestock numbers are the same that were used in previous sub-category: CH<sub>4</sub> from enteric fermentation. Although for this source category more species are considered in the emissions estimates: birds. Livestock data are therefore already presented in Table 6.2 and Table 6.3.

Differences between number of horses, mules, asses and turkeys reported in National Statistics (INE) and FAO have also a minor importance for this source. As already noticed FAO reports sheep numbers are about 70% higher than those reported in National Statistics.

#### 6.2.B.5 RECALCULATIONS

Livestock numbers were revised for some animal types, and for all animal types in what concerns year 2001, in a consistent way to what was done for Enteric Fermentation emissions, and was already discussed in the previous chapter.

IPCC Default Emission Factors suffered changes in result of the inclusion of the new MCF values proposed by GP (Table 4.10), which partly changed table 4-8 of IPCC 1996 Revised Guidelines (IPCC,1997). The following modifications were made (Table 6.7):

Table 6.8 – CH<sub>4</sub> from Manure Management: Modifications of MCF parameter between submission 2003 and submission 2004

MMS	MCF (sub 2003)	MCF (sub 2004)
Lagoon	90	45
Liquid/Slurry	35	45
Pit <1 month	18	0
Pit >1 month	35	45

The emission factor for sheep and goats has also suffered an appreciable reduction but as result of the revision of the quantity of manure that is produced per animal. The former value was found to be too high when in comparison to other countries as mentioned by the UNFCCC secretariat (S&A and 2003 Centralized Review), and also when the comparison is made to cattle. The same finding was also done by the Ministry of Agriculture in its submission of Nitrogen Balance to the OECD. The assumptions used to derive these indicators from original data (Seixas et al, 1999) were revised and new figures were obtained that are in much close consistency to the values for other parties and in bibliography references.

A small correction was made to pigs. In submission 2003 the percentage of pigs in pasture was wrongly applied only to sows. In this submission the same percentage is applied to all swine. This change has minor consequences.

Total final change in emission factors is presented in Table 6.9. Emission Factors were therefore substantially reduced for Cattle, sheep, goats and pigs.

Table 6.9 – Change of emission factors in CH<sub>4</sub> from Manure Management, from Submission 2003 to Submission 2004

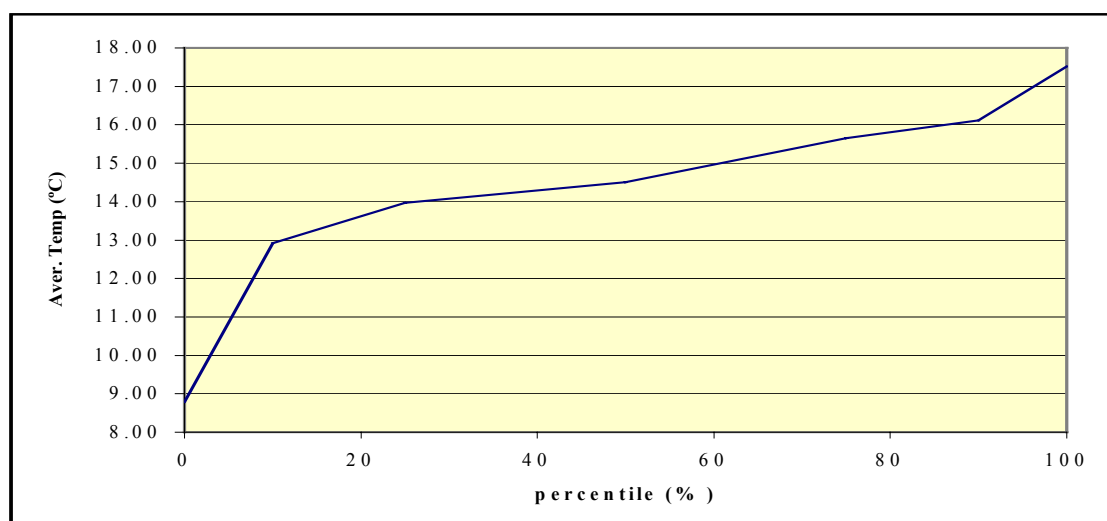
Animal	EF (kg CH <sub>4</sub> /hd/yr)		% Change
	Submission 2003	Submission 2004	
Dairy Cows	25.7	3.4	-86.6
Other Cattle	1.9	1.9	0.0
Ewes	1.6	0.3	-83.1
Other sheep	1.6	0.3	-83.1
Female goats	1.4	0.2	-88.0
Other goats	1.4	0.2	-88.0
Sows	95.8	47.1	-50.8
Other swine	47.9	23.5	-50.8
Horses	3.8	3.8	0.0
Mules & asses	3.8	3.8	0.0
Rabbits	0.102	0.102	0.0
Broilers & male breeders	0.035	0.035	0.0
Hens	0.074	0.074	0.0
Turkeys	0.154	0.154	0.0
Ducks, geese, Guinea-fowl, etc	0.074	0.074	0.0

#### 6.2.B.6 FURTHER IMPROVEMENTS

Under the procedures set together with the Ministry of Agriculture to improve the methodology and activity data used in the inventory, and for the development of the National Inventory System, it is expected that the percentage of each manure management system will be revised, with the probable consideration of time evolution in the emission factors.

For the sake of MCF determination it was assumed that Portugal is a temperate climatic region, although this classification does not follow strictly the rule in IPCC 1996 Revised Guidelines (IPCC,1997). In page 4.25 of the guidelines it is said that “Cool climate have an average temperature below 15°C; temperate climate have an average temperature from 15°C to 25°C inclusive; warm climates have an average temperature above 25°C.” Actually from long-term time series the average temperature in Portugal is about 14.55°C<sup>102</sup>, value that is precisely at the edge between climate regions cool and temperate. Except for two out of 3 regions, most regions have an annual average temperature very near 15°C. It was felt however that classifying most of Portuguese areas as cool regions, as would outcome from Figure 6.8, would not be in agreement with most climatic classification systems and it would be misleading at end to use default parameters for cool regions or to compare IEF (Implied Emission Factors) also with cool areas. Because a new limit could not be defined it was decided to include all areas under temperate region for the time being. It must be recognised that this needs to be eventually discussed and potentially revised in next submissions.

Figure 6.8 – Cumulative distribution areas in Portugal according to average annual temperature



## 6.2.C CH<sub>4</sub> Emissions from Rice Cultivation (CRF 4C)

### 6.2.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 through transport inside plant stems.

### 6.2.C.2 METHODOLOGY

Methane emissions from rice production were estimated following the equation 4.41 of GPG (IPCC,2000), 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:

<sup>102</sup> Average Annual Temperature in national territory (including Madeira and Azores islands) estimated from climatic monitoring data in the period 1950-81. Average values were established for each out of 3 territorial unit from monitoring stations and then weighted over all territory from land area. Climatic data is from the Meteorology Institute and calculation by the Institute for the Environment.

$$E_{\text{Rice}_{\text{CH}_4(y)}} = EF * \text{Rice}_{\text{Area}(y)} * 10^{-2}$$

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).

### 6.2.C.3 EMISSION FACTORS

According to GPG formulation (IPCC,2000), 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  $\text{g}/\text{m}^2/\text{yr}$ ) (IPCC,2000) was not used, but 36  $\text{g}/\text{m}^2/\text{yr}$  was used instead, which is the value proposed by IPCC (1997) 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.

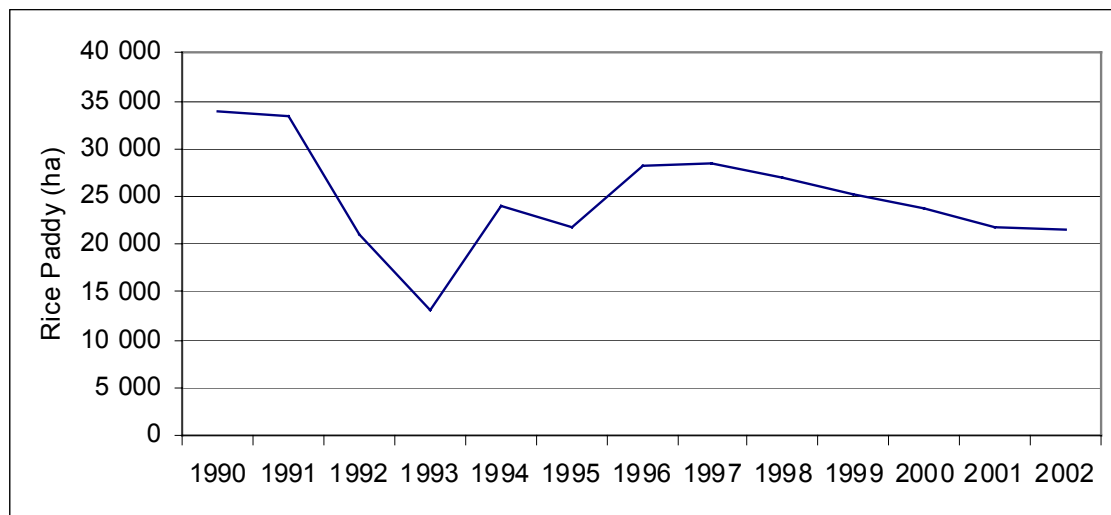
Rice culture in Portugal is almost homogeneous, in what concerns hydrologic management regime and characterized by cultivation being done under irrigated continuous flooded areas, where water regime is controlled by human activity (water diversion, irrigation and dikes). Rice fields are in standing water 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  $SF_s$  was also set to one.

#### 6.2.C.4 ACTIVITY DATA

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 6.9. 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 6.9 – Area under rice cultivation in Portugal (1990-2002)



Relevant characteristics of rice cultivated areas, such as water management regime, organic amendments and soil type are included already in emission factor setting.

#### 6.2.C.5 RECALCULATIONS

No changes have occurred since last submission, besides the replacement of the provisional value for rice cultivated area for year 2001.

#### 6.2.C.6 FURTHER IMPROVEMENTS

No improvements 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.

### 6.2.D N<sub>2</sub>O Emissions from Manure Management (CRF 4B)

#### 6.2.D.1 OVERVIEW

Part of the Nitrogen that is in manure, either in faeces or urine, is emitted as N<sub>2</sub>O during management or during storage of manure, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen. Although there is no extensive information concerning the factors that affect this process it is believed that N<sub>2</sub>O emissions increase with aeration 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 more anaerobic systems like liquid systems and anaerobic lagoons.

#### 6.2.D.2 METHODOLOGY

Emissions of N<sub>2</sub>O from manure for each Manure Management Systems s were estimated with the following formula:

$$EN2O_{(s)} = 44/28 * \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)}$$

where,

$EN2O_{(s)}$  - N<sub>2</sub>O emissions from manure in Manure Management System S;

S - Manure Management System;

i - Animal/species category of livestock;

$N_{(i)}$  - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s;

$EF3_{(s)}$  - N<sub>2</sub>O emission factor for Manure Management System S (kg N<sub>2</sub>O-N/kg N).

This formulation follows the one proposed in GPG (equation 4.18 in IPCC,2000).

The following Manure Management Systems were considered to estimate total N<sub>2</sub>O emissions from manure management:

- Anaerobic Lagoons;
- Liquid Systems;
- Solid Storage;
- Used as Fuel;
- Other MMS

This same methodology was used to assess Direct N<sub>2</sub>O soil emissions from manure deposited in soil during grazing (Pasture Range and Paddock) and also Direct N<sub>2</sub>O soil emissions from manure that is applied to soil as fertilizers. This will be further discussed under next 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".

### 6.2.D.3 EMISSION FACTORS

N<sub>2</sub>O emission factors are presented in next table for all MMS (although the uses of daily spread, use for fuel and other systems are not considered in the Portuguese inventory). These emission factors are the default IPCC (1997) emission factors (table 4-22 which were maintained in table 4.12 in IPCC,2000) because there are no country-specific emission factors.

Table 6.10 – N<sub>2</sub>O from Manure Management: Emission factors per Manure Management System

MMS	EF3 (kg N <sub>2</sub> O-N/kg N)
Anaerobic Lagoon	0.001
Liquid Systems	0.001
Daily Spread	0
Solid Storage and Drylot	0.02
Pasture Range and Paddock	0.02
Used for Fuel	0
Other System	0.005

#### 6.2.D.4 ACTIVITY DATA

Livestock populations used to estimate total nitrogen excretion are the same that are also used to estimate emissions of CH<sub>4</sub> from Enteric Fermentation and CH<sub>4</sub> from Manure Management, and are therefore referenced back to Table 6.2 and Table 6.3.

The quantity of nitrogen excreted per head was estimated from the dry weight of manure emitted per head, already presented in the chapter concerning CH<sub>4</sub> from Manure Management (6.2.2), and also considering the nitrogen percentage in manure, which was set from information received from the Agriculture Ministry (Seixas et al, 2000). The percentage of nitrogen in manure includes nitrogen both in urine and in faeces. Basic data is presented in next table together with the default nitrogen excretion rates from IPCC for Western Europe (table 4-20 of IPCC, 1997).

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: Canada (4.1), NZ (11.8), Spain (9.82), Sweden (5.6), United Kingdom (6.73) and USA (4.14).

Table 6.11 – N excretion rate per head and by animal species/category (Nex)

Animal Type	N content kg N/t dm	Nex (N-excretion rate)	
		kg N/head/yr	IPCC Default
Dairy Cows	45.21	108.07	100
Other Cattle	45.21	54.03	70
Ewes	45.01	6.90	20
Other sheep	45.01	6.90	20
Female goats	45.01	4.93	(1) 20
Other goats	45.01	4.93	(1) 20
Sows	74.99	29.78	20
Other swine	74.99	14.89	20
Horses	45.21	54.03	(2) 25
Mules & asses	45.21	54.03	(2) 25
Rabbits	45.21	1.50	(2) 25
Broilers & male breeders	63.26	0.74	(3) 0.6
Hens	63.26	1.58	(3) 0.6
Turkeys	63.26	3.29	(3) 0.6
Ducks, geese, Guinea-fowl, etc	63.26	1.58	(3) 0.6

(1) IPCC (1997) does not set N excretion rate for goats. Comparison is with value for sheep; (2) IPCC (1997) default value for other animals; (3) IPCC (1997) reports only for poultry in general

The percentage of manure that is attributed to each Manure Management System was set coherently with the share considered in CH<sub>4</sub> emissions from Manure Management, but here is presented in a different aggregation in accordance with the request by UNFCCC reporting procedures<sup>103</sup>.

Table 6.12 – Percentage of manure handled by each manure management system for each animal type.

Animal	Anaerobic Lagoons		Liquid Systems		Daily Spread		Solid Storage and Drylot		Pasture Range and Paddock		Other System	
	CS	IPCC	CS	IPCC	CS	IPCC	CS	IPCC	CS	IPCC	CS	IPCC
Dairy Cows			35	46		24	35	21	30	8		1
Other Cattle				55			60	2	40	33		9
Ewes							20	2	80	87		11
Other sheep							20	2	80	87		11
Female goats							20	2	80	87		11
Other goats							20	2	80	87		11
Sows	90		8	77			2	23	1			
Other swine	90		8	77			2	23				
Horses							60		40	96		4
Mules & asses							60		40	96		4
Rabbits							100					
Broilers & male breeders				13			100	1		2		84
Hens							100					
Turkeys							100					
Ducks, geese, Guinea-fowl, etc						100						

According to national share of MMS it is major the percentage of cattle in pasture range than according to what it is recommended by the IPCC (IPCC,1997), particularly for dairy cattle. Cattle not in pasture in Portugal is managed in dry storage manure systems and the percentage of dairy cows in solid storage is also bigger than that assumed by IPCC. Therefore N<sub>2</sub>O emissions from manure are bigger than if default MMS from IPCC (1997) were used.

For pigs, the fact that IPCC assumes most manure managed is Liquid systems, while national information considers Anaerobic Lagoons is not much relevant because EF<sub>3</sub> is the same for both MMS. However IPCC (1997) recommends a higher level of solid storage systems than it is considered according to the experts of the Portuguese Ministry of Agriculture.

For sheep, goats and equines, there is a different percentage of animals in closed systems and in Pasture, but that does not affect total N<sub>2</sub>O estimates - because EF<sub>3</sub> is similar 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.

<sup>103</sup> In the 1996 Revised IPCC Guidelines, however, there is no coherence between the default Manure Management System share proposed to estimate CH<sub>4</sub> from Manure Management and that for N<sub>2</sub>O from Manure Management.



### 6.2.D.5 RECALCULATIONS

The complete time series of N<sub>2</sub>O emissions from Manure Management has been changed since last year submission. Changes resulted from:

- Update and revision of livestock population for certain animal types, which was already discussed in chapter 6.2.1;
- Revision of the quantity of manure produced per head for sheep and goats. The annual production value, expressed in dry matter, was substantially reduced as was already discussed in chapter 6.2.2. The nitrogen content of manure remained equal to previous submission and therefore, nitrogen excretion rates per head for these two animal types decreased proportionally to the reduction in dry matter production per year. Modifications were therefore applied in a consistent way between source N<sub>2</sub>O from Manure Management and CH<sub>4</sub> from Manure Management. The N excretion rates used in submission 2003 and submission 2004 are compared in the next table;

Table 6.13 - Changes in Nitrogen Excretion Rate per head between submission 2003 and submission 2004

Animal Type	Nex (kg N/head/yr)		Difference %
	sub. 2003	sub. 2004	
Dairy Cows	108.07	108.07	0
Other Cattle	54.03	54.03	0
Ewes	40.93	6.90	-83
Other sheep	40.93	6.90	-83
Female goats	40.93	4.93	-88
Other goats	40.93	4.93	-88
Sows	29.78	29.78	0
Other swine	14.89	14.89	0
Horses	54.03	54.03	0
Mules & asses	54.03	54.03	0
Rabbits	1.50	1.50	0
Broilers & male breeders	0.74	0.74	0
Hens	1.58	1.58	0
Turkeys	3.29	3.29	0
Ducks, geese, Guinea-fowl, etc	1.58	1.58	0

- In submission 2003 nitrogen escaping from manure as ammonia volatilisation was removed before the N<sub>2</sub>O emission factors were multiplied. This procedure does not mimic the methodology proposed by GPG (IPCC,2000), where N<sub>2</sub>O emission factors are applied before NH<sub>3</sub> subtraction. This discrepancy was noticed in NIR 2003 and also in the report from the Centralized Review 2003. Therefore, in submission 2004 the methodology was modified in accordance with GPG. This results in an increase of emissions of N<sub>2</sub>O from Manure Management, while NH<sub>3</sub> emissions and indirect N<sub>2</sub>O from soil remain constant. However, when estimating N<sub>2</sub>O emissions from droppings during grazing (Pasture Range and Paddock) the NH<sub>3</sub> volatilisation is still subtracted before application of the N<sub>2</sub>O emission factor, to be consistent with the methodology used to estimate direct N<sub>2</sub>O emissions from manure applied to soil as fertilizer (see chapter 6.2.5).

The changes that were made in total nitrogen excreted for this source category are reflected, in a coherent way, with change of the quantity of nitrogen that was added to soil as manure and also during pasture range and paddock. Indirect changes in

ammonia volatilisation, due to fact that less nitrogen remains in manure, were also reflected in less indirect N<sub>2</sub>O emission in agricultural soils.

#### 6.2.D.6 FURTHER IMPROVEMENTS

Nitrogen excretion per head is expected to be revised again, particularly for sheep, goats and non-dairy cattle, under the Methodology Development Program that is being developed with the collaboration of the Agriculture Ministry. This revision will be probably done applying a mass balance to the nitrogen ingested and expelled (retention rates estimation method), and the consideration of adjustments for age/sex classes, in accordance with GPG (IPCC,2000). Under the same program it is expected that NH<sub>3</sub> emission factors will be also revised accordingly.

The percentage of each Manure Management Systems was defined by the Ministry of Agriculture in 1999. As already explained in chapter 6.2.2, it is expected a revision of these percentages and the possible inclusion of a time trend component. Results are expected from the on-going efforts that are being made by the Ministry of Agriculture under the Methodological Development Program that is being implement together with the Institute for the Environment.

The exact distinction of grazing during pasture and paddock will also be subjected to improvements.

### 6.2.E Direct N<sub>2</sub>O Emissions from Agricultural Soil (CRF 4D1)

#### 6.2.E.1 OVERVIEW

In agricultural soils, emission of N<sub>2</sub>O is enhanced by an increase in available mineral nitrogen which promotes soil biogenic activities of nitrification and denitrification. Increase of available nitrogen in soil may be caused by anthropogenic activities such as adding nitrogen to soil as a fertilizer or crop residues or as consequence of cultivation of organic soils where degradation of organic matter is enhanced liberating fixed nitrogen. N<sub>2</sub>O emissions considered in this inventory include therefore only N<sub>2</sub>O soil emissions increase due to human management of (in managed) soils over the emissions that would occur in the same area under unmanaged conditions (background emissions).

Although some scientific references indicate that soils may also be soil sinks of N<sub>2</sub>O, there are no available sound estimate techniques and consequently these were not estimated in this inventory.

Direct emissions of N<sub>2</sub>O resulting from the increase of nitrogen added to cultivated soils due to agricultural activities include the following sub-categories:

- application of synthetic fertilisers;
- application of animal manure;
- animal manure (droppings) deposited directly by animals on pasture, range and paddock;
- nitrogen fixation by N-fixing crops (leguminous plants);
- nitrogen input from incorporation of crop residues into soils.

Most effort was placed to made estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;

- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources: N<sub>2</sub>O, CH<sub>4</sub> and NH<sub>3</sub>.

The inventory of N<sub>2</sub>O from Direct Soil Emissions from Agricultural Soils is almost complete, except the non inclusion of estimates for N<sub>2</sub>O emissions from histosols and from the application of sewage sludge. However, both sources are probably minor in importance.

In what concerns histosols, calculations for these emissions could not be done due to lack of activity data (histosols under cultivation) but they represent most probably a minor emission quantity in Portugal. 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.

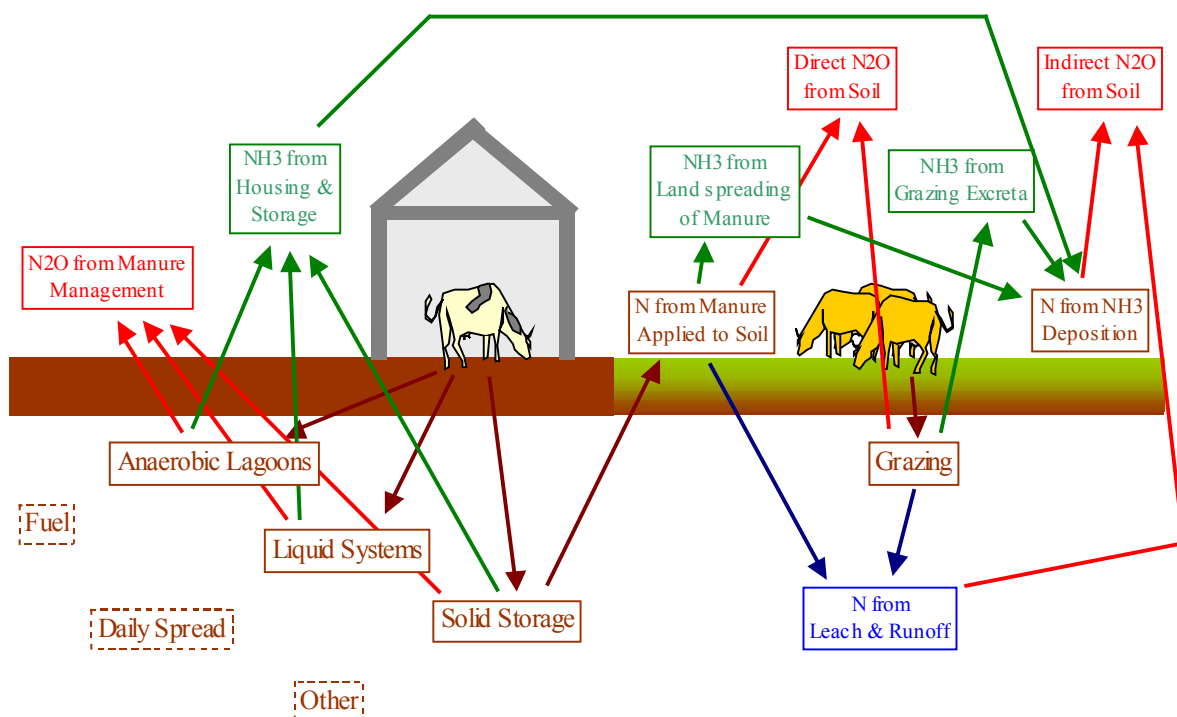
It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

The situation concerning N<sub>2</sub>O emissions from manure is somehow complex because nitrogen originally in manure may give origin to N<sub>2</sub>O emissions that are considered in different IPCC categories:

- emissions of N<sub>2</sub>O, 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<sub>2</sub>O emissions from Manure Management;
- emissions from nitrogen in manure added to soil as fertilizer is included in source category "direct N<sub>2</sub>O from agricultural soils". In Portugal it was assumed that only nitrogen from manure managed as solid storage, from all animal species, is used as soil fertilizer.

The following figure synthesizes the livestock system in what concerns nitrogen fluxes and direct and indirect N<sub>2</sub>O emissions.

Figure 6.10 – Nitrogen fluxes from livestock system



#### 6.2.E.2 METHODOLOGY

##### N<sub>2</sub>O EMISSIONS FROM AGRICULTURAL SOILS OTHER THAN ANIMAL PRODUCTION

The approach used to estimate N<sub>2</sub>O emissions from agricultural soils other than animal production (emissions of N<sub>2</sub>O in Pasture Range and Paddock) may be better classified as Tier 1a, because the same emission factor was used to all nitrogen sources to soil<sup>104</sup>.

Final N<sub>2</sub>O emissions are estimated with a formulation derived from equation 4.20 of GPG (IPCC,2000):

$$EN_{2O_{Direct}} = 44/28 * (FSN + FAM + FBN + FCR) * EF_1$$

where:

EN<sub>2O<sub>Direct</sub></sub> - Annual emission of N<sub>2</sub>O

FSN - Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilises as NH<sub>3</sub>

FAM - Annual amount of animal manure nitrogen intentionally applied to soils adjusted to account for the amount that volatilises as NH<sub>3</sub>

FBN - Amount of nitrogen fixed by N-fixing crops cultivated annually

FCR - Amount of nitrogen in crop residues returned to soil annually

<sup>104</sup> However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

EF<sub>1</sub> - N<sub>2</sub>O emission factor from N input to soil (kg N<sub>2</sub>O-N/kg N input)

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<sub>Fert</sub> - total amount of nitrogen in synthetic fertilizers consumed annually

Frac<sub>GASF</sub> - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as NH<sub>3</sub> or NO<sub>x</sub>

The amount of nitrogen in animal manure that is used as fertilizer (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:

$$FAM = \sum_i \{N_{(i)} * Nex_{(i)} * Ss[MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * (1 - EF_{NH3SD(i)})\}$$

where

FAM - total amount of nitrogen in manure from Manure Management System that is applied to soil as fertilizer;

N<sub>(i)</sub> - Number (head) of individuals from livestock category i in the country;

Nex<sub>(i)</sub> - Annual country average N excretion per head of animal species/category i;

MS<sub>(i,s)</sub> - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

MSSD<sub>(i,s)</sub> - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

EF<sub>NH3(i,s)</sub> - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

EF<sub>NH3SD(i)</sub> - 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 (IPCC,2000) if one considers that Frac<sub>GASM</sub> equals the sum of EF<sub>NH3(i,s)</sub> and EF<sub>NH3SD</sub> and being aware that Frac<sub>PRP</sub> is represented by parameter MSSD. Emissions of N<sub>2</sub>O from manure handled in Anaerobic Lagoons and Liquid Storage are already included in Liquid and Solid Waste emission source categories and are not double counted here.

Estimates of nitrogen fixed by crops follows exactly the Tier1b approach of the GPG (Equation 4.26 in IPCC,2000) 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<sub>BF(i)</sub> - Crop production of nitrogen fixing crops (ton/yr)

Res<sub>BF</sub>/Crop<sub>BF(i)</sub> - Residue to crop product mass ratio for nitrogen fixing crop i (ton/ton)

Frac<sub>DM(i)</sub> - Fraction of dry matter in the aboveground biomass of crop type i

Frac<sub>NCRBF(i)</sub> - 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 in IPCC (2000):

$$FCR = \sum_i [(Crop_i * Res/Crop_i) * Frac_{DM(i)} * Frac_{NCR(i)}] * [1 - Frac_{BURN(i)} - Frac_{FUEL(i)} - Frac_{CNST(i)} - Frac_{FOD(i)}]$$

where

i - Crop type

Crop<sub>(i)</sub> - Crop production (ton/yr)

Res/Crop<sub>(i)</sub> - Residue to crop product mass ratio for crop i (ton/ton)

Frac<sub>DM(i)</sub> - Fraction of dry matter in the aboveground biomass of crop type i (assumed to be equal to the fraction in the all plant)

Frac<sub>NCRBF(i)</sub> - nitrogen fraction in crop dry biomass (ton/ton)

Frac<sub>BURN(i)</sub> - fraction of crop residue burned in the field before and after harvest

Frac<sub>FUEL(i)</sub> - fraction of crop residue burned as fuel outside field

Frac<sub>CNST(i)</sub> - fraction of crop residue used for construction

Frac<sub>FOD(i)</sub> - fraction of crop residue used as animal fodder.

## EMISSIONS OF N<sub>2</sub>O IN PASTURE RANGE AND PADDOCK

Emissions of N<sub>2</sub>O due to the input of nitrogen to soils from pasture, range and paddock were estimated with a methodology similar to that used to estimate emissions of N<sub>2</sub>O from Manure Management, differing only because ammonia volatilisation is subtracted before nitrous oxide emission factor is applied<sup>105</sup>. Emissions were therefore estimated with the following formula:

$$Emi_{N_2O} = 44/28 * FGR * EF_3$$

where,

<sup>105</sup> This difference was made to achieve coherence with the methodology used to estimate N<sub>2</sub>O emissions from nitrogen added to soil. The correct procedure depends on the conditions from which EF<sub>3</sub> was derived which are not clear from IPCC96 (Verificar)

$Emi_{N_2O}$  -  $N_2O$  emissions from manure in Pasture, range and paddock;

$EF_3$  -  $N_2O$  emission factor (kg  $N_2O$ -N/kg N);

FGR - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that volatilises as  $NH_3$ . This variable is determined from equation:

$$FGR = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * (1 - EF_{NH3(i)})]$$

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.

### 6.2.E.3 EMISSION FACTORS

$EF_1$ , the emission factor relating N input to soil with  $N_2O$  emissions, was set equal to the IPCC default value of 0.0125 kg  $N_2O$ -N/kg N input (table 4.17 of GPG (IPCC,200) and table 4.18 of IPCC, 1997)<sup>106</sup>.

The emission factor of  $N_2O$  for Pasture, Range and Paddock ( $EF_3$ ) was set at 0.02 kg  $N_2O$ -N/kg N which is the default IPCC 1996 Revised Guidelines (IPCC,1997) emission factor (table 4-22) that is also maintained in GPG (table 4.12 in IPCC,2000).

### 6.2.E.4 ACTIVITY DATA

The quantities of nitrogen added to agricultural soils from each specific source are shown in Table 6.14 and Table 6.15 below and are also represented graphically in Figure 6.11. On average the majority (43 %) of nitrogen added to soil results from synthetic fertilizers, followed by nitrogen in manure applied as fertilizer (25 %) and as direct droppings during grazing (21 %). Smaller quantities came from nitrogen returning to soil as crop residues (10 %) and from nitrogen fixed by leguminous plants (2 %). Total nitrogen added to agricultural soils in Portugal has been decreasing steadily and are in 2002 about 15% lower than in 1990.

<sup>106</sup> Which is the same as stating that 1.25% of nitrogen input to soil is emitted as  $N_2O$

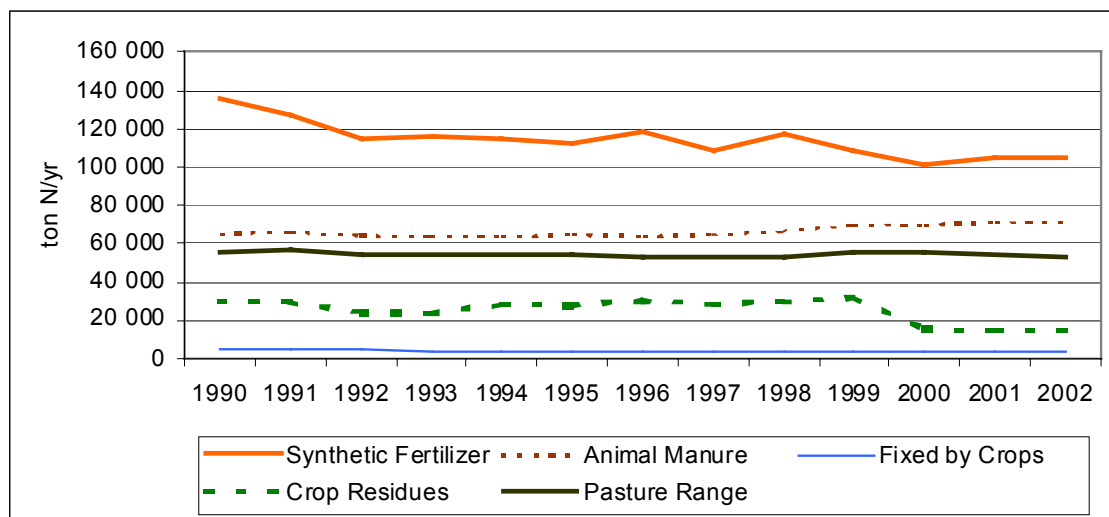
Table 6.14 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1990-1996

ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizer	135 180	126 900	114 300	116 100	115 200	112 500	118 800
Animal Manure	65 099	66 021	64 266	63 630	63 541	64 392	63 943
Pasture Range	55 789	56 636	54 569	53 562	53 626	53 672	53 001
Fixed by Crops	5 140	4 922	4 443	4 008	3 968	3 981	4 049
Crop Residues Returned to Soil	29 639	29 320	23 925	23 570	28 276	27 538	30 291
Total	290 847	283 799	261 503	260 869	264 611	262 083	270 083

Table 6.15 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1997-2002

ton N/yr	1997	1998	1999	2000	2001	2002
Synthetic Fertilizer	108 900	117 000	108 000	101 700	105 300	105 300
Animal Manure	64 547	66 562	69 771	70 120	70 619	71 167
Pasture Range	52 621	52 731	55 461	55 014	53 666	53 296
Fixed by Crops	3 874	3 694	3 101	3 449	3 433	3 389
Crop Residues	28 255	29 734	31 484	14 957	14 494	14 438
Total	258 197	269 720	267 817	245 240	247 513	247 590

Figure 6.11 – Sources of direct input of Nitrogen to agricultural soil (1990-2002)



The time series from 1990 to 2001 of the quantity of nitrogen used as synthetic fertilizers was obtained from FAO statistical database (<http://www.apps.fao.org>) which itself results from information gathered in Portugal. The value for 2002 is provisional and was set equal to 2001 in agreement with the observed trend in time series. This time series shows an abrupt decrease until 1992 and thereafter a lighter reduction. Nitrogen in fertilizers is the first source of nitrogen to soils in Portugal just above nitrogen in animal manure applied to soil, as may be seen in Figure 6.11.

Losses of nitrogen from volatilisation of  $\text{NH}_3$  and  $\text{NO}_x$  were estimated considering a constant  $\text{Frac}_{\text{GASF}}$  of 0.1kg  $(\text{NH}_3 + \text{NO}_x)\text{-N/kg N}$  input, which is the default value from table 4-19 of IPCC



1996 Revised Guidelines (IPCC,1997). In what concerns acidification emissions it was assumed that these emissions are fully ammonia.

The quantity of nitrogen in manure that is applied to soil as fertilizer resulting in  $N_2O$  emissions is estimated using the same data that was used to estimate nitrogen excreted in  $N_2O$  from Manure Management and assuming that only manure treated under Solid Storage is used as soil fertilizer, i.e.  $MSSD_{(i,s)}$  equals 1 only for Solid Storage and is zero for all other Manure Management Systems. Quantities applied each year are also presented in figure 6.11 above, where is shown that manure is the second main source of nitrogen applied to soil. Ammonia volatilisation factors,  $EF_{NH_3(i,s)}$  and  $EF_{NH_3SD}$ , are presented and discussed in more detail in chapter  $NH_3$  Emissions from Agriculture (Chapter 6.2.8) and they result from EMEP/CORINAIR Emission Inventory Guidebook - 3rd ed (EEA, 2002) (table 3A in chapter B1050). These volatilisation fractions depend only on animal class and not on the specific Manure Management System.

Table 6.16 – Emission factors used for calculation of  $NH_3$  volatilisation emissions from land spreading of manure as fertilizer

Animal Type	Losses after land spreading (kg $NH_3$ -N/kg N)
Cattle	0.17
Sheep, goats	0.07
Swine	0.16
Equines	0.07
Poultry	0.16
Rabbits	0.16

In the same way, the factors for calculation of ammonia volatilisation from excreta and urine deposited into grasslands during grazing are from EMEP/CORINAIR (EEA,2002) (chapter B1010 version 4.0 (Sutton, 2003)) and are presented in Table 6.17 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 6.17 – Emission factors used for calculation of  $NH_3$  volatilisation from animal droppings during grazing (Pasture Range and Paddock)

Animal Type	Grazing in Pasture
Dairy Cows	0.08
Other Cattle	0.08
Sheep	0.04
Goats	0.04
Swine	0.08
Equines	0.08

The use of emission factors of ammonia volatilisation from EMEP/CORINAIR (EEA,2002) results, therefore, in obtaining a value for  $Frac_{GASM}$  that is different and lower than the default value for  $Frac_{GASM}$  (0.2 kg  $N-NH_3 + N-NO_x$ / kg of N excreted, in table 4-19 of IPCC 1996 Revised Guidelines (IPCC,1997)). The resultant implied  $Frac_{GASM}$  is constant and equals 16%.

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 6.18 for leguminous crops and Table 6.19 and Table 6.20 non leguminous crops. It must be stressed that not only pulses and beans were included in nitrogen fixing crops but all leguminous crops, including therefore 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 6.18 – Annual Production of Leguminous Crops (metric tons)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Peanut	19	21	29	21	21	18	13	30	25	25	25	25	25
Broad Beans (1)	18 801	18 798	18 749	18 628	18 628	14 000	16 000	14 487	15 000	15 000	15 000	15 000	15 000
Broad Beans, green	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000
Beans	31 007	28 083	22 565	16 613	15 480	14 758	15 075	14 414	13 648	6 689	11 962	11 355	10 851
Chick-Peas	3 563	3 485	2 194	2 069	2 040	1 701	1 956	1 789	1 684	960	1 728	1 886	1 914
Lupins	57	30	42	34	34	34	34	34	34	34	34	34	34
Peas Green (1)	6 300	6 000	5 300	5 000	6 300	6 300	7 000	8 329	6 921	6 921	7 000	7 000	7 000
Carobs (1)	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green (1)	25 000	25 000	25 000	25 000	25 000	46 600	40 700	33 625	26 059	20 847	16 101	17 373	16 563
Total	134 747	131 417	123 879	117 365	117 503	133 411	130 778	122 708	113 371	100 476	101 850	102 673	101 387

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.19 - Annual Production of non-leguminous Crops (metric tons) (1/2)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Wheat	296 623	618 697	361 963	421 926	462 624	360 094	406 071	329 481	151 148	352 373	226 252	183 492	230 693
Triticale	60 549	63 500	60 000	78 000	85 388	48 268	55 768	39 004	17 289	33 067	23 832	18 820	17 609
Maize	665 560	656 187	628 415	638 143	725 976	766 493	854 352	913 017	1 023 949	935 115	153 005	155 133	139 440
Barley	78 532	124 104	63 000	98 500	96 213	53 058	69 950	28 792	26 203	29 293	21 755	11 759	11 197
Rye	96 502	80 358	69 500	66 727	63 792	36 263	53 924	40 689	32 488	55 614	44 674	37 570	33 532
Oats	72 104	76 100	45 103	76 400	79 217	57 636	60 480	44 295	28 714	99 724	85 034	61 344	57 127
Rice Paddy	156 072	170 477	109 704	69 000	131 741	124 554	172 230	164 189	161 774	151 650	23 859	24 936	25 198
Sunflower	60 741	34 190	51 000	45 064	40 000	26 120	38 297	26 980	37 679	17 538	51 840	41 523	37 583
Hops	171	164	102	39	97	127	164	102	56	50	50	80	80
Tomatoes	825 862	697 957	450 000	509 073	879 000	838 850	914 300	792 736	1 088 549	1 010 406	12 934	11 491	11 898
Tobacco	4 911	5 457	4 335	2 536	4 699	4 945	6 206	5 845	6 880	5 780	2 118	2 020	1 902
Tea	184	129	69	21	40	82	63	25	24	27	27	27	27
Chicory	2 095	2 600	2 905	2 778	3 423	2 365	2 143	2 666	2 060	2 300	2 300	3 300	3 300
Potatoes	1 343 005	1 420 870	1 568 953	1 241 192	1 326 654	1 435 663	1 325 854	1 049 314	1 224 932	1 367 327	1 250 000	1 150 000	1 200 000
Sugar Beet	12 692	11 931	19 259	31 962	50 085	56 991	32 400	149 514	187 649	506 611	475 000	277 927	600 000
Yams (1) after 1994	1 360	1 163	1 792	1 153	997	1 395	1 137	2 074	2 100	2 100	2 100	2 100	2 100
Sugar Cane (1) after 1991	3 646	3 989	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Sweet Potatoes (1)	26 000	27 000	27 000	30 000	25 000	24 000	22 000	22 000	22 000	22 000	22 000	22 000	22 000
Maize for Forage (1)	3 500 000	3 465 000	3 670 000	4 515 000	4 500 000	4 520 000	4 880 000	4 900 000	5 000 000	5 000 000	5 000 000	5 000 000	5 000 000
Sorghum for Forage (1)	350 000	335 000	405 000	345 000	320 000	360 000	360 000	360 000	360 000	360 000	360 000	360 000	360 000
RootsFodder (1)	375 000	385 000	390 000	390 000	400 000	370 000	415 000	420 000	420 000	420 000	420 000	420 000	420 000
Forage (1)	6 500 000	6 400 000	5 200 000	5 900 000	7 000 000	6 400 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000
Pumpkins (1)	4 500	4 300	3 800	4 000	3 800	12 000	13 300	12 500	12 000	12 000	12 000	12 000	12 000
Lettuce (1) until 1996	32 000	32 000	32 000	40 000	48 000	59 800	61 300	67 184	93 722	93 722	50 962	53 887	59 192
Garlic (1)	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Eggplants (1)	7 200	6 800	6 000	5 500	6 000	6 000	5 500	5 500	5 500	5 500	5 500	5 500	5 500
Onions (1) until 1996	57 200	57 200	57 200	90 000	100 000	115 800	107 900	104 920	100 618	120 742	34 497	31 846	37 079
Carrots (1) until 1996	83 000	83 000	83 000	83 000	83 000	127 100	174 300	115 785	144 615	173 538	51 730	47 426	50 170
Cauliflower (1) until 1996	20 000	20 000	20 000	20 000	20 000	29 900	30 200	28 224	31 046	34 151	13 407	13 577	17 161
Cabbages (1) until 1996	180 000	170 000	150 000	140 000	150 000	160 000	140 000	287 115	316 982	345 310	144 074	137 947	179 489
Spinach (1)	18 000	17 000	15 000	14 000	15 000	15 000	14 000	14 000	14 000	14 000	14 000	14 000	14 000
Watermelons (1) until 1996	2 000	2 000	2 000	2 000	2 000	2 000	2 000	53 833	56 202	56 202	19 473	21 606	26 355
Melons (1) until 1996	20 000	20 000	20 000	20 000	20 000	20 000	20 000	116 394	126 404	139 044	64 461	71 756	85 122
Cucumbers (1)	9 000	8 500	7 500	7 000	7 500	7 500	7 000	7 000	7 000	7 000	7 000	7 000	7 000
Chillies (1) until 1996	1 000	1 000	1 000	1 000	1 000	1 000	1 000	45 611	54 688	54 688	36 981	43 596	52 461
Mushrooms (1)	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.20 - Annual Production of non-leguminous Crops (metric tons) (2/2)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Quinces	4 900	3 300	4 000	3 380	4 000	2 065	1 877	1 805	1 775	1 800	1 800	1 800	1 800
Loquat	1 619	1 543	1 619	1 419	1 829	1 569	1 600	1 486	1 079	1 656	1 682	1 682	1 814
Pomegranate	1 800	1 800	1 810	1 700	1 700	1 600	1 608	1 058	760	1 532	1 528	1 528	1 505
Pineapples (1) until 1992	1 500	1 500	2 280	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Bananas (1) until 1991	45 568	39 900	38 000	37 000	38 000	30 000	30 000	35 000	30 000	35 000	40 000	30 000	30 000
Peach	85 116	95 131	108 148	92 240	91 648	89 735	75 884	94 919	66 034	71 326	7 149	7 007	6 723
Apples	282 521	263 350	281 033	264 088	211 981	234 965	256 780	286 212	165 404	295 368	21 213	21 332	21 430
Kiwi	2 515	5 025	10 048	10 136	9 239	8 854	10 546	10 438	5 055	10 895	978	988	1 003
Pears	94 730	94 573	100 618	95 558	116 715	73 728	101 480	173 947	120 033	131 592	12 570	12 609	12 706
Sour Cherries	576	750	720	670	640	580	597	154	53	600	600	600	600
Fig	14 800	15 500	13 750	11 500	7 176	6 313	6 479	3 853	3 767	4 236	7 566	7 436	7 396
Kakee	4 700	4 700	4 500	4 180	4 500	2 220	1 634	892	457	2 117	2 156	2 156	2 347
Apricots	4 650	4 480	4 700	4 260	5 124	5 052	4 693	4 968	3 859	6 040	628	612	550
Cherry	11 310	13 570	13 068	10 868	9 868	7 831	9 438	9 362	3 155	16 704	5 733	5 801	5 875
Plum	17 964	15 219	16 733	15 933	17 733	18 065	17 722	17 928	14 879	18 447	1 953	2 007	2 027
Avocados (1)	21 300	20 300	19 400	16 300	13 000	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	2 500	2 500	2 500	2 500	2 500
Raspberries (1)	100	100	100	100	100	100	100	100	100	100	100	100	100
Berries nes (1)	100	100	200	100	100	100	100	100	100	100	100	100	100
Tangerine	23 425	26 468	26 977	26 777	34 822	34 983	34 502	35 234	37 707	46 253	4 655	4 661	4 671
Lemon	10 200	10 250	10 863	10 363	10 988	11 063	8 782	9 656	9 023	10 461	989	1 004	1 009
Orange	176 597	171 127	177 198	173 080	189 198	209 133	179 102	212 838	271 670	212 892	21 368	21 575	21 714
Pomelo	4 700	5 500	5 600	5 550	6 576	6 833	6 898	6 859	6 848	3 740	371	389	394
Grapefruit	900	700	800	780	975	1 017	997	878	766	326	37	28	28
Walnut	5 850	5 800	4 200	3 523	2 927	2 864	3 369	3 502	3 121	4 598	3 088	3 105	3 111
Chestnuts	20 405	15 713	15 102	12 825	18 682	19 194	20 423	20 643	22 022	30 913	29 101	29 190	29 522
Hazelnuts	1 900	2 000	1 800	1 271	1 234	842	852	901	649	702	632	629	627
Almonds	18 190	20 963	19 530	18 815	9 819	7 172	8 322	12 158	24 796	34 631	38 827	38 709	38 525
Olives (Oil) (1) until 1998	177 476	420 643	140 625	237 511	222 210	311 257	275 143	309 091	225 615	322 371	249 474	260 437	309 426
Olives (fruit)	20 210	22 990	16 500	10 974	10 000	8 495	8 974	10 274	8 578	11 629	10 526	10 563	10 574
Wine grapes	1 500 289	1 329 516	1 026 941	634 941	816 249	1 053 333	1 238 955	755 172	460 156	984 985	893 998	1 036 927	893 876
Grapes (1)	54 711	55 484	53 059	50 059	53 218	57 059	55 925	61 408	39 844	55 815	6 002	6 073	6 124
Total	17 499 631	17 693 168	15 673 022	16 674 415	18 590 997	18 291 526	19 852 121	19 472 125	19 526 076	20 986 202	17 238 188	16 995 211	17 377 292

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

N 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 IPCC, 1997) 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 6.21

Table 6.21 – Parameters considered for determination of N fixed by nitrogen fixing plants

Crop	ResBF/CropBF	FracDM (%)	FracNCRBF (%)
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 6.21). The values for other non-leguminous crops were determined from IPCC defaults (IPCC,1997 and IPCC,2000) and other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in next table.

Table 6.22 - Parameters for determination of N added to soil in crop residue from non-leguminous plants

Crop	ResBF/CropBF	FracDM (%)	FracNCRO (%)
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
RootsFodder	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 <sup>(a)</sup>	1.00	15.0	1.50
Dry Fruits <sup>(b)</sup>	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 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.

### 6.2.E.5 RECALCULATIONS

There were no specific methodological changes made for this source category. Concerning activity data only crop production was updated for the most recent year and some revisions were made in all time series from the option of using National Statistics rather than FAO database, whenever possible.

Nevertheless, changes in activity data, such as the quantity of manure produced per head and the revision of some livestock populations, had indirectly influenced the emissions of this source. These changes were already discussed in chapter 6.2.2 and 6.2.3. Minor changes were also made in ammonia volatilisation factors that affect these estimates and are discussed in chapter 6.2.8.

### 6.2.E.6 FURTHER IMPROVEMENTS

Some improvements in this emission source will result indirectly from improvements in activity data used primarily in other source estimates, such as a better knowledge of nitrogen excretion rates and the percentage of manure that is managed under each management system.

Major efforts will be placed in the improvement of activity data for the most important nitrogen contributor to soil: synthetic fertilizers. The time series for nitrogen in synthetic fertilizers applied to soil should be cross-checked with other sources of information, namely production, import and export data and also a different estimate of nitrogen input using agricultural area and nitrogen input rates per hectare. Efforts for that end are being made together with the Agriculture Ministry under a program for the inventory methodological development and the implementation of the Portuguese National Inventory System.

To avoid double counting of nitrogen added to soils the part of crop residues that is submitted to grazing should be assessed and corrected in  $Frac_{FOD}$  parameter.

Efforts will be made to quantify the nitrogen in sewage sludge that is used as soil fertilizer.

In a similar process that was already done for manure emissions, clarification will be pursued whether the emission factor for Pasture Range and Paddock EF3 should be applied before or after removal of  $NH_3$  volatilisation.

## 6.2.F Indirect $N_2O$ Emissions from Agricultural Soils (CRF 4D2)

### 6.2.F.1 OVERVIEW

Emissions of  $N_2O$  from agriculture are considered indirect emissions from agriculture when they result from nitrogen that was not emitted when was applied the first time into soil but that has first suffered a path through the atmospheric system - after volatilisation as ammonia or nitrogen oxides and intermediate transformation in nitric acid and ammonium salts in particulate or aerosol form- or in the soil-water system - after leaching and/or runoff as ammonia, nitrite, nitrate or light organic compounds.

Actually  $N_2O$  indirect emissions result from the same microbial process associated to nitrification and denitrification that causes direct emissions. The only difference results from the fact that direct emissions occur solely in agricultural soils whether indirect emissions will occur in whenever conditions are adequate: in agricultural soils, non agricultural soils and even aquatic, Bentic and wetland systems.

Also, all  $NO_x$  and  $NH_3$  emissions from other emissions sources may settle in soil and water and result in similar  $N_2O$  emissions. However, estimates of indirect emissions from these sources are not included in the portuguese inventory.

Indirect emissions of N<sub>2</sub>O from ammonia and NO<sub>x</sub> volatilisation were estimated from ammonia volatilised whether actual indirect N<sub>2</sub>O emissions occurred in the Portuguese territory or not. In the case of N<sub>2</sub>O indirect emissions from leaching and runoff the geographical characteristics of the territory - where there are no water basins discharging to other countries - cause that all indirect emissions will occur still on the national territory or nearby ocean waters<sup>107</sup>.

### 6.2.F.2 METHODOLOGY

Different methodologies were used to estimate emissions from:

N<sub>2</sub>O<sub>(G)</sub>, Indirect N<sub>2</sub>O emissions from atmospheric deposition of nitrogen that has volatilised as NO<sub>x</sub> and ammonia from nitrogen used in agriculture as an external input<sup>108</sup>, either synthetic or in animal manure. The following equation, that is similar to GPG Tier1a equation, was utilized for N<sub>2</sub>O emissions from volatilisation:

$$N_2O_{(G)} = 44/28 * (SF\_NVol + MMS\_NVol + AM\_NVol + GR\_NVol) * EF_4$$

where

SF\_NVol - Total volatilisation, as ammonia or nitrogen oxides, of the nitrogen from synthetic fertilizers applied to soil (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

MMS\_NVol - Volatilisation of nitrogen from manure in Manure Management Systems (emissions in housing and outside storage) (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

AM\_NVol - Volatilisation of nitrogen from manure applied to soil as fertilizer (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

GR\_NVol - Volatilisation of nitrogen from animal excreta deposited in soil during grazing in pasture range and paddock (ton NH<sub>3</sub>-N+NO<sub>x</sub>-N/yr);

EF<sub>4</sub> - Emission factor for N<sub>2</sub>O emissions from atmospheric deposition of nitrogen on soil and water surfaces (kg N<sub>2</sub>O-N/kg NH<sub>3</sub>-N+kg NO<sub>x</sub>-N).

Methodologies for the estimation of ammonia from synthetic fertilizers, manure and animal excreta are explained in chapter NH<sub>3</sub> Emissions from agriculture (6.2.8). It was assumed that volatilisation emissions are mostly ammonia.

Indirect N<sub>2</sub>O 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, which differs from the methodology proposed in GPG (equation 4.35 or 4.37 in IPCC,2000) because ammonia volatilisation is subtracted before Frac<sub>LEACH</sub> is applied to estimate leachate and estimates are therefore smaller:

$$N_2O_{(L)} = 44/28 * (FSN + FAM + FGR) * Frac_{LEACH} * EF_5$$

where,

<sup>107</sup> In fact, part of indirect N<sub>2</sub>O 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.

<sup>108</sup> No indirect N<sub>2</sub>O emissions are estimated from nitrogen leached or removed in runoff from nitrogen fixation by leguminous plants or from nitrogen in crop residues.



FSN - Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilises as  $\text{NH}_3$ ;

FAM - Annual amount of animal manure nitrogen intentionally applied applied to soils adjusted to account for the amount that volatilises as  $\text{NH}_3$ ;

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  $\text{NH}_3$ .

Frac<sub>LEACH</sub> – Fraction of N input that is lost through leaching and runoff

EF<sub>5</sub> – Emission factor for leaching/runoff ( $\text{Kg N}_2\text{O} / \text{kg NH}_3\text{-N} + \text{NO}_x\text{-N}$ )

### 6.2.F.3 EMISSION FACTORS

Default IPCC emission factors where used for EF<sub>4</sub> and EF<sub>5</sub> (table 4-23 of the IPCC (1997) and table 4.18 of the GPG (IPCC,2000)):

Table 6.23 – Emission factors for  $\text{N}_2\text{O}$  indirect emissions from agricultural soil

Emission Factor	Kg $\text{N}_2\text{O}$ / kg $\text{NH}_3\text{-N} + \text{NO}_x\text{-N}$
EF <sub>4</sub> (Deposited nitrogen from volatilization)	0.010
EF <sub>5</sub> (Leaching and Runoff)	0.025

GPG (IPCC,2000) recommends strongly the use of the default IPCC emission factor for deposited nitrogen after volatilisation (EF<sub>4</sub>). According to GPG the default value for EF<sub>5</sub> will be probably revised in the near future.

### 6.2.F.4 ACTIVITY DATA

Emissions of  $\text{N}_2\text{O}$  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 6.24 and Table 6.25 and in Figure 6.12. Nitrogen from  $\text{NH}_3$  volatilisation from Manure Management Systems is the major contributor to indirect emissions with about 51% of total average deposition in the 1990-2002 period. The following most important components are nitrogen volatilised from synthetic fertilizers (22 %) and nitrogen in manure applied to soil as fertilizer (21 %). Nitrogen in droppings during grazing is a less important source with 7 % of average emissions in the 1990-2002 period. Total ammonia emissions and deposition has grown about one percent from the base year to 2002.

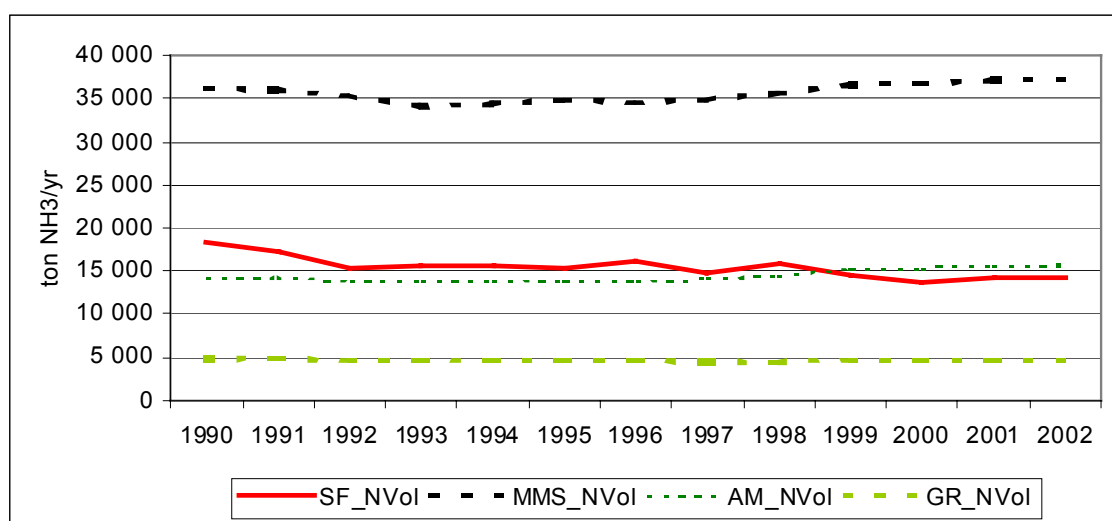
Table 6.24 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1990-1996)

ton $\text{NH}_3\text{/yr}$	1990	1991	1992	1993	1994	1995	1996
SF_NVol	18 239	17 121	15 421	15 664	15 543	15 179	16 029
MMS_NVol	36 167	36 056	35 323	34 162	34 482	34 888	34 519
AM_NVol	13 981	14 226	13 841	13 727	13 718	13 940	13 854
GR_NVol	4 733	4 812	4 608	4 519	4 497	4 502	4 449
Total	73 120	72 215	69 193	68 072	68 239	68 508	68 850

Table 6.25 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1997-2002)

ton NH <sub>3</sub> /yr	1997	1998	1999	2000	2001	2002
SF_NVol	14 693	15 786	14 571	13 721	14 207	14 207
MMS_NVol	34 939	35 623	36 663	36 828	37 219	37 333
AM_NVol	13 984	14 419	15 215	15 332	15 484	15 626
GR_NVol	4 398	4 377	4 681	4 637	4 542	4 508
Total	68 014	70 205	71 130	70 518	71 452	71 674

Figure 6.12 – Nitrogen added to soil from volatilization of ammonia applied to agricultural soils, by emission source/component (1990-2002)



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 IPCC 1996 Revised Guidelines (IPCC, 1997). The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in tables Table 6.26 and Table 6.27 and in Figure 6.13, 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 of nitrogen while nitrogen deposited in soil directly from grazing is the smaller source. From 1990 to 2002 nitrogen deposited into soil has decreased by 10 %.

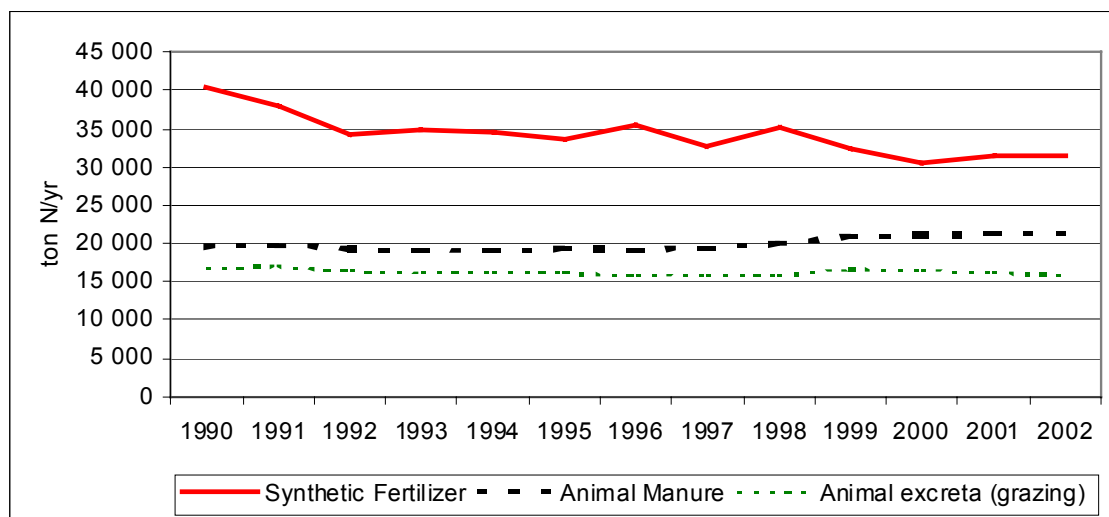
Table 6.26 – Nitrogen Lost from soil from lixiviation and runoff (1990-1996)

ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizer	40 554	38 070	34 290	34 830	34 560	33 750	35 640
Animal Manure	19 530	19 806	19 280	19 089	19 062	19 318	19 183
Animal excreta (grazing)	16 737	16 991	16 371	16 069	16 088	16 101	15 900
Total	76 820	74 867	69 940	69 988	69 710	69 169	70 723

Table 6.27 – Nitrogen Lost from soil from lixiviation and runoff (1990-1996)

ton N/yr	1997	1998	1999	2000	2001	2002
Synthetic Fertilizer	32 670	35 100	32 400	30 510	31 590	31 590
Animal Manure	19 364	19 968	20 931	21 036	21 186	21 350
Animal excreta (grazing)	15 786	15 819	16 638	16 504	16 100	15 989
Total	67 820	70 888	69 970	68 050	68 876	68 929

Figure 6.13 – Nitrogen Lost from soil from lixiviation and runoff



#### 6.2.F.5 RECALCULATIONS

No changes have been made in the methodology. Changes in emission estimates of N<sub>2</sub>O Indirect emissions resulted indirectly from changes in the quantity of manure that is produced (discussed in chapter 6.2.3) and some smaller changes in the volatilisation factors (discussed in 6.2.8). The major change has occurred in variable GR\_NVol, volatilisation of nitrogen from animal excreta deposited on soil during grazing.

#### 6.2.F.6 FURTHER IMPROVEMENTS

It is envisaged that indirect N<sub>2</sub>O emissions from ammonia and NO<sub>x</sub> emissions from other non-agricultural sources will in the future be estimated using the same methodology that it is used for NH<sub>3</sub> from agriculture. These emissions will be allocated to the original ammonia emitting source because although they occur mainly in soils and may contribute with nitrogen to plant growth they are not a result of agriculture activity and they do not necessarily occur in agricultural soils, but also in forest soils, unmanaged soils and even in inland and ocean waters.

### 6.2.G Field Burning of Agriculture Residues (CRF 4F)

#### 6.2.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.

### 6.2.G.2 METHODOLOGY

Emissions of in-site burning of agriculture residues were estimated from the following equation:

$$\text{Emission}_{(p,crop,y)} = EF_{(p,crop)} * \text{Crop}_{\text{BURN}(crop,y)} * 10^{-3}$$

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);

$EF_{(p,crop)}$  - 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 IPCC (1997) except for the fact that residue biomass is not estimated from crop production but from residue production quantities by cultivated area.

### 6.2.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<sub>2</sub>, CH<sub>4</sub> and CO) or nitrogen containing pollutants (NO<sub>x</sub> and N<sub>2</sub>O). This methodology - after IPCC 1996 Revised Guidelines (IPCC, 1997) - 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:

$$EF_{(pol,crop)} = C_{\text{Fraction}(Crop)} * \text{Frac}_{\text{RESOXI}(crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

For nitrogen containing compounds the equation is:

$$EF_{(pol,crop)} = C_{\text{Fraction}(Crop)} * \text{Frac}_{\text{RESOXI}(crop)} * NC_{\text{Ratio}(crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

where

$EF_{(pol,crop)}$  - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$C_{\text{Fraction}(Crop)}$  - Ratio of carbon content in dry biomass matter (kg C/kg dm);

$\text{Frac}_{\text{RESOXI}(crop)}$  - Fraction or ratio of carbon that it is oxidized during the active burning period (kg C/kg C);

$NC_{\text{Ratio}(crop)}$  - Ratio of nitrogen to carbon in crop residue (kg N/kg C);

$ER_{(crop,pol)}$  - Emission ratio, the fraction of total carbon/nitrogen content that it is emitted as pollutant pol (kg C/kg C or kg N/kg N);

$MWC_{(Pol)}$  - Stechiometric correction fraction to convert emissions in carbon/nitrogen units to total molecular weight emissions (kg/kg C or kg/kg N respectively for carbon compounds or nitrogen compounds).

The parameters used to establish emission factors for each crop are presented in next table.

Table 6.28 – Parameters used for determination of emission factors for field burning of agricultural residues

Crop	Cfraction	FracRESOXI	NCRatio
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 IPCC (1997) and which were still not updated in GPG (IPCC,2000) (Annex 4.A.2).

Table 6.29 – Pollutant specific emission ratios for determination of emissions from field burning of agricultural residues

Pollutant	Emission Ratio (ER)	Units	MWC Ratio
CH <sub>4</sub>	0.5	% Carbon Released from fuel	16/12
N <sub>2</sub> O	0.7		44/28
CO	6.0		28/12
NO <sub>x</sub>	12.1		46/14

The emission factors for NMVOC and Particulate Matter are those proposed by AP-42 (USEPA,1992), which are reproduced in Table 6.30, together with final emission factors for all other pollutants and all crops.

Table 6.30 – Final emission factors for field burning of agricultural residues by pollutant and crop

Crop	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	TSP	PM10-PM1
Rice	2.1	0.3	5	44.2	15.6	15.6	100%
Fresh Fruits	0.4	0.1	1.3	9.1	2.0	2.2	100%
Citrines	0.4	0.1	1.3	9.1	4.0	2.4	100%
Dry fruits	0.4	0.1	1.3	9.1	2.4	2.4	100%
Wine/grapes	1.8	0.2	4.3	37.8	7.5	7.5	100%
Olive oil	0.7	0.1	1.6	14.2	2.6	2.3	100%

## 6.2.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 orchards<sup>109</sup> 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 establish 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);

$\text{Frac}_{\text{RESBURN (crop)}}$  - Fraction of total residues from a specific crop that are burnt in site (%).

Parameters  $\text{Resid}_{\text{PROD}}$ ,  $\text{Dm}_{\text{Content}}$  and  $\text{Frac}_{\text{RESBURN}}$  are the same considered in (Seixas et al, 2000) and are presented in Table 6.31. Final activity data expressed in dry matter content may be seen in Figure 6.14 and also in Table 6.32.

Table 6.31 – Parameters used for the estimation of the quantity of burnt crop residues

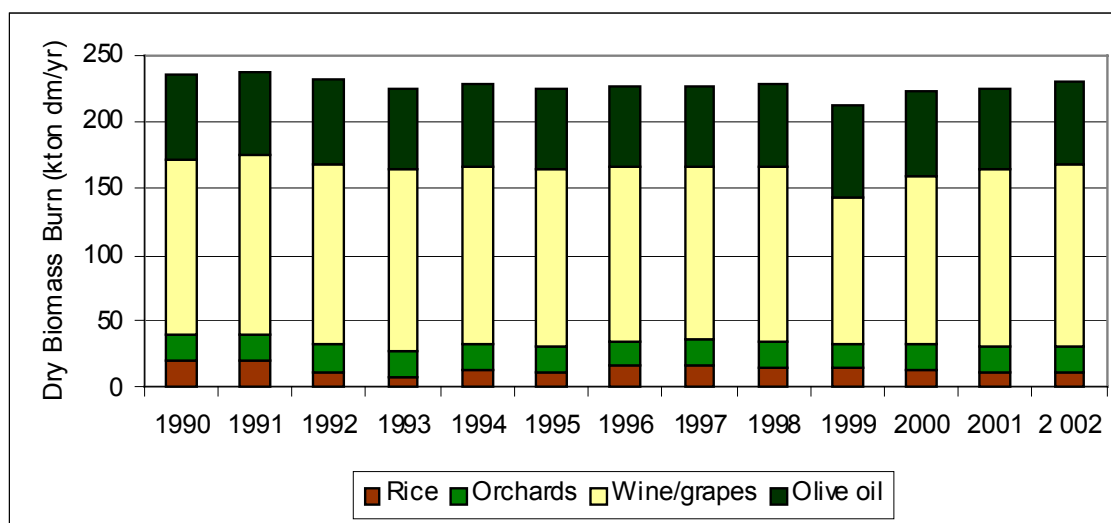
Crop	ResidPROD kg live weight/ha	FracRESBURN %	DMContent %
Rice	3 900	50	30
Orchards	800	30	50
Wine/Grapes	2 500	40	50
Olive oil	375	100	50

Table 6.32 – Estimated quantities of burnt crop residues per crop (kton dm/yr)

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Rice	20	20	12	8	14	13	17	17	16	15	14	13	13
Orchards	20	20	20	20	19	19	19	19	19	19	19	19	19
Wine/grapes	132	136	137	136	133	132	132	132	132	110	127	132	138
Olive oil	63	63	62	62	62	60	60	61	62	69	62	61	62
Total	235	238	232	225	228	224	227	228	229	213	223	225	231

<sup>109</sup> Comprehending fresh fruit, citrines and dry fruits (nuts)

Figure 6.14 – Estimated total quantities of burnt crop residues per crop (1990-2002)



### 6.2.G.5 RECALCULATIONS

Emissions of NMVOC and Particulate Matter were estimated for the first time. In what concerns the other pollutants no modifications were made either in methodology or emission factors.

### 6.2.G.6 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.

## 6.2.H NH<sub>3</sub> Emissions from Volatilization of Fertilizers

### 6.2.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\_NH<sub>3</sub>) 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 NH<sub>3</sub> or NO<sub>x</sub>

Ammonia emission from manure may occur in 4 different places in the life cycle of manure, with differentiated emission factors according to EMEP/CORINAIR Emission Factor Handbook (EEA,2002):

- Emission in housing;

- Emission in outside storage;
- Emissions from land spreading of manure collected in each Manure Management Systems;
- Emissions of ammonia volatilised from droppings deposited directly in soil during grazing.

Emissions from manure during housing and storage (MMS\_NH<sub>3</sub>) are not differentiated and are estimated according to equation:

$$MMS\_NH3 = \sum_i [N_{(i)} * Nex_{(i)} * (1 - MS_{GRAZ(i)}) * EF_{NH3(i)}]$$

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\_NH<sub>3</sub>) is calculated from:

$$AM\_NH3 = \sum_i \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

where

$N_{(i)}$  - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category T that is managed in Manure Management System s, except grazing;

$MSSD_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i)}$  - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$  - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

Emissions from volatilisation of nitrogen added to soil during grazing (GZ\_NH<sub>3</sub>) 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.

### 6.2.H.2 EMISSION FACTORS

The emission factors that were used to estimate ammonia emissions from manure from domestic livestock were already presented in source categories N<sub>2</sub>O emissions from Manure Management and Direct nitrous Oxide Emissions from Agricultural Soils and are present again in Table 6.33. These emission factors result from EMEP/CORINAIR (EEA,2002) 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 6.33 - Emission factors used for calculation of NH<sub>3</sub> volatilisation from animal housing, land spreading and grazing in pasture (kg N-NH<sub>3</sub>/kg N excreted)

Classe	Housing & Outside Storage	Land spreading of Manure	Grazing in Pasture	Total
Dairy Cows	0.17	0.17	0.08	0.42
Other Cattle	0.17	0.17	0.08	0.42
Sheep	0.1	0.07	0.04	0.21
Goats	0.1	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/CORINAIR (EEA,2002) results therefore in values for  $Frac_{GASM}$  that are different and higher than the default value for  $Frac_{GASM}$  (0.2 kg N-NH<sub>3</sub> + N-NO<sub>x</sub>/ kg of N excreted, in table 4-19 of IPCC (1997)).

Emission of ammonia volatilisation from synthetic fertilizers were calculated using the following emission factor: 01 kg (NH<sub>3</sub>-N+NO<sub>x</sub>-N)/kg N, which in fact is the default IPCC value for  $Frac_{GASF}$ .

## 6.2.H.3 ACTIVITY DATA

The quantity of nitrogen that is subjected to volatilisation is presented in Table 6.34 and Table 6.35 and Figure 6.15.

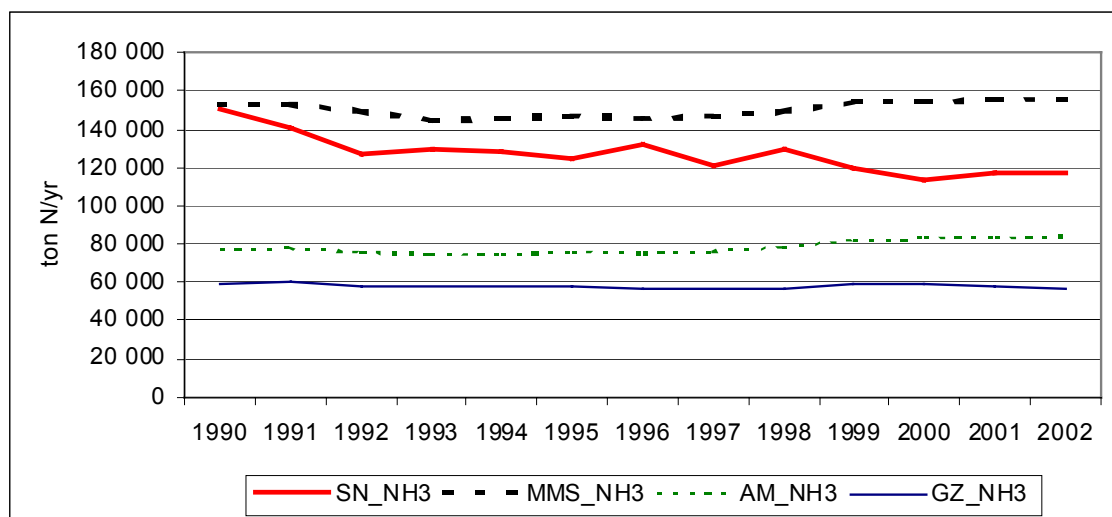
Table 6.34 – Nitrogen applied to soils from each emission source/component

ton N/yr	1990	1991	1992	1993	1994	1995	1996
SN_NH3	150 200	141 000	127 000	129 000	128 000	125 000	132 000
MMS_NH3	153 271	153 049	149 434	144 706	145 632	147 126	145 546
AM_NH3	76 612	77 737	75 664	74 934	74 837	75 872	75 352
GZ_NH3	59 688	60 598	58 363	57 283	57 330	57 379	56 665
Total	439 771	432 384	410 461	405 924	405 800	405 378	409 562

Table 6.35 – Nitrogen applied to soils from each emission source/component

ton N/yr	1997	1998	1999	2000	2001	2002
SN_NH3	121 000	130 000	120 000	113 000	117 000	117 000
MMS_NH3	146 887	149 229	154 127	154 474	155 469	155 731
AM_NH3	76 063	78 436	82 302	82 746	83 370	84 036
GZ_NH3	56 243	56 336	59 315	58 833	57 407	57 008
Total	400 193	414 001	415 744	409 053	413 246	413 775

Figure 6.15 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation (1990-2002)



## 6.2.H.4 RECALCULATIONS

The volatilisation of manure of swine during grazing was made equal to the EMEP/CORINAIR (EEA,2002) value for cattle. This results in minor modifications because pasture for this animals is less representative.

Changes in the quantity of manure produced per animal, which was already discussed in chapter 6.2.4, made indirect changes in ammonia emissions.

### 6.2.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 volatilisation rate will be function of the type of synthetic fertilizer that is used.

## 6.3 Recalculations

Total GHG emissions have suffered expressive changes since last submission, having been reduced for all years. Modifications were only significant for sub-sources 4B, manure Management, and 4D, N<sub>2</sub>O from agricultural soils (Figure 6.16). Change in GHG emissions from Manure Management apply both to CH<sub>4</sub> and N<sub>2</sub>O. More detailed explanation of recalculations will be presented during explanation of each sub-source category.

Figure 6.16 - Differences between submission 2003 and submission 2004 for CH<sub>4</sub> and N<sub>2</sub>O emissions from agriculture

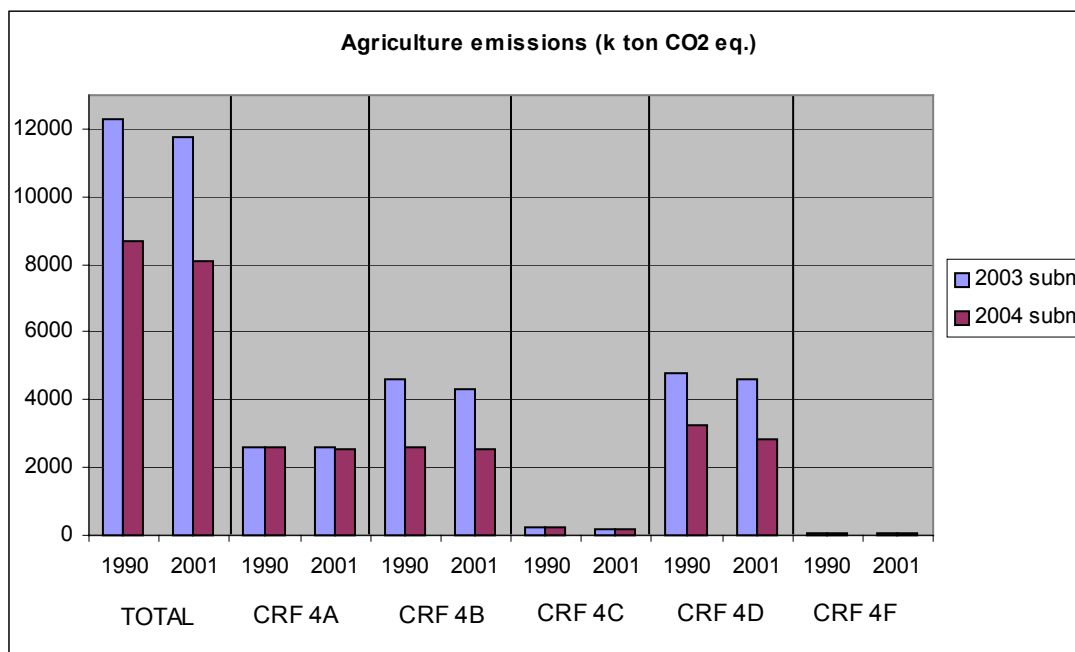


Table 6.36 – Recalculations. Differences between submission 2003 and submission 2004 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2			CH4			N2O		
			2003	2004	Difference	2003	2004	Difference	2003	2004	Difference
			subm.	subm.	(1)	subm.	subm.	(1)	subm.	subm.	(1)
			CO2 equivalent (Gg)			CO2 equivalent (Gg)			CO2 equivalent (Gg)		
			(%)			(%)			(%)		
<b>1990</b>											
4. Agriculture			0.00	0.00	0.00	6,343.17	4,504.86	-28.98	5,955.70	4,206.27	-29.37
4.A. Enteric Fermentation			0.00	0.00		2,605.55	2,605.55	0.00		0.00	
4.B. Manure Management			0.00	0.00		3,464.14	1,625.83	-53.07	1,127.35	945.72	-16.11
4.C. Rice Cultivation			0.00	0.00		255.71	255.71	0.00		0.00	
4.D. Agricultural Soils			0.00	NE	0.00	0.00	0.00	0.00	4,791.39	3,223.59	-32.72
4.E. Prescribed Burning of Savannas			0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
4.F. Field Burning of Agricultural Residues			0.00	0.00		17.77	17.77	0.00	36.96	36.96	0.00
4.G. Other			0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
<b>2001</b>											
4. Agriculture			0.00	0.00	0.00	5,876.15	4,189.74	-28.70	5,879.30	3,908.28	-33.52
4.A. Enteric Fermentation			0.00	0.00		2,581.26	2,526.48	-2.12		0.00	
4.B. Manure Management			0.00	0.00		3,097.75	1,482.03	-52.16	1,212.13	1,030.14	-15.01
4.C. Rice Cultivation			0.00	0.00		181.09	164.25	-9.30		0.00	
4.D. Agricultural Soils <sup>(2)</sup>			0.00	NE	0.00	0.00	0.00	0.00	4,633.76	2,842.83	-38.65
4.E. Prescribed Burning of Savannas			0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
4.F. Field Burning of Agricultural Residues			0.00	0.00		16.05	16.98	5.80	33.41	35.31	5.69
4.G. Other			0.00	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% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

## CHAPTER: 7 LAND-USE CHANGE AND FORESTRY (LUCF) (CRF 5)

### 7.1 Overview

Emissions of GHGs related to Land-use and Land-Use Changes refer predominantly to CO<sub>2</sub>. Other significant direct gases include CH<sub>4</sub> and N<sub>2</sub>O; indirect GHGs include CO, NO<sub>x</sub> and NMVOC. Particulate matter is also emitted in significant quantities from biomass burning.

Forestry activity is included in a broad category - Changes in Forest and Other Woody Biomass Stocks (IPCC 5A) – that should account for all significant human interactions with forests that affect CO<sub>2</sub> fluxes to and from the atmosphere, but which do not result in a land-use change. Changes in forest and other woody biomass stocks include tree-planting activities, which can result in land-use changes. For practical reasons, these activities are however included in this category.

Forest and Grassland Conversion (IPCC 5B) includes conversion of existing forests and natural grasslands to a wide variety of other uses, such as agriculture, highways and urban development. Abandonment of Managed Lands (IPCC 5C), e.g., croplands and pastures, can lead to the natural re-accumulation of carbon, or to the opposite situation, where the accumulation of biomass does not occur or even degrade.

Tree plantations are accounted in forest areas covered by the National Forest Inventory. Estimates for carbon sequestration from land-use changes resulting from these new forest stocks, corresponding to IPCC categories 5B (Forest and Grassland Conversion) and 5C (Abandonment of Managed Lands), are accounted in category 5A.

Another source/sink of CO<sub>2</sub> refers to soils, which is related with changes in the amount of organic carbon stored in soils. This depends on the quantity and quality of organic matter inputs and the rate of decomposition that is a function of climate, soil and land-use and management practices (forest and agriculture). In Portugal, there are some regional studies about the organic carbon content of the soils, but there are few elements about its relation to land use changes. Also is not possible to evaluate the net change in carbon stocks as a result of soil management practices and its evolution in time. In this way, IPCC category 5D (CO<sub>2</sub> Emissions and Removals from Soils) cannot be quantified.

Biomass burning generates emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO, NO<sub>x</sub>, NMVOC and Particulates. At present, the inventory covers emissions of CH<sub>4</sub>, N<sub>2</sub>O, CO, NO<sub>x</sub> and NMVOC from wildfires occurring in forest land. (category 5E Other)

This section covers emissions and removals from changes in forest, and emissions from wildfires. Despite the fact that IPCC Guidelines recommends Parties to consider only managed forest land, the inventory considers the all national forest. All forests are considered to be affected by human intervention, and consequently considered as non-natural/ managed. Other wooded land (bush land, shrubs), are mostly non-managed areas and were not accounted in the estimates.

## 7.2 Source categories

### 7.2.A Changes in forest and other woody biomass stocks (CRF 5 A)

#### 7.2.A.1 METHODOLOGY

The methodology that was used follows the IPCC Basic Calculation method (IPCC,1997) and relies on the carbon flux approach. It assesses net CO<sub>2</sub> flux due to changes in forest carbon stocks taking account of emissions caused by tree fellings and uptakes from the atmosphere due to tree growth.

##### 1. INCREMENT

$$= \text{area of forest (ha)} * \text{annual growth rate (m}^3/\text{ha/y)} * \\ \text{volume stem conversion factor into biomass above ground (t dm/m}^3) * \\ \text{C-fraction of dry matter}$$

##### 2. BIOMASS LOSS

$$= \text{total harvest (m}^3) * \text{expansion factor} * \text{volume stem conversion factor into} \\ \text{biomass above ground (t dm/m}^3) * \text{C-fraction of dry matter}$$

##### 3. NET ANNUAL CO<sub>2</sub> CHANGE (emission or removal)

$$= [ \text{INCREMENT} - \text{BIOMASS LOSS} ] * \text{molecular weight (44/12)}$$

#### 7.2.A.2 ACTIVITY DATA AND PARAMETERS

##### INCREMENT

Estimates of biomass increment 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)).

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.

Forest area data used to calculate growth increments come from NFIs. Available inventory surveys for the period analysed (1990-2002) are the NFI 2<sup>nd</sup> revision (1982) and the NFI 3<sup>rd</sup>

revision (1995<sup>110</sup>). Forest area data for 1990 are estimates from the General Direction for Forestry Resources based on NFIs. Figures for 2002 are also estimates based on 1995 NFI data, summed up with new forest areas from forestry plans (which already exclude unsuccessful plantations), and a discount rate based on an annual average estimate for deforestation of 0.3%. This figure was calculated as the difference from the annual rate of reforestation and the annual increase of the total Portuguese forest. The annual rate of reforestation was determined taking the area of new plantations for the period 1982-02 in relation to the total forest area in 1982 (2<sup>nd</sup> NFI): 0.7%. The annual increase of the Portuguese forest (0.4%) was determined based on the total forest area for 1982 and 1995, respectively, from the 2<sup>nd</sup> and 3<sup>rd</sup> NFI, presented in table below.

Forest areas for the intermediate years were calculated by interpolation from figures presented in the following table. Forest area presented in the table below, exclude burnt areas from forest fires.

Table 7.1 – Forest area trends (1000 ha)

	1982 (NFI 2nd rev.)	1990 (DGF estimates)	1995 (NFI 3rd rev.)	2002 (estimates)
<i>Pinus pinaster</i>	1217	1069	976	970
<i>other softwood</i>	104	104	105	133
<i>Eucalyptus</i>	366	554	672	689
<i>Quercus suber</i>	662	693	713	768
<i>Quercus ilex</i>	464	462	462	475
<i>other Quercus</i>	109	123	131	128
<i>Castanea sativa</i>	30	37	41	40
<i>other hardwood</i>	89	98	102	119
Total	3041	3140	3202	3321

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).

2002: estimates based on 1995 data plus plantations data from forestry plans, and an annual estimated average rate for deforestation of 0.3%.

Data concerning plantations (Table 7.2) 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.

New trees (plantations) are included in forest areas surveyed on NFIs. However, as carbon sequestration associated to plantations have different growth rates, these areas have been considered separately in the estimates. In the calculation it was taken into consideration the difference of time for species to reach a dbh of 7.5 cm: *Pinus* 8 years; *Quercus* 12 years, *Eucalyptus* 4 years and other softwood and hardwood 10 years.

Carbon uptake increment had been calculated separately for mature forests and new tree plantations, using different national average growth rates representing national circumstances.

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.

<sup>110</sup> 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.

Other wooded land (bushes, shrubs) had not been quantified, as they are generally non-managed areas.

Table 7.2 – Area of plantations (1000 ha)

	1980-89	1990-94	1995-2002
<i>Pinus pinaster</i>	58	24	16
<i>other softwood</i>	27	17	34
<i>Eucalyptus</i>	15	36	35
<i>Quercus suber</i>	14	24	80
<i>Quercus ilex</i>	0	3	26
<i>other Quercus</i>	0	0	0
<i>Castanea sativa</i>	1	0	0
<i>other hardwood</i>	11	19	22
Total	126	123	213

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.

Table 7.3 – Percentage of plantations in relation to forest area in 1982 (NFI 2nd rev.)

	1982-02
<i>Pinus pinaster</i>	8.0
<i>other softwood</i>	68.7
<i>Eucalyptus</i>	23.5
<i>Quercus suber</i>	17.5
<i>Quercus ilex</i>	6.3
<i>other Quercus</i>	0.0
<i>Castanea sativa</i>	4.7
<i>other hardwood</i>	56.3
Total	14.8
<b>Annual growth rate</b>	<b>0.7</b>

Growth rates refer to m<sup>3</sup> of roundwood over bark per ha and per year. This requires the use of coefficients for the conversion of stem volumes into biomass above ground. In the case of mature forests, the new parameters used results from a study performed by a Portuguese University under a contract with the IA for the development of PNAC. In what refers to biomass increment calculations for new trees, growth rates were multiplied by biomass density factors. 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 <sup>3</sup> /ha/y)	Volume stem conversion factor into biomass above ground (t dm/m <sup>3</sup> )	Biomass density Factors (t dm/m <sup>3</sup> )
<b>total forest</b>			
Pinus pinaster	5.6	0.780	..
other softw ood	5.0	1.440	..
Eucalyptus	9.5	0.700	..
Quercus suber	0.5	0.570	..
Quercus ilex	0.5	0.570	..
other Quercus	0.5	0.570	..
Castanea sativa	5.0	0.560	..
other hardw ood	2.9	0.570	..
<b>plantations</b>			
Pinus pinaster	6.2	..	0.200
other softw ood	5.0	..	0.200
Eucalyptus	10.9	..	0.500
Quercus suber	0.6	..	0.500
Quercus ilex	0.6	..	0.500
other Quercus	0.6	..	0.500
Castanea sativa	..	..	0.500
other hardw ood	2.9	..	0.500

Sources:

DGRF; PNAC July 2003 - Santos Pereira et al, "Quantificação dos sumidouros terrestres de carbono em Portugal Continental", Julho 2002, ISA, UTL

## BIOMASS LOSS

Tree harvesting data is based on annual statistical data of wood consumption, and refer mainly to the species - *pinus pinaster* and *eucalyptus*. Data considered was obtained from FAO database. 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-CO<sub>2</sub> 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).

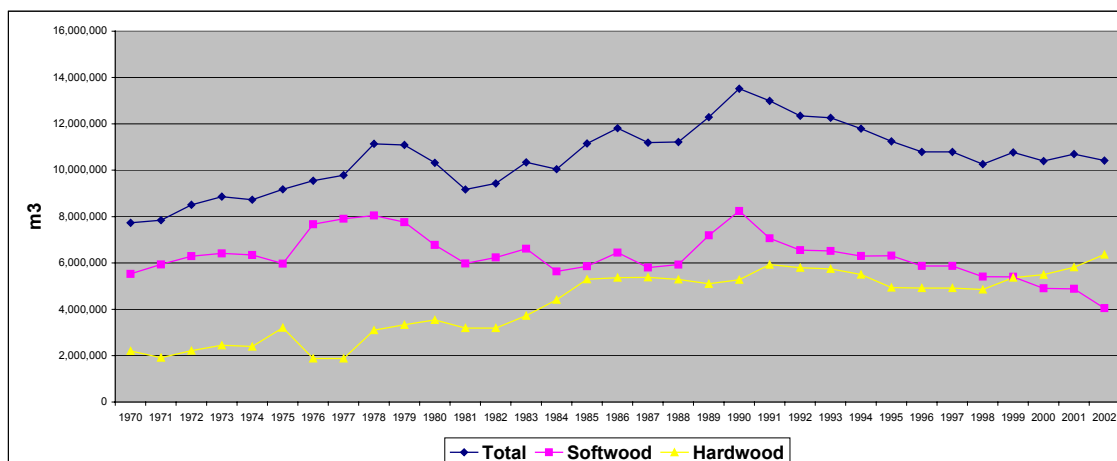
Values for tree feelings refer to roundwood over bark and do not include residues from exploration, i.e. branches, etc. To account for the whole tree volume, the expansion factors used were: for softwood 1.24; hardwood 1.2. The conversion to dry matter was done using the same parameters used for increment growth estimates.

Table 7.5 – Volumes of harvested wood (1000 m<sup>3</sup> over bark) (1990-2002)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Pinus pinaster	8,242	7,061	6,549	6,515	6,298	6,310	5,870	5,870	5,406	5,401	4,900	4,881	4,051
Eucalyptus	5,273	5,929	5,794	5,743	5,496	4,937	4,920	4,920	4,857	5,363	5,493	5,818	6,365
Total	13,515	12,990	12,343	12,258	11,794	11,247	10,790	10,790	10,263	10,764	10,393	10,699	10,416

Source: FAO, DGRF

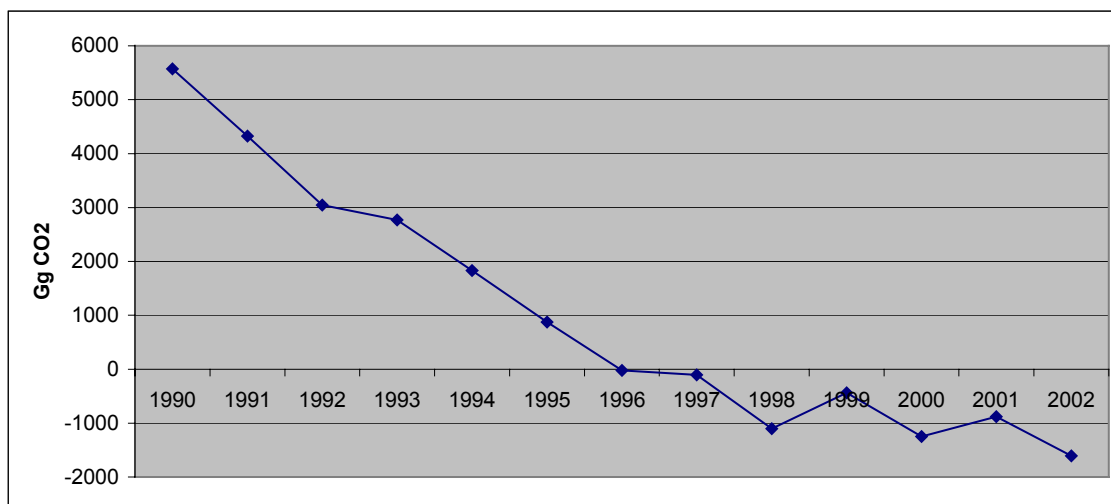
The analysis of the last 30 years time series for tree harvesting, shows that 1990 corresponds to a peak driven by a period of steady economic growth and expansion of the paper and pulp industries.

Figure 7.1 – Volumes of harvested wood (1000 m<sup>3</sup> over bark) (1970-2002)

Source: DGRF; FAO

### NET ANNUAL CO<sub>2</sub> CHANGE

As shown previously, harvest quantities have been decreasing since 1990. On the other hand, forest area has been increasing its sequester capacity, as a consequence of the conversion of marginal agriculture or non-cultivated land, and to the greater importance of fast growing species. The combination of these two facts has made this source shift from a net emitter to a sink in the period 1990-2002.

Figure 7.2 – Net Annual CO<sub>2</sub> Change from Forest (Gg CO<sub>2</sub>) 1990-2002

### 7.2.B Other: Forest Fires (CRF 5 E)

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.

IPCC (2000) for LULUCF considers good practice to estimate CO<sub>2</sub> and non-CO<sub>2</sub> emissions from biomass burning on managed forest lands. The uptake of the quantity of carbon released in a fire by the forest re-growth may take several years. However, if the method applied in the quantification of carbon sequestration (increment), does not consider the removals by re-growth after the disturbances, it is not mandatory to report the CO<sub>2</sub> emissions associated with disturbance events.

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.

### 7.2.B.1 METHODOLOGY

The estimates of non-CO<sub>2</sub> gas emissions are based on the IPCC 1996 Revised Guidelines (IPCC,1997) proposed methodology, as presented in the three steps and the equations presented below.

The carbon trace gas emissions (CH<sub>4</sub>, CO and CO<sub>2</sub>) are calculated using direct ratios to total carbon. To estimate nitrogen trace gas releases (N<sub>2</sub>O and NO<sub>x</sub>), the total carbon released is first multiplied by the N/C ration (0.01) to get the total nitrogen released; the emissions of N<sub>2</sub>O and NO<sub>x</sub> are then calculated multiplying the total N released by the N<sub>2</sub>O and NO<sub>x</sub> emissions ratios to the total N released.

#### 1. Total C released

$$= \text{burnt area (ha)} * \text{burnt biomass (t dm/ha)} * \text{C-fraction of dry matter (0.5)}$$

#### 2. Application of emission ratios

IPCC 1996 - CH<sub>4</sub>: 0.012; CO: 0.06; N<sub>2</sub>O: 0.007; NO<sub>x</sub>: 0.121;

AP-42 - CO<sub>2</sub>: 0.0068

#### 3. Emission estimation

$$\text{Emissions CH}_4 = \text{C released} * \text{emission ratio} * 16/12$$

$$\text{Emissions CO}_2 \text{ (expressed as CH}_4\text{)} = \text{C released} * \text{emission ratio} * 16/12$$

$$\text{Emissions CO} = \text{C released} * \text{emission ratio} * 28/12$$

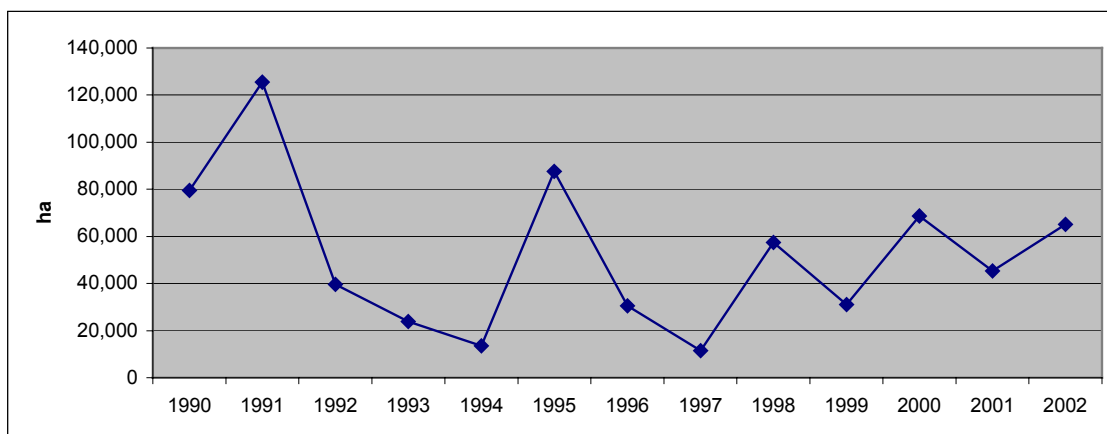
$$\text{Emissions N}_2\text{O} = \text{C released} * \text{ratio N/C (0.01)} * \text{emission ratio} * 44/28$$

$$\text{Emissions NO}_x = \text{C released} * \text{ratio N/C (0.01)} * \text{emission ratio} * 46/14$$

### 7.2.B.2 ACTIVITY DATA AND PARAMETERS

Yearly data on burnt area are available from DGRF (General Direction for Forest Resources). The estimates consider the forest area and undergrowth cover forest trees. Bush land ("matos") was not considered in the inventory, as it is generally non-managed land.

Figure 7.3 – Forest fires: human and natural origin (1990-2002)



Source: DGRF

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. 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 3<sup>rd</sup> 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 7.6 – Estimates for biomass above ground in trees

	Volume stem factor into above ground (t dm/m <sup>3</sup> )	1990			
		Forest area (1000 ha)	Stem Volume a) (1000 m <sup>3</sup> )	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
<b>Total/ Average b)</b>		<b>3,140</b>	<b>189,865</b>	<b>143,219</b>	<b>45.61</b>

Note:

a) Estimated based on the relation area/volume for 1995 (INF 3rd revision).

b) Weighted average based on 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. The dry biomass per hectare for these materials was estimated in 11.5 t dm/ha. This figure resulted

from the relation biomass/herbal-volume (3.24 kg/m<sup>3</sup>) developed by Tiago Oliveira (1998)<sup>111</sup> applied to the herbal-volume for each type of coverage, as presented in the next table.

Table 7.7 – Biomass for undergrowth cover

	Area 1990 (ha)	Volume of under- -growth cover (m <sup>3</sup> /m <sup>2</sup> )	Biomass a) (t dm/ha)
<i>Pinus pinaster</i>	1068828	0.42	13.6
<i>other softwood</i>	104498	0.52	16.8
<i>Eucalyptus</i>	554418	0.23	7.5
<i>Quercus suber</i>	693209	0.36	11.7
<i>Quercus ilex</i>	462446	0.24	7.8
<i>other Quercus</i>	122662	0.49	15.9
<i>Castanea sativa</i>	36654	0.46	14.9
<i>other hardwood</i>	97128	0.47	15.2
<b>Average b)</b>	3139843	0.35	11.49

Notes:

a) Estimates based on the relation biomass/ phyto-volume 3.24 kg/m<sup>3</sup> (Tiago Oliveira, 1998).

b) Weighted average based on area.

The degree of combustion of wood materials depends on the temperature gradient, the oxygen supply, and the burning time. In average, for forestland, it is estimated that 50% of trees and 80% of branches and leaves burn. These correspond approximately to 10% of total forest biomass. In which refers to undergrowth cover it is considered, in average, that 80% of biomass are consumed in a fire. (PNAC, 2003)<sup>112</sup>

Taking the estimated biomass presented previously, the biomass combusted was estimated for both forest trees (24.2 t dm/ha) and undergrowth cover (8.8 t dm/ha).

IPCC (2000) for LULUCF considers good practice to estimate CO<sub>2</sub> and non-CO<sub>2</sub> emissions from biomass burning on managed forestland.

In a large period of time (20 years) the net CO<sub>2</sub> flux may be zero, in the case the disturbed areas are reforested and the sink capacity restored. In a shorter time period, however, the carbon release is not immediately recaptured by the forest re-growth, and the uptake of the quantity of carbon released in a fire by the forest re-growth may take several years. Such an estimate implies a better knowledge of the average carbon stocks and the evolution in time of the damaged areas.

At present, in the absence of this information and in order to avoid double counting, Portuguese CO<sub>2</sub> emissions from wildfires are quantified by the removal of salvaged wood volumes, which are largely used in industry. These amounts are included in the harvest volumes considered, which refer to wood consumption. The emission estimates also includes the use of expansion factors, to consider the fine part of the tree (branches and leaves), which are combusted in large majority during a wildfire.

In what refers to the forest undergrowth cover it has only been considered non-CO<sub>2</sub> emissions from biomass burning. Despite the fact that GPG for LULUCF considers good practice to estimate both CO<sub>2</sub> and non-CO<sub>2</sub> 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

<sup>111</sup> Oliveira, T. (1998), Cartografia quantitativa de formações arbustivas empregando dados de detecção remota. Tese de Dissertação para obtenção do grau de Mestre. Universidade Técnica de Lisboa, 125 pp.

<sup>112</sup> PNAC (Julho 2003), Floresta e Produtos Florestais – Cenário de Referência, Volume 8.

after the disturbances (which has not been estimated), it is not mandatory to report the CO<sub>2</sub> emissions associated with the disturbance events.

## 7.3 Recalculations

Changes in this section refer mainly to CO<sub>2</sub> recalculations referring to the use of different parameters (new coefficients for the conversion of stem volumes into biomass above ground and historical) and new data series for harvest, following the UNFCCC centralised review recommendations that the wood harvest data should be updated on an annual basis.

These revisions have changed considerably the level and trends of the estimates. As presented previously, category 5A is now estimated to shift from a net emitter in 1990 to a sink source after 1996. This situation result largely from the combination of two factors: the decrease in harvest quantities since 1990 and the growth of forested areas.

Figure 7.4 – Differences between 2003 and 2004 submissions for CO<sub>2</sub> estimates

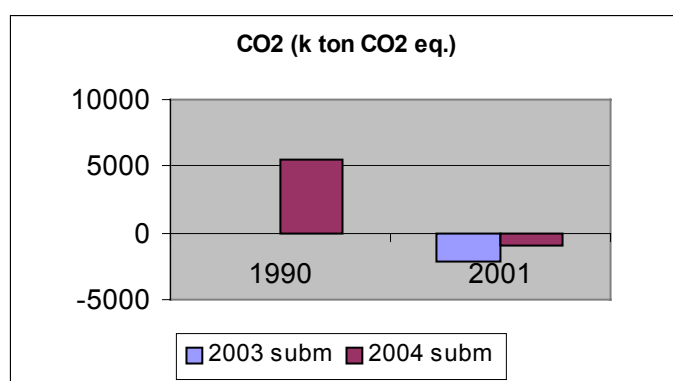


Table 7.8 – Recalculations (differences between 2003 to 2004 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)
	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)
<b>1990</b>									
<b>5. Land-Use Change and Forestry (net)</b>	-2,76	5.572,83	-202.034,52	0,00	440,86	0,00	0,00	44,74	0,00
5.A. Changes in Forest and Other Woody Biomass Stocks	-2,76	5.572,83	-202.034,52						
5.B. Forest and Grassland Conversion	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5.C. Abandonment of Managed Lands	0,00	0,00	0,00						
5.D. CO <sub>2</sub> Emissions and Removals from Soil	0,00	0,00	0,00						
5.E. Other	0,00	0,00	0,00	0,00	440,86	0,00	0,00	44,74	0,00
<b>2001</b>									
<b>5. Land-Use Change and Forestry (net)</b>	-2.151,61	-880,60	-59,07	0,00	251,20	0,00	0,00	25,49	0,00
5.A. Changes in Forest and Other Woody Biomass Stocks	-2.151,61	-880,60	-59,07						
5.B. Forest and Grassland Conversion	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5.C. Abandonment of Managed Lands	0,00	0,00	0,00						
5.D. CO <sub>2</sub> Emissions and Removals from Soil	0,00	0,00	0,00						
5.E. Other	0,00	0,00	0,00	0,00	251,20	0,00	0,00	25,49	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).

### Changes in Forest and other biomass stocks (5A)

Changes related to this section result from changes in parameters and historical data changes for harvest.

Expansion factors and biomass density factors were replaced by new coefficients for the conversion of stem volumes into biomass above ground (developed by a Portuguese University under a contract with the IA for the PNAC).

Table 7.9 – Parameters considered in 2003 and 2004 submissions

	<b>Growth Rates</b> (m <sup>3</sup> /ha/y)	<b>Volume stem conversion factor into biomass above ground</b> (t dm/m <sup>3</sup> )	<b>Expansion Factors</b>	<b>Biomass density Factors</b> (t dm/m <sup>3</sup> )
<b>total forest</b>				
Pinus pinaster	5.6	0.780	1.247	0.260
other softwood	5.0	1.440	1.247	0.260
Eucalyptus	9.5	0.700	1.237	0.522
Quercus suber	0.5	0.570	1.237	0.522
Quercus ilex	0.5	0.570	1.237	0.522
other Quercus	0.5	0.570	1.237	0.522
Castanea sativa	5.0	0.560	1.237	0.522
other hardwood	2.9	0.570	1.237	0.522
<b>plantations</b>				
Pinus pinaster	6.2	..	1.00	0.200
other softwood	5.0	..	1.00	0.200
Eucalyptus	10.9	..	1.00	0.500
Quercus suber	0.6	..	1.00	0.500
Quercus ilex	0.6	..	1.00	0.500
other Quercus	0.6	..	1.00	0.500
Castanea sativa	..	..	1.00	0.500
other hardwood	2.9	..	1.00	0.500

Note: In grey: Expansion factors and biomass density factors - parameters used in 2003 submission.

Sources: DGRF; PNAC July 2003 - Santos Pereira et al, "Quantificação dos sumidouros terrestres de carbono em Portugal Continental", Julho 2002, ISA, UTL

The harvest time series were revised according to UNFCCC centralized review recommendations to consider annual data; previous figures referred to 1990, 95 and an estimated value for 2000; new time series considered refer to annual estimates for round wood production from FAO.

Table 7.10 –Harvest time series considered in 2003 and 2004 submissions (1000 m<sup>3</sup>)

## 2003 Submission

	<b>1990</b>	<b>1995</b>	<b>2000 a)</b>
Pinus pinaster	7 562	6 674	6 000
Eucalyptus	5 726	5 440	5 500
Total	13 288	12 114	11 500

a) Estimates based on 1995-2000 average.

Source: DGF

## 2004 Submission

	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>
Pinus pinaster	8,242	7,061	6,549	6,515	6,298	6,310	5,870	5,870	5,406	5,401	4,900	4,881	4,051
Eucalyptus	5,273	5,929	5,794	5,743	5,496	4,937	4,920	4,920	4,857	5,363	5,493	5,818	6,365
Total	13,515	12,990	12,343	12,258	11,794	11,247	10,790	10,790	10,263	10,764	10,393	10,699	10,416

Source: DGRF; FAO

**Other (5E): forest wildfires**

Following UNFCCC centralized review recommendations forest fire estimates in managed forest land were included in the national totals. Previously, they were only reported as additional information and were not included in the country total.

**7.4 Further improvements**

National estimates continue not to refer to national total but only to Portugal Mainland. Information on Azores and Madeira Islands is still not available (NFI refer to Portugal Mainland only).

Despite the fact that the new conversion factors coefficients result from a national study which pretends to reflect national circumstances, it is recognised that they represent a first approximation and that a further investment should be done in the improvement of their quality.

CO<sub>2</sub> Emissions and Removals from Soils are not quantified. In Portugal, the information allowing the evaluation of the net change in carbon stocks of the soils is scarce and dispersed. There are few regional studies about the organic carbon content of the soils and its relation to land use. However there is no information concerning the evolution in the time of the net carbon storage of the soils due to management practices, land use changes, etc. Some work is being done under the context of the National System implementation, concerning the research of potential sources of information to estimate this source.

For the future estimation of emissions from wildfires, it is foreseen to consider the characterisation of the burnt species, taking into account data on the share of burnt area by specie for each year.



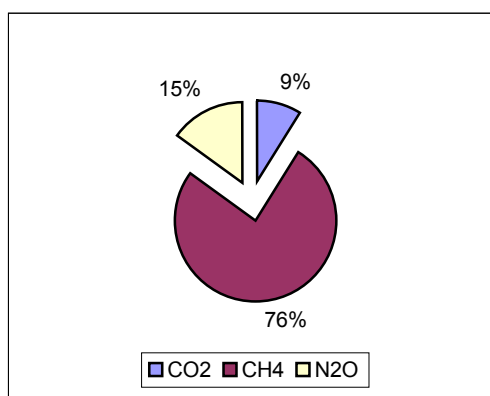
## CHAPTER: 8 WASTE (CRF 6)

### 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 CH<sub>4</sub>, resulting from the anaerobic decomposition of organic waste disposed on land and from handling of wastewater treatment under anaerobic conditions.

Figure 8.1 – Emissions of GHG from waste by gas (2002)



Decomposition of organic waste does not occur instantaneously after disposition on land, but rather over a long period of time, and CH<sub>4</sub> is emitted at a diminishing rate. Different factors affect the generation of CH<sub>4</sub>: Waste disposal practices (degree of control of disposal sites – in general, controlled placement of waste 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 CO<sub>2</sub>. In fact, the decomposition of organic materials originates landfill gas or biogas consisting of approximately 50 percent CH<sub>4</sub> and 50 percent CO<sub>2</sub> by volume. However, this carbon dioxide results in its major part from oxidation of biomass materials and does not contribute hence to ultimate CO<sub>2</sub>. Additionally, a much smaller percentage of landfill gas is composed of NMVOC and NH<sub>3</sub>.

The biodegradation of soluble organic matter in wastewater can occur under aerobic or anaerobic conditions. CH<sub>4</sub> emissions result from handling of wastewater and the biomass (sludge) produced under anaerobic conditions. The amount of CH<sub>4</sub> produced depends on the extent of biodegradation occurring under anaerobic versus aerobic conditions. CH<sub>4</sub> produced during deliberate anaerobic wastewater treatment processes can be collected and flared or combusted for energy. Untreated wastewater may originate CH<sub>4</sub> if held under anaerobic circumstances.

CH<sub>4</sub> emissions are affected by:

- Wastewater characteristics. Determines how much organic compounds are degraded. Also the degradable organic content of wastewater determines the CH<sub>4</sub> producing potential of wastewater, because it affects the extent to which oxygen is removed from the system. Under anaerobic conditions and all the same conditions, such as

temperature, wastewater with higher BOD (Biochemical Oxygen Demand) or COD (Chemical Oxygen Demand) concentrations will produce more CH<sub>4</sub> than wastewater with lower BOD or COD concentrations);

- Handling Systems – anaerobic versus aerobic conditions in system design and operation (the management conditions of collection and wastewater treatment systems determine the potential of CH<sub>4</sub> generation; systems providing anaerobic conditions will generally produce higher CH<sub>4</sub> emissions than systems having aerobic conditions);

- Temperature (CH<sub>4</sub> generation increases with temperature; CH<sub>4</sub> production occurs with temperatures higher than 15°; this factor is specially important in uncontrolled systems and warm climates);

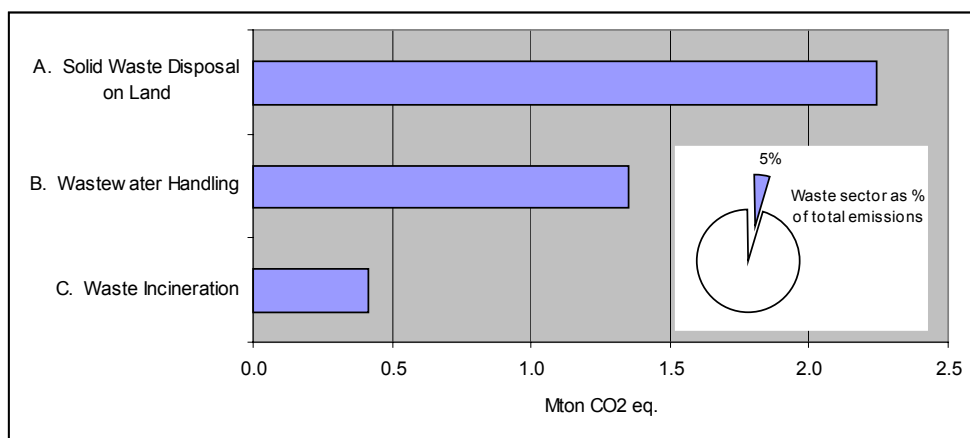
- Systems characteristics (other factors affecting CH<sub>4</sub> production are retention time, degree of wastewater treatment, and other site specific conditions).

Wastewater treatment is also potentially a source of NMVOC and N<sub>2</sub>O. Although the available methodologies to estimate these pollutants are far from suitable, N<sub>2</sub>O 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 CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO, NO<sub>x</sub> and NMVOC. Out of the direct GHG, CH<sub>4</sub> emissions are considered to be the less significant due to combustion conditions in incinerators. According to the IPCC Guidelines (IPCC,1997), only CO<sub>2</sub> emissions resulting from the incineration of carbon in waste of fossil origin (e.g. plastics, certain textiles, rubber, liquid solvents, and waste oil) are to be included in emissions estimates, while the carbon fraction that is derived from biomass materials (e.g. paper, food waste, and wooden material) should not be included. Thus, CO<sub>2</sub> emissions from waste combustion depends, on the quantities of waste incinerated, the carbon content of the waste, and the fraction of the carbon that is of fossil origin. 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 did represent in 2002 approximately 5% of total GHG emissions (excluding CO<sub>2</sub> from LULUCF). The biggest sub-category within the sector refers to solid waste disposed on land – 2.24 Mton CO<sub>2</sub> eq. - corresponding to more than a half of the sector emissions.

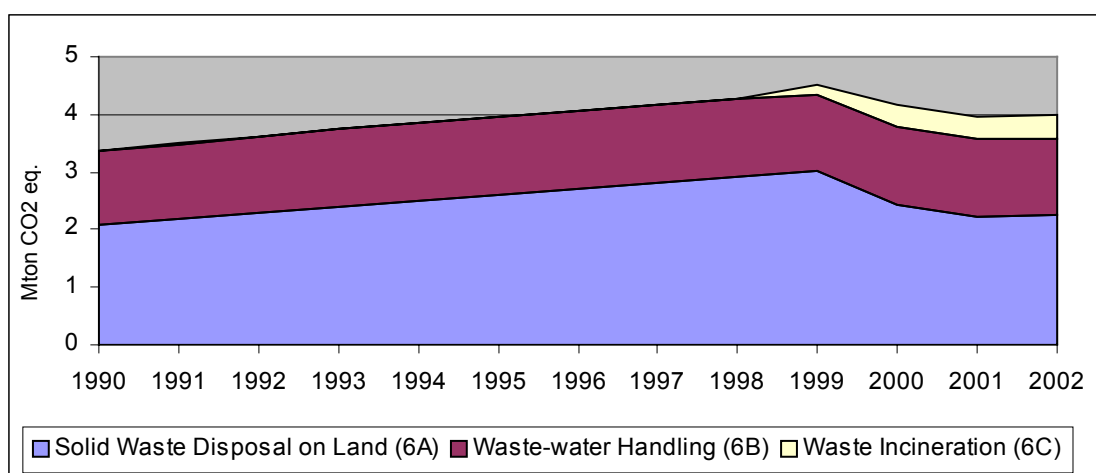
Figure 8.2 – Sources of GHG in waste sector (2002)



In the period 1990-2002 GHG emissions from waste activities have grown almost 19%, having reached a peak in 1999. The increase in the sector is strongly related to the change of consumption patterns registered in Portugal in the last decades, associated with new commercial structures. The opening of the first supermarket occurred in 1961. By the end of that decade/ beginning of the next one, several distribution companies appeared. The late 70s/ beginning of the 80s registered another increase of these commercial units, with the number of supermarkets rising from 196 in 1974 to 375 in 1985. The following years, which recorded a steady economic growth in particular since the Portuguese accession to the EU in 1986, have lead to the reduction of customs barriers and the revival of domestic demand, and have definitively changed the consumption habits of the Portuguese population. Since 1985, year of the opening of the first hypermarket in Portugal, until 1997, they were settled 40 hypermarkets and 943 supermarkets in the country (APED)<sup>113</sup>.

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 trend 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.

<sup>113</sup> 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 CH<sub>4</sub> EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

##### METHODOLOGY

To better take into account the fact that CH<sub>4</sub> emissions from SWDS occur over a long period of time and not immediately after disposal of waste on land, the methodological approach considered was the First Order Decay Method (Tier 2).

This method can be represented by equations (1) and (2):

$$Q = L_0 R (e^{-kc} - e^{-kt}) \quad (1)$$

where:

Q - methane generated in current year (Mg CH<sub>4</sub>/yr);

L<sub>0</sub> - methane generation potential (Mg CH<sub>4</sub>/Mg waste);

R - quantity of waste landfilled - average annual waste acceptance rate during the SWDS's active life (Mg/yr);

k - methane generation rate constant (1/yr);

c - time since SWDS closure (yr) (c = 0 for active SWDS);

t - time since SWDS opened (yr).

$$\text{CH}_4 \text{ emitted (Gg/yr)} = [\text{CH}_4_{\text{generated}} - \text{Rec}] * (1 - \text{OX}) \quad (2)$$

where:

Rec - CH<sub>4</sub> recovered (Gg/yr);

OX - oxidation factor (fraction).

CH<sub>4</sub> recovery (Rec) is the amount of CH<sub>4</sub> generated at SWDS that is recovered and combusted (e.g. flared or used for energy) and not emitted as CH<sub>4</sub> but as CO<sub>2</sub><sup>114</sup>. On the other hand, the CH<sub>4</sub> that is recovered but subsequently vented to atmosphere is not subtracted from emissions.

Oxidation factor (OX) reflects the portion of CH<sub>4</sub> from SWDS that is oxidised to CO<sub>2</sub> in the soil or other material covering the waste. If the OX is zero, no oxidation takes place, and if OX is 1 then 100% of CH<sub>4</sub> is oxidised. Well-managed disposal sites tend to have higher oxidation results than unmanaged dump sites with no cover or where large amounts of CH<sub>4</sub> can escape through cracks in the cover.

The methane generation potential (L<sub>0</sub>) depends upon the composition of waste, waste disposal practices and of the physical characteristics of the SWDS. It is estimated by the formula:

<sup>114</sup> Although not ultimate CO<sub>2</sub>.

$$Lo = MCF * DOC * DOC_F * F * 16/12$$

where:

MCF - CH<sub>4</sub> correction factor (fraction);

DOC - degradable organic carbon (fraction) (Mg C/Mg waste);

DOCF - fraction DOC dissimilated;

F - fraction (volume) of CH<sub>4</sub> in landfill gas.

Methane correction factor (MCF) accounts for the effect of management practices on CH<sub>4</sub> generation. Unmanaged disposal sites present lower methane-generating potential, because a larger fraction of waste decomposes aerobically in the top layers.

Degradable organic carbon (DOC) is the organic carbon that is accessible to biochemical decomposition. It is a function of the composition of waste and can be calculated from a weighted average of carbon content of various components of waste.

$$DOC = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)$$

where:

A = fraction of waste that is paper and textiles;

B = fraction of waste that is garden waste, park waste or other non-food organic putrescibles;

C = fraction of waste that is food waste;

D = fraction of waste that is wood or straw.

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 CH<sub>4</sub> in landfill gas landfill gas is usually considered to be composed dominantly by half of CO<sub>2</sub> and half of CH<sub>4</sub><sup>115</sup>.

## ACTIVITY DATA AND PARAMETERS

SWDS include solid municipal or urban waste (household, garden, commercial-services wastes) and industrial wastes.

<sup>115</sup> Other gases exist in lesser quantities however.

**Urban waste**Quantities of waste landfilled

In 2002, 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. Estimates for 2002 are still provisional as data collected from municipal management systems were not available at the time of the inventory preparation.

For previous years, information on urban waste was not collected on a regular basis, and most information was available from:

- PERSU - “Plano Estratégico dos Resíduos Sólidos Urbanos” (Strategic Plan on Municipal Solid Waste), which was approved by the Government in 1997. This plan includes data from annual municipal registries;
- a study performed by Quercus (1995) – “Caracterização dos Resíduos Sólidos Urbanos e Inventariação dos Locais de Deposição em Portugal” (Characterization of Municipal Solid Waste and Survey of Disposal Sites in Portugal). The study of Quercus (1995) considered open dump sites, managed landfills, composting and incineration units, covering aspects as the quantities of waste treated or landfilled and other characteristics (opening and closure year of operation, waste composition, existence of flaring equipment, etc). Data was based on a survey performed in 1994, which enabled the calculation of per capita generation rates for 1994, based on the amounts of waste collected and the population served by waste collection.

The use of the FOD method requires building a data time series for several decades in the past concerning waste quantities, composition and disposal practices. According to IPCC (2000), it is good practice to estimate historical data if such data are not available, when this is a key source category (Annex A). In what concerns the extent of the time series, it was adopted the criteria from USA, based on the emissions model from EPA(1993), and it was considered that landfill waste produces CH<sub>4</sub> 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:

[Population (inhabitants) \* Annual per capita generation rate (ton/inhabitants/year)]

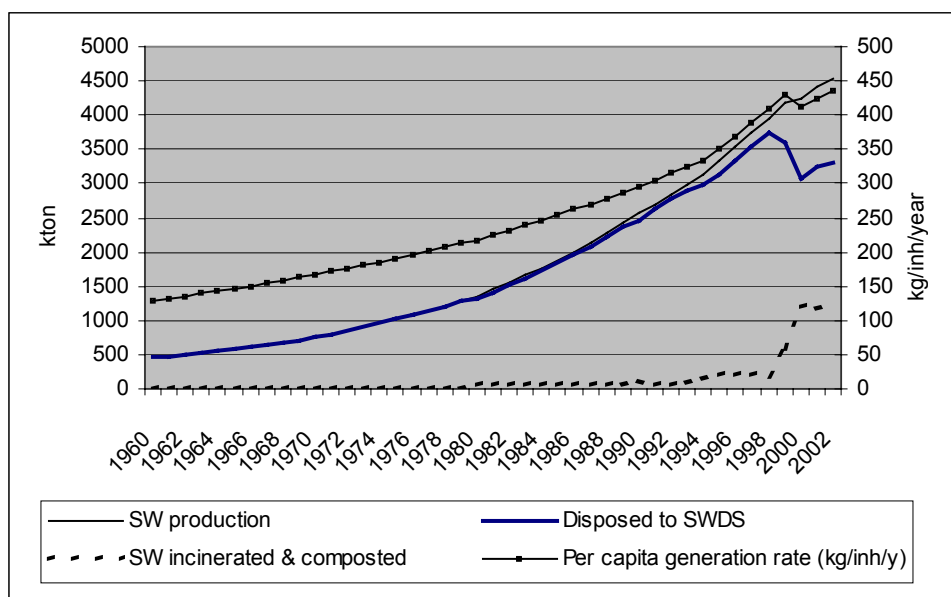
Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991 e 2001. Data for intermediate years were estimated, by interpolation, for each municipality. Figures for 2002 were calculated by data by forecast from previous years.

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:

$$\text{Waste disposed to SWDS} = [\text{Population} * \text{Annual per capita generation rate} * \\ \text{Percentage of Population served by waste collection}] \\ - \text{Quantity of incinerated waste} - \text{Quantity of composted waste}$$

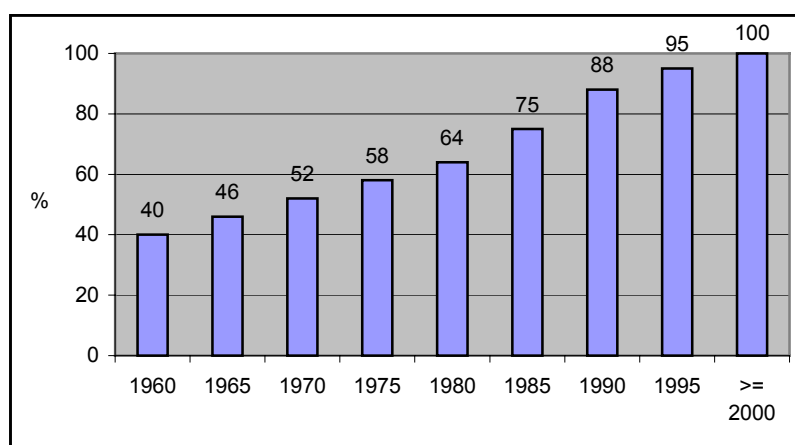
Next figure presents trends for per capita generation rates, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series. For the more recent years (for 1994, and since 1999) the information refers 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 1960-2002



Source: IA estimates; INR; Quercus study

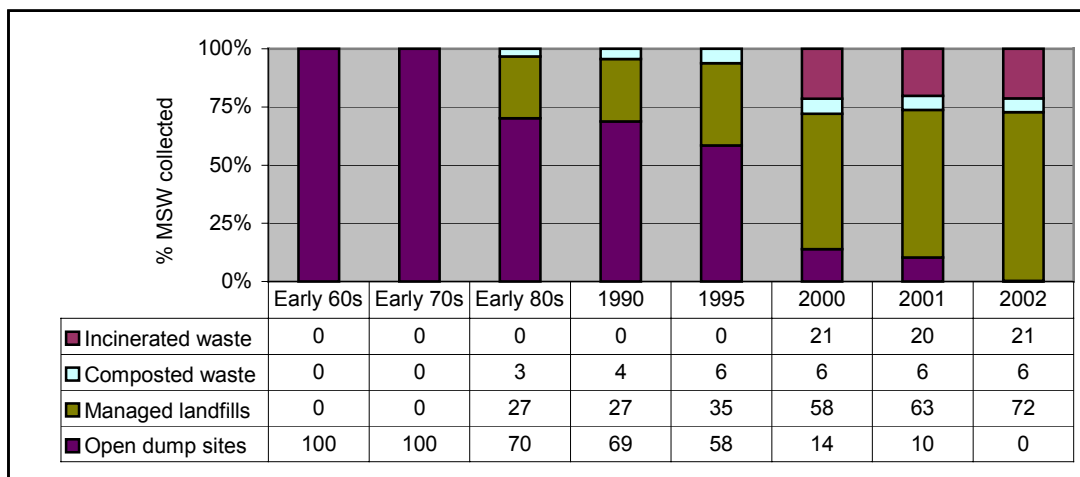
Figure 8.5 - Population served by solid waste collection systems



Source: INR

The share of final disposal destiny for the beginning years of the 1960-2002 time series was calculated having as a basis the Quercus survey. Data for recent years 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 2002 this figure fall to 72%, and the percentage of waste incinerated grew to 21%).

Figure 8.6 – Final disposal of waste (% of municipal solid waste collected)



Source: IA estimates; Quercus; INR

#### CH<sub>4</sub> generation potential (Lo)

The parameters used in the calculation are mainly IPCC default values.

Table 8.1 – Parameters used in Lo calculation

Parameter	Explanation	Value considered
MCF	IPCC defaults	Managed landfills = 1.0 Open dump sites = 0.6
DOC	National estimate	18.8
DOCF	IPCC default (considering T = 35°)	0.77
F	IPCC default	0.5

The estimation of Degradable Organic carbon (DOC) was based on information on the waste composition from annual municipal registries, and also from the Quercus survey, presented in the following table.

Table 8.2 - Composition of waste disposed to SWDS (fermentable fractions)

Fermentable fractions	Percentage of weight
Paper and textiles (fraction A)	25.8
Non-food fermentable materials (fraction B)	18.7
Food waste (fraction C)	34.8
Wood or straw (fraction D)	0.3

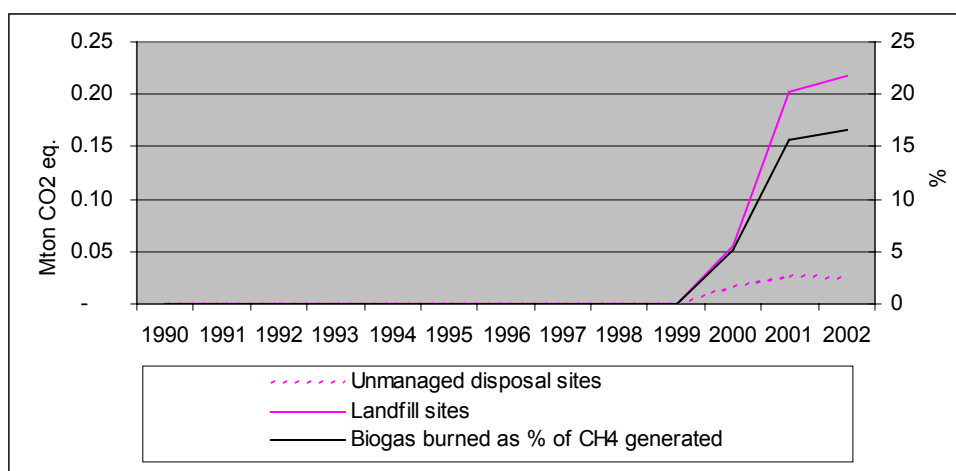


### Other parameters

Two different values were considered for the CH<sub>4</sub> generation rate constant (k), to take into consideration diverse regional circumstances. A higher k value (0.04) was applied for municipalities above Tagus River reflecting higher moisture conditions; a lower k figure (0.02) was used for the others.

In the absence of metering landfill gas recovered data, estimates of recovered CH<sub>4</sub> 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 CH<sub>4</sub> 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 CH<sub>4</sub>. 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 CH<sub>4</sub> recovered.

### Industrial waste

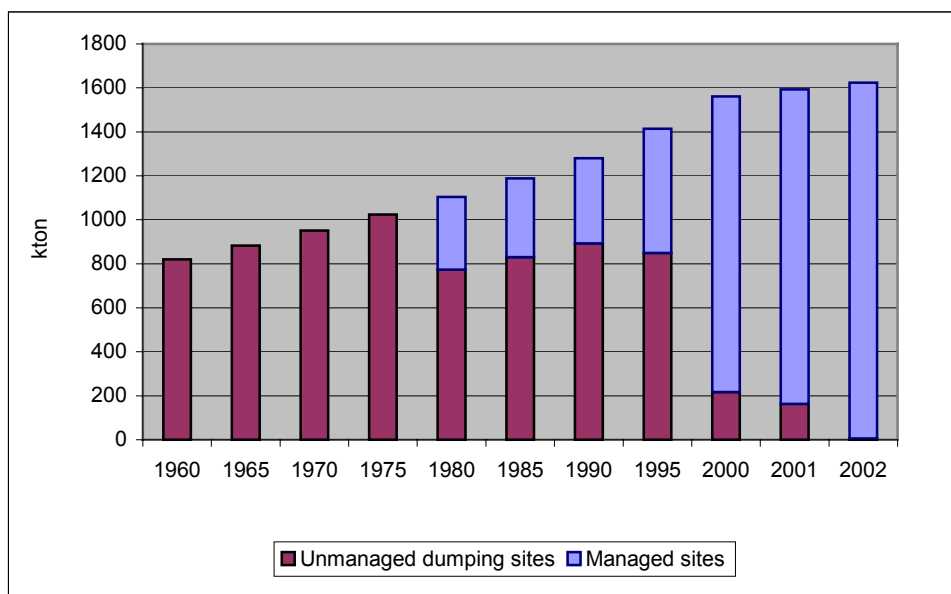
#### Quantities of waste landfilled

Industrial wastes considered in this inventory refer only to the fermentable part of industrial waste. Time series are based on 1999 data which refer to annual registries relating to industrial units declarations sent to the regional environment directorates (CCDR).

Historical waste disposal data 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 to 2002 are also estimates based on 2% per year growth rate.

Until now there are no dedicated industrial disposal sites in Portugal. Hence, all industrial waste generated was considered to be disposed in SWDS together with urban waste. However, as there is no available information concerning final industrial waste disposal, it was assumed that all estimated waste produced until 2002 have followed the urban disposal pattern between uncontrolled and controlled SWDS.

Figure 8.8 – Quantities of fermentable industrial waste disposed to SWDS



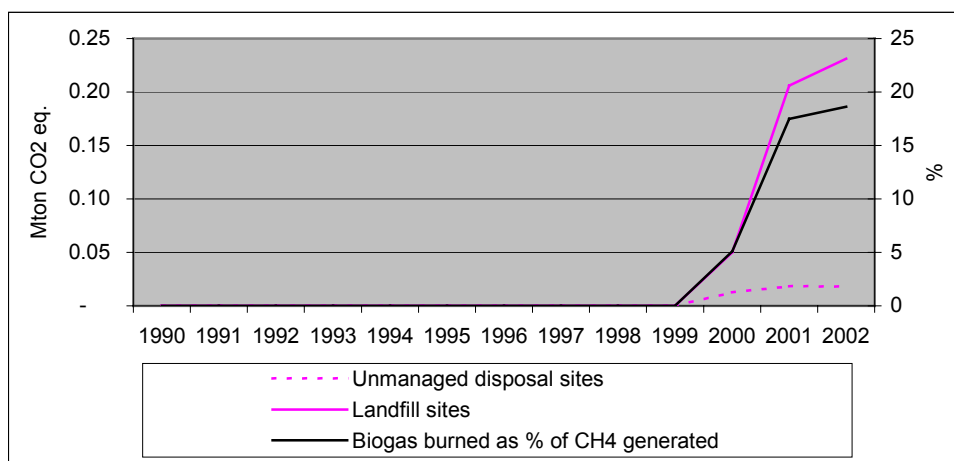
Source: IA estimates; INR

#### CH<sub>4</sub> 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 varied: 0.28 (1960 – 1999), and 0.20 for later years, referring to the composition of industrial waste for 1999 and 2000, respectively.

#### Other parameters

Data on quantities of CH<sub>4</sub> 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 CH<sub>4</sub> recovered and combusted (industrial waste)

#### 8.2.A.2 COVNM EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

COVNM emissions are calculated using the same methodology as for CH<sub>4</sub>, i.e. the FOD method. Activity data and parameters are the ones presented in CH<sub>4</sub> 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 NH<sub>3</sub> EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

NH<sub>3</sub> emissions are calculated using the same methodology as for CH<sub>4</sub>, i.e. the FOD method. Activity data and parameters are the ones presented in CH<sub>4</sub> sub-session, with an exception for F – the fraction of NH<sub>3</sub> by volume in landfill gas is 0.005.

#### 8.2.A.4 NH<sub>3</sub> EMISSIONS FROM COMPOST PRODUCTION

##### METHODOLOGY

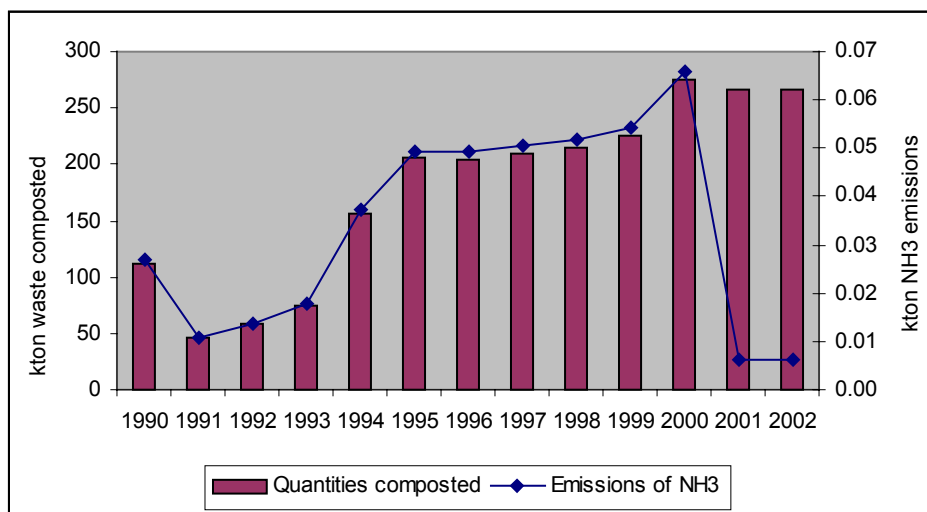
Emission estimates follow a simpler methodology indicated in Corinair 3<sup>rd</sup> rev., which is based on the quantities of composted waste and the application of an emission factor, as follows:

$$\text{NH}_3 \text{ emitted (ton/y)} = \text{Quantity of composted waste} * \text{EF (g NH}_3\text{/ton RSU)} / 10^6$$

##### 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 8.3 – Ammonia emission factors for compost production

	EF g NH3/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

#### 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<sub>dom</sub> - total domestic/commercial organic waste in kg BOD/yr;

P - population in 1000 persons;

D<sub>dom</sub> - domestic/commercial degradable organic component in kg BOD/1000 persons/yr.

Calculations have been made separately for TOW<sub>dom</sub> for wastewater and sludge.

## 2 – Estimation of emission factors

The emission factor for each wastewater and sludge type depends on the maximum CH<sub>4</sub> producing potential of each waste type (B<sub>o</sub>) and a weighted average of CH<sub>4</sub> conversion factors (MCF) for the different wastewater treatment systems existing in a country.

$$EF_i = B_{oi} \times \sum_x (WS_{ix} \times MCF_x)$$

where:

EF<sub>i</sub> - emission factor (kg CH<sub>4</sub> /kg DC) for waste type i (e.g., domestic wastewater or sludge, etc);

B<sub>oi</sub> - maximum methane producing capacity (kg CH<sub>4</sub>/kg DC) for waste type i;

WS<sub>ix</sub> - fraction of waste type i treated using wastewater handling system x;

MCF<sub>x</sub> - methane conversion factors of each wastewater system x.

Maximum CH<sub>4</sub> producing capacity (B<sub>o</sub>) is the maximum amount of CH<sub>4</sub> that can be generated from a given quantity of wastewater or sludge.

Methane Conversion Factor (MCF) is an estimate of the fraction of DC that will ultimately degrade anaerobically. The MCF varies between 0 for a completely aerobic system to 1.0 for a completely anaerobic system.

## 3 – Calculation of emissions

Emissions are a function of total organic waste generated and an emission factor characterising the extent of CH<sub>4</sub> generation for each wastewater handling system. CH<sub>4</sub> that is recovered and flared or used for energy should be subtracted from total emissions, as it is not emitted into the atmosphere.

$$M = \sum_i (TOW_i \times EF_i - MR_i)$$

where:

M - Total CH<sub>4</sub> emissions from wastewater and sludge handling in kg CH<sub>4</sub>

TOW<sub>i</sub> - total organic waste for waste type i in kg DC/yr. (Step 1)

$EF_i$  - emission factor for waste type  $i$  in kg CH<sub>4</sub>/kg DC (Step 2)

$MR_i$  - total amount of methane recovered or flared from wastewater type  $i$  in kg CH<sub>4</sub>.

This method can be applied at different levels of desegregation according to data availability.

In the national inventory all calculations have been done at municipal territorial units. National totals result from the summation of estimates performed for each municipality.

### Activity data and parameters

Total organic content of domestic sewage ( $TOW_{dom}$ ) was determined multiplying the total population for each year by a per capita wastewater BOD<sub>5</sub> production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation. The BOD<sub>5</sub> factor considered was 56 g BOD<sub>5</sub>/cap/day.

Data for population included in wastewater treatment systems at regional level was established from Environmental State Reports, which incorporates data from the National Plan for Environmental Policy (PNPA 1995) and data from INAG (National Water Institute).

Total organic waste (TOW in terms of BOD<sub>5</sub> produced) was then divided into four fractions, according to the wastewater handling types considered: wastewater treatment plants, septic tanks, discharge into water, and the amount of sludge produced. The quantities of sludge are assumed to be, for all years, 20% of TOW originated in wastewater treatment plants.

Figure 8.11 – Wastewater BOD produced according to handling systems (ton BOD<sub>5</sub>) and national population trends

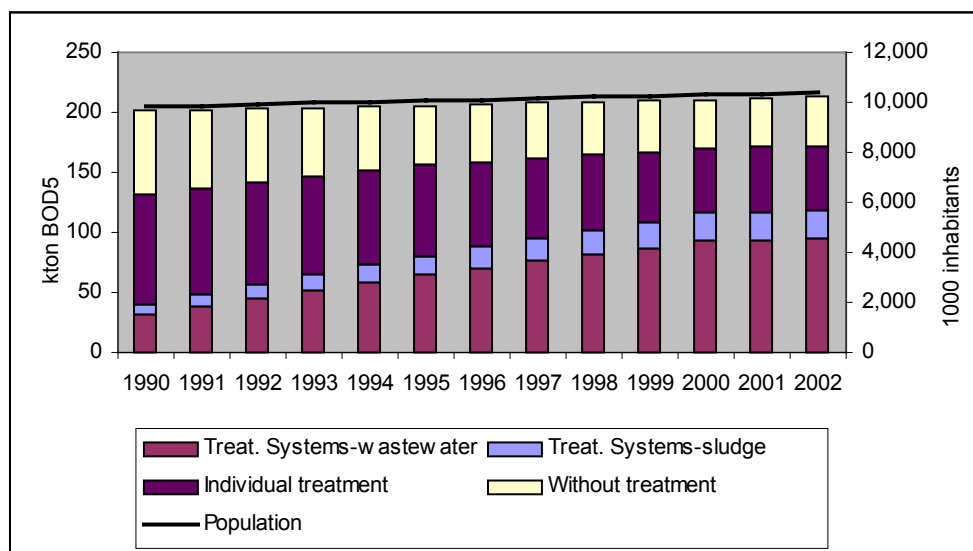


Table 8.4 - Percentage of population by wastewater handling system

Region	Treatment Systems			Individual treatment (a)			Discharge into waterways or ocean		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
Norte	11.0	32.0	42.0	64.0	56.0	41.0	25.0	12.0	17.0
Centro	18.0	30.0	51.0	61.0	48.0	29.0	21.0	22.0	20.0
Lisboa e Vale do Tejo	26.0	47.0	64.0	21.0	14.0	11.0	53.0	39.0	25.0
Alentejo	32.0	58.0	74.0	31.0	17.0	15.0	37.0	25.0	11.0
Algarve	37.0	60.0	83.0	24.0	32.0	16.0	39.0	8.0	1.0
Açores	24.8	45.4	62.8	40.2	33.4	22.4	35.0	21.2	14.8
Madeira	24.8	45.4	62.8	40.2	33.4	22.4	35.0	21.2	14.8
Average	20.1	39.3	55.2	45.1	36.7	25.4	34.7	24.0	19.3

a) Population served by individual private treatment facilities (e.g. septic tanks)

**Parameters: Bo and MCF:** The default IPCC (2000) value for Bo 0.6 kg CH<sub>4</sub>/kg BOD was used for wastewater and sludge.

Average MCF factors for wastewater treatment systems were weighted by the percentage of each type of treatment for each region, and using the MCF values established by expert judgement for each treatment type (Table 8.5). Information for THE percentage of wastewater that is handled according to a specific wastewater treatment system and final resultant MCF are presented in next table for each region.

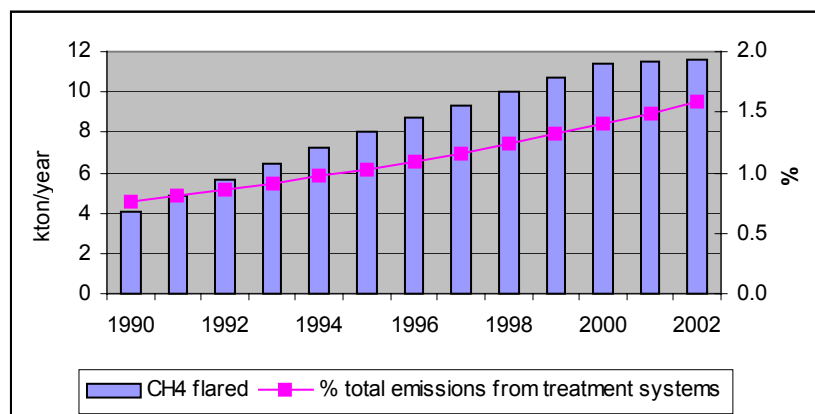
Table 8.5 - Wastewater treated by type of treatment system (%) and associated Methane Conversion Factors (MCF)

Region	Anaerobic digestion	Imhoff tank	Percolation beds	Other treatment	MCF estimated
	%				
Norte	2.08	12.50	31.25	54.17	0.21
Centro	0.00	6.52	44.56	48.92	0.16
Lisboa e Vale do Tejo	0.00	4.35	28.26	67.39	0.17
Alentejo	0.00	0.00	32.10	67.90	0.15
Algarve	0.00	1.72	17.24	81.04	0.17
Açores	..	..	..	..	..
Madeira	..	..	..	..	..
Average	0.42	5.02	30.68	63.88	0.17
MCF	1.00	0.50	0.10	0.18	

MCF value used for individual private treatment facilities, such as septic tanks was set as 0.5; MCF figure considered for sludge was 0.15. The fraction of wastewater discharged into rivers and coastal waters, was considered to degrade aerobically (MCF = 0).

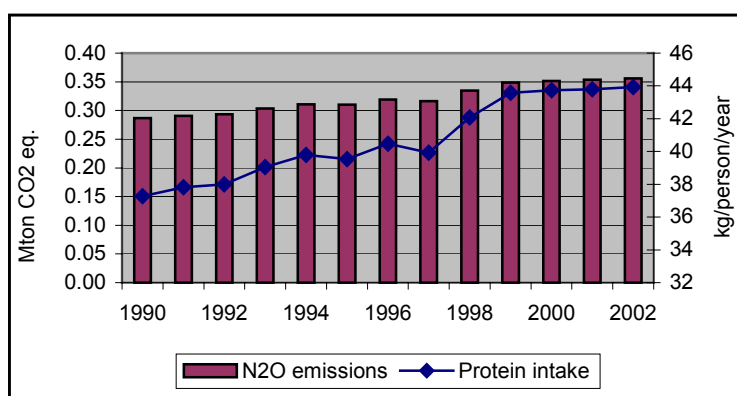
MCF evolution over time was estimated considering an annual average variation rate of: -2% for wastewater treatment plants, and +5% for sludge.

Recovery of CH<sub>4</sub> data was estimated as a percentage of the calculated emissions for each wastewater treatment systems and sludge. The percentage considered for the base year (1990) for wastewater treatment systems was 0.5%, and for sludge 2%. CH<sub>4</sub> recovery trends were calculated considering an annual increase rate of 4% for CH<sub>4</sub> recovery.

Figure 8.12 - Estimated quantities of CH<sub>4</sub> flared

### N<sub>2</sub>O EMISSIONS FROM WASTEWATER (HUMAN SEWAGE)

Human sewage can be disposed on land or discharged into aquatic environments (e.g. rivers and estuaries), either directly without treatment or after treatment in septic systems or wastewater treatment facilities. N<sub>2</sub>O can be generated during all these stages through nitrification/denitrification of the nitrogen in faeces, urine and other liquid wastes, which are typically in the form of urea and proteins. In general, temperature, pH, BOD, and nitrogen concentration influence N<sub>2</sub>O production from human sewage.

Figure 8.13 – N<sub>2</sub>O emissions from human sewage and per capita protein intake

Source: Protein intake: FAO database (December 2003); 2002 figure: IA estimate.

### Methodology

Emissions of N<sub>2</sub>O from domestic wastewater were estimated following the proposal of IPCC 1996 Revised Guidelines (IPCC, 1997), that considers that the amount of protein consumed by humans determines the quantity of nitrogen contained in sewage.

$$N_{2O(s)} = \text{Protein} * \text{Frac}_{NPR} * \text{Pop} * \text{EF} * 44/28$$

where:

N<sub>2</sub>O<sub>(s)</sub> - N<sub>2</sub>O emissions from human sewage (kg N<sub>2</sub>O-N/yr);



Protein - annual per capita protein intake (kg/person/yr);

Fra<sub>CNPR</sub> - fraction of nitrogen in protein (kg N/kg protein);

Pop - number of inhabitants in country;

EF - emissions factor (kg N<sub>2</sub>O-N/kg sewage-N produced);

44/28 is the molecular weight ratio of N<sub>2</sub>O to N<sub>2</sub>.

### Activity data and parameters

Activity data results of protein intake, according to FAO database (Table 8.6), 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 8.6 - Data and parameters used calculation of N<sub>2</sub>O emissions from wastewater

Parameter	Explanation	Values considered	
		Year	Value (kg/person/year)
Annual per capita protein intake	FAO data (December 2003)	1990	37.3
		1991	37.8
		1992	38.0
		1993	39.1
		1994	39.8
		1995	39.5
		1996	40.5
		1997	39.9
		1998	42.1
		1999	43.6
		2000	43.7
		2001	43.8
		2002	43.9
Fraction of nitrogen in protein	IPCC96 default	16%	(constant)
Emission factor	IPCC96 default	0.01 kg N <sub>2</sub> O-N/kg N	(constant)

Note: 2002 figure: IA estimate.

### 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:

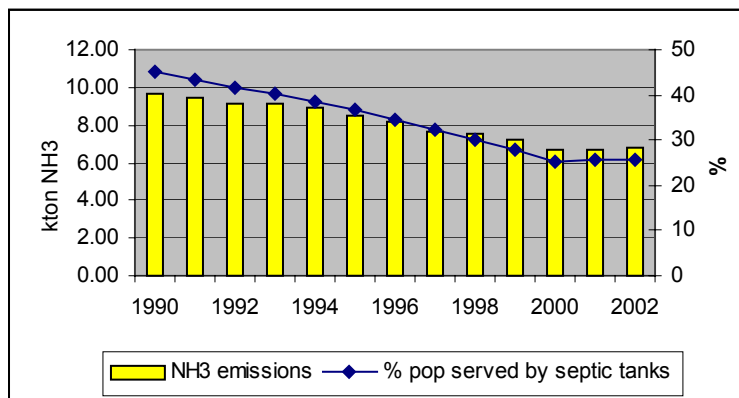
$$EF = 0.36 \text{ kg/106 l wastewater} * 125 \text{ l/inhabitant/year} * 365$$

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 8.14 – NH3 emissions from individual private treatment and % population served by individual private treatment



#### Methodology

Emissions were calculated, as follows:

$$\text{NH3(S)} = \text{Protein} * \text{Frac}_{\text{NPR}} * \text{EF} * \text{Pop} * \text{Stor} * 17/14$$

where:

NH3<sub>(s)</sub> - NH3 emissions from human sewage (kg NH3-N/yr);

Protein - annual per capita protein intake (kg/person/yr);

Frac<sub>NPR</sub> - 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

## METHODOLOGY

Emissions from industrial wastewater are first rough estimates based on national estimates for industry wastewater organic content, and default emission factors from Corinair Guidebook (CH<sub>4</sub> and N<sub>2</sub>O) and national data for domestic wastewater (COVNM). Quantities of industrial wastewater organic charge (in millions of inh. eq.) were multiplied by an emission factor for each pollutant considered.

## ACTIVITY DATA AND PARAMETERS

Estimates are based in The State of the Environment Report (1993) data. Total organic load was reported to be 26 million inh.eq (inhabitants equivalent) in 1990, and 33 million inh.eq. in 1993. Quantities associated at each industrial sector are presented in the following table.

Table 8.7 - Industrial wastewater: total organic charge (million inh.eq.)

Sectors	1990	1993
Paper and pulp	5	7
Textile	3	4
Olive Oil	3	3
Other Agro-Food	3	4
Pig breeding units	3	3
Alcohol and derived	1	2
Resins	1	1
Yeast	1	1
Refineries	1	1
Other Chemical	3	4
Other	1	2
<b>Total</b>	<b>26</b>	<b>33</b>

Emission estimates were determined using the emission factors presented in the table below, considering the 1993 figure for industry wastewater organic content as the best available estimate for recent years.

Table 8.8 - Emissions factors

Pollutant	Unit	EF	Source
CH <sub>4</sub>	Kg/ inh.eq.	0.30	CORINAIR (3rd edition), chp B9101
N <sub>2</sub> O	Kg/ inh.eq.	0.02	CORINAIR (3rd edition), chp B9101
NM VOC	Kg/ inh.eq.	0.02	National estimate for domestic sewage

## 8.2.C Waste Incineration (CRF 6 C)

8.2.C.1 CO<sub>2</sub> EMISSIONS

## METHODOLOGY

IPCC Guidelines (IPCC,1997) proposes the following method for ultimate CO<sub>2</sub> emissions estimation from waste incineration, for each waste type (e.g. municipal solid waste (MSW), hazardous waste, clinical waste, and sewage sludge):

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IWi * CCW_i * FCF_i * EF_i * 44 / 12)$$

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  $i$ ;

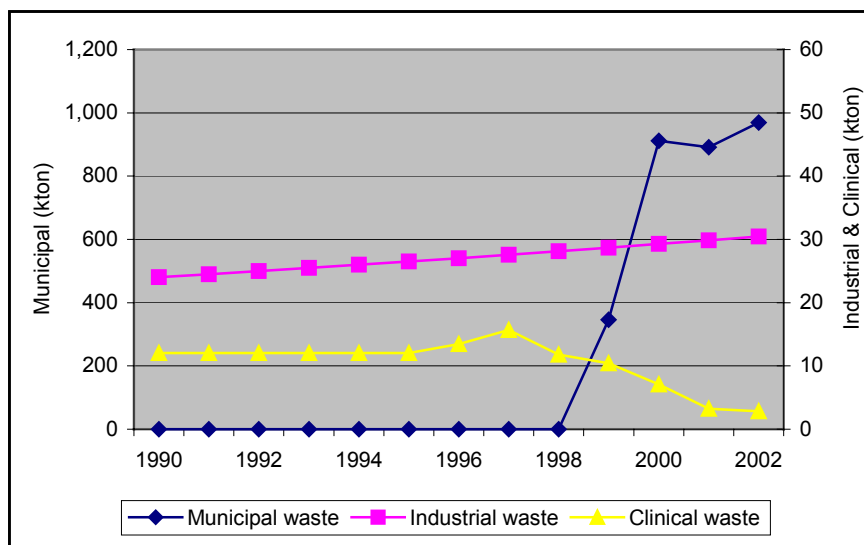
$FCF_i$  - Fraction of fossil carbon in waste of type  $i$ ;

$EF_i$  - Burn out efficiency of combustion of incinerators for waste of type  $i$  (fraction).

## ACTIVITY DATA AND PARAMETERS

Until 1999, incineration of solid wastes refers to uncontrolled combustion of industrial solid waste on land, and to incineration of hospital hazardous wastes. Data on the quantities of industrial waste combusted have been estimated for the years previous to 1999, based on the same assumption used for Industrial Solid Waste Disposed on Land (a per year growth rate of 2%). In what refers to clinical waste, the figure for 1995 was used as an estimated for the former years.

Figure 8.15 – Quantities of municipal, industrial and clinical wastes incinerated (1990-2002)



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, industrial solid waste and clinical waste. Data are presented in the following table.

Table 8.9 - Parameters considered

	Unit	MSW	Industrial Solid Waste	Clinical waste
C content of waste	%	30 a)	14 a)	60 b)
Fraction of fossil carbon in waste	% total C	37 a)	20.3-0.3 a) c)	40 b)
Efficiency of combustion	%	95 b)		

a) National figure; b) IPCC default; c) Industrial waste - % total C: until 1999 - 20.3; since 2000 - 0.3.

In all cases it was assumed incineration occurring without any control emission systems. It was assumed that all incineration occurs without energy recovery.

## 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 8.10 - Emissions factors considered for estimates of non-CO2 gases from incineration of MSW

Pollutants	Unit	EF	Source
SOx	kg/ton MSW	0.0220	Country measured data
NOx	kg/ton MSW	0.7240	Country measured data
COVNM	kg/ton MSW	0.0200	Corinair 3rd version. Activity 090201. Uncontrolled
CH4	g/GJ	6.5000	CORINAIR 94
CO	kg/ton MSW	0.0360	Country measured data
N2O	kg/ton MSW	0.1000	Corinair 3rd version. Activity 090201. No NOx abatement
NH3	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 8.11 - Emissions factors considered for estimates of non-CO2 gases from incineration of Industrial Solid Wastes

Pollutants	Unit	EF	Source
SOx	kg/ton MSW	0.5000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
NOx	kg/ton MSW	3.0000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
COV	kg/ton MSW	15.0000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
CH4	kg/ton MSW	6.5000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
CO	kg/ton MSW	42.0000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
N2O	kg/ton MSW	0.1000	Corinair 3rd version. Activity 090201. No NOx abatement
PST	kg/ton MSW	8.0000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
PM10	%	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)

a) Mass Burn Waterwall Combustor (MW/WW) with Eletrostatic Prec. And Semi-wet scrubber (same as Spray Dryer) SD/ESP

Table 8.12 - Emissions factors considered for estimates of non-CO2 gases from incineration of clinical wastes

Pollutants	Unit	EF	Source
SOx	kg/ton	1.0900	AP-42 Uncontrolled
NOx	kg/ton	1.7800	AP-42 Uncontrolled
COVNM	kg/ton CW	7.4000	Corinair 3rd version. Activity 090202. Particle abatement
CH4	g/GJ	6.5000	CORINAIR 94
CO	kg/ton	1.4800	AP-42 Uncontrolled
N2O	kg/ton	0.1000	Corinair 3rd version. Activity 090201. No NOx abatement
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

### 8.3 Recalculations

Some revisions have been done in the 2004 inventory submission in what refers to: background data, correction of errors detected and parameters. Synthesis of changes may be observed in Figure 8.16 and Table 8.13.

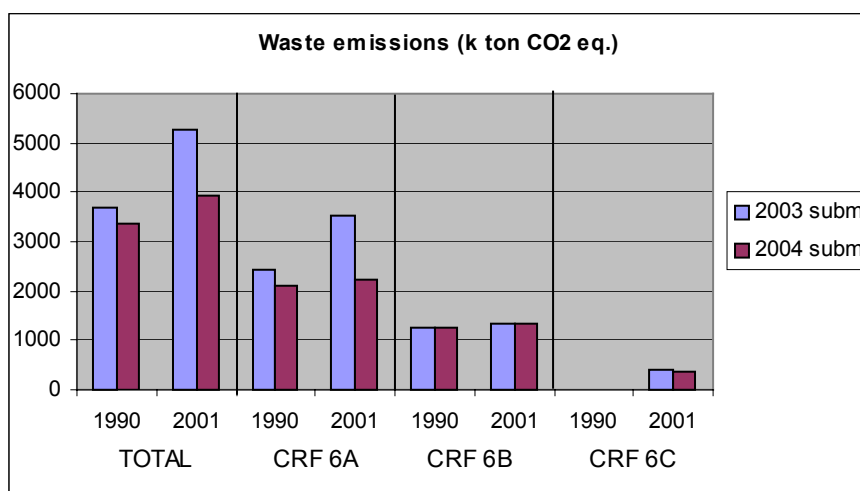
Figure 8.16 – Differences between 2003 and 2004 submissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O)

Table 8.13 – Recalculations (differences between 2003 to 2004 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
			2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)	2003 subm.	2004 subm.	Difference (1)
			CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)	CO <sub>2</sub> equivalent (Gg)		(%)
<b>1990</b>											
6. Waste			10.14	10.10	-0.34	3,244.38	2,911.82	-10.25	448.83	448.83	0.00
6.A. Solid Waste Disposal on Land			0.00	0.00	0.00	2,421.85	2,089.29	-13.73			
6.B. Wastewater Handling						822.49	822.49	0.00	447.71	447.71	0.00
6.C. Waste Incineration			10.14	10.10	-0.34	0.04	0.04	-0.64	1.13	1.12	-0.64
6.D. Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>2001</b>											
6. Waste			375.99	350.10	-6.89	4,297.87	3,010.88	-29.94	595.48	586.81	-1.45
6.A. Solid Waste Disposal on Land			0.00	0.00	0.00	3,511.13	2,224.20	-36.65			
6.B. Wastewater Handling						785.69	785.69	0.00	564.88	558.15	-1.19
6.C. Waste Incineration			375.99	350.10	-6.89	1.05	0.99	-6.30	30.59	28.67	-6.30
6.D. Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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).

### 8.3.A Solid Waste Disposal on Land

Data on MSW for 2001 were updated with data collected by municipal management systems. Data used in 2003 submission for that year was a provisional estimate.

Some corrections were done relating to errors related to the starting year of operation of some municipal waste management systems, which affected mainly CH<sub>4</sub> and CO<sub>2</sub> emissions estimates.

The final disposal of fermentable industrial waste between unmanaged and managed SWDS was changed. In the previous submission it was assumed that until 1999 all industrial waste generated was disposed into unmanaged SWDS, and for the following years into managed SWDS. In the 2004 submission, the disposal between unmanaged and managed SWDS was done following the same distribution as for municipal waste.

Concerning CH<sub>4</sub> amounts recovered and burned:

- Industrial waste - new estimates considered; previously these quantities were not considered.

- Change in starting years concerning recovering and burning to reflect new available information. And some errors corrected.

OX parameter: previously default value 0 was used for all SWDS; in last submission this parameter was changed to 0.1 for well-managed SWDS as recommended in GPG (IPCC,2000); for non-managed SWDS the value of 0 was kept.

### 8.3.B Wastewater Handling

No changes were done since last submission, except in what concerns N<sub>2</sub>O emissions from Human Sewage, which were revised based on new estimates for protein intake (data taken from FAO database in December 2003).

### 8.3.C Waste Incineration

New EF (CO, NO<sub>x</sub> and SO<sub>x</sub>) were used for the estimation of emissions from MSW incineration based on monitored values from one of the two new units of MSW incineration plants.

For fermentable industrial waste burnt on land:

- Time series slightly revised.
- EF changed to AP-42 "Open burning" referring to uncontrolled combustion: CH<sub>4</sub>, NMVOC, CO, NO<sub>x</sub> and SO<sub>x</sub>. Previous EF were the same as the ones used for new MSW incineration plants which have pollution abatement technologies

Estimates for new pollutants were done based on EF collected from international literature.

## 8.4 Further improvements

Despite the improvements made in the waste inventory sector in the most recent years, there are still several aspects that must be improved in the near future. Among these is the need to better quantify the amount of CH<sub>4</sub> that is recovered and burned in flares. Data used presently refer to estimates of CH<sub>4</sub> 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). Data on waste composition should also be updated each year according to information from waste management systems.

CH<sub>4</sub> emissions estimates for industrial wastewater are by far the source that should be further developed and subject to a specific study to better characterise the industrial organic wastewater load. Background data used in the calculations are out of date (most recent available data refer to 1993).

N<sub>2</sub>O 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 N<sub>2</sub>O emissions related with land disposal and sewage treatment. In Portugal, part of nitrogen present in sewage is applied to soils through sewage sludge applications. This is not accounted for the moment but could be estimated in the future, if data on sewage sludge application on land is collected.

Emissions from incineration were assumed to occur without energy recovery. However this assumption does not reflect the reality. Consequently this issue should be addressed in the future submissions.



## 8.5 Annex WASTE: Background Data Tables

Table W-1 – National population, per capita generation rates, and urban waste: 1960-2002

Year	Population	Annual per capita generation rate	Pop. served by waste collection syst.	Solid Waste produced	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	369.3	95	3,542.8	2,027.8	1,310.3	204.7	0.0
1997	10,160,529	388.9	95	3,748.6	2,007.1	1,531.4	210.1	0.0
1998	10,209,426	408.7	95	3,958.7	1,507.5	2,236.0	215.2	0.0
1999	10,258,323	428.8	95	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	436.7	100	4,543.7	14.8	3,293.4	266.6	968.8

Sources:IA estimates; INR; Quercus Study

Table W - 2 – Fermentable industrial waste disposal: 1960-2002

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	217	1,345
1971	965	0	1986	842	365	2001	164	1,429
1972	980	0	1987	854	370	2002	6	1,619
1973	994	0	1988	867	376			
1974	1,009	0	1989	880	382			

Source: IA estimates; INR

Table W - 3 – Quantities of CH<sub>4</sub> recovered and combusted (Urban waste)

	Unmanaged disposal sites	Landfill sites	Unmanaged disposal sites	Landfill sites	Biogas burned as % of CH <sub>4</sub> generated
	kton CH <sub>4</sub>		Mton CO <sub>2</sub> 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	0.82	2.67	0.02	0.06	5
2001	1.23	9.64	0.03	0.20	16
2002	1.18	10.37	0.02	0.22	17

Source: IA estimates

Table W - 4 – Quantities of CH<sub>4</sub> recovered and combusted (Fermentable industrial waste)

	Unmanaged disposal sites	Landfill sites	Unmanaged disposal sites	Landfill sites	Biogas burned as % of CH <sub>4</sub> generated
	kton CH <sub>4</sub>		Mton CO <sub>2</sub> 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	0.61	2.38	0.01	0.05	5
2001	0.87	9.82	0.02	0.21	17
2002	0.85	11.00	0.02	0.23	19

Source: IA estimates

Table W - 5 – National population and wastewater BOD produced by handling systems

	Population (1000 inhabitants)	BOD <sub>5</sub> produced (kton/year)				
		Total	Treatment systems		Individual treatment (a)	Discharge into waterways or ocean
			wastewater	sludge		
1990	9,864	202	32	8	91	70
1991	9,867	202	39	10	88	66
1992	9,916	203	45	11	85	62
1993	9,965	204	52	13	82	58
1994	10,014	205	58	15	79	54
1995	10,063	206	65	16	75	49
1996	10,112	207	70	18	71	48
1997	10,161	208	76	19	67	46
1998	10,209	209	82	20	62	44
1999	10,258	210	87	22	58	42
2000	10,307	211	93	23	54	41
2001	10,356	212	94	23	54	41
2002	10,405	213	94	24	54	41

Source: IA estimates

Table W - 6 – Estimated quantities of CH<sub>4</sub> flared

Year	Wastewater treatment systems		Sludge treatment systems	
	kton/year	% emissions of wastw. treat.	kton/year	% emissions of sludge treat.
1990	0.02	0.5	0.01	2.0
1991	0.02	0.5	0.02	2.1
1992	0.02	0.5	0.02	2.2
1993	0.03	0.6	0.03	2.2
1994	0.03	0.6	0.04	2.3
1995	0.04	0.6	0.05	2.4
1996	0.04	0.6	0.05	2.5
1997	0.05	0.7	0.06	2.6
1998	0.05	0.7	0.07	2.7
1999	0.05	0.7	0.09	2.8
2000	0.06	0.7	0.10	3.0
2001	0.06	0.8	0.11	3.1
2002	0.06	0.8	0.12	3.2

Source: IA estimates

Table W - 7 – Quantities of waste incinerated

Year	MSW quantities incinerated	Industrial solid waste incinerated	Clinical waste quantities incinerated
	kton		
1990	-	24	12
1991	-	24	12
1992	-	25	12
1993	-	25	12
1994	-	26	12
1995	-	27	12
1996	-	27	13
1997	-	28	16
1998	-	28	12
1999	346	29	10
2000	911	29	7
2001	892	30	3
2002	969	30	3

Note: Estimates in italics Sources: INR; DGS; IA estimates.

## 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 ( $\alpha$ -pinene,  $\beta$ -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  $\alpha$ -pinene and  $\beta$ -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/m<sup>2</sup>) 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/m<sup>2</sup>/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/m<sup>2</sup>/s).

Values for D and  $\varepsilon$  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 9.1<sup>116</sup>:

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	Latim		D	Vegetation	ε					
					μgC/g dm/h @standart L,T					
					kd dm/m2		Period	Isoprene		Monoterpenes
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	(UA,doc1); 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 xpto		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, xpto(Average Q. robur and Q. petrae)	1.5	
Chetnut	Castanea sativa	375	Guenther et al (1994)	Apr-Sept	0	-	8.71	(Luchetta et al, xpto)	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	

<sup>116</sup> During this period emissions from foliage are obviously zero.

Values for  $\gamma$  are estimated according to empirical equations that are functions of 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/m<sup>2</sup>/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  $\beta$  is a constant, assumed 0.09 K<sup>-1</sup> (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).

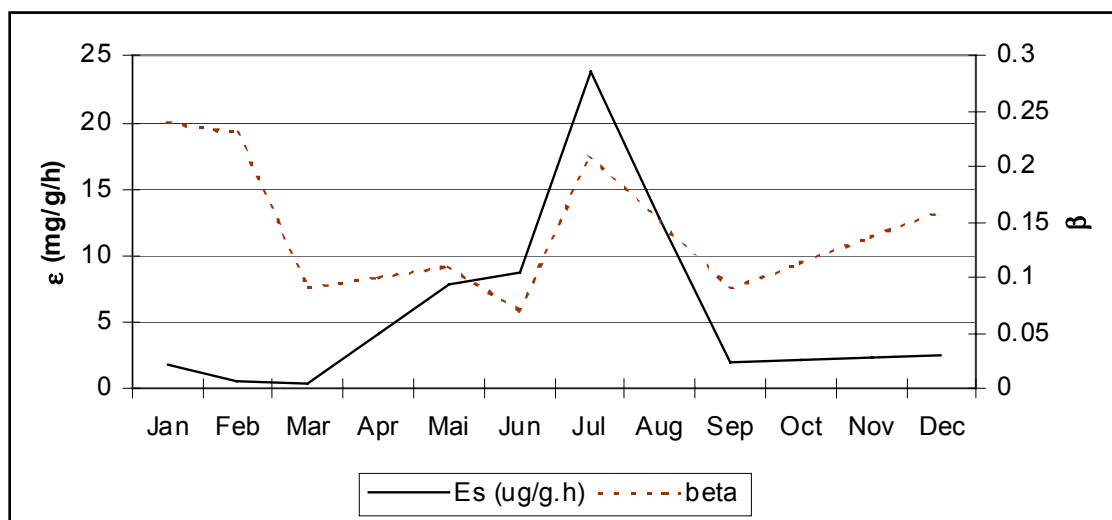
For some species however, this general formulation is not used but it is replaced by country specific equations. This is particularly the case for cork and Holm oaks, where monoterpene emissions are also function of light<sup>117</sup>. These equations are summarized in table 9.2.

<sup>117</sup> 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  $\gamma$ 

Tree Specie	Compound	Equation	Reference
P. Pinaster	Monoterpernes	$\gamma = \exp[0.138 * (T-30)]$	Pio et al (1999)
Eucapypthus	Monoterpenes	$\gamma = \exp[0.07 * (T-30)]$	Nunes (1996)
		$\gamma = \{CL*CT + \exp[\beta * (T-T_s)]\}$	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
Cork Oak	Isoprene		
Holm Oak	Isoprene	$\gamma = \{CL*CT + \exp[0.09 * (T-T_s)]\}$	

Figure 9.1 - Time variable  $\epsilon$  for Cork OakFigure 9.2 (adapted from Silva et al (1999))

The  $\gamma$  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,

$\gamma[PAR_{(n,m,h)}, T_{(n,m,h)}, s]$  -  $\gamma$  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/m<sup>2</sup>h. 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
	$\mu\text{gC/m}^2/\text{h}$			$\mu\text{g/m}^2/\text{h}$
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,

EF\_tapping<sub>(m,h)</sub> - VOC emission rate from resin-tapping (mg VOC/hr/tree) for a specific time;

T - Air temperature (°C).

The annual emission factor for each territorial unit is 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 is available from DGRF for years 1990 and 1995 and was interpolated and extrapolated<sup>118</sup> for the remaining time-series. Foliage areas for each tree specie 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,

Foliage\_Area<sub>(n,s)</sub> - total area covered by foliage of tree specie s in territorial unit n (ha);

Pure<sub>(n,s)</sub> - Land area occupied by pure strands of specie s in territorial unit n (ha);

<sup>118</sup> Linear interpolation

Dominant<sub>(n,s)</sub> - Land area occupied by mixed strands where specie s is dominant, in territorial unit n (ha);

Dominated<sub>(n,s)</sub> - Land area occupied by mixed strands where specie s is non-dominant, in territorial unit n (ha);

Dispersed<sub>(n,s)</sub> - 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	1 449 295	1 374 929	1 300 563	1 226 197	1 151 831	1 077 465	1 003 099
P. pinea	39 442	49 095	58 747	68 400	78 052	87 704	97 458
Other coniferous	71 164	68 496	65 829	63 161	60 494	57 826	55 176
Quercus suber	766 980	782 989	798 997	815 005	831 013	847 022	863 070
Quercus rotundifolia	668 192	656 527	644 862	633 197	621 532	609 867	598 203
Other oaks	116 127	136 337	156 547	176 757	196 967	217 177	237 650
Castanea sativa	47 847	51 593	55 339	59 085	62 831	66 577	70 422
Eucalyptus sp.	447 395	496 974	546 553	596 133	645 712	695 292	744 871
Other broadleaves	212 639	234 416	256 193	277 970	299 747	321 524	343 301
Other mixed	33 103	35 626	38 149	40 673	43 196	45 720	48 271
Bush (Matos)	1 734 822	1 734 822	1 734 822	1 734 822	1 734 822	1 734 822	1 734 822
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	35	35	35	35	35	35	35

Table 9.5 - Forest Area per tree specie (ha) (1997-2002)

Specie	1997	1998	1999	2000	2001	2002
Pinus pinaster	928 733	855 075	789 569	734 954	684 129	639 280
P. pinea	107 411	117 415	127 423	137 443	147 532	157 623
Other coniferous	53 336	51 789	50 253	48 766	47 763	46 760
Quercus suber	879 150	895 235	911 605	928 386	945 172	961 958
Quercus rotundifolia	586 538	574 874	563 210	551 545	539 881	528 216
Other oaks	261 491	285 331	309 172	333 535	358 010	382 486
Castanea sativa	74 380	78 672	82 964	87 255	91 563	95 886
Eucalyptus sp.	794 451	844 030	893 609	943 189	992 768	1 042 348
Other broadleaves	365 078	392 175	420 579	448 984	477 388	505 996
Other mixed	51 434	55 254	59 230	63 339	67 448	71 557
Bush (Matos)	1 734 822	1 734 822	1 734 822	1 734 822	1 734 822	1 734 822
Olive	297 299	291 379	285 460	279 540	279 540	279 540
Orchards and Vine	389 055	381 308	373 562	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
Rice	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
Market Gardening	29 598	29 245	28 891	28 538	28 538	28 538
Resin-tapping *	35	35	35	35	35	35

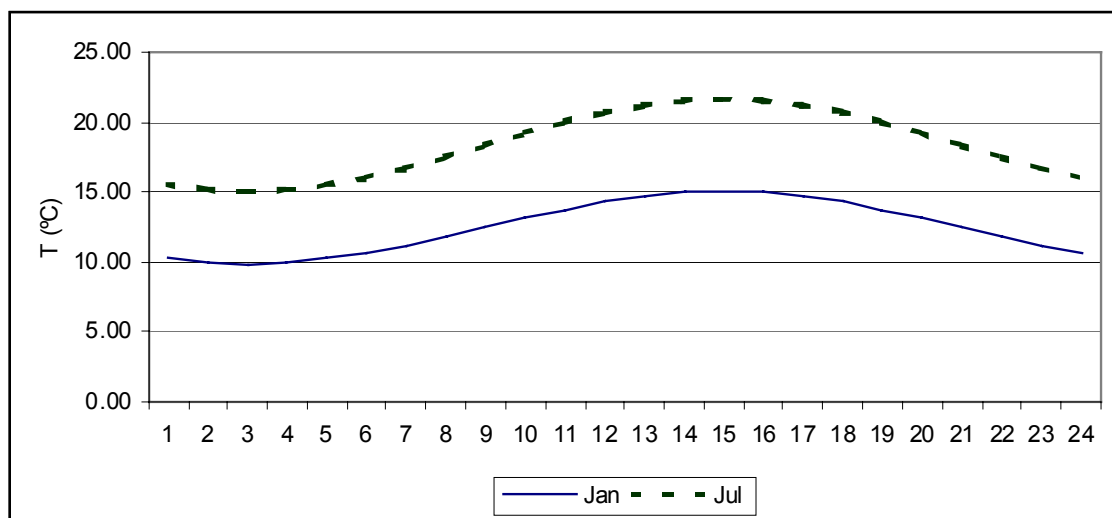
\* million tree

For 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

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 9.3 - 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)

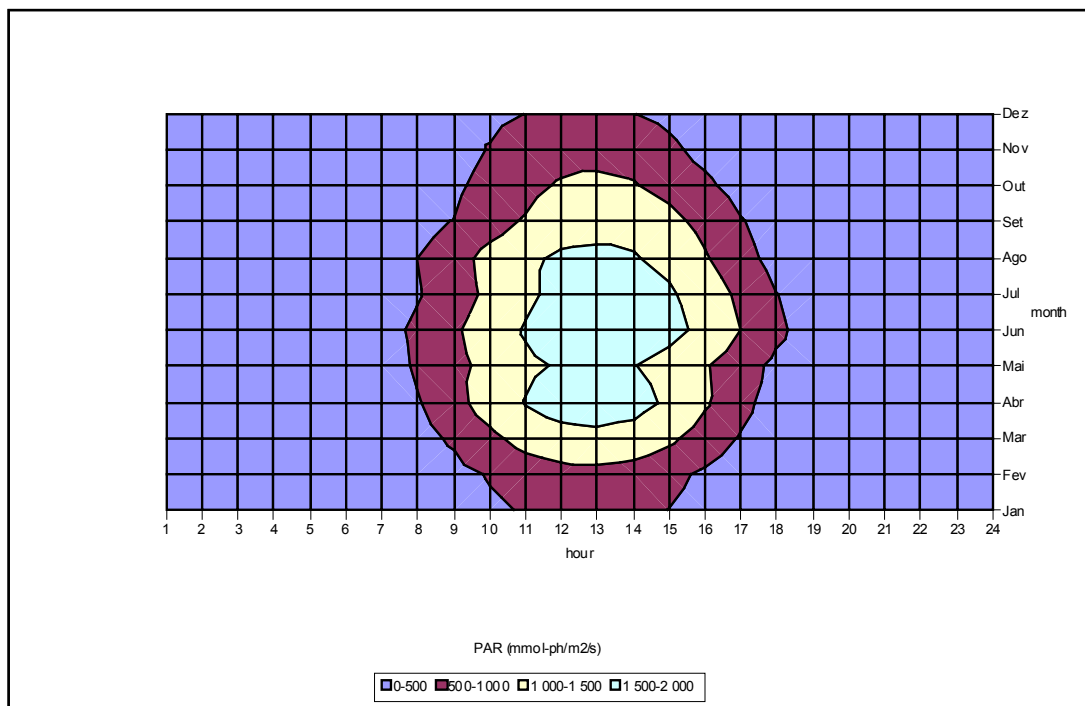


Source: INMG

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 9.4 - Pattern of evolution of PAR (mmol/m<sup>2</sup>/s) according to month and hour of day (Nunes,1996)



## 9.5 Recalculations

No recalculations of NMVOC from agriculture have been made since last submission to LRTAP convention.

## 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.

The activity data (area covered for each species) must be revised according to new information from National Forest Inventory in a consistent mode with the estimates for 2002 performed for the estimates of category 5A.

## LIST OF ACRONYMS

ABS	Acrylonitrile Butadiene Styrene	Acrilo Nitrilo Butadieno Estireno
AC	Air Conditioning	Ar condicionado
ACAP	Portuguese Association of Automobile Business	Associação do Comércio Automóvel de Portugal
AG	Aviation Gasoline	Gasolina de Aviação
AN	Ammonium Nitrate	Nitrato de Amónio
ANA	Airports and Air Navigation	Aeroportos e Navegação Aérea
ANAM	Madeira Island Airports and Air Navigation	Aeroportos e Navegação Aérea da Madeira
ANECRA	National Association of Companies of Automobile Business and Reparation	Associação Nacional das Empresas do Comércio e da Reparação Automóvel
APED	Portuguese Association of Distribution Companies	Associação Portuguesa de Empresas de Distribuição
APIRAC	National Association of Industry of Refrigeration and Air Conditioning	Associação Portuguesa dos Industriais da Refrigeração e Ar Condicionado
APORBET	Portuguese Association of Bituminous Mixes Producers	Associação Portuguesa de Fabricantes de Misturas Betuminosas
AS	Ammonium Sulphate	Sulfato de Amónia
ASN	Ammonium Sulphate Nitrate	Sulfonitrato de Amónia
BAT	Best Available Technologies	-
BOD	Biochemical Oxygen Demand	Carência Bioquímica de Oxigénio
BOF	Basic Oxygen Furnace	-
CAFE	Clean Air For Europe	-
CAN	Calcium Ammonium Nitrate	Nitrato de Cálcio-amónio
CCDR-LVT	Lisbon and Tagus Valley Coordination and Regional Development 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
CH4	Methane	Metano
CITEPA	Interprofessional Technical Center of Studies of Atmospheric Pollution	Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique
CKD	Cement Kiln Dust	-
CMN	Calcium Magnesium Nitrate	-
CN	Calcium Nitrate	Nitrato de Cálcio0
CO	Carbon Monoxide	Monóxido de Carbono
CO2	Carbon Dioxide	Dióxido de Carbono ou anidrido carbónico
COD	Chemical Oxygen Demand	Carência Química de Oxigénio
CONCAWE	-	-
Concelho	Portuguese territorial unit under the responsibility of a municipal authority	-
CORINAIR	Core Inventory Air Emissions	Inventário de Emissões Atmosféricas
CRF	Common Reporting Format	-
CTCV	Technological Centre for Ceramics and Glass	Centro Tecnológico da Cerâmica e do Vidro
DAP	Di-ammonium phosphate	-
DBH	Diameter at Breast Height	Diâmetro à Altura do Peito (DAP)
DC	Degradable Organic Component	Fracção Orgânica Degradável
DGA	General Directorate of Environment	Direcção Geral do Ambiente
DGF	General Directorate of Forests	Direcção-Geral das Florestas
DGGE	General Directorate for Geology and Energy	Direcção Geral de Geologia e Energia

DGI	Industry General Directorate	Direcção Geral da Indústria
DGRF	General Directorate for Forestry Resources	Direcção Geral dos Recursos Florestais
DGTT	General Directorate of Terrestrial Transportation	Direcção Geral dos Transportes Terrestres
DGV	National Entity responsible for road traffic	Direcção Geral de Viação
Distrito	Portuguese territorial unit comprehending several concelhos but not coincident with a region which is NUT II.	-
DOC	Degradable Organic Carbon	Carbono Orgânico Degradável
DOCF	Degradable Organic Carbon Dissimilated	-
DRAOT	Regional Directorate of Environment and Land Use Planning	Direcção Regional do Ambiente e Ordenamento do Território
EAF	Electric Arc Furnace	Forno Arco Eléctrico
EAPA	European Asphalt Pavement Association	-
EF	Emission Factors	Factores de Emissão
EMEP	Cooperative Programme for Monitoring and Evaluation of the Longrange Transmission of Air Pollutants in Europe	-
EPER	European Pollutant Emission Register	Registo Europeu de Emissões Poluentes
E-PRTR	European Pollutant Release and Transfer Register	-
FAEED	Federal Aviation Administration Aircraft Engine Emission Database	-
FAM	Animal Manure Nitrogen Applied to Soils	-
FAO	Food and Agriculture Organization of the United Nations	-
FCC	Fluidized-bed Catalytic Cracking	Cracking catalítico de leito fluidizado
FCR	Fixation in Crop Residues	-
FCT-UNL	Faculty of Science and Technology of New University of Lisbon	Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
FGR	Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that volatilises as NH <sub>3</sub>	-
FOD	First Order Decay	Decaimento de Primeira Ordem
FSN	Nitrogen in Synthetic Fertilizers	-
GASA	Analysis Group of Ambiental Systems	Grupo de Análises de Sistemas Ambientais
GCV	Gross Calorific Value	-
GHG	Green House Gases	Gases Com Efeito de Estufa
GHV	Gross Heating Value	Poder Calorífico Superior
GIC	Large Combustion Plants (LCP)	Grandes Instalações de Combustão
GPG	Good Practice Guidance	-
GWP	Global Warming Potential	-
H <sub>2</sub> S	Hydrogen Sulfide	Sulfureto de Hidrogénio
HCFC	Hydrochlorofluorcarbons	-
HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias
HFC	Hydrofluorcarbons	-



IA	Institute for The Environment	Instituto do Ambiente
IAIT	Annual Survey to Manufacturing Industry	Inquérito Anual à Indústria Transformadora
IAPI	Annual Survey to Industrial Production	Inquérito Anual à Produção Industrial
ICAO	International Civil Aviation Organization	
IEF	Implied Emission Factors	Factores de Emissão Implícitos
IEP	Portuguese Road Institute	Instituto de Estradas de Portugal
IFADAP	Institute for Financing and Support of Development of Agriculture and Fisheries	Instituto de Financiamento e Apoio ao Desenvolvimento da Agricultura e das Pescas
INAG	National Water Institute	Instituto da Água
INE	National Statistics Institute	Instituto Nacional de Estatística
INR	National Wastes Institute	Instituto Nacional de Resíduos
INRA	National Institute for Agronomic Investigation (France)	Institut National de la Recherche Agronomique (França)
IPCC	Intergovernmental Panel on Climate Change	-
ISP	Portuguese Insurance Institute	Instituto de Seguros de Portugal
IST-UNL	Technical Superior Institute - Lisbon Technical University	Instituto Superior Técnico - Universidade Técnica de Lisboa
JP	Jet Fuel	-
LCP	Large Combustion Plants (the same as GIC)	o mesmo que GIC
LDPE	Low Density Poly Ethylene	Polietileno de Baixa Densidade (PEBD)
LDV	Light Duty Vehicles	Veículos Ligeiros de Mercadorias
LNG	Liquified Natural Gas	Gás Natural Liquefeito
LOSP	Light Organic Solvent-based Preservatives	-
LPS	Large Point Sources (Corinair definition)	Grandes Fontes Poluidoras
LRTAP	Long-range Transboundary Air Pollution	Poluição Atmosférica Transfronteiras a Longa Distância
LTO	Landing and Take-off	Aterragens e Descolagens
LUCF	Land-use Change and Forestry	Alteração do Uso do Solo e Florestas
LULUCF	Land Use, Land-use Change and Forestry	Uso do Solo, Alteração do Uso do Solo e Florestas
MAC	Mobile Air-conditioning systems	-
MADRP	Ministry of Agriculture, Rural Development and Fisheries	Ministério da Agricultura, Desenvolvimento Rural e Pescas
MAOT	Ministry of Environment and Land Use Planning	Ministério do Ambiente e Ordenamento do Território
MCF	Methane Conversion Factor	Factor de Conversão de Metano
MCOTA	Ministry of Urban Affairs, Land Use Planning and Environment	Ministério das Cidades, Ordenamento do Território e Ambiente
MDI	Metered Dose Inhalers	-
MEET	Methodologies For Estimating Air Pollutant Emissions From Transport	-
MMS	Manure Management Systems	Sistema de Gestão de Estrumes
MSW	Municipal Solid Wastes	Resíduos Sólidos Municipais
MTBE	Methyl Tertiary Butyl Ether	Metil-Ter-Butil-Éter
Na <sub>2</sub> S	Sodium Sulphide	Sulfureto de Sódio
NaOH	Sodium Hydroxide	Hidróxido de Sódio
NATO	North Atlantic Treaty Organisation	Organização do Tratado do Atlântico Norte
NAVE	National Entity responsible for air	Navegação Aérea

	traffic	
NCV	Net Calorific Value	-
NFI	National Forestry Inventories	Inventário Florestal Nacional
NFR	New Format Reporting	-
NH3	Ammoniac	Amoníaco
NMVOC	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NOx	Nitrogen Oxides (NO + NO2)	Óxidos de Azoto (NO+NO2)
NPK	Nitrogen, Phosphorus and Potassium	Nitrogénio, Fósforo e Potássio
NSS	Normal Super Phosphates	Superfosfatos simples
NUTS (0..III)	Nomenclature of Territorial Units for Statistics	Nomenclatura de Unidades Territoriais para fins estatísticos
OD	Origin - Destiny	Origem - Destino
ODS	Ozone Depleting Substances	-
OECD	Organization for Economic Co-operation and Development	Organização para a Cooperação e Desenvolvimento Económico (OCDE)
OX	Oxidation Factor	Factor de Oxidação
PAF	Florestal Action Program	Programa de Acção Florestal
PAH	Polycyclic Aromatic Hydrocarbons	Hidrocarbonetos Aromáticos Policíclicos
PCI	Low Heating Value (LHV)	Poder Calorífico Inferior
PEN	National Energetic Program	Plano Energético Nacional
PER	Perchloro-ethylene	Percloroetileno
PERSU	Strategic Plan on Municipal Solid Wastes	Plano Estratégico dos Resíduos Sólidos Urbanos
PETROGAL	Portuguese Petroleum Company	Empresa de Petróleos de Portugal
PFC	Perfluorinated Hydrocarbons	-
PM1	Particles with Aerodynamic Diameter smaller than 1 micrometer	Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro
PM10	Particles with Aerodynamic Diameter smaller than 10 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros
PM2.5	Particles with Aerodynamic Diameter smaller than 2.5 micrometers	Partículas cujo diâmetro aerodinâmico é inferior a 2.5 micrómetros
PNAC	National Climate Change Program	Programa Nacional para as Alterações Climáticas
PNPA	National Plan for Environmental Policy	Plano Nacional da Política de Ambiente
PP	Poly Propylene	Polipropileno
PS	Poly Styrene	Poliestireno
PTEN	National Emission Ceilings Program	Programa para os Tectos de Emissão Nacional
PVC	Poly Vinyl Chloride	Cloreto de Polivinil
RA	Agricultural Region	Região Agrária
REN	National Electric System	Rede Eléctrica Nacional
RVP	Reid Vapour Pressure	Pressão de Vapor de Reid
SF6	Sulphur Hexafluoride	Hexafluoreto de Enxofre
SNIERPA	National System of Inventories of Emissions and Remotions of Atmospheric Pollutants	Sistema Nacional de Inventários de Emissões e Remoções de Poluentes Atmosféricos
SOx	Sulphur Oxides	Óxidos de Enxofre
SW	Solid Wastes	Resíduos Sólidos
SWDS	Solid Waste Disposal Sites	Locais para Deposição de Resíduos Sólidos
TANKS	Software designed to estimate air emissions from organic liquids in 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

---

## BIBLIOGRAPHY

- ACAP, 2003. Estatísticas do Sector Automóvel. Associação do Comércio Automóvel de Portugal.
- ANA, 2003. Estatísticas do Tráfego Aéreo 2002. ANA – Aeroportos de Portugal.
- APED, 1999. Anuário da Distribuição Portuguesa 1999.
- BEMA - 1997, Biogenic Emissions in the Mediterranean Area, Atmospheric Environment, Special issue 31-S1,1-256
- CEC, 1992. CORINAIR Inventory. Default Emission Factors Handbook. 2nd ed. Comission of the European Comission.
- Carreira, 2002. Fluorocarbonetos – Actividade 2001, AIR LIQUIDE
- CPPE, 2000 - Companhia Portuguesa de Produção de Electricidade, 2001. Relatório de Ambiente 2000.
- DGE, 2003. Energy in Portugal. The 1990s. Direcção-Geral de Energia. Statistical Division (Eurostat file nº 200245501003).
- Direcção-Geral das Florestas, 2001. Inventário Florestal Nacional – Portugal Continental – 3ª Revisão, 1995-1998, Relatório Final
- Direcção-Geral de Energia, 1989. Informação Energia nº14. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1990. Informação Energia nº15. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1991. Informação Energia nº16. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1992. Informação Energia nº17. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1993. Informação Energia nº18. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1994. Informação Energia nº19. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1995. Informação Energia nº20. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1996. Informação Energia nº21. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1997. Informação Energia nº22. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 1998. Informação Energia nº23. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.

- Direcção-Geral de Energia, 1999. Informação Energia nº24. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 2000. Informação Energia nº25. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 2001. Informação Energia nº26. Direcção de Serviços e Planeamento e Assuntos Económicos e Divisão de Estatística.
- Direcção-Geral de Energia, 2002. Balanços Energéticos - Séries Temporais 1990-2000.
- Direcção-Geral de Energia, 2003. Energy in Portugal. The 1990s. Statistical Division (Eurostat file nº 200245501003).
- EAPA, 2002. ASphalt in Figures. European Asphalt Pavement Association. Breukelen. The Netherlands.
- EDP - Electricidade de Portugal, 2000. Relatório de Ambiente 1999.
- EDP - Electricidade de Portugal, 2001. Relatório de Ambiente 2000.
- EDP - Electricidade de Portugal, 2002. Emissões Atmosféricas das Centrais do SEP - Previsões para 2002.
- EDP-Electricidade de Portugal, 2002. Relatório de Ambiente 2001.
- EDP-Electricidade de Portugal, 2003. Relatório de Ambiente 2002 - Ambiente e Sociedade.
- EEA, 2002. EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition October 2002 UPDATE Technical report No 30, Environment European Agency.
- EMEP/CORINAIR, 1996. Atmospheric Emission Inventory Guidebook (first edition). EMEP Task Force on Emission Inventories. European Environment Agency. Copenhagen.
- EPA, 2001. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999
- EPA, 2002. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000
- European Commission, 1994. Corinair. Technical annexes. Volume 2. Default Emission Factors Handbook. Directorate-General Environment, Nuclear Safety and Civil Protection. 327 pp
- FAA, Federal Aviation Administration Aircraft Engine Emission User Guide and Database (AEE-110). Office of Environment and Energy within the Federal Aviation Administration
- Geron, C.D., A.B. Guenther and T.E. Pierce - 1994, An Improved Model for Estimating Emissions of Volatile Organic Compounds from Forests in the Eastern United States, J. Geophys. Res. 99 (D6) 12773-12791.
- Guenther, A., . Nicholas Hewitt, N., David Erickson, Ray Fall, Chris Geron, Tom Graedel, Peter Harley, Lee Klinger, Manuel Lerdau, W.A. McKay, Tom Pierce, Bob Scholes, Rainer Steinbrecher, Raja Tallamraju, John Taylor and Pat Zimmerman

- 1995, A Global Model of Natural Volatile Organic Compound Emissions, J. Geophys. Res., 100(D5), 8873-8892.
- Guenther, A., Zimmerman, P.R., Harley, P. And Wildermuth, M. - 1994, Natural Volatile Organic Compound Emission rate estimates for U.S. Woodland landscapes, Atmos. Environ., 28, 1197-1210
- ICAO, 1989. ICAO Engine Exhaust Emission Databank. ICAO Committee on Aviation Environmental Protection Working Group 3 meeting, Mariehamn, Aland. October 10-13, 1989.
- IPCC, 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The Intergovernmental Panel on Climate Change (IPCC).
- IPPC, 1995. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2 - Workbook. United Nations Environment Programme (UNEP), the Organization for Economic Co-operation and Development (OECD), the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC).
- IPPC, 1995b. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3 - Reference Manual. United Nations Environment Programme (UNEP), the Organization for Economic Co-operation and Development (OECD), the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC).
- IPPC, 1997. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2 - Workbook. The Intergovernmental Panel on Climate Change (IPCC), the Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA).
- IPPC, 1997b. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3 - Reference Manual. The Intergovernmental Panel on Climate Change (IPCC), the Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA).
- IPPC/OECD, 1994. IPCC Draft Guidelines for National Greenhouse Gas Inventories. Volume 2 - Workbook. IPCC/OECD Joint Programme.
- IPPC/OECD, 1994b. IPCC Draft Guidelines for National Greenhouse Gas Inventories. Volume 3 - Reference Manual. IPCC/OECD Joint Programme.
- Luchetta, L., V. Simon and L. Torres - 1999 (confirmar data), Estimation of the Yeraly Emission of non-methanic Volatile Organic Compounds (VOCs) from the Forest Ecosystem in France
- Nunes, T.V. - 1996, Biogenic Emissions of non-methane hydrocarbons. Contribution to the evaluation of VOC emission rates by portuguese ecosystems (in Portuguese). Ph. Thesis, University of Aveiro, Portugal.
- Nunes, T.V. And C.A. Pio - 1999, Emission of Volatile Organic Compounds from Portuguese Eucalyptus Forests, unpublished?
- Pereira et al, 2002. Quantificação dos Sumidouros Terrestres de Carbono em Portugal Continental. Universidade Técnica de Lisboa - Instituto Superior de Economia.

- Pio, C.A. And A.A. Valente - 1998, Atmospheric Fluxes and Concentrations of Monoterpenes in Resin-Tapped Pine Forests, *Atmosph. Env.* Vol 32 nº 4, 683-691
- Pio, C.A., Nunes, T.V. And A.R. Valente - 1999 (Confirmar data), Emission of Volatile Organic Compounds from Portuguese Maritime Pine Forests, Universidade de Aveiro, Portugal
- PNAC, 2003. Medidas Adicionais Visando o Cumprimento do Protocolo de Quioto, Documento de trabalho.
- PNALE, 2004. Plano Nacional de Atribuição de Licenças de Emissão de CO<sub>2</sub> (PNALE) 2005-2007, Grupo de Trabalho PNALE
- PTEN, 2002. Programa para os Tectos de Emissão Nacional - Estudos de Base - Cenário de Referência, Departamento de Ciências e Engenharia do Ambiente da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa - Instituto do Ambiente - Centro de Estudos em Economia da Energia, dos Transportes e Ambiente
- REN-Rede Eléctrica Nacional, 2003. Emissões Atmosféricas das Centrais do SEN - Previsões para 2003.
- Seixas, J., V. Gois, F. Ferreira, R. Diniz, F. Moura, P. Torres, C. Furtado, S. Martinho, P. Matos, S. Fava, M. Remédio e J. Gonçalves, 2000. Emissão e Controlo de Gases com Efeito de Estufa em Portugal. Ministério do Ambiente e Ordenamento do Território, GASA-DCEA-FCT, Março 2000
- Silva, P., T. Nunes, C. Campos, M. Mariz and C.Pio - 1999, Emissões de Compostos Orgânicos Voláteis pela Floresta de Sobreiro em Portugal, 6ª Conferência Nacional sobre a Qualidade do Ambiente, 627-637, 1999
- Simpson - 1996, Inventorying Biogenic VOC Emissions in Europe, EMEP MSC-W, Norwegian Meteorological Institute, Oslo.
- Simpson, D., Alex Guenther, C. Nicholas Hewitt and Rainer Steinbrecher - 1995. Biogenic Emissions in Europe. 1. Estimates and Uncertainties, *J. Geophys. Res.*, 100 (D11), 22875-22890
- Simpson, D., Wilfried Winiwarter, Gynnar Borjesson, Steve Cinderby, Antonio Ferreiro, Alex Guenther, C. Nicholas Hewitt, Robert Janson, M. Aslam K. Khalil, Susan Owen, Tom E. Pierce, Hans Puxbaum, Martha Shearer, Ute Skiba, Rainer Steinbrecher, Leonor Tarrasón and Mats H. Oquist - 1999. Inventorying emissions from nature in Europe, *J. Geophys. Res.*, 104 (D7), 8113-8152.
- USEPA, 1979. AP-42, Compilation of Air Pollutant Emission Factors, Section 4.5, Final Section, "Asphalt Paving Operations", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1980. AP-42 Supplement 10 for Compilation of Air Pollutant Emission Factors, Third Edition. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, February, 1980.
- USEPA, 1980b. AP-42, Compilation of Air Pollutant Emission Factors, Section 13.3, Final Section, "Explosive Detonation", U.S. Environmental Protection Agency,

Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1981. AP-42, Compilation of Air Pollutant Emission Factors, Section 4.1, Final Section, "Dry Cleaning", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1981b. AP-42, Compilation of Air Pollutant Emission Factors, Section 4.9.1, Final Section, "General Graphic Arts", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1981c. AP-42, Compilation of Air Pollutant Emission Factors, Section 4.9.1, Final Section, "Publication Gravure Printing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1983. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.5, Final Section, "Phthalic Anhydride", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1983b. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.5, Final Section, "Explosives", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1983c. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.4, Final Section, "Paint and Varnishes", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1986. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.15, Final Section, "Glass Manufacturing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1986b. AP-42, Compilation of Air Pollutant Emission Factors, Section 12.3, Final Section, "Primary Copper Smelting", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1986c. AP-42, Compilation of Air Pollutant Emission Factors, Section 12.4, Final Section, "Ferroalloy Production", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1986d. AP-42, Compilation of Air Pollutant Emission Factors, Section 12.5, Final Section, "Iron and Steel Production", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1986e. AP-42, Compilation of Air Pollutant Emission Factors, Section 12.8, Final Section, "Secondary Aluminum Operations", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.



- USEPA, 1990. AP-42, Compilation of Air Pollutant Emission Factors, Section 10.2, Final Section, "Chemical Wood Pulping", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1991. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.6.3, Final Section, "Polystyrene", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1991b. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.6.4, Final Section, "Polypropylene", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1991c. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.6.1, Final Section, "Poly vinyl Chloride", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1991d. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.7, Final Section, "Printing Ink", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1991e. AP-42, Compilation of Air Pollutant Emission Factors, Section 13.5, Final Section, "Industrial Flares", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1992. AP-42, Compilation of Air Pollutant Emission Factors, Section 2.5, Final Section, "Open Burning", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1993. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.1, Final Section, "Synthetic Ammonia", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1993b. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.10, Final Section, "Sulphuric Acid", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1993c. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.2, Final Section, "Urea", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1993d. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.3, Final Section, "Ammonium Nitrate", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1993e. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.5.1, Final Section, "Normal Superphosphates", U.S. Environmental Protection

Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1993f. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.5.2, Final Section, "Triple Superphosphates", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1993g. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.5.3, Final Section, "Ammonium Phosphate", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.6, Final Section, "Portland Cement Manufacturing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995b. AP-42, Compilation of Air Pollutant Emission Factors, Section 12.13, Final Section, "Steel Foundries", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995c. AP-42, Compilation of Air Pollutant Emission Factors, Section 5.1, Final Section, "Petroleum Refining", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995d. AP-42, Compilation of Air Pollutant Emission Factors, Section 5.3, Final Section, "Natural Gas Processing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995e. AP-42, Compilation of Air Pollutant Emission Factors, Section 6.2, Final Section, "Adipic Acid", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995f. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.5, Final Section, "Refractory Manufacturing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995g. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.11.1, Final Section, "Vegetable Oil Processing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995h. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.5.2, Final Section, "Meat Smokehouses", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1995i. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.12.2, Final Section, "Wines and Brandy", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

- USEPA, 1995j. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.13.1, Final Section, "Fish Processing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1995k. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.13.2, Final Section, "Coffee Roasting", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1996. AP-42, Compilation of Air Pollutant Emission Factors, Section 1.2, Final Section, "Anthracite Coal Combustion", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1996b. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.4, Final Section, "Ammonium Sulphate", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1996b. AP-42, Compilation of Air Pollutant Emission Factors, Section 1.5, Final Section, "Liquified Petroleum Gas Combustion", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1996c. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.6, Final Section, "Ceramic Products Manufacturing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1996d. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.4, Final Section, "Ammonium Sulfate", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1996e. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.12.1, Final Section, "Malt Beverages", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1997. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.3, Final Section, "Bricks and Related Clay Products", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1997b. AP-42, Compilation of Air Pollutant Emission Factors, Section 7.1, Final Section, "Organic Liquids Storage Tanks", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1997c. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.5.1, Final Section, "Meat Packing Houses", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 1997d. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.9.6, Final Section, "Bread Baking", U.S. Environmental Protection Agency,

Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1997e. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.12.3, Final Section, "Distilled Spirits", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1998. AP-42, Compilation of Air Pollutant Emission Factors, Section 1.1, Final Section, "Bituminous And Subbituminous Coal Combustion", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1998b. AP-42, Compilation of Air Pollutant Emission Factors, Section 1.3, Final Section, "Fuel Oil Combustion", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1998c. AP-42, Compilation of Air Pollutant Emission Factors, Section 1.4, Final Section, "Natural Gas Combustion", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1998d. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.17, Final Section, "Lime Manufacturing", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1998e. AP-42, Compilation of Air Pollutant Emission Factors, Section 8.8, Final Section, "Nitric Acid", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1998f. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.9.1, Final Section, "Grain Elevators and Processes", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 1999. USER'S GUIDE to TANKS. Storage Tank Emissions Calculation Software. Version 4.0

USEPA, 2000. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.1, Final Section, "Hot Mix Asphalt Plants", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.

USEPA, 2001. EIIP, Volume III, Chapter 11, Revised Final, "Gasoline Marketing (Stage I and Stage II)", U.S. Environmental Protection Agency, Emissions Inventory Branch, Eastern Research Group, USA.

USEPA, 2001b. EIIP, Volume III, Chapter 12, Revised Final, "Marine Vessel Loading, Ballasting, and Transit", U.S. Environmental Protection Agency, Emissions Inventory Branch, Eastern Research Group, USA.

USEPA, 2001c. EIIP, Volume III, Chapter 17, Revised Final, "Asphalt Paving", U.S. Environmental Protection Agency, Emissions Inventory Branch, Eastern Research Group, USA.

- USEPA, 2000d. AP-42, Compilation of Air Pollutant Emission Factors, Section 12.2, Final Section, "Coke Production", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 2003. AP-42, Compilation of Air Pollutant Emission Factors, Section 1.6, Final Section, "Wood Residue Combustion in Boilers", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 2003b. AP-42, Compilation of Air Pollutant Emission Factors, Section 9.9.1, Final Section, "Grain Elevators and Processes", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- USEPA, 2004. AP-42, Compilation of Air Pollutant Emission Factors, Section 11.1, Final Section, "Hot Mix Asphalt Plants", U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, New York, USA.
- Valente A.J.R., Nunes, T.V. And C.A. Pio - 1996, Emission of Volatile Organic Compounds by the Portuguese coniferous forests in Portugal (in Portuguese), 5<sup>a</sup> Conferência Nacional sobre a Qualidade do Ambiente, 771-782, University of Algarve, Portugal.
- Veldt, C - 1988, Inventorying natural VOC emissions for the CORINAIR project. In Corinair Defaukt Emission Factor handbook, Technical Annexes Volume 2, European Comission EUR 12586/2, 101-128
- Veldt, C. - 1991, The use of biogenic VOC measurements in emissions inventories, Apeldoorn, The Netherlands, MT-TNO Report 91-323
- Veldt, C. -1989, Leaf biomass data for the estimation of biogenic VOC emissions, Apeldoorn, The Netherlands, MT-TNO Report 89-306

## 9.6.A Annex A: Key Source Category Analysis

### 9.6.B A.1 Introduction

This chapter provides an analysis of key sources categories following recommendations of the IPCC's Good Practice Guidance (IPCC 2000). A key source category "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 sources is the improvement of the inventory's accuracy. As key sources categories are the most important sources 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 sources is also important for the development of policies and measures for emissions reduction.

IPCC's 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.

### 9.6.C A. 2 Methodology for key source identification: Portuguese inventory

The determination of key source categories was conducted using the Tier 1 and the qualitative approach having as a basis the 2004 Portuguese inventory estimates (1990-2002). The Tier 2 method could not be used, as uncertainty estimates are not yet available. This method is however more sophisticated, as it incorporates source category uncertainty estimates, and should be applied in the future, when uncertainty analysis is developed.

#### *Tier 1 - Level assessment*

The contribution of each source category to the total national inventory was calculated for all years for which inventory estimates were available (1990-2002), according to the following equation:

<p>Source Category Level Assessment = Source Category estimate / Total estimate</p> $L_{x,t} = E_{x,t} / E_t$
---

Where,

$L_{x,t}$  = level assessment for source category x in year t

$E_{x,t}$  = total emissions estimate for year t

$E_t$  = emissions estimate for source category  $x$  in year  $t$

Only emission source categories were considered. Key source 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<sup>119</sup>.

#### *Tier 1 - Trend assessment*

The trend assessment is the product of the source category level assessment and the absolute difference between the source category trend and the total trend. This analysis enables the identification of source categories that have a different trend to the trend of the overall inventory. The source category trend assessment will be large if the source category represents a large percentage of emissions 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:

Source Category Trend Assessment = (Source Category Level assessment) • | (Source Category Trend – Total trend) |

$$T_{x,t} = L_{x,t} \cdot | [((E_{x,t} - E_{x,0}) / E_{x,t}) - ((E_t - E_0) / E_t)] |$$

Where,

$T_{x,t}$  = trend assessment for source category  $x$  in year  $t$

$L_{x,t}$  = level assessment for source category  $x$  in year  $t$

$E_{x,t}$  and  $E_{x,0}$  = emissions estimates for source category  $x$  in years  $t$  and 0, respectively

$E_t$  and  $E_0$  = total inventory estimates in years  $t$  and 0, respectively

0 = base year (1990)

#### *Qualitative approach*

Several qualitative criteria are purposed by the IPCC's Good Practice Guidance (IPCC 2000). In addition to the Tier 1 quantitative assessment, some qualitative criteria were used to identify additional key source categories.

<sup>119</sup> This threshold is intended to be applied to sources and to exclude sinks. The pre-determined threshold of 95% for both level assessment and trend assessment was determined to be the level at which 90% of the uncertainty in a "typical" inventory would be covered by key source categories, and was based on an analysis (Flugsrud et al., 1999 and Norwegian Pollution Control Authority, 1999) of selected inventories where sinks were excluded.

## 9.6.D A.3 Presentation of results

Key source 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. The source category level used in this analysis was based on the sectoral breakdown defined in the CRF (Common Report Format), which is the base format for inventory reporting under the UNFCCC.

Table A-1 presents the key source categories identified in the analysis, and the criteria used (level, trend, qualitative approach) in the identification. Tables A-2.1 to A-2.14 contain data for each inventory year's level assessment and trend assessment for 1990-2002.

The most important sources for all year's level assessment are CO<sub>2</sub> emissions from combustion of fossil fuels in Public Electricity and Heat Production (1A1a) (solid fuels – coal and liquid fuels – Oil) and Road Transportation (1A3b) (Diesel and Gasoline). CO<sub>2</sub> emissions from combustion in Manufacturing Industries and Construction (1A2f) (liquid fuels – Oil) are also one of the most significant contributors to the level assessment for each year, which is partly due to the level of aggregation of this category, which includes: textile, ceramic, glass, cement, cloths, wood, rubber, metal equipment and other transformation industry. Some of these sub-categories would probably have been considered as non key sources if considered separately. This category has however switched its rank position with CO<sub>2</sub> emissions from Cement production (2A1), which is now the fifth most important source.

Other main large contributors to the level assessment for each year are: CO<sub>2</sub> emissions from Commercial/Institutional and residential categories (1A4a and 1A4b) (liquid fuels); CO<sub>2</sub> emissions from Petroleum refining (1A1b) (liquid fuels); CO<sub>2</sub> emissions from Ammonia Production (2B1); CH<sub>4</sub> emissions from Swine Manure Management (4B8); N<sub>2</sub>O from Agriculture Soils (4D1 and 4D3); CH<sub>4</sub> emissions from non-dairy cattle enteric fermentation (1A1b); N<sub>2</sub>O emissions from solid storage and dry lot (4B12); CH<sub>4</sub> emissions from Industrial Waste Disposal on Land (6A3).

Among other main emissions are: CO<sub>2</sub> emissions from Food Processing, Beverages and Tobacco (1A2e) (liquid fuels); CH<sub>4</sub> emissions from Municipal Waste Disposal on Land (6A2) (unmanaged waste disposal which represented the main disposal practice until mid 90s); CH<sub>4</sub> emissions from enteric fermentation of dairy cattle and sheep (4A1a and 4A3); CO<sub>2</sub> emissions from Paper, Pulp and Print industries (1A2d) (liquid fuels – level key source for all years; and gaseous fuels - level key source since 2001); N<sub>2</sub>O emissions from processes in Nitric Acid Production (2B2); CH<sub>4</sub> emissions from Domestic and Commercial Wastewater Handling (6B2).

CO<sub>2</sub> emissions from diesel road transports appear as the biggest contributor to the trend 1990-2002. This situation is related to the big increase of transportation during the last decade, in particular road traffic, reflecting the strong investment in the road infrastructure of the country.



Among other sectors that contribute the most to the overall trend is: Public Electricity and Heat Production (1A1a) (gaseous and liquid fuels). Since the introduction of natural gas in 1998, CO<sub>2</sub> emissions from the combustion of gaseous fuels from several sources, start to contribute significantly to the level assessment and to the trend assessment: Public Electricity and Heat Production (1A1a) (gaseous fuels), Manufacturing Industries and Construction (1A2f) (gaseous fuels), which was accompanied, in the last case, by the decline of combustion of solid fuels (1A2f). CO<sub>2</sub> emissions from Commercial/Institutional (1A4a) (liquid fuels) are also an important contributor to the overall inventory trend, reflecting the expansion of the service sector and the development of air conditioning systems.

The start of operation in 2000 of two new installation units dedicated to the incineration of municipal waste made CO<sub>2</sub> emissions from Waste Incineration (6C) become a key source.

Other source categories were determined to be key source using the qualitative criteria. This is the case of estimates for HFCs and SF<sub>6</sub> emissions, which are associated with high uncertainty due to poor coverage. Due to the lack of resources it was still not possible to ameliorate the estimation of these sources in the last submission. This should be done in the future.

Table A-1 – Portuguese key source categories (1990-2002) based on Tier 1 approach

						(1/2)
IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Key source Category Flag	Criteria for Identification	Comments	2002 emissions estimate (kton CO <sub>2</sub> eq.)
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	√	Level Trend	All years	12448
1 A 3 b Road Transportation	Diesel Oil	CO <sub>2</sub>	√	Level Trend	All years	12425
1 A 3 b Road Transportation	Gasoline	CO <sub>2</sub>	√	Level Trend	All years	6633
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	6565
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	√	Level Trend	1998, 1999, 2000, 2001, 2002	3253
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	√	Level Trend	All years	3033
1 A 2 f Other	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	2985
1 A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	2552
1 A 1 b Petroleum refining	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	2517
1 A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	√	Level Trend	1998, 1999, 2000, 2001, 2002	2063
1 A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	1959
2 B 1 Ammonia Production	Production Quantities	CO <sub>2</sub>	√	Level Trend	All years	1528
1 A 2 c Chemicals	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	1365
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	1332
4 B 8 Swine	Population size	CH <sub>4</sub>	√	Level Trend	All years	1315
4 D 1 Direct Soil Emissions	Input to soils	N <sub>2</sub> O	√	Level Trend	All years	1195
4 D 3 Indirect Emissions	Input to soils	N <sub>2</sub> O	√	Level Trend	All years	1127
4 A 1 b Non-Dairy Cattle	Population size	CH <sub>4</sub>	√	Level Trend	All years	1062
6 A 3 Other	Industrial Waste Disposal on Land	CH <sub>4</sub>	√	Level Trend	All years	1046
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N <sub>2</sub> O	√	Level Trend	All years	1013
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	949
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	√	Level Trend	All years	920
1 A 2 f Other	Solid Fuels	CO <sub>2</sub>	√	Level Trend	All years	727
4 A 1 a Dairy Cattle	Population size	CH <sub>4</sub>	√	Level Trend	All years	716
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO <sub>2</sub>	√	Level Trend	All years	699

2 B 2 Nitric Acid Production	Production Quantities	N2O	√	Level Trend	All years	590
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	√	Level Trend	All years	581
4 A 3 Sheep	Population size	CH4	√	Level Trend	All years	581
4 D 2 Animal Production	Input to soils	N2O	√	Level Trend	All years	519
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	√	Level Trend	2001, 2002	488

						(2/2)
IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Key source Category Flag	Criteria for Identification	Comments	2002 emissions estimate (kton CO2 eq.)
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	√	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002	433
6 C WASTE INCINERATION	Waste Incinerated	CO2	√	Level Trend	2000, 2001, 2002	380
1 A 3 a ii Domestic	Jet Kerosene	CO2	√	Level	All years	375
5 E OTHER	Wildfires	CH4	√	Level Trend	1990, 1991, 1992, 1995, 1998, 2000, 2001, 2002	361
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	√	Level	All years	356
1 A 4 b Residential	Gaseous Fuels	CO2	√	Level Trend	2000, 2001, 2002	345
1 A 3 b Road Transportation	Diesel Oil	N2O	√	Level Trend	1998, 1999, 2000, 2001, 2002	324
1 A 4 b Residential	Biomass	CH4	√	Level Trend	All years	302
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	√	Level Trend	2001, 2002	277
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	√	Level	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002	275
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH4	√	Level Trend	1999, 2001, 2002	254
2 A 7 Other	Production Quantities	CO2	√	Level	1999, 2000, 2001, 2002	231
1 A 3 b Road Transportation	Gasoline	N2O	√	Level Trend	2000	228
1 A 2 c Chemicals	Gaseous Fuels	CO2	√	Trend		219
6 B 1 Industrial Wastewater	Wastewater	CH4	√	Level	1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001	208
6 B 1 Industrial Wastewater	Wastewater	N2O	√	Level	1992, 1993, 1994, 1996, 1997, 1998, 1999, 2000	205
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	√	Trend		180
1 B 2 d Other (Geothermal)	Energy Production	CO2	√	Trend		179
4 C 1 Irrigated	Culture Surface	CH4	√	Level Trend	1990, 1991, 1996, 1997, 1999, 2000	162
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	√	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997	144
1 A 3 c Railways	Liquid Fuels	CO2	√	Level Trend	1990, 1991	111
1 A 2 a Iron and Steel	Liquid Fuels	CO2	√	Level	1993	108
1 A 2 c Chemicals	Solid Fuels	CO2	√	Level	2000	59
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	√	Qual		31
2 F 2 Foam Blowing	Consumption	HFCs	√	Qual		19
2 F 7 Electrical Equipment	Consumption	SF6	√	Qual		7
1 A 2 a Iron and Steel	Solid Fuels	CO2	√	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000,	0

2001		
Sub-Total	All gases	79962
% of Total	All gases	97.5
TOTAL EMISSIONS	All gases	81982

Tables A-2.1 to A.2-13 – Tier 1 Level assessment: 1990 to 2002

## Tier 1 Level Assessment (1990)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1990		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	7816	0.13	0.13
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	6364	0.11	0.24
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	4941	0.08	0.33
1 A 3 b Road Transportation	Gasoline	CO2	4622	4622	0.08	0.41
1 A 2 f Other	Liquid Fuels	CO2	3349	3349	0.06	0.46
2 A 1 Cement Production	Production Quantities	CO2	3107	3107	0.05	0.52
1 A 2 f Other	Solid Fuels	CO2	2146	2146	0.04	0.55
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	1929	0.03	0.59
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1675	0.03	0.62
1 A 4 b Residential	Liquid Fuels	CO2	1630	1630	0.03	0.64
4 B 8 Swine	Population size	CH4	1489	1489	0.03	0.67
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1451	0.02	0.69
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1324	0.02	0.72
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1229	0.02	0.74
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1226	0.02	0.76
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	980	0.02	0.78
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	917	0.02	0.79
4 A 1 a Dairy Cattle	Population size	CH4	846	846	0.01	0.81
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	828	0.01	0.82
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	761	0.01	0.83
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	751	0.01	0.85
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	744	0.01	0.86
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	659	0.01	0.87
2 B 1 Ammonia Production	Production Quantities	CO2	569	569	0.01	0.88
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	567	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	564	0.01	0.90
4 D 2 Animal Production	Input to soils	N2O	544	544	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	468	0.01	0.92
5 E OTHER	Wildfires	CH4	441	441	0.01	0.92
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	433	0.01	0.93
1 A 4 b Residential	Biomass	CH4	343	343	0.01	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	287	0.00	0.94
4 C 1 Irrigated	Culture Surface	CH4	256	256	0.00	0.95
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	245	0.00	0.95
1 A 3 c Railways	Liquid Fuels	CO2	175	175	0.00	0.95
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	166	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	164	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	161	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	151	0.00	0.96
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	103	0.00	0.97
1 A 3 b Road Transportation	Diesel Oil	N2O	100	100	0.00	0.97
2 A 7 Other	Production Quantities	CO2	97	97	0.00	0.97
4 A 4 Goats	Population size	CH4	90	90	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	86	0.00	0.97
4 A 8 Swine	Population size	CH4	84	84	0.00	0.97
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 B 1 a i Underground Mines	Solid Fuels	CH4	65	65	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	52	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	51	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	51	0.00	0.98
1 B 2 c i Oil	Liquid Fuels	CO2	49	49	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	48	0.00	0.98
1 A 2 c Chemicals	Solid Fuels	CO2	45	45	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	45	0.00	0.99
5 E OTHER	Wildfires	N2O	45	45	0.00	0.99
1 A 3 d ii National navigation	Residual Oil	CO2	44	44	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	39	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	38	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	34	0.00	0.99
1 A 3 b Road Transportation	Gasoline	N2O	33	33	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	29	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	29	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	26	0.00	0.99
4 A 7 Mules and Asses	Population size	CH4	24	24	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	22	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	21	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	20	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	19	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	17	0.00	0.99
4 F 5 Other	Residues Burning	CH4	16	16	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	15	15	0.00	1.00
4 A 6 Horses	Population size	CH4	14	14	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	13	0.00	1.00
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	13	0.00	1.00

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis					
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	12	0.00 1.00
1 B 2 a iii Transport	Liquid Fuels	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
4 B 11 Liquid Systems	Animal Excretion	N2O	9	9	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	9	0.00 1.00
1 B 1 a I Underground Mines	Solid Fuels	CO2	9	9	0.00 1.00
1 A 5 Other	Solid Fuels	CO2	8	8	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	6	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	5	0.00 1.00
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	3	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	3	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	3	0.00 1.00
4 B 6 Horses	Population size	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 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
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	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 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	2	0.00 1.00
1 A 2 f Other	Solid Fuels	CH4	2	2	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	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 3 a ii Domestic	Aviation Gasoline	CO2	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
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
1 B 1 a ii Surface Mines	Solid 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
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	1	1	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	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	0.437	0.437	0.00 1.00
1 A 2 c Chemicals	Other Fuels	N2O	0.434	0.434	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0.349	0.349	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.331	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.271	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.249	0.00 1.00
1 A 5 Other	Solid Fuels	CH4	0.151	0.151	0.00 1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.133	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.129	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.126	0.00 1.00
1 B 1 a ii Surface Mines	Solid Fuels	CO2	0.113	0.113	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.099	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.099	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.068	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CO2	0.059	0.059	0.00 1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.055	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.046	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.043	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.038	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.033	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.031	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.029	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.023	0.00 1.00
1 A 5 Other	Solid Fuels	N2O	0.018	0.018	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.017	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.016	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.009	0.00 1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.009	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0.008	0.008	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0.003	0.003	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.003	0.00 1.00
1 B 2 c I Oil	Liquid Fuels	CH4	0.002	0.002	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.002	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0.001	0.001	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.000	0.00 1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00 1.00

## Analysis

1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00



## Tier 1 Level Assessment (1991)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1991		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	8289	0.14	0.14
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	6722	0.11	0.25
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	5131	0.08	0.33
1 A 3 b Road Transportation	Gasoline	CO2	4622	5072	0.08	0.42
1 A 2 f Other	Liquid Fuels	CO2	3349	3476	0.06	0.47
2 A 1 Cement Production	Production Quantities	CO2	3107	3200	0.05	0.53
1 A 2 f Other	Solid Fuels	CO2	2146	2291	0.04	0.56
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	1770	0.03	0.59
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1733	0.03	0.62
1 A 4 b Residential	Liquid Fuels	CO2	1630	1709	0.03	0.65
4 B 8 Swine	Population size	CH4	1489	1433	0.02	0.67
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1401	0.02	0.70
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1386	0.02	0.72
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1269	0.02	0.74
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1201	0.02	0.76
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	1020	0.02	0.78
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	930	0.02	0.79
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	902	0.01	0.81
4 A 1 a Dairy Cattle	Population size	CH4	846	848	0.01	0.82
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	837	0.01	0.84
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	812	0.01	0.85
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	791	0.01	0.86
5 E OTHER	Wildfires	CH4	441	695	0.01	0.87
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	653	0.01	0.88
4 A 3 Sheep	Population size	CH4	564	568	0.01	0.89
4 D 2 Animal Production	Input to soils	N2O	544	552	0.01	0.90
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	534	0.01	0.91
2 B 1 Ammonia Production	Production Quantities	CO2	569	447	0.01	0.92
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	416	0.01	0.93
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	388	0.01	0.93
1 A 4 b Residential	Biomass	CH4	343	328	0.01	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	291	0.00	0.94
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	256	0.00	0.95
4 C 1 Irrigated	Culture Surface	CH4	256	253	0.00	0.95
1 A 3 c Railways	Liquid Fuels	CO2	175	183	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	CH4	164	179	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	176	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	158	0.00	0.96
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	125	0.00	0.96
1 A 3 b Road Transportation	Diesel Oil	N2O	100	105	0.00	0.97
2 A 7 Other	Production Quantities	CO2	97	105	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	96	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	94	0.00	0.97
4 A 4 Goats	Population size	CH4	90	93	0.00	0.97
3 D OTHER	Other Use of Chemicals	CO2	80	86	0.00	0.97
4 A 8 Swine	Population size	CH4	84	81	0.00	0.98
5 E OTHER	Wildfires	N2O	45	71	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	69	0.00	0.98
1 B 1 a i Underground Mines	Solid Fuels	CH4	65	63	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	0.98
1 A 2 f Other	Biomass	CH4	29	57	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	57	0.00	0.98
1 A 3 d ii National navigation	Residual Oil	CO2	44	57	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	56	0.00	0.98
1 B 2 c i Oil	Liquid Fuels	CO2	49	52	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	51	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	50	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	47	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	45	46	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	40	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	38	0.00	0.99
1 A 3 b Road Transportation	Gasoline	N2O	33	36	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	36	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	34	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	31	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	29	0.00	0.99
4 A 7 Mules and Asses	Population size	CH4	24	22	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	21	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	20	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	19	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	19	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	18	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	18	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00	1.00
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	16	0.00	1.00
4 A 6 Horses	Population size	CH4	14	14	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	13	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	12	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	12	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	12	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00

Analysis		Key Source Category				
1 B 2 a iii Transport	Liquid Fuels	CO2	12	11	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00	1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	9	0.00	1.00
4 B 7 Mules and Asses	Population size	CH4	9	8	0.00	1.00
1 B 1 a i Underground Mines	Solid Fuels	CO2	9	8	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	8	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	6	0.00	1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	6	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	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
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00	1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00	1.00
4 A 10 Other	Population size	CH4	4	4	0.00	1.00
2 B 5 Carbon black	Production Quantities	CH4	3	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
4 B 4 Goats	Population size	CH4	3	3	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	3	0.00	1.00
4 F 1 Cereals	Residues Burning	N2O	3	3	0.00	1.00
4 B 6 Horses	Population size	CH4	3	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	3	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	3	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	2	0.00	1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	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 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	1	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	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	Biomass	CH4	1	1	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 4 b Residential	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
1 B 1 a ii Surface Mines	Solid Fuels	CH4	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 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	1	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	1	1	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0.349	0.451	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.451	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0.434	0.431	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.329	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.325	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.321	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.261	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	CO2	0.059	0.156	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.138	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0.151	0.110	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.107	0.00	1.00
1 B 1 a ii Surface Mines	Solid Fuels	CO2	0.113	0.105	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.103	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3.123	0.094	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.088	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.076	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.069	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.050	0.00	1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.044	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.040	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.039	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.039	0.00	1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.031	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.029	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.024	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.015	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.014	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0.018	0.013	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.008	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.005	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.004	0.00	1.00
1 B 2 c i Oil	Liquid Fuels	CH4	0.002	0.003	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0.003	0.001	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.001	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0.001	0.000	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0.008	0.000	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.000	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00	1.00

## Analysis

1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1992)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1992		
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	9388	0.15	0.15
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	8514	0.13	0.28
1 A 3 b Road Transportation	Gasoline	CO2	4622	5651	0.09	0.37
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	5450	0.09	0.45
1 A 2 f Other	Liquid Fuels	CO2	3349	3442	0.05	0.51
2 A 1 Cement Production	Production Quantities	CO2	3107	3067	0.05	0.56
1 A 2 f Other	Solid Fuels	CO2	2146	2131	0.03	0.59
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	1933	0.03	0.62
1 A 4 b Residential	Liquid Fuels	CO2	1630	1810	0.03	0.65
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1695	0.03	0.67
4 B 8 Swine	Population size	CH4	1489	1423	0.02	0.70
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1359	0.02	0.72
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1313	0.02	0.74
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1273	0.02	0.76
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1129	0.02	0.78
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	972	0.02	0.79
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	943	0.01	0.81
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	918	0.01	0.82
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	906	0.01	0.83
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	889	0.01	0.85
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	822	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	800	0.01	0.87
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	677	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	651	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	562	0.01	0.90
4 D 2 Animal Production	Input to soils	N2O	544	532	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	502	0.01	0.92
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	342	0.01	0.93
2 B 1 Ammonia Production	Production Quantities	CO2	569	335	0.01	0.93
1 A 4 b Residential	Biomass	CH4	343	317	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	294	0.00	0.94
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	265	0.00	0.94
5 E OTHER	Wildfires	CH4	441	220	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	CH4	164	193	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	190	0.00	0.95
1 A 3 c Railways	Liquid Fuels	CO2	175	183	0.00	0.96
4 C 1 Irrigated	Culture Surface	CH4	256	160	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	160	0.00	0.96
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	148	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	129	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	113	0.00	0.97
1 A 3 b Road Transportation	Diesel Oil	N2O	100	113	0.00	0.97
1 A 2 c Chemicals	Other Fuels	CO2	63	99	0.00	0.97
4 A 4 Goats	Population size	CH4	90	90	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	90	0.00	0.97
1 A 2 f Other	Biomass	CH4	29	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	81	0.00	0.98
4 A 8 Swine	Population size	CH4	84	80	0.00	0.98
1 A 3 d ii National navigation	Residual Oil	CO2	44	75	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	74	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	67	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	64	0.00	0.98
1 B 2 c i Oil	Liquid Fuels	CO2	49	63	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	61	0.00	0.98
1 B 1 a i Underground Mines	Solid Fuels	CH4	65	59	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	58	0.00	0.99
2 B 5 Carbon black	Production Quantities	CO2	51	51	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	48	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	43	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	42	0.00	0.99
1 A 3 b Road Transportation	Gasoline	N2O	33	40	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	39	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	38	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	35	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	28	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	26	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	24	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	23	0.00	0.99
5 E OTHER	Wildfires	N2O	45	22	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	21	0.00	0.99
4 A 7 Mules and Asses	Population size	CH4	24	21	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	20	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	20	0.00	1.00
4 B 3 Sheep	Population size	CH4	19	19	0.00	1.00
4 B 10 Anaerobic	Animal Excretion	N2O	20	19	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	15	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	14	0.00	1.00
4 A 6 Horses	Population size	CH4	14	13	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	12	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	12	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	12	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis					
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	9	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	8	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	8	0.00 1.00
1 B 1 a i Underground Mines	Solid Fuels	CO2	9	8	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	6	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00 1.00
1 A 2 f Other	Other Fuels	CO2	20	6	0.00 1.00
1 A 5 Other	Solid Fuels	CO2	8	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
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	3	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	3	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	3	0.00 1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00 1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	3	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	2	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	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	2	2	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	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 c Chemicals	Biomass	N2O	1	1	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	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 c Chemicals	Other Fuels	N2O	0	1	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	1	1	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.459	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.452	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.368	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.320	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CO2	0.059	0.274	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.261	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.178	0.00 1.00
1 B 1 a ii Surface Mines	Solid Fuels	CH4	0.862	0.164	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.157	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.115	0.00 1.00
1 A 5 Other	Solid Fuels	CH4	0.151	0.104	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.101	0.00 1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.091	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.076	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.068	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.055	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.046	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1.192	0.041	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.040	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.031	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.024	0.00 1.00
1 B 1 a ii Surface Mines	Solid Fuels	CO2	0.113	0.021	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.013	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.012	0.00 1.00
1 A 5 Other	Solid Fuels	N2O	0.018	0.012	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.008	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.008	0.00 1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.006	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.004	0.00 1.00
1 B 2 c i Oil	Liquid Fuels	CH4	0.002	0.003	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.002	0.00 1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0.003	0.000	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0.001	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00 1.00

## Analysis

1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1993)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1993		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	9375	0.15	0.15
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	6508	0.11	0.26
1 A 3 b Road Transportation	Gasoline	CO2	4622	5934	0.10	0.35
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	5616	0.09	0.44
1 A 2 f Other	Liquid Fuels	CO2	3349	3561	0.06	0.50
2 A 1 Cement Production	Production Quantities	CO2	3107	3125	0.05	0.55
1 A 2 f Other	Solid Fuels	CO2	2146	1926	0.03	0.58
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	1925	0.03	0.61
1 A 4 b Residential	Liquid Fuels	CO2	1630	1899	0.03	0.64
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1717	0.03	0.67
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1356	0.02	0.69
4 B 8 Swine	Population size	CH4	1489	1299	0.02	0.72
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1270	0.02	0.74
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1195	0.02	0.75
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1125	0.02	0.77
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	987	0.02	0.79
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	956	0.02	0.80
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	915	0.01	0.82
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	898	0.01	0.83
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	880	0.01	0.85
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	855	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	788	0.01	0.87
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	701	0.01	0.89
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	648	0.01	0.90
4 A 3 Sheep	Population size	CH4	564	555	0.01	0.91
4 D 2 Animal Production	Input to soils	N2O	544	522	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	321	0.01	0.92
1 A 4 b Residential	Biomass	CH4	343	310	0.01	0.92
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	305	0.00	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	303	0.00	0.93
2 B 1 Ammonia Production	Production Quantities	CO2	569	281	0.00	0.94
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	257	0.00	0.94
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.95
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	191	0.00	0.95
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	173	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	168	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	166	0.00	0.96
5 E OTHER	Wildfires	CH4	441	132	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	121	0.00	0.96
1 A 3 b Road Transportation	Diesel Oil	N2O	100	118	0.00	0.97
1 A 3 d ii National navigation	Residual Oil	CO2	44	116	0.00	0.97
4 C 1 Irrigated	Culture Surface	CH4	256	100	0.00	0.97
1 A 2 c Chemicals	Other Fuels	CO2	63	90	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	88	0.00	0.97
4 A 4 Goats	Population size	CH4	90	88	0.00	0.97
1 B 2 c I Oil	Liquid Fuels	CO2	49	83	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	75	0.00	0.98
4 A 8 Swine	Population size	CH4	84	71	0.00	0.98
1 A 3 b Road Transportation	Gasoline	N2O	33	70	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	66	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	64	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	60	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	59	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	56	0.00	0.99
1 B 1 a I Underground Mines	Solid Fuels	CH4	65	55	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	50	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	44	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	44	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	40	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	37	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	37	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	34	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	34	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	27	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	23	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	22	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	20	0.00	0.99
4 A 7 Mules and Asses	Population size	CH4	24	19	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	18	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	14	0.00	1.00
5 E OTHER	Wildfires	N2O	45	13	0.00	1.00
4 A 6 Horses	Population size	CH4	14	13	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	13	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	12	0.00	1.00

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis					
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	8	0.00 1.00
1 B 1 a i Underground Mines	Solid Fuels	CO2	9	7	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	7	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	6	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	6	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	5	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	4	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00 1.00
1 A 2 f Other	Solid Fuels	N2O	5	4	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
1 A 5 Other	Solid Fuels	CO2	8	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	3	0.00 1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	2	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	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 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	2	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00 1.00
1 A 2 f Other	Solid Fuels	CH4	2	2	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	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 a Iron and Steel	Solid Fuels	N2O	1	1	0.00 1.00
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	1	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	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 c Chemicals	Other Fuels	N2O	0	1	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.464	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.463	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.356	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.314	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CO2	0.059	0.306	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.239	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.181	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.179	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.162	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.138	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.093	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.073	0.00 1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.069	0.00 1.00
1 A 5 Other	Solid Fuels	CH4	0.151	0.057	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.043	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.042	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.040	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.034	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.029	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.022	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.011	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.010	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.008	0.00 1.00
1 A 5 Other	Solid Fuels	N2O	0.018	0.007	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.006	0.00 1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.004	0.00 1.00
1 B 2 c i Oil	Liquid Fuels	CH4	0.002	0.004	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.002	0.00 1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0.000	0.000	0.00 1.00



## Analysis

1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1994)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1994		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	9813	0.15	0.15
1 A 3 b Road Transportation	Gasoline	CO2	4622	6079	0.10	0.25
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	6057	0.10	0.35
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	4722	0.07	0.42
1 A 2 f Other	Liquid Fuels	CO2	3349	3725	0.06	0.48
2 A 1 Cement Production	Production Quantities	CO2	3107	3220	0.05	0.53
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2410	0.04	0.57
1 A 2 f Other	Solid Fuels	CO2	2146	2097	0.03	0.60
1 A 4 b Residential	Liquid Fuels	CO2	1630	1920	0.03	0.63
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1788	0.03	0.66
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1398	0.02	0.68
4 B 8 Swine	Population size	CH4	1489	1358	0.02	0.70
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1295	0.02	0.72
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1274	0.02	0.74
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	1147	0.02	0.76
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1123	0.02	0.78
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	1053	0.02	0.79
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	969	0.02	0.81
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	897	0.01	0.82
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	893	0.01	0.84
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	886	0.01	0.85
2 B 1 Ammonia Production	Production Quantities	CO2	569	775	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	748	0.01	0.88
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	648	0.01	0.89
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	645	0.01	0.90
4 A 3 Sheep	Population size	CH4	564	574	0.01	0.91
4 D 2 Animal Production	Input to soils	N2O	544	522	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	489	0.01	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	311	0.00	0.93
1 A 4 b Residential	Biomass	CH4	343	307	0.00	0.93
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	269	0.00	0.94
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	257	0.00	0.94
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	234	0.00	0.94
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.95
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	199	0.00	0.95
4 C 1 Irrigated	Culture Surface	CH4	256	182	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	168	0.00	0.96
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	167	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	166	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	153	0.00	0.97
1 A 3 b Road Transportation	Diesel Oil	N2O	100	131	0.00	0.97
1 B 2 c i Oil	Liquid Fuels	CO2	49	109	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	96	0.00	0.97
1 A 3 b Road Transportation	Gasoline	N2O	33	94	0.00	0.97
4 A 4 Goats	Population size	CH4	90	86	0.00	0.97
1 A 3 d ii National navigation	Residual Oil	CO2	44	85	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	83	0.00	0.98
4 A 8 Swine	Population size	CH4	84	76	0.00	0.98
5 E OTHER	Wildfires	CH4	441	75	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	69	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	67	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	65	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	63	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	61	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	48	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	48	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	47	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	46	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	46	0.00	0.99
1 B 1 a i Underground Mines	Solid Fuels	CH4	65	41	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	38	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	37	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	34	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	28	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	28	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	27	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	26	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	24	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	20	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	20	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	18	0.00	1.00
4 A 7 Mules and Asses	Population size	CH4	24	17	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	17	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	15	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	14	0.00	1.00
4 A 6 Horses	Population size	CH4	14	13	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	13	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	11	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	1.00

Analysis					
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00 1.00
1 A 2 f Other	Other Fuels	CO2	20	10	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	9	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00 1.00
5 E OTHER	Wildfires	N2O	45	8	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	7	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	7	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00 1.00
1 B 1 a I Underground Mines	Solid Fuels	CO2	9	5	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	5	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	4	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	4	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	4	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	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	Liquid Fuels	N2O	2	3	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	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	Jet Kerosene	N2O	2	2	0.00 1.00
1 A 2 f Other	Solid Fuels	CH4	2	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 2 c Chemicals	Biomass	N2O	1	1	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 2 c Chemicals	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
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	Liquid Fuels	CH4	1	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	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 3 d ii National navigation	Residual Oil	N2O	0	1	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00 1.00
1 A 5 Other	Solid Fuels	CO2	8.291	0.491	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.438	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.408	0.00 1.00
1 A 2 c Chemicals	Other Fuels	N2O	0.434	0.331	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CO2	0.059	0.328	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.314	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.288	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.237	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.167	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.151	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.131	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.115	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.100	0.00 1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.072	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.057	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.041	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.037	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.035	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.023	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.022	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.022	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.012	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.009	0.00 1.00
1 A 5 Other	Solid Fuels	CH4	0.151	0.009	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.008	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.007	0.00 1.00
1 B 2 c I Oil	Liquid Fuels	CH4	0.002	0.006	0.00 1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.005	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.002	0.00 1.00
1 A 5 Other	Solid Fuels	N2O	0.018	0.001	0.00 1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0.000	0.000	0.00 1.00

## Analysis

1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1995)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1995		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	11256	0.17	0.17
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	6503	0.10	0.26
1 A 3 b Road Transportation	Gasoline	CO2	4622	6258	0.09	0.35
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	5811	0.09	0.44
1 A 2 f Other	Liquid Fuels	CO2	3349	3912	0.06	0.50
2 A 1 Cement Production	Production Quantities	CO2	3107	3386	0.05	0.55
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2417	0.04	0.58
1 A 2 f Other	Solid Fuels	CO2	2146	1972	0.03	0.61
1 A 4 b Residential	Liquid Fuels	CO2	1630	1922	0.03	0.64
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1674	0.02	0.66
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1486	0.02	0.69
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1445	0.02	0.71
4 B 8 Swine	Population size	CH4	1489	1353	0.02	0.73
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1283	0.02	0.75
2 B 1 Ammonia Production	Production Quantities	CO2	569	1199	0.02	0.76
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	1119	0.02	0.78
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1117	0.02	0.80
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	968	0.01	0.81
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	936	0.01	0.83
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	918	0.01	0.84
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	910	0.01	0.85
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	886	0.01	0.87
4 A 1 a Dairy Cattle	Population size	CH4	846	764	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	642	0.01	0.89
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	600	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	576	0.01	0.90
4 D 2 Animal Production	Input to soils	N2O	544	523	0.01	0.91
5 E OTHER	Wildfires	CH4	441	485	0.01	0.92
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	447	0.01	0.92
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	404	0.01	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	310	0.00	0.94
1 A 4 b Residential	Biomass	CH4	343	307	0.00	0.94
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	282	0.00	0.94
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	243	0.00	0.95
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	226	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	170	0.00	0.96
4 C 1 Irrigated	Culture Surface	CH4	256	164	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	162	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	160	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	151	0.00	0.97
1 A 3 b Road Transportation	Diesel Oil	N2O	100	142	0.00	0.97
1 A 3 b Road Transportation	Gasoline	N2O	33	115	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	103	0.00	0.97
1 B 2 c i Oil	Liquid Fuels	CO2	49	90	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	84	0.00	0.98
4 A 4 Goats	Population size	CH4	90	84	0.00	0.98
4 A 8 Swine	Population size	CH4	84	76	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	73	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	71	0.00	0.98
1 A 3 d ii National navigation	Residual Oil	CO2	44	71	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	69	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	66	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	65	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	45	61	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	53	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	52	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	50	0.00	0.99
5 E OTHER	Wildfires	N2O	45	49	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	44	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	38	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	38	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	33	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	31	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	27	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	26	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	26	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	23	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	22	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	21	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	20	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	1.00
4 B 10 Anaerobic	Animal Excretion	N2O	20	18	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	16	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
4 A 7 Mules and Asses	Population size	CH4	24	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	15	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	14	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	14	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	14	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
4 A 6 Horses	Population size	CH4	14	13	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	1.00

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis					
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00 1.00
1 A 2 f Other	Other Fuels	CO2	20	9	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	8	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	7	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	6	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	6	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	5	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00 1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	5	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	4	0.00 1.00
1 A 2 f Other	Solid Fuels	N2O	5	4	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	3	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	3	0.00 1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	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	Jet Kerosene	N2O	2	2	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	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 2 f Other	Solid Fuels	CH4	2	2	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	1	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00 1.00
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	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 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CO2	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	Other Fuels	CO2	3	1	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00 1.00
1 A 2 c Chemicals	Other Fuels	N2O	0.434	0.500	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.494	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.406	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.369	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.314	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.242	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.226	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.171	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.110	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.107	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.107	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.105	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.056	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.041	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.039	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.034	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.027	0.00 1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.026	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.025	0.00 1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.024	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.023	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.020	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.018	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.010	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.008	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.006	0.00 1.00
1 B 2 c I Oil	Liquid Fuels	CH4	0.002	0.005	0.00 1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.002	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0.008	0.001	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.000	0.00 1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00

## Analysis

1 A 2 b Non-ferrous Metals	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1996)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1996		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	10368	0.16	0.16
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	6994	0.11	0.27
1 A 3 b Road Transportation	Gasoline	CO2	4622	6408	0.10	0.37
1 A 2 f Other	Liquid Fuels	CO2	3349	4313	0.07	0.43
2 A 1 Cement Production	Production Quantities	CO2	3107	3313	0.05	0.48
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	2840	0.04	0.53
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2349	0.04	0.56
1 A 4 b Residential	Liquid Fuels	CO2	1630	2065	0.03	0.60
1 A 2 f Other	Solid Fuels	CO2	2146	1900	0.03	0.63
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1808	0.03	0.65
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1491	0.02	0.68
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1353	0.02	0.70
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1338	0.02	0.72
4 B 8 Swine	Population size	CH4	1489	1322	0.02	0.74
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	1205	0.02	0.76
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1138	0.02	0.77
2 B 1 Ammonia Production	Production Quantities	CO2	569	975	0.02	0.79
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	962	0.01	0.80
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	957	0.01	0.82
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	956	0.01	0.83
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	951	0.01	0.85
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	905	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	760	0.01	0.87
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	632	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	629	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	568	0.01	0.90
4 D 2 Animal Production	Input to soils	N2O	544	516	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	442	0.01	0.92
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	353	0.01	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	319	0.00	0.93
1 A 4 b Residential	Biomass	CH4	343	308	0.00	0.93
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	298	0.00	0.94
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	257	0.00	0.94
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	228	0.00	0.94
4 C 1 Irrigated	Culture Surface	CH4	256	214	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.95
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	179	0.00	0.96
5 E OTHER	Wildfires	CH4	441	169	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	161	0.00	0.96
1 A 3 b Road Transportation	Diesel Oil	N2O	100	156	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	155	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	144	0.00	0.97
1 A 3 b Road Transportation	Gasoline	N2O	33	135	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	117	0.00	0.97
1 A 3 d ii National navigation	Residual Oil	CO2	44	85	0.00	0.97
3 D OTHER	Other Use of Chemicals	CO2	80	84	0.00	0.98
4 A 4 Goats	Population size	CH4	90	82	0.00	0.98
1 B 2 c i Oil	Liquid Fuels	CO2	49	80	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	76	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	76	0.00	0.98
4 A 8 Swine	Population size	CH4	84	74	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	70	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	68	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	66	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	64	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	56	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	51	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	48	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	48	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	38	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	37	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	37	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	33	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	26	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	26	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	25	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	25	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	21	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	18	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00	0.99
5 E OTHER	Wildfires	N2O	45	17	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	16	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	15	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	15	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	15	0.00	1.00
4 A 7 Mules and Asses	Population size	CH4	24	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	14	0.00	1.00
4 A 6 Horses	Population size	CH4	14	14	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	13	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	11	0.00	1.00



# Portuguese National Inventory Report 2004

## Key Source Category

Analysis					
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00 1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	10	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	8	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	7	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	7	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	6	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	6	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CO2	0	5	0.00 1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	5	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	5	0.00 1.00
1 A 2 f Other	Solid Fuels	N2O	5	4	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	3	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00 1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	3	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	2	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	2	0.00 1.00
1 A 2 f Other	Solid Fuels	CH4	2	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 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00 1.00
1 A 4 a Commercial / Institutional	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 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00 1.00
1 A 2 a Iron and Steel	Solid 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 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00 1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.470	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3.123	0.434	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.407	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.347	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.333	0.00 1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0.000	0.229	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.221	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.189	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.182	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0.002	0.142	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.131	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.109	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.102	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.102	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.060	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.043	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.042	0.00 1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.038	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.035	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.035	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.035	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.024	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.023	0.00 1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.017	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.015	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.014	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.008	0.00 1.00
1 B 2 c I Oil	Liquid Fuels	CH4	0.002	0.004	0.00 1.00
1 A 3 c Railways	Solid Fuels	N2O	0.009	0.002	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0.008	0.001	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.000	0.00 1.00
1 A 3 c Railways	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 a Iron and Steel	Biomass	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0.000	0.000	0.00 1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0.000	0.000	0.00 1.00

## Analysis

1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0.000	0.000	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1997)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1997		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	10684	0.16	0.16
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	7649	0.11	0.27
1 A 3 b Road Transportation	Gasoline	CO2	4622	6351	0.09	0.36
1 A 2 f Other	Liquid Fuels	CO2	3349	4834	0.07	0.44
2 A 1 Cement Production	Production Quantities	CO2	3107	3483	0.05	0.49
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	3114	0.05	0.53
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2419	0.04	0.57
1 A 4 b Residential	Liquid Fuels	CO2	1630	2027	0.03	0.60
1 A 2 f Other	Solid Fuels	CO2	2146	1654	0.02	0.62
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1601	0.02	0.65
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	1541	0.02	0.67
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1539	0.02	0.69
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1501	0.02	0.71
2 B 1 Ammonia Production	Production Quantities	CO2	569	1433	0.02	0.74
4 B 8 Swine	Population size	CH4	1489	1335	0.02	0.76
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1261	0.02	0.77
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	1108	0.02	0.79
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1099	0.02	0.81
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	987	0.01	0.82
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	983	0.01	0.84
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	930	0.01	0.85
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	914	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	760	0.01	0.87
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	641	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	615	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	574	0.01	0.90
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	545	0.01	0.91
4 D 2 Animal Production	Input to soils	N2O	544	513	0.01	0.92
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	445	0.01	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	316	0.00	0.93
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.93
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	304	0.00	0.94
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	292	0.00	0.94
4 C 1 Irrigated	Culture Surface	CH4	256	216	0.00	0.94
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.95
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	181	0.00	0.95
1 A 3 b Road Transportation	Diesel Oil	N2O	100	175	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	161	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	154	0.00	0.96
1 A 3 b Road Transportation	Gasoline	N2O	33	150	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	149	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	147	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	122	0.00	0.97
1 B 2 c i Oil	Liquid Fuels	CO2	49	102	0.00	0.97
1 A 2 f Other	Gaseous Fuels	CO2	0	102	0.00	0.97
1 A 2 c Chemicals	Other Fuels	CO2	63	90	0.00	0.97
4 A 4 Goats	Population size	CH4	90	82	0.00	0.97
3 D OTHER	Other Use of Chemicals	CO2	80	82	0.00	0.98
4 A 8 Swine	Population size	CH4	84	74	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	72	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	71	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	67	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.98
1 A 3 d ii National navigation	Residual Oil	CO2	44	64	0.00	0.98
5 E OTHER	Wildfires	CH4	441	64	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	63	0.00	0.98
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	56	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	55	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	53	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	51	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	50	0.00	0.99
1 A 3 b Road Transportation	Natural Gas	CO2	0	48	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	41	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	40	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	40	0.00	0.99
1 B 1 b Non-Dairy Cattle	Population size	CH4	38	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	33	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	27	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	27	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	26	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	26	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	22	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	21	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	19	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	19	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	18	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	17	0.00	0.99
1 A 2 f Other	Liquid Fuels	N2O	11	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	16	0.00	1.00
4 A 6 Horses	Population size	CH4	14	14	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	14	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	14	0.00	1.00

Analysis					
4 A 7 Mules and Asses	Population size	CH4	24	14	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	13	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	13	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	11	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00 1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	10	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	8	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	8	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO2	0	7	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00 1.00
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH4	0	6	0.00 1.00
5 E OTHER	Wildfires	N2O	45	6	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	5	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	5	0.00 1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	5	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
1 A 2 f Other	Solid Fuels	N2O	5	4	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	3	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	3	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	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 a ii Domestic	Jet Kerosene	N2O	2	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	2	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00 1.00
1 A 4 b Residential	Gaseous Fuels	CO2	0	2	0.00 1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	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 2 f Other	Solid Fuels	CH4	2	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 3 a ii Domestic	Aviation Gasoline	CO2	1	1	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	1	0.00 1.00
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	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 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	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 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00 1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	1	0.00 1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	1	0.00 1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	1	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00 1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0.000	0.433	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.416	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.411	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.333	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.331	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.275	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0.000	0.217	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.212	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.199	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.149	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.123	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.102	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.099	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0.000	0.099	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.088	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0.000	0.056	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.046	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.042	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.041	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.039	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.036	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.024	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.020	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.018	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.017	0.00 1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.014	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.010	0.00 1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0.000	0.007	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.007	0.00 1.00
1 B 2 c I Oil	Liquid Fuels	CH4	0.002	0.005	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.004	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.002	0.00 1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0.000	0.002	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0.000	0.002	0.00 1.00

## Analysis

1 A 2 a Iron and Steel	Other Fuels	N2O	0.008	0.002	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0.003	0.001	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0.000	0.000	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.000	0.00	1.00

## Tier 1 Level Assessment (1998)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1998		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	9819	0.14	0.14
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	8881	0.12	0.26
1 A 3 b Road Transportation	Gasoline	CO2	4622	6552	0.09	0.35
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	5633	0.08	0.43
1 A 2 f Other	Liquid Fuels	CO2	3349	4536	0.06	0.49
2 A 1 Cement Production	Production Quantities	CO2	3107	3458	0.05	0.54
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2494	0.03	0.57
1 A 4 b Residential	Liquid Fuels	CO2	1630	2133	0.03	0.60
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	1963	0.03	0.63
2 B 1 Ammonia Production	Production Quantities	CO2	569	1789	0.02	0.65
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1581	0.02	0.67
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1530	0.02	0.69
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1456	0.02	0.72
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1327	0.02	0.73
4 B 8 Swine	Population size	CH4	1489	1318	0.02	0.75
1 A 2 f Other	Solid Fuels	CO2	2146	1189	0.02	0.77
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1145	0.02	0.78
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	1120	0.02	0.80
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	1002	0.01	0.81
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	944	0.01	0.83
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	938	0.01	0.84
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	919	0.01	0.85
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	835	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	746	0.01	0.87
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	602	0.01	0.88
4 A 3 Sheep	Population size	CH4	564	591	0.01	0.89
4 D 2 Animal Production	Input to soils	N2O	544	514	0.01	0.90
1 A 2 f Other	Gaseous Fuels	CO2	0	491	0.01	0.90
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	487	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	448	0.01	0.92
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	418	0.01	0.92
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	338	0.00	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	335	0.00	0.93
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	330	0.00	0.94
5 E OTHER	Wildfires	CH4	441	318	0.00	0.94
1 A 4 b Residential	Biomass	CH4	343	306	0.00	0.94
1 A 3 b Road Transportation	Diesel Oil	N2O	100	210	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.95
4 C 1 Irrigated	Culture Surface	CH4	256	204	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	193	0.00	0.96
1 A 3 b Road Transportation	Gasoline	N2O	33	171	0.00	0.96
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	143	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	138	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	131	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	124	0.00	0.97
1 A 2 c Chemicals	Other Fuels	CO2	63	118	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	110	0.00	0.97
1 B 2 c i Oil	Liquid Fuels	CO2	49	99	0.00	0.97
2 B 5 Carbon black	Production Quantities	CO2	51	90	0.00	0.97
4 A 4 Goats	Population size	CH4	90	84	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	82	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	76	0.00	0.98
4 A 8 Swine	Population size	CH4	84	74	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	72	0.00	0.98
1 A 3 b Road Transportation	Gasoline	CH4	51	65	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.98
1 A 3 d ii National navigation	Residual Oil	CO2	44	61	0.00	0.98
1 A 2 f Other	Biomass	CH4	29	56	0.00	0.98
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH4	0	56	0.00	0.98
1 A 3 b Road Transportation	Natural Gas	CO2	0	55	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	55	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	53	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	46	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	44	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	44	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	42	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	36	0.00	0.99
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	33	0.00	0.99
5 E OTHER	Wildfires	N2O	45	32	0.00	0.99
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	32	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO2	0	30	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	28	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	27	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	26	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	23	0.00	0.99
1 A 4 b Residential	Gaseous Fuels	CO2	0	22	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	22	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	22	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	21	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	20	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	20	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00	0.99
1 B 2 a iii Transport	Liquid Fuels	CH4	13	17	0.00	1.00

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis					
4 F 5 Other	Residues Burning	CH4	16	16	0.00 1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	15	0.00 1.00
4 A 6 Horses	Population size	CH4	14	15	0.00 1.00
1 A 2 f Other	Other Fuels	CO2	20	15	0.00 1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	15	0.00 1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	15	0.00 1.00
1 A 2 f Other	Liquid Fuels	N2O	11	14	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	14	0.00 1.00
4 A 7 Mules and Asses	Population size	CH4	24	13	0.00 1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00 1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	10	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00 1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	9	0.00 1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	9	0.00 1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	9	0.00 1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00 1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	6	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	6	0.00 1.00
2 B 5 Carbon black	Production Quantities	CH4	3	6	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00 1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	5	0.00 1.00
4 B 7 Mules and Asses	Population size	CH4	9	5	0.00 1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00 1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	4	0.00 1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	4	0.00 1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00 1.00
4 A 10 Other	Population size	CH4	4	4	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00 1.00
4 B 6 Horses	Population size	CH4	3	3	0.00 1.00
4 B 4 Goats	Population size	CH4	3	3	0.00 1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00 1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00 1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00 1.00
1 A 2 f Other	Solid Fuels	N2O	5	3	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	2	0.00 1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00 1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00 1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	2	0.00 1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00 1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	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 2 f Other	Solid Fuels	CH4	2	2	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	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 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	1	0.00 1.00
1 A 2 c Chemicals	Biomass	N2O	1	1	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	1	0.00 1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00 1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	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 c Chemicals	Other Fuels	N2O	0	1	0.00 1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0.349	0.480	0.00 1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.456	0.00 1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0.000	0.438	0.00 1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00 1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.374	0.00 1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.334	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0.000	0.323	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.288	0.00 1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0.000	0.275	0.00 1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0.000	0.245	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0.000	0.235	0.00 1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.218	0.00 1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.197	0.00 1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0.000	0.170	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.163	0.00 1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.141	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.113	0.00 1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.093	0.00 1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.074	0.00 1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.055	0.00 1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.055	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.047	0.00 1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.043	0.00 1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.033	0.00 1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.031	0.00 1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.026	0.00 1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.023	0.00 1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.022	0.00 1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.021	0.00 1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0.000	0.021	0.00 1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.020	0.00 1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.019	0.00 1.00

## Analysis

1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.017	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.016	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.016	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0.000	0.014	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0.000	0.012	0.00	1.00



## Tier 1 Level Assessment (1999)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 1999		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	12530	0.16	0.16
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	9565	0.12	0.28
1 A 3 b Road Transportation	Gasoline	CO2	4622	6614	0.08	0.36
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	5713	0.07	0.43
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3944	0.05	0.48
1 A 2 f Other	Liquid Fuels	CO2	3349	3769	0.05	0.53
2 A 1 Cement Production	Production Quantities	CO2	3107	3742	0.05	0.58
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2589	0.03	0.61
1 A 4 b Residential	Liquid Fuels	CO2	1630	2240	0.03	0.64
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	2143	0.03	0.66
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1633	0.02	0.68
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1586	0.02	0.70
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1581	0.02	0.72
4 B 8 Swine	Population size	CH4	1489	1323	0.02	0.74
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1306	0.02	0.76
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1137	0.01	0.77
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	1073	0.01	0.78
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	1072	0.01	0.80
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	1004	0.01	0.81
1 A 2 f Other	Gaseous Fuels	CO2	0	998	0.01	0.82
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	990	0.01	0.84
1 A 2 f Other	Solid Fuels	CO2	2146	976	0.01	0.85
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	943	0.01	0.86
2 B 1 Ammonia Production	Production Quantities	CO2	569	843	0.01	0.87
4 A 1 a Dairy Cattle	Population size	CH4	846	750	0.01	0.88
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	747	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	602	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	588	0.01	0.90
4 D 2 Animal Production	Input to soils	N2O	544	540	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	506	0.01	0.92
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	404	0.01	0.92
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	369	0.00	0.93
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	368	0.00	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	348	0.00	0.94
1 A 4 b Residential	Biomass	CH4	343	302	0.00	0.94
1 A 3 b Road Transportation	Diesel Oil	N2O	100	232	0.00	0.94
2 A 7 Other	Production Quantities	CO2	97	211	0.00	0.94
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.95
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH4	0	202	0.00	0.95
4 C 1 Irrigated	Culture Surface	CH4	256	191	0.00	0.95
1 A 3 b Road Transportation	Gasoline	N2O	33	189	0.00	0.96
5 E OTHER	Wildfires	CH4	441	172	0.00	0.96
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	167	0.00	0.96
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	144	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	141	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	175	136	0.00	0.97
1 A 2 c Chemicals	Other Fuels	CO2	63	134	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	125	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	116	0.00	0.97
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	104	0.00	0.97
1 A 3 d ii National navigation	Residual Oil	CO2	44	91	0.00	0.97
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	89	0.00	0.97
2 B 5 Carbon black	Production Quantities	CO2	51	87	0.00	0.98
1 A 4 b Residential	Gaseous Fuels	CO2	0	84	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	81	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	79	0.00	0.98
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	77	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	75	0.00	0.98
4 A 8 Swine	Population size	CH4	84	74	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	67	0.00	0.98
1 A 3 b Road Transportation	Natural Gas	CO2	0	67	0.00	0.98
4 A 4 Goats	Population size	CH4	90	66	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.99
1 A 3 b Road Transportation	Gasoline	CH4	51	62	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	61	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	58	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	57	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	45	53	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	45	0.00	0.99
1 B 2 c i Oil	Liquid Fuels	CO2	49	45	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	44	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO2	0	42	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	42	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	31	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	31	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	27	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	26	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	26	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	23	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	23	0.00	0.99
4 B 3 Sheep	Population size	CH4	19	20	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	19	0.00	0.99
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	19	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH4	0	18	0.00	0.99

# Portuguese National Inventory Report 2004

## Key Source Category

1 A 2 f Other	Liquid Fuels	CH4	15	18	0.00	1.00
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00	1.00
5 E OTHER	Wildfires	N2O	45	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	16	0.00	1.00
4 A 6 Horses	Population size	CH4	14	16	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	15	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	15	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	14	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	14	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	14	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	12	0.00	1.00
4 A 7 Mules and Asses	Population size	CH4	24	12	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00	1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	10	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	9	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	9	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	9	0.00	1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	8	0.00	1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	8	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	7	0.00	1.00
2 B 5 Carbon black	Production Quantities	CH4	3	6	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	6	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	5	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
4 B 7 Mules and Asses	Population size	CH4	9	4	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00	1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00	1.00
4 A 10 Other	Population size	CH4	4	4	0.00	1.00
4 B 6 Horses	Population size	CH4	3	3	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	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 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00	1.00
4 B 4 Goats	Population size	CH4	3	2	0.00	1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	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 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	2	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	1	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
4 F 1 Cereals	Residues Burning	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 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 c Chemicals	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.472	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.448	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.423	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0.038	0.412	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0.000	0.347	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.329	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0.000	0.327	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.252	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.194	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52.264	0.153	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.148	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0.000	0.147	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.145	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.144	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.141	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0.000	0.114	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.113	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.084	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0.000	0.079	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.063	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.054	0.00	1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.053	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.042	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0.000	0.040	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.035	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0.000	0.035	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.027	0.00	1.00

## Analysis

1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.026	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.024	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0.000	0.022	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.018	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0.033	0.018	0.00	1.00

## Tier 1 Level Assessment (2000)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO <sub>2</sub> eq.) 1990	Estimate (kton CO <sub>2</sub> eq.) 2000		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	7816	12138	0.15	0.15
1 A 3 b Road Transportation	Diesel Oil	CO <sub>2</sub>	4941	11002	0.14	0.30
1 A 3 b Road Transportation	Gasoline	CO <sub>2</sub>	4622	6721	0.09	0.38
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	6364	4612	0.06	0.44
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	3107	3723	0.05	0.49
1 A 2 f Other	Liquid Fuels	CO <sub>2</sub>	3349	3252	0.04	0.53
1 A 1 b Petroleum refining	Liquid Fuels	CO <sub>2</sub>	1929	2262	0.03	0.56
1 A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	1630	2215	0.03	0.59
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	0	2154	0.03	0.61
1 A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	751	2087	0.03	0.64
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	1675	1889	0.02	0.66
1 A 2 c Chemicals	Liquid Fuels	CO <sub>2</sub>	1324	1612	0.02	0.69
1 A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	0	1598	0.02	0.71
4 B 8 Swine	Population size	CH <sub>4</sub>	1489	1316	0.02	0.72
1 A 2 f Other	Solid Fuels	CO <sub>2</sub>	2146	1242	0.02	0.74
4 D 1 Direct Soil Emissions	Input to soils	N <sub>2</sub> O	1451	1171	0.01	0.75
6 A 3 Other	Industrial Waste Disposal on Land	CH <sub>4</sub>	1226	1122	0.01	0.77
4 D 3 Indirect Emissions	Input to soils	N <sub>2</sub> O	1229	1112	0.01	0.78
4 A 1 b Non-Dairy Cattle	Population size	CH <sub>4</sub>	980	1067	0.01	0.80
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N <sub>2</sub> O	917	996	0.01	0.81
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO <sub>2</sub>	744	991	0.01	0.82
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	761	977	0.01	0.83
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO <sub>2</sub>	828	940	0.01	0.85
2 B 1 Ammonia Production	Production Quantities	CO <sub>2</sub>	569	935	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH <sub>4</sub>	846	746	0.01	0.87
4 A 3 Sheep	Population size	CH <sub>4</sub>	564	601	0.01	0.87
1 A 2 a Iron and Steel	Solid Fuels	CO <sub>2</sub>	468	599	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	659	574	0.01	0.89
4 D 2 Animal Production	Input to soils	N <sub>2</sub> O	544	536	0.01	0.90
2 B 2 Nitric Acid Production	Production Quantities	N <sub>2</sub> O	567	435	0.01	0.90
1 A 3 a ii Domestic	Jet Kerosene	CO <sub>2</sub>	245	380	0.00	0.91
5 E OTHER	Wildfires	CH <sub>4</sub>	441	380	0.00	0.91
6 C WASTE INCINERATION	Waste Incinerated	CO <sub>2</sub>	10	361	0.00	0.92
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO <sub>2</sub>	39	358	0.00	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	N <sub>2</sub> O	287	351	0.00	0.93
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	103	346	0.00	0.93
1 A 4 b Residential	Biomass	CH <sub>4</sub>	343	301	0.00	0.93
1 A 3 b Road Transportation	Diesel Oil	N <sub>2</sub> O	100	275	0.00	0.94
2 A 7 Other	Production Quantities	CO <sub>2</sub>	97	224	0.00	0.94
1 A 2 c Chemicals	Solid Fuels	CO <sub>2</sub>	45	218	0.00	0.94
6 B 1 Industrial Wastewater	Wastewater	CH <sub>4</sub>	164	208	0.00	0.95
1 A 3 b Road Transportation	Gasoline	N <sub>2</sub> O	33	206	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	N <sub>2</sub> O	161	205	0.00	0.95
4 C 1 Irrigated	Culture Surface	CH <sub>4</sub>	256	180	0.00	0.95
1 A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	0	179	0.00	0.95
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH <sub>4</sub>	0	172	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N <sub>2</sub> O	151	170	0.00	0.96
1 A 2 a Iron and Steel	Liquid Fuels	CO <sub>2</sub>	166	147	0.00	0.96
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	0	146	0.00	0.96
1 A 3 d ii National navigation	Gas/Diesel Oil	CO <sub>2</sub>	433	143	0.00	0.96
1 A 2 c Chemicals	Other Fuels	CO <sub>2</sub>	63	137	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO <sub>2</sub>	175	134	0.00	0.97
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO <sub>2</sub>	0	133	0.00	0.97
1 A 2 c Chemicals	Gaseous Fuels	CO <sub>2</sub>	0	129	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO <sub>2</sub>	86	117	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO <sub>2</sub>	2	111	0.00	0.97
1 A 3 d ii National navigation	Residual Oil	CO <sub>2</sub>	44	110	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO <sub>2</sub>	0	101	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO <sub>2</sub>	51	90	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO <sub>2</sub>	45	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO <sub>2</sub>	80	80	0.00	0.98
2 C 1 Iron and Steel Production	Production Quantities	CO <sub>2</sub>	48	78	0.00	0.98
4 A 8 Swine	Population size	CH <sub>4</sub>	84	74	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO <sub>2</sub>	13	70	0.00	0.98
4 A 4 Goats	Population size	CH <sub>4</sub>	90	65	0.00	0.98
1 A 4 b Residential	Biomass	N <sub>2</sub> O	73	64	0.00	0.99
1 A 3 b Road Transportation	Natural Gas	CO <sub>2</sub>	0	62	0.00	0.99
1 A 2 f Other	Biomass	CH <sub>4</sub>	29	61	0.00	0.99
1 A 3 b Road Transportation	Gasoline	CH <sub>4</sub>	51	61	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO <sub>2</sub>	0	58	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N <sub>2</sub> O	36	56	0.00	0.99
4 B 9 Poultry	Population size	CH <sub>4</sub>	36	45	0.00	0.99
1 B 2 c i Oil	Liquid Fuels	CO <sub>2</sub>	49	43	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH <sub>4</sub>	38	42	0.00	0.99
5 E OTHER	Wildfires	N <sub>2</sub> O	45	39	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO <sub>2</sub>	0	36	0.00	0.99
4 F 5 Other	Residues Burning	N <sub>2</sub> O	34	33	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N <sub>2</sub> O	1	29	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO <sub>2</sub>	17	27	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH <sub>4</sub>	29	26	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH <sub>4</sub>	22	24	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO <sub>2</sub>	52	24	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH <sub>4</sub>	0	24	0.00	0.99
1 A 2 f Other	Biomass	N <sub>2</sub> O	21	23	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH <sub>4</sub>	19	23	0.00	0.99

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis						
4 B 3 Sheep	Population size	CH4	19	20	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	19	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	18	0.00	1.00
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	17	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	15	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	15	0.00	1.00
4 A 6 Horses	Population size	CH4	14	15	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	15	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	15	13	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	13	0.00	1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	12	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	12	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	12	0.00	1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	11	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	11	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	10	0.00	1.00
4 A 7 Mules and Asses	Population size	CH4	24	9	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	9	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	8	0.00	1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	7	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	6	0.00	1.00
2 B 5 Carbon black	Production Quantities	CH4	3	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00	1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00	1.00
4 B 7 Mules and Asses	Population size	CH4	9	4	0.00	1.00
4 A 10 Other	Population size	CH4	4	4	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
4 B 6 Horses	Population size	CH4	3	3	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	3	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	3	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
4 B 4 Goats	Population size	CH4	3	2	0.00	1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00	1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	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 3 a ii Domestic	Aviation Gasoline	CO2	1	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	2	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
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	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 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	1	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	Gaseous Fuels	N2O	0.000	0.450	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.436	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.429	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.398	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.396	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0.000	0.282	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0.000	0.274	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.217	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.201	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0.000	0.196	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.191	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.170	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0.000	0.167	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.165	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.108	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.099	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.081	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0.000	0.070	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.068	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.068	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0.000	0.066	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.064	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.061	0.00	1.00

## Analysis

2 B 5 Carbon black	Production Quantities	N2O	0.031	0.055	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0.000	0.053	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.046	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.040	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.030	0.00	1.00

## Tier 1 Level Assessment (2001)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO2 eq.) 1990	Estimate (kton CO2 eq.) 2001		
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	12261	0.16	0.16
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	11234	0.14	0.30
1 A 3 b Road Transportation	Gasoline	CO2	4622	6330	0.08	0.38
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	5231	0.07	0.45
2 A 1 Cement Production	Production Quantities	CO2	3107	3545	0.05	0.49
1 A 2 f Other	Liquid Fuels	CO2	3349	3189	0.04	0.53
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	2506	0.03	0.56
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	2415	0.03	0.59
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2404	0.03	0.62
1 A 4 b Residential	Liquid Fuels	CO2	1630	1968	0.03	0.65
1 A 2 f Other	Gaseous Fuels	CO2	0	1872	0.02	0.67
2 B 1 Ammonia Production	Production Quantities	CO2	569	1434	0.02	0.69
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1415	0.02	0.71
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1370	0.02	0.73
4 B 8 Swine	Population size	CH4	1489	1341	0.02	0.74
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1195	0.02	0.76
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1125	0.01	0.77
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	1075	0.01	0.79
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1023	0.01	0.80
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	1005	0.01	0.81
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	974	0.01	0.83
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	952	0.01	0.84
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	774	0.01	0.85
1 A 2 f Other	Solid Fuels	CO2	2146	770	0.01	0.86
4 A 1 a Dairy Cattle	Population size	CH4	846	710	0.01	0.87
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	582	0.01	0.87
4 A 3 Sheep	Population size	CH4	564	581	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	578	0.01	0.89
4 D 2 Animal Production	Input to soils	N2O	544	523	0.01	0.89
1 A 2 a Iron and Steel	Solid Fuels	CO2	468	517	0.01	0.90
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	439	0.01	0.91
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	430	0.01	0.91
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	373	0.00	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	354	0.00	0.92
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	350	0.00	0.93
1 A 3 b Road Transportation	Diesel Oil	N2O	100	313	0.00	0.93
1 A 4 b Residential	Biomass	CH4	343	302	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	276	0.00	0.94
5 E OTHER	Wildfires	CH4	441	251	0.00	0.94
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	249	0.00	0.94
2 A 7 Other	Production Quantities	CO2	97	236	0.00	0.95
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	213	0.00	0.95
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH4	0	212	0.00	0.95
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.95
1 A 3 b Road Transportation	Gasoline	N2O	33	207	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.96
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	200	0.00	0.96
4 C 1 Irrigated	Culture Surface	CH4	256	164	0.00	0.96
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	147	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	145	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	142	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	130	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	129	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	175	119	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	102	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO2	51	93	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	81	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	79	0.00	0.98
4 A 8 Swine	Population size	CH4	84	75	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	68	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.98
1 A 3 b Road Transportation	Natural Gas	CO2	0	60	0.00	0.98
4 A 4 Goats	Population size	CH4	90	59	0.00	0.98
1 A 2 c Chemicals	Solid Fuels	CO2	45	59	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	56	0.00	0.99
1 A 3 b Road Transportation	Gasoline	CH4	51	54	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	52	0.00	0.99
1 B 2 c i Oil	Liquid Fuels	CO2	49	52	0.00	0.99
4 B 9 Poultry	Population size	CH4	36	46	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	46	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	42	0.00	0.99
1 A 3 d ii National navigation	Residual Oil	CO2	44	36	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	33	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	32	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	29	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	26	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	26	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH4	0	26	0.00	0.99
5 E OTHER	Wildfires	N2O	45	25	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	24	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	24	0.00	0.99
1 A 2 f Other	Biomass	N2O	21	23	0.00	0.99
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	21	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO2	0	20	0.00	0.99

# Portuguese National Inventory Report 2004

## Key Source Category

Analysis						
4 B 3 Sheep	Population size	CH4	19	20	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	19	0.00	0.99
1 A 2 f Other	Other Fuels	CO2	20	19	0.00	1.00
4 B 10 Anaerobic	Animal Excretion	N2O	20	18	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	16	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	16	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	15	0.00	1.00
4 A 6 Horses	Population size	CH4	14	15	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	14	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	14	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	14	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	13	0.00	1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	12	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	15	12	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	11	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	10	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	26	9	0.00	1.00
4 A 7 Mules and Asses	Population size	CH4	24	8	0.00	1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	8	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	7	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00	1.00
2 B 5 Carbon black	Production Quantities	CH4	3	6	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
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00	1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00	1.00
4 A 10 Other	Population size	CH4	4	4	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	1.00
4 B 6 Horses	Population size	CH4	3	3	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00	1.00
4 B 7 Mules and Asses	Population size	CH4	9	3	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00	1.00
4 B 4 Goats	Population size	CH4	3	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	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
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	2	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	2	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	2	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 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	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
4 F 1 Cereals	Residues Burning	CH4	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	Other Fuels	CO2	3	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.429	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0.000	0.422	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.393	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.386	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.376	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0.000	0.353	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.304	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0.349	0.282	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0.000	0.258	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0.000	0.225	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.205	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.170	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0.000	0.153	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0.099	0.146	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.125	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.100	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0.000	0.096	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.095	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0.271	0.093	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0.000	0.087	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.077	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0.000	0.068	0.00	1.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.057	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.055	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0.000	0.051	0.00	1.00



## Analysis

1 A 2 f Other	Other Fuels	CH4	0.016	0.041	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.041	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.037	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.029	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.024	0.00	1.00

## Tier 1 Level Assessment (2002)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year	Current year	Level	Cumulative
			Estimate (kton CO <sub>2</sub> eq.) 1990	Estimate (kton CO <sub>2</sub> eq.) 2002		
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	7816	12448	0.15	0.15
1 A 3 b Road Transportation	Diesel Oil	CO <sub>2</sub>	4941	12425	0.15	0.30
1 A 3 b Road Transportation	Gasoline	CO <sub>2</sub>	4622	6633	0.08	0.38
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	6364	6565	0.08	0.46
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	0	3253	0.04	0.50
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	3107	3033	0.04	0.54
1 A 2 f Other	Liquid Fuels	CO <sub>2</sub>	3349	2985	0.04	0.58
1 A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	751	2552	0.03	0.61
1 A 1 b Petroleum refining	Liquid Fuels	CO <sub>2</sub>	1929	2517	0.03	0.64
1 A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	0	2063	0.03	0.66
1 A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	1630	1959	0.02	0.69
2 B 1 Ammonia Production	Production Quantities	CO <sub>2</sub>	569	1528	0.02	0.71
1 A 2 c Chemicals	Liquid Fuels	CO <sub>2</sub>	1324	1365	0.02	0.72
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	1675	1332	0.02	0.74
4 B 8 Swine	Population size	CH <sub>4</sub>	1489	1315	0.02	0.76
4 D 1 Direct Soil Emissions	Input to soils	N <sub>2</sub> O	1451	1195	0.01	0.77
4 D 3 Indirect Emissions	Input to soils	N <sub>2</sub> O	1229	1127	0.01	0.78
4 A 1 b Non-Dairy Cattle	Population size	CH <sub>4</sub>	980	1062	0.01	0.80
6 A 3 Other	Industrial Waste Disposal on Land	CH <sub>4</sub>	1226	1046	0.01	0.81
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N <sub>2</sub> O	917	1013	0.01	0.82
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO <sub>2</sub>	828	949	0.01	0.83
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	761	920	0.01	0.85
1 A 2 f Other	Solid Fuels	CO <sub>2</sub>	2146	727	0.01	0.85
4 A 1 a Dairy Cattle	Population size	CH <sub>4</sub>	846	716	0.01	0.86
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO <sub>2</sub>	744	699	0.01	0.87
2 B 2 Nitric Acid Production	Production Quantities	N <sub>2</sub> O	567	590	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	659	581	0.01	0.89
4 A 3 Sheep	Population size	CH <sub>4</sub>	564	581	0.01	0.89
4 D 2 Animal Production	Input to soils	N <sub>2</sub> O	544	519	0.01	0.90
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO <sub>2</sub>	0	488	0.01	0.90
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO <sub>2</sub>	39	433	0.01	0.91
6 C WASTE INCINERATION	Waste Incinerated	CO <sub>2</sub>	10	380	0.00	0.91
1 A 3 a ii Domestic	Jet Kerosene	CO <sub>2</sub>	245	375	0.00	0.92
5 E OTHER	Wildfires	CH <sub>4</sub>	441	361	0.00	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	N <sub>2</sub> O	287	356	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	0	345	0.00	0.93
1 A 3 b Road Transportation	Diesel Oil	N <sub>2</sub> O	100	324	0.00	0.94
1 A 4 b Residential	Biomass	CH <sub>4</sub>	343	302	0.00	0.94
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	0	277	0.00	0.94
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH <sub>4</sub>	103	275	0.00	0.95
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH <sub>4</sub>	0	254	0.00	0.95
2 A 7 Other	Production Quantities	CO <sub>2</sub>	97	231	0.00	0.95
1 A 3 b Road Transportation	Gasoline	N <sub>2</sub> O	33	228	0.00	0.96
1 A 2 c Chemicals	Gaseous Fuels	CO <sub>2</sub>	0	219	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH <sub>4</sub>	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N <sub>2</sub> O	161	205	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO <sub>2</sub>	0	180	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO <sub>2</sub>	2	179	0.00	0.97
4 C 1 Irrigated	Culture Surface	CH <sub>4</sub>	256	162	0.00	0.97
1 A 3 d ii National navigation	Gas/Diesel Oil	CO <sub>2</sub>	433	144	0.00	0.97
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO <sub>2</sub>	86	133	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO <sub>2</sub>	175	111	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N <sub>2</sub> O	151	108	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO <sub>2</sub>	166	108	0.00	0.98
2 B 5 Carbon black	Production Quantities	CO <sub>2</sub>	51	97	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO <sub>2</sub>	45	89	0.00	0.98
1 A 3 d ii National navigation	Residual Oil	CO <sub>2</sub>	44	81	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO <sub>2</sub>	80	81	0.00	0.98
4 A 8 Swine	Population size	CH <sub>4</sub>	84	74	0.00	0.98
2 A 3 Limestone and Dolomite Use	Production Quantities	CO <sub>2</sub>	13	72	0.00	0.98
1 A 4 b Residential	Biomass	N <sub>2</sub> O	73	64	0.00	0.98
1 A 2 a Iron and Steel	Gaseous Fuels	CO <sub>2</sub>	0	61	0.00	0.98
1 A 2 c Chemicals	Solid Fuels	CO <sub>2</sub>	45	59	0.00	0.99
1 A 3 b Road Transportation	Natural Gas	CO <sub>2</sub>	0	59	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N <sub>2</sub> O	36	58	0.00	0.99
1 A 2 f Other	Biomass	CH <sub>4</sub>	29	57	0.00	0.99
4 A 4 Goats	Population size	CH <sub>4</sub>	90	57	0.00	0.99
1 A 3 b Road Transportation	Gasoline	CH <sub>4</sub>	51	54	0.00	0.99
1 B 2 c i Oil	Liquid Fuels	CO <sub>2</sub>	49	53	0.00	0.99
4 B 9 Poultry	Population size	CH <sub>4</sub>	36	48	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO <sub>2</sub>	63	47	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH <sub>4</sub>	38	42	0.00	0.99
5 E OTHER	Wildfires	N <sub>2</sub> O	45	37	0.00	0.99
4 F 5 Other	Residues Burning	N <sub>2</sub> O	34	34	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N <sub>2</sub> O	1	31	0.00	0.99
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	31	0.00	0.99
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO <sub>2</sub>	17	28	0.00	0.99
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH <sub>4</sub>	22	28	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH <sub>4</sub>	0	25	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N <sub>2</sub> O	0	25	0.00	0.99
1 A 2 d Pulp, Paper and Print	Biomass	CH <sub>4</sub>	19	25	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH <sub>4</sub>	29	25	0.00	0.99
1 A 2 f Other	Biomass	N <sub>2</sub> O	21	23	0.00	0.99
1 A 2 f Other	Other Fuels	CO <sub>2</sub>	20	20	0.00	1.00
4 B 3 Sheep	Population size	CH <sub>4</sub>	19	20	0.00	1.00

# Portuguese National Inventory Report 2004

## Key Source Category

Activity	Key Source Category	Value	Value	Value	Value
2 F 2 Foam Blowing	Consumption	HFCs	0	19	0.00
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	17	0.00
4 F 5 Other	Residues Burning	CH4	16	17	0.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00
1 A 2 f Other	Gaseous Fuels	N2O	0	16	0.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00
4 A 6 Horses	Population size	CH4	14	16	0.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	15	0.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	14	0.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00
1 A 2 f Other	Liquid Fuels	CH4	15	12	0.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	12	0.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	11	0.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00
1 A 2 f Other	Liquid Fuels	N2O	11	9	0.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	8	0.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00
1 A 3 c Railways	Liquid Fuels	N2O	11	7	0.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00
4 A 7 Mules and Asses	Population size	CH4	24	7	0.00
2 B 5 Carbon black	Production Quantities	CH4	3	6	0.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	5	0.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	4	0.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	4	0.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00
4 A 10 Other	Population size	CH4	4	4	0.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00
4 B 6 Horses	Population size	CH4	3	3	0.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	3	0.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00
4 B 7 Mules and Asses	Population size	CH4	9	3	0.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	2	0.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00
4 B 4 Goats	Population size	CH4	3	2	0.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	2	0.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	2	0.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	2	0.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	2	0.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00
1 A 2 f Other	Solid Fuels	N2O	5	2	0.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	1	0.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	1	0.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00
1 A 2 f Other	Solid Fuels	CH4	2	1	0.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	1	0.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0.000	0.473	0.00
2 D 2 Food and Drink	Production Quantities	CO2	0.437	0.437	0.00
1 A 2 c Chemicals	Biomass	CH4	0.331	0.429	0.00
1 A 3 b Road Transportation	Natural Gas	CH4	0.000	0.376	0.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	0.545	0.372	0.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	0.502	0.355	0.00
1 A 4 b Residential	Gaseous Fuels	CH4	0.000	0.323	0.00
1 A 2 c Chemicals	Other Fuels	N2O	0.434	0.320	0.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0.000	0.302	0.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0.000	0.256	0.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	0.662	0.218	0.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0.000	0.175	0.00
1 A 3 c Railways	Liquid Fuels	CH4	0.249	0.159	0.00
1 A 2 c Chemicals	Solid Fuels	N2O	0.099	0.126	0.00
1 A 3 d ii National navigation	Residual Oil	CH4	0.068	0.126	0.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0.000	0.125	0.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0.000	0.115	0.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0.000	0.107	0.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0.000	0.094	0.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0.129	0.091	0.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0.000	0.061	0.00
2 B 5 Carbon black	Production Quantities	N2O	0.031	0.059	0.00
1 A 2 f Other	Other Fuels	N2O	0.043	0.044	0.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0.000	0.032	0.00
1 A 2 c Chemicals	Solid Fuels	CH4	0.023	0.029	0.00
1 A 2 f Other	Other Fuels	CH4	0.016	0.022	0.00
1 A 2 c Chemicals	Other Fuels	CH4	0.029	0.022	0.00
1 A 3 a ii Domestic	Aviation Gasoline	CH4	0.017	0.020	0.00

## Analysis

1 A 3 a ii Domestic	Aviation Gasoline	N2O	0.009	0.015	0.00	1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0.055	0.012	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0.046	0.011	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0.126	0.010	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0.133	0.010	0.00	1.00

Tables A-2.14 – Tier 1 Trend assessment: 1990-2002

## Tier 1 Trend Assessment (1990-2002)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2002	Trend Assess.	Contribution to Trend	Cumulative Total
1 A 3 b Road Transportation	Diesel Oil	CO2	4941	12425	0.05	0.15	0.15
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3253	0.03	0.09	0.24
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6364	6565	0.02	0.07	0.31
1 A 2 f Other	Solid Fuels	CO2	2146	727	0.02	0.06	0.37
1 A 2 f Other	Gaseous Fuels	CO2	0	2063	0.02	0.06	0.43
1 A 2 f Other	Liquid Fuels	CO2	3349	2985	0.01	0.05	0.48
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	751	2552	0.01	0.04	0.52
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7816	12448	0.01	0.04	0.56
2 A 1 Cement Production	Production Quantities	CO2	3107	3033	0.01	0.04	0.60
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1675	1332	0.01	0.03	0.62
4 D 1 Direct Soil Emissions	Input to soils	N2O	1451	1195	0.01	0.02	0.65
4 B 8 Swine	Population size	CH4	1489	1315	0.01	0.02	0.67
2 B 1 Ammonia Production	Production Quantities	CO2	569	1528	0.01	0.02	0.69
6 A 3 Other	Industrial Waste Disposal on Land	CH4	1226	1046	0.01	0.02	0.71
4 D 3 Indirect Emissions	Input to soils	N2O	1229	1127	0.01	0.02	0.72
1 A 2 c Chemicals	Liquid Fuels	CO2	1324	1365	0.00	0.01	0.74
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	488	0.00	0.01	0.75
4 A 1 a Dairy Cattle	Population size	CH4	846	716	0.00	0.01	0.77
1 A 3 d ii National navigation	Gas/Diesel Oil	CO2	433	144	0.00	0.01	0.78
1 B 2 a iv Refining/ Storage	Liquid Fuels	CO2	39	433	0.00	0.01	0.79
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	380	0.00	0.01	0.80
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	744	699	0.00	0.01	0.81
1 A 4 b Residential	Gaseous Fuels	CO2	0	345	0.00	0.01	0.82
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	659	581	0.00	0.01	0.83
1 A 4 b Residential	Liquid Fuels	CO2	1630	1959	0.00	0.01	0.84
4 A 1 b Non-Dairy Cattle	Population size	CH4	980	1062	0.00	0.01	0.85
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	277	0.00	0.01	0.85
4 B 12 Solid Storage and Dry Lot	Animal Excretion	N2O	917	1013	0.00	0.01	0.86
5 E OTHER	Wildfires	CH4	441	361	0.00	0.01	0.87
1 B 2 b ii Transmission/ Distribution	Gaseous Fuels	CH4	0	254	0.00	0.01	0.87
4 D 2 Animal Production	Input to soils	N2O	544	519	0.00	0.01	0.88
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	219	0.00	0.01	0.89
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	828	949	0.00	0.01	0.89
4 A 3 Sheep	Population size	CH4	564	581	0.00	0.01	0.90
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	590	0.00	0.01	0.91
4 C 1 Irrigated	Culture Surface	CH4	256	162	0.00	0.01	0.91
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1929	2517	0.00	0.01	0.92
1 A 3 b Road Transportation	Diesel Oil	N2O	100	324	0.00	0.01	0.92
1 A 3 b Road Transportation	Gasoline	N2O	33	228	0.00	0.01	0.93
1 A 4 b Residential	Biomass	CH4	343	302	0.00	0.01	0.93
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	180	0.00	0.00	0.94
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	179	0.00	0.00	0.94
6 A 2 Unmanaged Waste Disposal	Municipal Waste Disposal on Land	CH4	761	920	0.00	0.00	0.95
1 A 3 b Road Transportation	Gasoline	CO2	4622	6633	0.00	0.00	0.95
1 A 3 c Railways	Liquid Fuels	CO2	175	111	0.00	0.00	0.95
6 A 1 Managed Waste disposal	Municipal Waste Disposal on Land	CH4	103	275	0.00	0.00	0.96
1 A 2 a Iron and Steel	Liquid Fuels	CO2	166	108	0.00	0.00	0.96
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	108	0.00	0.00	0.96
2 A 7 Other	Production Quantities	CO2	97	231	0.00	0.00	0.97
4 A 4 Goats	Population size	CH4	90	57	0.00	0.00	0.97
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	52	4	0.00	0.00	0.97
2 C 1 Iron and Steel Production	Production Quantities	CO2	48	5	0.00	0.00	0.97
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	61	0.00	0.00	0.97
1 A 3 b Road Transportation	Natural Gas	CO2	0	59	0.00	0.00	0.97
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	13	72	0.00	0.00	0.98
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	287	356	0.00	0.00	0.98
4 A 8 Swine	Population size	CH4	84	74	0.00	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	47	0.00	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	81	0.00	0.00	0.98
1 A 3 a ii Domestic	Jet Kerosene	CO2	245	375	0.00	0.00	0.98
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	31	0.00	0.00	0.98
6 C WASTE INCINERATION	Waste Incinerated	N2O	1	31	0.00	0.00	0.98
4 A 7 Mules and Asses	Population size	CH4	24	7	0.00	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	45	89	0.00	0.00	0.99
5 E OTHER	Wildfires	N2O	45	37	0.00	0.00	0.99
2 B 5 Carbon black	Production Quantities	CO2	51	97	0.00	0.00	0.99
1 A 2 f Other	Gaseous Fuels	CH4	0	25	0.00	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	25	0.00	0.00	0.99
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.00	0.99
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.00	0.99
1 A 3 d ii National navigation	Residual Oil	CO2	44	81	0.00	0.00	0.99
2 F 2 Foam Blowing	Consumption	HFCs	0	19	0.00	0.00	0.99
1 A 3 b Road Transportation	Gasoline	CH4	51	54	0.00	0.00	0.99
4 B 1 a Dairy Cattle	Population size	CH4	29	25	0.00	0.00	0.99
1 A 2 f Other	Gaseous Fuels	N2O	0	16	0.00	0.00	0.99
1 A 2 f Other	Biomass	CH4	29	57	0.00	0.00	0.99
1 B 2 c i Oil	Liquid Fuels	CO2	49	53	0.00	0.00	0.99
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	14	0.00	0.00	0.99
4 F 5 Other	Residues Burning	N2O	34	34	0.00	0.00	0.99
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	133	0.00	0.00	0.99
4 B 1 b Non-Dairy Cattle	Population size	CH4	38	42	0.00	0.00	0.99
4 B 7 Mules and Asses	Population size	CH4	9	3	0.00	0.00	0.99
4 B 10 Anaerobic	Animal Excretion	N2O	20	17	0.00	0.00	0.99
1 A 2 f Other	Liquid Fuels	CH4	15	12	0.00	0.00	0.99

## Portuguese National Inventory Report 2004

## Key Source Category

Analysis						
1 A 3 c Railways	Liquid Fuels	N2O	11	7	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	11	0.00	1.00
4 B 3 Sheep	Population size	CH4	19	20	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	58	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	9	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	23	0.00	1.00
4 F 5 Other	Residues Burning	CH4	16	17	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00	1.00
4 B 11 Liquid Systems	Animal Excretion	N2O	9	8	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	2	0.00	1.00
1 B 2 a v Distribution of Oil Products	Liquid Fuels	CO2	17	28	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	8	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	45	59	0.00	1.00
1 A 3 b Road Transportation	Diesel Oil	CH4	6	12	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	4	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	N2O	3	1	0.00	1.00
4 A 6 Horses	Population size	CH4	14	16	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 B 2 a iv Refining/ Storage	Liquid Fuels	CH4	22	28	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
2 B 5 Etileno (Borealis)	Production Quantities	CH4	5	4	0.00	1.00
2 B 5 Etileno (Borealis)	Production Quantities	CO2	7	7	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
4 B 4 Goats	Population size	CH4	3	2	0.00	1.00
4 F 1 Cereals	Residues Burning	N2O	3	2	0.00	1.00
4 B 9 Poultry	Population size	CH4	36	48	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CH4	13	17	0.00	1.00
2 B 5 Carbon black	Production Quantities	CH4	3	6	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	N2O	0	2	0.00	1.00
1 B 2 a iii Transport	Liquid Fuels	CO2	12	15	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	Solid Fuels	CH4	2	1	0.00	1.00
2 B 5 Explosivos e Anid. Ftálico	Production Quantities	CO2	4	4	0.00	1.00
4 A 10 Other	Population size	CH4	4	4	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	1	0.00	1.00
4 F 1 Cereals	Residues Burning	CH4	1	1	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
2 B 5 Produção de Monómeros e Polímeros Orgânicos	Production Quantities	CO2	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
4 B 6 Horses	Population size	CH4	3	3	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	1	0.00	1.00
1 A 3 d ii National navigation	Gas/Diesel Oil	CH4	1	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	N2O	2	3	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00	1.00
1 A 3 a ii Domestic	Jet Kerosene	CH4	1	0	0.00	1.00
1 A 3 b Road Transportation	Natural Gas	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 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	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	Biomass	N2O	1	2	0.00	1.00
1 A 3 d ii National navigation	Residual Oil	N2O	0	1	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous 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 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 a ii Domestic	Aviation Gasoline	CO2	1	2	0.00	1.00
2 B 5 Ammonium sulphate	Production Quantities	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	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 2 c Chemicals	Biomass	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 3 d ii National navigation	Residual Oil	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other 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 Carbon black	Production Quantities	N2O	0	0	0.00	1.00

## Analysis

1 A 2 c Chemicals	Solid Fuels	N2O	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 a Iron and Steel	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 c Chemicals	Solid Fuels	CH4	0	0	0.00	0.00	1.00