



**Instituto do Ambiente**

MINISTÉRIO DO AMBIENTE, DO ORDENAMENTO DO TERRITÓRIO  
E DO DESENVOLVIMENTO REGIONAL

**PORTUGUESE NATIONAL INVENTORY REPORT  
ON GREENHOUSE GASES, 1990 - 2003**

Submitted under the United Nations Framework Convention on  
Climate Change

*Vitor Gois Ferreira, Teresa Costa Pereira  
Pedro Torres, Tiago Seabra*

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## **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 2005 NIR report refers to the 2005 Portuguese Submission on GHG data (CRF tables) sent to the UNFCCC in April 2005 and replaces previous submissions.

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

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## 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 2005 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 issues that need to be improved and work is ongoing.

Since last submission, the Portuguese inventory has suffered some amendments and improvements, most of them performed to accommodate the recommendations issued from the in-depth review realised in September last year.

Major improvements refer to the application of QA/QC procedures and the development of a QA/QC plan, and the uncertainties quantification whose results are included for the first time in this report. The work undertaken to establish the National System, which has resulted in the formal adoption by the Council of Ministers in January 2005 of a legal resolution defining the "National System", includes the annual elaboration of a Methodological Development Programme (PDM). A first PDM has been developed in cooperation with the different sectors reflecting, in some cases, the proposals of the intra-sectoral auditing of the national inventory.

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 1990-2003.

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>) and Heavy Metals. The NIR covers also biogenic NMVOC emissions resulting from vegetation foliage, which emissions are also not included in UNFCCC emission reporting.

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

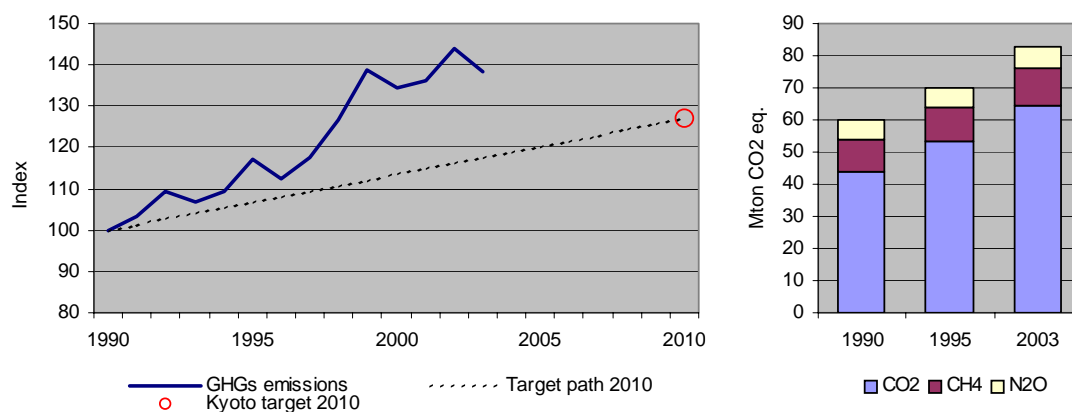
Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for all years in the period from 1990 to 2003, i.e., the inventory is internally consistent.

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

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

In 2003, total Portuguese GHG emissions without CO<sub>2</sub> from land-use change and forestry (LUCF) were estimated about 82.9 Mton CO<sub>2</sub>eq., representing an increase of 38.5% 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 1990-2003 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2003, 20.9 % above this target path (Figure ES. 1).

Figure ES. 1 – GHG emissions (without CO<sub>2</sub> from LUCF)



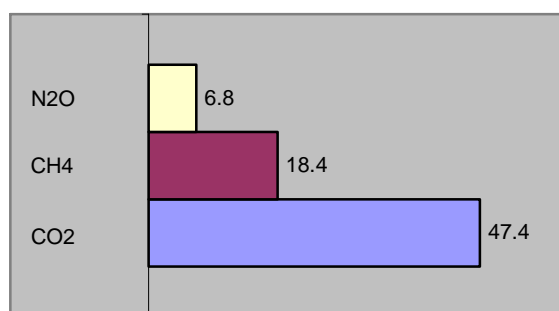
Despite the positive effect in emissions levels of some measures, such as the introduction of natural gas (1997), the new combined cycle thermoelectric unit of natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial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

The principal source of GHGs in Portugal is associated with the energy sector and is primarily related to fossil fuel combustion. The largest gas emitted is CO<sub>2</sub> which represented in 2003 77.6% of total GHGs emissions in global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for 70% of total CO<sub>2</sub> emissions in the same year.

Energy-related CO<sub>2</sub> emissions are dependent on the type of fuel and its carbon intensity. In average, during the period considered, 84% of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas); the percentage of renewable energy represents the remaining part, i.e. 16% in average, which refer to domestic sources.

Figure ES. 2 illustrates the growth of GHG in the period 1990-2003. CO<sub>2</sub> is the gas having registered the biggest increase (47.4%). Portugal has chosen 1995 as the base year for fluorinated gases. However, F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2003: 0.08%).

Figure ES. 2– Increase of emissions by gas over the 1990-2003 period



The overall trend for direct GHG emissions in the 1990-2003 period are presented in Table ES. 1.

Table ES. 1 – GHG emissions and removals in Portugal by gas: 1990-2003

GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO <sub>2</sub> equivalent (Gg)														
Net CO <sub>2</sub> emissions/removals	49,185	49,738	52,563	50,890	51,090	54,051	50,260	53,344	56,948	64,332	62,358	63,806	67,239	69,623
CO <sub>2</sub> emissions (without LUCF)	43,612	45,415	49,517	48,122	49,256	53,176	50,280	53,451	58,054	64,767	63,609	64,687	68,844	64,293
CH <sub>4</sub>	10,184	10,573	10,196	10,198	10,404	10,914	10,839	10,963	11,527	11,771	10,821	10,485	10,830	12,063
N <sub>2</sub> O	6,064	5,966	5,765	5,633	5,847	6,050	6,163	6,090	6,112	6,403	6,107	6,315	6,374	6,478
HFCs	0	0	0	0	0	0	0	1	6	12	24	37	49.05	62.17
PFCs	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
SF <sub>6</sub>	0	0	0	0	0	5	5	5	5	6	6	7	7.00	7.47
Total (with net CO <sub>2</sub> emis./removals)	65,433	66,278	68,524	66,721	67,341	71,019	67,268	70,402	74,598	82,524	79,316	80,649	84,499	88,233
Total (without CO <sub>2</sub> from LUCF)	59,860	61,955	65,478	63,953	65,507	70,144	67,287	70,510	75,704	82,959	80,567	81,530	86,105	82,903

NE - not Estimated; NO - not occurring

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

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

Figure ES. 4 present direct GHG emissions by sector for 1990 and 2003, respectively. Emissions have risen in almost all these sectors. The exception was agriculture, where the emissions have declined.

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”.

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

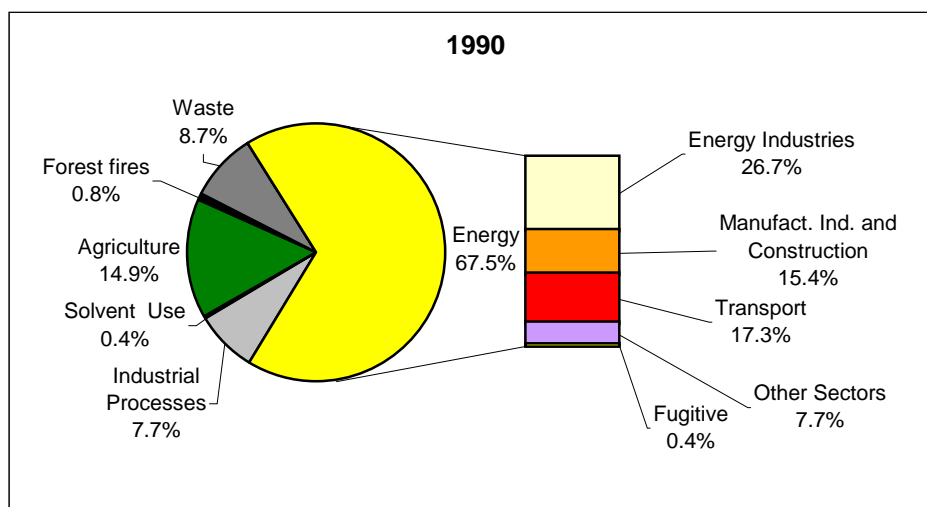
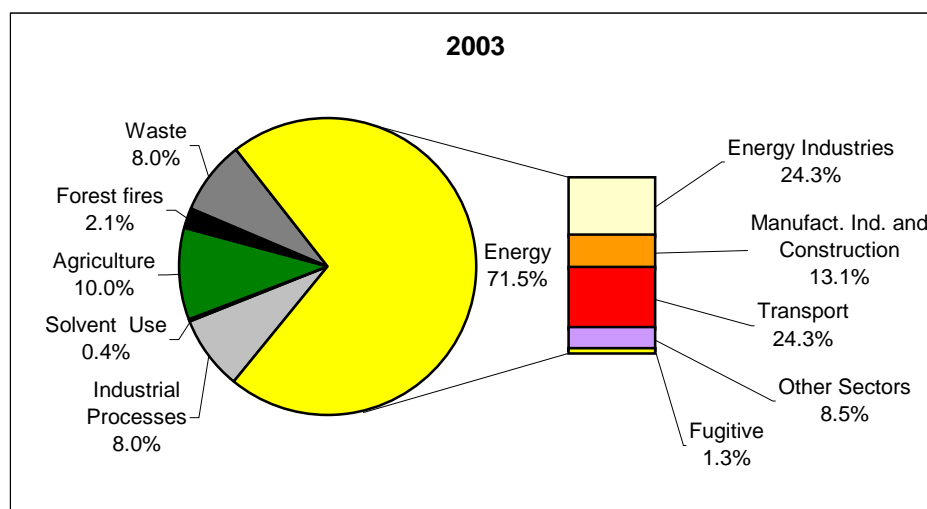


Figure ES. 4 – GHG emissions in Portugal by sector: 2003



Using this aggregated division, Energy was by far the most important sector, accounting for 71.5% of total emissions in 2003, and showing an increase of 47% over the 1990-2003 period. Energy industries and transport are the two most important sources representing each 24.3% of total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation (which continues to grow following the continued increase of electricity demand) and transport sources. Transportation sources, which are largely dominated by road traffic, are one of the sectors that are rising faster. In the period 1990-2003 these emissions increased 95%, due to the steady growth of vehicle fleets and road travel, in association with the increase in family income and the strong investment in road infrastructure of the country, that was done in the 90s decade. Indirectly the increase in road traffic activity also augments 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 in the analysed period (-7%). Industrial processes and Waste represent both 8% of Portuguese emissions in 2003, recording an

increase of approximately 44% (industrial processes) and 27% (waste). Solvent use represents less than 1% of total emissions, and is mainly related to NMVOC emissions<sup>1</sup>.

Estimates of emissions and sinks from land use change and forestry category, show 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. The situation has been reinversed in 2003, where this source appears as a net emitter (7.1 Mt CO<sub>2</sub> eq.), which is due to the exceptional occurrences in that year in what refers to the extension of the forest area burnt in wildfires.

Table ES. 2 presents the overall sectoral trend for direct GHG emissions in the 1990-2003 period.

Table ES. 2 – GHG emissions and removals in Portugal by sector: 1990-2003

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	CO <sub>2</sub> equivalent (Gg)													
1. Energy	40,401	42,195	46,519	45,111	45,618	48,904	46,312	48,824	53,070	60,506	58,999	59,804	63,682	59,270
2. Industrial Processes	4,614	4,578	4,338	4,202	5,008	5,755	5,498	6,169	6,397	6,067	5,903	6,395	6,771	6,641
3. Solvent and Other Product Use	220	234	243	236	253	256	275	285	290	285	290	304	312	318
4. Agriculture	8,920	8,755	8,492	8,392	8,477	8,428	8,540	8,474	8,627	8,514	8,402	8,397	8,334	8,295
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	7,076
6. Waste	5,220	5,427	5,644	5,866	6,068	6,267	6,475	6,688	6,971	7,397	6,554	6,353	6,608	6,633
7. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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

Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO<sub>x</sub>, and 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 ES. 3– Indirect GHG and SO<sub>x</sub> emissions: 1990-2003

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	(Gg)													
CO	1038.0	1151.9	979.8	919.4	870.2	1027.5	873.9	799.0	894.9	811.6	884.8	781.1	814.4	1306.0
NO <sub>x</sub>	259.8	276.0	289.8	280.6	279.2	292.8	283.0	276.7	286.5	297.6	293.0	289.0	296.5	290.7
NMVOC	274.0	288.8	285.1	275.6	281.8	293.5	287.5	286.5	293.3	280.7	279.5	277.9	282.3	316.0
SO <sub>2</sub>	322.9	313.3	374.6	320.9	299.3	334.7	273.7	293.7	342.8	343.8	307.4	294.6	293.8	201.8

In 2003 SO<sub>2</sub> emissions have decreased from 1990 levels: -37.5%. The other gases, CO, NMVOC and NO<sub>x</sub> emissions have increased, respectively, 25.8%; 15.3% and 11.9% (Table ES. 3).

Energy is the major responsible sector for emissions of NO<sub>x</sub>, SO<sub>x</sub> and CO. Its contribution for NMVOC emissions is also significant, together with Solvent use and Industrial processes.

Within energy, transportation is responsible for the greatest share of NO<sub>x</sub>, CO, and NMVOC emissions, respectively 38.1%, 21.4% and 11.7% of 2003 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 14.3% increase over the 1990-2003 period; NMVOC and CO recorded significant reductions, approximately -50% and -41%, respectively.

<sup>1</sup> These are converted into ultimate carbon dioxide after being emitted to atmosphere.



SO<sub>x</sub> emissions are mainly generated in the energy industry sector (61.8% of total emissions in 2003) and combustion in manufacturing industries (19.2% of total emissions in 2003), 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 1990-2003 shows a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries -38% and manufacturing industries -52.1%. 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 1997, is also another positive factor that has contributed to control of SO<sub>x</sub> emissions.

The registered decrease of SO<sub>x</sub> and NO<sub>x</sub> emissions from energy industries in 2003 has however been significantly influenced by the hydrologic year, characterised by higher precipitation and the considerable increase of hydroelectric power generation.

## 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 2005 national inventory submission of GHG. Inventory data in CRF format were already sent previously (April 2005) to the EC and UNFCCC.

It was also envisaged that this report should serve the reporting requirements under the UNECE/CLRTAP for the time being. In this way it 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 (IPCC, 1995) and latter of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), has result in substantial improvement of the methodologies that are used in the inventory, particularly for agriculture and wastes, and that were included at first time in the First National Communication in 1994. The inventory that resulted from CORINAIR90 (CEC,1992) and subsequent modifications from IPCC methodology still structures the present day methodology in what concerns activity data and methodology. Under the evaluation of the first communication the inventory was subjected to a review made by an international team. The second and third communications was also reviewed by international experts. These exercises had an important role in problem detection and contribute to overall improvement.

Since its first compilation, the Portuguese inventory 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);
- Bilateral meetings (IA/UE) for the revision of the National Emission Ceilings (NEC) (under preparation);
- Methodological Development Programme (PDM) under the implementation of the National Inventory System ;
- UNFCCC in-depth review (September/October 2004).

The report is structured generally in accordance with the UNFCCC Reporting Guidelines on Annual Inventories (SBSTA 2002).

## 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>, Particulate Matter and Heavy Metals.

Emissions are estimated for each civil year from 1990 to 2003. Emission estimates for 2003 are however preliminary for some source sectors and may suffer changes in next report when better information on activity data will be available.

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 GWP 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.

INVENTAR (InventAr, Estudos e Projectos Unip Lda), was contracted by the Institute for the Environment to organize the inventory and, in close collaboration with the team at Institute for the Environment, to perform emission estimates and to elaborate the National Inventory Report and the CRF and NFR tables. It also provides technical advice concerning all aspects of inventory development: methodologies, methodological improvements, sources of information and emission factors. It was responsible for the elaboration of the Uncertainty Analysis.

ECOPROGRESSO, Consultores em Ambiente e Desenvolvimento, was contracted by the Institute for the Environment to develop and implement the Quality Control (QC) tier 2.

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.

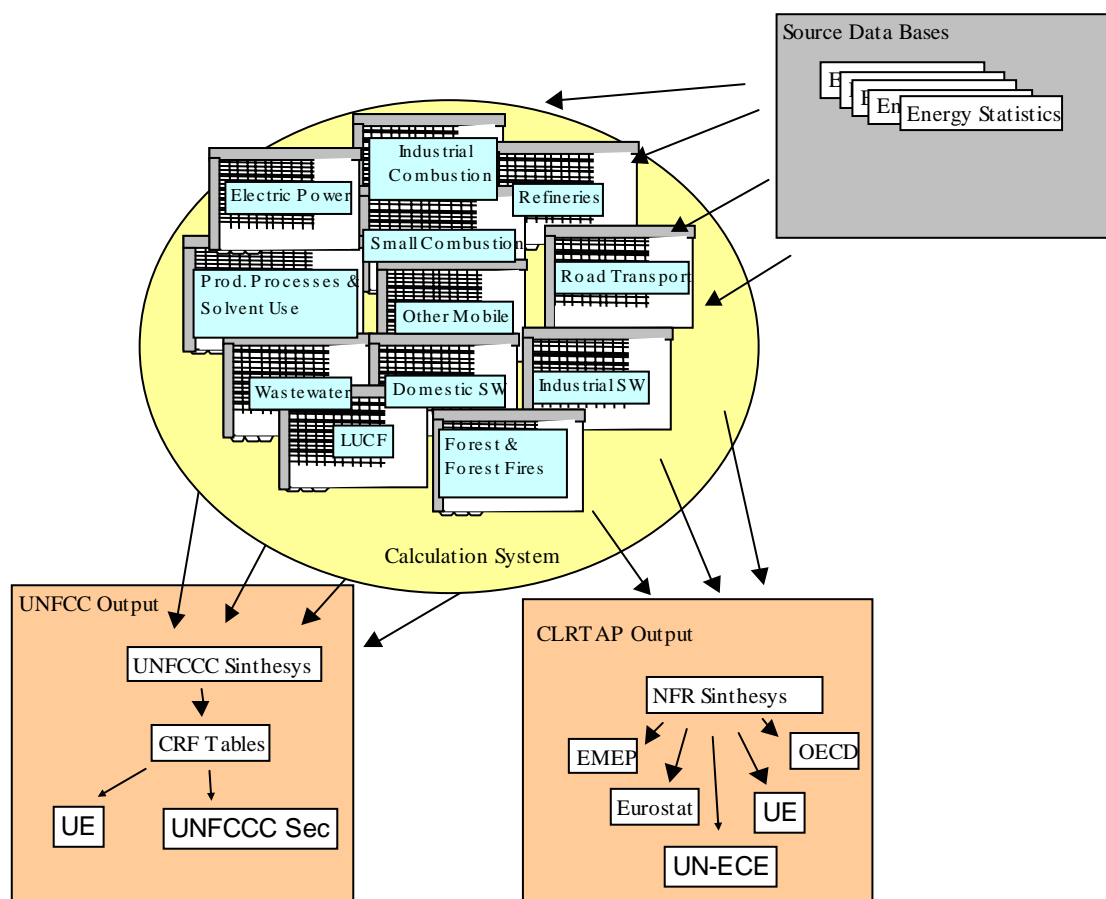
Table 1.2 – Inventory Institutional Arrangements and Data Sources

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 (DGT)</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); EU-NEC Directive; 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. Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003) has not yet been implemented for the compilation of the 2005 submission.

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

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

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		HFCs		PFCs		SF <sub>6</sub>	
	Meth. <sup>(1)</sup>	EF <sup>(2)</sup>	Meth. <sup>(1)</sup>	EF <sup>(2)</sup>	Meth. <sup>(1)</sup>	EF <sup>(2)</sup>	Meth. <sup>(1)</sup>	EF <sup>(2)</sup>	Meth. <sup>(1)</sup>	EF <sup>(2)</sup>	Meth. <sup>(1)</sup>	EF <sup>(2)</sup>
<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+CS	T2	D+C+CS						
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+CS	C+T2	D+C	C+T2							
<b>2. Industrial Processes</b>												
A. Mineral Products	D	D+C+CS	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+CS	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 2005 Portuguese inventory estimates (1990-2003) was conducted using a Tier 1 approach and a qualitative approach. Guidance from IPCC (2000) was followed.



The source category level adopted in previous submissions was revised in order to take account of the in-depth review recommendations. In a general way, the source categories have been split into (sub)categories that have been estimated using the same methodology and emission factors.

Level assessment was undertaken for all years; the trend assessment was performed for the 1990-2003 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 45 key sources that are listed in Table 1.4, which cover 97.3% of total GHG emissions in 2003.

Table 1.4 – Portuguese key source categories (1990-2003) based on Tier 1 approach

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Criteria for Identification	Comments	2003 emissions estimate (kton CO <sub>2</sub> eq.)
1A 3 b Road Transportation	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	6747
1A 1 a Public Electricity and Heat Production	Solid Fuels	CO <sub>2</sub>	Level Trend	All years	1648
1A 2 f Other	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	3991
2 A 1 Cement Production	Production Quantities	CO <sub>2</sub>	Level Trend	All years	3538
1A 1 a Public Electricity and Heat Production	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	3190
4 D AGRICULTURAL SOILS	Input to Soils	N <sub>2</sub> O	Level Trend	All years	3170
6 A MUNICIPAL SOLID WASTE DISPOSAL ON	SW Disposal on Land	CH <sub>4</sub>	Level Trend	All years	2969
1A 4 a Commercial / Institutional	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	2890
1A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO <sub>2</sub>	Level Trend	1998, 1999, 2000, 2001, 2002, 2003	2674
1A 1 b Petroleum refining	Liquid Fuels	CO <sub>2</sub>	Level	All years	2497
4 A ENTERIC FERMENTATION	Population size	CH <sub>4</sub>	Level Trend	All years	2493
1A 2 f Other	Gaseous Fuels	CO <sub>2</sub>	Level Trend	1998, 1999, 2000, 2001, 2002, 2003	2177
1A 4 b Residential	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	1903
6 A 3 Other	Industrial W. Disposal on Land	CH <sub>4</sub>	Level Trend	All years	1892
2 B 1 Ammonia Production	Production Quantities	CO <sub>2</sub>	Level Trend	All years	1622
5 E OTHER	Wildfires	CH <sub>4</sub>	Level Trend	1990, 1991, 1995, 2000, 2001, 2002, 2003	1585
4 B MANURE MANAGEMENT	Animal Excretion	CH <sub>4</sub>	Level Trend	All years	1388
1A 2 c Chemicals	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	1231
1A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	1068
4 B MANURE MANAGEMENT	Animal Excretion	N <sub>2</sub> O	Level Trend	All years	1032
1A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	893
1A 2 d Pulp, Paper and Print	Liquid Fuels	CO <sub>2</sub>	Level Trend	All years	632
6 B 2 Domestic and Commercial wastewater	Wastewater	CH <sub>4</sub>	Level Trend	All years	627
2 B 2 Nitric Acid Production	Production Quantities	N <sub>2</sub> O	Level Trend	All years	597
1A 2 f Other	Solid Fuels	CO <sub>2</sub>	Level Trend	All years	539
1A 3 b Road Transportation	Liquid Fuels	N <sub>2</sub> O	Level Trend	1997, 1998, 1999, 2000, 2001, 2002, 2003	518
1B 2 a Oil	Liquid Fuels	CO <sub>2</sub>	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003	503
2 A 2 Lime Production	Production Quantities	CO <sub>2</sub>	Level	1997, 1998, 1999, 2000, 2001, 2002, 2003	503
1A 3 a ii Domestic	Liquid Fuels	CO <sub>2</sub>	Level	1992, 1993, 1994, 1996, 1998, 1999, 2000, 2001, 2002, 2003	394
1A 4 b Residential	Gaseous Fuels	CO <sub>2</sub>	Level Trend	2001, 2002, 2003	371
1A 4 a Commercial / Institutional	Gaseous Fuels	CO <sub>2</sub>	Level Trend	2003	356
1A 2 c Chemicals	Gaseous Fuels	CO <sub>2</sub>	Level Trend	2003	354
6 B 2 Domestic and Commercial wastewater	Wastewater	N <sub>2</sub> O	Level	All years	354
6 C WASTE INCINERATION	Waste Incinerated	CO <sub>2</sub>	Level Trend	2000, 2001, 2002, 2003	350
1A 3 d ii National navigation	Liquid Fuels	CO <sub>2</sub>	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 2000, 2003	347
1A 2 d Pulp, Paper and Print	Gaseous Fuels	CO <sub>2</sub>	Trend		334
1A 4 b Residential	Biomass	CH <sub>4</sub>	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 2000, 2001	307
1A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO <sub>2</sub>	Trend		257
1B 2 b Natural gas	Gaseous Fuels	CH <sub>4</sub>	Trend		244
1B 2 d Other (Geothermal)	Energy Production	CO <sub>2</sub>	Trend		209
4 C RICE CULTIVATION	Culture Surface	CH <sub>4</sub>	Trend		159
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	Qual		40
2 F 2 Foam Blowing	Consumption	HFCs	Qual		22
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	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999	0
<b>Sub-Total</b>		All gases			<b>80624</b>
<b>% of Total</b>		All gases			<b>97.3</b>
<b>TOTAL EMISSIONS</b>		All gases			<b>82903</b>

## 1.6 Quality Assurance/ Quality Control (QA/QC)

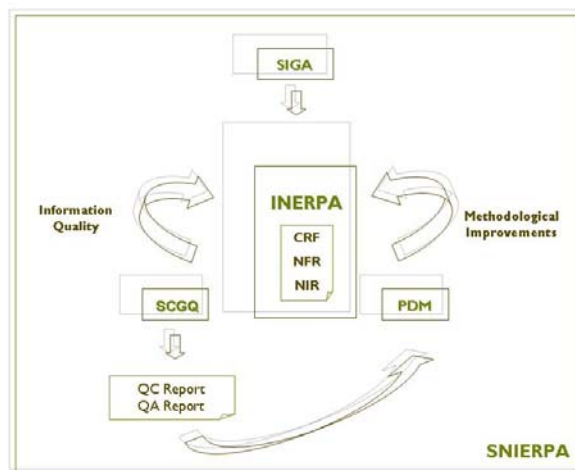
A Plan for Quality Assurance/ Quality Control (QA/QC) has been developed and applied to this year's submission. The Institute for the Environment is the national responsible entity for the Quality Assurance and Quality Control System of the inventory. The conceptualization of the system and the application of Quality Control tier2 procedures, have been however done under an external consultancy with Ecoprogesso.

The QA/QC system is an integral part of the National System for the Inventory of Emission by Sources and Removal by Sinks of Air Pollutants (SNIERPA), which was created by the March,

17th Resolution of the Council of Ministers nr. 68/2005, and includes three technical instruments (Figure 1.2):

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

Figure 1.2 – SNIERPA 's main elements relations



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

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

The quality control system requires the elaboration of a report of the application of QA/QC procedures to the inventory. QC tier 1 checks were generally applied by the inventory team who produces and compiles the national inventory. The conclusions of the Quality Control tier2 procedures – “Quality Control tier 2 procedures INERPA 2005 – final report” is available for consultation (Ecoprogresso,2005). This sub-section is a summary of this report.

## Methodology

In the 2005 submission, QC2 procedures were applied to the source categories listed in Table 1.5. In year 2003, the emission estimates associated with these source categories accounted for 49% of total national emissions excluding LULUCF (40 317 kt CO<sub>2</sub>e).

Table 1.5 - Key source categories subject to QC2 procedures

CRF code	Name
1 A 1 a	Public electricity and heat production
1 A 1 b	Petroleum refining
1 A 2 c	Chemicals
1 A 2 d	Pulp, paper and print
1 A 2 e	Food processing, beverages and tobacco
1 A 2 f	Other
1 A 4 a	Commercial/Institutional
1 A 4 b	Residential
1 B 2 b ii	Transmission/Distribution
2 B 1	Ammonia production
2 B 2	Nitric acid production
6 B 2	Domestic and commercial wastewater
6 B 3	Industrial wastewater
6 C	Waste incineration

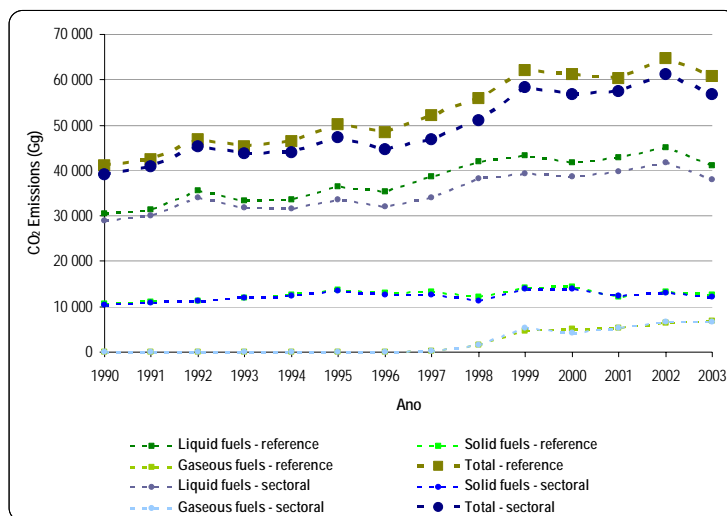
## Main results

The comparison between the results obtained by the application of different approaches was made for the energy combustion and wastewater handling. In the first case, the sectoral<sup>2</sup> and reference<sup>3</sup> approaches were compared and differences between the emissions estimates were noted. Figure 1.3 illustrates the discrepancies between the emissions estimates obtained by the application of both approaches. The global difference is, in great part, due to the existing discrepancies between liquid fuels estimations obtained by the application of the reference and the sectoral approach. On the other hand, the emission estimates of gaseous and solid fuels are similar when we compare the emissions estimates obtained using sectoral and reference approaches.

<sup>2</sup> Emission estimates are obtained based on data from the emission sources. These values are complemented with energy balance's information.

<sup>3</sup> Emission estimates are obtained based on national information, by fuel type. The source of the data is the annual energy balances.

Figure 1.3 - Emission estimates obtained applying reference and national approaches, by fuel type.



Concerning wastewater handling, the emissions estimates obtained using the check method are 35% and 43% higher than the ones obtained with the national approach, in 1990 and 2003 respectively (chapter 8.2.B.1 of the NIR). This could be justified due to existing disparities between the national calculated factors and the IPCC defaults.

Considering the application of QC2 procedures to activity data and more precisely in the energy sector, the elaboration of energy balances in energy units and in mass units wasn't applied because it was considered feasible.

The NCV/LHV used in the Portuguese inventory was compared with other values obtained from recognized sources and the national energy statistics and some differences were observed. This fact was verified in the case of the fugitive emissions associated with natural gas, more precisely in transmission/distribution activities.

Related to fuel consumption in the various sectors, some differences between the values used in the inventory and the energy balance were noted. This fact is illustrated for biomass and natural gas used in the residential sector.

The verification of national energy statistics with the ones submitted to international organizations was made in the sectors that were comparable (International Energy Agency and Eurostat) for the years 2000 and 2002. The divergences found may be due to different ways used to aggregate the values or to the use of different LHV.

The emission factors used in the inventory are mainly from IPCC Revised Guidelines (IPCC, 1997), IPCC Good Practice Guidance (IPCC, 2000), EMEP/CORINAIR Emission Inventory Guidebook – 3rd edition (EEA, 2002) e AP-42 (USEPA, 1996; USEPA, 1996b; USEPA, 1998; USEPA, 1998b; USEPA, 1998c). In cases where national emission factors were used, those were compared with other bibliographical references and other countries' values. There are some minor differences that should be related with particular circumstances and national variability.

In wastewater handling, the values used for BOD and Bo are IPCC defaults. On what concerns MCF, there are some differences between the Portuguese values and those reported by other countries.

For waste incineration, the carbon and fossil carbon content of waste (national figures) were compared with the IPCC defaults and were inside the proposed intervals.

## Conclusions

The differences between the emission estimates resulting from the application of the reference and the sectoral approach can have various reasons, mainly the fact that the sectoral approach uses data (fuel mass consumption and NCV/LHV) from Large Point Sources (LPS), which can be different from the ones reported to DGGE (Energy Agency). On the other hand, the reference approach is based on apparent consumption whereas the sectoral approach uses values related to the final consumption of energy. The statistical adjustments between apparent consumption and final consumption may originate some discrepancies, thus providing a possible explanation for the differences encountered.

On what concerns wastewater handling, the factors used in the check method are considered to be inadequate to the national reality of wastewater treatment systems.

The noted discrepancies between the consumptions from DGGE and the ones used in INERPA can be due to the use of LPS data. Furthermore, the differences between the national energy balance and the ones from international agencies can reflect different ways of aggregation among the various sectors or to the use of different LHV/NCV.

Finally, the emission factors differences can result from the national circumstances, the different tiers used in the emission estimates or the emission factors calculation.

## Further developments

Efforts are proposed to harmonize the differences between the reference and the sectoral approach.

In the next submission, the QC2 procedures will be applied to the remaining key sources, as well as to the ones previously analyzed but remain methodologically relevant.

## 1.7 Uncertainty Assessment

Emission estimates from the GHG inventory pretend to result in the best estimate of emissions, which should not be over-estimated neither under-estimated. Nevertheless, natural variability of certain emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameter due to errors in original monitoring data, reference studies and expert judgement, all this factors lead to a certain error or level of uncertainty in emission estimates. However, the main purpose of the realization of the uncertainty assessment is not to contest the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of future inventories and guide future methodological developments. The uncertainty Analysis tier 1 level have been done under an external consultancy with InventAr.

The uncertainty analysis was performed only for the direct GHG: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC and SF<sub>6</sub>, considering all emissions in CO<sub>2</sub> equivalent (CO<sub>2</sub>e). The uncertainty of all source activities was determined, with the exception of the source category IPCC 5.

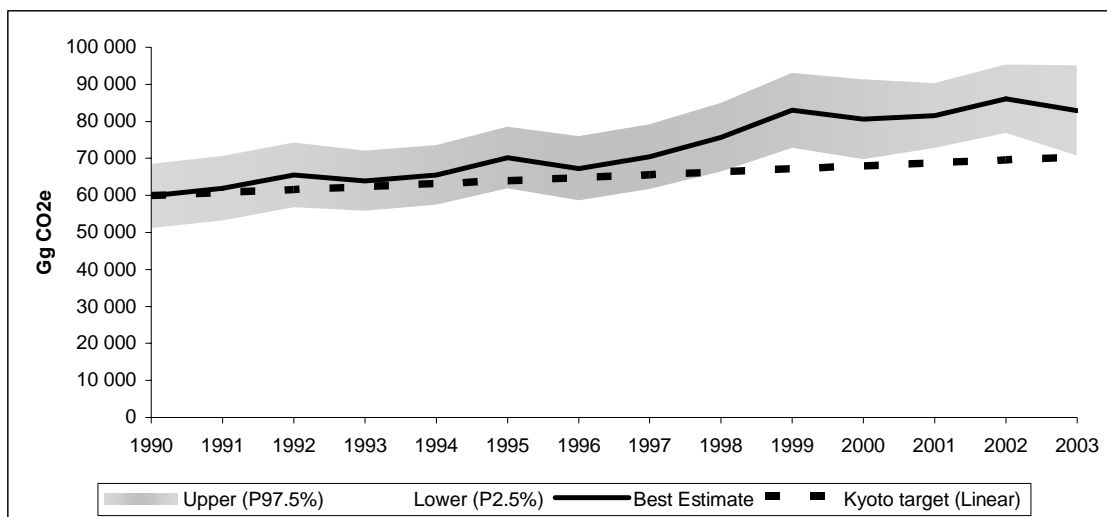
A tier 1 methodology was used to estimate total uncertainty for the inventory, for each individual year and also the uncertainty in trend. Basically this method of classical analysis, which is explained in more detail in IPCC(2000), attributes uncertainty values to activity data and emission factors,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

The uncertainty assessment was performed using inventory data for all years from 1990 to 2003. The results are presented in Table 1.6. The full range of emission possibilities, considering the confidence limit may be observable in Figure 1.4. The uncertainty in trend from 1990 to 2003 is 13.3%. Uncertainty values are defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

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

Year	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	F Gas	Total
	%				
1990	13.4	27.9	99.8	-	14.4
1991	13.1	34.1	97.9	-	14.0
1992	12.4	34.1	95.2	-	13.3
1993	10.9	34.2	98.2	-	12.6
1994	10.5	33.7	93.9	-	12.3
1995	10.0	33.7	91.0	-	11.8
1996	11.3	33.5	90.9	62	12.8
1997	11.1	33.3	88.5	186	12.3
1998	11.0	33.0	92.5	261	12.2
1999	11.8	32.5	85.2	450	12.1
2000	13.6	32.8	87.1	421	13.3
2001	9.7	29.0	84.7	456	10.7
2002	10.0	29.6	83.8	479	10.7
2003	15.3	30.2	91.9	491	14.7

Figure 1.4 – Trend of total GHG emissions without LULUCF and lower and upper estimates considering the 95% confidence interval



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

## 1.8 Overview of the completeness

Table 1.7 gives an overview of the level of completeness of the 2005 submitted inventories to the UNFCCC and EC.

## 1.9 Future developments

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

Table 1.7 – 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>A. Fuel Combustion Activities</b>																				
Reference Approach	All	H																		
Sectoral Approach																				
1. Energy Industries	All	H	All	L	All	L							All	M	All	M	All	M	All	H
2. Manufacturing Industries														M						
and Construction	All	H	All	L	All	L							All	M	All	M	All	M	All	H
3. Transport	All	H	All	M	All	M							All	M	All	M	All	M	All	H
4. Other Sectors	All	H	All	L	All	L							All	M	All	M	All	M	All	H
5. Other																				
<b>B. Fugitive Emissions from Fuels</b>																				
1. Solid Fuels	All	L	All	L	NE															
2. Oil and Natural Gas	Part	L	Part	L	NE								NE		NE		NE		NE	
<b>2 Industrial Processes</b>																				
A. Mineral Products	All	M																	All	M
B. Chemical Industry	All	M	All	L	All	M							All	M	Part	M	All	M	All	M
C. Metal Production	All	L	NE		NE				NO		NO		All	M	All	M	All	M	All	M
D. Other Production	All	L											All	H	All	M	All	M	All	H
<b>E. Production of Halocarbons and SF6</b>							NE		NE		NE									
<b>F. Consumption of Halocarbons and SF6</b>																				
Potential							NE				NE									
Actual							Part	L			All	M								
<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	L	Part	L							Part	L	Part	L	Part	L	Part	L
<b>5 Land-Use Change and Forestry</b>																				
A. Changes in Forest and Other Woody Biomass Stocks	Part	M																		
B. Forest and Grassland Conversion																				
C. Abandonment of Managed Lands	Part	M																		
D. CO2 Emissions and Removals from Soil	NE																			
E. Other	All	M	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/L	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>Memo Items:</b>																				
<b>International Bunkers</b>																				
Aviation	All	M	All	M	All	M							All	M	All	M	All	M	All	M
Marine	All	L	All	L	All	L							All	L	All	L	All	L	All	L
<b>Multilateral Operations</b>	NO		NO		NO															
<b>CO2 Emissions from Biomass</b>	All	H																		

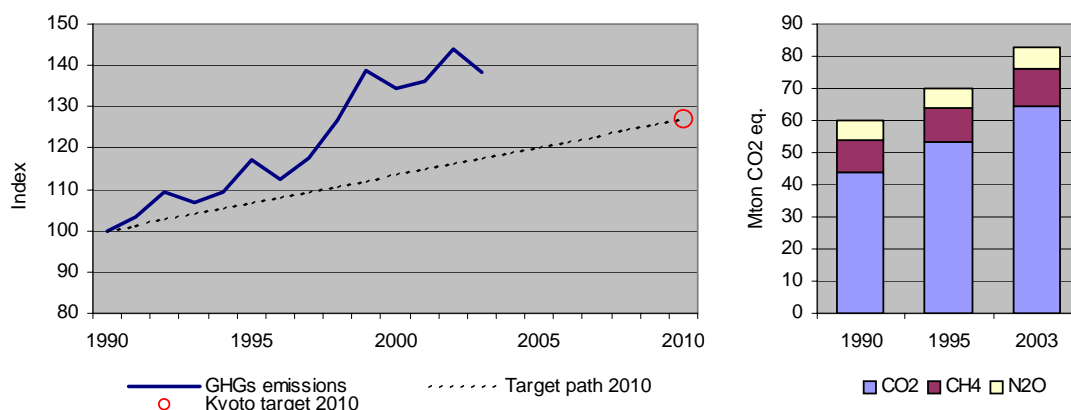


## CHAPTER: 2 TRENDS IN PORTUGUESE GHG EMISSIONS

### 2.1 Trends of Total Emissions

In 2003, total Portuguese GHG emissions without CO<sub>2</sub> from land-use change and forestry (LUCF) were estimated about 82.9 Mton CO<sub>2</sub>eq., representing an increase of 38.5% 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 1990-2003 growth with the linear target path from 1990 to 2010, Portuguese GHG emissions were, in 2003, 20.9 % above this target path.

Figure 2.1– GHG emissions (CO<sub>2</sub> from LUCF excl.)



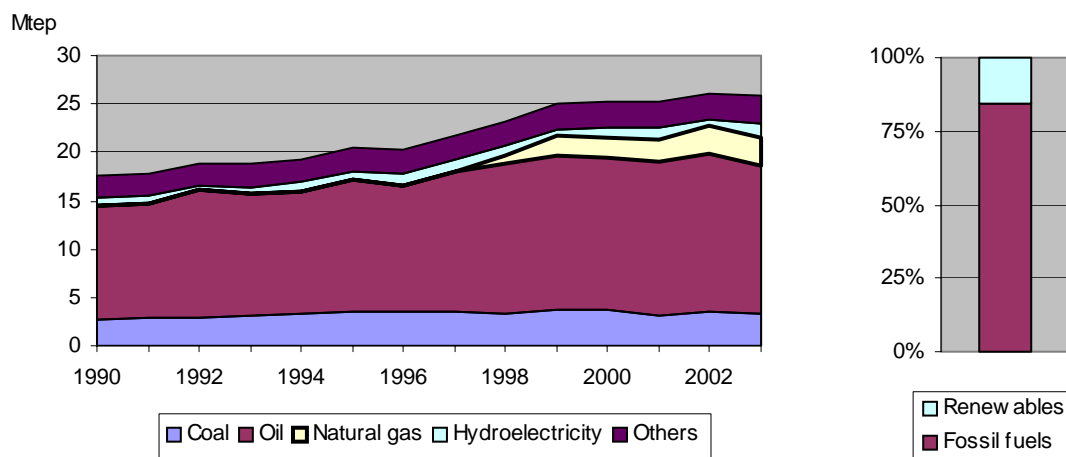
The principal source of GHGs in Portugal is associated with the energy sector and is primarily related to fossil fuel combustion. The largest gas emitted is CO<sub>2</sub> which represented in 2003 77.6% of total GHGs emissions in global warming potential (GWP) weighted emissions. The majority of these emissions are generated in energy-related activities, which are responsible for 70% of total CO<sub>2</sub> emissions in the same year.

Energy-related CO<sub>2</sub> emissions are dependent on the type of fuel and its carbon intensity. In average, during the period considered, 84% of the primary energy consumed was produced from fossil fuel combustion (coal, oil and natural gas); the percentage of renewable energy represents the remaining part, i.e. 16% in average, which refer to domestic sources. (Figure 2.2)

The average annual emissions growth rate for the overall period 1990-2003 is 3%. However, as illustrated in Figure 2.1, roughly three different periods can be identified in terms of the annual average rate evolution: from 1990 to 1995 3.4%; from 1995 to 1999 4.6%, and since 1999 a more moderate increase can be recognised.

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

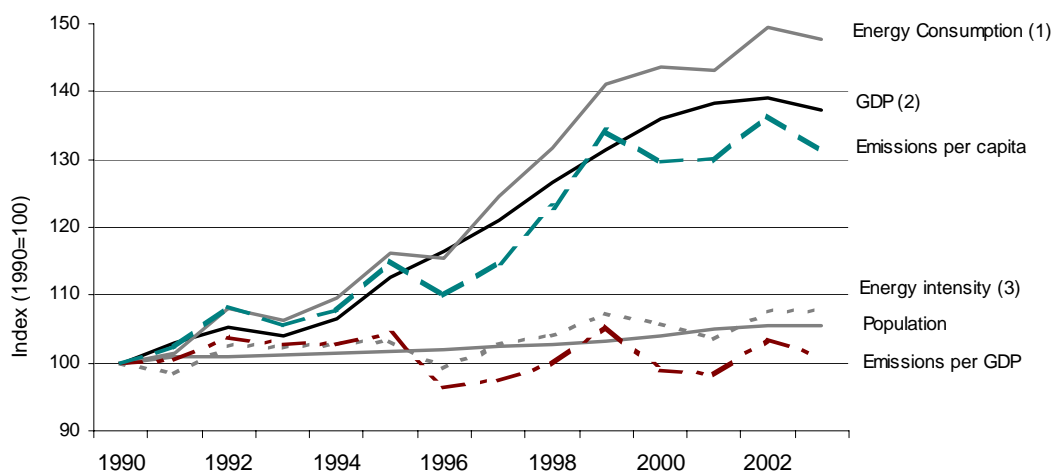
Figure 2.2 – Primary energy consumption



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

During the 1990s, Portugal experienced a rapid economic growth with an increase in GDP of about 37% in the period 1990-2003 (39% for the 1990-2002 period), corresponding to an average annual increase of 2.9% (3.3% for the 1990-2002 period). The most rapid growth occurred from the years 1993 to 2000, where the average annual growth rate reached the 4.4%. This increase was accompanied by the rise of primary energy consumption, which has registered an average annual growth of 5% during the 1993-2000 years. In 2003 the primary energy consumption in the country was almost one and half times the value of 1990.

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



- (1) Primary Energy Consumption.  
(2) 1995 prices.  
(3) Energy Consumption per GDP.  
Sources: INE, DGGE.

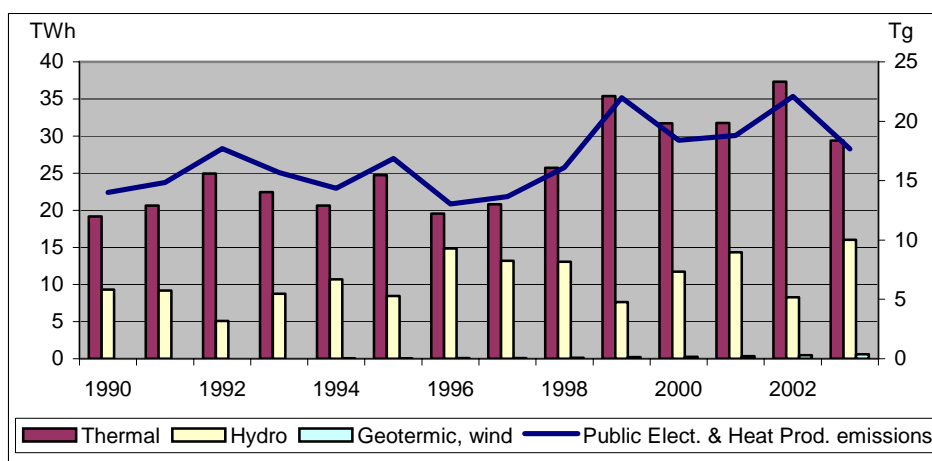
During the period analysed, the country has not achieved a clear decoupling of emission trends from economic growth. However a slight decrease of carbon intensity (emissions per GDP unit) can be observed in the most recent years (see previous figure). This fact can be related to the

implementation of some measures that had a positive effect in the emissions levels, such as the introduction of natural gas (1997), the new combined cycle thermoelectric unit of natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial processes, and the improvement of fuels quality.

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

Since 2001, economic growth slowed considerably, contributing, at least partially, to the more moderate emissions growth registered in the most recent years. Emissions levels of recent years show however significant variations, which are related to the pronounced fluctuations of hydroelectric power generation, that is highly dependent on annual variations in precipitation. The year 2002 corresponded to a dry year (hydraulic index of 0.76), registering a reduction of the quantities of hydroelectric power generated and the consequent growth of emissions. On the opposite, 2003 was a year with higher precipitation (hydraulic index of 1.33, meaning that it rained 33% more than an average hydrologic year) which enabled a considerable increase of hydroelectric power and subsequent reduction in CO<sub>2</sub> emissions from electricity production in thermal plants. (see Figure 2.4)

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



Source: DGGE.

## 2.2 Trends by Gas

Over the 1990-2003 period, all GHG emission levels grew (Figure 2.5). CO<sub>2</sub> is the gas having registered the biggest increase (47.4%). F-gases are excluded from the figure as they represent a small fraction of the emissions total (in 2003: 0.08%).

Figure 2.5 – Increase of GHG emissions by gas over the 1990-2003 period

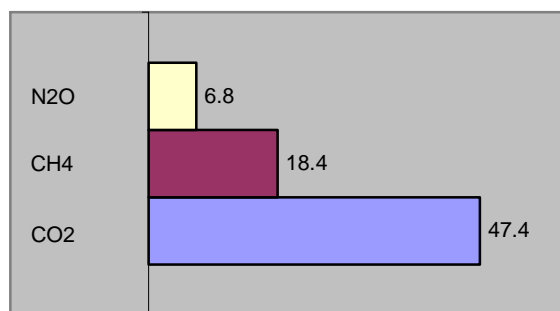


Figure 2.6 illustrates the relative contribution of direct GHG to the total emissions for 1990 and 2003, being evident CO<sub>2</sub> as the primary GHG, accounting for about 78% of Portuguese emissions on a carbon equivalent basis in 2003 (CO<sub>2</sub> from LUCF excluded). The second most important gas is CH<sub>4</sub>, followed by N<sub>2</sub>O, representing, respectively, about 15% and 8% of total emissions in 2003. Portugal has chosen 1995 as the base year for fluorinated gases. In 2003 these gases represented about 0.08% 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 2.6 – GHG emissions by gas: 1990 and 2003

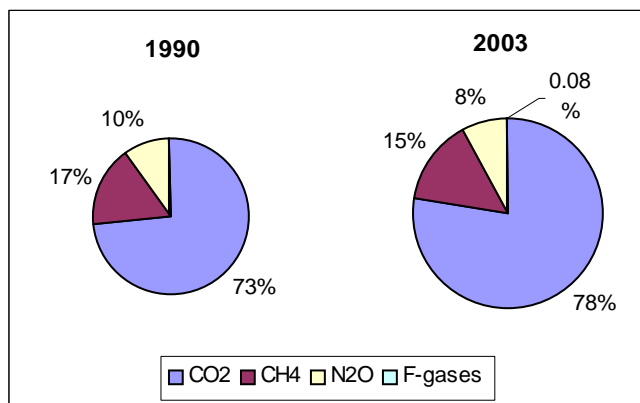
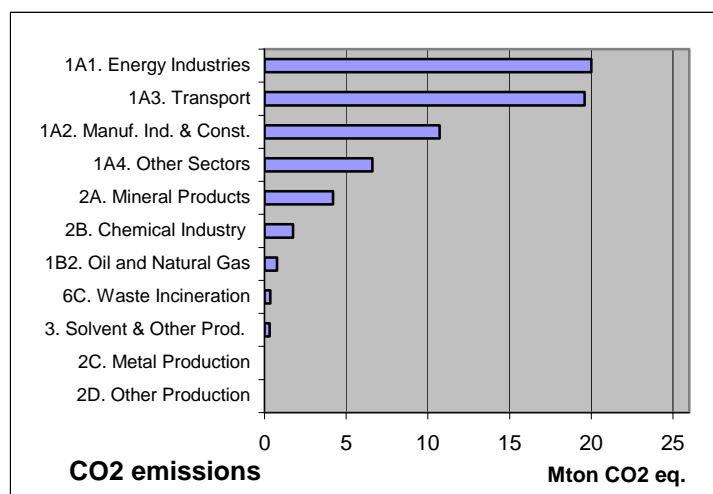


Table 2.1 – GHG emissions and removals in Portugal by gas: 1990-2003

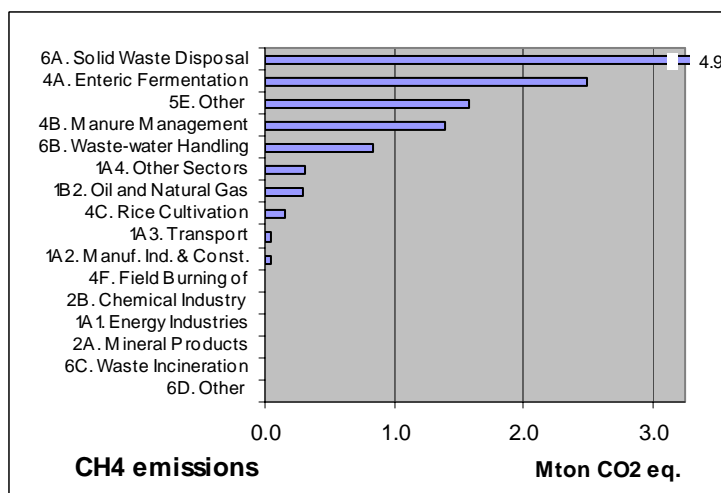
GHGs EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO <sub>2</sub> equivalent (Gg)														
Net CO <sub>2</sub> emissions/removals	49,185	49,738	52,563	50,890	51,090	54,051	50,260	53,344	56,948	64,332	62,358	63,806	67,239	69,623
CO <sub>2</sub> emissions (without LUCF)	43,612	45,415	49,517	48,122	49,256	53,176	50,280	53,451	58,054	64,767	63,609	64,687	68,844	64,293
CH <sub>4</sub>	10,184	10,573	10,196	10,198	10,404	10,914	10,839	10,963	11,527	11,771	10,821	10,485	10,830	12,063
N <sub>2</sub> O	6,064	5,966	5,765	5,633	5,847	6,050	6,163	6,090	6,112	6,403	6,107	6,315	6,374	6,478
HFCs	0	0	0	0	0	0	0	1	6	12	24	37	49.05	62.17
PFCs	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
SF <sub>6</sub>	0	0	0	0	0	5	5	5	5	6	6	7	7.00	7.47
Total (with net CO <sub>2</sub> emis./removals)	65,433	66,278	68,524	66,721	67,341	71,019	67,268	70,402	74,598	82,524	79,316	80,649	84,499	88,233
Total (without CO <sub>2</sub> from LUCF)	59,860	61,955	65,478	63,953	65,507	70,144	67,287	70,510	75,704	82,959	80,567	81,530	86,105	82,903

NE - not Estimated; NO - not occurring

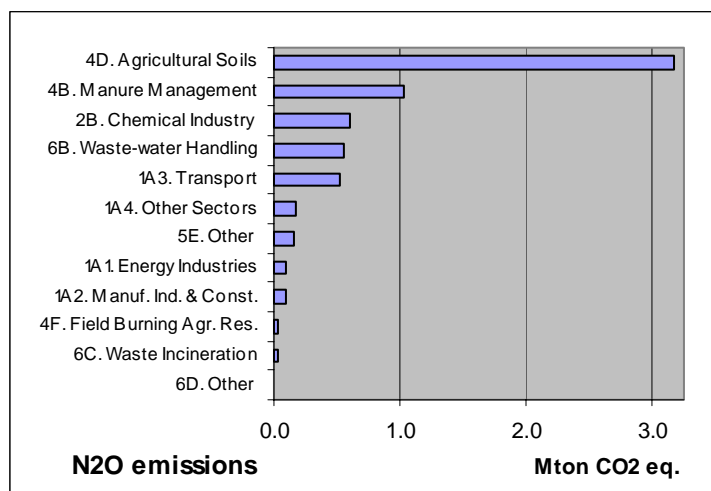
Next figures summarise the sources categories of emissions by gas (F-gases not presented).

Figure 2.7 – 2003 sources categories of CO<sub>2</sub>

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

Figure 2.8 – 2003 sources categories of CH<sub>4</sub>

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

Figure 2.9 – 2003 sources categories of N<sub>2</sub>O

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

## 2.3 Trends by Sector

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

Figure 2.10 – GHG emissions and removals by sector: 1990-2003

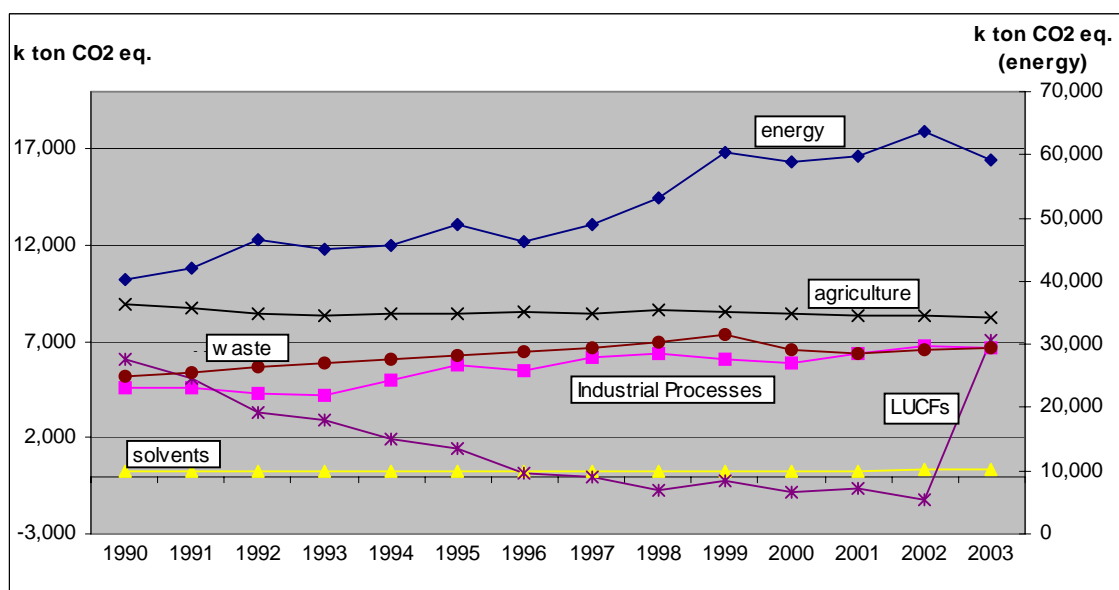


Figure 2.11 – GHGs emissions percentage change (1990-2003) by IPCC category (LUCF excluded)

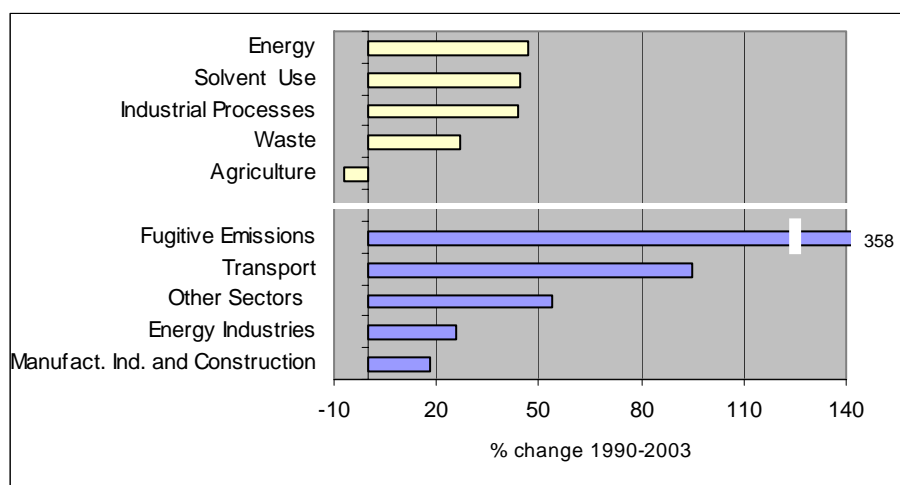


Table 2.2 – GHG emissions and removals by sector: 1990-2003

GHGs SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO <sub>2</sub> equivalent (Gg)														
1. Energy	40,401	42,195	46,519	45,111	45,618	48,904	46,312	48,824	53,070	60,506	58,999	59,804	63,682	59,270
2. Industrial Processes	4,614	4,578	4,338	4,202	5,008	5,755	5,498	6,169	6,397	6,067	5,903	6,395	6,771	6,641
3. Solvent and Other Product Use	220	234	243	236	253	256	275	285	290	285	290	304	312	318
4. Agriculture	8,920	8,755	8,492	8,392	8,477	8,428	8,540	8,474	8,627	8,514	8,402	8,397	8,334	8,295
5. Land-Use Change and Forestry <sup>(7)</sup>	6,058	5,089	3,289	2,913	1916	1,409	167	-37	-755	-245	-832	-604	-1,208	7,076
6. Waste	5,220	5,427	5,644	5,866	6,068	6,267	6,475	6,688	6,971	7,397	6,554	6,353	6,608	6,633
7. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

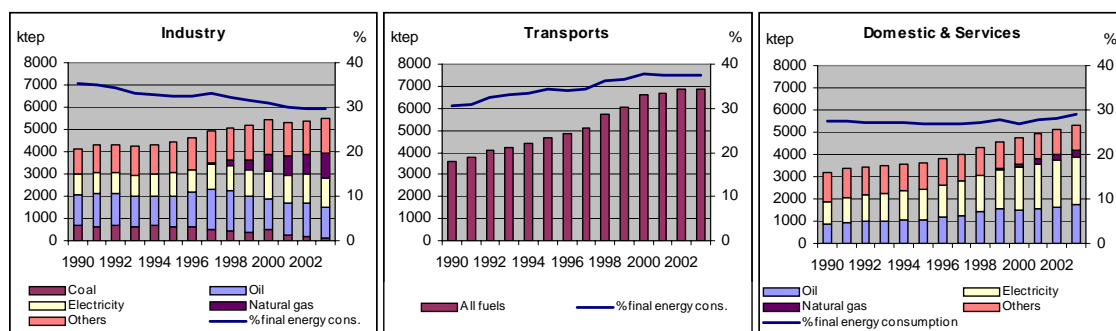
As previously mentioned, throughout the report, the reference to “total emissions” is meant to refer to “total emissions without CO<sub>2</sub> from LUCF on a carbon equivalent basis”.

Energy is by far the most important sector, accounting for 71.5% of total emissions in 2003, and presenting an increase of almost 47% over the 1990-2003 period. Energy industries and transport are the two most important sources representing each 24.3% of total emissions. Within the energy industries, public electricity and heat production represents alone 21.2% of the total emissions. This reflects the country heavy dependence on fossil fuels for electricity generation and transportation, which continues to grow due to the continued increase of electricity demand driven in particular by the residential/commercial sector, and the grow of mobility.

The total final energy consumption raised 58% between 1990 and 2003, and is related to the fact that the country has one of the lowest energy per capita ratio in the EU (1.77 tep per capita in 2003).

The sectoral evolution of energy consumption presented in the next figure, shows that the sectoral structure of the energy demand has been changing. The share of the industrial sector, which represented in 1990, 35% of the final energy demand, decreased to 30% in 2003. On the other hand, as previously mentioned, transports have been increasing importance, having raised from 31% in 1990 to 37% of the final energy consumption in 2003. The increase of energy consumption of this sector was 92% from 1990 to 2003. Also, services is one of the sectors that are increasing the most, having registered a 193% rise of energy consumption from 1990 to 2003. In 2003, this sector together with the domestic sector, represented 29% of the share of the total energy consumed.

Figure 2.12 – Final energy consumption by main sectors and fuel



Mobile sources, which are largely dominated by road traffic, are one of the sectors that are rising faster. The overall energy consumed for transportation is supplied by petroleum-based products, with nearly one third being gasoline (30% in 2003). This fuel has been losing relatively importance since 1990, when the share was 40% of the sectoral energy consumption. In the period 1990-2003 the emissions of transportation sources increased 95%, due to the steady growth of vehicle fleets (in particular with more powerful engines) and road travel, reflecting the increase in family income and the strong investment in the road infrastructure of the country in the 1990s decade. Indirectly the increase in road traffic activity also augments the emissions from fossil fuel storage, handling and distribution.

Still within the energy sector, other sectors, which include the residential and commercial activities, also registered a significant increase with almost 54% rise in the 1990-2003 period. As previously mentioned this relates to the significant growth of these sectors with reflects on the energy consumed and emissions generated.

Agriculture is the second most significant source of GHGs emissions (10% of total emissions) and is the only category showing a negative trend or emissions decrease in the period analysed (-7% reduction from 1990 to 2003). This fact is related to the relatively decrease of importance of the sector in terms of the national economy, and is associated for instance with the reduction of the livestock production of certain categories of animals (e.g. swine), and the decrease of fertilizer consumption.

Industrial processes and Waste represent both 8% of Portuguese emissions in 2003, recording an increase of approximately 44% (industrial processes) and 27% (waste). The growth of the industrial processes sector, whose emissions are generated as by-product of many non-energy-related activities, are mostly related to the increase of cement production, road paving, limestone and dolomite use, lime production, glass and ammonia production. The increase in the waste sector emissions, is primarily related to the rise of waste generation (associated with development of the family income and the urbanisation growth registered in the country during the last decade) and the deposition of waste in landfills.

Solvent use represents less than 1% of total emissions, and is mainly related to NMVOC emissions<sup>4</sup>.

Estimates of emissions and sinks from land use change and forestry category, show 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. The situation has been reinversed in 2003, where this source appears as a net emitter (7.1 Mt CO<sub>2</sub> eq.), which is due to the exceptional extension of the forest area burnt in wildfires in that year.

<sup>4</sup> These are converted into ultimate carbon dioxide after being emitted to atmosphere.



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

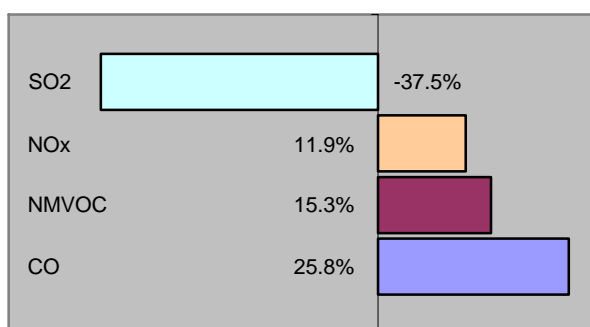
Several gases do not have a direct influence in climate change but affect the formation or destruction of other GHG. CO, NO<sub>x</sub>, and NMVOC are precursor substances for ozone which is a GHG. SO<sub>x</sub> produce aerosols, which are extremely small particles or liquid droplets, that can also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

Table 2.3 – Indirect GHG and SO<sub>x</sub> emissions: 1990-2003

Gas emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	(Gg)													
CO	1038.0	1151.9	979.8	919.4	870.2	1027.5	873.9	799.0	894.9	811.6	884.8	781.1	814.4	1306.0
NO <sub>x</sub>	259.8	276.0	289.8	280.6	279.2	292.8	283.0	276.7	286.5	297.6	293.0	289.0	296.5	290.7
NM VOC	274.0	288.8	285.1	275.6	281.8	293.5	287.5	286.5	293.3	280.7	279.5	277.9	282.3	316.0
SO <sub>2</sub>	322.9	313.3	374.6	320.9	299.3	334.7	273.7	293.7	342.8	343.8	307.4	294.6	293.8	201.8

In 2003 SO<sub>2</sub> emissions have decreased from 1990 levels: -37.5%. The other gases, CO, NMVOC and NO<sub>x</sub> emissions have increased, respectively, 25.8%; 15.3% and 11.9%.

Figure 2.13 – Variation of indirect GHG and SO<sub>x</sub> emissions by gas: 1990-2003 period



Energy is the major responsible sector for emissions of NO<sub>x</sub>, SO<sub>x</sub> and CO. Its contribution for NMVOC emissions is also significant, together with Solvent use and Industrial processes.

Within energy, transportation is responsible for the greatest share of NO<sub>x</sub>, CO, and NMVOC emissions, respectively 38.1%, 21.4% and 11.7% of 2003 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 14.3% increase over the 1990-2003 period; NMVOC and CO recorded significant reductions, approximately -50% and -41%, respectively.

SO<sub>x</sub> emissions are mainly generated in the energy industry sector (61.8% of total emissions in 2003) and combustion in manufacturing industries (19.2% of total emissions in 2003), 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 1990-2003 shows a decrease in SO<sub>x</sub> emissions in both sub-categories: energy industries -38% and manufacturing industries -52.1%. 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 1997, is also another positive factor that has contributed to control of SO<sub>x</sub> emissions.

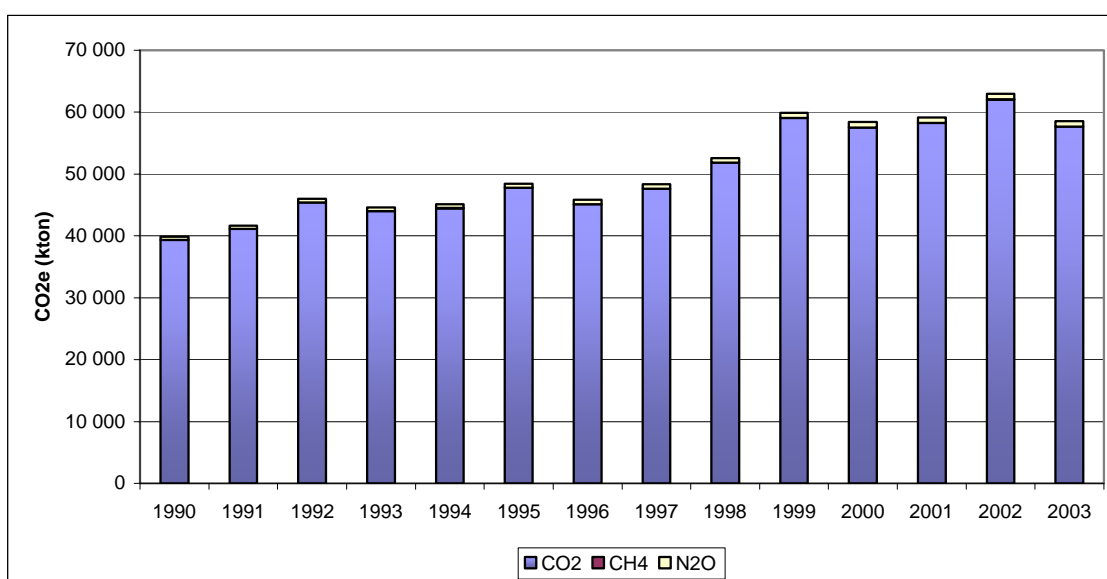
The registered decrease of SO<sub>x</sub> and NO<sub>x</sub> emissions from energy industries in 2003 has however been significantly influenced by the hydrologic year, characterised by higher precipitation and the considerable increase of hydroelectric power generation.

## CHAPTER: 3 ENERGY (CRF SECTOR 1)

### 3.1 Overview

Energy-related activities are the major sources of Portuguese GHG emissions, accounting for 71.5% of total emissions of CO<sub>2</sub>e excluded of LULUCF in 2003. Total emissions from this sector have increased 47 % from base year to last year, although a slight decrease has occurred from 2002 to 2003, as may be seen in Figure 3.1. The relative importance of total CO<sub>2</sub>e emissions from the Energy sector has also been increasing, from 67% in 1990 to 71% in 2003. By far the most important gas emitted by this sector is CO<sub>2</sub>, with 97.3 % of sector emissions expressed in CO<sub>2</sub> equivalent.

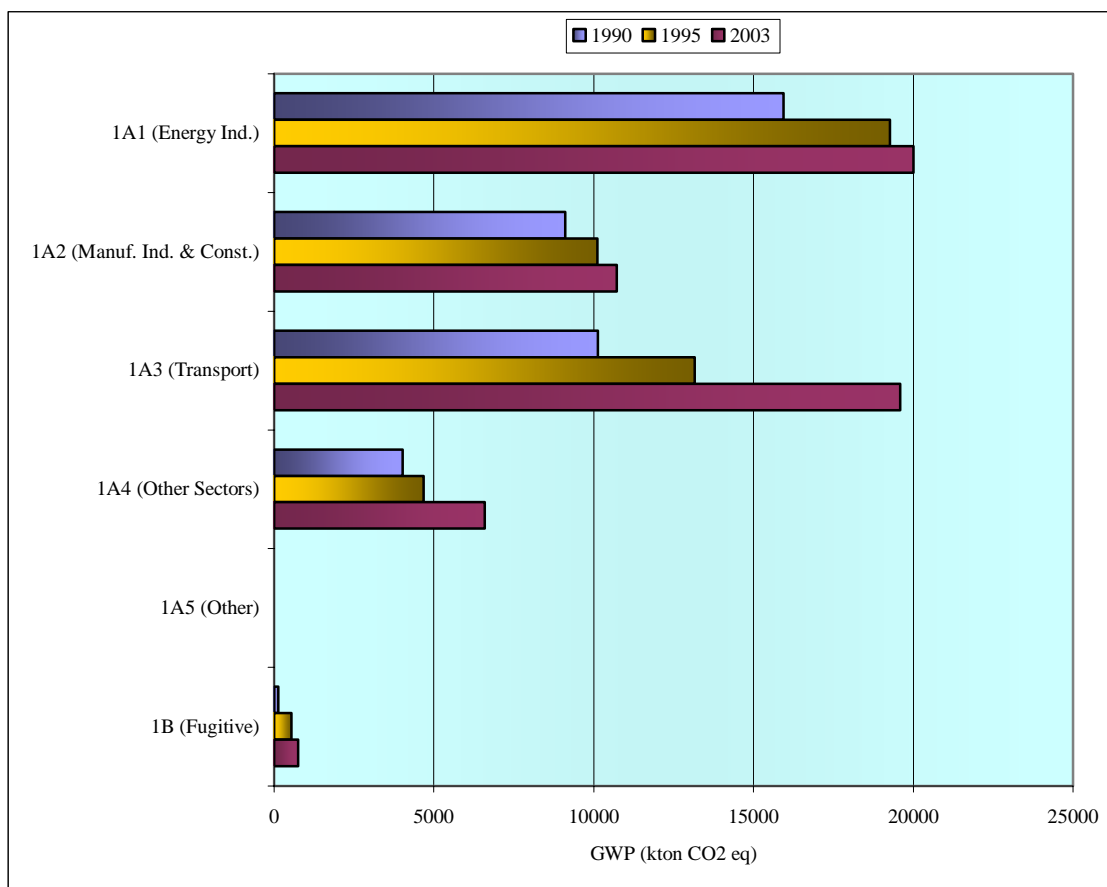
Figure 3.1 – Total CO<sub>2</sub> equivalent emissions from the Energy Sector (CRF Sector 1)<sup>5</sup>



In terms of the importance, in the Energy sector, of the CO<sub>2</sub>e emissions from each of the sub-sectors, which are presented in Figure 3.2, it is visible the dominance of emissions from the Energy Industry (1A1) and from Transportation (1A3). It is also noticeable the accentuated increase that emissions from this last sector have suffered during the period.

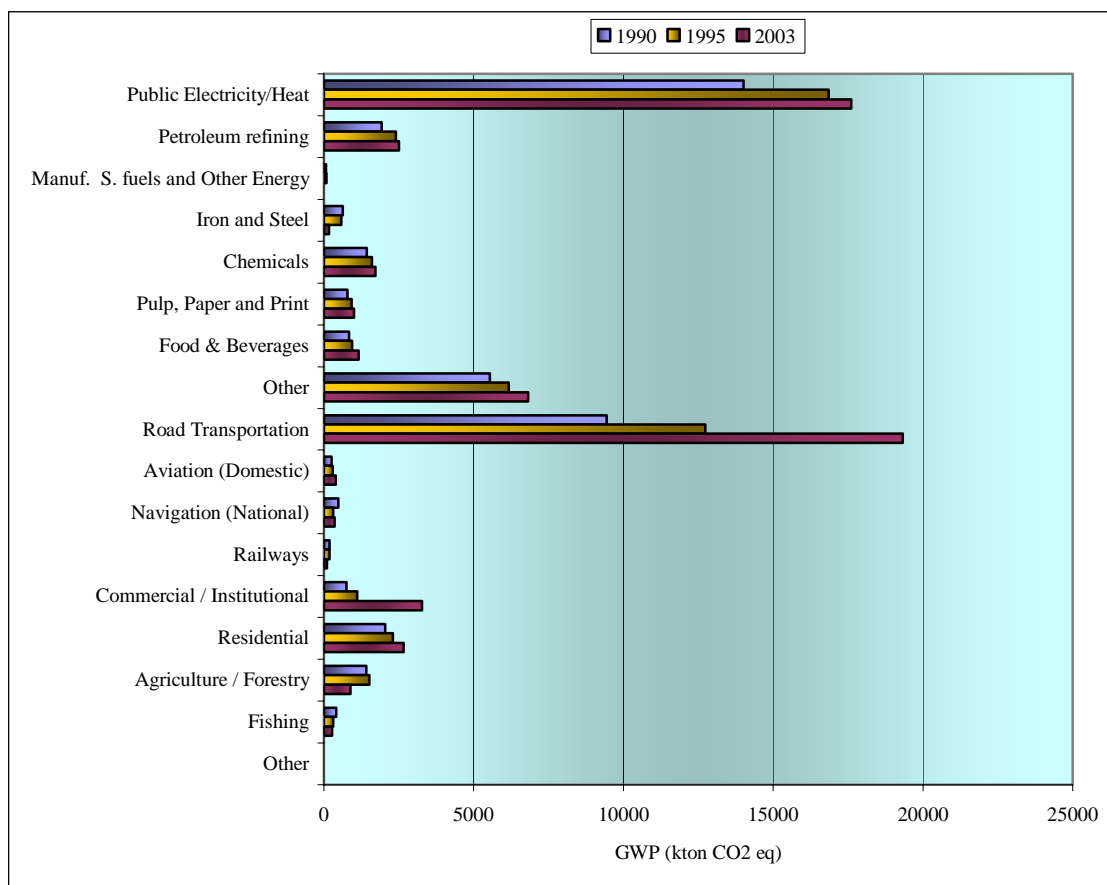
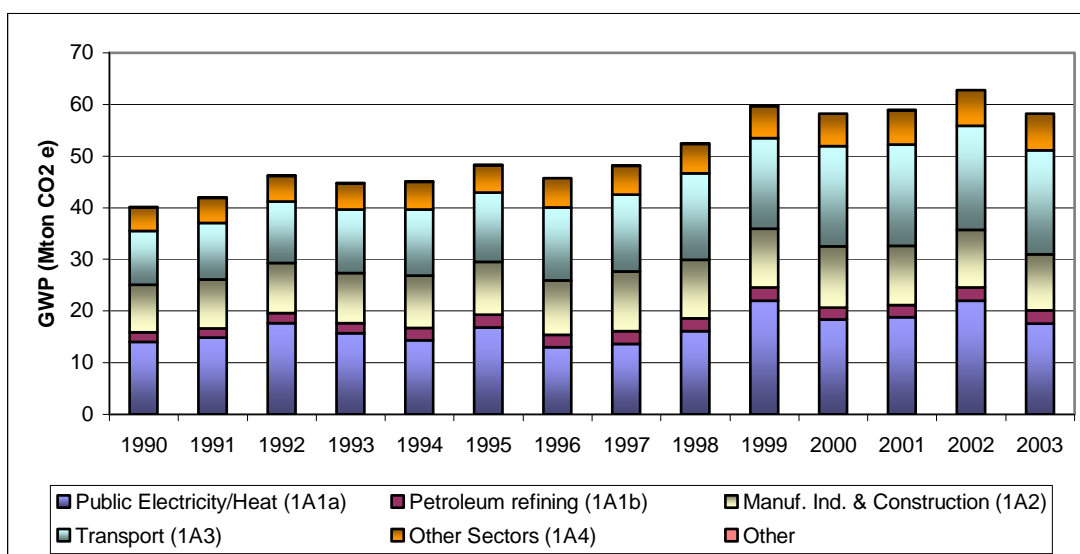
<sup>5</sup> Emissions of CH<sub>4</sub> and N<sub>2</sub>O are comparatively very small and are not well visible in graph.

Figure 3.2 – Importance of CO<sub>2</sub>e emissions from sub-sectors in Energy sector in selected years.



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

Energy emissions are primarily related to fossil fuel combustion. In Portugal, due to the heavy dependence on fossil fuels for electricity generation and transportation, transport and public electricity and heat production industries appear as the primary sources of Portuguese GHG emissions, representing, respectively, 24.3% and 21.2% of total GHG emissions in year 2003. In 2003, for the first time, emissions from transportation have surpassed emissions from Public Electricity and Heat Production and are now the predominant source. Manufacturing industries and construction is the third larger source within Fuel Combustion Activities with 13.1% of total emissions in 2003. GHG emissions from Refining of Petroleum Products is another relevant source with 4.3% of total emissions for this sector. Other sectors which include residential, commercial/institutional, agriculture/forestry and fisheries (excluding bunkers) represents 12.2% of total sector emissions. Emissions for each sector in selected years are presented in Figure 3.3, and the full time trend in Figure 3.4.

Figure 3.3 – Total GHG emissions in source 1A, expressed as CO<sub>2</sub>e, in 1990, 1995 and 2003Figure 3.4 – Trend of total GHG emissions in source 1A, expressed as CO<sub>2</sub>e, by sub-sector (1990-2003)

GHG emissions from this activity sector are almost fully dominated by direct CO<sub>2</sub> emissions, which represents about 97.7 % of total GHG emissions in 2003. CH<sub>4</sub> and N<sub>2</sub>O are minor sources, respectively 0.7 % and 1.5% of total GHG emissions from the 1A sector in 2003.

CO<sub>2</sub> emissions are dependent on the carbon content of the fuel used and, for this reason, estimates of CO<sub>2</sub> emissions are more accurate and methodology simpler to apply using fuel consumption data only. During the combustion process some carbon is released in smaller amounts in the form of other gases, including CH<sub>4</sub>, CO, NMVOC and airborne particulate matter. It is presumed that all these other carbon containing non-CO<sub>2</sub> gases oxidise to CO<sub>2</sub> in the atmosphere and are include in carbon dioxide estimates (ultimate CO<sub>2</sub>)<sup>6</sup>.

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

Fossil fuel combustion from international bunkers, i.e., international aviation and marine transportation, also generates air emissions in a similar way to other fuel combustion activity. In accordance with international guidelines, these emissions are not included in national totals, but are reported separately as a memo item. Portuguese emissions from maritime navigation sources are still not correctly reported because they are based on fuel consumption by flag (foreign companies), instead of a real share between traffic inside and outside the country. This inventory problem will be solved in the future, as it was already solved for international/national aviation.

Biomass combustion also generates gas emissions. CO<sub>2</sub> emissions from this source are estimated in the inventory but not included in national emissions totals being considered that there are no net emissions of CO<sub>2</sub>, as carbon released during biomass combustion had been in fact fixed from atmosphere by the photosynthetic process and when is burnt and returns to atmosphere does not increase the atmospheric/biosphere CO<sub>2</sub> pool. This activity is reported separately for information purposes only. Nevertheless non-CO<sub>2</sub> emissions from combustion of biofuels are however considered in inventory totals.

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

Apart from fuel combustion emissions, the Energy sector includes also emission estimates from production, transmission, storage and distribution of fossil fuels. Generated gases from these sources are CO<sub>2</sub>, NMCOV, SO<sub>x</sub>, CH<sub>4</sub>, NO<sub>x</sub> and CO, and emissions per sub-sector source are presented in Figure 3.5, where the major importance of emissions due to oil refining, transport and distribution may be seen.

GHG emissions realized as CO<sub>2</sub> also dominate in this source sector, with 72 % in 2003, although methane has been increasing its importance, mainly because of the increased use of natural gas. Emissions by gas are represented in Figure 3.6.

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<sup>6</sup> Three CO<sub>2</sub> quantities may be referred in the inventory with different definitions: (1) End of pipe CO<sub>2</sub> - Carbon dioxide effectively emitted from the source: exhaust, chimney, etc; (2) Ultimate CO<sub>2</sub> - carbon dioxide increase contribution to atmosphere. Includes end of pipe CO<sub>2</sub> but also the conversion of other gases and particles that are emitted to atmosphere containing carbon and that are supposedly latter converted in CO<sub>2</sub>; (3) Fossil ultimate CO<sub>2</sub> - CO<sub>2</sub> emissions resulting from carbon with fossil origin: fossil fuels, mineral rocks and all other non biomass carbon.

Figure 3.5 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>e, by sub-sector (1990-2003)

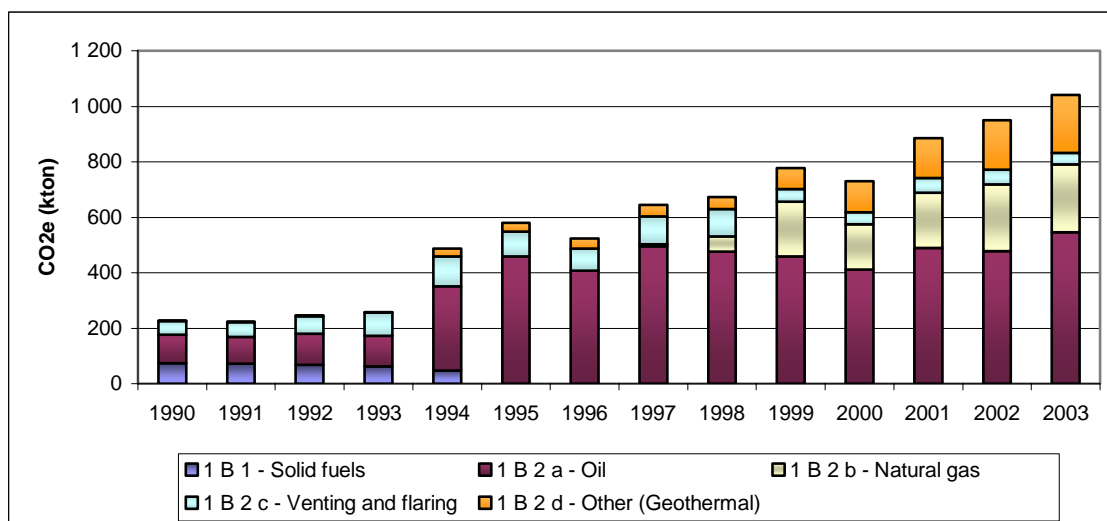
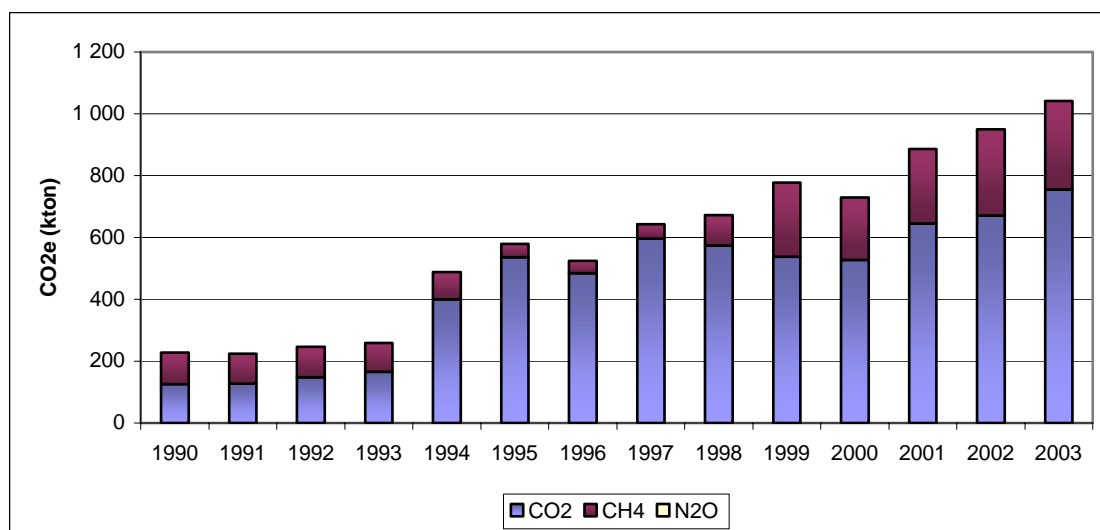


Figure 3.6 – Trend of total GHG emissions in source 1B, expressed as CO<sub>2</sub>eq, by GHG (1990-2003)



## 3.2 Category sources

### 3.2.A Energy Industries (CRF 1A1)

#### 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 for industry consumers cause the development of hydro-electric production units and the built of *Tapada do Outeiro* power plant using low energy coal (lignite) obtained from Portuguese mines. The next decade saw the entrance of petroleum products as the main energy sources, and three additional power plants were built: *Carregado*, *Barreiro* and *Setúbal*. After the energy crisis of 1973/74 and 1979/81 there was a political shift towards the preference for imported coal (*Sines* and *Pêgo* power plants, started in 1985 and 1993 respectively) and, more recently, towards natural gas

(*Turbogás* power plant already in operation and the new TER<sup>7</sup> unit, build near the old unit in *Carregado* entered its final testing period at the end of 2003 ).

Apart from the dedicated electric power plants, auto-producers generate electric energy for own consumption and to sales to the public system. However not all combustion from these sources are included here because, according to the Revised 1996 IPCC Guidelines, emissions from auto-producers are to be reported under the industrial or commercial branch in which their main economic activity occurs. The present source sector includes only emissions resulting from main power producers<sup>8</sup>.

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

### 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 at present. Power plants and installed power are listed in Table 3.1 together with their main relevant characteristics.

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

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
Turbogás	Gondomar	1998	NG	990			Combined Cycle
Soporgen	Lavos	2001	NG	67	n.a.		Co-generation. Combined Cycle
Energim	Alhambra	2002	NG	43.7	n.a.		Co-generation. Combined Cycle
Mortágua	Mortágua	1999	Wood wastes & NG	9	ESP		
Pêgo	Abrantes	1993	HC	615.2	ESP & Low NOx Burner	225 (1)	
Carregado	Alenquer	1968	FO & NG	710 (250*)	ESP	100 (3)	Natural Gas introduced in 1997
TER	Alenquer	2004	NG				
Alto do Mira	Amadora	1975	GO	132	-	10-11	Gas turbine
Barreiro	Lavradio	1978	FO	56	-	104 (1)	Co-generation
Setúbal	Setúbal	1979	FO	946	ESP	200 (2)	
Sines	Sines	1985	HC	1 192	ESP & Low NOx burners (after 2000)	225 (2)	
Tunes	Silves	1973	GO	197	-	9-17	Gas Turbine

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

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

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

<sup>7</sup> TER – Termoelétrica do Carregado

<sup>8</sup> Main Power Producers generate and sell electricity or heat as their main activity (primary activity) either public owned or private owned. In contrast there are other Auto-producer of electricity or heat, that also are agents producing or selling electricity or heat, but as a secondary activity and not as main business.



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

There has also been a change in the production structure along the 1990-2003 period, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase of the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was Orimulsion, that was used as fuel in *Setúbal* power plant but only in 1994 and its use had no continuation.

- In 1990 three units (*Carregado*, *Setúbal* and *Barreiro*) were using fuel-oil, one unit (*Sines*) was consuming imported hard coal and another unit (*Tapada do Outeiro*) was using lignite coal and fuel-oil;
- A new build coal unit (*Pêgo*) using hard coal, started producing electricity in 1993 and doubled its production capacity in 1995;
- The old unit in northern Portugal (*Tapada do Outeiro*) that was burning low heating value lignite coal, partly mined in Portugal, stopped using this fuel in 1997 but was kept producing electricity with a small consumption of fuel-oil since;
- Between 1995 and 1997 *Carregado* power plant shifted part of its production groups from residual fuel-oil to natural gas. In the end of 2003 and beginning of 2004, *TER*, a new thermal power plant on Natural Gas has started operation in *Carregado*, near the old unit that is maintained in operation;
- A new unit (*Turbogás*) consuming natural gas was build in northern Portugal near the old unit of *Tapada do Outeiro* and started producing in 1998;
- *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 (*Soporgen* in 2001 and *Energim* in 2002) producing electricity from natural gas in close connection, respectively, with an industrial paper pulp plant and to a chemical industry plant.

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

Fuel	Number of units		
	1990	1995	2003
Lignite coal/Fuel-oil	1	1	0
Hard coal	1	2	2
Fuel oil	3	3	3
Diesel Oil	2	2	2/1
Natural gas	0	0	3
Natural gas/ Fuel-oil	0	0	1
Natural gas/ Wood Wastes	0	0	1

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

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

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

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

### ***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 pollutants from this activity. For carbon dioxide, a mass balance approach could be used in principle to estimate emissions from the carbon content of fuels. But because that information is not available from most power plants, the IPCC recommendation of using emission factors based on energy consumption was used: "Emission factors for CO<sub>2</sub> from fossil fuel combustion are expressed on a per unit energy basis because the carbon content of fuels is generally less variable when expressed on a per unit energy basis than when expressed on a per unit mass basis" (GPG).

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

$$U_{CO_2(u,f,y)} = 44/12 * EF_C * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3}$$

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

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

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

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

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

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

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

This formula reflects the fact that some carbon in fuel is not oxidized and not emitted to atmosphere. Although, some carbon in the fuel is not released directly as carbon dioxide but instead in the form of carbon monoxide, methane, volatile organic compounds and even in soot,

ash and particulate matter as consequence of the incomplete combustion of fuel. Emissions of these compounds in airborne fraction are transformed sooner or latter into 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:

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

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).

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

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

Where

SOx<sub>(u,f,y)</sub> - Sulphur oxide emission estimated from consumption of fuel f in power plant u in year y (ton);

Fuel<sub>Cons(u,f,y)</sub> - Consumption of fuel f in power plant u in year y (any unit in agreement with CF);

S<sub>(u,f,y)</sub> - Sulphur content of fuel f, specific of each power plant and year (mass percentage);

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

AshRet<sub>(u,f)</sub> - Sulphur retention in ash (mass percentage).

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

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

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

where:

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

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

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

Presently for most pollutants, EF 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 emissions of Heavy Metals the following equation was used instead:

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

and,

HM<sub>p(u,f,y)</sub> - Heavy Metal p emission estimated from consumption of fuel f in power plant u in year y (ton);

Fuel<sub>Cons(u,f,y)</sub> - Consumption of fuel f in power plant u in year y (ton);

EF<sub>HM(u,f,y,p)</sub> - Emission Factor for heavy metal p from fuel f in power plant u and in year y (g/ton);

AshRet<sub>(u,f,p)</sub> - Retention of Heavy Metal p in ash from fuel f under burning conditions in power plant u (mass percentage).

### **Geothermic Energy**

Since 1994, in Azores, the Regional Authority of Economy (Secretaria Regional da Economia. Direcção Regional do Comércio, Indústria e Energia) performs own estimates of carbon dioxide to atmosphere from geothermic units and these were considered in the National Inventory. For the years prior to 1994, when the only available activity data for geothermic electricity production is from General-Directorate of Geology and Energy (DGGE), emission factors estimated for the post-1994 time series were used.

## **EMISSION FACTORS**

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

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

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

Table 3.3 – Emission Factors for energy production sector. Greenhouse Gases

Fuel	U <sub>CO2</sub> kg/GJ	F <sub>acox</sub> 0..1	Fossil <sub>c</sub> %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O g/GJ
Lignite	101.2	0.980	100	1.0	1.4
Hard Coal	92.0	0.980	100	0.7	1.4
Fuel-oil	77.4	0.990	100	0.7	0.6
Orimulsion	80.7	0.990	100	0.7	0.6
Natural Gas	56.1	0.995	100	0.1 - 1.4	1.4
Biomass	109.6	1.000	0	15	4.3
Diesel (GT)	74.1	0.990	100	0.14	2.5

Emissions of Nitrogen Oxides (NO<sub>x</sub>) and Particulate Material (TSP) are function of both fuel type and burning conditions (burning device and control equipment) and are therefore specific of each power plant and change over years. The range of emission factors for each fuel type is also presented in Figure 3.4 and Figure 3.5. For most units (*Sines*, *Pêgo*, *Carregado*, *Barreiro*, *Setúbal* and *Turbogas*) emission factors reflect actual monitoring data under *Autocontrolo* program.

Table 3.4 – Emission Factors for energy production sector. Indirect Precursors and other pollutants

Fuel	NO <sub>x</sub> g/GJ	NMVOC g/GJ	CO g/GJ	AshRet <sub>(s)</sub> %
Lignite	310	1.5	16	5
Hard Coal	260 - 500	1.5	10	5
Fuel-oil	180 - 300	3.0	15	0
Orimulsion	300	3.0	15	0
Natural Gas	75 - 120	5.0	13 - 19	0
Biomass	70	150	500	0
Diesel (GT)	350	4.0	15	0

Table 3.5 – Emission Factors for energy production sector. Particulate Matter

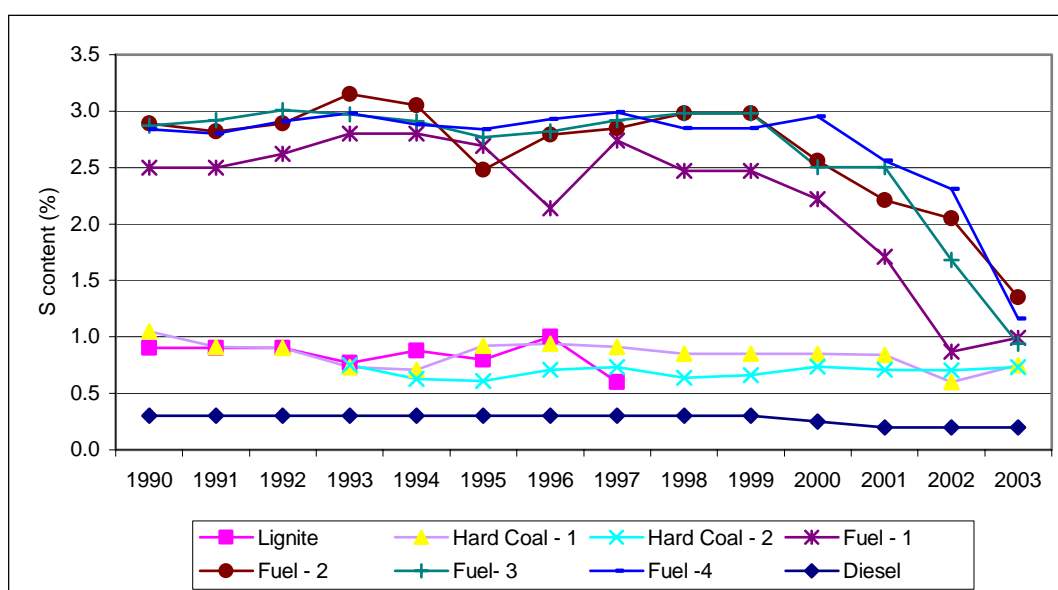
Fuel	PM g/GJ	PM10 %	PM2.5 %	PM1.0 %
Lignite	9.3	67	29	14
Hard Coal	6.8 – 40.1	67	29	14
Fuel-oil	0.26 – 69 (a)	63	41	28
Orimulsion	1.03	63	63	63
Natural Gas	0.82 – 2.54	100	100	100
Biomass	23.2	74	65	65
Diesel (GT)	30	100	100	100

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

Table 3.6 – Emission Factors for energy production sector. Heavy Metals

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

Average sulphur content for each fuel type has evolved along the 1990-2003 time series as shown in Figure 3.7 for the most important fuel types and power plants .

Figure 3.7 – Trends of sulphur content by fuel type<sup>9</sup>

### Other Thermo-electricity Power Plants

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

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

<sup>9</sup> Power plants are denominated by number and not by name due to confidentiality constraints

The emission factors that were used in the inventory are shown from Table 3.7 to Table 3.10 for the public power plants belonging to the public system in Azores and Madeira, and from Table 3.11 to Table 3.14 for the non public co-generation self producers<sup>10</sup>.

Table 3.7 – Emission Factors for thermo-electricity production in Azores and Madeira. Greenhouse Gases

Region	Fuel	U <sub>CO2</sub> kg/GJ	Fac <sub>OX</sub> 0.1	Fossil <sub>C</sub> %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O g/GJ
Azores	Fuel-oil	77.4	0.990	100	2.9	0.6
Azores	Diesel oil	74.1	0.990	100	0.14	0.6
Madeira	Fuel-oil	77.4	0.990	100	2.9	0.6

Table 3.8 – Emission Factors for thermo-electricity production in Azores and Madeira. Indirect Precursors and other pollutants.

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

Table 3.9 - Emission Factors for thermo-electricity production in Azores and Madeira. Particulate Matter

Region	Fuel	PM g/GJ	PM <sub>10</sub> %	PM <sub>2.5</sub> %	PM <sub>1.0</sub> %
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 3.10 - Emission Factors for thermo-electricity production in Azores and Madeira. Heavy Metals

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

Table 3.11 – Emission Factors for non public co-generation self producers. Greenhouse Gases

Fuel	U <sub>CO2</sub> kg/GJ	Fac <sub>OX</sub> 0.1	Fossil <sub>C</sub> %	CH <sub>4</sub> g/GJ	N <sub>2</sub> O g/GJ
LPG	63.1	0.995	100	0.06	1.4
Fuel –oil	77.4	0.990	100	2.9	0.6
Diesel oil	74.1	0.990	100	5	0.6
Natural Gas	56.1	56.1	100	1.4	1.4

<sup>10</sup> Power producers as main activity only.

Table 3.12 – Emission Factors for non public co-generation self producers. Precursor gases and other pollutants

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

Table 3.13 - Emission Factors for non public co-generation self producers. Particulate Matter

Fuel	PM g/GJ	PM <sub>10</sub> %	PM <sub>2.5</sub> %	PM <sub>1.0</sub> %
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

Table 3.14 - Emission Factors for non public co-generation self producers. Heavy Metals

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

### Geothermal 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 was available until 1998 from the Large Combustion Plants (LCP) directive - which relies in direct information reported from the individual plant producer to the Environment Ministry - for all power plants except the two gas turbines. From 1999 onwards consumption of fuels was also collected directly from energy plants but under the Self-control program (*Programa Autocontrolo*)<sup>11</sup> or, when the unit is not obliged to this

<sup>11</sup> The *Auto-controlo* program is a legal obligation for major emitters.



agreement, from plant activity reports (EDP, 2000; EDP, 2001; EDP, 2002; EDP, 2003; EDP, 2004). Activity data for both gas turbine units is from DGGE until 1997 and from industry reports (EDP, 2000; EDP, 2001; EDP, 2002; EDP, 2003; EDP, 2004) 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>12</sup> for that specific year from where consumption of fuels in energy units are calculated from:

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

or

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

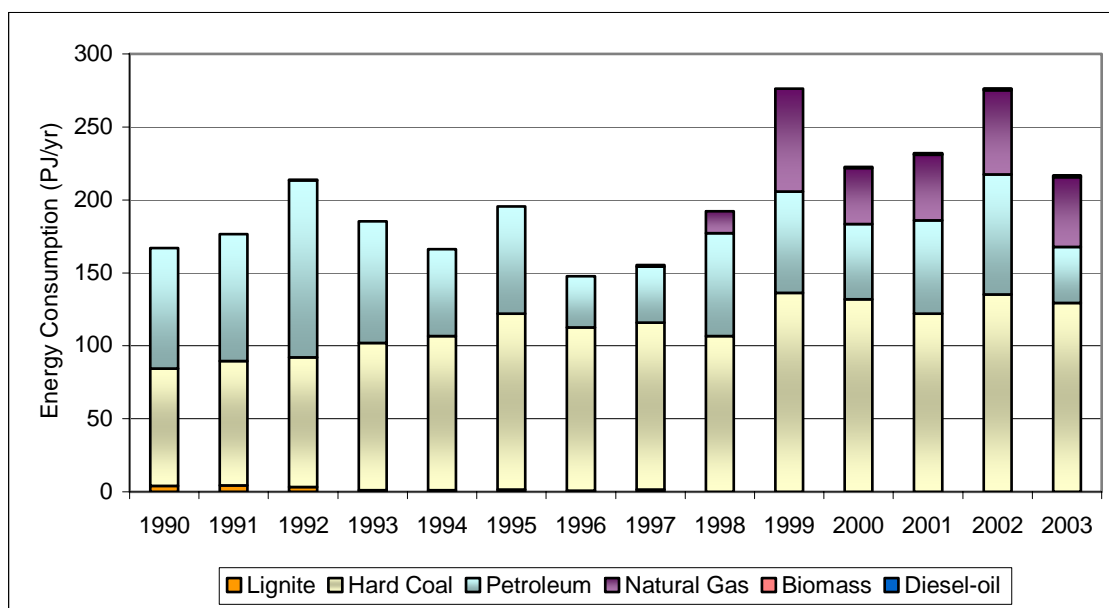
When LHV/NCV was not available it was estimated from interpolation or extrapolation from the remaining available time series. The average value and range of the reported LHV per fuel type is presented in next table.

Table 3.15 – Low Heating Value per fuel type

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

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

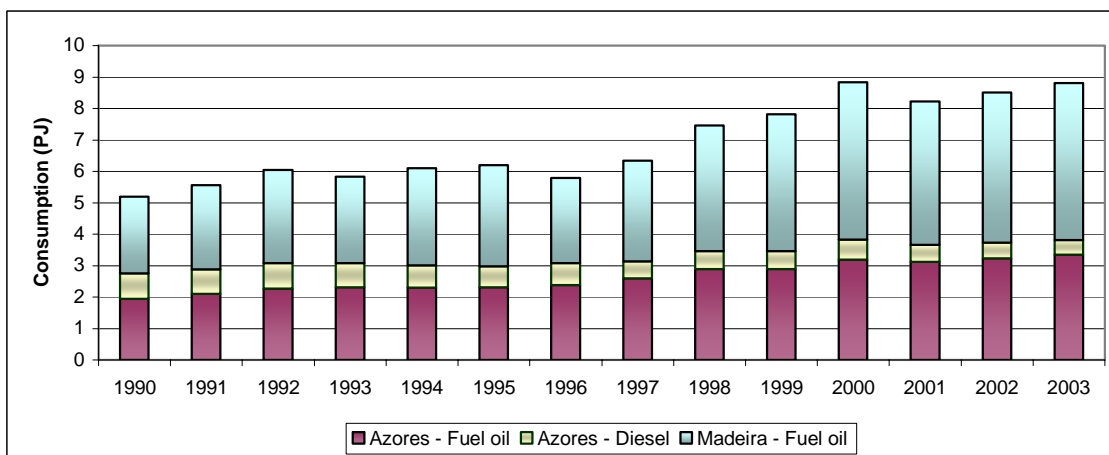
<sup>12</sup> Low Heating Value (LHV) or Net Calorific Values (NCV) measure the quantity of heat liberated by the complete combustion of a unit volume or mass of a fuel, assuming that the water resulting from combustion remains as a vapour and the heat of the vapour is not recovered (GPG). In contrast, 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 3.8 – Trends of fuel consumption per fuel type <sup>13</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 next figure. Figures for 2001, 2002 and 2003 are still provisional and result from a forecast based in 1990-2000 data using a linear interpolation.

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



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

<sup>13</sup> Time series not visible in the graph: Consumption of diesel oil in gas turbines increased from 29 TJ in 1990 to a peak value of 784 TJ in 2001 and thereafter decreased again until 510 TJ in 2003. Biomass (wood wastes) consumption was only 86 TJ in 1999, 147 TJ in 2000, 316 TJ in 2001, 555 TJ in 2002 and 700 TJ in 2003. Orimulsion and fuel-oil are represented together as Petroleum products.

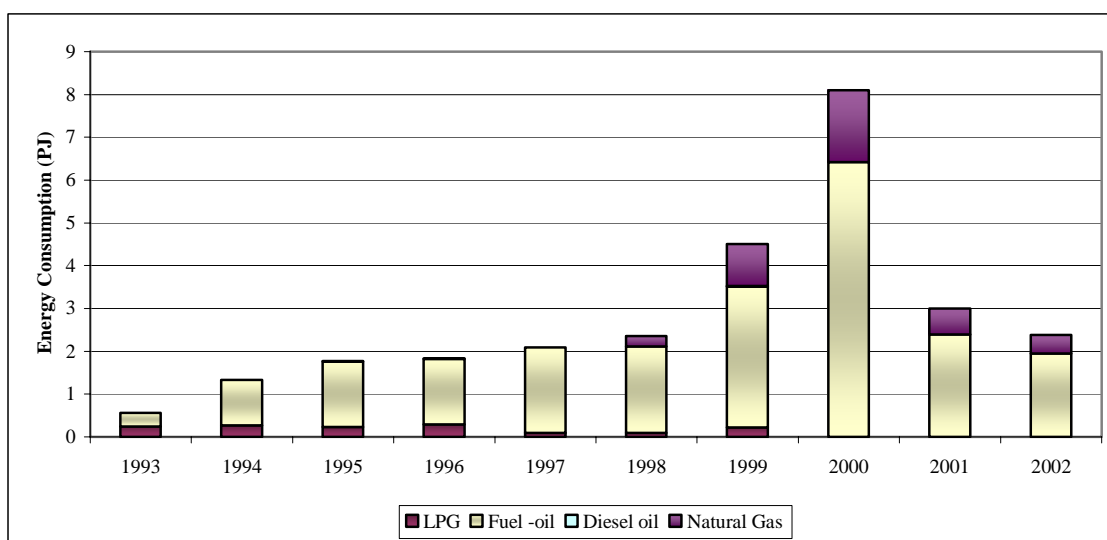
Table 3.16 - LHV per fuel type

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

### Non-public co-generation Energy Producers

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

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



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

Table 3.17 - LHV per fuel type used for non-public co-generation plants estimates

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

### UNCERTAINTY ASSESSMENT

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

- for LPS the uncertainty value was set at 1%, which is in the higher range of the uncertainty considered in GPG when good quality surveys are considered, which is the case;
- for area sources an uncertainty of 4 % was considered for this sector, which is fixed according to a conservative approach, considering the double of the upper range of the

values that IPCC proposes when data was obtained from surveys in a less developed statistical system. This conservativeness factor is used because the surveys were made indirectly to industrial plants via fuel suppliers.

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

## RECALCULATIONS

The most relevant change was the downward revision of CO<sub>2</sub> emission estimates, which was done in a consistent way for the all time series of all sub-sources, and as consequence of the incorporation in the methodology of the oxidation factor. Apart from that improvement in methodology toward the IPCC guidelines, there were no further modifications of activity data or emission factors for GHG. Concerning the non-GHG pollutants, the emission factors of NO<sub>x</sub> and Particulate Matter were revised with the consideration of plant specific emission factors for more power plant units, which were obtained from monitoring data.

## FURTHER IMPROVEMENTS

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

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

### 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, lubricants and aromatics (Benzene, Hexane, toluene, xylene, etc). Sines refinery, installed in 1978 in southern Portugal, has also extensive transformation of crude products after atmospheric and vacuum distillation, which are subjected to Fluid Catalytic Cracking (FCC), platforming, hydrocracking, alquilation and asphalts blowing. The now closed refinery at Lisbon performed mostly cracking. Refinery gas from this unit was used as combustible gas for domestic, service and industry use in Lisbon city.

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

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

## METHODOLOGY

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

As explained in more detailed for sector “Public Electricity and Heat Production”, emissions to atmosphere of total CO<sub>2</sub> and of ultimate CO<sub>2</sub> from fossil origin were estimated using the following equation set:

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

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

where,

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

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

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

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

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

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

For all other pollutants other than sulphur oxides (SO<sub>x</sub>) and Heavy Metals the following equation was applied to estimate air emissions:

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

Where

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

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

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

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

$$SOx_{(e,f,y)} = 2 * Fuel_{Cons(e,f,y)} * S_{(e,f,y)} * 10^{-2} * (1 - AshRet_{(e,f)} * 10^{-2})$$

Where

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

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

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

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

For emissions of Heavy Metals the following equation was used:

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

and,

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

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

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

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

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

## EMISSION FACTORS

The same set of emission factors was used for all three refineries and was set from international bibliography such as IPCC (1997), EMEP/CORINAIR (EEA,2002) and AP-42 (USEPA,1996b; USEPA, 1998b; USEPA,1991e; USEPA,1995c). The chosen Emission Factors are presented in Table 3.18 through Table 3.20 below.

Table 3.18 – Emission Factors for combustion sources in Refining of Petroleum Products. Greenhouse Gases.

Fuel	Equipment	$U_{CO_2}$ kg/GJ	$Fac_{CO_2}$ 0..1	Fossil <sub>c</sub> %	$CH_4$ g/GJ	$N_2O$ g/GJ
Fuel-oil	Boilers	77.4	0.990	100	2.9	0.6
	Furnaces	77.4	0.990	100	2.9	0.6
Fuel gas	Boilers	60.0	0.990	100	2.5	1.4
	Furnaces	60.0	0.990	100	2.5	1.4
LPG	Boilers	63.1	0.995	100	4	1.4
	Furnaces	63.1	0.995	100	4	1.4
Diesel oil	Engines	74.1	0.990	100	9.9	0.6

Table 3.19 – Emission Factors for combustion sources in Refining of Petroleum Products. Indirect Precursors, Particulate Matter and other pollutants

Fuel	Equipment	NO <sub>x</sub>	NM VOC	CO	PM	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>1.0</sub>
		g/GJ	g/GJ	g/GJ	g/GJ	%		
Fuel-oil	Boilers	180-190 <sup>(a)</sup>	3	15	66-135 <sup>(b)</sup>	86	56	36
	Furnaces	210	3	15	66-135 <sup>(b)</sup>			
Fuel gas	Boilers	140	2.5	17	3	100	100	100
	Furnaces	150	2.5	17	3			
LPG	Boilers	160	4	17	6.9	100	100	100
	Furnaces	160	4	17	6.9			
Diesel oil	Engines	1 100	100	12	6.6	50	12	8

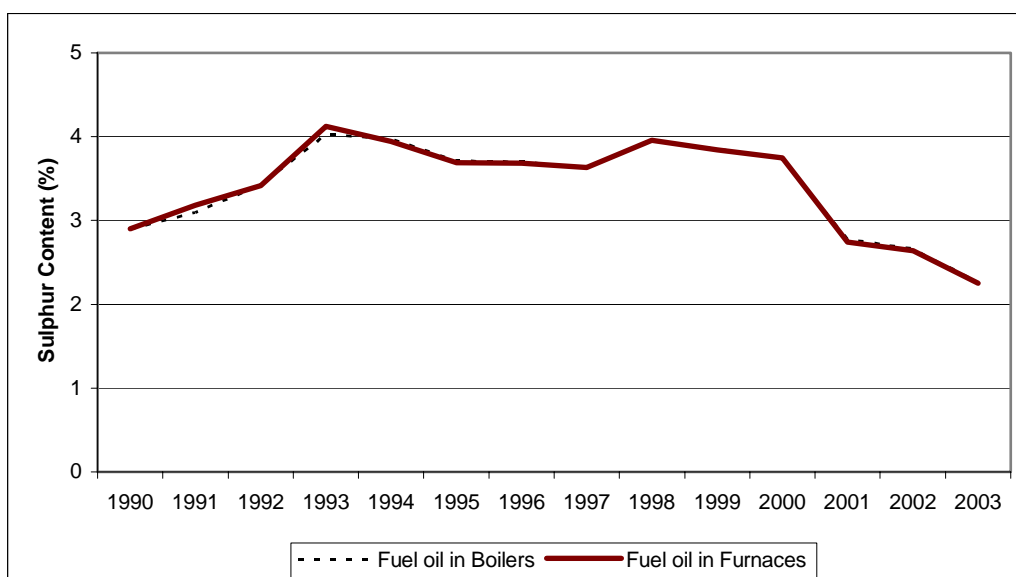
(a) variable according to equipment; (b) variable with sulphur content (AP-42)

Table 3.20 – Emission Factors for combustion sources in Refining of Petroleum Products. Heavy Metals

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

Composition of fuels, in what concern sulphur, were reported for each year and for each pollutant directly from refineries under the LCP directive. Weighted average values from 1990 to 2003 are reported in Figure 3.11 for fuel-oil and show a decrease since 1998. Fuel gas was reported to have no sulphur.

Figure 3.11 - Trends of sulphur content by fuel type



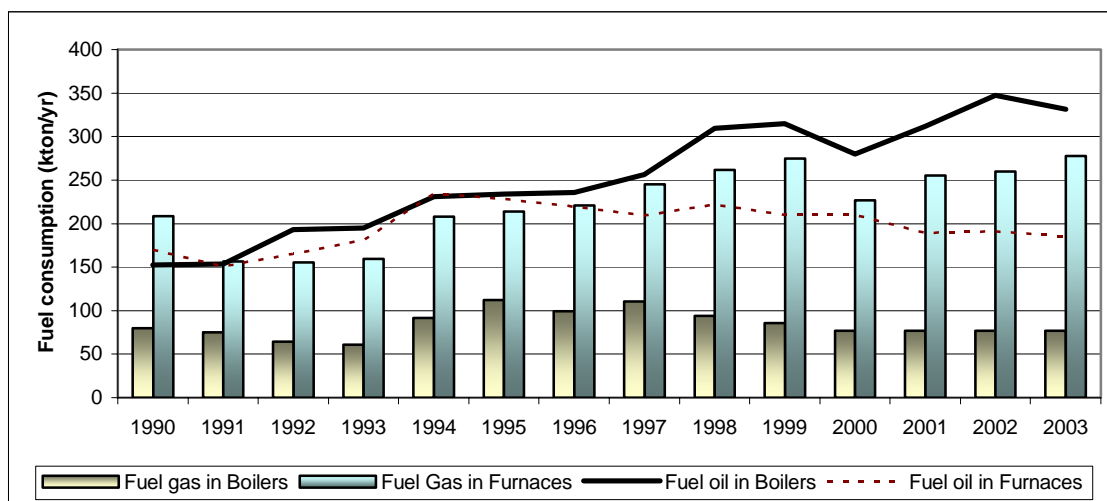
## ACTIVITY DATA

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

The three refinery units consume self produced residual fuel-oil<sup>14</sup>, fuel-gas, liquefied petroleum gases (LPG) and diesel oil.

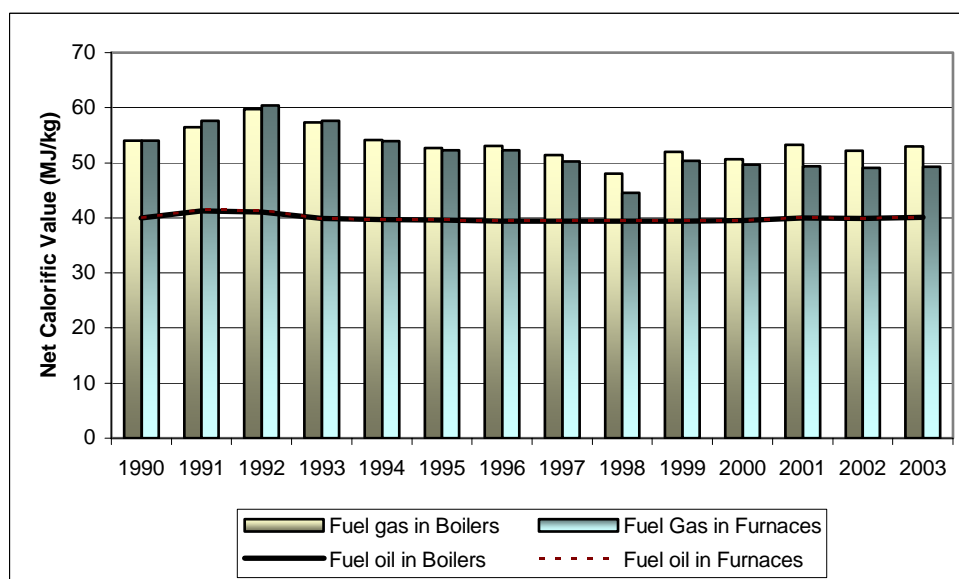
Values of fuel consumption from 1990 to 2003 in boilers and furnaces were collected directly from individual units under the Large Combustion Plants (LCP) directive and may be observed in Figure 3.12 for fuel oil and fuel gas. Use of other fuels such as diesel oil and LPG although included in inventory estimates are not at all significant and do not need to be reported here.

Figure 3.12 – Fuel consumption per year by type of equipment



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

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



<sup>14</sup> In strict terms this fuel is not traded and must not be named fuel-oil, to avoid confusion to traded fuel oil.



## UNCERTAINTY ASSESSMENT

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

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

## RECALCULATIONS

The only change that was made in emission estimates for the refinery sector was the incorporation of the Oxidation Factor in the calculation of CO<sub>2</sub> emission factors.

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

#### OVERVIEW

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

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

#### METHODOLOGY

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

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

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

where,

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

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

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

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

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

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

For all pollutants other than sulphur oxides (SO<sub>x</sub>) and Heavy Metals, the following equation was applied to estimate emissions:

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

where

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

$\text{Energy}_{\text{Cons}(y)}$  - 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 fuel consumption quantities and considering 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) or fuel f in city gas production (ton/yr);

S - Sulphur content of coke gas used in the coquerie (g S/Nm<sup>3</sup>) or sulphur fraction of fuel f in city gas production (0..1).

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

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

and,

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

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

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

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

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

## EMISSION FACTORS

Emissions factors for combustion of coke gas in the coquerie unit and in the city gas factory were set from IPCC96, EMEP/CORINAIR and AP-42. They are reported in Table 3.21.

Table 3.21 – Emission Factors used for the coquerie and city gas production

Source	Coquerie	City Gas Production			Unit
		FO	Naphta	NG	
U <sub>CO2</sub>	41	77	77	56	kg/GJ
Fac <sub>OX</sub>	0.995	0.990	0.990	0.995	ratio
Fossil <sub>C</sub>	100	100	100	100	%
CH <sub>4</sub>	2.5	2.9	2.9	1.4	g/GJ
N <sub>2</sub> O	1.40	0.60	0.60	1.40	
SO <sub>x</sub>	7.05 gS/Nm3	2.6-2.9	0.1	0.0007	% S
NO <sub>x</sub>	120	160	160	100	
NM VOC	2.5	3.0	3.0	5.0	g/GJ
CO	17	15	15	13	
PST	3	85	6.5	0.8	
PM <sub>10</sub>	95.9	86.0	50.0	100	
PM <sub>2.5</sub>	93.5	56.0	12.0	100	% PST
PM <sub>1</sub>	77.4	36.0	8.0	100	
Cd	NE	6.84E-01	2.55E-01	1.76E-05	
Hg	NE	5.07E-01	0.00E+00	4.18E-03	
Ar	NE	5.56E-01	0.00E+00	3.20E-06	
Cr	NE	1.70E+00	5.00E-02	2.24E-05	g/t
Cu	NE	7.41E-01	1.10E+00	1.36E-05	
Ni	NE	2.69E+01	2.85E-01	3.36E-05	
Se	NE	6.84E-02	3.00E-02	3.84E-07	

## ACTIVITY DATA

### Coke Production

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

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

where

Coquerie<sub>CONS(y)</sub> - consumption of coke gas in the coquerie in year y;

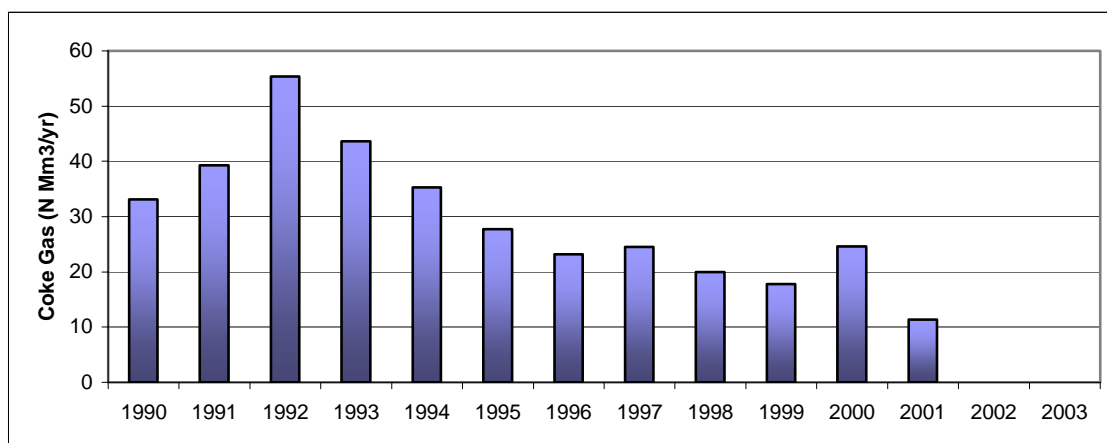
Coquerie<sub>CONS(91-94)</sub> - consumption of coke gas in the coquerie from 1990 till 1994;

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

TotalPlant<sub>CONS(y)</sub> - total consumption of coke gas in year y.

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

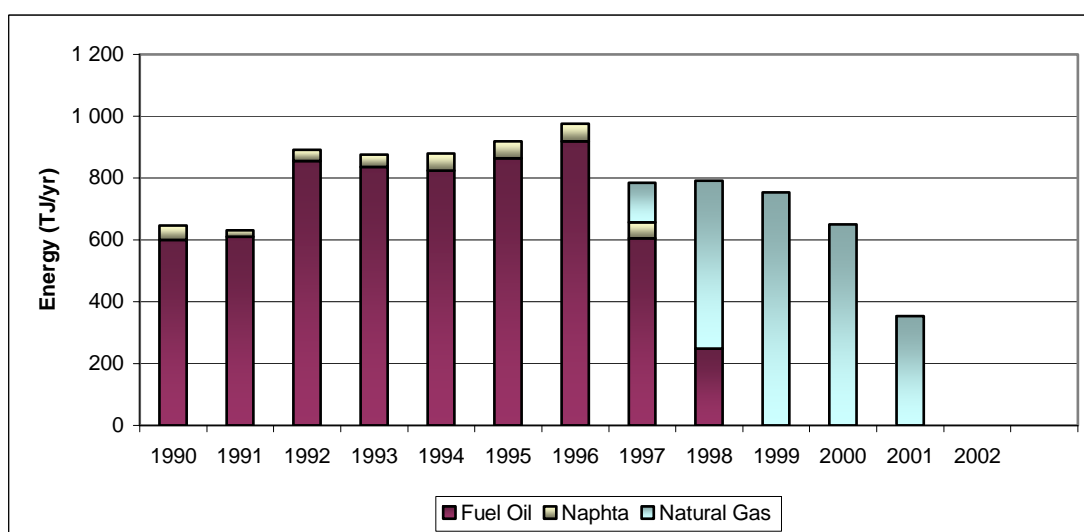
Figure 3.14 – Coke gas consumption in the coquerie: 1990-2003



### City Gas Production

According to the energy balances from DGGE, this activity has used fuel oil, naphta and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001<sup>15</sup>. The available time series is presented in Figure 3.15.

Figure 3.15 – Consumption of fuels in co-generation in city gas production 1990-2003



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

<sup>15</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 3.22 – NCV/LHV per fuel type for city gas production

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

## UNCERTAINTY ASSESSMENT

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

In a similar way to all other stationary combustion sources, the uncertainty associated with the CO<sub>2</sub> emission factor was set at 5%, which is the value proposed for traded fuels (IPCC,2000), and the uncertainty values for methane and nitrous oxide, are in accordance with the GPG proposed values, 150 % for CH<sub>4</sub> and 1000% for N<sub>2</sub>O.

## RECALCULATIONS

Estimates of combustion emissions for the extraction of coal were moved to source sector 1A2, in accordance of the revision that DGGE made in the energy balances.

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

Emissions covered in this source category are those resulting from combustion activities in manufacturing industry and building and construction industry, excluding decarbonising emissions of 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 combustion emissions of the industry sector: boilers, process dedicated fuel combustion in furnaces and kilns and all emissions originated in co-generation units<sup>16</sup>.

### 3.2.B.1 METHODOLOGY

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

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

<sup>16</sup> Only when the co-generation activity is reported to the energy balance as referring to the manufacturing industry. When economic activity is referred as Energy Production then emissions are included in source category CRF 1a1a (See chapter 3.2.A.1 for further explanations).

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

$$U_{CO_2(y)} = 44/12 * EF_C * Fac_{OX(f)} * Energy_{Cons(u,f,y)} * 10^{-3}$$

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

where,

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

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

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

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

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

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

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

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

where:

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

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

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

When in the production process occurs 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 licquor), 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).

Emissions of SO<sub>x</sub> are directly related to the sulphur content of the fuel<sup>17</sup>. Estimates for SO<sub>x</sub> were calculated assuming that there were no abatement technologies. The following equation applies:

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

where:

$Em_{SO_x}$  - 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);

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

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

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

and,

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

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

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

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

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

The following scheme was therefore used:

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

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

<sup>17</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 were estimated based on production data or consumption of energy obtained for each individual industrial plant, according to the original units of the emission factors. For this sector most emission factors are plant specific and obtained from information monitored at industrial plants. The remaining fuel use in this sector, that in cement production and in equipments other than kilns, is converted into emission using the general purpose emission factors (energy approach). Carbon dioxide originated from decarbonising of limestone and dolomite is quantified in production processes and reported in CRF sector 2A;

- Emissions of SO<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 and reported in CRF sector 2;

- 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 resulting from the iron and steel industry, were estimated using the energy approach. For simplicity activity data and emission factors for this source are discussed in chapter 4.3.3.1 – Industrial Processes: Iron and Steel Production.

### 3.2.B.2 ACTIVITY DATA

Activity data comprehends consumption of fuels and industrial production rates.

### COMBUSTION DATA

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

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

Where,



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

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

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

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

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

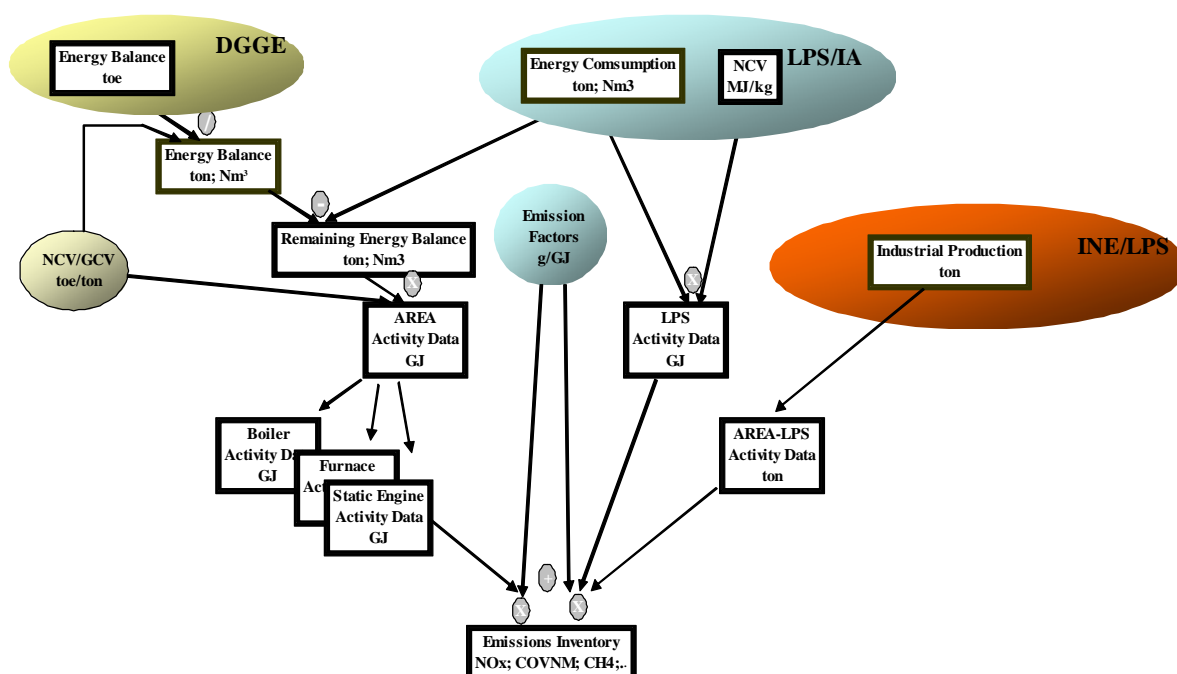
$Frac_{Equi(s,f)}$  – fraction of consumption of fuel  $f$  in sector  $s$  that is used in equipment  $e$  (0..1);

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

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

$LHV_{AREA(f,s,e)}$  – Low Heating Value/ Net Calorific Value used in the Inventory for fuel  $f$  in equipment  $e$  for area sources (combustion in non LPS) (MJ/kg or MJ/ $Nm^3$ )<sup>18</sup>.

Figure 3.16 – General procedure for emissions estimate



<sup>18</sup> In most cases similar values to Energy Balance are used

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

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 six LCP units summed together.

Table 3.23 – Low Heating Values (LHV/NCV) in the Iron and Steel Industry (MJ/kg)

LPG	Kerosene	Gas Oil	Residual Oil	Natural Gas	Coke oven gas (MJ/Nm <sup>3</sup> )	Blast furnace gas (MJ/Nm <sup>3</sup> )	Tar	Gasoline
46.1-47.3	43.7	43.3	40.2-40.35	38.7	18.78	2.87	34.1	44.8

Table 3.24 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (1/2)

Year	LPG	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas
1990	461 183	1 342	22 985	1 231 825	0
1991	452 052	1 630	14 950	323 588	0
1992	520 339	1 349	16 393	338 976	0
1993	598 721	1 787	18 807	1 211 575	0
1994	594 734	2 890	16 258	1 136 114	0
1995	602 784	2 915	15 671	941 816	0
1996	558 584	2 809	17 333	984 083	0
1997	408 806	3 293	5 663	941 594	205 705
1998	280 599	3 156	6 792	623 019	673 357
1999	326 145	2 925	6 898	712 034	723 011
2000	410 522	586	7 796	821 247	937 138
2001	395 179	0	7 999	748 872	992 909
2002	351 303	0	9 581	737 769	986 044
2003	239 687	0	13 896	640 649	1 338 709

Table 3.25 – Fuel consumption in the Iron and Steel industry in boilers and furnaces (GJ) (2/2)

Year	Coke oven gas (GJ)	Blast furnace gas (GJ)	FO 1% (GJ)	Tar (GJ)	Waste oils (GJ)
1990	1 041 796	1 460 387	0	341 000	40 348
1991	1 525 059	1 244 462	0	357 845	1 210
1992	1 943 130	2 079 874	0	388 263	0
1993	1 753 741	2 158 502	158 588	311 278	0
1994	1 562 652	1 981 945	0	227 791	0
1995	1 175 219	1 343 038	0	272 878	7 318
1996	1 211 854	1 306 474	0	198 643	5 608
1997	1 715 874	1 585 069	0	300 377	8 282
1998	1 655 684	1 396 770	0	251 115	7 196
1999	1 626 560	1 453 276	0	281 529	8 401
2000	1 856 360	1 746 675	0	333 420	10 255
2001	1 455 916	1 547 215	0	333 420	10 255
2002	0	0	0	333 420	10 255
2003	0	0	0	333 420	10 255

Table 3.26 – Fuel consumption in the Iron and Steel industry in Static Engines (GJ)

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

Figure 3.17 – Total Energy Consumption in the Iron and Steel Industry between 1990 and 2003

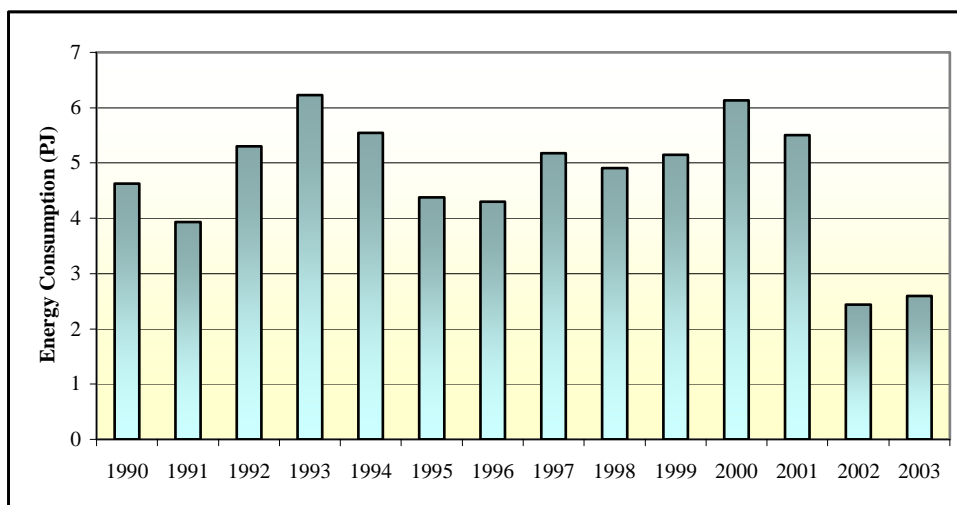


Figure 3.18 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2003

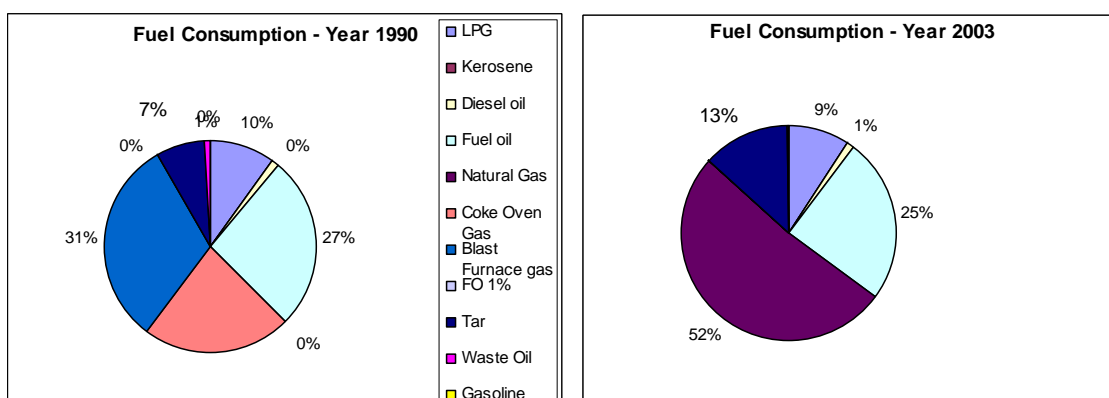


Table 3.27 – Low Heating Values (LHV/NCV) values in Metallurgy Industry

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

Table 3.28 – Fuel Consumption in Metallurgy Industry – Boilers and Furnaces (GJ)

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

Table 3.29 – Fuel Consumption in Metallurgy Industry – Static Engines (GJ)

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

Figure 3.19 – Total Energy Consumption in the Metallurgy Industry between 1990 and 2003

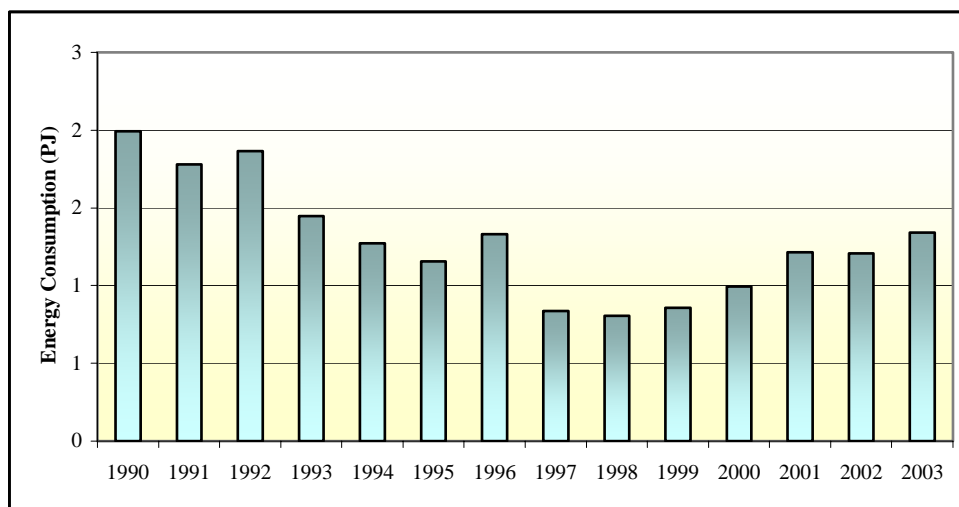


Figure 3.20 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2003

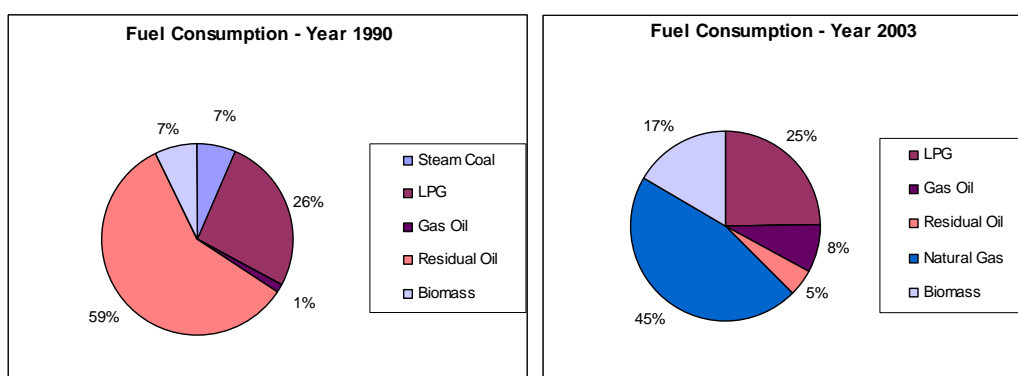


Table 3.30 – Low Heating Values (LHV/NCV) values in Chemical and Plastics Industry

	Coal	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil <sup>19</sup>	Natural Gas (GJ/KNm <sup>3</sup> )	Biomass	Fuel Gas <sup>20</sup>
LHV (MJ/kg)	29.3	47.3	44.8	43.7	43.3	39.3-40.2	38.7	12.6	2.0-52.8

<sup>19</sup> Including non commercial residual fuel oils as intermediate products in the chemical industry

<sup>20</sup> Several streams of intermediate gaseous products and tail gases that are used as energy source

Table 3.31 - Fuel consumption in Chemical and Plastics Industry – Boilers and Furnaces (GJ)

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

Table 3.32 - Fuel consumption in Chemical and Plastics Industry – Static Engines (GJ)

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

Figure 3.21 – Total Energy Consumption in the Chemical and Plastic Industry between 1990 and 2003

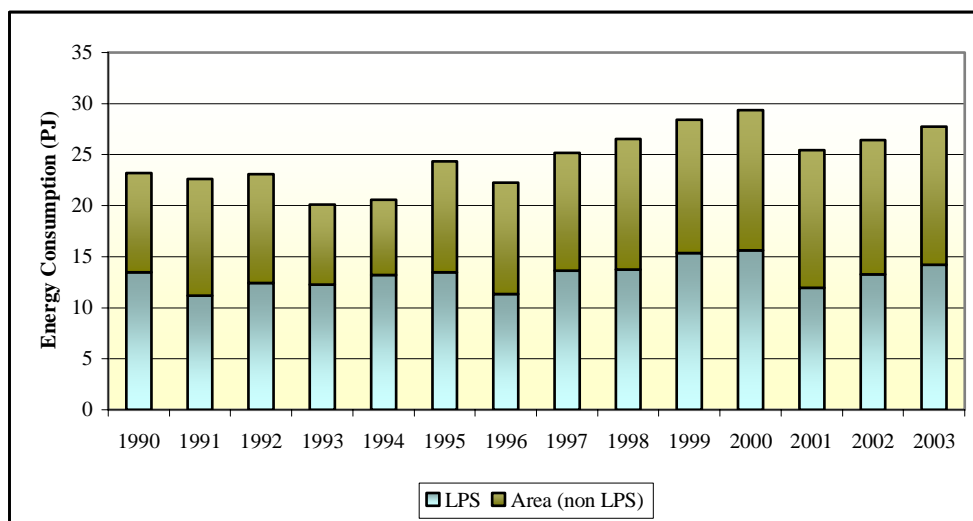


Figure 3.22 - Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2003

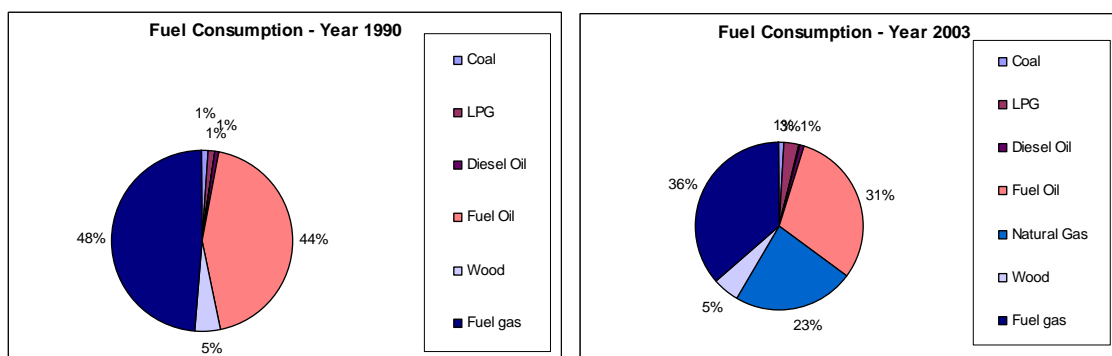


Table 3.33 – Low Heating Values (LHV/NCV) values in Paper and Paper Pulp Industry (MJ/kg)

LPG	Gasoline	Kerosene	Diesel Oil	Residual Fuel Oil	Natural Gas (GJ/KNm <sup>3</sup> )	Wood & Wood Wastes	Liquor	Biogas	Other <sup>21</sup>
47.3	44.8	43.7	43.3	39.7-40.2	38.7	10.5-20.3	7.4-16.6	34.7	34.2-52.7

<sup>21</sup> Tall Oil, non condensable gases and other sub-products



Table 3.34 - Fuel consumption in Paper and Paper Pulp Industry – Boilers and Furnaces (GJ)

Year	LPG (GJ)	Kerosene (GJ)	Gas Oil (GJ)	Residual Oil (GJ)	Natural Gas (GJ)	Liquors (GJ)	Wood & W. wastes (GJ)	Other (GJ)
1990	103 357	7	90 115	9 445 240	0	24 607 749	5 105 745	39 843
1991	190 436	51	78 814	10 256 575	0	28 333 851	5 982 805	353 670
1992	236 264	32	76 148	11 226 864	0	28 687 604	7 348 581	364 647
1993	199 374	7	70 927	11 614 769	0	27 141 730	8 660 247	350 407
1994	271 869	4	66 278	13 357 405	0	26 583 344	6 868 103	374 799
1995	282 906	23	72 499	11 179 480	0	27 204 795	7 656 588	378 662
1996	301 572	5	71 699	12 159 666	0	27 078 923	7 115 364	380 045
1997	325 960	6	80 280	12 433 356	0	30 006 253	7 684 886	381 443
1998	345 875	0	60 994	11 822 305	7 065	29 923 805	7 616 532	382 292
1999	265 142	0	59 581	11 954 494	305 186	30 849 031	8 180 982	382 096
2000	248 947	26	54 727	12 609 863	2 145 436	32 197 744	6 823 719	376 907
2001	240 115	109	79 587	9 734 393	4 342 236	32 379 039	6 221 961	439 571
2002	103 112	78	76 841	8 893 070	5 232 845	33 061 888	6 852 148	456 284
2003	99 442	79	77 100	8 003 064	5 981 049	33 744 737	5 909 725	472 998

Table 3.35 - Fuel consumption in Paper and Paper Pulp Industry – Static Engines (GJ)

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

Figure 3.23 – Total Energy Consumption in the Paper and Paper Pulp Industry between 1990 and 2003

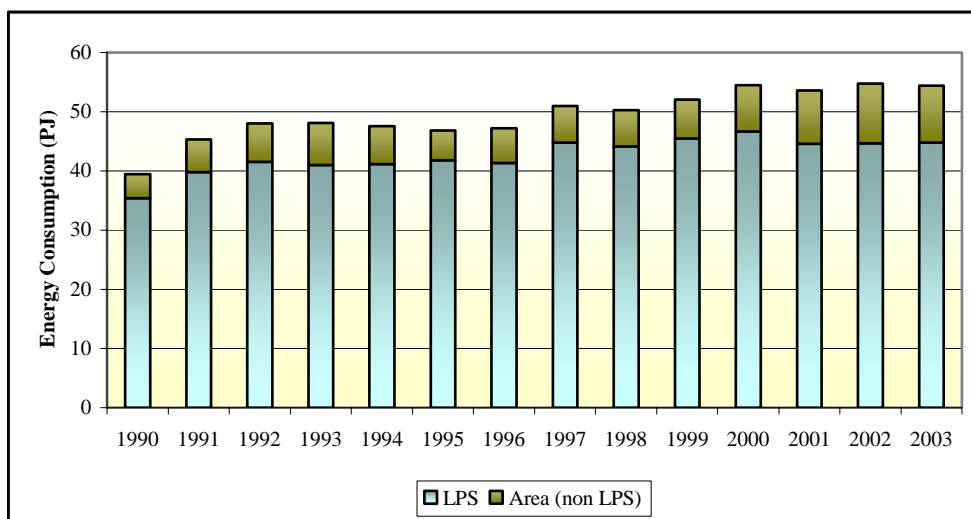


Figure 3.24 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2003

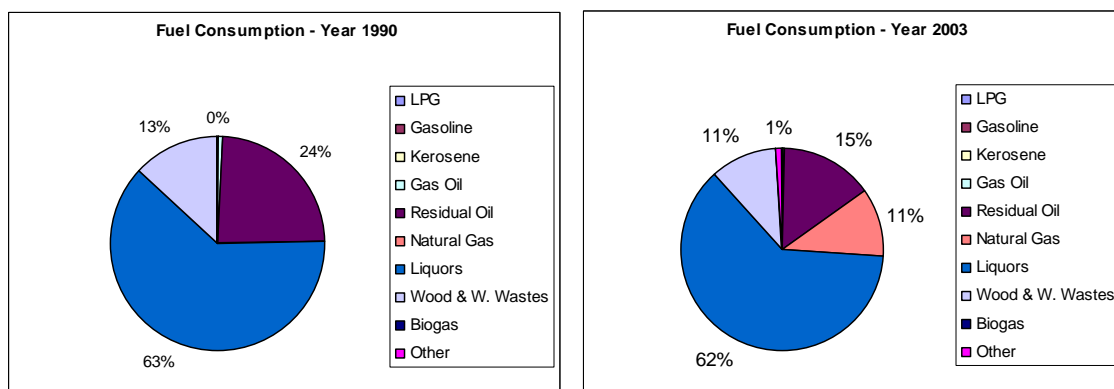


Table 3.36 – Low Heating Values (LHV/NCV) values in Food processing, Beverages and Tobacco Industries

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

Table 3.37 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

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

Table 3.38 – Fuel consumption in Food processing, Beverages and Tobacco Industries – Static Engines

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

Figure 3.25 – Total Energy Consumption in the Food processing, Beverages and Tobacco Industry between 1990 and 2003

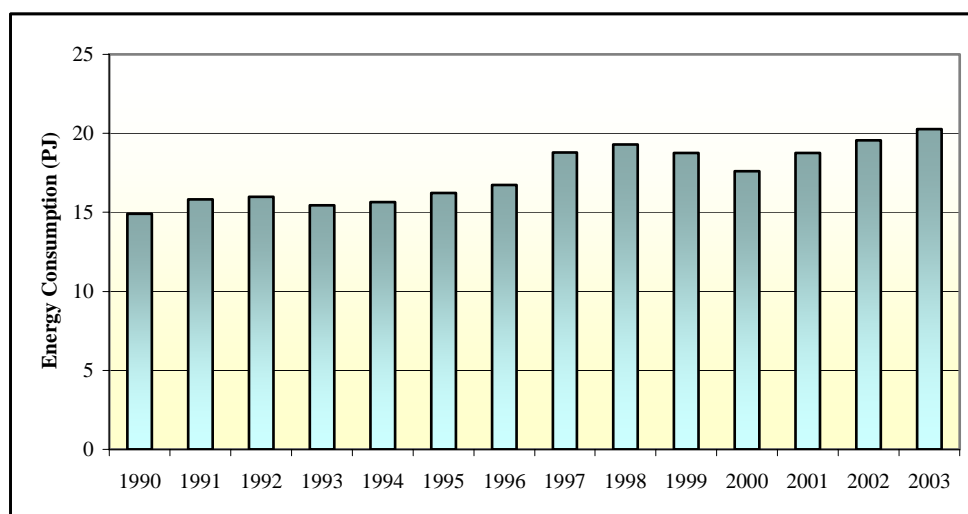


Figure 3.26 - Fuel consumption per fuel type in the Food processing, Beverages and Tobacco Industries in 1990 and 2003

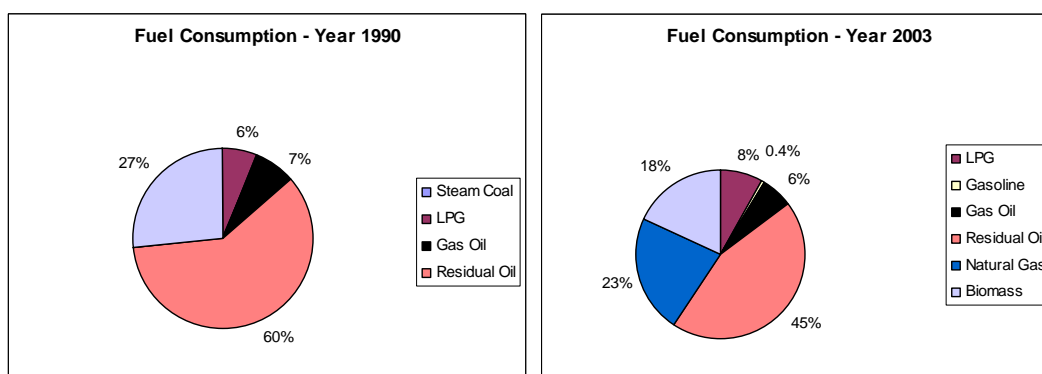


Table 3.39 – Low Heating Values (LHV/NCV) values in Textile Industry

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

Table 3.40 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces

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

Table 3.41 – Fuel consumption in Textile Industry – Static Engines

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

Figure 3.27 – Total Energy Consumption in the Textile Industry between 1990 and 2003

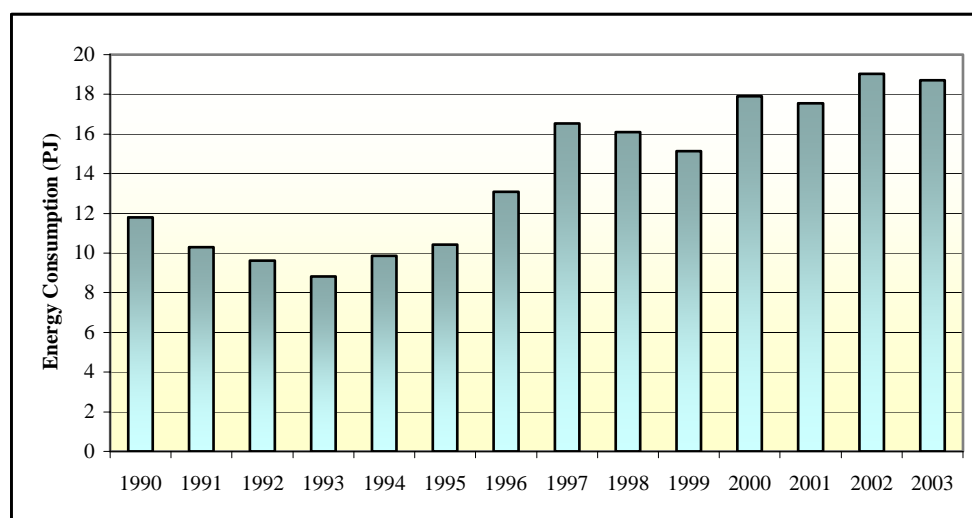


Figure 3.28 – Fuel consumption per fuel type in Textile Industry in 1990 and 2003

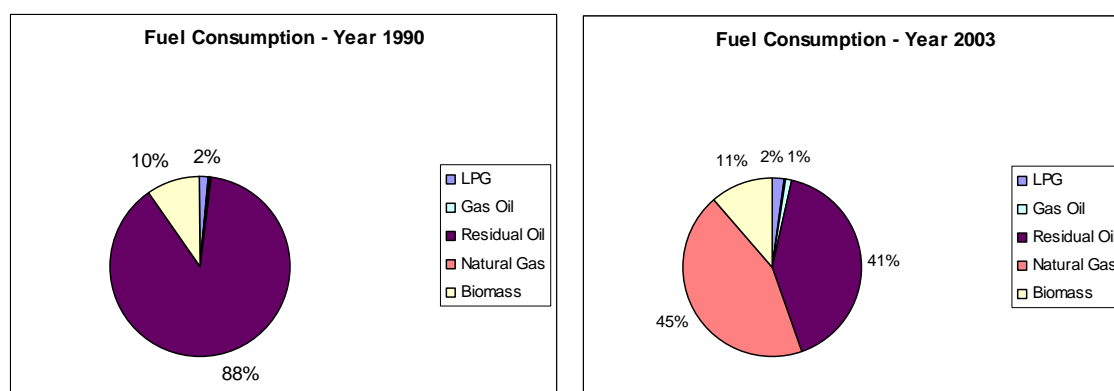


Table 3.42 – Low Heating Values (LHV/NCV) values in Ceramic Industry

	Steam Coal	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm3)	Biomass
LHV (MJ/kg)	29.3	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.43 - Fuel consumption in Ceramic Industry – Boilers and Furnaces

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

Table 3.44 – Fuel consumption in Ceramic Industry – Static Engines

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

Figure 3.29 – Total Energy Consumption in the Ceramic Industry between 1990 and 2003

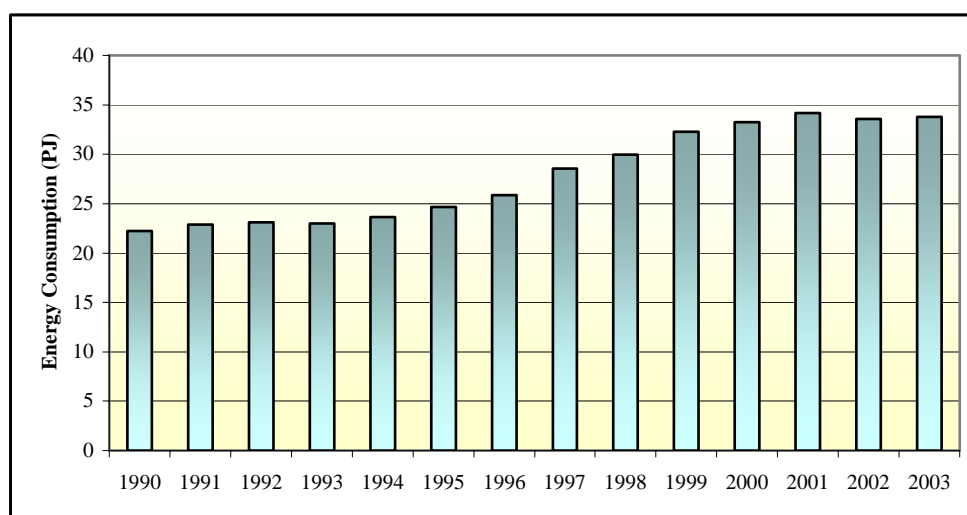


Figure 3.30 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2003

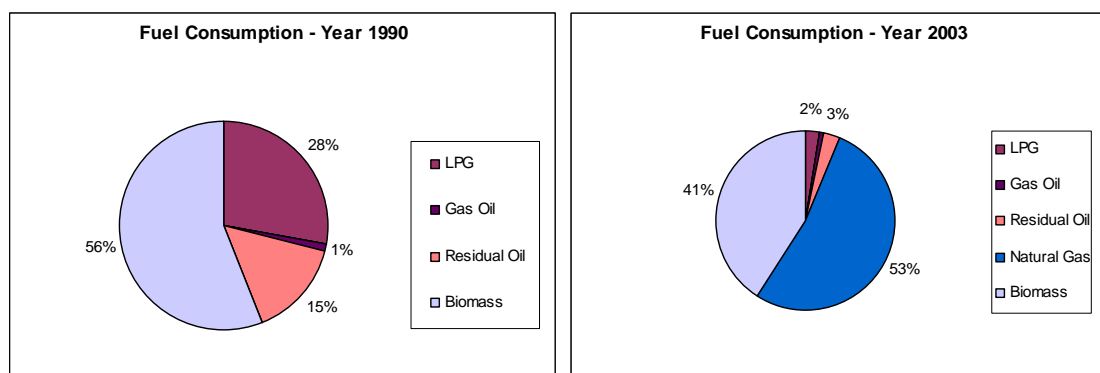


Table 3.45 – Low Heating Values (LHV/NCV) values in the Glass Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.46 – Fuel consumption in the Glass Industry – Boilers and Furnaces

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



Table 3.47 – Fuel consumption in the Glass Industry – Static Engines

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

Figure 3.31 – Total Energy Consumption in the Glass Industry between 1990 and 2003

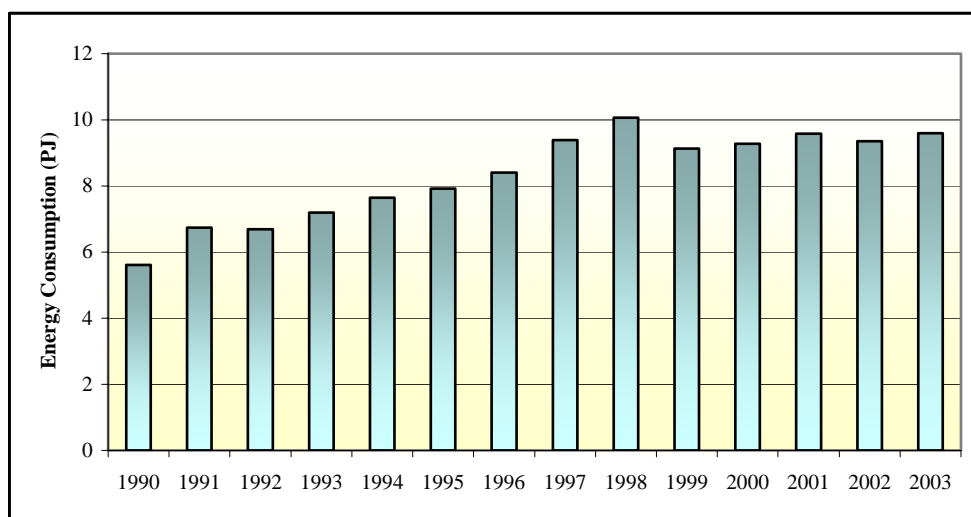


Figure 3.32 – Fuel consumption per fuel type in Glass Industry in 1990 and 2003

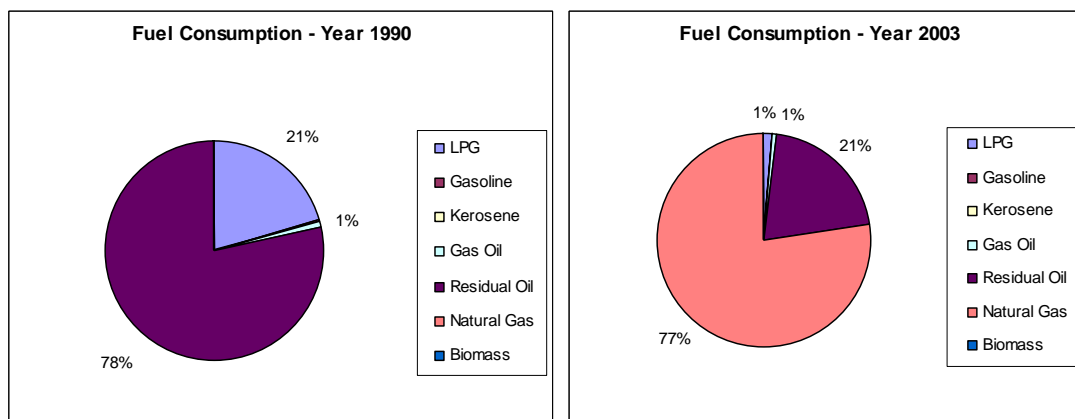


Table 3.48 – Low Heating Values (LHV/NCV) in the Cement Industry (MJ/kg)

Steam Coal	Coke	Old Tires	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm3)	Biomass
26.2	27.0	23.9	47.3	44.8	43.7	43.3	40.2	38.7	12.6

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

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

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

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

Figure 3.33 – Total Energy Consumption in the Cement Industry between 1990 and 2003

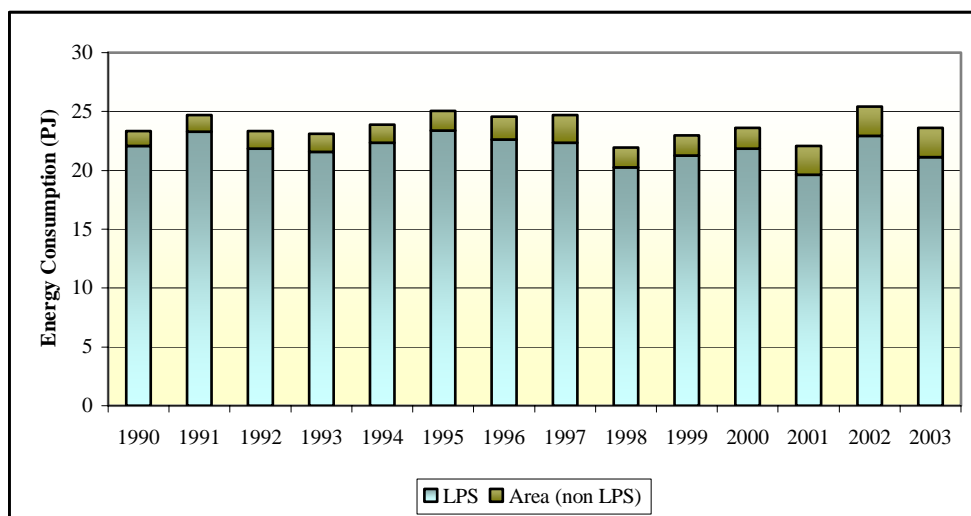


Figure 3.34 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2003

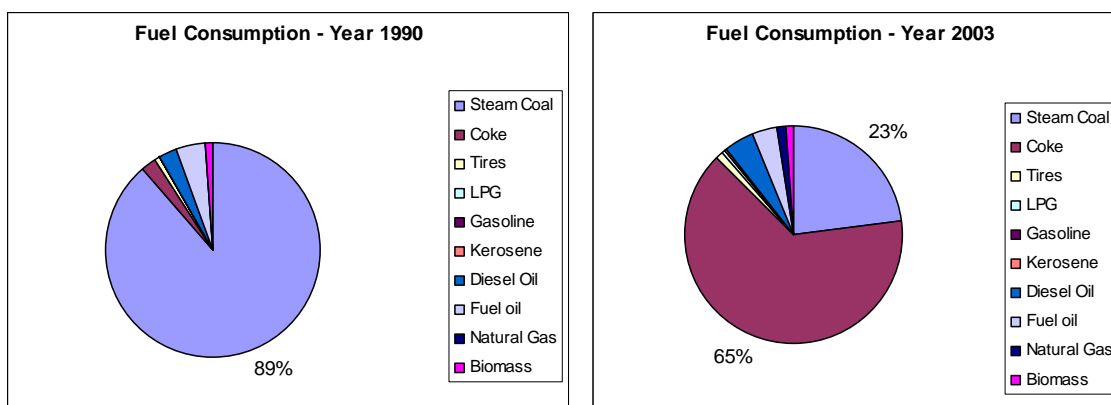


Table 3.51 – Low Heating Values (LHV/NCV) in clothing, shoes and leather Industry

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

Table 3.52 – Fuel consumption in the clothing, shoes and leather Industry – Boilers and Furnaces (GJ)

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

Table 3.53 – Fuel consumption in the clothing, shoes and leather Industry – Static Engines (GJ)

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

Figure 3.35 – Total Energy Consumption in the clothing, shoes and leather Industry between 1990 and 2003

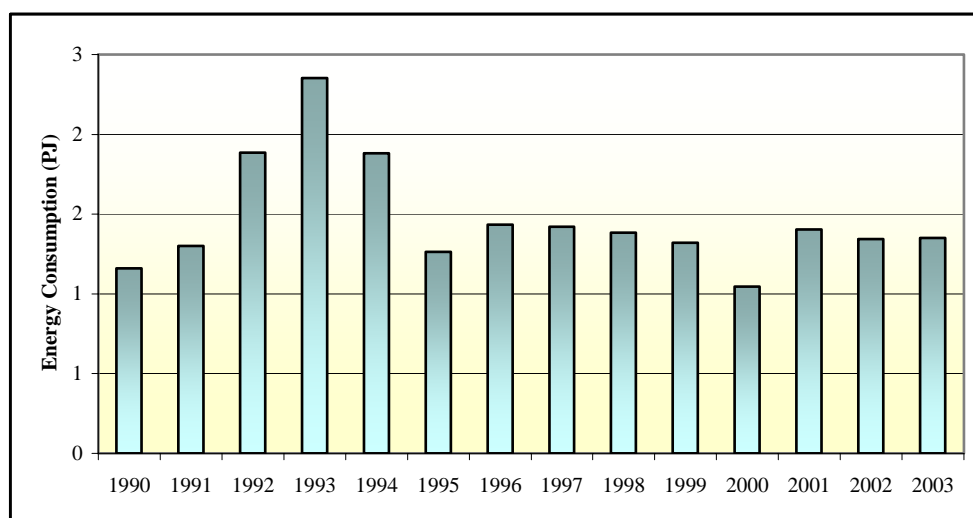


Figure 3.36 - Fuel consumption per fuel type in the clothing, shoes and leather Industry in 1990 and 2003

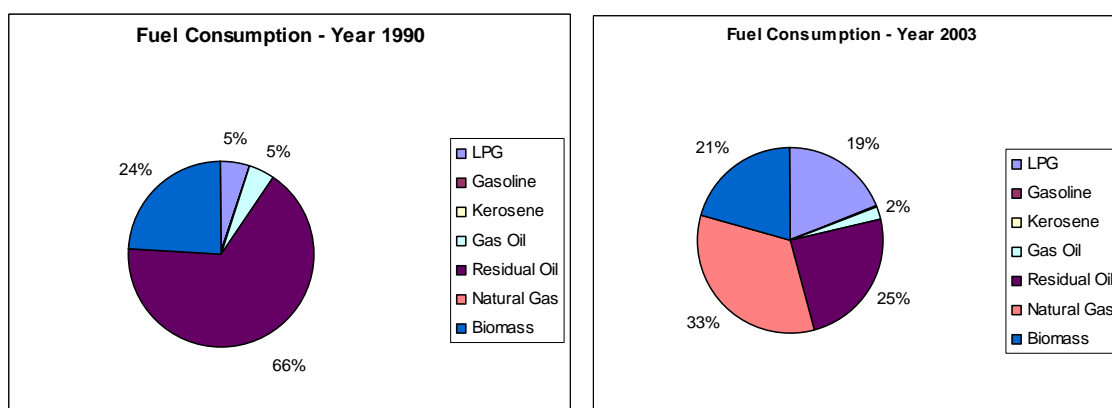


Table 3.54 – Low Heating Values (LHV/NCV) in the Wood Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.55 – Fuel consumption in the Wood Industry – Boilers and Furnaces (GJ)

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

Table 3.56 – Fuel consumption in the Wood Industry – Static Engines (GJ)

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

Figure 3.37 – Total Energy Consumption in the Wood Industry between 1990 and 2003

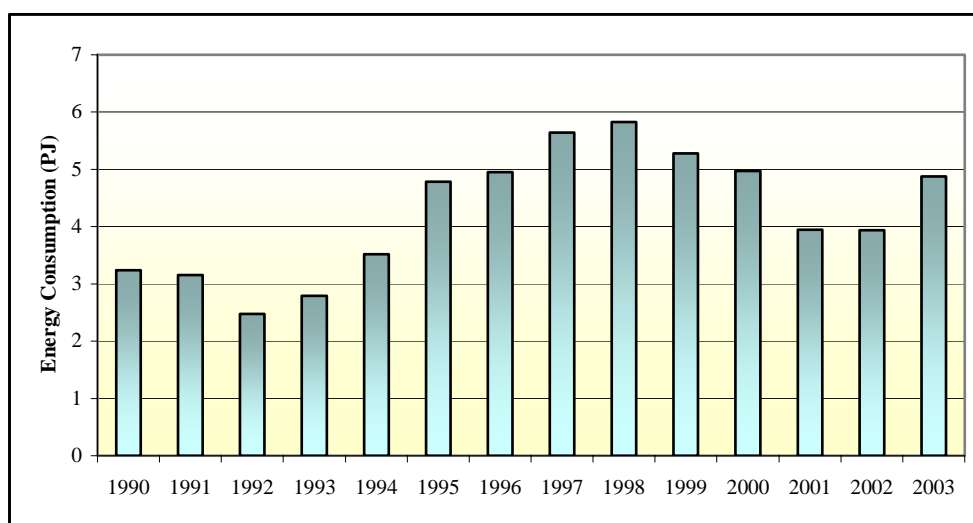


Figure 3.38 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2003

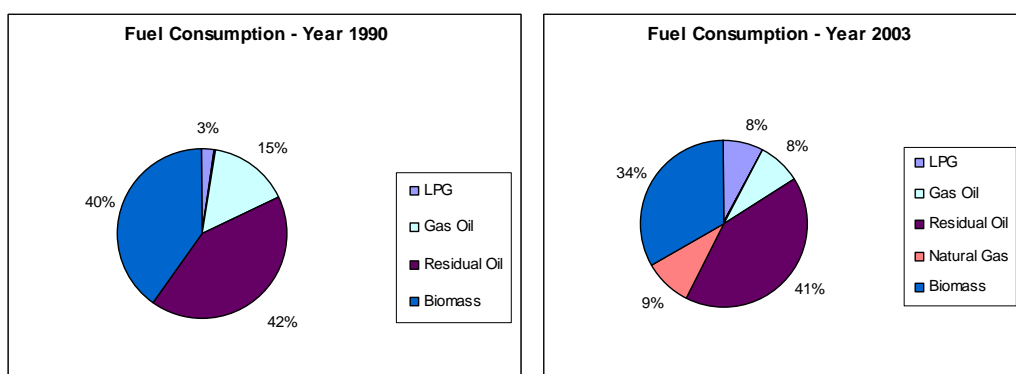


Table 3.57 – Low Heating Values (LHV/NCV) in the Rubber Industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

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

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

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

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



Figure 3.39 – Total Energy Consumption in the Rubber Industry between 1990 and 2003

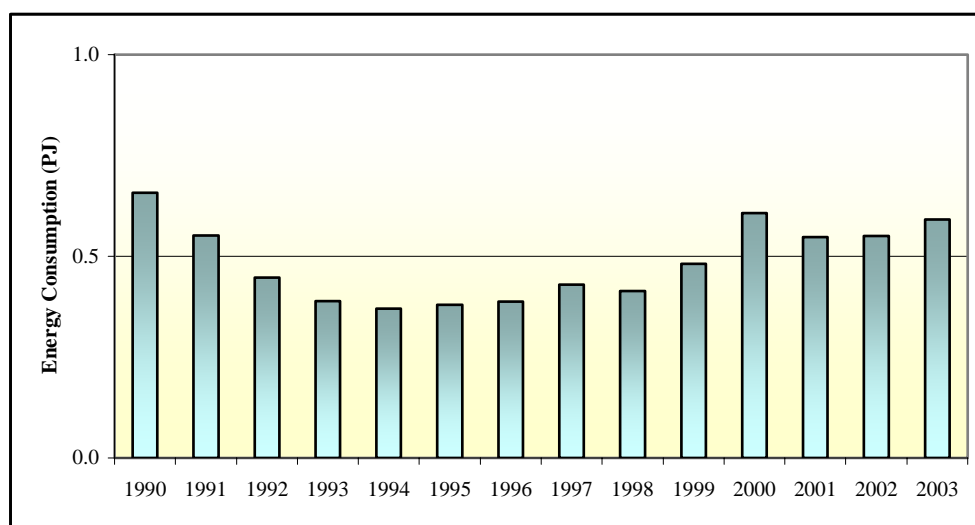


Figure 3.40 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2003

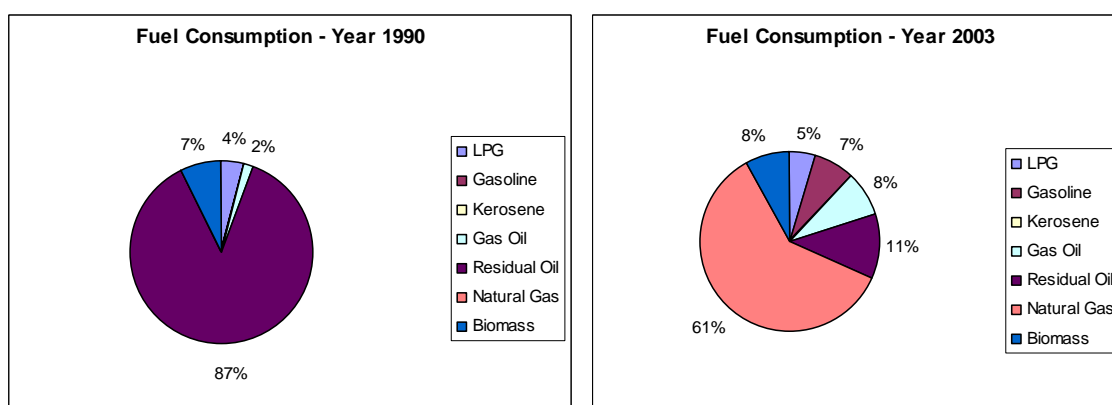


Table 3.60 – Low Heating Values (LHV/NCV) in the Manufacturing of Machines and Metallic Equipments Industry (GJ)

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

Table 3.61– Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Boilers and Furnaces (GJ)

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

Table 3.62 – Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Static Engines (GJ)

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

Figure 3.41 – Total Energy Consumption in the Manufacturing of Machines and Metallic Equipments Industry between 1990 and 2003

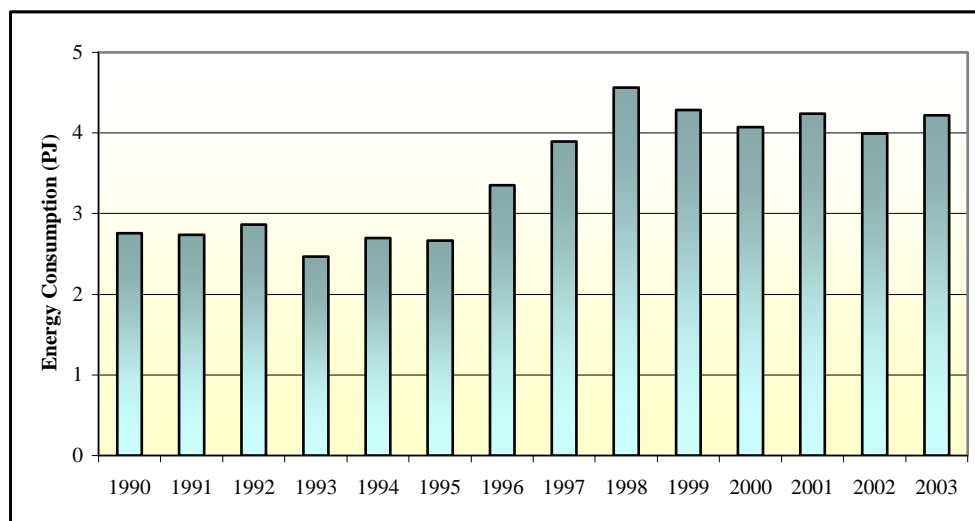


Figure 3.42 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2003

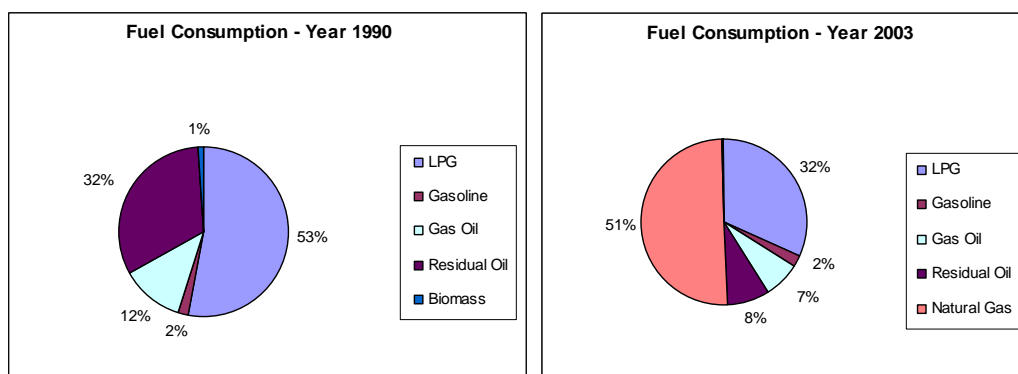


Table 3.63 – Low Heating Values (LHV/NCV) in other transformation industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/KNm3)	Biomass
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	38.7	12.6

Table 3.64 – Fuel consumption in other transformation industry – Boilers and Furnaces (GJ)

Year	LPG (GJ)	Kerosene (GJ)	Gas Oil (GJ)	Residual Oil (GJ)	Natural Gas (GJ)	Biomass (GJ)
1990	152 386	4 088	169 274	1 449 574	0	6 234
1991	203 448	3 982	219 224	1 386 088	0	6 109
1992	234 555	3 310	238 538	1 260 654	0	6 025
1993	340 825	2 197	363 460	938 562	0	5 900
1994	395 903	1 008	292 137	811 178	0	5 900
1995	430 781	37	180 548	168 320	0	5 900
1996	490 663	1 051	262 280	179 097	0	6 276
1997	114 667	0	20 021	331	0	6 276
1998	96 638	0	31 761	0	429	6 289
1999	128 737	0	27 403	0	18 688	6 276
2000	79 442	0	17 835	0	111 958	6 276
2001	49 970	30	24 944	0	148 858	6 276
2002	40 456	0	8 164	0	154 903	6 276
2003	33 267	0	7 449	0	209 904	33 985

Table 3.65 – Fuel consumption in other transformation industry – Static Engines (GJ)

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

Figure 3.43 – Total Energy Consumption in other transformation Industry between 1990 and 2003

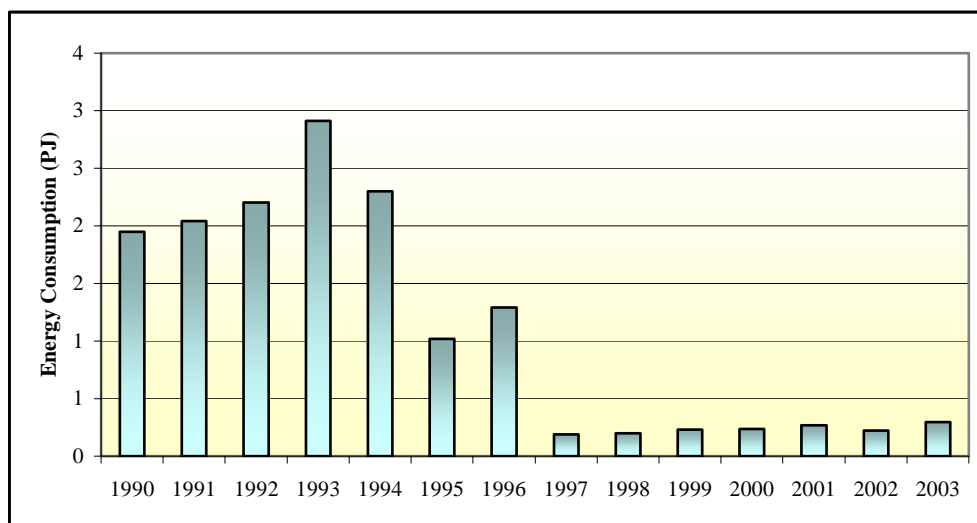


Figure 3.44 – Fuel consumption per fuel type in other transformation industry in 1990 and 2003

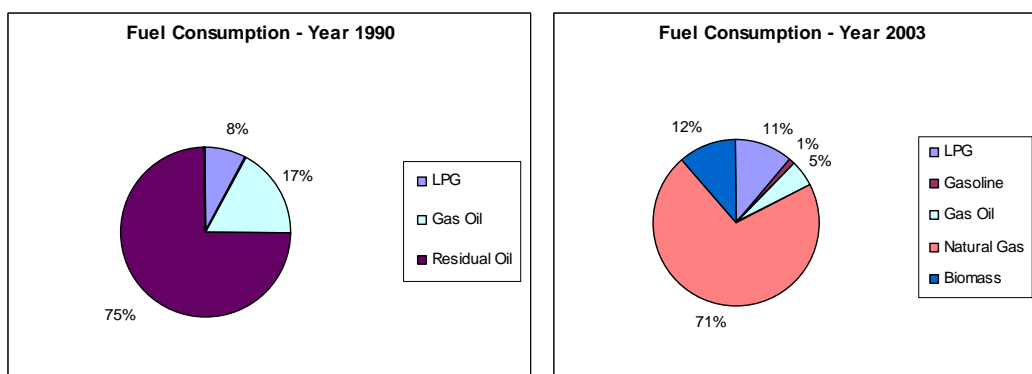


Table 3.66 – Low Heating Values (LHV/NCV) in the extractive industry

	LPG	Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas (GJ/kNm <sup>3</sup> )	Brown Coal
LHV (MJ/kg)	47.3	44.8	43.7	43.3	40.2	46.0	17.2

Table 3.67 – Fuel consumption in the extractive industry – Boilers and Furnaces

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

Table 3.68– Fuel consumption in the extractive industry – Static Engines

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

Figure 3.45 – Total Energy Consumption in the Extractive Industry between 1990 and 2003

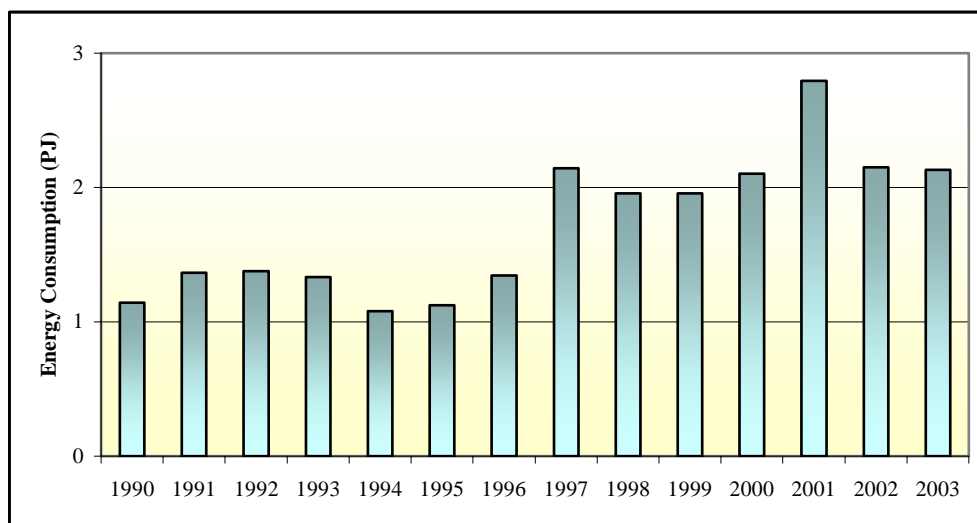


Figure 3.46– Fuel consumption per fuel type in the extractive industry in 1990 and 2003

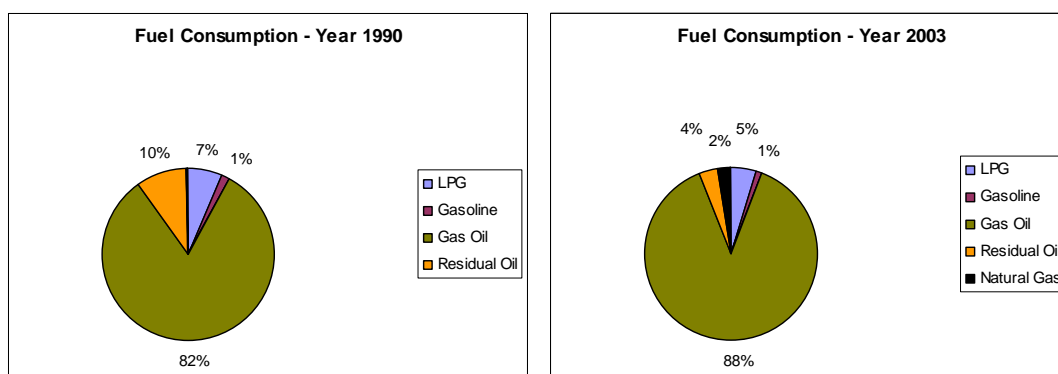


Table 3.69 – Fuel consumption in Construction and Building Industry

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

Figure 3.47 – Total Energy Consumption in the Construction and Building Industry between 1990 and 2003

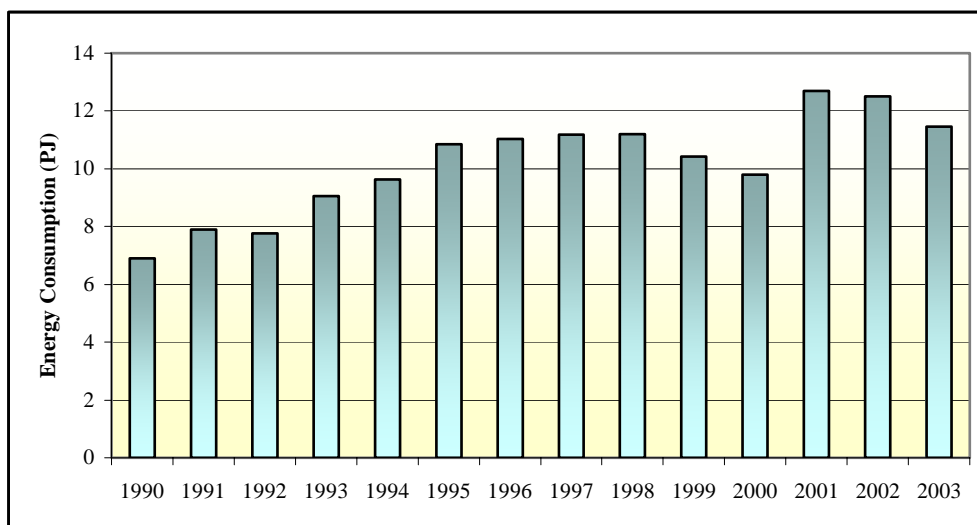
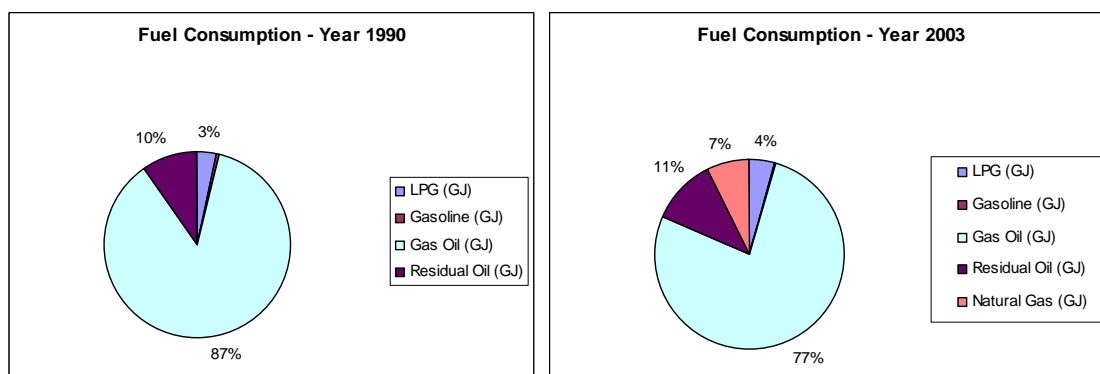


Figure 3.48 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2003



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

Table 3.70 – Total Paper Pulp Production (Kraft and sulphide paper pulp)

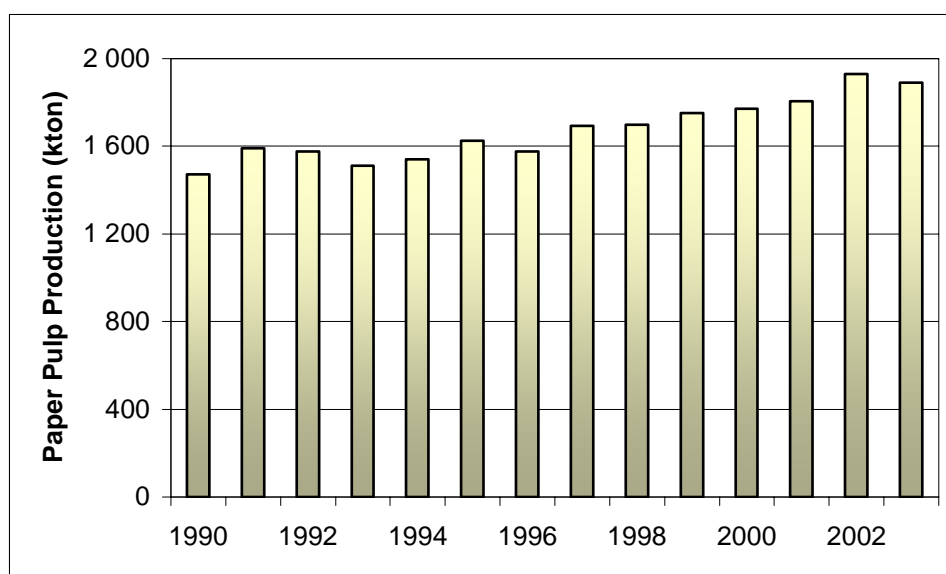
Year	1990	1991	1992	1993	1994	1995	1996
Pulp Production (kton)	1 471	1 591	1	1 511	1 540	1 626	1 577

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



Figure 3.49 – Total paper pulp production: Kraft and sulphide paper pulp (1990-2003)

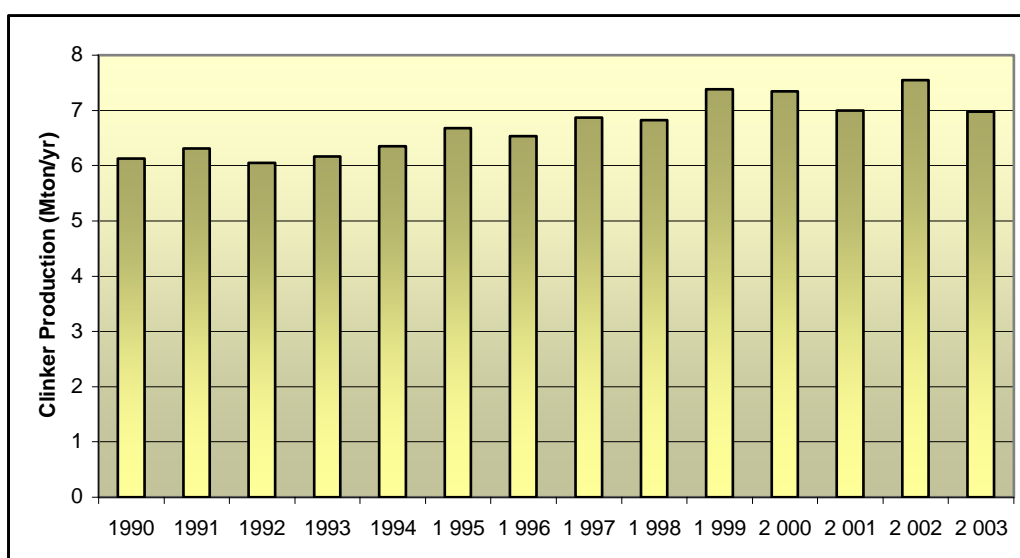


Production of clinker, presented in Table 3.71 and in Figure 3.50, results from data collected directly from the industrial plants.

Table 3.71 – Total clinker production (1990-2003)

Year	1990	1991	1992	1993	1994	1995	1996
Clinker (kton)	6 128	6 311	6 050	6 165	6 352	6 679	6 535
Year	1997	1998	1999	2000	2001	2002	2003
Clinker (kton)	6 870	6 821	7 380	7 343	6 992	7 744	6 980

Figure 3.50 – Total clinker production (1990-2003)



Data on annual manufacturing of ceramic products is available from 1990 to 2000 from INE statistical database. Values for 2001, 2002 and 2003 are provisional forecasts made by IA.

Time series for total production may be seen in Table 3.72 and Figure 3.51, according to type of ceramic.

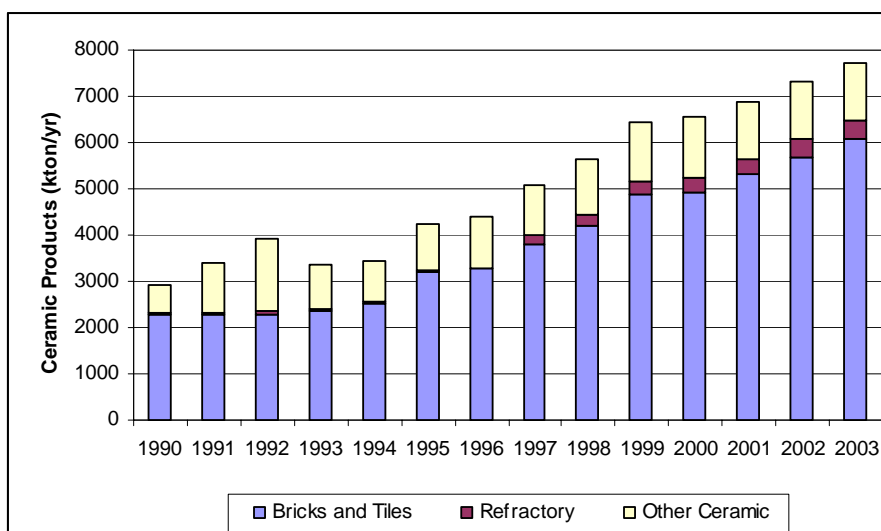
Table 3.72 – Ceramic Production according to type of ceramic

Year	1990	1991	1992	1993	1994	1995	1996
Bricks and Tiles (kton)	2 290	2 290	2 290	2 367	2 513	3 200	3 261
Refractory (kton)	31	42	53	40	32	32	37
Other Ceramic (kton)	582	1 070	1 558	943	915	1 028	1 097

Year	1997	1998	1999	2000	2001	2002	2003
Bricks and Tiles (kton)	3 786	4 203	4 874	4 932	5 330	5 698	6 065
Refractory (kton)	225	241	275	300	329	368	406
Other Ceramic (kton)	1 082	1 212	1 310	1 313	1 226	1 239	1 252

Figure 3.51 – Ceramic Production according to type of ceramic



Production values for container glass, lead crystal glass and other glass is presented in Figure 3.52 and in Table 3.73, resulting from INE statistical databases and information received from Technology Centre for Ceramics and Glass (CTCV). More detailed discussion of the origins of data sources should be consulted in chapter 4.2.A.5. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 3.52 - Glass production by glass type (excluding flat glass production)

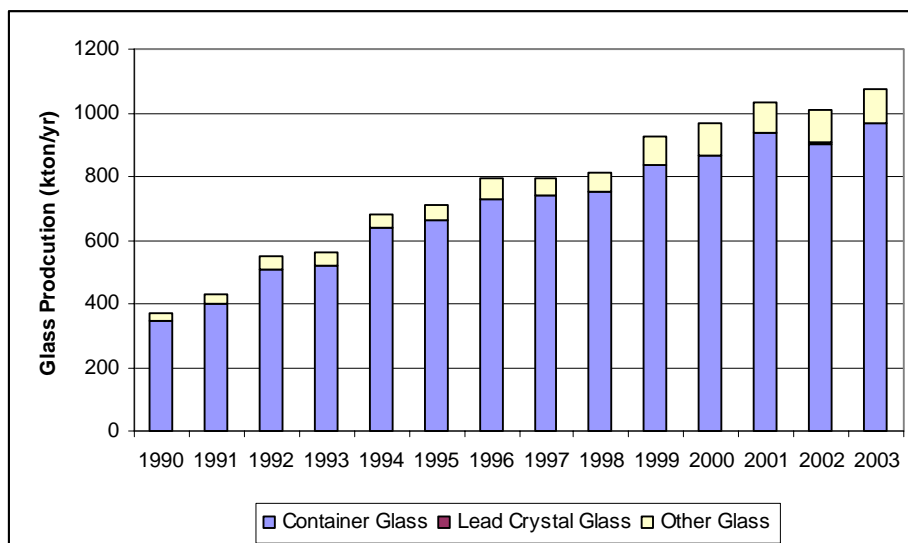


Table 3.73- Glass production by glass type (kton/yr) excluding flat glass production

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

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

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

### 3.2.B.3 EMISSION FACTORS

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

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

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

Table 3.74 to Table 3.79 present the emission factors that were used as default national emission factors in all cases where no specific emission factors may be used, either because there are specific methodologies and emission factors available in the bibliography or either

because country specific emission factors were developed from national studies and monitoring data. They are presented in the subsequent tables.

Table 3.74 – Default emissions factors of Greenhouse gases for combustion equipments in Manufacturing Industry

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

Table 3.75 – Default emissions factors of Indirect precursor gases for combustion equipments in Manufacturing Industry

Equipment	Fuel	NAPFUE	NO <sub>x</sub> (g/GJ)	NMVOC (g/GJ)	CO (g/GJ)
Boilers	Steam Coal	S 102	170	190.0	150
	Brown Coal/Lignite	S 105	200	190.0	160
	Coke from Coal	S 107	300	12.0	160
	LPG	L 303	90	2.5	17
	Gasoline	L 208	60	1.0	12
	City Gas	G 308	140	25.0	160
	Coke Oven Gas	S 304	90	2.5	160
	Blast Furnace Gas	S 305	55	0.0	160
	Fuel Gas, Hydrogen	G 399	90	2.5	17
	Biomass Wood	B 111	70	150.0	500
	Biogas	B 309	90	2.5	17
	Kerosene	L 206	60	1.0	12
	Diesel Oil	L 204	60	1.0	12
	Residual Fuel Oil	L 203	160	3.0	15
	Natural Gas	G 301	67	5.0	13
Static Engines	Gasoline	L 208	1 300	100.0	12
	Gas Oil	L 204	1 100	100.0	12

Table 3.76 – Default sulphur content of fuels for combustion equipments in Manufacturing Industry (1990-1996)

Fuel	Unit	1990	1991	1992	1993	1994	1995	1996
Steam Coal	S %	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Brown Coal/Lignite	S %	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Coke from Coal	S %	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LPG	L %	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Gasoline	L %	0.100	0.100	0.100	0.100	0.100	0.100	0.100
City Gas	G g S/Nm3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coke Oven Gas	S g S/Nm3	7.05	7.05	7.05	7.05	7.05	7.05	7.05
Blast Furnace Gas	S g S/Nm3	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Fuel Gas, Hydrogen	G %	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Biomass Wood	B %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogas	B %	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Kerosene	L %	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Diesel Oil	L %	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Residual Fuel Oil	L %	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Natural Gas	G g S/Nm3	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3.77 - Default sulphur content of fuels for combustion equipments in Manufacturing Industry (1997-2003)

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

Table 3.78 – Default emissions factors of Particulate Matter for combustion equipments in Manufacturing Industry

Equipment	Fuel	NAPFUE	TSP (g/GJ)	PM <sub>10</sub> (%TSP)	PM <sub>2.5</sub> (%TSP)	PM <sub>1.0</sub> (%TSP)
Boilers	Steam Coal	S 102	68.3	20	20	20
	Brown Coal/Lignite	S 105	1165.9	35	10	6
	Coke from Coal	S 107	68.3	20	20	20
	LPG	L 303	3.0	100	100	100
	Gasoline	L 208	0.0	0	0	0
	City Gas	G 308	0.8	100	100	100
	Coke Oven Gas	S 304	0.8	100	100	100
	Blast Furnace Gas	S 305	0.8	100	100	100
	Fuel Gas, Hydrogen	G 399	0.8	100	100	100
	Biomass Wood	B 111	172.0	90	76	67
	Biogas	B 309	0.8	100	100	100
	Kerosene	L 206	6.5	50	12	8
	Diesel Oil	L 204	6.5	50	12	8
	Residual Fuel Oil	L 203	53 – 30 <sup>(a)</sup>	86	56	36
	Natural Gas	G 301	0.8	100	100	100
Static Engines	LPG	L 303	6.9	100	100	100
	Gasoline	L 208	43.0	100	100	100
	Kerosene	L 206	133.3	100	100	100
	Gas Oil	L 204	133.3	100	100	100
	Biogas	B 309	6.9	100	100	100
	Residual Oil	L 203	30.0	82	77	77
	Natural Gas	G 301	6.9	100	100	100

(a) Decreasing function of sulphur content (USEPA)

Table 3.79 – Default emissions factors of Heavy Metals for combustion equipments in Manufacturing Industry

Equipment	Fuel	Cd	Hg	Ar	Cr	Cu	Ni	Se	Zn
		g/ton fuel							
Boilers	Steam Coal	5.2E-02	1.7E-01	4.5E-01	3.6E-01	4.7E-01	7.2E-01	2.7E-01	1.3E+00
	Brown Coal/Lignite	4.0E-03	6.0E-02	4.0E-02	3.0E-02	2.0E-02	4.0E-02	0.0E+00	1.0E-01
	Coke from Coal	5.2E-02	1.7E-01	4.5E-01	3.6E-01	4.7E-01	7.2E-01	2.7E-01	1.3E+00
	LPG	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Gasoline	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	City Gas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Coke Oven Gas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Blast Furnace Gas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Fuel Gas, Hydrogen	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Biomass Wood	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
	Biogas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Kerosene	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Diesel Oil	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
	Residual Fuel Oil	6.8E-01	5.1E-01	5.6E-01	1.7E+00	7.4E-01	2.7E+01	6.8E-02	1.9E+00
	Natural Gas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Static Engines	LPG	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Gasoline	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Kerosene	2.6E-01	0.0E+00	0.0E+00	5.0E-02	1.1E+00	2.9E-01	3.0E-02	3.0E+00
	Gas Oil	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
	Biogas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
	Residual Oil	6.8E-01	5.1E-01	5.6E-01	1.7E+00	7.4E-01	2.7E+01	6.8E-02	1.9E+00
	Natural Gas	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04

The following emission factors were used for specific industrial sectors.

Table 3.80 –Emission factors of Greenhouse gases in the extractive industry

Equipment	Fuel	NAPFUE	CO <sub>2</sub> (kg/GJ)	Oxidation factor (ratio)	% C fossil	N <sub>2</sub> O (g/GJ)
Boilers	LPG L	303	63.1	0.995	100	1.4
	Gasoline L	208	69.3	0.990	100	0.6
	Kerosene L	206	71.9	0.990	100	0.6
	Gas Oil L	204	74.1	0.990	100	0.6
	Residual Oil L	203	77.4	0.990	100	0.6
	Natural Gas G	301	56.1	0.995	100	1.4
	Brown Coal S	105	101.2	0.980	100	0.7
Static Engines	LPG L	303	63.1	0.995	100	0.6
	Gasoline L	208	69.3	0.990	100	0.6
	Kerosene L	206	100	0.990	100	0.6
	Gas Oil L	204	74.1	0.990	100	0.6
	Residual Oil L	203	77.4	0.990	100	0.6
	Natural Gas G	301	56.1	0.995	100	1.4

Table 3.81 – Emission factors of Indirect precursor gases in the extractive industry

Equipment	Fuel	NAPFUE	NO <sub>x</sub> (g/GJ)	NMVOC (g/GJ)	CO (g/GJ)
Boilers	LPG	L 303	65	2.5	50
	Gasoline	L 208	60	1	12
	Kerosene	L 206	60	1	20
	Diesel Oil	L 204	60	1	20
	Residual Oil	L 203	160	3	20
	Natural Gas	G 301	67	5	13
	Brown Coal	S 105	200	190	160
Static Engines	LPG	L 303	90	2.5	17
	Gasoline	L 208	1300	100	20
	Kerosene	L 206	60	100	20
	Gas Oil	L 204	1100	100	20
	Residual Oil	L 203	160	3	15
	Natural Gas	G 301	67	5	13

Table 3.82 – Sulphur content in fuels used in the extractive industry (%S)

Year	LPG	Gasoline	Unleaded Gasoline	Kerosene	Gas Oil	Residual Oil	Natural Gas	Brown Coal
1990	0.0016	0.1	0.1	0.15	0.3	2.84	0.0007	0.65
1991	0.0016	0.1	0.1	0.15	0.3	2.3	0.0007	0.65
1992	0.0016	0.1	0.1	0.15	0.3	2.5	0.0007	0.65
1993	0.0016	0.1	0.1	0.15	0.3	2.23	0.0007	0.65
1994	0.0016	0.1	0.1	0.15	0.3	2.26	0.0007	0.65
1995	0.0016	0.1	0.1	0.15	0.3	2.26	0.0007	0.65
1996	0.0016	0.1	0.05	0.15	0.3	2.26	0.0007	0.65
1997	0.0016	0.1	0.05	0.15	0.3	2.26	0.0007	0.65
1998	0.0016	0.1	0.05	0.15	0.3	2.26	0.0007	0.65
1999	0.0016	0.1	0.05	0.15	0.3	2.26	0.0007	0.65
2000	0.0016	0.1	0.05	0.15	0.3	2.26	0.0007	0.65
2001	0.0016	0.015	0.015	0.15	0.2	2.26	0.0007	0.65
2002	0.0016	0.015	0.015	0.15	0.2	2.26	0.0007	0.65
2003	0.0016	0.015	0.015	0.15	0.2	1	0.0007	0.65

Table 3.83 – Emission factors of Particulate Matter gases in the extractive industry

Equipment	Fuel	NAPFUE	TSP (g/GJ)	PM <sub>10</sub> (%TSP)	PM <sub>2.5</sub> (%TSP)	PM <sub>1.0</sub> (%TSP)
Boilers	LPG	L 303	3	100	100	100
	Gasoline	L 208	43	100	100	100
	Kerosene	L 206	6.5	50	12	8
	Diesel Oil	L 204	6.5	50	12	8
	Residual Oil	L 203	89 – 30	86	56	36
	Natural Gas	G 301	0.8	100	100	100
	Brown Coal	S 105	1 166	35	10	6
Static Engines	LPG	L 303	6.9	100	100	100
	Gasoline	L 208	43	100	100	100
	Kerosene	L 206	133	100	100	100
	Gas Oil	L 204	133	100	100	100
	Residual Oil	L 203	30	82.2	77.3	77.1
	Natural Gas	G 301	6.9	100	100	100



Table 3.84 – Emission factors of Heavy Metals in the extractive industry

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

Table 3.85 – Emission factors for Greenhouse gases in the building and construction industry

	NAPFUE	Fuel	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
L	203	Residual Oil	77.4	0.990	100	1.6	0.6
L	204	Gas Oil	74.1	0.990	100	5.0	0.6
L	205	Diesel Oil	74.1	0.990	100	0.6	0.6
L	206	Kerosene	71.9	0.990	100	5.0	0.6
L	208	Gasoline	69.3	0.990	100	9.9	0.6
L	303	LPG	63.1	0.995	100	1.5	1.4
G	301	Natural Gas	56.1	0.995	100	9.9	1.4

Table 3.86 – Emission factors for Indirect Precursor gases in the building and construction industry

	NAPFUE	Fuel	NO <sub>x</sub>	NMVOC	CO
			g/GJ	g/GJ	g/GJ
L	203	Residual Oil	160	3	20
L	204	Gas Oil	1100	50.5	20
L	205	Diesel Oil	60	1	20
L	206	Kerosene	60	50.5	20
L	208	Gasoline	1300	100	20
L	303	LPG	1200	2.5	50
G	301	Natural Gas	1200	100	20

Table 3.87 – Sulphur content in the fuels used in the building and construction industry (%S)

Year	LPG	Gasoline	Kerosene	Gas Oil	Diesel Oil	Residual Oil	Natural Gas
	%S						
1990	0.0016	0.1	0.15	0.3	0.3	2.84	0.0007
1991	0.0016	0.1	0.15	0.3	0.3	2.6	0.0007
1992	0.0016	0.1	0.15	0.3	0.3	2.6	0.0007
1993	0.0016	0.1	0.15	0.3	0.3	2.6	0.0007
1994	0.0016	0.1	0.15	0.3	0.3	2.6	0.0007
1995	0.0016	0.1	0.15	0.2	0.3	2.6	0.0007
1996	0.0016	0.1	0.15	0.05	0.3	2.6	0.0007
1997	0.0016	0.1	0.15	0.05	0.3	2.6	0.0007
1998	0.0016	0.1	0.15	0.05	0.3	2.6	0.0007
1999	0.0016	0.1	0.15	0.05	0.3	2.6	0.0007
2000	0.0016	0.1	0.15	0.05	0.25	2.6	0.0007
2001	0.0016	0.015	0.15	0.05	0.2	2.6	0.0007
2002	0.0016	0.015	0.15	0.04	0.2	2.6	0.0007
2003	0.0016	0.015	0.15	0.04	0.2	1	0.0007

Table 3.88 – Emission factors for Particulate Matter in the building and construction industry

	NAPFUE	Fuel	TSP	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>1.0</sub>
			g/GJ	(% TSP)	(% TSP)	(% TSP)
L	203	Residual Oil	53	62	23	14
L	204	Gas Oil	6.52	55	42	37
L	205	Diesel Oil	6.52	55	42	37
L	206	Kerosene	6.52	55	42	37
L	208	Gasoline	43	100	100	100
L	303	LPG	2.5	100	100	100
G	301	Natural Gas	0.81	100	100	100

Table 3.89 – Emission factors for Heavy Metals in the building and construction industry (5/5)

Fuel	Pb	Cd	Hg	Ar	Cr	Cu	Ni	Se	Zn
	g/ton								
Residual Oil	1.3	0.0004	0.5	0.001	0.004	0.74	26.91	0.07	1.9
Gas Oil	0.2	0.04	0.02	0.06	0.3	0.65	0.06	0.04	0.4
Diesel Oil	0.2	0.04	0.02	0.06	0.3	0.65	0.06	0.04	0.4
Kerosene	0.2	0.04	0.02	0.06	0.3	0.65	0.06	0.04	0.4
Motor Gasoline	526.3	0.04	0.02	0.06	0.3	0.65	0.06	0.04	0.4
LPG	0	0.00002	0.004	0.000003	0.00002	0.00001	0.00003	0.0000004	0.0005
Natural Gas	0	0.00002	0.004	0.000003	0.00002	0.00001	0.00003	0.0000004	0.0005

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

Table 3.90 – Emission factors for use in LPS units in the Iron and steel Industry: Greenhouse Gases from combustion

Equipment		NAPFUE	Fuel	CO <sub>2</sub>			CH <sub>4</sub> (g/GJ)	N <sub>2</sub> O (g/GJ)
				kg/GJ	Oxidation Factor	% C fossil		
Coquerie	S	304	Coke oven gas	40.79	0.995	100	2.5	1.4
Sintering	S	304	Coke oven gas	40.79	0.995	100	2.5	1.4
Blast Furnace Cowpers	S	304	Coke oven gas	40.79	0.995	100	2.5	1.4
	S	305	Blast furnace gas	296.23	0.995	100	2.5	1.4
Rolling mills	L	203	Residual oil	76.59	0.990	100	3.0	0.6
	S	304	Coke oven gas	40.79	0.995	100	2.5	1.4
Thermo-Electric Power plant	S	304	Coke oven gas	40.79	0.995	100	2.5	1.4
	S	305	Blast furnace gas	296.23	0.995	100	2.5	1.4
	L	203	Residual oil (3.5%)	76.59	0.990	100	3.0	0.6
	L	203	Residual oil (1%)	76.59	0.990	100	3.0	0.6
	L	299	Tar	79.86	0.990	100	3.0	0.6
Heat power plant	L	303	LPG	62.75	0.995	100	4.0	1.4
	L	299	Tar	79.86	0.990	100	3.0	0.6
	O	115	Waste oils	76.59	0.990	100	3.0	0.6
Lime kiln	L	-	-	76.59	0.990	100	3.0	0

Table 3.91 – Emission factors (Energy Approach) for use in LPS units in the Iron and steel Industry: Indirect Precursors from combustion

Equipment	Fuel	NO <sub>x</sub> (g/GJ)	%S		NMVOC (g/GJ)	CO (g/GJ)
			%	Units		
Coquerie	Coke oven gas	120	7.05	g S/Nm3	2.5	17
Sintering	Coke oven gas	PA	7.05	g S/Nm3	PA	PA
Blast Furnace Cowpers	Coke oven gas	120	7.05	g S/Nm3	2.5	17
	Blast furnace gas	70	0.045	g S/Nm3	2.5	17
Rolling mills	Residual oil	190	3.5	% S	3	15
	Coke oven gas	120	7.05	g S/Nm3	2.5	17
Thermo Electric Power plant	Coke oven gas	120	7.05	g S/Nm3	2.5	17
	Blast furnace gas	70	0.045	g S/Nm3	2.5	17
	Residual oil (3.5%)	190	3.5	% S	3	15
	Residual oil (1%)	190	1	% S	3	15
	Tar	300	0.6	% S	3	15
Heat power plant	LPG	160	0.005	% S	4	17
	Tar	300	0.6	% S	3	15
	Waste Oils	190	0	% S	3	15
Lime kiln	-	PA	3.5	% S	3	PA

Note: PA = Process Approach

Table 3.92 – Emission factors (Production Approach) for use in LPS units in the Iron and steel Industry: Indirect Precursors from combustion

Equipment		Code	Fuel	NO <sub>x</sub> (kg/ton)	SO <sub>x</sub> (kg/ton)	NM VOC (kg/ton)	CO (kg/ton)
Sintering	S	304	Coke oven gas	0.5	1	0.1	30
Lime kiln	L	-	-	0.1	0.42	-	2

Table 3.93 – Emission factors (Energy Approach) for use in LPS units in the Iron and steel Industry: Particulate Matter from combustion

Equipment		NAPFUE	Fuel	TSP g/GJ	PM <sub>10</sub> (% TSP)	PM <sub>2.5</sub> (% TSP)	PM <sub>1.0</sub> (% TSP)
Cokery	S	304	Coke oven gas	3	96	94	77
Sintering	S	304	Coke oven gas	PA	15	7	4
Blast Furnace Cowpers	S	304	Coke oven gas	3	100	100	100
	S	305	Blast furnace gas	3	100	100	100
Thermo Electric Power plant	S	304	Coke oven gas	3	100	100	100
	S	305	Blast furnace gas	3	100	100	100
	L	203	Residual oil (3.5%)	108	86	56	36
	L	203	Residual oil (1%)	37.5	86	56	36
	L	299	Tar	108	86	56	36
Heat power plant	L	303	LPG	3	100	100	100
	L	299	Tar	108	86	56	0
	O	115	Waste Oils	108	86	56	36
Lime kiln	L	-	-	PA	100	100	100

Note: PA = Process Approach

Table 3.94 – Emission factors (Production Approach) for use in LPS units in the Iron and steel Industry: Particulate Matter from combustion

Equipment		Code	Fuel	TSP (kg/ton)	PM <sub>10</sub> (% TSP)	PM <sub>2.5</sub> (% TSP)	PM <sub>1.0</sub> (% TSP)
Sintering	S	304	Coke oven gas	3.9	15	6.5	4
Lime kiln	L	-	-	6.8	100	100	100

Table 3.95 – Emission factors for use in LPS units in the Chemical Industry: Greenhouse Gases from combustion

Equipment	Fuel		NAPFUE	CO <sub>2</sub> (kg/GJ)	Oxidation Factor (ratio)	% C fossil	CH <sub>4</sub> (g/GJ)	N <sub>2</sub> O (g/GJ)
Boilers	Residual Fuel Oil	L	203	77.37	0.990	100	3	0.6
	Pyrolysis Fuel Oil	L	203	77.37	0.990	100	3	0.6
	Fuel Gas	L	307	50.05 – 64.5	0.995	100	1.4 - 2.5	1.4
Furnaces	Fuel Gas	L	307	50.05 – 64.5	0.995	100	1.4 - 2.5	1.4
	Propane	L	303	63.07	0.995	100	2.5	1.4
Static Engines	Residual Fuel Oil	L	203	77.37	0.990	100	60	0.6
	Diesel Oil	L	204	74.07	0.990	100	60	0.6
Flares	Refinery Gas	L	307	59.17 - 65.62	0.995	100	-	-

Table 3.96 – Emission factors for use in LPS units in the Chemical Industry: Indirect Precursor Gases and Sulphur Oxides (SO<sub>x</sub>) from combustion

Equipment	Fuel		NAPFUE	NO <sub>x</sub> (g/GJ)	SO <sub>x</sub> (g/GJ)	NMVOC (g/GJ)	CO (g/GJ)
Boilers	Residual Fuel Oil	L	203	140 - 170	3.5-1.13	3	15
	Pyrolysis Fuel Oil	L	203	170	0.35	3	15
	Fuel Gas	L	307	90 - 147	0.0005	2.5	13 - 17
Furnaces	Fuel Gas	L	307	88 - 90	0.0005	2.5	13 - 17
	Propane	L	303	88	0.0005	2.5	13
Static Engines	Residual Fuel Oil	L	203	900	3.5-1.13	60	15
	Diesel Oil	L	204	900	0.3 - 0.2	60	12

Table 3.97 – Emission factors for use in LPS units in the Chemical Industry: Particulate Matter from combustion

Equipment	Fuel		NAPFUE	TSP (g/GJ)	PM <sub>10</sub> (%TSP)	PM <sub>2.5</sub> (%TSP)	PM <sub>1.0</sub> (%TSP)
Boilers	Residual Fuel Oil	L	203	105.2-41.2 <sup>(a)</sup>	86	56	36
	Pyrolysis Fuel Oil	L	203	19.2 <sup>(a)</sup>	86	56	36
	Fuel Gas	L	307	3	100	100	100
Furnaces	Fuel Gas	L	307	3	100	100	100
	Propane	L	303	3	100	100	100
Static Engines	Residual Fuel Oil	L	203	30	82	77	77
	Diesel Oil	L	204	133	100	100	100

(a) Function of sulphur content (USEPA)

Table 3.98 – Emission factors used in LPS units in the Paper Pulp Industry: Greenhouse Gases from combustion

Equipment	Fuel	CO <sub>2</sub> (g/GJ)		CH <sub>4</sub> (g/GJ)			N <sub>2</sub> O (g/GJ)
		kg/ton pulp	% C fossil	Estimation Approach	EF	Unit	g/GJ
Recuperation Boilers	Residual Fuel Oil	76.6	100	EA	3	g/GJ	0.6
	Kraft Black Liquor	73.3	0	PA	0.49	kg/ton pulp	0.6
	Bisulfite Liquor	73.3	0	PA	0.625	kg/ton pulp	0.6
Biomass Boilers	Bark	100.8	0	EA	30	g/GJ	4.3
	Residual Fuel Oil	76.6	100	EA	3	g/GJ	0.6
	Natural Gas	55.8	100	EA	1.4	g/GJ	1.4
	LPG	62.4	100	EA	0.72	g/GJ	1.4
Auxiliary Boilers	Residual Oil	76.6	100	EA	3	g/GJ	0.6
Lime Kilns	Residual Oil	76.6	100	PA	0.065	kg/ton pulp	0.6
	Gasified Biomass	100.8	0	PA	0.065	kg/ton pulp	4.3
	Tall-Oil	73.3	0	PA	0.065	kg/ton pulp	0.6
	NCG	73.3	100	PA	0.065	kg/ton pulp	1.4
Flares	LPG	62.4	100	EA	0.72	g/GJ	1.4

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

Table 3.99 – Emission factors used in LPS units in the Paper Pulp Industry: Indirect Gases from combustion

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

Table 3.100 – Emission factors used in LPS units in the Paper Pulp Industry: Sulphur Oxides (SO<sub>x</sub>) emissions

Equipment	Fuel	SO <sub>x</sub>		
		Approach	EF	Unit
Recuperation Boilers	Residual Fuel Oil	EA	1-3.5	% S
	Kraft Black Liquor	PA	3.5	kg/ton pulp
	Bisulfite Liquor	PA	12.5	kg/ton pulp
Biomass Boilers	Bark	EA	0	% S
	Residual Fuel Oil	EA	1-3.5	% S
	Natural Gas	EA	0	% S
	LPG	EA	0	% S
Auxiliary Boilers	Residual Oil	EA	1-3.5	% S
Lime Kiln	Residual Oil	PA	0.15	kg/ton pulp
	Gasified Biomass	PA	0.15	kg/ton pulp
	Tall-Oil	PA	0.15	kg/ton pulp
	NCG	PA	0.15	kg/ton pulp
Flares	LPG	EA	0	% S

Table 3.101 – Emission factors used in LPS units in the Paper Pulp Industry: Particulate Matter

Equipment	Fuel	TSP			PM <sub>10</sub> (%TSP)	PM <sub>2.5</sub> (%TSP)	PM <sub>1.0</sub> (%TSP)
		Estimation Approach	EF	Unit			
Recuperation Boilers	Residual Fuel Oil	PA	1	kg/ton pulp	93.5	83.5	45.3
	Kraft Black Liquor	PA	1	kg/ton pulp	93.5	83.5	45.3
	Bisulfite Liquor	PA	2	kg/ton pulp	100	100	100
Biomass Boilers	Bark	EA	23-172	g/GJ	90	76	67
	Residual Fuel Oil	EA	108	g/GJ	86	56	36
	Natural Gas	EA	0.8	g/GJ	100	100	100
	LPG	EA	3	g/GJ	100	100	100
Auxiliary Boilers	Residual Fuel Oil	EA	108	g/GJ	100	100	100
Lime Kiln	All	PA	0.25-28	kg/ton pulp	16.8	10.5	7.1

Table 3.102 – Emission factors used in LPS units in the Paper Pulp Industry: Heavy Metals

Fuel	Pb	Cd	Hg	Ar	Cr	Cu	Ni	Se	Zn
	g/GJ								
Residual Fuel Oil	9.3E-01	6.8E-01	5.1E-01	5.6E-01	1.7E+00	7.4E-01	2.7E+01	6.8E-02	1.9E+00
Kraft Black Liquor	5.0E-02	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
Bisulfite Liquor	5.0E-02	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
Bark	5.0E-02	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
Natural Gas	8.0E-06	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
LPG	8.0E-06	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04

For the cement source sector emissions were estimated using either activity data as energy consumption (energy approach) or either cement produced (production approach), although both represent similar emissions in cement kiln. Emission factors are presented in Table 3.103 and **Error! Reference source not found..** Most emission factors result from plant specific emission factors developed from monitoring at each installation, as reported to EPER exercise.

Table 3.103 – Emission Factors for clinker production units (LPS) using the Energy Approach  
(b)

Fuel		NAPFUE	CO <sub>2</sub> <sup>(a)</sup> (kg/GJ)	% C fossil	N <sub>2</sub> O (g/GJ)
Residual Oil	L	203	76.6	100	0.6
Steam Coal	S	102	99.2	100	0.7
coke	L	110	99.8	100	0.7
Tires	O	115	98.8	100	0.7

(a) – Only CO<sub>2</sub> from fuels and not including decarbonising limestone and dolomite rocks

(b) – Methane emissions estimated using the Production Approach

Table 3.104 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Greenhouse Gases

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

Table 3.105 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Indirect Precursors and SO<sub>x</sub>

Parameter	EF (kg/ton clinker)
SO <sub>x</sub>	0.05 - 4.10
NO <sub>x</sub>	1.11 - 3.70
NM VOC	0.007 - 2.570
CO	0.06 - 1.80
NH <sub>3</sub>	0.005 - 1.041

Table 3.106 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Particulate Matter

Parameter	EF (kg/ton clinker)
PST	0.014 - 0.309
PM <sub>10</sub>	100% - 100%
PM <sub>2.5</sub>	100% - 100%
PM <sub>1</sub>	100% - 100%

Table 3.107 – Range of emission Factors for clinker production units (LPS) using the Production Approach: Heavy Metals

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



Table 3.108 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Greenhouse gases

	Fuel		NAPFUE	CH <sub>4</sub> (kg/ton product)
<b>Bricks and Tiles</b> <sup>(a)</sup>	LPG	L	303	0.03
	Residual Oil	L	203	0.03
	Natural Gas	G	301	0.03
	Biomass Wood	B	111	0.03
<b>Refractory</b> <sup>(b)</sup>	LPG	L	303	0.03
	Residual Oil	L	203	0.03
	Natural Gas	G	301	0.03
	Biomass Wood	B	111	0.03
<b>Other Ceramic</b> <sup>(c)</sup>	LPG	L	303	0.02
	Residual Oil	L	203	0.02
	Natural Gas	G	301	0.02
	Biomass Wood	B	111	0.02

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

Table 3.109 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Indirect Precursor gases and SO<sub>x</sub>

	Fuel		Code	NO <sub>x</sub> (kg/ton)	SO <sub>x</sub> (kg/ton)	NMVOC (kg/ton)
<b>Bricks and Tiles</b> <sup>(a)</sup>	LPG	L	303	0.45	1.5	0.03
	Residual Oil	L	203	0.45	1.1	0.03
	Natural Gas	G	301	0.45	1.5	0.03
	Biomass Wood	B	111	0.47	0.4	0.1
<b>Refractory</b> <sup>(b)</sup>	LPG	L	303	0.87	3.8	0.03
	Residual Oil	L	203	0.87	3.8	0.03
	Natural Gas	G	301	0.87	3.8	0.03
	Biomass Wood	B	111	0.87	3.8	0.1
<b>Other Ceramic</b> <sup>(c)</sup>	LPG	L	303	0.27	0.01	0.2
	Residual Oil	L	203	0.27	62.5	0.2
	Natural Gas	G	301	0.27	0.05	0.2
	Biomass Wood	B	111	0.27	0	0.2

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

Table 3.110 – Greenhouse Gases Emission Factors for ceramic production using the Production Approach: Particulate Matter

	Fuel		Code	TSP (kg/ton)	PM <sub>10</sub> (%TSP)	PM <sub>2.5</sub> (%TSP)	PM <sub>1.0</sub> (%TSP)
<b>Bricks and Tiles</b> <sup>(a)</sup>	LPG	L	303	0.14	100	100	100
	Residual Oil	L	203	0.14	88	88	88
	Natural Gas	G	301	0.14	100	100	100
	Biomass Wood	B	111	0.13	62	62	62
<b>Refractory</b> <sup>(b)</sup>	LPG	L	303	67.6	25	25	25
	Residual Oil	L	203	67.6	25	25	25
	Natural Gas	G	301	67.6	25	25	25
	Biomass Wood	B	111	67.6	25	25	25
<b>Other Ceramic</b> <sup>(c)</sup>	LPG	L	303	10.9	27	27	27
	Residual Oil	L	203	10.9	27	27	27
	Natural Gas	G	301	10.9	27	27	27
	Biomass Wood	B	111	10.9	27	27	27

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

Table 3.111 – Emission Factors for glass production using the Production Approach: Greenhouse Gases

	CH <sub>4</sub>
Type of Glass	kg/ton glass
Flat Glass	0.01
Container Glass	0.45
Lead Crystal Glass	0.47
Other Glass	0.47

Source: USEPA (1986)

Table 3.112 – Emission Factors for glass production using the Production Approach: SO<sub>x</sub> and Indirect Precursor gases

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

Source: USEPA (1986)

Table 3.113 – Emission Factors for glass production using the Production Approach: Particulate Matter

	TSP	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>1.0</sub>
Type of Glass	kg/ton glass			
Flat Glass	1	0.95	0.91	0.91
Container Glass	0.7	0.67	0.64	0.64
Lead Crystal Glass	8.4	7.98	7.64	7.64
Other Glass	8.4	7.98	7.64	7.64

Source: USEPA (1986)

Table 3.114 – Emission Factors for glass production using the Production Approach: Heavy Metals

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

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

### 3.2.B.4 UNCERTAINTY ASSESSMENT

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

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

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

### 3.2.C Transport (CRF 1A3)

#### 3.2.C.1 ROAD TRANSPORTATION

##### OVERVIEW

Road transportation is one of the most important emitter of greenhouse gases (GHG) such as carbon dioxide (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 volatile organic compounds (NMVOC) and are indirectly responsible for the formation of ozone (O<sub>3</sub>) in the lower troposphere. Substantial emissions of ammonia, particulate matter and heavy metals also results from this activity.

Exhaust emissions result from the combustion gases in the engine and include all the gases considered in the inventory. Exhaust emissions were estimated for each of the following vehicle classes<sup>22</sup>:

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

Table 3.115 - 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>23</sup>
	Urban Buses
	Coaches
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:

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

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

<sup>23</sup> Heavy duty vehicles with weight greater than 32 t were assumed not representative in national fleet.

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

Exhaust greenhouse gases emissions from road transportation were estimated about 19.3 Mt CO<sub>2</sub>e. in 2003 representing an increase of 104.8% when compared to 9.4 Mt CO<sub>2</sub>e., estimated for 1990 (see Figure 3.53 and Table 3.115). Between 2002 to 2003 GHGs emissions registered a slight decrease from 19.4 to 19.3 Mt CO<sub>2</sub>e. CO<sub>2</sub> is the most important gas, representing in 2003, 97.1% of total emissions from this sector. N<sub>2</sub>O and CH<sub>4</sub> are responsible for, respectively, 2.7% and 0.3% of the GHG emissions in 2003.

Emissions of N<sub>2</sub>O have increased by a factor of 4.2 since 1990 due to the introduction of catalytic converters. Some authors suggested that in some cases N<sub>2</sub>O emissions could increase by as much as a factor of 10 (Wade et al., 1994; de Soete and Sharp, 1991; Dasch, 1992). As could be observed the introduction of catalytic converters have some disadvantages including also the increase of CO<sub>2</sub> and NH<sub>3</sub> emissions which contribute to climate change and acid deposition. It is difficult to assess the extent to which CO<sub>2</sub> emissions have increased as a result of fitting catalytic converters, because improvements in fuel economy have been made at the same time as development of the engine management systems that are required to minimise NO<sub>x</sub> and VOC emissions.

Estimated emissions from road transport for the period between 1990 and 2003 are summarised in Figure 3.53 and Table 3.115.

Figure 3.53 – Estimated GHG emissions from road transport [1990-2003]

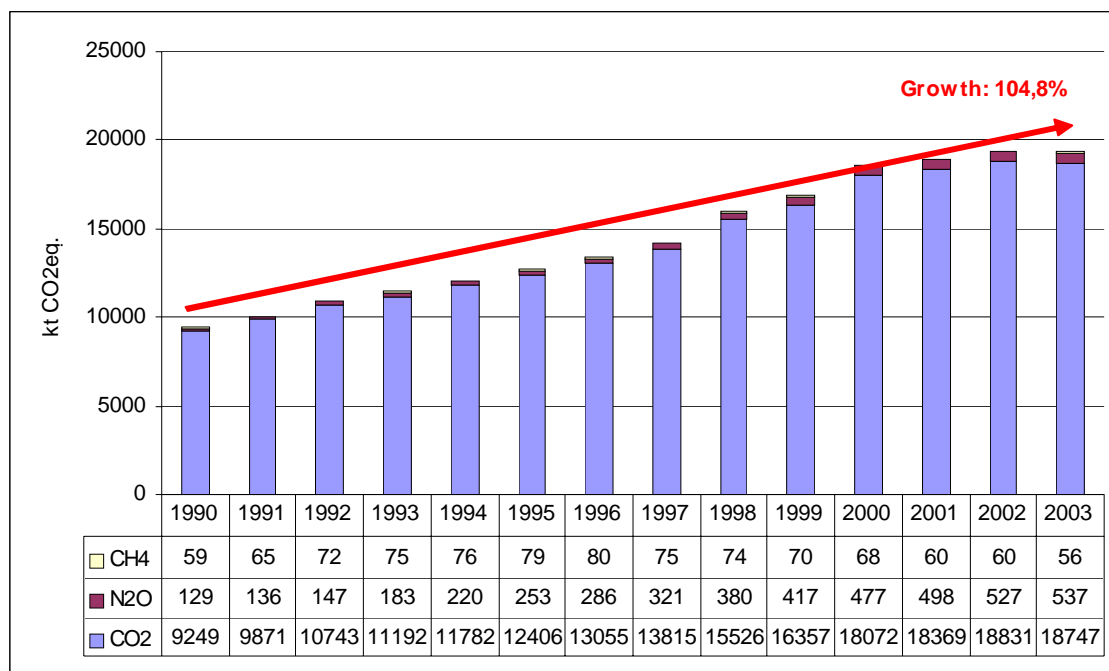


Table 3.116 – Estimated emissions from road transport [1990-2003] and annual variation rates

	1990	1991	1992	1993	1994	1995	1996
Kt CO2 eq.	9 434	10 066	10 956	11 441	12 067	12 725	13 405
Δ(%)	-	6.7	8.8	4.4	5.5	5.5	5.3
Δ1990(%)	-	6.7	16.1	21.3	27.9	34.9	42.1
	1997	1998	1999	2000	2001	2002	2003
Kt CO2 eq.	14 194	15 960	16 824	18 597	18 906	19 396	19 316
Δ(%)	5.9	12.4	5.4	10.5	1.7	2.6	-0.4
Δ1990(%)	50.5	69.2	78.3	97.1	100.4	105.6	104.8

## METHODOLOGY

Exhaust emission estimate follows a country specific integrated methodology being developed since 2003. The methodology was developed according with the following main objectives:

- Ameliorate emission estimates for those pollutants that are most dependent on vehicle class and abatement technology, such as N<sub>2</sub>O, NO<sub>x</sub> and NMVOC;
- To improve attribution of total emission estimates for each vehicle type and driving mode;
- Integration of emission inventory models with projection and management models (Policies and Measures)

Two calculation models, or tools, were programmed by InventAr using a Visual Basic programming language combined with Excel: one comprehending a model for road transport

emission calculation – BURNN; together with a module to determine the national vehicle fleet – KAR. This last module estimates annual fleet from long-time series of vehicle sales and abatement.

BURNN model is compatible and based extensively in EMEP/CORINAIR Emission Inventory Guidebook methodology and emission factors. KAR and BURNN data flow is summarized in Figure 3.54 from where main following steps may be identified:

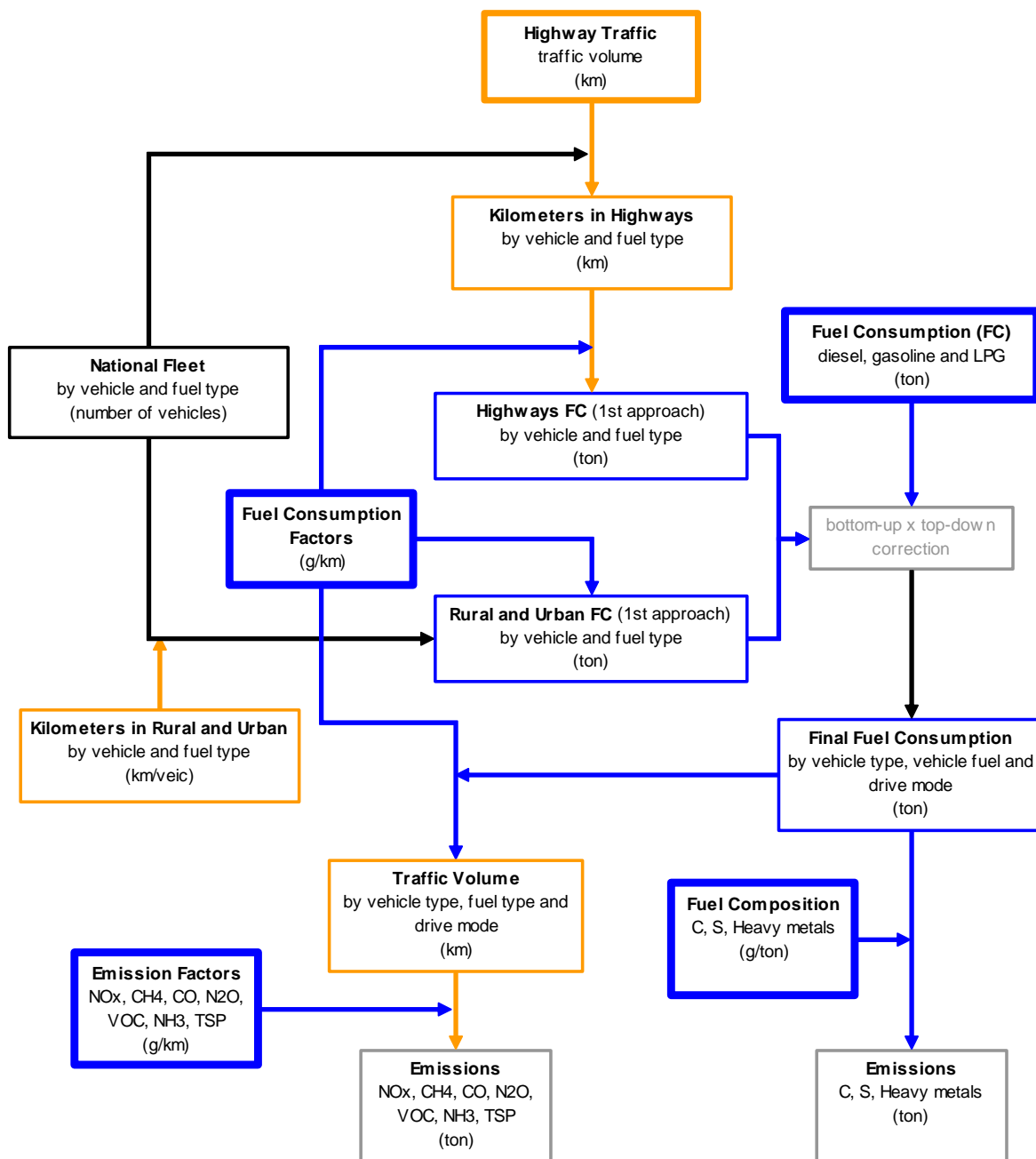
- Estimate national fleet per vehicle type<sup>24</sup> (KAR module output);
- Estimate kilometres driven per vehicle type, driving conditions and vehicle technology;
- Estimate fuel consumption per vehicle type, driving conditions and vehicle technology (bottom-up approach);
- Correct fuel consumption using bottom-up approach in conjunction with top-down approach;
- Emission factors, corrected for hot and cold-start emissions;
- Estimate emissions from kilometres travelled or fuel consumption.

Although emission estimates incorporate a substantial level of spatial disaggregated data such as distance travelled and fuel consumption, emissions are calculated at national level for highway, rural and urban driving modes. Meteorological information disaggregated at NUT III is used to derive evaporative emission factors and to correct cold-start emission factors.

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<sup>24</sup> Vehicle type is disaggregated by vehicle category, age and fuel type. Vehicle technology is function of vehicle age (see **Error! Reference source not found.**).

Figure 3.54 – General scheme of methodology applied for road transport emission estimate



### Vehicle Fleet

## Light vehicles

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



- Passenger cars;
- Light duty vehicles
- 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 distinguish gasoline engines and diesel 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, derived from ACAP data, is summarized in the following couple of equations:

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

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

Where,

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

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

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

The number of light vehicles using LPG fuel was estimated from LPG fuel sales and assuming the same activity rate, expressed in kilometres per vehicle, as gasoline passenger cars. Accordingly, ratio of LPG sales to gasoline sales together with LPG fuel consumption factors were used to estimate the number of LPG vehicles.

### Heavy Vehicles

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

Data of heavy duty vehicles sales in 2001 and 2002 was available from ACAP with adequate weight disaggregation as needed for calculation. The ratio per weight class was therefore adapted and applied to active fleet for all years of the emission estimation period (1990 to 2003).

Table 3.117 – Percentage of heavy duty vehicles per weight class

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

Fleet disaggregation by vehicle age was also performed according with fleet data available from ACAP for the years of 2000 and 2002, which is presented in Table 3.118.

Table 3.118 – Percentage of heavy duty vehicles by age

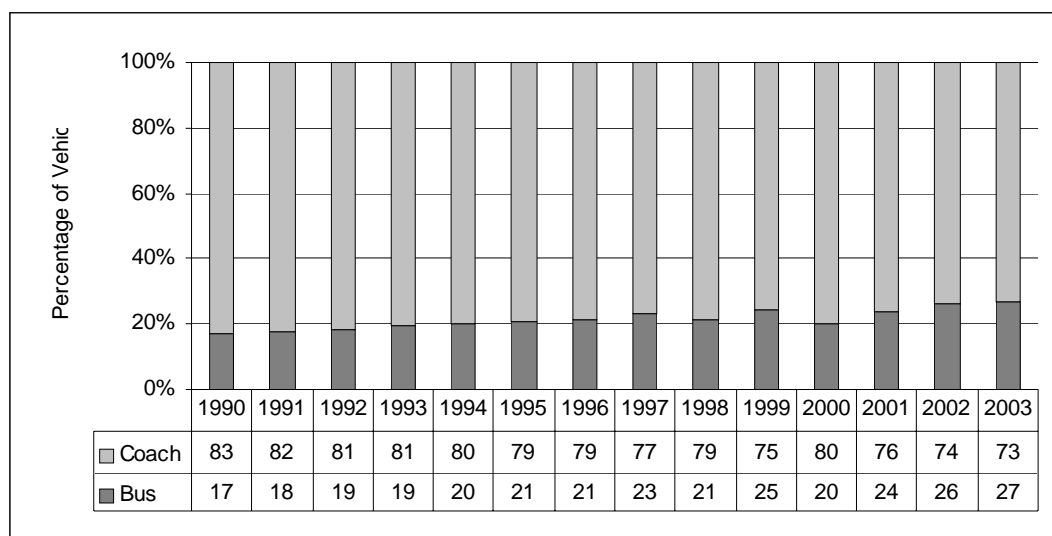
Age		Fleet (%)
From	To	
0	1	4,5
1	2	5,1
2	3	4,9
3	4	4,6
4	5	3,9
5	10	27,6
10	15	30,3
15	19	10,9
≥20		8,2

The same age pattern was assumed for all years analysed. All heavy duty vehicles were assumed to be equipped with diesel engines.

Number of buses and coaches in active fleet were estimated according with data from the Direcção Geral de Viação (DGV) which is the Portuguese national vehicle authority, from Instituto de Seguros de Portugal (ISP) and from Instituto Nacional de Estatística (INE). Data was adapted in order to obtain the necessary disaggregation for calculations.

There were no available distinction made between buses and coaches in data provided by DGV and ISP but only from the available information from INE, given since 1997. For previous years a trend line was established to estimate the split between buses and coaches - 1990 to 1996.

Figure 3.55 – Estimated percentage of buses and coaches



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

#### ***Distance driven estimate***

Distances travelled were estimated for three driving conditions:

- highway;
- rural;
- urban.

For each driving condition distances travelled were estimated for the following vehicle types:

- passenger cars;
- light duty vehicles;
- heavy duty vehicles;
- buses and coaches;
- two wheelers.

For some of the vehicle types distances travelled were further estimated at sub-category level.

For rural and urban activity, where traffic counters are scarce, activity data was estimated according with a study about energy consumption in transportation sector conducted by the Direcção Geral de Geologia e Energia (DGGE) which establishes the actual and forecasted energy consumption for transportation at national level based on demand projections.

Data regarding vehicle activity is collected at the vehicle inspection centres which are under the DGV authority. The data from the inspection centres is believed to be a significant input parameter to estimate emissions since relies on real vehicle activity. However this data is still not available from the DGV.

A traffic model is under implementation at the Instituto de Estradas de Portugal (IEP) for the national road network. This tool could help on future traffic emission estimations by supplying

supplementary activity data such as traffic densities and traffic speeds by vehicle type with a detail level of disaggregation.

#### Highway traffic

Distance driven on highways was estimated in kilometres. Information about traffic volume is available annually for highways, either subject to toll or not, for each specific link with a constant vehicle flow. The length of the highway system and its evolution between 1990 and 2003 period was available from IEP.

The fraction of heavy duty vehicles in highways was proposed by IEP and is based on highway toll data. For highways where toll data was not available it was assumed 10% of heavy duty traffic (see Table 3.119).

Table 3.119 – Fraction of heavy duty vehicles per highway (Source: IEP)

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

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

Since light vehicle traffic includes also motorcycles which represent a small fraction of distances travelled in highways it is necessary to distinguish the share of distances driven by two wheelers from light vehicles traffic. The fraction of distances driven by two wheelers in highways was assumed to be 3% of total light vehicles traffic as proposed by Joumard, 1999.

Table 3.120 – Distances travelled per vehicle type (Source: Joumard, 1999)

Vehicle Type	km/year	%
PassCar	12000	93%
Moped	528	4%
Moto	380	3%

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

$$\begin{aligned}
 Km_{LVhighway}(LV,t,f,y) &= C_{LV}(c,t,f,y) \times \sum_{(l,r)} [L_{Length}(l,r) \times L_{Traffic}(l,r,y) \times (1 - F_{HV}(l,r)) \times (1 - F_{2W})] \\
 Km_{2Whighway}(2W,t,f,y) &= C_{2W}(c,t,f,y) \times \sum_{(l,r)} [L_{Length}(l,r) \times L_{Traffic}(l,r,y) \times (1 - F_{HV}(l,r)) \times F_{2W}] \\
 Km_{HVhighway}(HV,t,f,y) &= C_{HV}(c,t,f,y) \times \sum_{(l,r)} [L_{Length}(l,r) \times L_{Traffic}(l,r,y) \times F_{HV}(l,r)]
 \end{aligned}$$

Where,

$Km_{LV-highway}(LV,t,f,y)$  = total kilometres driven in highway net-road by light vehicles

(motorcycles excluded) of class c, equipped with technology t, using fuel f in year y (km/yr);

$Km_{2W-highway}(LV,t,f,y)$  = total kilometres driven in highway net-road by motorcycles of class c, equipped with technology t, using fuel f in year y (km/yr);

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

$C_{LV}(c,t,f,y)$  = ratio of class c light vehicles using fuel f in year y within light vehicle national fleet (motorcycles excluded);

$C_{2W}(c,t,f,y)$  = ratio of class c motorcycles using fuel f in year y within motorcycles national fleet;

$C_{HV}(c,t,f,y)$  = ratio of class c heavy vehicles using fuel f in year y within heavy vehicles national fleet;

$F_{HV}(l,r)$  = Estimated fraction of heavy vehicles in inter-nodal link l from highway road r;

$F_{2W}$  = Fraction of distance driven by motorcycles within light vehicles;

$L_{Length}(l,r)$  = full length of inter-nodal link l from highway road r (km);

$L_{Traffic}(l,r,y)$  = traffic volume (vehicles per year) registered in link l in year y (vehicles per year);

l = link that connects two nodes of the highway. Traffic volume is constant along each link;

r = highway code;

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

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

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

y = civil year.

### 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 from energy demand scenarios for transportation sector available at DGGE in which are established a set of figures present here.

Table 3.121 – Road transportation figures for urban and long distance transportation (Source: DGGE, 1999 in PNAC<sup>25</sup>, 2003).

	Unit	1990	1995	2000	2005
<b>General Data</b>					
use of private cars	vkm/year	9195	11302	13214	14794
number of vehicles	10 <sup>6</sup>	2.144	2.935	3.532	4.172
<b>Long Distance Transportation</b>					
vehicle occupancy	passengers/vehicle	2.2	1.8	1.8	1.6
personal mobility	pkm/year	3300	3900	4300	5950
<b>Urban Transportation</b>					
vehicle occupancy	passengers/vehicle	1.4	1.3	1.3	1.2
personal mobility	pkm/year	4300	5500	6500	6900

Long distance was further disaggregated between highways and rural by subtracting the estimated distances driven in highways from driven long distances proposed by DGGE.

### Light Duty Vehicles

Data concerning annual driving distance for duty vehicles was available from INE for the period from 1997 to 2003. However, data concerning LDV is not clearly separated and it is included as HDV with weight less than 7,5 ton. Therefore, distances driven and number of vehicles were assumed to be the same for LDV and HDV < 7,5 t. Vehicle activity, in kilometres per vehicle, was determined simply by dividing the registered distance by the correspondent number of vehicles for the considered period.

<sup>25</sup> PNAC, Plano Nacional para as Alterações Climáticas

Distances driven per vehicle from 1990 to 1996 were assumed to be equal to 1997 since there was no more statistical data available.

Urban and long distance kilometres driven by duty vehicles were calculated for 1995, using a percentage from INE and assuming the same split for all periods in analysis. Rural activity was derived by subtracting the highway from long distance activity.

Duty vehicles activity was estimated only for public freight carriers since data concerning distance driven by private freight carriers was not available.

#### Heavy Duty Vehicles

The number of HDV in moving fleet and the distances driven by this type of vehicles were estimated as for light duty vehicles described above.

#### Buses and Coaches

Distances driven and number of buses and coaches were available from the INE for the period between 1997 and 2003. Activity, in kilometres per vehicle, was determined for all driving modes and it was established an average distance for the referred period. 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.

Kilometres travelled under urban and rural mode is a function of fuel consumption and is estimated with a top-down approach. This approach requires earlier evaluation of fuel consumption. Vehicle activity under urban and rural driving conditions, expressed in kilometres per vehicle, is multiplied by the number of vehicles and fuel consumption factors to obtain a fuel consumption first approach which is 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.

#### **Speed**

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

Table 3.122 – Assumed vehicle speeds by driving mode and vehicle type.

Driving Mode	Vehicle Type	Assumed Speed (km/h)	Data Source
Highway	Passenger Car	124	PNAC, 2003
	Light Duty Vehicles	124	PNAC, 2003
	Heavy Duty Vehicles	90	Maximum Legal Value
	Coaches	90	Maximum Legal Value
	Motorcycles	124	PNAC, 2003
Rural	Passenger Car	70	Maximum Legal Value
	Light Duty Vehicles	70	Maximum Legal Value
	Heavy Duty Vehicles	60	Maximum Legal Value
	Coaches	60	Maximum Legal Value
	Mopeds	40	Maximum Legal Value
	Motorcycles	70	Maximum Legal Value
Urban	Passenger Car	24.9	Gois et al., 2005
	Light Duty Vehicles	24.9	Gois et al., 2005
	Heavy Duty Vehicles	24.9	Gois et al., 2005
	Buses	14.8	Carris, 2005
	Coaches	24.9	Gois et al., 2005
	Mopeds	24.9	Gois et al., 2005
	Motorcycles	24.9	Gois et al., 2005

### Fuel consumption

#### Highway Fuel Consumption

Fuel consumption under highway driving mode was estimated for each fuel type according with the kilometres travelled in highways. Therefore:

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

where,

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

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



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

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

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

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

y = civil year.

Individual fuel consumption for each vehicle type was estimated from:

$$Highway_{FC(c,t,f,y)} = Highway_{Km(c,t,f,y)} \times FC_{(c,t,f,Hway)} \times 10^{-6}$$

#### Urban and Rural Fuel Consumption

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

$$Urban_{FC(f,y)} + Rural_{FC(f,y)} = Total_{FC(f,y)} - Highway_{FC(f,y)}$$

where:

$Urban_{FC(f,y)}$ ,  $Rural_{FC(f,y)}$  = total fuel consumption of fuel type f, under urban and rural driving conditions in year y (t);

$Highway_{FC(f,y)}$  = fuel consumption of fuel type f in highway driving condition by vehicles of all classes in year y (t);

$Total_{FC(f,y)}$  = total national fuel consumption of fuel type f in year y (t).

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

$$Rural_{1stFC(c,t,f,y)} = T_{class(c,t,f,y)} \times Km_{rural(c,f,y)} \times FC_{(c,t,f,s)} \times 10^6$$

$$Urban_{1stFC(c,t,f,y)} = T_{class(c,t,f,y)} \times Km_{urban(c,f,y)} \times FC_{(c,t,f,s)} \times 10^6$$

where,

$Rural_{1stFC(c,t,f,y)}$ ,  $Urban_{1stFC(c,t,f,y)}$  = first approach fuel consumption in rural and urban areas made by vehicles of class c, with technology t, using fuel f in year y (t);

$T_{class(c,t,f,y)}$  = number of vehicles of class c, with technology t, using fuel f in year y;

$Km_{rural(c,f,y)}$ ,  $Km_{urban(c,f,y)}$  = rural and urban kilometres driven per vehicle of class c, using fuel f in year y (km/vehicle);

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

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

Fuel adjustments are necessary because, presently, in the process of splitting total fuel among car types and fuel types not all class percentages add to unity. Therefore a correction must be made so that the sum of estimated fuel consumption equals the original statistical data from the Direcção-Geral de Geologia e Energia (DGGE). Urban and rural fuel consumption estimates were corrected with the following factor for car type  $c$ , technology  $t$ , fuel  $f$ , driving mode  $d$  and year  $y$ .

$$Correc_{Factor(f,y)} = \frac{[Total_{FC(f,y)} - Highway_{FC(f,y)}]}{\sum_c \sum_t [Rural_{1stFC(c,t,f,y)} + Urban_{1stFC(c,t,f,y)}]}$$

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

$$Urban_{FC(f,y)} = Correc_{Factor(f,y)} \times \sum_c \sum_t [Urban_{1stFC(c,t,f,y)}]$$

$$Rural_{FC(f,y)} = Correc_{Factor(f,y)} \times \sum_c \sum_t [Rural_{1stFC(c,t,f,y)}]$$

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

**Distances Travelled**

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

$$Km_{urban(c,t,f,y)} = \frac{[Urban_{FC(c,t,f,y)} \times 10^6]}{FC_{(c,t,f,s)}}$$

$$Km_{rural(c,t,f,y)} = \frac{[Rural_{FC(c,t,f,y)} \times 10^6]}{FC_{(c,t,f,s)}}$$

$$Km_{total(c,t,f,y)} = Km_{highway(c,t,f,y)} + Km_{urban(c,t,f,y)} + Km_{rural(c,t,f,y)}$$

Where,

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

$Urban_{FC(c,t,f,y)}$ ,  $Rural_{FC(c,t,f,y)}$  = total fuel consumption allocated to vehicles of class  $c$ , equipped with technology  $t$ , using fuel type  $f$ , under urban and rural driving conditions in year  $y$  (t);

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

## ***Emission Factors***

### 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 EMEP/CORINAIR, 2002, which results from a compilation for the CORINAIR85 and CORINAIR90 programs and updated with results from the MEET project and the COST319 action. This set of equations allows the estimation of emission factors as function of driving conditions and vehicle properties:

- Vehicle class: Light Passenger Vehicles, LDV, HDV, Mopeds & Motorcycles with cylinder capacity under 50 cc and; Motorcycles with cinder capacity greater than 50 cc;
- Fuel type: gasoline, diesel and LPG;
- Technology standard;
- Vehicle dimensions: motor size (cubic centimetres) for light vehicles and two wheelers and vehicle weight for Heavy Vehicles;
- Average vehicle speed under each driving mode.

Although vehicle load and road slope have a significant influence on heavy duty vehicles emissions (Journard, 2003), these variables were not considered in this study.

European technology standards were determined according with the vehicle built year as present in Table 3.123.

Fuel consumption factors here presented are similar in development and use to emission factors and constitute the first step of the methodology to help sharing total fuel consumption by vehicle class.

Table 3.123 – Technology classification according to built year

Vehicle Category	Legislation	Built year	
		from	to
Passenger Cars	PRE ECE	...	1971
	ECE 15/00-01	1972	1977
	ECE 15/02	1978	1980
	ECE 15/03	1981	1985
	ECE 15/04	1986	1991
	Euro I	1992	1996
	Euro II	1997	2000
	Euro III	2001	2004
	Euro IV	2005	...
Light Duty Vehicles	Conv	...	1991
	Euro I	1992	1997
	Euro II	1998	2001
	Euro III	2002	2006
	Euro IV	2006	...
Heavy Duty Vehicles	Conv	...	1991
	Euro I	1992	1995
	Euro II	1996	2000
	Euro III	2001	2005
	Euro IV	2006	2008
	Euro V	2009	...
Mopeds	Conv	...	1999
	97/24/EC Stage I	2000	2003
	97/24/EC Stage II	2004	...
Motorcycles	Conv	...	1999
	97/24/EC	2000	...

### Hot and Cold emission factors

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

- Hot emission 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>26</sup> increases to normal operation temperature, have generally increased emissions over *normal* hot emissions.

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

<sup>26</sup> Cold engines are defined as those with water temperature below 70°C (EMEP/CORINAIR)

$$ef_{(c,t,d,f,p)}^T = \frac{\sum_m \{ef_{(c,t,d,f,p)}^{hot} \times [1 + \beta_m \times (cf_{(c,t,d,f,p)}^{cold/hot} - 1)]\}}{12}$$

where,

$ef_{(c,t,d,f,p)}^T$  = average annual total (hot and cold-start) emissions from vehicle type c with technology t and using fuel type f (g/km);

m = Month;

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

$\beta_m$  = average monthly value for the fraction of mileage driven with cold engines or catalyst operated below the light-off temperature<sup>27</sup>.

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

Cold-start corrections were applied for cars using all three fuels: gasoline, diesel and LPG, and for urban and rural modes. Correction factors  $cf_{cold/hot}$ , were set from EMEP, 2002.

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

Disaggregation of fleet for evaporative emission calculation was derived from KAR output.

### Exhaust Emissions

Two different sets of pollutants are distinguishable:

- Pollutants for which a mass balance may be performed such as 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);

<sup>27</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)

$FC_{(c,t,d,f,y)}$  = fuel consumption in year y allocated to vehicle type c, with technology t, using fuel type f and under driving conditions d (t/yr);

$EF_{CO_2(f)}$  = emission factor for fuel type f (t/t).

Emissions of  $SO_x$  are also estimated by a mass balance approach:

$$SO_{x(y)} = 2 \times \sum_c \sum_t \sum_d \sum_f [Fuel_{Cons(c,t,d,f,y)} \times S_{(f,y)} \times 10^{-2}]$$

where,

$SO_{x(y)}$  = sulphur oxide emission estimated in exhaust gas from road vehicles in year y (ton/yr);

$Fuel_{Cons(c,t,d,f,y)}$  = fuel consumption in year y allocated to vehicle type c, with technology t, using fuel type f and under driving conditions d (ton/yr);

$S_{(f,y)}$  = sulphur content of fuel (mass percentage).

Emissions of heavy metals are estimated in a similar way:

$$Emission_{HM(p,y)} = \sum_c \sum_t \sum_d \sum_f [Fuel_{Cons(c,t,d,f,y)} \times HM_{(f,y)} \times 10^{-6}]$$

where,

$Emission_{HM(p,y)}$  = emission of heavy metal p in year y (t/yr);

$Fuel_{Cons(c,t,d,f,y)}$  = fuel consumption in year y allocated to vehicle type c, with technology t, using fuel type f and under driving conditions d (t/yr);

$HM_{(p,f,y)}$  = mass content in heavy metal p in fuel f (g/t).

Emission estimate for pollutants function of distance driven are estimated from:

$$Emission_{(p,y)} = \sum_c \sum_t \sum_d \sum_f [Km_{(c,t,d,f,y)} \times EF_{(c,t,d,f,p)} \times 10^{-6}]$$

where,

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

$Km_{(c,t,d,f,y)}$  = total distance driven in year y by vehicles of type c, with technology t, using fuel type f and under driving conditions d (km/yr);

$EF_{(c,t,d,f,p)}$  = emission factor for pollutant p for vehicles of type c, with technology t, using fuel type f and under driving conditions d (g/km).

### Evaporative Emissions

Calculation of evaporative emissions was adapted from the methodology presented in section B760 from EMEP/CORINAIR Handbook (3<sup>rd</sup> edition).

Disaggregation of fleet for evaporative emission calculation was derived from KAR output. Evaporative emissions were determined for powered gasoline vehicles of classes  $j$  present in Table 3.124.

Table 3.124 – Gasoline powered vehicles categories

Vehicle Class	SNAP	Fuel	Category	Environmental Technology
Passenger Car	070101	Gasoline	< 1.4 l	Canister
Passenger Car	070102	Gasoline	1.4 – 2.0 l	Canister
Passenger Car	070103	Gasoline	> 2.0 l	Canister
Passenger Car	070101	Gasoline	< 1.4 l	Conventional
Passenger Car	070102	Gasoline	1.4 – 2.0 l	Conventional
Passenger Car	070103	Gasoline	> 2.0 l	Conventional
Light Duty Vehicle	070201	Gasoline		Conventional
Moped	0704	Gasoline		Conventional
Moto_2t	070501	Gasoline	> 50 cc	Conventional
Moto_4t	070503	Gasoline	50 – 250 cc	Conventional
Moto_4t	070504	Gasoline	250 – 750 cc	Conventional
Moto_4t	070505	Gasoline	> 750 cc	Conventional

Reliable statistical information concerning vehicles equipped with canister was not available. Therefore it was assumed that all new vehicles built after 1992 were equipped with canister, year in which EURO I was implemented.

Total evaporative emissions are estimated from:

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

where,

$Evap_{NMVOC(y)}$  = NMVOC evaporative emissions in year  $y$  (t/yr);

$a_j$  = number of gasoline vehicles of category  $j$ ;

$e^d$  = mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly ambient temperature, temperature variation and fuel volatility (RVP) (g/day);

$S^c$  = hot and warm soak emission of gasoline powered vehicles equipped with carburettor (g/day);

$S^{fi}$  = hot and warm soak emission of gasoline powered vehicles equipped with fuel injection (g/day);

$R$  = hot and warm running losses (g).

and,

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

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

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

where,

q = fraction of gasoline powered vehicles equipped with fuel injection;

p = fraction of trips finished with hot engine (dependent of the average monthly ambient temperature);

w = fraction of trips finished with cold or warm engine (shorter trips) or with catalyst below its light-off temperature<sup>28</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 EMEP/CORINAIR Emission Inventory Guidebook;

$e^{s,warm}$  = mean emission factor for cold and warm soak emission (g/day/vehicle). This parameter is also dependent on fuel volatility RVP and average monthly temperature. Estimated from EMEP, 2002;

$e^{fi}$  = mean emission factor for hot and warm soak emission of gasoline powered vehicles equipped with fuel injection. Estimated from EMEP, 2002;

$e^{r,hot}$  = average emission factor for hot running losses of gasoline powered vehicles, dependent on fuel volatility RVP and average monthly ambient temperature. Estimated from EMEP, 2002;

$e^{r,warm}$  = average emission factor for warm running losses of gasoline powered vehicles, dependent on fuel volatility RVP and average monthly ambient temperature. Estimated from EMEP, 2002;

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

It was considered that fuel injection vehicles started to enter the market in 1997 (year in which EURO II was implemented) and it was assumed that all new gasoline passenger cars sold in 1997 were equipped with fuel injection systems whereby a fraction of fuel injection vehicles can be derived for the following year. Gasoline light duty vehicles and two-wheelers were treated as non-fuel injected vehicles.

The fraction of trips finished with hot engine, p, was obtained by subtracting to one the fraction of trips finished with cold or warm engine which is similar to factor  $\beta$ :

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

where,

<sup>28</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:  $w \approx \beta$



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

$t_a$  = ambient temperature;

$l_{trip}$  = average trip length (12 km)<sup>29</sup>.

Distance travelled, in kilometres per vehicle, was determined for each vehicle category from Table 3.124 in the following manner:

$$V_{i(c,t,y)} = \frac{Km_{(c,t,y)}}{N_{(c,t,y)}}$$

where,

$V_{j(c,t,y)}$  = distance driven, in kilometres per vehicle, by vehicles of class  $c$ , equipped with environmental technology  $t$  in year  $y$  (km/vehicle);

$Km_{(c,t,y)}$  = kilometres driven by vehicles of class  $c$ , equipped with environmental technology  $t$  in year  $y$  for all driving modes (km);

$N_{(c,t,y)}$  = number of vehicles of class  $c$ , equipped with environmental technology  $t$  in year  $y$ .

Mean number of trips of a vehicle per day ( $x$ ) can then be obtained from:

$$x = \frac{V_i}{365 \times l_{trip}}$$

Finally, emission 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, 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.

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, 2002 recommendations to set  $w$  (fraction of trips finished with cold or warm engine) equal to  $\beta$ .

Reid vapour pressure values needed to calculate evaporative emissions are given in national legislation and summarised in Table 3.132.

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.

<sup>29</sup> Obtained from Table 6.3 (Chapter B710) of EMEP/CORINAIR Emission Inventory Guidebook.

A global national correction factor was then obtained after weighting each individual NUT III area with fuel consumption for each specific territorial unit thus estimating a representative national average temperature  $T_a$  (°C) for each year.

Table 3.125 – Estimated ambient temperature for evaporative emissions calculation.

1990 to 1995	1996 to 1999	2000 to 2002
14.836 °C	14.874 °C	14.885 °C

## EMISSION FACTORS

### Carbon Dioxide

Ultimate CO<sub>2</sub> emission factors were established considering CORINAIR/EMEP Emission Inventory Guidebook equation:

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

Where

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

$R_{H/C}$  = the ratio of hydrogen to carbon atoms in the fuel. Values for this ratio and the resulting CO<sub>2</sub> emission factor are presented in Table 3.126.

Table 3.126 -  $R_{H/C}$  ratio and CO<sub>2</sub> emission factor

Fuel	$R_{H/C}$	EF <sub>CO<sub>2</sub></sub> (t CO <sub>2</sub> /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 1990-2003 period. The sulphur contents were set as presented in next table.

Table 3.127 – 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 Factor Functions***

#### Variable Emission Factors

Emission factors were subjected to variations as the result of the use of new technologies, particularly the introduction of catalyst converter in passenger cars. The use of new technologies is function of vehicle built year, which was used as a variable for emission factor estimation (see Table 3.123).

Emission factors were determined for:

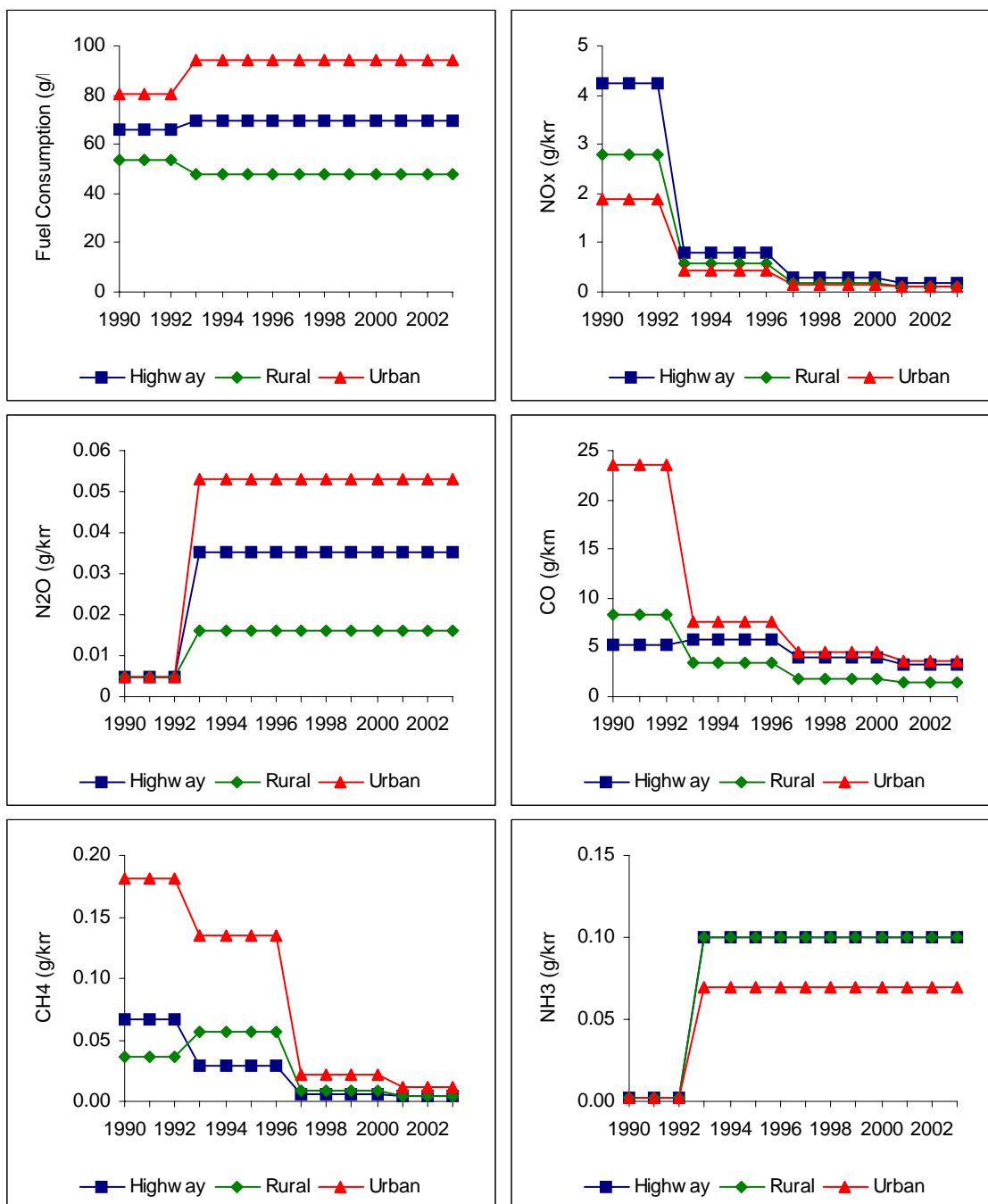
- 10 pollutants<sup>30</sup> (CO, NO<sub>x</sub>, N<sub>2</sub>O, SO<sub>2</sub>, VOC, CH<sub>4</sub>, CO<sub>2</sub>, NH<sub>3</sub>, diesel particulates and lead);
- 6 vehicle types (gasoline passenger cars, diesel passenger cars, LPG passenger cars, light duty vehicles, heavy duty vehicles and two wheelers) and each correspondent category (<1.4 l, 1.4 - 2.0 l, etc);
- 3 driving conditions (urban, rural and highways).

For gasoline passenger cars with cylinder capacity 1.4l<cc<2.0l the influence of a catalyst results in a significant decrease of pollutants dependent on driving conditions such as CO, NO<sub>x</sub> and CH<sub>4</sub>. For example, the introduction of catalyst leads to a decrease in NO<sub>x</sub> emission factor of about 80% on average and to a decrease of 55% of CO averaged emission factor. On the other hand, NH<sub>3</sub> and N<sub>2</sub>O increased by a factor of 45 and 7, respectively.

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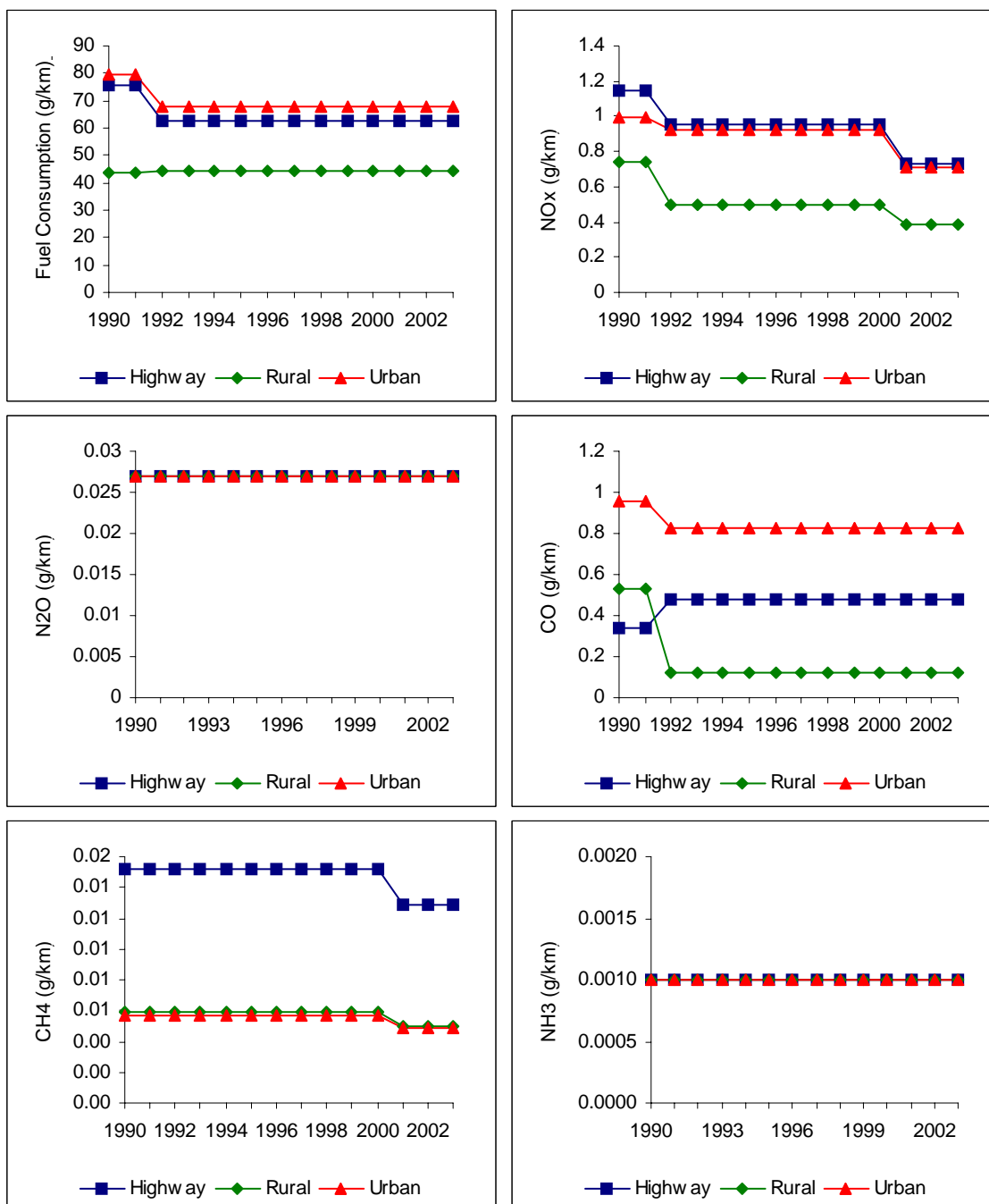
<sup>30</sup> For some pollutants (SO<sub>2</sub>, CO<sub>2</sub>, Heavy Metals) very simply "bulk" emission factors or equations are provided in EMEP/CORINAIR.

Figure 3.56 –Fuel consumption and emission factors for new gasoline passenger cars in each year ( $1.4 \text{ l} < \text{CC} < 2.0 \text{ l}$ )



For passenger diesel vehicles with cylinder capacity less than 2.0l the introduction of Euro I technology in 1992 lead to an average reduction of CO, NO<sub>x</sub> and fuel consumption of about, 22%, 17% and 12%, respectively. From EURO I to EURO II decreases in averaged emissions factors are only observed for NO<sub>x</sub> (-23% when compared to EURO I averaged emission factor) and CH<sub>4</sub> (-15% of EURO I averaged emission factor).

Figure 3.57 –Fuel consumption and emission factors for new diesel passenger cars in each year (CC < 2.0 l)



### Evaporative Emissions

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

Table 3.128 – Mean evaporative emission factors (values in g/vehicle/day)

Emission Factor	Category	1990	1991	1992	1993	1994	1995	1996
$e^d$	Conventional	5.860	5.860	5.860	5.860	5.860	5.860	5.841
	Canister	1.172	1.172	1.172	1.172	1.172	1.172	1.168
$e^{s,warm}$	Conventional	3.235	3.235	3.235	3.235	3.235	3.235	3.220
	Canister	0.521	0.521	0.521	0.521	0.521	0.521	0.520
$e^{s,hot}$	Conventional	16.897	16.897	16.897	16.897	16.897	16.897	16.584
	Canister	0.782	0.782	0.782	0.782	0.782	0.782	0.780
$e^{fi,hot} \& e^{fi,warm}$	Conventional	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
	Canister	0.014	0.014	0.014	0.014	0.014	0.014	0.014
$e^{r,hot}$	Conventional	0.192	0.192	0.192	0.192	0.192	0.192	0.195
	Canister	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Emission Factor	Category	1997	1998	1999	2000	2001	2002	2003
$e^d$	Conventional	5.841	5.841	5.841	5.258	5.258	5.258	5.258
	Canister	1.168	1.168	1.168	1.052	1.052	1.052	1.052
$e^{s,warm}$	Conventional	3.220	3.220	3.220	2.822	2.822	2.822	2.822
	Canister	0.520	0.520	0.520	0.446	0.446	0.446	0.446
$e^{s,hot}$	Conventional	16.584	16.584	16.584	14.758	14.758	14.758	14.758
	Canister	0.780	0.780	0.780	0.668	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
	Canister	-	-	-	-	-	-	-
$e^{r,warm}$	Conventional	0.143	0.143	0.143	0.107	0.107	0.107	0.107
	Canister	0.014	0.014	0.014	0.011	0.011	0.011	0.011
$e^{r,hot}$	Conventional	0.195	0.195	0.195	0.146	0.146	0.146	0.146
	Canister	0.019	0.019	0.019	0.015	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.

$$EF_{implied(p,c,t,f,y)} = \frac{Emission_{(p,c,t,f,y)}}{Km_{(c,t,f,y)} \times 10^6}$$

Where.

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

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

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

Table 3.129 – Implied emission factors.

Class	Pol.	Unit	1990	1991	1992	1993	1994	1995	1996
LV	NOx	g/km	2.605	2.619	2.618	2.453	2.389	2.329	2.294
HV	NOx	g/km	1.577	1.559	1.484	1.443	1.309	1.244	1.187
LV	CH4	g/km	0.122	0.122	0.122	0.120	0.119	0.120	0.117
HV	CH4	g/km	0.012	0.012	0.012	0.012	0.011	0.010	0.010
LV	CO	g/km	22.935	21.813	20.628	18.726	17.201	16.258	14.912
HV	CO	g/km	0.585	0.578	0.548	0.533	0.480	0.454	0.431
LV	N2O	g/km	0.014	0.014	0.013	0.017	0.020	0.023	0.026
HV	N2O	g/km	0.007	0.007	0.007	0.007	0.007	0.006	0.006
LV	VOC	g/km	2.056	2.005	1.947	1.769	1.630	1.545	1.418
HV	VOC	g/km	0.303	0.298	0.285	0.279	0.253	0.240	0.230
LV	NM VOC	g/km	1.934	1.883	1.825	1.649	1.511	1.425	1.300
HV	NM VOC	g/km	0.290	0.286	0.273	0.267	0.242	0.230	0.220
LV	NH3	g/km	3.92E-04	3.52E-04	3.21E-04	3.17E-04	3.09E-04	3.14E-04	3.07E-04
HV	NH3	g/km	6.12E-05	6.13E-05	5.98E-05	5.98E-05	5.53E-05	5.37E-05	5.29E-05
LV	PST	g/km	0.065	0.059	0.053	0.051	0.049	0.049	0.047
HV	PST	g/km	0.019	0.019	0.019	0.018	0.017	0.016	0.015
LV	CO2	g/km	332.449	325.157	318.314	314.758	324.248	333.674	339.599
HV	CO2	g/km	141.100	140.900	136.982	136.184	126.100	122.060	120.260
Class	Pol.	Unit	1997	1998	1999	2000	2001	2002	2003
LV	NOx	g/km	2.323	2.386	2.338	2.451	2.545	2.389	2.357
HV	NOx	g/km	1.053	0.930	0.909	0.745	0.645	0.596	0.557
LV	CH4	g/km	0.111	0.104	0.097	0.092	0.086	0.081	0.077
HV	CH4	g/km	0.009	0.008	0.009	0.007	0.006	0.006	0.006
LV	CO	g/km	13.862	12.888	11.976	11.266	10.534	9.848	9.351
HV	CO	g/km	0.380	0.333	0.324	0.268	0.235	0.218	0.203
LV	N2O	g/km	0.029	0.034	0.037	0.043	0.047	0.048	0.051
HV	N2O	g/km	0.006	0.005	0.005	0.004	0.004	0.004	0.004
LV	VOC	g/km	1.325	1.234	1.137	1.062	0.986	0.909	0.852
HV	VOC	g/km	0.204	0.181	0.178	0.150	0.133	0.124	0.118
LV	NM VOC	g/km	1.214	1.130	1.040	0.970	0.900	0.828	0.775
HV	NM VOC	g/km	0.195	0.173	0.169	0.143	0.126	0.118	0.112
LV	NH3	g/km	3.08E-04	3.19E-04	3.40E-04	3.20E-04	3.50E-04	3.27E-04	3.25E-04
HV	NH3	g/km	4.89E-05	4.68E-05	4.64E-05	4.54E-05	3.76E-05	3.68E-05	4.08E-05
LV	PST	g/km	0.045	0.045	0.046	0.041	0.042	0.037	0.035
HV	PST	g/km	0.013	0.012	0.012	0.011	0.009	0.008	0.008
LV	CO2	g/km	364.069	398.098	411.352	455.131	494.809	486.774	500.108
HV	CO2	g/km	110.361	100.650	101.213	86.084	78.564	76.515	75.019

Legend:

LV – Light Vehicles

HV – Heavy Vehicles

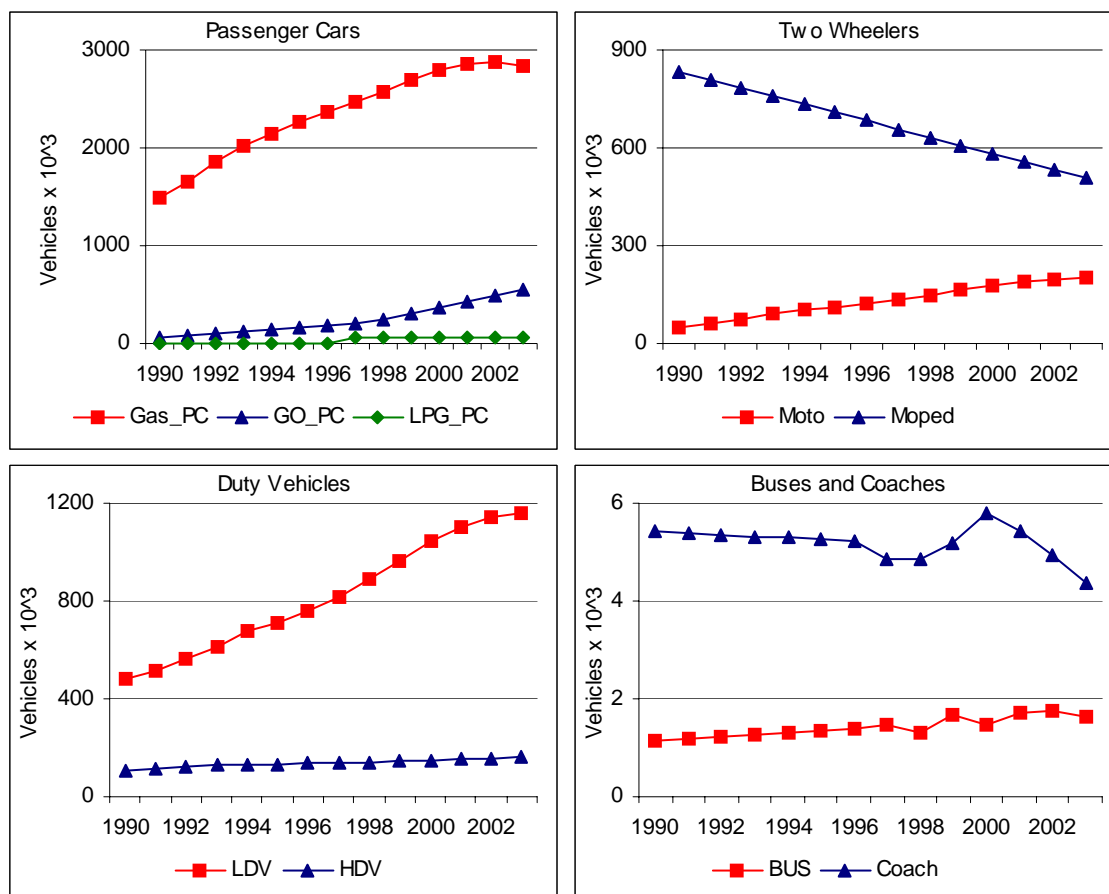
## ACTIVITY DATA

**Vehicle Fleet**

The number of vehicles between 1990 and 2003 was based in data available from ACAP, ISP and INE.

Vehicle data was adapted in accordance with the methodology described in 0. A national fleet was determined for each year of the calculation period (Figure 3.58).

Figure 3.58 – Vehicle fleet synthesis: 1990-2003



The growth of gasoline passenger cars has decreased over the last years. It was observed a decrease in the number of this type of vehicles while diesel passenger cars have increased. After an initial growth, LPG fuelled vehicles have stabilised as a small percentage of passenger cars. The number of buses and coaches result from INE statistics which only includes public transport carriers. The number of mopeds is decreasing according to ISP data for 1990 and 2002.

**Distances Travelled**

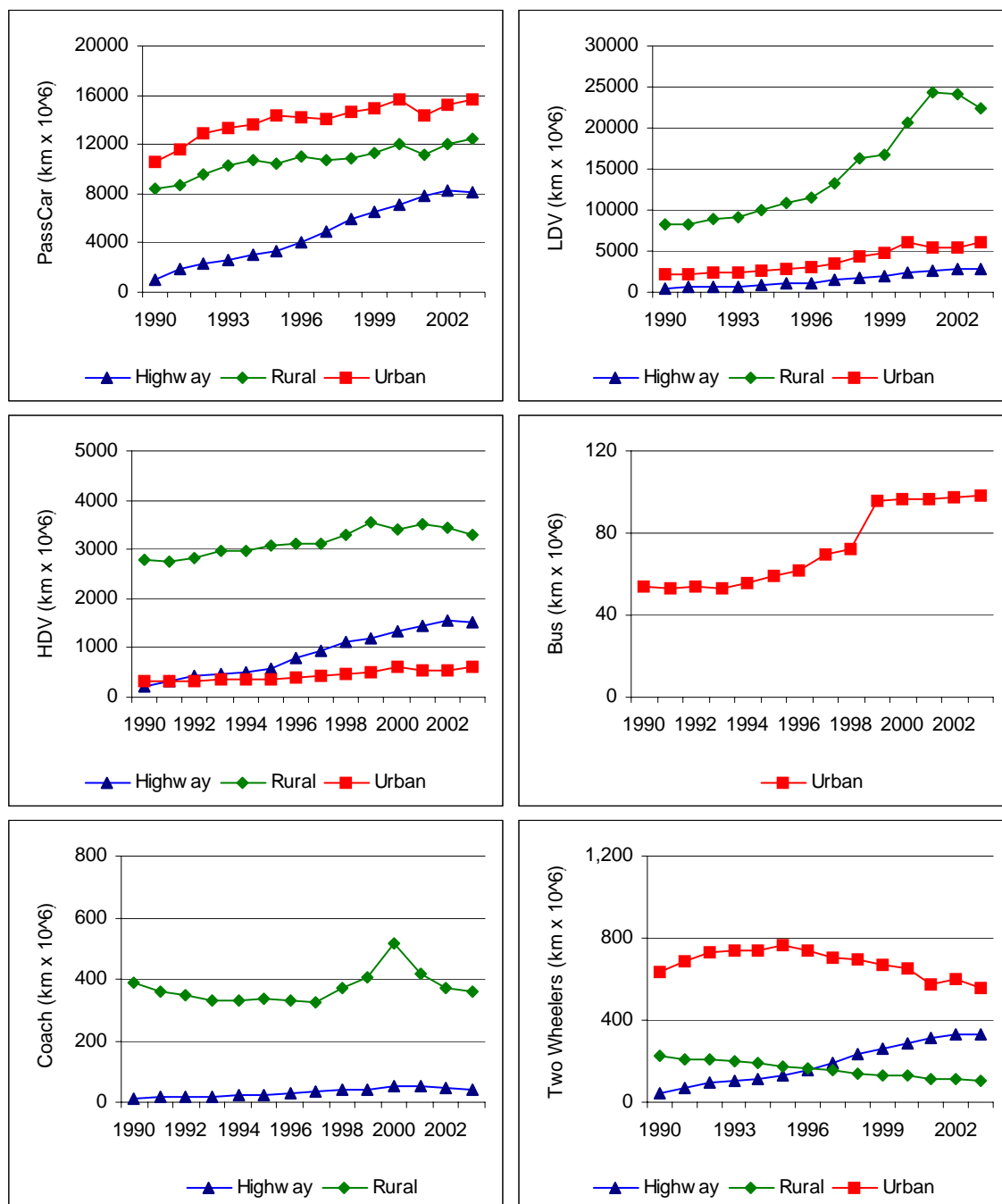
Total distance driven in highways was obtained from highway commissioners data collected by IEP. Time evolution road length was set from IEP's GIS system and concerns the date from which each link was set open to road traffic circulation.

Total national figures have increased steadily between 1990 and 2002. The increase in highway circulation of 7.8 times in twelve years, reflects not only the growth of the Portuguese highway



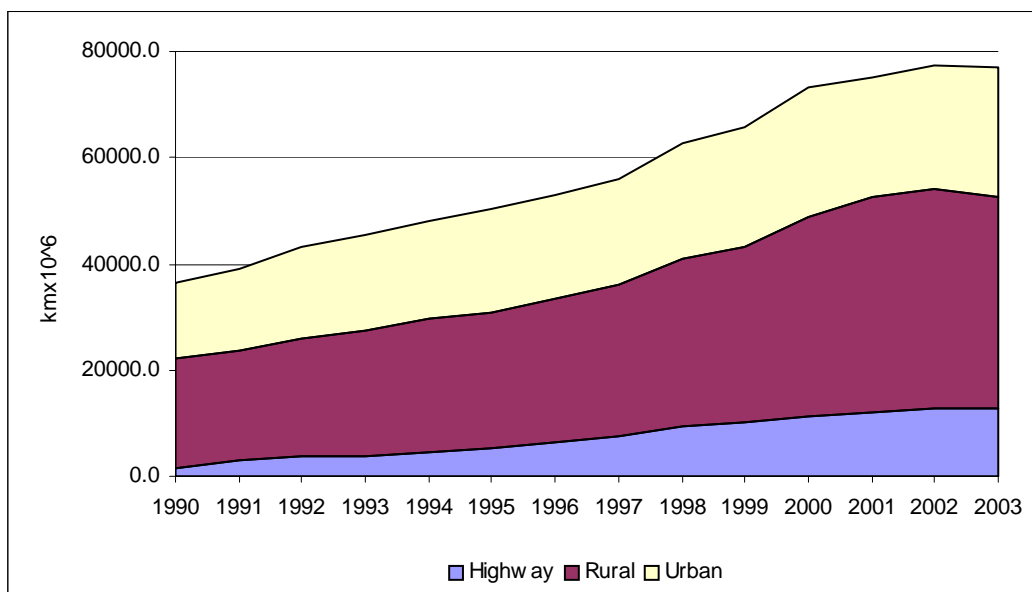
road-net but also an increase in intensity of road use. For the same period, rural and urban circulation has increased 2.0 and 1.6 times, respectively. Total road traffic activity has increased 110.7% since 1990. From 2002 to 2003 total road traffic activity registered a slight decrease of 0.47%.

Figure 3.59 - Distance driven for passenger cars, light duty vehicles, heavy duty vehicles, urban buses, coaches and two wheelers



Rural activity is the most significant share of total distance travelled being responsible for 51.6% of the overall kilometers travelled in 2003 followed by urban and highway activity with 37.1 and 16.7%, respectively (Figure 3.60 and Table 3.130).

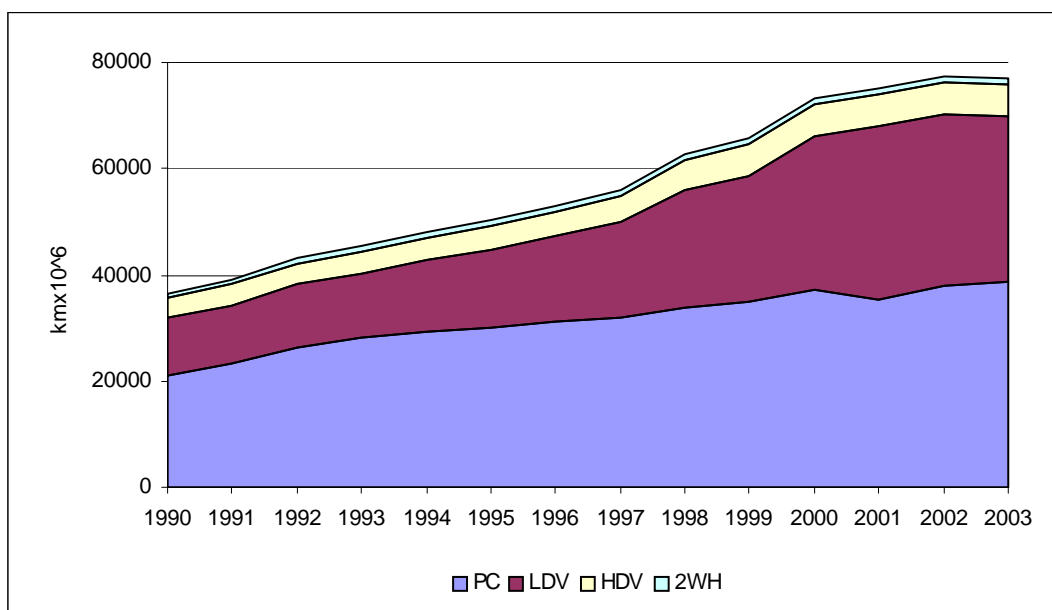
Figure 3.60 – Kilometres travelled by driving mode

Table 3.130 – Kilometres travelled (km×10<sup>6</sup>)

Class	Mode	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
PassCar	Highway	1063	1863	2362	2603	2974	3355	4027	4907	5986	6474	7114	7761	8260	8186
PassCar	Rural	8477	8692	9626	10313	10669	10370	11058	10771	10862	11367	12024	11179	12046	12530
PassCar	Urban	10619	11626	12889	13396	13661	14339	14152	14058	14627	14901	15584	14379	15276	15723
LDV	Highway	328	555	681	747	877	985	1193	1472	1845	2025	2310	2569	2754	2754
LDV	Rural	8288	8259	8807	9038	10097	10970	11629	13231	16210	16818	20727	24272	24134	22454
LDV	Urban	2102	2143	2304	2366	2655	2900	3109	3543	4412	4879	6035	5494	5460	6094
HDV	Highway	208	340	423	459	522	580	791	938	1127	1213	1333	1455	1543	1539
HDV	Rural	2793	2767	2843	2960	2972	3087	3118	3099	3304	3565	3406	3504	3435	3314
HDV	Urban	310	319	334	347	355	374	398	417	487	523	619	559	559	627
Bus	Highway	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bus	Rural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bus	Urban	53	53	54	53	55	59	62	70	72	96	97	97	97	98
Coach	Highway	11	16	19	19	21	23	29	33	39	43	52	51	48	42
Coach	Rural	389	360	351	329	329	338	330	323	369	406	517	420	371	361
Coach	Urban	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moped	Highway	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moped	Rural	218	203	195	185	173	155	151	136	125	116	109	93	94	88
Moped	Urban	626	674	715	725	721	746	717	686	676	646	627	552	571	531
Moto	Highway	42	73	92	102	117	132	158	193	238	258	286	313	334	332
Moto	Rural	9	10	12	14	15	15	17	17	17	18	19	18	20	20
Moto	Urban	11	13	16	18	20	21	21	22	23	24	25	24	26	26

Over the 1990-2003 period the distance driven grew for all vehicle types. As presented in Figure 3.61, LDV is the vehicle having registered the biggest increase in distance driven (192%). Nevertheless, passenger cars are the vehicles travelling more kilometres with a share of 50.2% from the total distance driven in 2003.

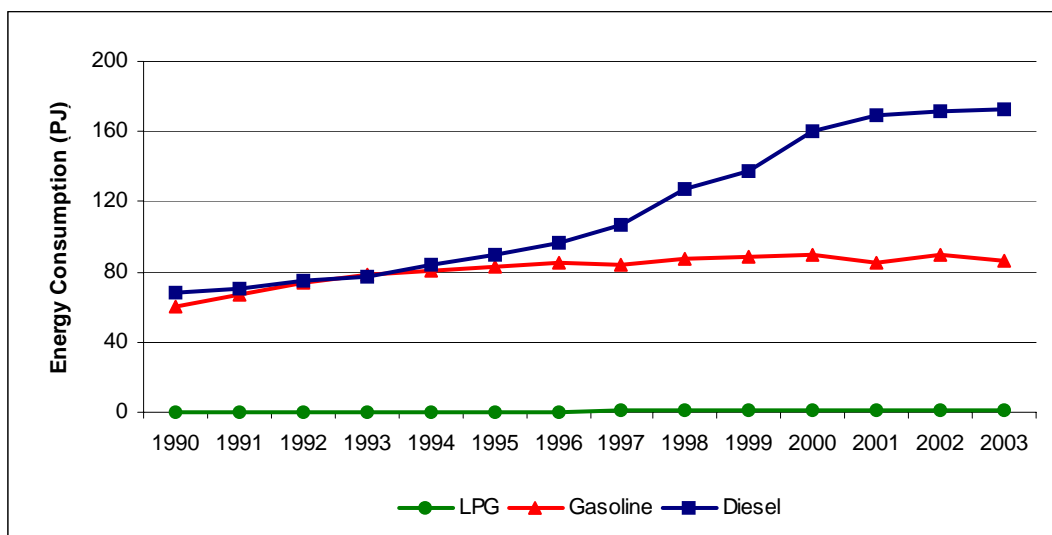
Figure 3.61 – Kilometers travelled by vehicle type



### Fuel Consumption

Fuel consumption from road transport sector is available for the years from 1990 to 2003 from the newly revised energy balances from DGGE. Total consumption of petrol, diesel-oil and LPG is shown in Figure 3.62.

Figure 3.62 – Fuel consumption from road transport sector



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

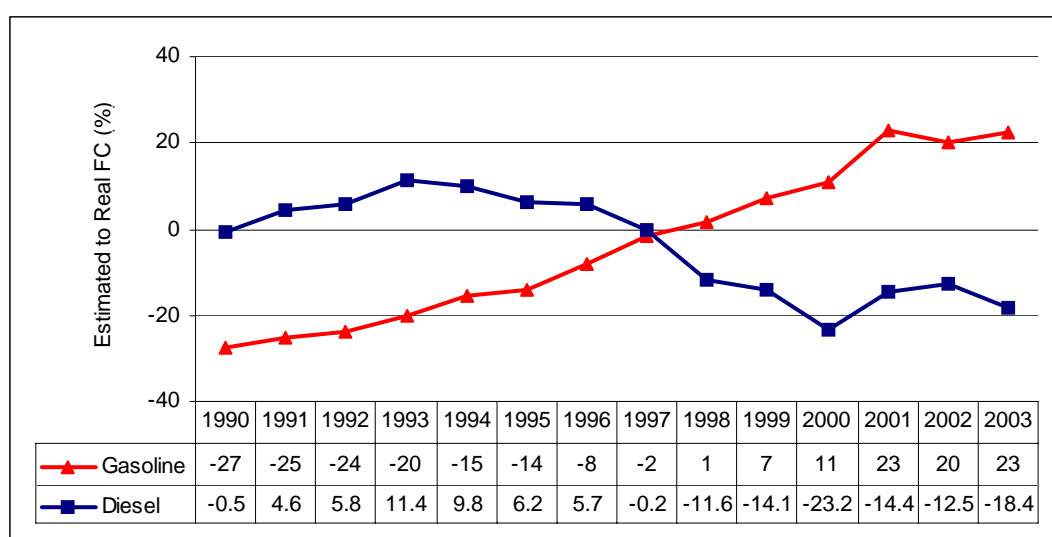
Table 3.131 – Low Heat Values (LHV) in Road Transportation

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

Fuel consumption was also estimated from the fuel consumption factors given from EMEP, 2002. The bottom-up versus top-down correction factor was derived from the differences between estimated and real fuel consumption as explained before.

Estimated fuel consumption varies within a maximum of  $\pm 30\%$  from real fuel consumption for all period of analysis. Very good estimations were performed for 1997 where gasoline and diesel differs from real values only by -2% and 0.2%, respectively. Moreover, the trend of estimated to real gasoline consumption suggests the presence of a systematic error in the model. This is maybe due to the vehicle activity input for passenger cars.

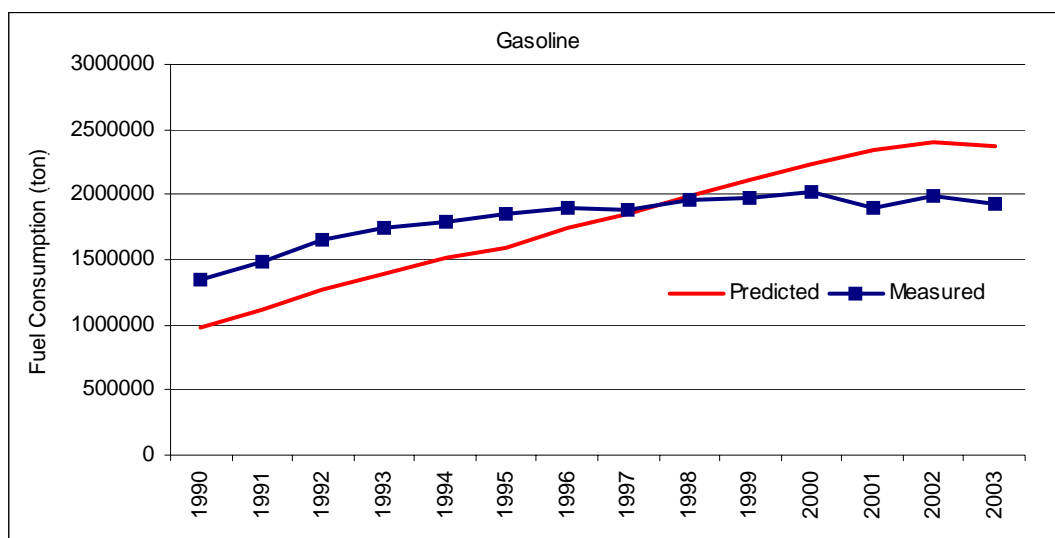
Figure 3.63 – Differences between estimated and real fuel consumption.



Since the input variable of vehicle activity is given in km/vehicle an increase in the number of vehicles leads to a linear increase of the vehicle kilometers travelled which could not be true. From a given number of vehicles the variable km/vehicles tends to stabilize.

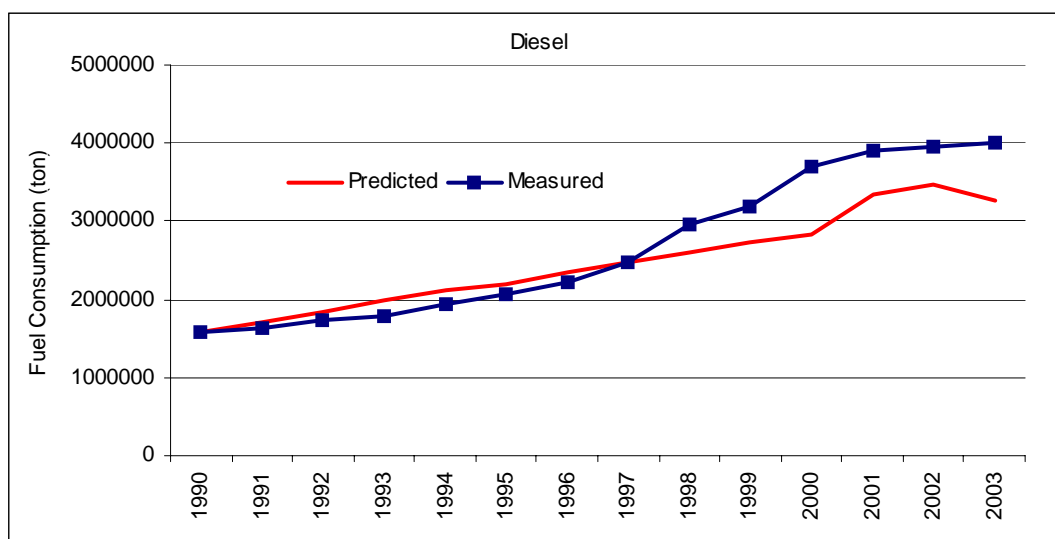
Therefore the activity input variable for passenger cars, actually estimated from the DGGE scenarios, should be derived using a different methodology. Figure 3.64 shows the measured and estimated figures for gasoline consumption.

Figure 3.64 – Measured and predicted gasoline fuel consumption



Estimated diesel consumption was similar to real consumption until 1997. Since then it seems that diesel vehicles are actually running more kilometres than the values predicted in DGGE scenarios. This assumption should be tested by using a different methodology to estimate the km/vehicle from diesel vehicles.

Figure 3.65 – Measured and predicted diesel fuel consumption.



### 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 recommendations to set  $w$  (fraction of trips finished with cold or warm engine) equal to  $\beta$ .

Monthly values of fuel volatility (RVP - Reid Vapour Pressure) were established from Portuguese legislation (Decreto-lei n.º 104/2000; Portaria 1489/95; Portaria 125/89)

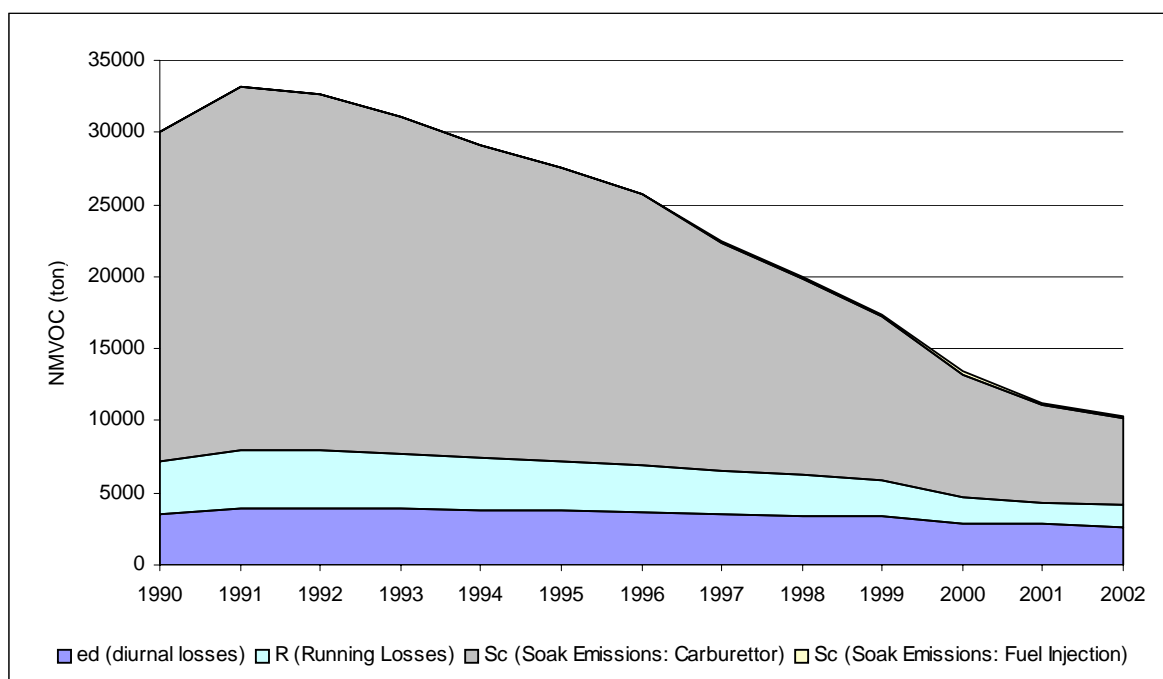
RVP values considered in national legislation 104/2000 are applicable since the beginning of year 2000 although the regulatory document was valid only after May 2000.

Table 3.132 - Legal values for Reid Vapour Pressure (RVP) (values in kPa)

Month	Year		
	1989 to 1995	1996 to 1999	≥ 2000
Jan	98	95	90
Feb	98	95	90
Mar	98	95	90
Apr	83	80	90
May	83	80	60
Jun	70	70	60
Jul	70	70	60
Aug	70	70	60
Sep	70	70	60
Oct	83	95	90
Nov	98	95	90
Dec	98	95	90

Major reductions were estimated for evaporative emissions for the period between 1990 and 2003 as new fuel injection vehicles replace old carburettor vehicles. Figure 3.66 shows that soak emissions from carburettor vehicles have contributed significantly for evaporative emission reduction, decreasing about 78% since 1990. Soak emissions from fuel injection vehicles represent a small fraction of evaporative emissions (less than 2% in 2003).

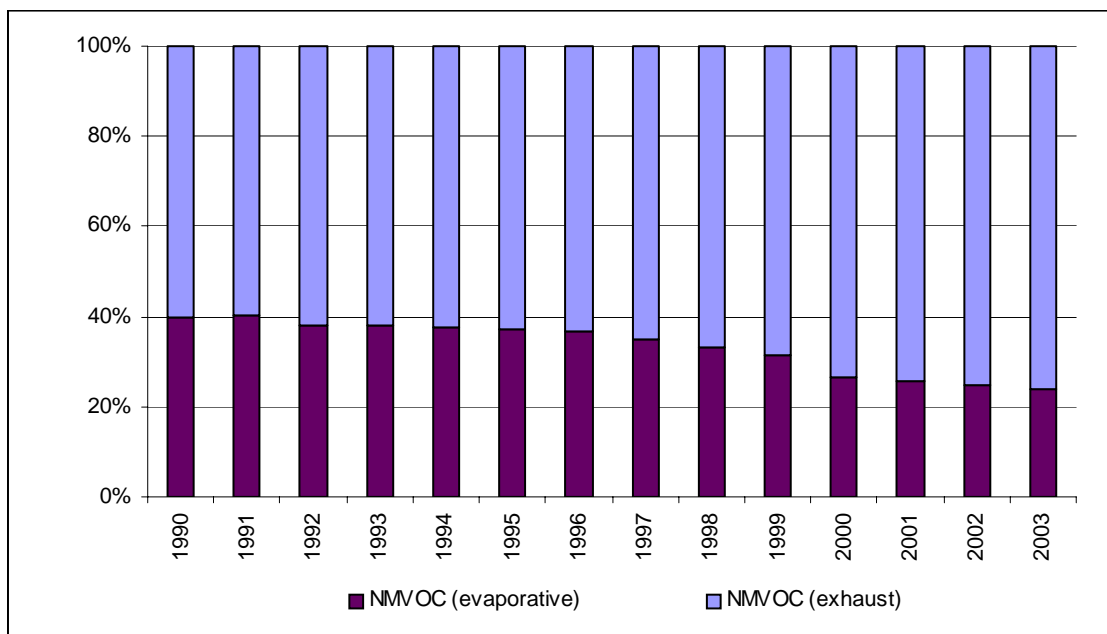
Figure 3.66 – Estimated evaporative emissions



From 1990 to 2000 the trend of evaporative emissions for diurnal and running losses and soak emissions from carburettor vehicles decreases faster. This results from the evaporative emission factors which are function of the fuel RVP. Therefore, reduction of evaporative emissions was achieved not only by the introduction of new vehicle technologies but also by fuel improvements.

The share of evaporative emissions from total NMVOC is decreasing since 1990 from about 40% to less than 25% in 2003 as shown in Figure 3.67.

Figure 3.67 – Share of evaporative and exhaust NMVOC.



#### Cold start

Ambient temperature parameter ( $T_a$ ) for cold start 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 start emission corrections for other years.

### UNCERTAINTY ASSESSMENT

In accordance with the chapter of Road Vehicles in the GPG, the uncertainty of methane emission factor is 40% and the uncertainty for nitrous oxide should be at least 50%. The uncertainty in CO<sub>2</sub> is 5%, also in accordance with the same source of information. The uncertainty of activity data was assumed to be 10%.

#### 3.2.C.2 RAILWAYS

##### OVERVIEW

Although there has been a growing electrification of railway lines in Portugal during last years, locomotives, shunting locomotives and railcars are still responsible for substantial part of rail transport and consequent emission of GHG in exhaust.

##### METHODOLOGY

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

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

where

Fossil<sub>CO2(y)</sub> - Emissions of carbon dioxide to atmosphere from combustion of fossil fuel f (ton);

EF<sub>CO2 (f)</sub> – Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

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

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

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

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

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

$$SO_{x (y)} = 2 * \sum_f [Fuel_{Cons(f,y)} * S_{(f,y)} * 10^{-2}]$$

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).

For all other pollutants the following formula was used:

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

where

Emission<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).

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

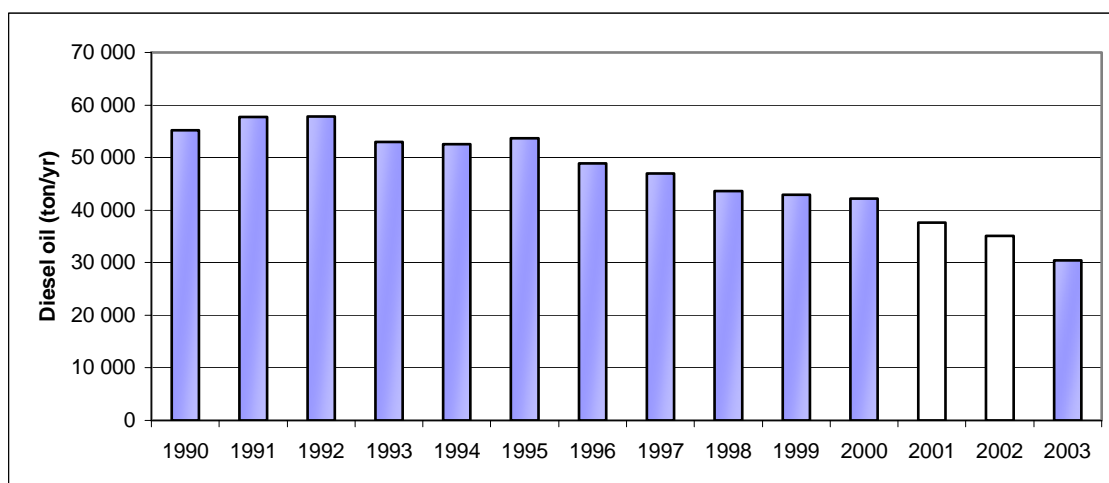
	Coal	Coke	Diesel-oil	Fuel-oil
LHV <sup>(a)</sup>	29.3	28.0	43.3	40.2
NO <sub>x</sub>	55.6			
COVNM	5.1			
CH <sub>4</sub>	0.22			
CO	20			
U <sub>CO2</sub>	3 168			
FAC <sub>OX</sub> <sup>(b)</sup>	0.980	0.990		
N <sub>2</sub> O	0.66			
NH <sub>3</sub>	0.01		0.007	0.01
PM	3.79			
Cd <sup>(c)</sup>	1.00E-02	1.00E-02	1.00E-02	1.00E-02
As <sup>(c)</sup>	5.00E-02	5.00E-02	5.00E-02	5.00E-02
Cr <sup>(c)</sup>	5.00E-02	5.00E-02	5.00E-02	5.00E-02
Cu <sup>(c)</sup>	1.70E+00	1.70E+00	1.70E+00	1.70E+00
Ni <sup>(c)</sup>	7.00E-02	7.00E-02	7.00E-02	7.00E-02
Se <sup>(c)</sup>	1.00E-02	1.00E-02	1.00E-02	1.00E-02
Zn <sup>(c)</sup>	1.00E+00	1.00E+00	1.00E+00	1.00E+00

(a) LHV/NCV expressed in MJ/kg; (b) Oxidation Ratio expressed as ratio; (c) expressed in g/ton

## ACTIVITY DATA

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2003 from the energy balance produced by General-Directorate of Geology and Energy (DGGE). Besides some very small use of coal and coke until 1996, the majority of combustible energy refers to use of gas oil<sup>31</sup>. The quantities that were consumed have been decreasing steadily since 1992, as can be seen in Figure 3.68.

Figure 3.68 - Consumption of diesel oil in the railway transport sector: 1990-2003



<sup>31</sup> Gas oil represents no less than 99.9% of total annual use of combustible energy.

## UNCERTAINTY ASSESSMENT

The uncertainty of fuel consumption was set equal to the uncertainty that was also considered for road traffic: 5%. In a similar way the uncertainties in methane and nitrous oxide emission factors were set at 40% and 50% respectively, the same values that were used for road traffic. The general error of 5%, set for most combustion sources, was used for the calculation of uncertainties of carbon dioxide emission factor.

### 3.2.C.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. The emissions resulting from navigation for transport purposes are 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 1.A.4c Fuel Combustion Activities in Agriculture, fisheries and forestry. Also emissions from additional consumption in fishing industry, aquaculture or sea ports that are realized inland and not in water vessels are not included here but under Fuel Combustion Activities, Other Sectors (1A4) and are discussed in chapter 3.2.A.6.

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

#### METHODOLOGY

The methodology that is used is akin to Tier2 approach although is not fully 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> were estimated for each ship type using the following formula:

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

where

Emission<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 were estimated from:

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

Where,

$\text{Fossil}_{\text{CO}_2(y)}$  - Emissions of carbon dioxide to atmosphere from combustion of fossil origin from ships of class n (ton);

$\text{EF}_{\text{CO}_2(f)}$  - Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg  $\text{CO}_2/\text{GJ}$ );

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

$\text{C}_{\text{Fossil}}$  - Percentage of carbon from fossil origin in fuel f (%);

$\text{Cons}_{\text{Fuel}(n,f,y)}$  - Consumption of fuel f in year y from ship type n (ton/yr);

$\text{LHV}_{(f)}$  - Low Heating Value (MJ/kg).

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

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

where

$\text{SO}_{x(n,y)}$  - Sulphur oxide emission estimated from consumption from navigation or fishing in year y from ships of class n (ton/yr);

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

$\text{S}_{(f,y)}$  - 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 3.134 – Emission factors for Water Borne Navigation and Fishing Vessels

EF	Units	Coastal Fisheries	Other Fisheries	Navigation	Coastal Fisheries	Other Fisheries	Navigation
		Gas-oil			Fuel-oil		
LHV	MJ/kg	43.31			40.17		
SO <sub>x</sub>	%	0.3			3		
NO <sub>x</sub>	g/kg	67.5	87		67.5	87	
NM VOC	g/kg	4.9					
CH <sub>4</sub>	g/kg	0.23					
CO	g/kg	21.3	1.9	1.9	21.3	1.9	1.9
EF <sub>CO2</sub>	kg/GJ	74.07			77.37		
C <sub>Fossil</sub>	%	100					
Fac <sub>OX</sub>	0..1	0.990					
N <sub>2</sub> O	g/kg	0.08					
PM	g/kg	1.2			7.6		
As	g/ton	0.05			0.5		
Cd	g/ton	0.01			0.03		
Cr	g/ton	0.04			0.2		
Cu	g/ton	0.05			0.5		
Hg	g/ton	0.05			0.02		
Ni	g/ton	0.07			30		
Pb	g/ton	0.2			1.3		
Se	g/ton	0.2			0.4		
Zn	g/ton	0.5			0.9		

## ACTIVITY DATA

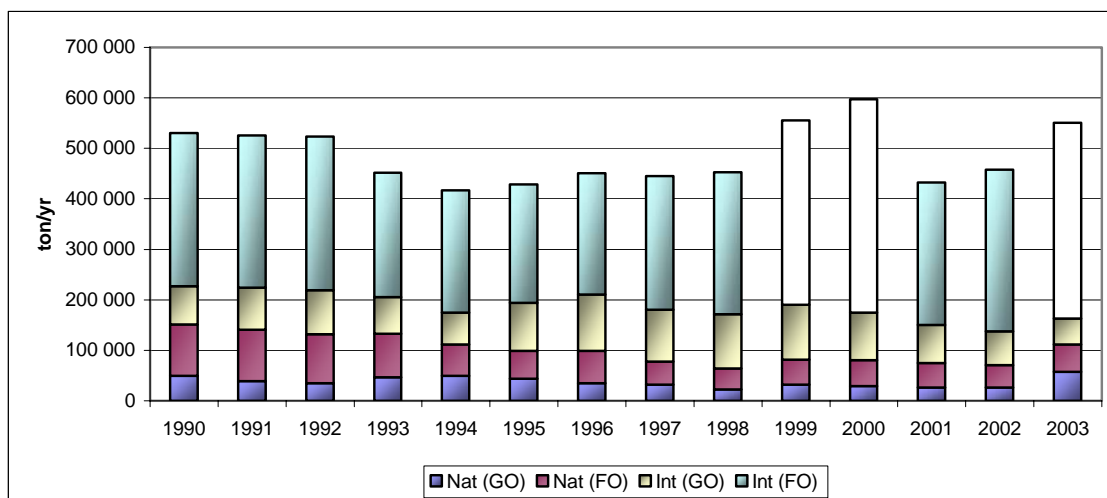
Fuel sales to navigation bunkers and fishing activities were used as basic activity data for both source sectors. This information was collected from the energy balances, produced under the responsibility of the General-Directorate of Geology and Energy (DGGE).

### 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>32</sup>. Disaggregated consumption of fuel-oil and diesel-oil is available annually from 1990 to 2003, which time series are represented in Figure 3.69.

<sup>32</sup> Separation is by ship's flag.

Figure 3.69 - Fuel consumption in Transport Navigation by fuel and by national and international navigation: 1990-2003



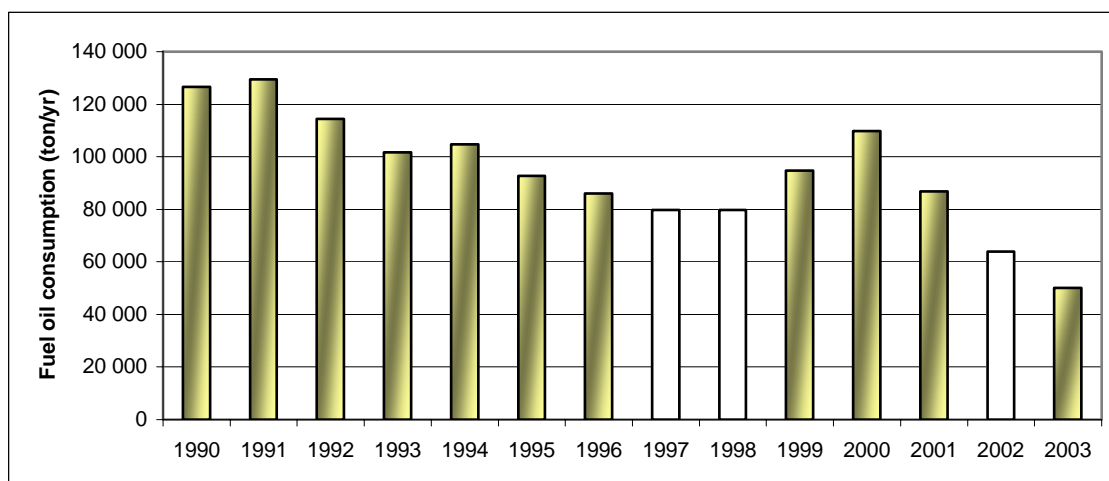
More information was however available from DGGE until 2002, namely it was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha and diesel-oil was further classified in gas-oil and diesel oil. This information was used to construct more disaggregated time series for each one of those fuels from 1990 to 2002. 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 3.70<sup>33</sup>.

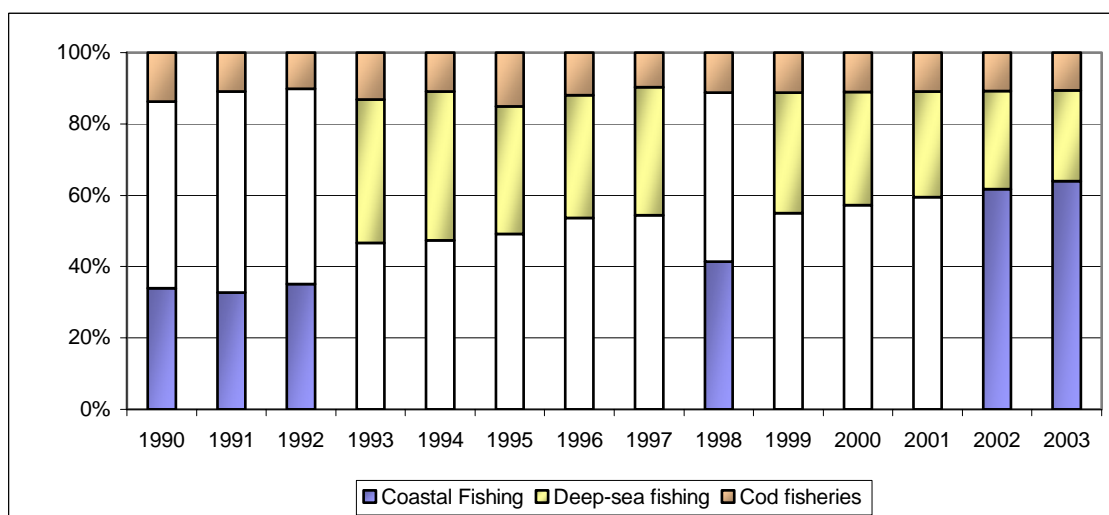
<sup>33</sup> Use of diesel oil and fuel oil is insignificant, always less than 2.5% of gas oil consumption.

Figure 3.70 – Consumption of fuel oil in fishing bunkers (1990-2003)



Additional information in DGGE annual reports, available only until 2001, allow the division<sup>34</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>35</sup>. Percentage for each type of fisheries is presented in next figure.

Figure 3.71 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries (1990-2003)



<sup>34</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>35</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.

## UNCERTAINTY ASSESSMENT

The activity data considered in the inventory for the estimate of emissions from domestic transport navigation have a high level of uncertainty reflecting the fact that the available methodology allocates emissions per flag and not by origin-destination as required by IPCC guidelines. The uncertainty value was estimated as the maximum percent increase in emissions, in the 1990-2003 period, if all fuel sold in maritime bunkers should be included in domestic navigation, and a value of 636% was therefore assumed to represent the uncertainty value of activity data. Concerning fishing the allocation problem does not affect results and the uncertainty was set as 5% in accordance to what was done for the other mobile sources.

Following the recommendations of GPG the uncertainties of emission factors for CH<sub>4</sub> and N<sub>2</sub>O, and for all types of vessels and navigation, were set respectively to 100% and 1000%.

### 3.2.C.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 UNFCCC good practice the separation is done according to the following table (IPCC,2000).

Table 3.135 – 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)

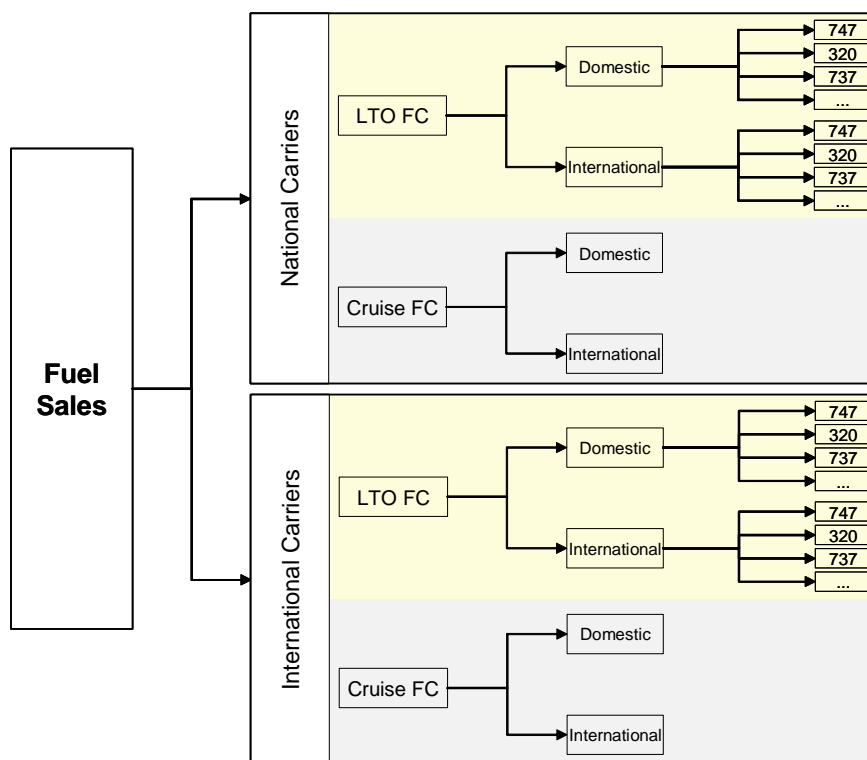
However, the Portuguese inventory presently can not fully achieve this level of detail and separation is done exclusively according to the location of departing and arriving airport, being considered domestic if both airports are situated in the national territory. Portuguese territorial area comprehends, in what concerns definition of domestic, mainland continental area and the autonomous regions of Azores and Madeira islands<sup>36</sup>.

Desegregation of emissions is therefore possible according to Figure 3.72 below.

<sup>36</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.



Figure 3.72 – Available Desegregation of total aviation emissions



## METHODOLOGY

The methodology that was used in the inventory is coherent with good practices and is equivalent to the Tier2b approach. Emissions were 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 were 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);

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

$Frac_{FLAG(a,n)}$  – Fraction of LTO movements at airport a done by planes of air carrier n (National/Foreign);

$Frac_{OD(n,d)}$  – 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 was no separation per aircraft type and the applied emission factor was an average value. In this case methodology is Tier 2a.

Cruise emissions are estimated solely from fuel consumption. Total fuel sales per fuel type ( $FC_{TOTAL(y)}$ ) were deduced from fuel consumption during LTO ( $FC_{LTO(y)}$ )<sup>37</sup>, and consumption during cruising ( $FC_{CRUISE(y)}$ ) is estimated as the remaining:

$$FC_{CRUISE(y)} = FS_{TOTAL(y)} - FC_{LTO(y)}$$

Total fuel consumption in cruise mode was segregated by fuel type, nationality and, only for JP, type of movement according to origin-destiny d. The following calculation procedure was used:

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

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);

$Frac_{pkm(f,d,y)}$  – 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 were estimated from:

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

where

$Emission_{CRUISE(n,p,y)}$  - 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).

<sup>37</sup> Fuel consumption in LTO movements is estimated from LTO movements and using emission factors in a manner similar to calculation of pollutant emissions.

## 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>38</sup> databases.

Table 3.136 - Emissions factors (kg/LTO) for LTO movements per aircraft type (1/2)

Aircraft	FC	NOx	NM VOC	CH4	CO	TSP <sup>(d)</sup>
320	1 190	17.4	2.7	0.28	15.9	48
737	885	8.0	1.3	0.31	9.9	48
EMB	64	0.3	1.1	0.13	1.8	48
100 <sup>(a)</sup>	702	5.5	17.0	0.23	22.7	48
ATP	570	4.2	0.8	0.20	9.7	48
310	1 556	23.2	4.3	0.45	22.2	48
757	1 282	21.0	0.8	0.30	11.8	48
M80	993	12.0	1.6	0.30	6.5	48
767	1 671	26.3	1.8	0.49	12.6	48
340	1 965	32.8	10.5	1.18	38.2	48
727	1 339	11.4	5.4	0.54	21.0	48
AB3	1 693	26.6	6.1	0.79	27.7	48
L10 <sup>(b)</sup>	2 394	36.6	55.6	6.18	85.2	48
AR1 <sup>(c)</sup>	1 056	13.9	10.6	1.08	23.3	48
BEC	87	0.5	1.9	0.21	3.0	48
DO8 <sup>(a)</sup>	130	1.3	10.6	1.08	0.7	48
F50 <sup>(a)</sup>	130	1.3	10.6	1.08	0.7	48
146	574	4.1	1.1	0.18	10.6	48
PAG <sup>(b)</sup>	13	0.0	0.2	0.02	12.7	48
D28 <sup>(a)</sup>	130	1.3	10.6	1.08	0.7	48
DO2 <sup>(a)</sup>	130	1.3	10.6	1.08	0.7	48
747	3 472	56.4	28.0	2.80	67.6	48
B11 <sup>(b)</sup>	639	5.3	6.5	0.72	18.4	48

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

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

(b) FAED Database

(c) Average for all other aircraft types

(d) Average value obtained from FAED Database for a limited number of aircrafts

<sup>38</sup> including information in spreadsheet 2

Table 3.137 - Emissions factors (kg/LTO) for LTO movements per aircraft type (2/2)

Aircraft	FC	NOx	NM VOC	CH <sub>4</sub>	CO	TSP <sup>(d)</sup>
AN2	217	2.8	6.4	0.71	5.4	48
L15 <sup>(b)</sup>	2 466	38.5	57.3	6.37	90.3	48
D9S <sup>(b)</sup>	937	7.6	4.1	0.46	14.4	48
DC9	856	7.2	2.0	0.23	8.7	48
D10	2 384	40.5	20.8	2.32	61.2	48
CVF <sup>(b)</sup>	263	0.4	3.9	0.43	16.4	48
BAT <sup>(b)</sup>	639	5.3	6.5	0.72	18.4	48
DHT	84	0.4	1.2	0.13	2.1	48
BNI <sup>(c)</sup>	1 056	13.9	10.6	1.08	23.3	48
F28	664	5.1	27.6	1.41	29.2	48
SF3	90	0.6	0.2	0.03	1.2	48
CRV <sup>(b)</sup>	866	6.7	4.4	0.49	16.0	48
TU5 <sup>(b)</sup>	2 112	13.6	82.5	9.17	123.0	48
M11 <sup>(b)</sup>	2 713	45.6	3.7	0.41	27.1	48
DFL <sup>(b)</sup>	97	0.7	0.6	0.07	4.5	48
TU6 <sup>(b)</sup>	1 807	15.4	54.9	6.10	83.0	48
ACD <sup>(b)</sup>	159	0.3	1.8	0.20	18.6	48
HS7 <sup>(b)</sup>	76	0.6	0.4	0.04	2.2	48
TUPOLEV <sup>(b)</sup>	1 807	15.4	54.9	6.10	83.0	48
DC8	1 253	13.2	23.6	2.82	29.7	48
707 <sup>(b)</sup>	1 833	16.9	45.8	5.09	60.4	48
AB4	1 875	30.9	12.2	1.36	40.1	48
Other <sup>(c)</sup>	1 056	13.9	10.6	1.08	23.3	48

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

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

(b) FAEED Database

(c) Average for all other aircraft types

(d) Average value obtained from FAEED Database for a limited number of aircrafts

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 3.138 – Evolution of Average National Emission Factors for LTO movements (1990-1996)

Parameter	Unit	1990	1991	1992	1993	1994	1995	1996
FC	kg/LTO	1 008	1 019	1 005	1 013	1 011	1 023	1 007
NOX		11.7	11.6	11.6	11.8	11.9	12.2	12.1
NM VOC		7.66	6.14	6.14	6.87	6.35	5.56	5.46
CH <sub>4</sub>		0.84	0.63	0.61	0.63	0.57	0.47	0.44
CO		19.3	17.2	16.6	17.1	16.5	15.9	15.5
PST		48.2	48.2	48.2	48.2	48.2	48.2	48.2

Table 3.139 – Evolution of Average National Emission Factors for LTO movements (1997-2002)

Parameter	Unit	1997	1998	1999	2000	2001	2002	2003
FC	kg/LTO	971	970	978	961	953	944	935
NOX		11.6	12.1	12.6	12.1	12.1	12.1	12.1
NMVOC		5.04	4.73	4.22	4.07	3.72	3.41	3.09
CH4		0.43	0.41	0.38	0.31	0.26	0.22	0.18
CO		14.7	14.6	14.4	13.4	12.9	12.4	11.8
PST		48.2	48.2	48.2	48.2	48.2	48.2	48.2

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 3.140 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>39</sup>.

Table 3.140 - 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.

<sup>39</sup> Efforts are under way to confirm this statement however. Otherwise some corrections need to be done.

Table 3.141 – 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	#	
Cd (g/ton)	0.26	0.26
Cr (g/ton)	0.05	0.05
Cu (g/ton)	1.10	1.10
Ni (g/ton)	0.29	0.29
Se (g/ton)	0.03	0.03
Zn (g/ton)	3	3

Source: IPCC (1997)

# Equal to LTO

## 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 2003. The information in energy balances differentiates total fuel consumption in air flight activity for the categories presented in Table 3.142. 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 3.142 – 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 3.73 and Figure 3.74 below.

Figure 3.73 – Aviation gasoline consumption in national and foreign aviation according to flag (1990-2003)

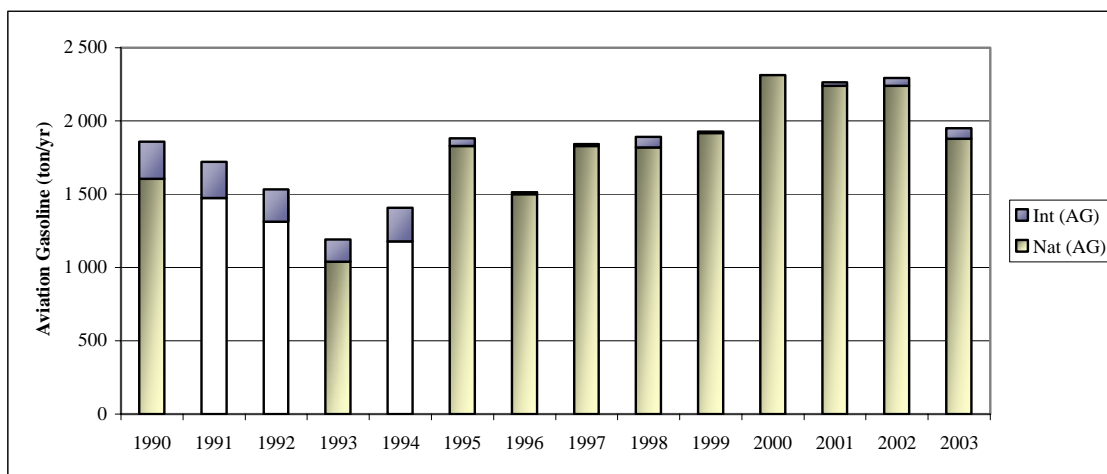
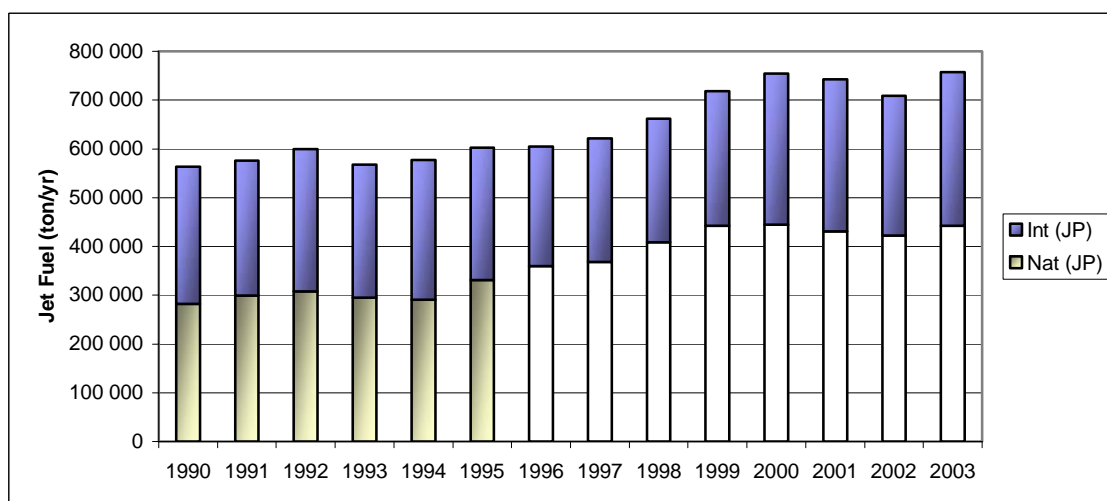


Figure 3.74 – Jet Fuel consumption in national and foreign aviation according to flag (1990-2003)



### Flight movements in Airports

The other necessary piece of activity data is the number of Land/Take-Off movements<sup>40</sup>. LTO movements by aircraft type from 1990 till 1999 were available for the international airports<sup>41</sup> in Portugal from ANA and ANAM<sup>42</sup>.

<sup>40</sup> A LTO movement is defined as both a single landing together with a single take-off.

<sup>41</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>42</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.

LTO movements in the other smaller airports<sup>43</sup>, and for ANA/ANAM airports for years 2000 and 2001, result from statistical information published by INE. LTO value for all airports for years 2002 and 2003 was forecasted at IA. The following Table 3.143 shows the list of codes used by ANA for desegregation of movements by aircraft type, together with the corresponding aircraft type.

Table 3.143 – 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 (Aero) Commander/Turbo Commander
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 3.75, and in Table 3.144 for selected years.

<sup>43</sup> Airports of Graciosa, Pico, S. Jorge and Corvo in Azores archipelago.



Figure 3.75 – Total number of LTO movements per airport (1990-2003)

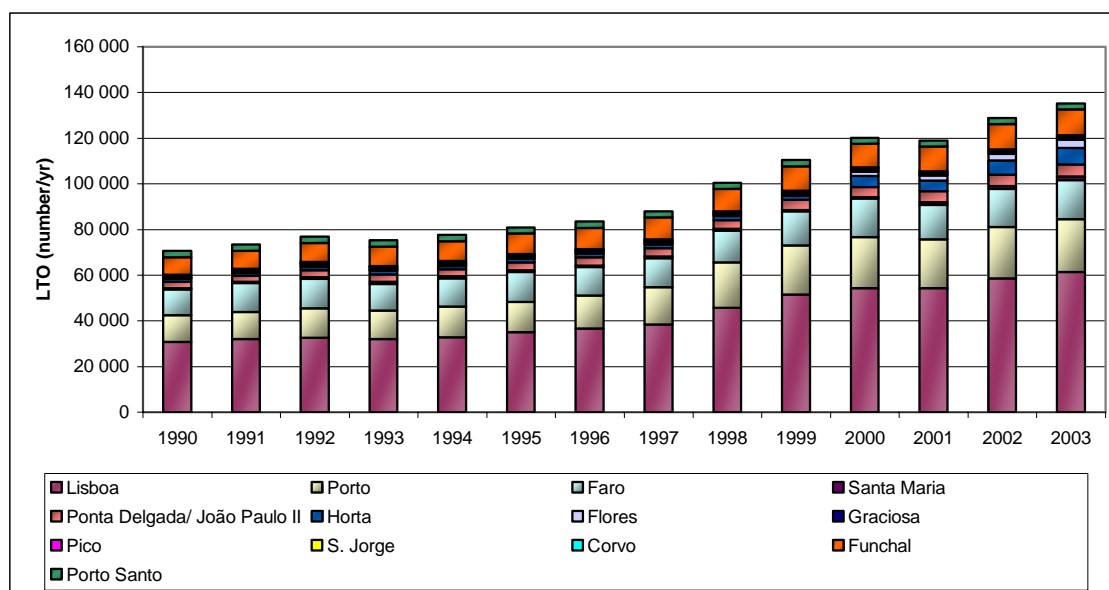


Table 3.144 – LTO movements by airport for selected years

Airport	1990	1995	2000	2003
Lisboa	30 840	34 937	54 260	61 315
Porto	11 565	13 350	22 446	23 194
Faro	11 238	13 067	16 797	17 193
Santa Maria	630	893	682	1 458
Ponta Delgada	2 955	3 381	4 514	5 326
Horta	1 238	1 542	4 676	7 332
Flores	281	357	1 951	3 478
Graciosa	431	423	418	409
Pico	344	509	703	773
S. Jorge	539	547	554	559
Corvo	152	200	253	278
Funchal	7 549	9 024	10 274	11 385
Porto Santo	2 903	2 777	2 570	2 574
Total	70 661	81 005	120 098	135 275

### 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 3.145. 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 segregated by aircraft type and airport.

Table 3.145 – 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 3.146 – Air traffic movements per airport and nationality of air carrier by Airport (2001)

Nº Planes	Air Carrier Flag		
	Total	National	Foreign
Total	119 385	76 882	42 504
Lisboa	54 264	38 289	15 975
Porto	21 317	12 435	8 882
Faro	15 166	1 942	13 224
Santa Maria	1 311	558	753
João Paulo II	4 808	4 370	438
Lajes	4 629	4 288	342
Horta	2 074	2 002	72
Flores	494	494	0
Graciosa	414	414	0
Pico	680	680	0
São Jorge	548	548	0
Corvo	250	250	0
Funchal	10 816	8 045	2 771
Porto Santo	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 3.147, 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>44</sup>.

<sup>44</sup> This assumption could be valid if cruise length for foreign flag flights does not vary substantially between domestic and international flights.

Table 3.147 – Passenger-kilometres by origin and destiny that have flew from and into Portugal (2001)

Origin (1E6)	Destiny		Portugal										N. Amer.	Lat. Amer. Car
	Total	UE	Total	Mainland	Açores	Madeira	EFTA	Oth. Europe	Mid East	Africa	Asia and P.			
TOTAL	12 857	9 850	7 206	5 883	669	654	217	67	-	579	-	667	1 477	
Regular	11 948	9 216	6 739	5 667	535	537	196	-	-	579	-	494	1 463	
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	
Non-Regular	909	634	467	216	134	117	21	67	-	-	-	173	14	
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	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

## UNCERTAINTY ASSESSMENT

The uncertainty in activity data was estimated to be 102% by comparison of estimates of fuel consumption in domestic flights in Energy Balance (where flag of aircraft was used separation indicator), submission 2005, EUROCONTROL and IEA. The uncertainties of emission factors were set at 5% for CO<sub>2</sub>, 100% for methane and one order of magnitude for N<sub>2</sub>O, following the recommendations from GPG.

### 3.2.C.5 OTHER MOBILE SOURCES

#### OVERVIEW

There is no much information allowing the estimation of emissions from off-road vehicles and machines, mainly because they are not individualized in the energy balances from DGGE. The only exception 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/diesel oil is assumed to be a energy source for mobile equipments in this activity. Although emissions from mobile sources in agriculture and forestry are reported under category source 1A4c, methodology used to estimate emissions from this activity is better presented here together with the other individualized mobile sources.

### Methodology

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

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

where

$\text{Fossil}_{\text{CO}_2(y)}$  - Emissions of carbon dioxide to atmosphere from combustion of diesel oil in agriculture off road vehicles and machinery (ton);

$\text{EF}_{\text{CO}_2}$  – Total carbon content of fuel expressed in total Carbon Dioxide emissions (kg CO<sub>2</sub>/GJ);

$\text{Fa}_{\text{CO}_X}$  – Oxidation factor for diesel oil (ratio 0..1);

$\text{Cons}_{\text{Fuel}(f,y)}$  - Consumption of diesel oil in year y (ton/yr);

$\text{LHV}_{(f)}$  - Low Heating Value (MJ/kg).

Sulphur oxides emission from combustion were 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

$\text{SO}_x (y)$  - Sulphur oxide emission in year y (ton/yr);

$\text{Fuel}_{\text{Cons}(y)}$  - Consumption of gas oil in off-road vehicles and machines in agriculture/forestry sector in year y (ton/yr);

$\text{S}_{(y)}$  - Sulphur content of gas oil (mass percentage).

Emissions for other pollutants were estimated with the following formula:

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

where

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

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

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

### Emission Factors

The set of emission factors utilized to estimate air emissions from use of gas oil in agriculture machines and other off-road vehicles were determined as the average value of the values proposed in tables I-47 and I-49 of the Revised 1996 IPCC Guidelines (IPCC,1997), except the emission factor for Particulate Matter, set from the EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002).

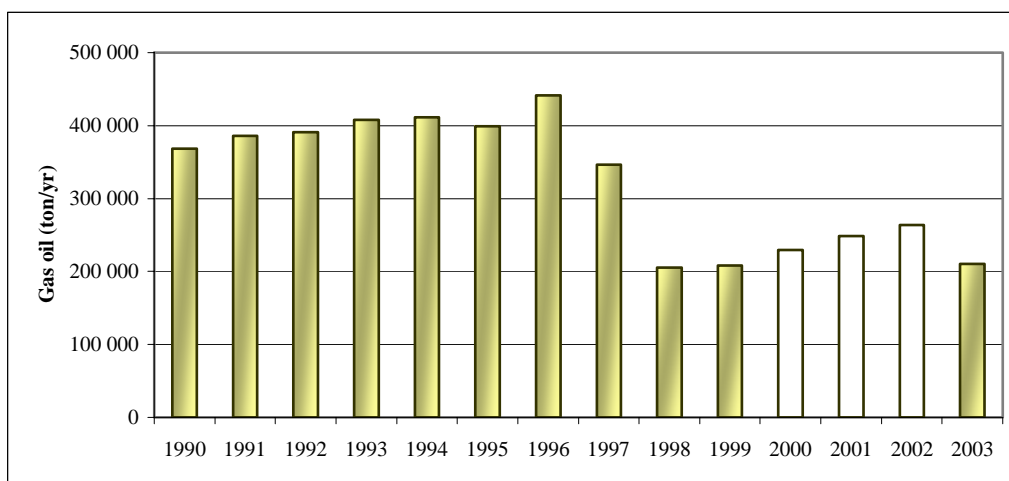
Table 3.148 – Emission factors for gas oil use in agriculture machines and other off-road vehicles

Parameter	EF	Unit
LHV	43.3	MJ/kg
SOx	0.3	%
NOx	56.9	g/kg
NMVOC	8.4	
CH4	0.3	
CO	20.7	
U CO2	3 136	
Fac <sub>ox</sub>	0.990	0..1
N2O	1.3	g/kg
NH3	0.007	
PM	5.87	
As	0.05	g/ton
Cr	0.05	
Cu	1.7	
Ni	0.07	
Se	0.01	
Zn	1	

### Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to 2003 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 3.76.

Figure 3.76 - Consumption of gas-oil in machines and other off-road vehicles (1990-2003)



### Uncertainty Assessment

The time trend of diesel oil consumption in this activity shows a sharp and unexpected decrease between 1996 and 1998. Although future developments are expected to correct this situation, in this year the uncertainty in activity data was set as the maximum inter-annual variation, 80 %. Concerning emission factors, because there is no specific information for this activity in the GPG, the same uncertainty values that were used for road transportation were used to estimate uncertainty from off-road emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O.

## 3.2.D Other Sectors (CRF 1A4)

### 3.2.D.1 OVERVIEW

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

### 3.2.D.2 METHODOLOGY

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

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

$$U_{CO2(s,f)} = 44/12 * EF_{C(f)} * Fac_{OX(f)} * Energy_{Cons(s,f)} * 10^{-3}$$

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

where,

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

Fossil<sub>CO2(s,f)</sub> - Emissions of carbon dioxide from fossil origin (non biomass) (ton);

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

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

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

Energy<sub>Cons(u,f)</sub> - Consumption of energy (Low Heating Value) from fuel f in sub-sector s (GJ).

Emissions were calculated from energy activity rate by the following basic formula (Energy Approach):

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

where:

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

EF<sub>(f,s,t,p)</sub> - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except CO<sub>2</sub> in kg/GJ);

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

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

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

where:

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

S<sub>(f,s,t)</sub> - Sulphur content of fuel f used in sub-sector s and equipment t in year y (%);

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

In the case of emissions of Heavy Metals the following equation was used:

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

and,

HM<sub>p(f,s)</sub> - Heavy Metal p emission estimated from consumption of fuel f in sub-sector s (ton/yr);

Fuel<sub>Cons(f,s)</sub> - Consumption of fuel f in sub-sector s (any unit in agreement with CF);

EF<sub>HM(f,y,p)</sub> - Emission Factor for heavy metal p from fuel f in year y (g/ton);



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

AshRet<sub>(f,s,p)</sub> - Retention of Heavy Metal p in ash from fuel f under burning conditions in sub-sector s (mass percentage).

### 3.2.D.3 ACTIVITY DATA

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

Table 3.149 - Fuels consumption in residential sector (GJ)

NAPFUE		Fuel	1990	1991	1992	1993	1994	1995	1996
L	203	Residual Fuel Oil	63 530	62 097	55 535	51 459	66 691	42 565	43 312
L	204	Gas Oil	158 214	210 819	285 505	205 027	190 282	200 936	132 606
L	206	Kerosene	793 373	753 052	626 060	530 505	513 747	355 816	415 879
L	208	Motor Gasoline	6 185	7 785	5 900	5 649	6 252	9 577	13 749
L	303	LPG	22 837 620	24 057 966	25 680 840	27 229 913	27 655 381	27 940 723	30 167 625
L	308	City Gas	1 923 876	1 950 110	1 984 435	2 073 096	1 984 456	1 929 958	1 977 160
G	301	Natural Gas	0	0	0	0	0	0	0
B	111	Wood	53 770 921	51 344 184	49 611 501	48 513 399	48 000 716	48 033 473	48 172 943
B	112	Charcoal	749 950	738 791	727 632	716 473	705 314	694 155	682 996

NAPFUE		Fuel	1997	1998	1999	2000	2001	2002	2003
L	203	Residual Fuel Oil	40 271	10 915	3 880	2 594	0	0	0
L	204	Gas Oil	91 896	105 979	144 221	90 426	82 408	120 300	380 121
L	206	Kerosene	728 302	761 508	705 271	365 327	194 406	147 838	89 780
L	208	Motor Gasoline	14 898	14 691	6 077	772	93	24 848	36 159
L	303	LPG	29 240 674	30 788 636	32 600 574	33 436 221	30 740 137	30 729 805	29 733 968
L	308	City Gas	1 991 632	2 106 088	2 039 388	1 212 913	156 763	0	0
G	301	Natural Gas	31 980	361 961	1 360 508	2 883 241	4 450 418	5 568 369	6 640 771
B	111	Wood	48 326 360	47 907 950	47 280 335	47 071 130	47 280 335	47 280 335	48 127 150
B	112	Charcoal	671 837	660 678	649 519	638 360	627 201	616 042	604 883

Figure 3.77 – Total Energy Consumption in fuels in the residential sector between 1990 and 2003

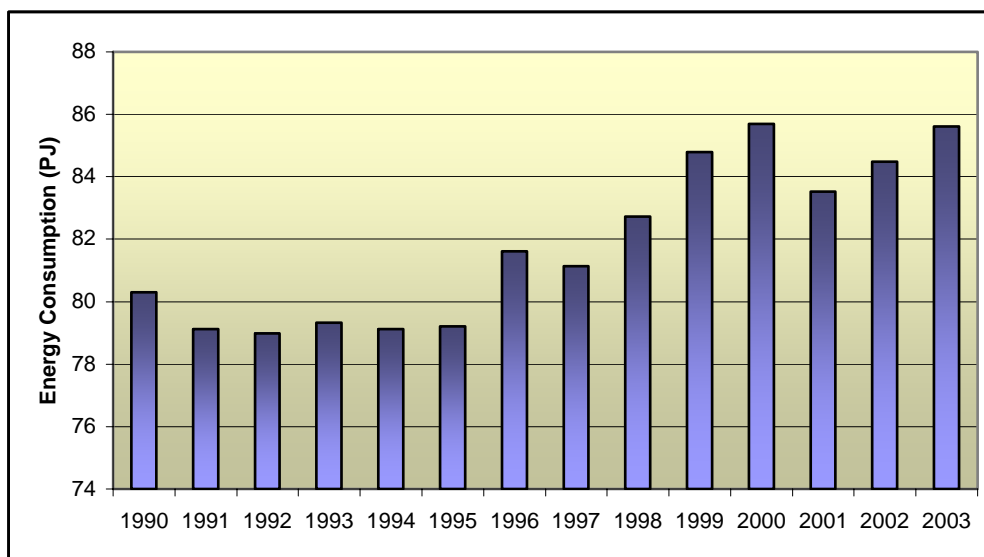


Figure 3.78 – Consumption of energy in fuels in the residential sector in 1990 and 2003

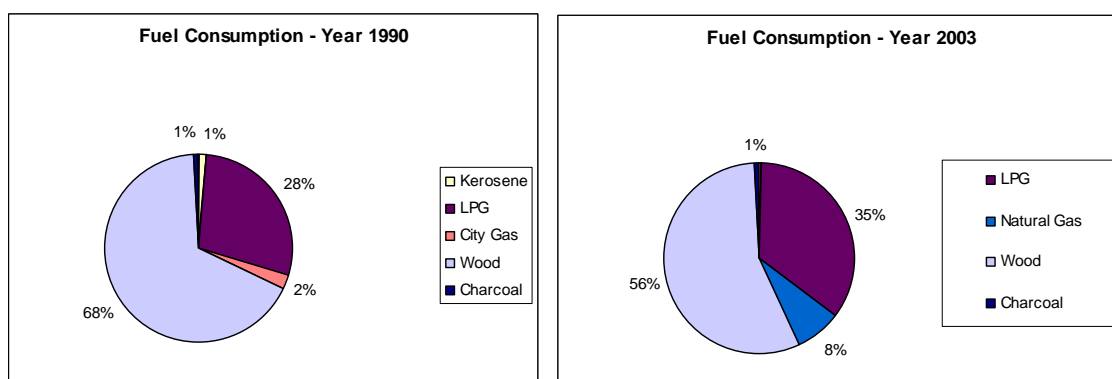


Table 3.150 - Fuels consumed in the commercial, services and institutional sector (GJ)

NAPFUE		Fuel	1990	1991	1992	1993	1994	1995	1996
L	203	Residual Oil	2 376 335	2 081 213	1 985 815	2 066 483	3 667 114	4 271 661	3 302 636
L	204	Gas Oil	5 632 044	6 908 924	8 270 647	8 435 891	8 581 923	7 879 630	8 716 558
L	205	Diesel Oil	4 226	4 226	4 226	4 226	4 226	4 226	4 226
L	206	Kerosene	74 874	33 376	64 163	73 739	24 495	13 459	12 677
L	208	Motor Gasoline	579 235	638 264	617 276	604 690	1 035 873	1 174 153	1 418 403
L	303	LPG	1 166 321	1 337 385	1 538 519	1 847 562	1 821 391	1 234 531	2 494 179
L	308	City Gas	504 399	556 773	528 075	643 808	647 871	732 803	785 507
G	301	Natural Gas	0	0	0	0	0	0	0
B	309	Biogas	0	0	0	0	0	0	0

NAPFUE		Fuel	1997	1998	1999	2000	2001	2002	2003
L	203	Residual Oil	1 387 822	2 836 712	3 438 705	3 312 313	3 447 019	3 532 016	2 905 392
L	204	Gas Oil	13 093 171	16 704 293	18 335 470	18 375 597	21 938 924	24 175 507	29 748 296
L	205	Diesel Oil	4 226	4 226	4 226	4 226	4 226	4 226	4 226
L	206	Kerosene	25 053	27 126	17 190	6 133	7 568	9 489	7 340
L	208	Motor Gasoline	2 592 133	3 260 397	3 216 908	2 215 997	2 852 911	2 485 291	2 362 703
L	303	LPG	3 734 954	3 904 492	4 121 761	4 297 205	5 068 917	4 978 362	5 147 243
L	308	City Gas	777 866	908 944	1 044 085	732 238	69 195	0	0
G	301	Natural Gas	14 258	509 290	1 438 849	2 360 834	3 854 223	4 966 543	6 384 576
B	309	Biogas	0	0	49 772	101 885	54 356	60 473	48 419

Figure 3.79 – Total Energy Consumption in fuels in the commercial/services/institutional sector between 1990 and 2003

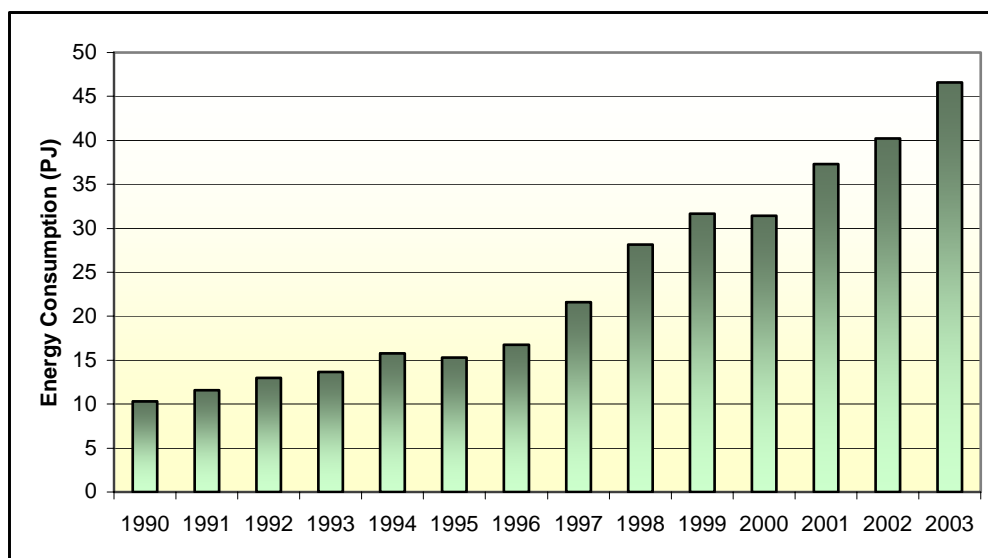


Figure 3.80 – Consumption of energy in fuels in the commercial/services/institutional sector in 1990 and 2003

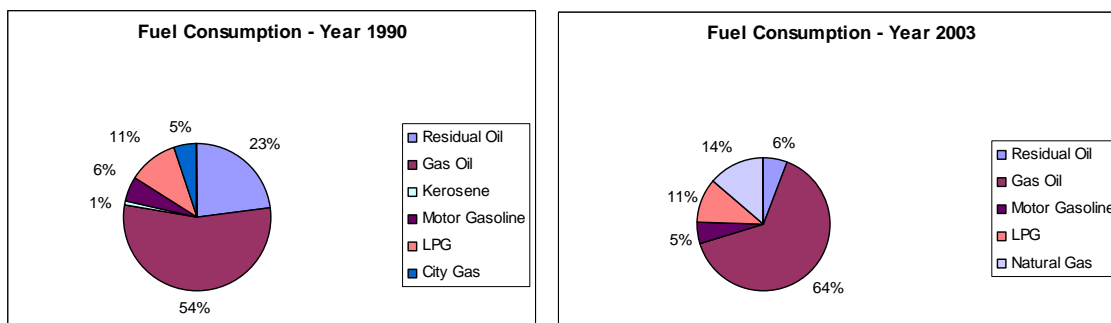


Table 3.151 - Fuels consumed in agriculture and forestry sector (GJ) (excluding mobile sources)

NAPFUE	Fuel	1990	1991	1992	1993	1994	1995	1996
L 203	Residual Oil	524 287	375 957	286 155	343 465	487 787	427 826	512 374
L 206	Kerosene	350 128	310 857	271 996	207 738	200 860	191 043	183 311
L 208	Motor Gasoline	33 627	35 658	47 375	44 906	134 673	129 562	162 538
L 303	LPG	329 646	405 169	478 657	575 533	580 437	572 079	826 427
G 301	Natural Gas	0	0	0	0	0	0	0
B 309	Biogas	0	0	0	0	0	0	0

NAPFUE	Fuel	1997	1998	1999	2000	2001	2002	2003
L 203	Residual Oil	548 092	475 768	678 844	891 798	802 636	1 210 609	1 086 402
L 206	Kerosene	426 745	493 714	24 152	44 370	47 054	50 254	47 209
L 208	Motor Gasoline	197 454	174 300	159 631	42 694	119 459	106 749	116 899
L 303	LPG	559 823	713 407	674 208	496 566	672 831	639 244	532 167
G 301	Natural Gas	0	32	158	4 423	192 700	257 274	276 779
B 309	Biogas	0	0	0	9 294	7 773	5 939	6 344

Figure 3.81 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources) between 1990 and 2003

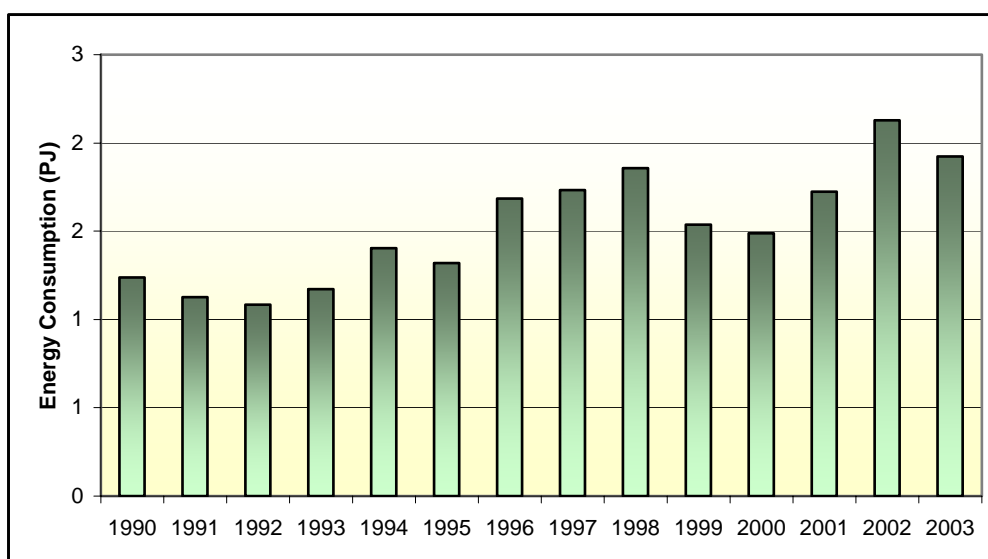


Figure 3.82 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2003

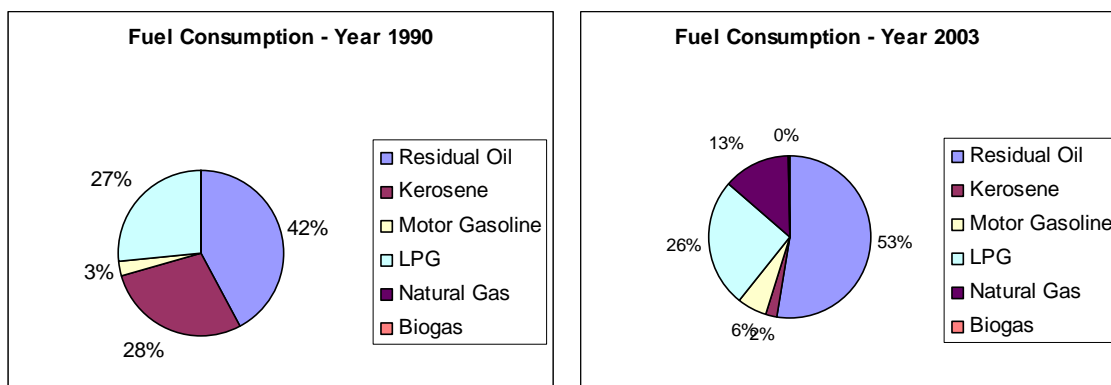
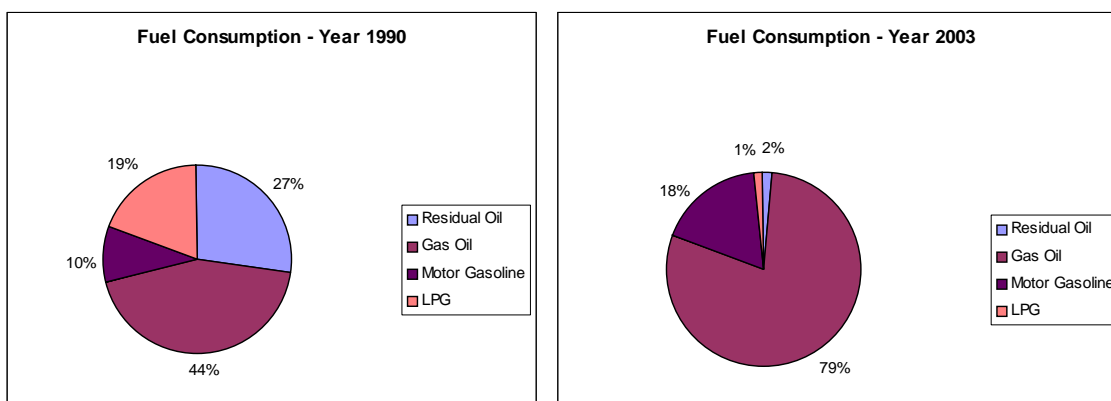


Table 3.152 - Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ)

NAPFUE	Fuel	1990	1991	1992	1993	1994	1995	1996
L 203	Residual Oil	4 002	5 397	7 454	9 101	5 353	11 778	4 994
L 204	Gas Oil	6 346	460	1 018	0	1 003	16 980	1 595
L 205	Diesel Oil	0	0	0	17	0	0	0
L 206	Kerosene	7	0	7	7	0	0	0
L 208	Motor Gasoline	1 405	0	214	85	277	706	985
L 303	LPG	2 845	5 789	4 074	1 498	2 146	0	110

NAPFUE	Fuel	1997	1998	1999	2000	2001	2002	2003
L 203	Residual Oil	8 782	6 225	49 567	6 469	18 044	28 112	25 325
L 204	Gas Oil	150 903	539 112	769 712	1 000 313	2 114 053	1 553 975	1 220 053
L 205	Diesel Oil	0	0	0	0	0	0	0
L 206	Kerosene	0	2 651	74 915	10 073	94	47	47
L 208	Motor Gasoline	727	4 038	61 546	278 979	286 123	280 695	278 521
L 303	LPG	3 900	2 529	8 429	20 796	32 627	21 126	20 695

Figure 3.83 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2003



## 3.2.D.4 EMISSION FACTORS

The emission factors that were used were collected from international bibliography sources, namely:

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

Table 3.153– Emissions factors for the domestic sector: Low Heating Value (LHV) and Greenhouse gases

	NAPFUE	Fuel	LHV	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
L	203	Residual Oil	40.17	77.4	0.990	100	5.1	0.14
L	204	Gas Oil	43.31	74.1	0.990	100	5.0	1.55
L	206	Kerosene	43.72	71.9	0.990	100	5.0	1.55
L	208	Motor Gasoline	44.77	69.3	0.990	100	9.9	0.6
L	303	LPG	47.28	63.1	0.995	100	1.5	1.4
L	308	City Gas	15.69	60.0	0.995	100	1.5	1.4
G	301	Natural Gas	45.97	56.1	0.995	100	2.5	0
B	111	Biomass Wood	12.55	109.6	1.000	0	300	4.3
B	112	Biomass Charcoal	25.10	109.6	1.000	0	300	4.3

Table 3.154– Emissions factors for the domestic sector: Indirect Precursor gases

	NAPFUE	Fuel	NO <sub>x</sub>	NMVOC	CO
			g/GJ	g/GJ	g/GJ
L	203	Residual Oil	160	3	5.1
L	204	Gas Oil	577.5	51	5
L	206	Kerosene	55	51	5
L	208	Motor Gasoline	1300	100	9.9
L	303	LPG	65	3	1.5
L	308	Refinery Gas	65	3	1.5
G	301	Natural Gas	40	3	2.5
B	111	Biomass Wood	67	400	300
B	112	Biomass Charcoal	67	400	300

Table 3.155– Emissions factors for the domestic sector: Sulphur content of fuel (%S)

Year	Gasoline	Kerosene	Gas Oil	Residual Fuel Oil	Natural Gas	LPG	City Gas	Wood/Charcoal
1990	0.10	0.15	0.3	2.8	0.0007	0.0016	0.0007	0
1991	0.10	0.15	0.3	2.6	0.0007	0.0016	0.0007	0
1992	0.10	0.15	0.3	2.6	0.0007	0.0016	0.0007	0
1993	0.10	0.15	0.3	2.6	0.0007	0.0016	0.0007	0
1994	0.10	0.15	0.3	2.6	0.0007	0.0016	0.0007	0
1995	0.10	0.15	0.2	2.6	0.0007	0.0016	0.0007	0
1996	0.10	0.15	0.05	2.6	0.0007	0.0016	0.0007	0
1997	0.10	0.15	0.05	2.6	0.0007	0.0016	0.0007	0
1998	0.10	0.15	0.05	2.6	0.0007	0.0016	0.0007	0
1999	0.10	0.15	0.05	2.6	0.0007	0.0016	0.0007	0
2000	0.10	0.15	0.05	2.6	0.0007	0.0016	0.0007	0
2001	0.015	0.15	0.05	2.6	0.0007	0.0016	0.0007	0
2002	0.015	0.15	0.035	2.6	0.0007	0.0016	0.0007	0
2003	0.015	0.15	0.035	1.0	0.0007	0.0016	0.0007	0

Table 3.156– Emissions factors for the domestic sector: Particulate Matter

	NAPFUE	Fuel	TSP g/GJ	PM <sub>10</sub> (%TSP)	PM <sub>2.5</sub> (%TSP)	PM <sub>1.0</sub> (%TSP)
L	203	Residual Oil	53	62	23	14
L	204	Gas Oil	6.5	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	City Gas	2.2	100	100	100
G	301	Natural Gas	0.8	100	100	100
B	111	Biomass Wood	405.1	100	100	100
B	112	Biomass Charcoal	405.1	100	100	100

Table 3.157– Emissions factors for the domestic sector: Heavy Metals

Fuel	Pb g/ton	Cd g/ton	Hg g/ton	Ar g/ton	Cr g/ton	Cu g/ton	Ni g/ton	Se g/ton	Zn g/ton
Residual Fuel Oil	1.3E+00	4.0E-04	5.1E-01	1.2E-03	4.0E-03	7.4E-01	2.7E+01	6.8E-02	1.9E+00
Gas Oil	2.0E-01	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
Kerosene	2.0E-01	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
Motor Gasoline	5.3E+02	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
LPG	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
City Gas	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Natural Gas	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Biomass Wood	0.0E+00	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
Biomass Charcoal	0.0E+00	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00

Table 3.158 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Low Heating Value and Greenhouse Gases

	NAPFUE	Fuel	LHV	CO <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
			MJ/kg	kg/GJ	Oxidation Factor	% C fossil	g/GJ	g/GJ
L	203	Residual Fuel Oil	40.17	77.4	0.990	100	1.6	0.6
L	204	Gas/ Diesel Oil	43.31	74.1	0.990	100	5.0	0.6
L	206	Kerosene	43.72	71.9	0.990	100	5.0	0.6
L	208	Motor Gasoline	44.77	69.3	0.990	100	9.9	0.6
L	303	LPG	47.28	63.1	0.995	100	1.5	1.4
L	308	City Gas	15.69	60.0	0.995	100	1.5	1.4
G	301	Natural Gas	45.97	56.1	0.995	100	1.2	1.4
B	111	Wood	12.55	109.6	1.000	0	15	4.3
B	309	Biogas	34.70	52.0	1.000	0	0.72	1.4

Table 3.159 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Indirect Precursor Gases

	NAPFUE	Fuel	NO <sub>x</sub>	NMVOC	CO
			g/GJ	g/GJ	g/GJ
L	203	Residual Fuel Oil	160	3	20
L	204	Gas Diesel Oil	580	50.5	20
L	206	Kerosene	60	51	20
L	208	Motor Gasoline	1300	100	20
L	303	LPG	65	3	50
L	308	City Gas	65	3	50
G	301	Natural Gas	48	10	20
B	111	Wood	67	400	500
B	309	Biogas	65	3	17



Table 3.160 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Sulphur content of fuels

Year	Motor Gasoline	Kerosene	Gas Oil <sup>(a)</sup>	Residual Fuel Oil	Natural Gas	Wood	Biogas	LPG	City Gas
1990	0.10	0.15	0.30	2.84	0.0007	0	0	0.0016	0
1991	0.10	0.15	0.30	2.60	0.0007	0	0	0.0016	0
1992	0.10	0.15	0.30	2.60	0.0007	0	0	0.0016	0
1993	0.10	0.15	0.30	2.60	0.0007	0	0	0.0016	0
1994	0.10	0.15	0.30	2.60	0.0007	0	0	0.0016	0
1995	0.10	0.15	0.25	2.60	0.0007	0	0	0.0016	0
1996	0.10	0.15	0.18	2.60	0.0007	0	0	0.0016	0
1997	0.10	0.15	0.18	2.60	0.0007	0	0	0.0016	0
1998	0.10	0.15	0.18	2.60	0.0007	0	0	0.0016	0
1999	0.10	0.15	0.18	2.60	0.0007	0	0	0.0016	0
2000	0.10	0.15	0.15	2.60	0.0007	0	0	0.0016	0
2001	0.015	0.15	0.13	2.60	0.0007	0	0	0.0016	0
2002	0.015	0.15	0.12	2.60	0.0007	0	0	0.0016	0
2003	0.015	0.15	0.12	1.00	0.0007	0	0	0.0016	0

(a) Weighted average of gas oil and diesel oil for heating

Table 3.161 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Particulate Matter

	NAPFUE	Fuel	TSP g/GJ	PM <sub>10</sub> (% TSP)	PM <sub>2.5</sub> (% TSP)	PM <sub>1.0</sub> (% TSP)
L	203	Residual Fuel Oil	53	62	23	14
L	204	Gas Diesel Oil	69.9	78	71	69
L	206	Kerosene	69.9	78	71	69
L	208	Motor Gasoline	43	100	100	100
L	303	LPG	2.5	100	100	100
L	308	City Gas	2.5	100	100	100
G	301	Natural Gas	0.8	100	100	100
B	111	Biomass Wood	172	90	76	67
B	309	Biogas	0.8	100	100	100

Table 3.162 – Emissions factors: commercial, services, institutional, agriculture, forestry and fisheries (excluding mobile sources): Heavy Metals

Fuel	Pb	Cd	Hg	Ar	Cr	Cu	Ni	Se	Zn
	g/ton	g/ton	g/ton	g/ton	g/ton	g/ton	g/ton	g/ton	g/ton
Residual Fuel Oil	1.3E+00	4.0E-04	5.1E-01	1.2E-03	4.0E-03	7.4E-01	2.7E+01	6.8E-02	1.9E+00
Gas Diesel Oil	2.0E-01	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
Kerosene	2.0E-01	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
Motor Gasoline	5.3E+02	4.0E-02	1.7E-02	6.4E-02	2.6E-01	6.5E-01	6.0E-02	3.7E-02	4.3E-01
LPG	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Refinery Gas	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Natural Gas	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04
Biomass Wood	0.0E+00	1.5E-02	1.0E-01	4.3E-02	5.0E-04	1.0E-01	6.0E-03	2.3E-02	2.0E+00
Biogas	0.0E+00	1.8E-05	4.2E-03	3.2E-06	2.2E-05	1.4E-05	3.4E-05	3.8E-07	4.6E-04

### 3.2.D.5 UNCERTAINTY ASSESSMENT

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

The uncertainty of CO<sub>2</sub> emission factors was assumed to be 5% for all situations, in coherence with the other stationary combustion sources. In a similar mode, the uncertainties for methane and N<sub>2</sub>O were set respectively at 150% and an order of magnitude.

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

### 3.2.E.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 in Portugal there was extraction of coal at only two coal mines, but both were latter closed down in 1992 and 1994 and did not resume activity since. Both mines - *Pejão* and *S. Pedro da Cova* - are located in northern region of Portugal. Coal from these mines is classified as lignite, it has a low energy value and it was used mainly as fuel for one public power energy plant near Oporto (*Tapada do Outeiro* power plant). One mine - *Pejão* - is an underground mine and the other is an open cast type.

Emissions of carbon dioxide and sulphur oxides may occur from mining activity when burning of coal deposits occurs or when flaring is used to control air emissions or recover energy. Because the occurrence of coal burning on-site or flaring is unknown for both Portuguese mines, emissions of these pollutants from this source are not included in the inventory.

Emissions of methane from abandoned mines may still continue after mine closure, even if mines are sealed, as it is recognized in the GPG. Because no methodology is available to calculate present day flux from abandoned mines - which would require knowledge of all abandoned mines, not only *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 IPCC96 (IPCC,1997):

$$Emi_{CH_4} = [(EF_U^{ex} + EF_U^{post}) * Coal_U + (EF_S^{ex} + EF_S^{post}) * Coal_S] * 0.67 * 10^{-3}$$

where

$Emi_{CH_4}$  - Methane emissions in year y (ton);

$Coal_U$ ,  $Coal_S$  - quantity of coal extracted from underground mines and open cast/surface mines, respectively (ton/yr);

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

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

$EF_S^{ex}$  - emission factor for extraction emissions in surface mining ( $m^3/ton$ );

$EF_S^{post}$  - emission factor for post-extraction emissions in surface mining ( $m^3/ton$ );

0.67 is the conversion factor, the density of methane at 20°C and at atmospheric pressure ( $kg/m^3$ ).

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

$$Emi_{CO_2} = 44 / 16 * Emi_{CH_4}$$

### Emission Factors

Although it is known that high rank coals contain usually more methane than lower rank coals such as lignite, average emission factors from IPCC96 (IPCC,1997) defaults were used for both

mines, which are presented in next table. The same emission factor range was maintained in GPG (IPCC,2002).

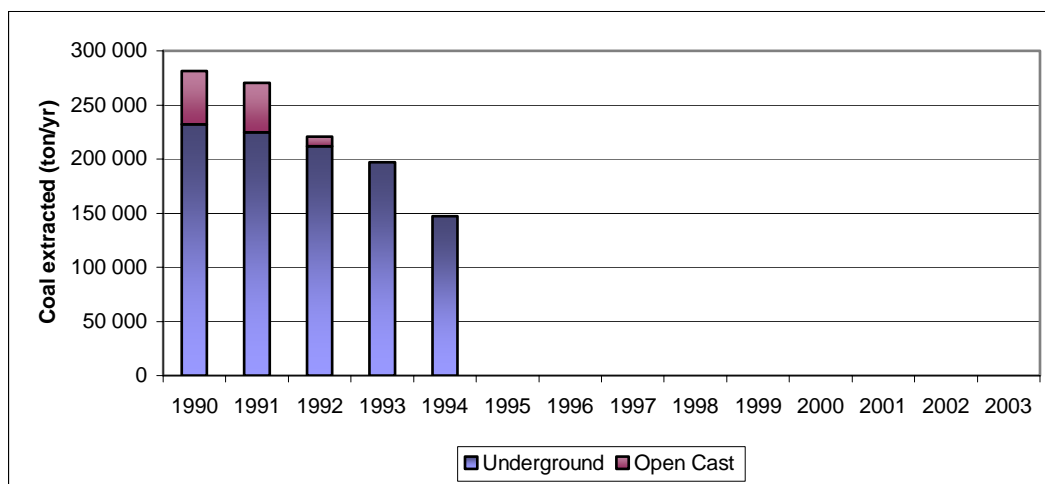
Figure 3.84 – Emission Factors for coal extraction and processing

Mine	Type of Emission	Emission Factor	Value (m <sup>3</sup> /ton)
Underground	Extraction	EF <sub>U</sub> <sup>ex</sup>	11.73
	Post-mining	EF <sub>U</sub> <sup>post</sup>	1.64
Open cast	Extraction	EF <sub>S</sub> <sup>ex</sup>	0.77
	Post-mining	EF <sub>S</sub> <sup>post</sup>	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 3.85 – Quantities of coal extracted from mines in Portugal (1990-2003)



### Uncertainty Assessment

A value of 5% was considered for the uncertainty of coal production (activity data) which is a conservative factor according to the proposed values by IPCC (2000). Also in accordance with table 2.14 of the GPG, the uncertainty values for methane emission factors were set at 100% for underground mines and 200% for surface mines. The uncertainty in CO<sub>2</sub> emission factors were set equal to uncertainties of CH<sub>4</sub> emission factor, considering that CO<sub>2</sub> emissions are simply atmospheric conversion of methane emissions.

### Recalculations

No recalculations of emissions were made on this source sector.

### Further Improvement

Due to the fact that this activity has stopped since 1994 it is not feasible to expect further improvements for estimate of emission from this source sector.

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

#### Overview

There occurs 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 consist mainly of volatile organic compounds, including methane, that escape to atmosphere during transport of crude oil to refineries for processing. The three oil refineries considered in the inventory where all located at a small distance from the sea coast. Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

##### Methodology

Emissions of methane and non-methane volatile organic compounds (NMVOC) where estimated from:

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

where

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

$\text{Crude}_{\text{InFlow}}$  - is total crude oil received at each refinery plant for processing (ton/yr);

EF - emission factor for methane or NMVOC (g/ton crude oil).

Emissions of VOC will ultimately be oxidized in atmosphere and contribute to ultimate carbon dioxide, which estimates are also included in the inventory. Emissions of ultimate carbon dioxide result from conversion of carbon in NMVOC and 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, US-EPA (AP-42) and IPCC96.

Figure 3.86 – Emission Factors for marine terminals and crude oil transportation

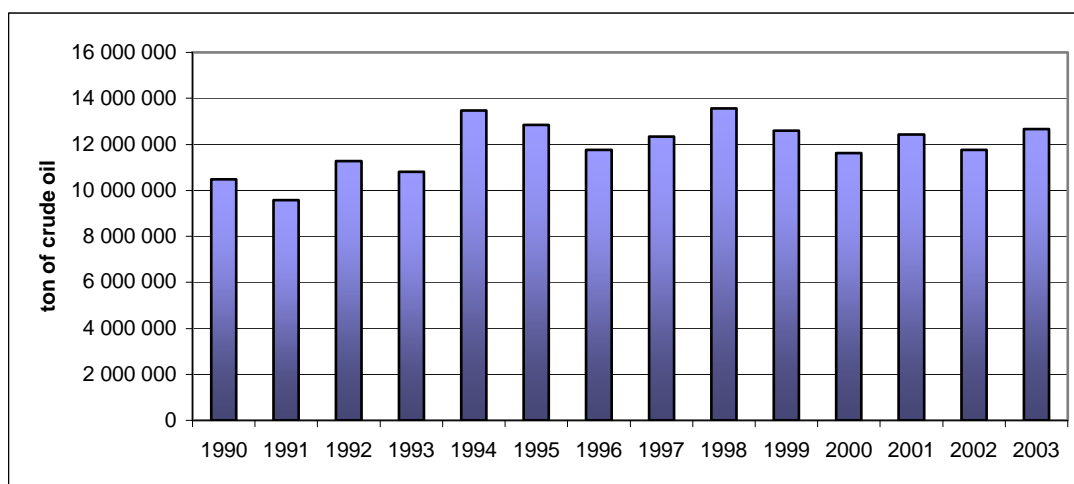
Component	Emission Factor (g/ton crude oil)
NMVOC	300
CH <sub>4</sub>	60 (2500 kg CH <sub>4</sub> /PJ <sup>(a)</sup> )
Ultimate CO <sub>2</sub>	1 100

(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. Total importation of crude in 2003 is 29 % higher than the quantity imported in year 1990.

Figure 3.87 – Total imports of crude oil: 1990-2003



### Uncertainty Assessment

An uncertainty value (3%) similar to that that was considered for fuel consumption data in industrial LPS was also used for quantification of uncertainty of activity data for this source sector reflecting the fact that in this case data was also collected directly from refinery plants, where crude oil is uploaded, and used to build the energy balance of DGGE. The uncertainty of NMVOC emissions, which in fact corresponds to the uncertainty of CO<sub>2</sub> emissions, was considered to be 50%, which is the double (conservative approach) of the value proposed in chapter 2.7 of GPG for high quality emission factors for most gases. The uncertainty of methane emission factor was set to 100%, the double of the emission factor for CO<sub>2</sub>/NMVOC in accordance with the fact that methane is obtained as a VOC fraction and hence with double uncertainty.

### **Recalculations**

No modifications were done for emission estimates for this sub-source.

## **REFINING AND STORAGE**

### **Overview**

In 1990 there were three oil refining plants in Portugal, located in Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed for all activity and only two units remain now operating.

The refining process converts crude oil - which is a complex mixture of hydrocarbon compounds with impurities of sulphur, nitrogen, oxygen and heavy metals - into oil products used as fuels, asphalts, lubricants or feedstock for the organic and inorganic chemical industry. Processes included in Portuguese refineries include:

- Separation process: isolation of individual constituents of crude using differences in boiling-point, using atmospheric and vacuum distillation and recovery of light end gases;
- Conversion process. These may be also classified as: (1) Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular height into smaller ones, including visbreaking; (2) Polymerisation of small molecules combined in bigger molecules with different characteristics. Alkylation has similar objectives and (3) chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing;
- Treatment processes. Operations which include hydrosulfurization, hydrotreating, chemical sweetening, acid gas removal, deasphalting and desalting, that are used to remove impurities, the most important is sulphur;
- Blending of individual fractions and intermediate products to obtain final commercial products with characteristics as desired.

Emissions of storage of crude oil and other materials, intermediate products and final products are also included in this source sector as they are fugitive emissions occurring as part of the refining process. Because emissions from organic liquids in storage occur both from the evaporative loss of the liquid as well as from changes in the liquid level, the emission sources vary significantly with tank design. Six basic tank designs are usually used for organic liquid storage vessels: fixed roof (vertical and horizontal), external floating roof, domed external (or covered) floating roof, internal floating roof, variable vapor space, and pressure (low and high).

NM VOC and methane emissions may also result from "normal" leaks<sup>45</sup> scattered through the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NM VOC emissions resulting from non-condensable fraction at the steam ejectors or vacuum pumps of the Vacuum distillation. Emissions in flares are discussed in "Venting and Flaring in Oil Industry" below.

Use of some catalytic converters, such as Fluid Catalytic Cracking and Platforming units, are used to convert heavy oils into lighter products, by action of heat, pressure and catalysts.

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<sup>45</sup> Sometimes only these emissions are referred as fugitive emissions from refineries.

Fluidized-bed Catalytic Cracking (FCC) use finely divided catalysts suspended in a riser with hot vapour from the fresh feed. Catalytic processes result in operations emissions, when the coke that is deposited in the catalytic bed over time has to be burned in the regenerator equipment. Emissions from catalyst regeneration are also included in this source category.

Finally sulphur oxide is emitted to the atmosphere when sulphur that is present in the tail gas of the refining process is not recovered in the Claus units and transformed into elemental sulphur, either because the normal recovery efficiency is actually not hundredth percent by design, or because the Claus unit was not at all operating and the sulphur flux had to oxidized to 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 years 2002 and 2003 lead to the establishing of plant specific emission factors for NMVOC losses from crude oil and oil products storage. Annual emissions of NMVOC (ton/yr) for the remaining time series are estimated using the emission factor (EF in g/ton) and relying in the time series of total throughput petroleum materials processed (ton/yr) as an indicator of activity<sup>46</sup>.

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

#### Fugitive Emissions and Catalyst Recovery

Air emissions from these refining operations were estimated from:

$$\text{Emission}_{(p,r)} = \text{ActivityRate} * \text{EF}_{(p,r)} * 10^{-6}$$

where

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

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

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

Total crude use was used as activity data to estimate fugitive emissions from leakages, according to the available emission factors in literature. Concerning Catalyst recovery activity data is coke burnt during catalyst regeneration.

#### Sulphur Recovery

Emissions of SO<sub>x</sub> occurring due to limitations of the sulphur recovery system were estimated annually according to the following procedure:

$$\text{Emi}_{\text{SO}_x} = 64/32 * [\text{S}_{\text{Inc}} + \text{S}_{\text{Prod}} * (100 - \text{Claus}_{\text{EFIC}})/\text{Claus}_{\text{EFIC}}]$$

<sup>46</sup> This methodology precludes that there was no changes in tanks and control equipment of losses from tanks between 1990 and 2002.



where

$Emi_{SO_x}$  – Emissions of sulphur oxides from sulphur recovery in tail gas (ton S/yr);

$S_{Inc}$  - sulphur in tail gas that is incinerated to  $SO_x$  because Claus unit was not operational (ton S/yr);

$Claus_{EFIC}$  – percent efficiency of overall Claus unit (%);

$S_{Prod}$  - total elemental sulphur produced in the Claus unit (ton S/yr).

#### Ultimate Carbon Dioxide Emissions

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

$$U_{CO_2} = 44/12 * (0.85 * NMVOC + 12/16 * CH_4 + 12/28 * CO) * 10^{-3}$$

#### ***Emission Factors***

##### Storage/ Tanks

For the year 2002, 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,1990). PETROGAL has updated the calculation of emission estimates from storage for year 2003.

Because it is obviously not possible to present all background information that was used to estimate storage and tank emissions, only a short summary is presented here in the National Inventory Report.

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

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

- Site information: meteorological data such as the daily average ambient temperature, the annual average minimum and maximum temperatures, the annual average wind speed, the annual average solar insolation factor, and the atmospheric pressure;
- Liquid characterization: For individual substances the model requires chemical nomenclature, average liquid temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. For mixtures, the information may be as detailed as the mixture name, average, minimum and maximum liquid surface temperatures, bulk temperature, vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights;
- tank information is slightly different according to tank type, but in general terms comprehends: shell and roof colour and condition, height, diameter, average and

maximum liquid height, working volume, turnover rate and net output, heating conditions and pressure and vacuum settings and the existence and type of seals<sup>47</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 Figure 3.90.

Figure 3.88 – 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
Domed	External	Floating	external floating roof tank that		
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:

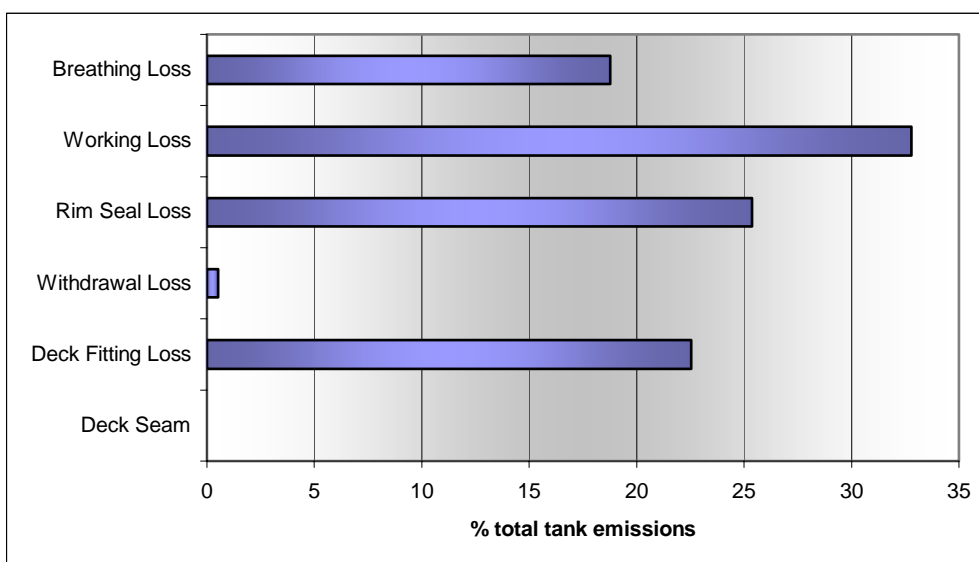
<sup>47</sup> This list is intended as presenting an overview. For precise description please consult USEPA (1997) or USEPA (2000).

Figure 3.89 – Types of losses from tanks for storage of organic compounds and petroleum products

Tank	Loss	Description
Fixed Roof	Breathing	Expulsion of vapour from a tank through vapour expansion and contraction, which are the results of changes in temperature and barometric pressure
	Working	Combined loss from filling and emptying. Evaporation during filling operations is a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapours are expelled from the tank. Evaporative loss during emptying occurs when air drawn into the tank during liquid removal becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space.
Floating Roof	Rim Seal	The majority of rim seal vapour losses have been found to be wind induced.
	Withdrawal	Occur as the liquid level, and thus the floating roof, is lowered. Some liquid remains on the inner tank wall surface and evaporates.
	Deck Fitting	Deck fittings can be a source of evaporative loss when they require openings in the deck, such as: access hatches, gauges, rim vents, deck drains, guide-poles, columns, wells, vacuum breakers and ladders.
Internal Floating	Deck Seam	Seams may not be completely vapor tight if the deck is not welded

The percentages of emission from each type of loss, from both Sines and Oporto refineries, are presented in Figure 3.90.

Figure 3.90 – Percentage of NMVOC emissions per type of emission from storage and tanks of petroleum products in 2002



Finally the resultant emission factors, obtained dividing total tank emissions by total throughput<sup>48</sup> in each refinery, are presented in next table.

Figure 3.91 – Final emission factor for evaporation of NMVOC from storage and tank in refineries

Refinery	Emission Factor	
	(g NMVOC/ton throughput)	
	2002 and before	2003 and beyond
Sines	118	115
Oporto <sup>49</sup>	204	204
Lisbon	161 <sup>(a)</sup>	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 (EMEP/CORINAIR 3<sup>rd</sup> ed).

Figure 3.92 – 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 (1995) were used, but because original emission in the original reference source are expressed in volume of fresh feed – and this activity rate it is not available from the refinery – the original emission factor was corrected, by multiplication by the ratio of the NO<sub>x</sub> emission factor in both information sources (monitoring data and USEPA). Carbon dioxide emission factor was set assuming that coke is 92% carbon. Final emission factors may be verified in Figure 3.93.

<sup>48</sup> Crude oil input added to input of other materials.

<sup>49</sup> The final estimated emission factor for 2003 was still being developed at the time the inventory was finalized.

Figure 3.93 – Emission Factors used to estimate emissions from catalyst regeneration (kg/ton coke burned)

Emission Factor	
Parameter	kg/ton coke
SO <sub>x</sub>	31.9
NO <sub>x</sub>	3.6
CO	5.8
UCO <sub>2</sub>	3 373
PM	6.8

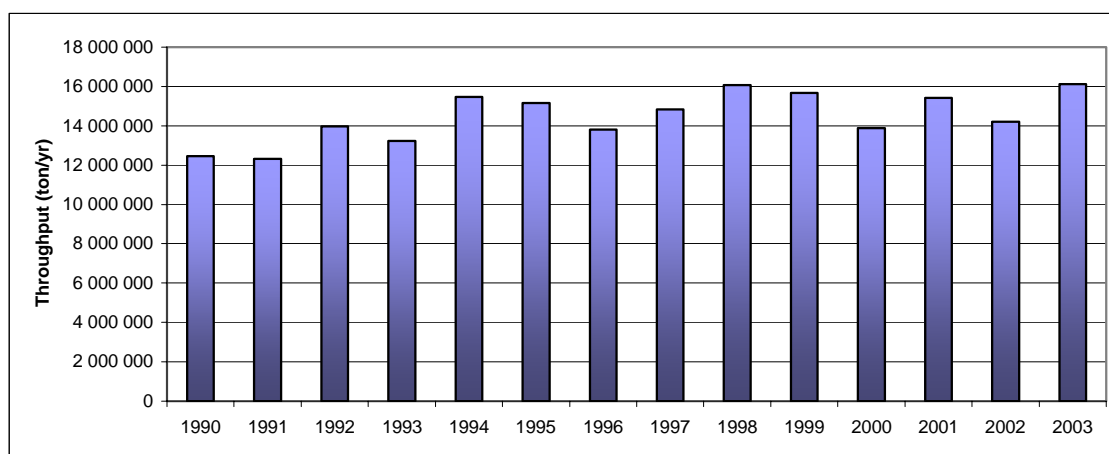
This set of emission factors was also applied to coke burning in the platforming unit, also in Sines refinery, and regeneration of catalysts at Oporto refinery.

### Activity data

The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed and it was already presented in “Transport of Crude” (Figure 3.87).

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 3.94.

Figure 3.94 – Total throughput entered in Lisbon, Oporto and Sines refineries: 1990-2003



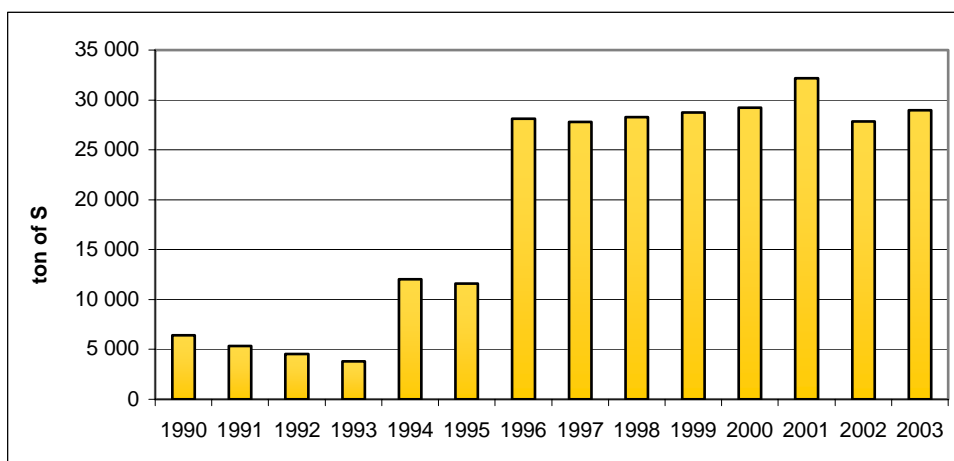
Source: Petrogal

For FCC, and other processes where there is recovery of catalysts, activity data is total coke burnt. Annual burning of coke in Sines refinery, both in FCC and in Platforming is available from PETROGAL up to 2003. Combustion of coke from catalysts in Oporto refinery was only available for 2001-2002, and was assumed constant over the all 1990-2003 period. Total coke burning was obtained from the industrial units and it is considered confidential data.

Total sulphur recovered in the refineries was available from the balance of petroleum products in annual publications from DGGE, from 1990 to 2002. Production of sulphur has been increasing, particularly after 1996, as could be seen in Figure 3.95, expressing the technology changes set by the auto-oil program. The value for 2003 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 3.95 – Total sulphur produced in Portuguese refineries recovered in Claus units



## UNCERTAINTY ASSESSMENT

Most of the activity data that was obtained to estimate emissions come directly from the refinery units or indirectly by the Energy Balance of DGGE (which is based also in information surveyed from the industrial plants). Therefore a low uncertainty of 3% may be assumed for this sub-source in a similar mode to other LPS combustion data.

Uncertainty of emission factors for NMVOC<sup>50</sup> were set as 50%, at the higher range of possible uncertainties proposed by IPCC (2000), although the fact that some emission factors use plant specific information. Estimates of methane emissions were assumed to have the double uncertainty that was determined for CO<sub>2</sub>.(100%)

## RECALCULATIONS

The only improvement in emission estimates that was done since last submission resulted from the update of the emission factor for NMVOC emissions from Sines crude oil refinery. No other modifications were made to this source sector.

## FURTHER IMPROVEMENTS

The efforts that the refineries are doing, in order to ameliorate emission estimates of storage in tanks, fugitive emissions, emissions from catalysts regeneration and from sulphur recovery, are expected to be reflected in improvements in the inventory methodologies and emission factors for the coming years.

<sup>50</sup> The uncertainty of NMVOC was considered to be the uncertainty of CO<sub>2</sub> emission factor.

## 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:

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

### Emission Factors

Emission Factors for NMVOC, corresponding to those proposed in the simpler methodology of EMEP/CORINAIR, which result from CONCAWE studies, are reported in next table.

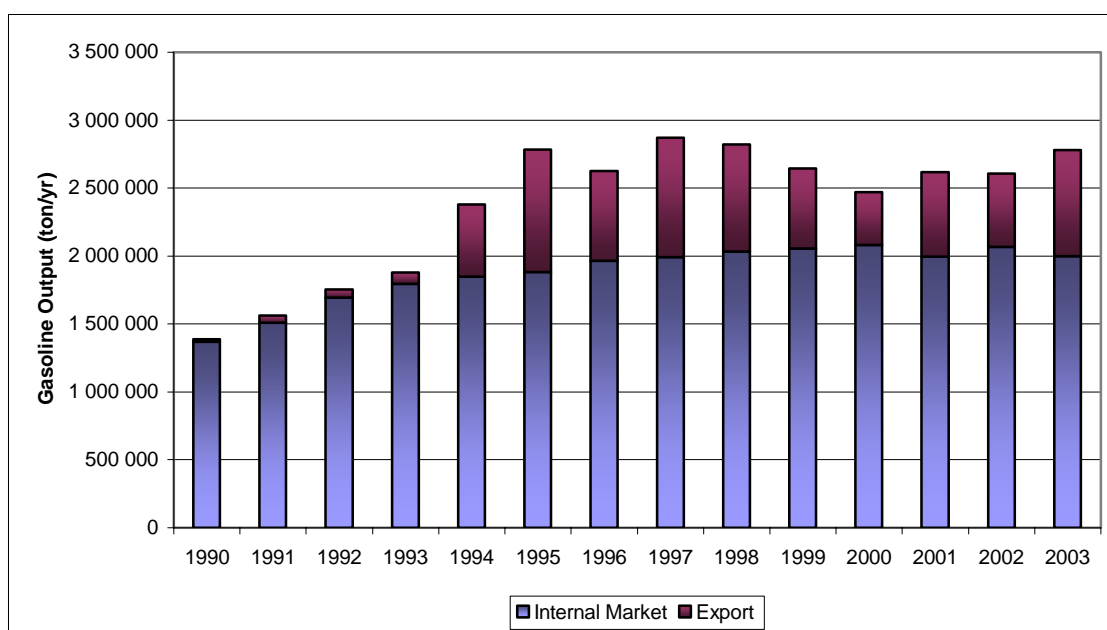
Figure 3.96 – Emission Factors

Sub-source category	Emission Factor (g /ton)
Refinery Dispatch Station	310
Transport and Depots	740
Service Stations	2 880

### Activity data

Activity data, in accordance to what was already defined in the methodology, for the years 1990 to 2002 is from the annual publications from the General-Directorate of Geology and Energy (DGGE). Values for 2003 are preliminary forecasts. Total gasoline output for internal market and exportation is presented in the Figure 3.97.

Figure 3.97 – 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);

$\text{EF}_{(p)}$  – Emission factor for pollutant p (g/GJ);

$\text{LHV}_{\text{GAS}(y)}$  – Low Heating Value of flared gas in year y (MJ/kg);

$\text{Flare}_{\text{GAS}(y)}$  – Quantity of gas flared in year y (ton/yr).

$\text{SO}_x$  emission were calculated according to emission factors based on total feed to refinery (US-EPA, 1995), because the sulphur content of flare gas is not known. The following formula was used:

$$\text{Flare}_{\text{SO}_x} = \text{Feed}_{\text{InFlow}} * \text{den}_{\text{FEED}} * \text{EF} * 10^{-6}$$

where

$\text{Flare}_{\text{SO}_x}$  – total emission of sulphur oxides in flare (ton/yr);

$\text{Feed}_{\text{InFlow}}$  - is total feed throughput received at all refinery plants for processing ( $\text{m}^3/\text{yr}$ );

$\text{den}_{\text{FEED}}$  – Feed density ( $\text{ton}/\text{m}^3$ );

$\text{EF}$  - 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:

$$\text{U}_{\text{CO}_2} = \text{EndofPipe}_{\text{CO}_2} + 44/12 * (0.85 * \text{NMVOC} + 12/16 * \text{CH}_4 + 12/28 * \text{CO}) * 10^{-3}$$

**Emission Factors**

Emission factors for all pollutants except  $\text{SO}_x$  where set from US-EPA (1991). Emission factor for  $\text{SO}_x$  is from (USEPA;1985 in EMEP/CORINAIR 3r ed).

Feed density was assumed as of 0.85 kg/L.

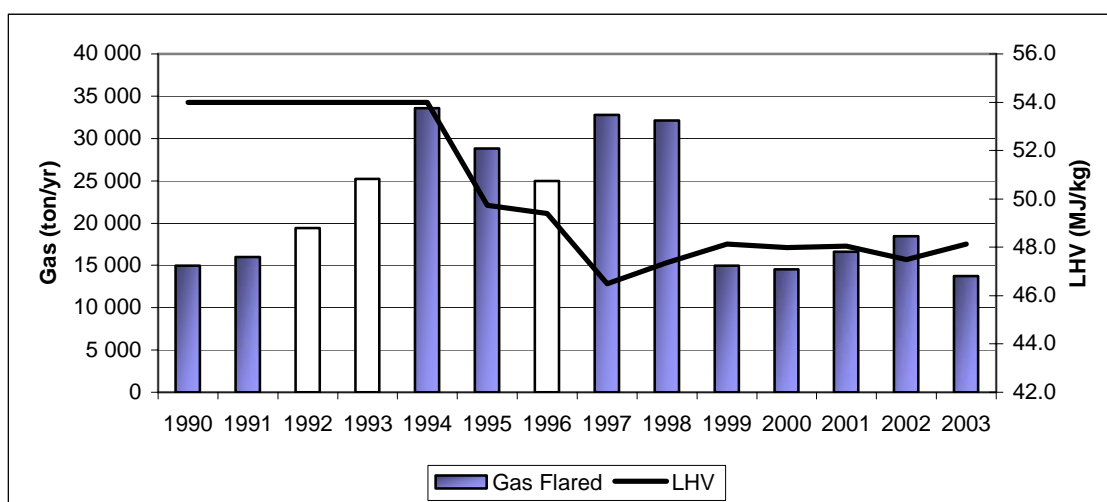
Figure 3.98 – Emission Factors for flaring in refineries

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**

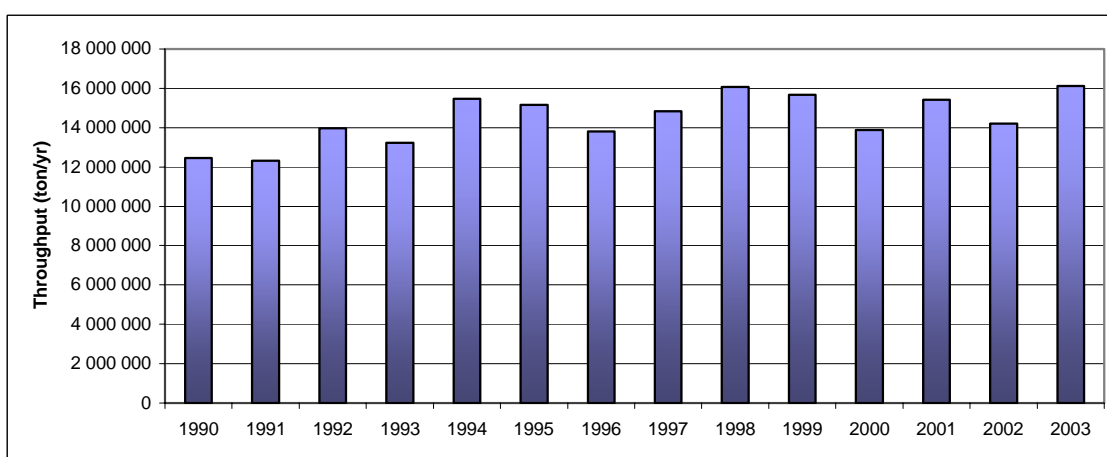
Total flare gas consumed in the three units and Low Heating Value was made available from PETROGAL and it is presented in Figure 3.99.

Figure 3.99 – Total consumption of flare gas in Portuguese refineries and Low Heating Value: (1990-2003)



Total throughput (feed) entered in refinery units is available from annual energy publications of (DGGE), and is again presented in Figure 3.100.

Figure 3.100– Total throughput entered in Lisbon, Oporto and Sines refineries (1990-2002)



### Uncertainty Assessment

The uncertainty in activity data was considered to be 5%, the same value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in NMVOC/CO<sub>2</sub> emission factor is 50% and the double of that value for methane emissions.

### Recalculations

No recalculations were done for this emission source.

### 3.2.E.3 FUGITIVE EMISSIONS FROM NATURAL GAS (CRF 1B2B)

#### Overview

There is no production of natural gas in Portugal. The use of natural gas in Portugal was initiated only in 1997 (DGGE). At that time this energy source was received by ship from Algeria and used mainly in electric power production and in combustion in industry. Since then its use has become more widespread and its now consumed also in the manufacturing industry, domestic, service, institutions, commerce, building and construction, agriculture and even a small quantity in road transport. All the gas is imported and received through shipping transport from Algeria 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

NG<sub>Cons(S)</sub> - 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 US-EPA and from information displayed in IPCC96 (GASA,1999). 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 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.

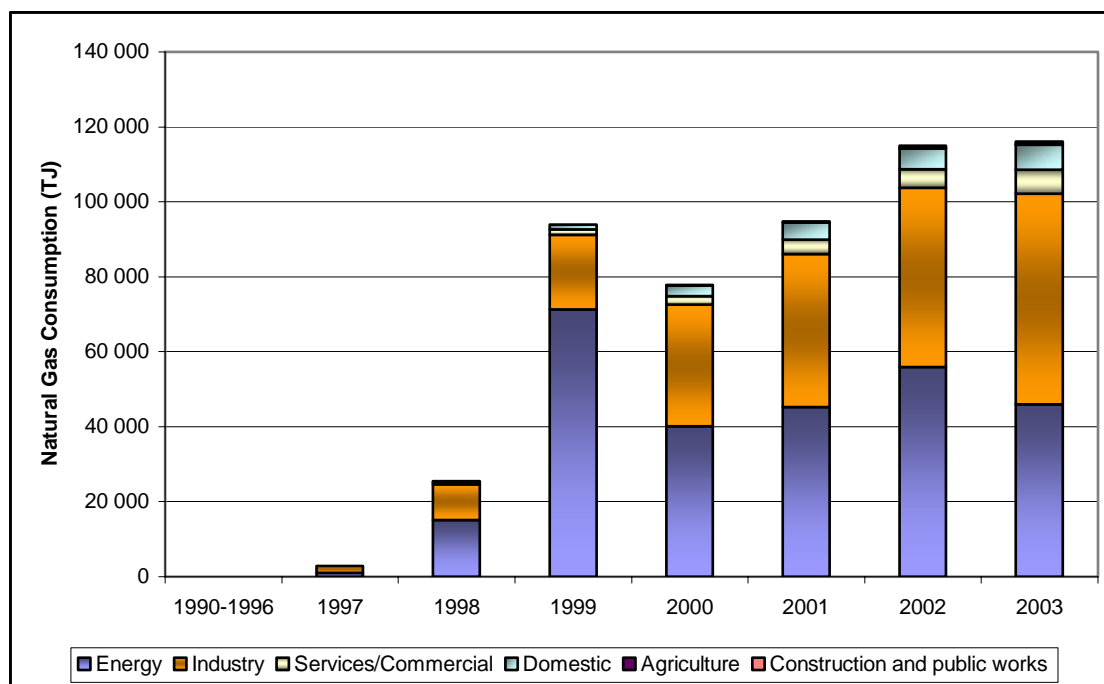
Figure 3.101 –Net Calorific Value and Emission Factor for fugitive emissions from natural gas

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 the next figure.

Figure 3.102 - Natural gas consumption per sector (1990-2003)



## Uncertainty Analysis

The uncertainty in activity data was considered to be 5%, the value that was used for other statistical information gathered from the Energy Balance as area sources. The uncertainty in CH<sub>4</sub> emission factor, considering a low quality inventory, was assumed to be 150%, and the

same value was considered for CO<sub>2</sub> emissions which were determined simply from simple conversion of emissions in methane form.

### Recalculations

No recalculations were done for this emission source in what concerns methodology and emission factors. However, activity data has changed as consequence of the fact that energy in natural gas is now determined from LHV/NCV whereas in last submission and for some activities HHV/GCV was used instead. More detailed explanation of this changes is presented already under discussion of activity data for combustion sources.

## 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 3.103, both in what concerns base year (1990) and year 2002.

Figure 3.103 – Differences between 2004 and 2005 submissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O)

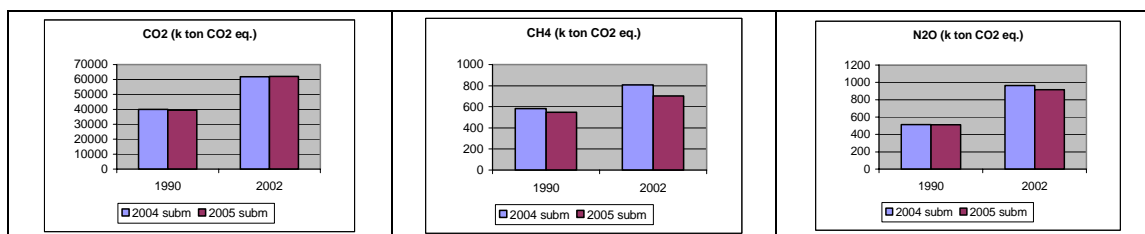


Table 3.163 – Recalculations (differences between 2004 to 2005 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2			CH4			N2O		
			2004	2005	Difference (1)	2004	2005	Difference (1)	2004	2005	Difference (1)
			subm.	subm.		subm.	subm.		subm.	subm.	
			CO2 equivalent (Gg)			CO2 equivalent (Gg)			CO2 equivalent (Gg)		
1990											
1. Energy			39 994.37	39 343.91	-1.63	583.16	547.08	-6.19	515.07	509.78	-1.03
1.A. Fuel Combustion Activities			39 868.20	39 217.73	-1.63	481.95	445.87	-7.49	515.07	509.78	-1.03
1.A.1. Energy Industries			16 186.80	15 944.40	-1.50	4.34	4.33	-0.15	61.04	61.04	-0.01
1.A.2. Manufacturing Industries and Construction			9 157.66	9 102.84	-0.60	70.75	35.33	-50.07	67.13	67.25	0.18
1.A.3. Transport			10 460.20	10 137.23	-3.09	58.42	57.76	-1.13	149.97	144.56	-3.60
1.A.4. Other Sectors			4 055.25	4 025.13	-0.74	348.30	348.30	0.00	236.92	236.92	0.00
1.A.5. Other			8.29	8.13	-2.00	0.15	0.15	0.00	0.02	0.02	0.00
1.B. Fugitive Emissions from Fuels			126.17	126.17	0.00	101.21	101.21	0.00	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			117.53	117.53	0.00	35.19	35.19	0.00	0.00	0.00	0.00
2002											
1. Energy			61 777.85	62 061.01	0.46	808.89	703.99	-12.97	961.85	917.06	-4.66
1.A. Fuel Combustion Activities			61 069.66	61 391.13	0.53	510.07	423.20	-17.03	961.85	917.06	-4.66
1.A.1. Energy Industries			24 787.89	24 411.73	-1.52	6.21	6.20	-0.21	110.44	110.26	-0.16
1.A.2. Manufacturing Industries and Construction			9 970.64	11 048.85	10.81	127.15	51.85	-59.22	90.28	90.41	0.14
1.A.3. Transport			19 830.59	19 538.56	-1.47	67.84	56.31	-17.00	565.72	521.01	-7.90
1.A.4. Other Sectors			6 480.54	6 391.99	-1.37	308.87	308.84	-0.01	195.40	195.37	-0.02
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			708.19	669.88	-5.41	298.82	280.80	-6.03	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			708.19	669.88	-5.41	298.82	280.80	-6.03	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.

## Cross-cutting issues

Two major actions have resulted in recalculations in emission estimates for the all time series:

- the revision of the Energy Balances by the General Directorate of Energy and Geology (DGGE) for the all time series (1990-2002). The major modification that was made in the Energy Balance was that now values for natural gas consumption in Low Heating Value (LHV/NCV) are reported for all sectors and activities in a consistent way. In last year's submission High Heating Value was used instead in all cases except in co-generation consumption;
- the inclusion of the oxidation factor in carbon dioxide emissions calculation. This methodological modification has caused the decrease of emission estimates for all years in a consistent way.

Apart from these major changes, some minor modifications were done in the Energy Balance by DGGE, which have been reflected in emission estimates in the inventory:

- in co-generation in the service sector it is now reported the consumption of LPG for 1998 and 1999, diesel for 1998 and 1999 and FO for 1998-2000 and biogas for 1999 and 2000. In previous Energy Balances these values were not reported;
- the all time series of diesel oil consumption in agriculture was revised for the all time series;
- in the construction and building activity only Natural Gas is still considered in co-generation consumption whereas biogas was considered before misplaced and moved to other source category.

Some errors in the emission factors applied to LTO movements in aviation were detected in last submission, and they were corrected in the present submission. Minor corrections were also made to the emission factors for the extractive industry.

In the road transport sector the major change resulted from the fact that in last submission NMVOC emissions from evaporative sources were converted to CO<sub>2</sub> emissions and added to total carbon dioxide emissions. During the in-country review process this was detected to be incorrect because all CO<sub>2</sub> was already estimated from fuel consumption data. This double counting is now corrected in the present submission. Also in road transport sector minor changes resulted from the review of average velocities per driving mode and the non consideration of cold start emissions in highway mode.

The emission factors, for other pollutants than carbon dioxide, for cement production and ceramics were revised using monitoring information from industrial plants.

### 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 in a final report and plan, the following preliminary routes may be here identified.

- Better integration between activity data in the air emissions inventory and other surveys such as LCP directive, *Autocontrolo* program, EPER and the energy surveys (co-generation) 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:

- consideration of annual distance driven per vehicle using information from the Inspection centres;
- incorporation of traffic monitoring data recorded in rural roads to estimate traffic emissions under rural driving mode and to improve specialisation of emissions;
- update of meteorological data for each specific emission year;
- incorporation of factors in emission factors calculation such as vehicle aging and maintenance;
- incorporation of regional and local emission estimates.

Water-borne navigation emissions are still not disaggregated in adequate categories to answer UNFCCC and LRTAP conventions, and efforts are being 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.

## 3.5 Reference Approach

### 3.5.A Overview

The reference approach consists in the estimate of CO<sub>2</sub> emissions using the simple approach tier 1 of IPCC (1997). Although the Portuguese National Inventory uses an sectoral approach of higher tier level, nevertheless the UNFCCC reporting guidelines request that parties make also a top-down “reference approach”<sup>51</sup> for estimation of CO<sub>2</sub> emissions from fossil fuel combustion, in addition to the bottom-up sectoral methodology.

The Reference approach uses a very simple methodology, assuming that all carbon input to the national economy in fuel form, it is either stored in some way (fuel stocks, products or even left unoxidized in ash) or it must be released to the atmosphere. In order to calculate the carbon released it is not necessary to know exactly how and where the fuel was used or what intermediate transformations it underwent. In this respect the methodology may be termed a “top-down” approach compared with the “bottom-up” methods used for other gases. (IPCC,1997)

The Reference Approach requires simple statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of values for the consumption of fossil products used for non-energy purposes, where carbon may be stored.

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<sup>51</sup> This does not mean that a “bottom-up” approach should not be followed for estimating CO<sub>2</sub> emissions but the total emissions must be compared with those obtained from the Reference Approach.

### 3.5.B Methodology

The following methodological steps were made in accordance with IPCC (1997):

- 1 Estimate consumption of fuels by fuel/product type;
- 2 Convert the fuel data to a common energy unit (TJ), if necessary;
- 3 Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels;
- 4 Estimate the amount of carbon stored in products for long periods of time;
- 5 Account for carbon not oxidized during combustion;
- 6 Convert emissions of carbon to full molecular weight of CO<sub>2</sub>.

#### 3.5.B.1 FUEL CONSUMPTION

Apparent consumption was estimated from the National Energy Balances produced by the General Directorate of Energy and Geology (DGGE) according to:

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{Stock Change.}$$

for primary fuels and,

$$\text{Apparent Consumption} = \text{Imports} - \text{Exports} - \text{Bunkers} - \text{Stock Change.}$$

for secondary fuels.

National production is not considered because the carbon in these fuels was already included in the supply of primary fuels from which they were derived.

#### 3.5.B.2 ENERGY CONSUMPTION

The Portuguese National Balance reports consumption in energy units (toe<sup>52</sup>), apparent consumption needs only to be converted to TJ using the multiplier 41.868 GJ/toe.

#### 3.5.B.3 CARBON CONTENT OF FUELS

Carbon content in apparent consumption is estimated in reference approach from:

$$\text{Apparent Consumption}_{(\text{Gg C})} = \text{Apparent Consumption}_{(\text{TJ})} * \text{Carbon Content}_{(\text{MgC} / \text{TJ})} * 10^{-3}$$

The carbon content of fuels was determined using the Carbon Emission Factors used in the sectoral approach, which are presented in Table 3.164.

<sup>52</sup> Ton of oil equivalent



Table 3.164 – Carbon content of fuels and Oxidation Factor used in the Reference Approach

Fuel			C content (t C/TJ)	Fac <sub>ox</sub> 0..1
Liquid Fossil	Primary Fuels	Crude Oil	20.0	0.99
		Orimulsion	22.0	0.99
		Natural Gas Liquids	17.2	
	Secondary Fuels	Gasoline	19.4	0.99
		Jet Kerosene	19.9	0.99
		Other Kerosene	20.0	0.99
		Gas / Diesel Oil	19.9	0.99
		Residual Fuel Oil	20.7	0.99
		LPG	17.7	0.99
		Naphtha	20.0	0.99
		Bitumen	22.0	0.99
		Lubricants	20.0	0.99
		Petroleum Coke	27.5	0.99
		Refinery Feedstocks	20.0	0.99
		Other Oil	20.0	0.99
Solid Fossil	Primary Fuels	Anthracite (a)	26.8	0.98
		Coking Coal	25.8	0.98
		Other Bit. Coal	25.1	0.98
		Sub-bit. Coal	26.2	0.98
		Lignite	27.3	0.98
		Oil Shale	29.1	0.99
		Peat	28.9	0.99
	Secondary Fuels	BKB & Patent Fuel	27.0	0.98
		Coke Oven/Gas Coke	29.5	0.98
Gaseous Fossil		Natural Gas (Dry)	15.3	1.00
Biomass		Solid Biomass	29.9	1.00
		Liquid Biomass	20.0	1.00
		Gas Biomass	30.6	1.00

### 3.5.B.4 CARBON STORED IN PRODUCTS

For the IPCC Reference Approach, the suggested formula for estimating carbon stored in products for each country is:

$\begin{aligned} \text{Total Carbon Stored (Mg C)} &= \text{Non-Energy Use (toe)} \\ &\times \text{Conversion Factor (TJ/toe)} \\ &\times \text{Emission Factor (t C/TJ)} \\ &\times \text{Fraction Carbon Stored} \end{aligned}$
---

Presently the following products are taken from the National Energy Balance: lubricants, bitumen, and naphtha and residual fuel oils used as raw materials. Original statistical

information was already expressed in toe. Emission factors and the fraction of carbon stored is reported in Table 3.165.

Table 3.165 – Reference Approach. Carbon Emission Factor and Fraction of carbon stored

Fuel	C content (t C/TJ)	FacOX 0..1
Naphtha	20	0.8
Lubricants	20	0.5
Bitumen	22	1
Fuel Oil	21.1	0.8

### 3.5.C Actual Carbon Dioxide Emissions

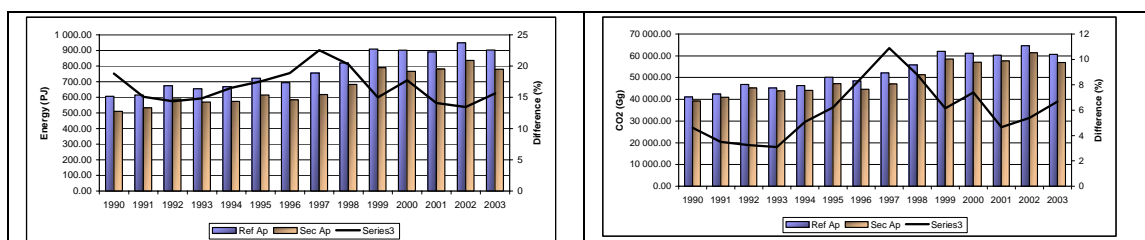
Estimated simply from:

$$\text{CO}_2 \text{ Emission} = 44/12 * (\text{Carbon Content} - \text{Carbon Stored}) * \text{Oxidation Factor}$$

### 3.5.D Results. Comparison of Reference Approach and Sectoral Approach

Detailed data used in the reference approach calculation is reported in CRF tables and is not duplicated in NIR. The emissions estimated according to reference approach and sectoral approach show differences in both energy consumption and carbon emissions, and are presented in Figure 3.104. They are mostly explained from differences in the Energy Balance and the energy activity data used by the inventory – where data collected directly from emission units (Large Point Sources) play a very representative role – and a different approach to account for emissions from carbon stored in products.

Figure 3.104 – Comparison of Energy Consumption and CO<sub>2</sub> emissions between the sectoral approach and the Reference Approach



### 3.6 Feedstock

Emissions of greenhouse gas emissions from feedstock use are only clearly accounted in the inventory in the following situations:

- emission of CO<sub>2</sub> resulting from use of feedstock sub-products as energy sources. That is the case of emissions from consumption of fuel gas in refinery and petrochemical industry;
- emission of CO<sub>2</sub> liberated as sub-product in production processes such as ammonia production;

- emission of NMVOC from fossil fuel origin, and occurring from solvent use and evaporation. Although in this case it is not possible to establish which part results from feedstock consumption in Portugal in the energy balance;

However, some potential emissions are not estimated or are only partly estimated. Those that are estimated in the reference approach but not in sectoral approach are:

- emissions from mineral oil use as lubricants;
- emissions from wear of bitumen in roads.

It is evident that more efforts should be made to estimate other emissions from feedstock use, although it is expected that reporting guidelines should give more clear guidance in the future.

## CHAPTER: 4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

### 4.1 Overview

In this source sector are included the GHG emissions resulting from the chemical and physical transformation of raw materials in the industrial transformation processes excluding emissions that result from combustion for energy production. According to UNFCCC reporting guidelines, also are included in this sector the emissions of fluorinated compounds (HFC, PFC and SF<sub>6</sub>) that are used in different applications - not solely industrial, but also in domestic and services sector - as substitutes to ozone depleting substances (ODS). Emissions occurring in production processes in industry but involving the use of solvents or solvent bearing substances (such as paint) are included in source sector "Use of solvent and other uses – CRF 3" and discussed in chapter 5.

Industrial processes, either involving combustion<sup>53</sup> or not, result also in the release of other atmospheric pollutants like acidifying gases and indirect GHG: NO<sub>x</sub>, NMVOC and SO<sub>x</sub>. Industrial processes are relevant sources of particulate matter (PM, PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub>) and local air pollutants such CO and Heavy Metals. The methodologies and emission factors that are used in the Portuguese air emission inventory for the estimate of emission from these sources are also discussed in this report as complementary information.

In terms of total GHG, emissions from the industrial production sector have increased from about 4.6 Mton CO<sub>2</sub>e in 1990 to 6.6 Mton CO<sub>2</sub>e in 2003, as may be seen from Figure 4.1, i.e. emissions estimated for 2003 are about 44% higher than the emissions estimated for base year (1990). However, in one hand the biggest total emission value occurred in year 2002 when 6.8 Mton CO<sub>2</sub>e were estimated to be emitted, and in the other hand the increase in emissions was not homogeneous having only occurred after 1993. The majority of emissions, expressed in CO<sub>2</sub> equivalent (GWP), are associated with mineral industry, with 73% of total emissions from this sector in base year, and 64% of total emissions from this sector in 2003, as may be seen in Figure 4.2. In second place of importance are the emissions from the chemical industry, which have increased from 26% of emissions from this sector in 1990 toward 35% of emissions in 2003. The remaining sub-source sectors (2C, 2D and 2F<sup>54</sup>) have a minor importance and globally they amounted to only 1.4 % of total emissions from this source sector in 2003. The importance of sub-category 2F, Consumption of Halocarbons and SF<sub>6</sub>, has been increasing since 1995 and represents in 2003 about 1% of total GHG emissions from this source sector.

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<sup>53</sup> Emissions of combustion are considered in this sector if they are considered a production process and not as a way to obtain energy, even if the energy is used directly in the production process such as in a furnace. Emissions from combustion processes in industry with the sole aim of obtaining energy (boilers, furnaces, engines) are included in Energy sector.

<sup>54</sup> No emissions were allocated to sub-category 2G – Other. Emissions for category 2 F - Production of Halocarbons and SF<sub>6</sub>, did not occur in Portugal.

Figure 4.1 – Total GHG emissions from Industrial Processes per source sub-sector (1990-2003)

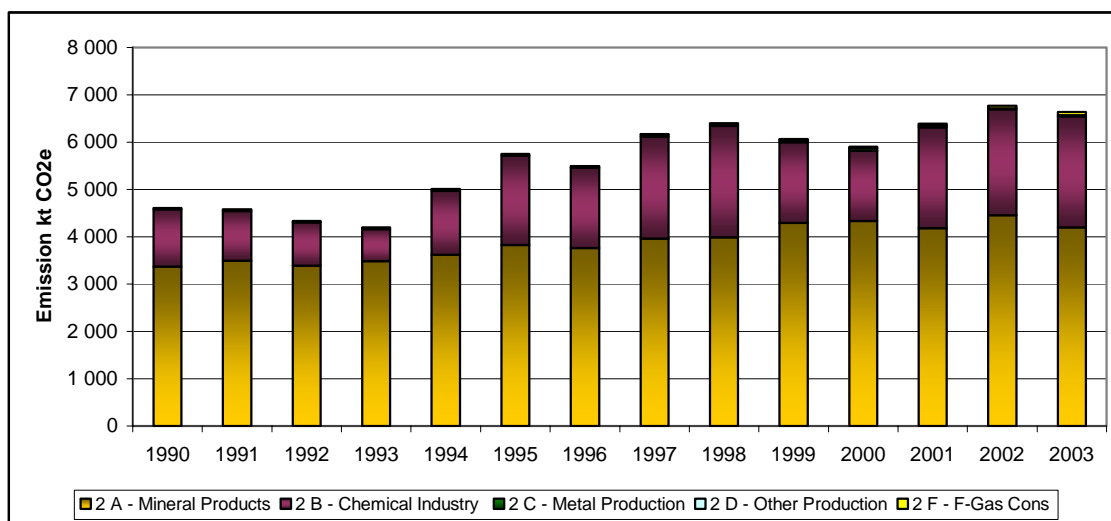
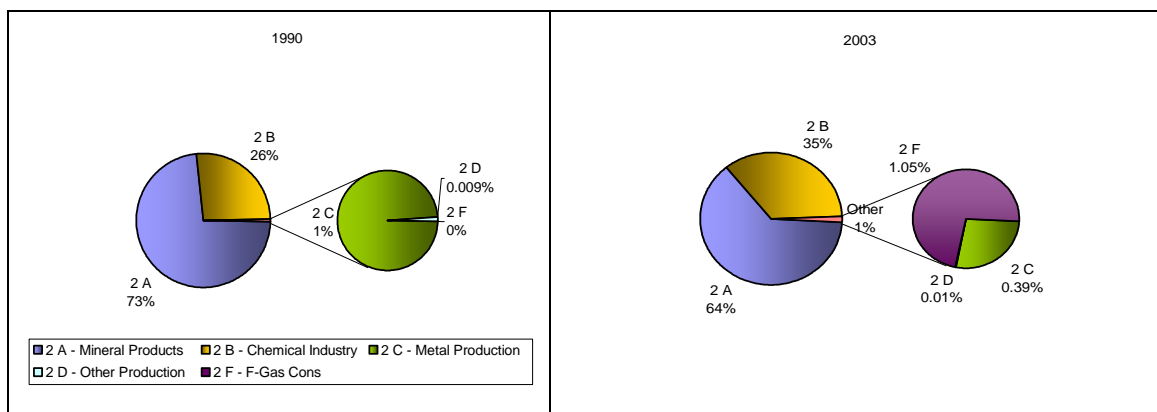


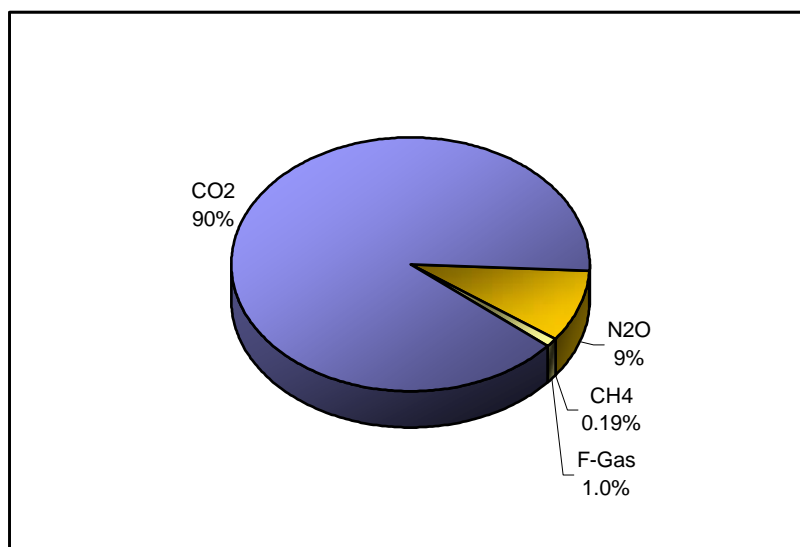
Figure 4.2 – Emissions of Industrial processes by sub-source sector in Portugal in year 1990 and 2003



Detalhar mais a importância de emissões em cada grupo.

The great major part of green-house gas emissions are realized directly as CO<sub>2</sub>; while N<sub>2</sub>O represents a smaller proportion of emissions and methane emissions are a non relevant part, as may be seen in Figure 4.3 for year 2003.

Figure 4.3 - GHG emissions from Industrial Processes per green-house gas in 2003



## 4.2 Recalculations

Figure 4.4 - Differences between 2004 and 2005 submissions for CO2, CH4 and N2O emissions

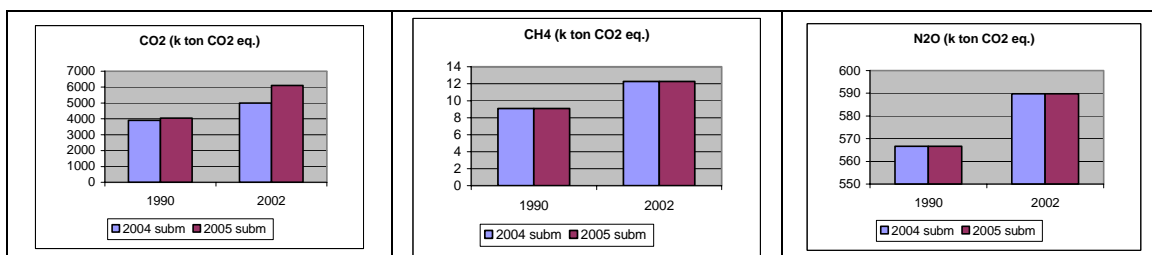


Table 4.1 - Recalculations (differences between 2004 and 2005 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			CO2			CH4			N2O			
			2004	2005	Difference (1)	2004	2005	Difference (1)	2004	2005	Difference (1)	
			subm.	subm.		subm.	subm.		subm.	subm.		
			CO2 equivalent (Gg)			(%)			CO2 equivalent (Gg)			(%)
1990												
2. Industrial Processes			3 903.72	4 037.96	3.44	9.08	9.08	0.00	566.68	566.68		0.00
2.A.	Mineral Products		3 219.50	3 375.21	4.84	0.76	0.76	0.00	0.00	0.00		0.00
2.B.	Chemical Industry		632.88	632.88	0.00	8.32	8.32	0.00	566.68	566.68		0.00
2.C.	Metal Production		50.90	29.44	-42.16	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		
2.G.	Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
2002												
2. Industrial Processes			4 993.11	6 112.99	22.43	12.27	12.27	0.00	589.78	589.78		0.00
2.A.	Mineral Products		3 346.85	4 450.90	32.99	1.69	1.69	0.00	0.00	0.00		0.00
2.B.	Chemical Industry		1 638.30	1 638.30	0.00	10.58	10.58	0.00	589.78	589.78		0.00
2.C.	Metal Production		7.52	23.35	210.42	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		
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 =  $100\% \times [(LS-PS)/PS]$ , where LS = Latest submission and PS = Previous submission).

## 4.3 Category Sources

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

#### 4.3.A.1 CEMENT PRODUCTION (CRF 2A1)

##### OVERVIEW

During the 1990-2003 period there were six cement production plants operating in Portugal, mostly dedicated to Portland cement production<sup>55</sup> and almost all localized in the southern half of the country. Five of these clinker producing units use the dry process while the remaining one uses both the dry and the semi-wet process - although the dry process is prevalent in that unit too. All dry process units have short kilns with pre-heaters, and 5 kilns in four units are provided with pre-calciners<sup>56</sup>. The importance of clinker production for each one of the six plants is presented in Table 4.2, from where it is evident that production of clinker and CO<sub>2</sub> decarbonising emissions are dominated by three plant units.

Table 4.2 - Main Characteristics of Cement Production Plants in Portugal

Unit	Nut III	Average % of total Clinker Production 1990-2003
Souzelas	RC122	25.9
Maceira	RC123	12.4
Pataias	RC123	4.6
Alhamdra	RC132	25.6
Outão	RC133	23.7
Loulé	RC150	7.8

Portland cement is broadly a mixture of clinker and gypsum with some minor additives. Cement production is in essence a pyro-processing operation on calcium carbonate, aluminium-siliceous and iron-oxide materials to form a mixture of calcium silicates, aluminates and aluminoferrites that forms a binder with water.

Carbon dioxide emissions from cement production process result from the conversion of CaCO<sub>3</sub> and MgCO<sub>3</sub>, the main constituents of limestone, to lime (CaO) and MgO, while leaving CO<sub>2</sub> as by product to atmosphere (Decarbonisation). Sulphur oxides emissions result from sulphur existence both in fuel and in some constituent materials such as clay. However contrary to what occurs with CO<sub>2</sub>, usually most of the SO<sub>x</sub> that is formed during calcination will be absorbed and long term immobilized in clinker and then in cement.

Only emissions of CO<sub>2</sub> from limestone decarbonising are reported here. Emissions of other pollutants, although they may result from both fuel and raw material, are reported in Energy (CRF 1A2) for simplicity sake. CO<sub>2</sub> 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.

<sup>55</sup> There is also some production of white Portland cement, which is characterized by a lower iron and manganese content, than grey cement, and it is used mainly for decorative purposes (EPA,1995). There are also in Portugal smaller additional cement plants in Portugal but that do not produce clinker.

<sup>56</sup> One calciner is a false pre-calciner.

## METHODOLOGY

Emissions of carbon dioxide resulting from carbon in raw materials are determined according to equation 3.1 of GPG, which is basically a mass balance:

$$Emi_{CO_2 (y)} = EF_{Clinker} * Prod_{CLINKER (y)} * CKD * 10^{-6}$$

where

$Emi_{CO_2 (y)}$  - emissions of CO<sub>2</sub> from cement production, originated from carbon in mineral constituent materials (kton/yr);

$EF_{Clinker}$  - emission factor (kg/ton clinker);

$Prod_{CLINKER (y)}$  - Total production of clinker (ton/yr);

CKD - Cement Kiln Dust correction factor, accounting for the fact that some part of calcinated raw materials and clinker collected at stack air emission control equipment can not be returned to process and is not included in clinker. But because this material includes calcinated constituents, it must be included in the mass balance accounts correcting activity data (clinker production).

## EMISSION FACTORS

The CO<sub>2</sub> emission factor was estimated according to the following formula, equivalent to the GPG equation 3.3:

$$EF_{Clinker} = 44.01 / 56.08 * Ratio_{CaO}$$

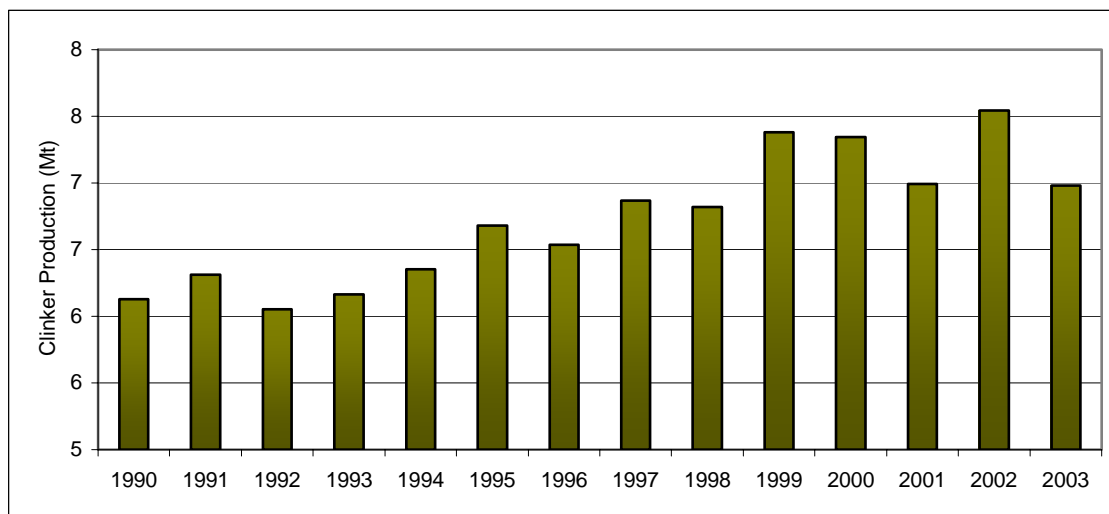
where  $Ratio_{CaO}$  is the Calcium oxide (lime) content of clinker (kg CaO/ kg clinker). The default IPCC CaO fraction in clinker was considered in the inventory (64.6%). Final emission factor is therefore 0.507 ton CO<sub>2</sub>/ ton clinker.

## ACTIVITY DATA

Clinker production, for all the years from 1990 to 2003, was received directly from each industrial plant, and the correspondent time series may be observed in next figure.



Figure 4.5 – Total Production of clinker in Portugal (1990-2003)



The CKD correction factor to clinker production was not considered, in accordance with information received from industry experts that consider that in all production lines in Portuguese cement plants, dust is fully returned back to the process and incorporated in final product.

#### UNCERTAINTY ASSESSMENT

The uncertainty value of the emission factor was determined to be 10 % for all years which results from the consideration of uncertainty error in the assumption that all CaO is from CaCO<sub>3</sub>, CaO content of clinker and CKD parameter. In all cases the maximum values of uncertainty in the GP (IPCC,2000) was considered using a conservative approach. In a similar conservative mode the uncertainty associated with activity data was set at 2%.

#### RECALCULATIONS

No changes occurred for this sector apart from update of the clinker production value for 2002 with more accurate data received this year from the industrial plants. No modifications were done in what concerns methodology and emission factors.

#### FURTHER IMPROVEMENTS

In accordance to the methodology proposed in the European Commission Decision 29/01/2004 (Annex VII) the formula for calculation of decarbonising emissions should be changed to:

$$EF_{\text{Clinker}} = 0.785 * \text{Ratio}_{\text{CaO}} + 1.092 * \text{Ratio}_{\text{MgO}}$$

The emission factors might 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>57</sup>. This modification is still under consideration in the elaboration of the Methodology Development Plan that is part of the National System.

It was also envisaged that consumption of raw materials and the knowledge of its carbon content could be used to make estimates of carbon dioxide emissions from consumption of

<sup>57</sup> Assuming CaO fraction in clinker of 64.5% and MgO 2%, the default value set by GHP Protocol (WBCSD/WRI).

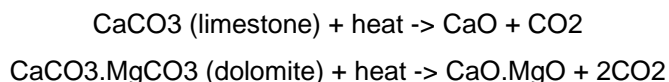
carbon in raw materials. This procedure would result in an alternative estimate method that could at least be useful to uncertainty assessment. In fact, apart from the data that is collected directly from each unit plant concerning clinker production, industrial plants also furnish information about consumption of raw materials (limestone, sand, carbonate shales, ash, gypsum, iron oxides, argyles and flue dust) . The information data that was received until now is not sufficient to derive country-specific CaO contents: CaO fractions are not available for all industrial plants; some raw materials, such as carbonate shales, have a very large range of possible carbonate content; and some carbon content materials are only used as fillers and will not result in emissions.

Probably more feasible, efforts are also under way in order to improve the knowledge of carbon content of products, or CaO and MgO content, for all plants with the possible outcome of a country-specific emission factor.

#### 4.3.A.2 LIME PRODUCTION (CRF 2A2)

##### OVERVIEW

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200°C) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving calcium oxide (CaO) or magnesium oxide (MgO) as valuable products. The following chemical conversion equation applies, where for each mol of oxide a mol of carbon dioxide is emitted.



Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO), it is produced by heating limestone with heavy 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.

Besides the production of lime in the lime industry to furnish market requirements, lime is also produced and consumed inside industrial sectors. That is the case of the production of lime in Kraft paper pulp plants, where quicklime is produced from carbonates in lime kilns and it is used to regenerate green liquor to white liquor. That is also the case of iron and steel production whereas emissions from this activity are also reported in this source category.

## METHODOLOGY

Carbon Dioxide emissions from lime production were estimated from the quantity of lime that was produced, according to the following equation, which is in accordance with equation 3.4 in GP:

$$\text{Emi}_{\text{CO}_2} = (\text{Prd}_{\text{Lime}} * \text{EF}_{\text{Lime}} + \text{Prd}_{\text{Slaked}} * \text{EF}_{\text{Slaked}} + \text{Prd}_{\text{HLime}} * \text{EF}_{\text{HLime}}) * 10^{-3}$$

Where,

$\text{Emi}_{\text{CO}_2}$  – CO<sub>2</sub> emission from total lime production (kton/yr);

$\text{Prd}_{\text{Lime}}$  – annual production of lime, either high calcium quicklime or dolomite lime as final product (ton/yr);

$\text{Prd}_{\text{Slaked}}$  – production of slaked lime as final product (ton/yr);

$\text{Prd}_{\text{HLime}}$  – Annual production of hydraulic lime (ton/yr);

$\text{EF}_{\text{Lime}}$ ,  $\text{EF}_{\text{Slaked}}$ ,  $\text{EF}_{\text{HLime}}$  – emission factors applied respectively to lime, slaked lime and hydraulic lime (ton CO<sub>2</sub>/ton lime).

## EMISSION FACTORS

In the case of lime industry emission factors were determined in accordance with equations 3.5 of GP and using table 3.4 of the same reference. They were calculated for each lime type from:

$$\text{EF} = [(1 - \text{Dol}_{\text{Lime}}) * \text{SR}_{\text{CaO}} * \text{Content}_{\text{CaO}} + \text{Dol}_{\text{Lime}} * \text{SR}_{\text{CaO.MgO}} * \text{Content}_{\text{CaO.MgO}}] * (1 - \text{Content}_{\text{H}_2\text{O}})$$

Where,

$\text{Dol}_{\text{Lime}}$  – Ratio of total lime produced that is Dolomite Lime (kg/kg);

$\text{SR}_{\text{CaO}}$  – stoichiometric ratio between CaO and CO<sub>2</sub> during production of pure high calcium quicklime (kg/kg);

$\text{SR}_{\text{CaO.MgO}}$  - stoichiometric ratio between CaO.MgO (50:50) and CO<sub>2</sub> during production of pure Dolomite lime (kg/kg);

$\text{Content}_{\text{CaO}}$  – Content of CaO in high calcium lime as in final product (kg/kg)<sup>58</sup>;

$\text{Content}_{\text{CaO.MgO}}$  - Content of CaO.MgO in Dolomite lime as final product (kg/kg);

$\text{Content}_{\text{H}_2\text{O}}$  – Water content in slaked lime (kg/kg)

The following table presents the values set for each parameter, for each lime type, and the final value for emissions factors. The values in this table are the default values in GP (table 3.4) while  $\text{Dol}_{\text{Lime}}$  is the proportion of both lime types according to GP also (page 3.22). The default water content values in table 3.5 were used to determine the emission factor for slaked lime.

<sup>58</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.

Table 4.3 – 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>).

In the case of the iron and steel industry all lime is high calcium quick lime and the emission factor, obtained from the above equation, is 0.76 kg CO<sub>2</sub>/kg lime.

### ACTIVITY DATA

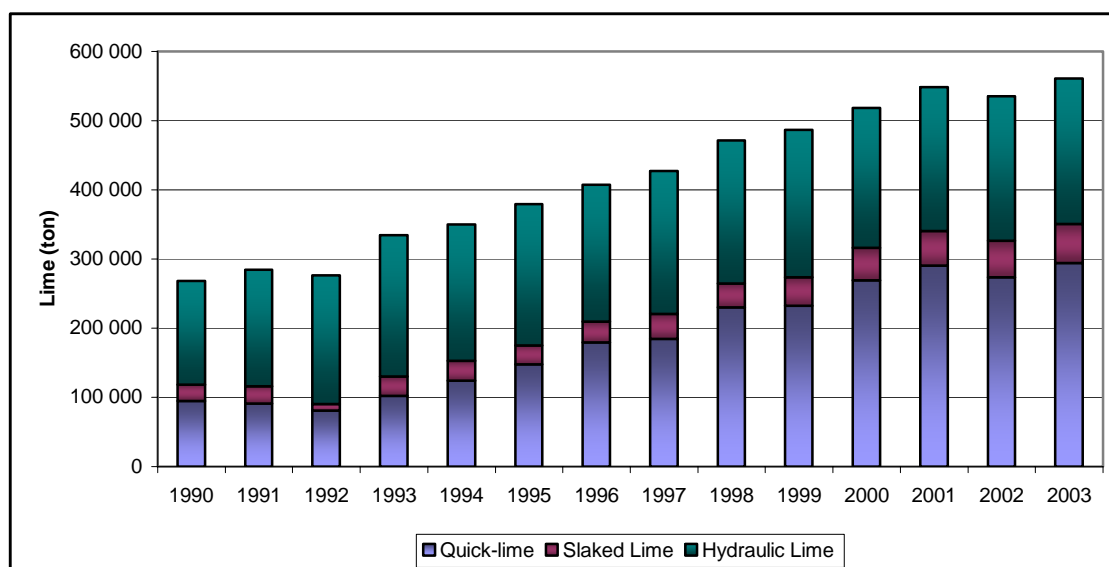
Production of lime products in industrial plants solely dedicated to this activity is available for the period 1989-2000 from National Statistics (INE): for the period 1989-1991 from IAIT industrial survey, and for 1992-2000 from the IAPI industrial survey. In order to avoid double counting of decarbonisation (calcination), only lime sold was quantified but not lime produced for internal consumption in unit plant. Production values for 2001-2003 are simple linear forecasts from the available statistical time series. From the available information, no distinction could be made between the high calcium lime and dolomite lime for lime produced and sold to market.

Lime production in the iron and steel industry was available from information received from the industry for the period 1991-1994. For the remaining years 1990 and 1995-2001 annual lime production, which data was unavailable, was forecasted using energy consumption as surrogate indicator. After year 2002 no more lime was produced in the industrial unit. All lime produced in the iron and steel plant is high calcium lime.

In the case of the paper pulp industry the IAIT/IAPI surveys have no available information in lime production but only of limestone and dolomite consumption. Lime production had to be estimated from consumption of those carbon bearing materials and assuming the stoichiometric ratios of limestone and dolomite rock.

The time-series of Lime production per lime type is presented in Figure 4.6, from where it is evident the pattern of production increase (109 %), particularly quick-lime which was more than doubled in the period, and the minor importance of slaked lime production.

Figure 4.6 – Production of lime in Portugal per lime type (1990-2003)



## UNCERTAINTY ASSESSMENT

According to the GP the uncertainty associated with the carbon dioxide emission factor for lime production is 15% for hydraulic lime and 2% for all other lime types (IPCC,2000). The resultant uncertainty value according to the share of each lime type in Portugal was set at about 8.5%.

The GP assumes that uncertainty in activity data is very high due to problems in gathering lime data. The national inventory recognizes that this is in fact the case for Portugal, particularly because in some situations lime is not produced for market but for internal consumption in the industrial plant, and may be not properly reported in statistical surveys. The maximum uncertainty value of 105% was therefore used in the uncertainty analysis.

## RECALCULATIONS

In submission 2004 CO<sub>2</sub> emissions from lime production in paper pulp production and iron and steel production were reported in diverse emission source categories, respectively 2 A 3 (Limestone Use) and 1 A 2 (Use of energy in Manufacturing Industry). The change in methodology in the case of paper pulp industry allows, in the present submission, the estimation of total lime production and reporting of emissions from lime production in the adequate source category. It must be stressed however that this has not resulted in substantial changes in overall CO<sub>2</sub> emissions from lime production, but only different allocation<sup>59</sup>.

The emission factor of CO<sub>2</sub> emissions from lime production in the iron and steel industry were revised, in such a way that to equal the emission factors that were already used in the case of lime production industry, and therefore they were slightly reduced from 0.79 kg CO<sub>2</sub>/kg lime to 0.76 kg CO<sub>2</sub>/kg lime.

## FURTHER IMPROVEMENTS

There is still some possibility that the inventory is doubling the estimate of CO<sub>2</sub> emissions, if part of the quick-lime that is produced in an industrial unit is sold and used again to produce slaked lime or hydraulic lime in a different industrial plant. To correct this effect, emissions estimated

<sup>59</sup> The change in methodology in iron and steel industry has resulted in slight changes in emission estimates.

from lime production should be cross checked with emission estimates from limestone and dolomite consumption. Another contribution factor to over-estimation of emissions is the possible use of calcium materials to other used than lime<sup>60</sup> production in the paper pulp industry.

A better and detailed knowledge of the proportion of lime that is high calcium lime and which is dolomite lime should be achieved – however this separation can not be done from National Statistical Databases except in the case of the paper pulp industry - allowing this differentiation to be used in activity data and not in emission factor as it was done in this submission.

#### 4.3.A.3 LIMESTONE, DOLOMITE AND CARBONATE USE (CRF 2A3)

##### OVERVIEW

Carbon dioxide liberation to atmosphere occurs from several industrial activities that use limestone ( $\text{CaCO}_3$ ), dolomite rock ( $\text{CaCO}_3\cdot\text{MgCO}_3$ ) or other carbonates, but only when original materials are not incorporated as inert components but suffer a chemical removal of carbon, as for example when calcium carbonate is added to nitric acid to form calcium nitrate:



Presently, in the inventory of GHG emissions, only  $\text{CO}_2$  emissions resulting from production of calcium and magnesium nitrates and consumption of sodium carbonates in paper pulp production are reported in source category 2A3.

Use of carbonate materials in glass industry is covered in sector activity 2A7. Although the use of carbonates in iron and steel industry as flux in blast furnace result in  $\text{CO}_2$  emissions, these were included in Energy (1A2), being assumed that the emission factor of  $\text{CO}_2$  from blast furnace consumption<sup>61</sup> already includes the carbon from limestone that was liberated from the flux in the blast furnace. While consumption of carbonate materials is reported in the National Statistics Database (INE) for other industrial activities, some do not correspond to uses where carbon is liberated and no emissions are estimated: 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.

Lime production involves as well the consumption and decarbonising of carbonate materials, limestone or dolomite rock. Albeit the similitude of both process, carbon dioxide emissions from lime production, including production in the paper pulp industry and in the iron and steel industry, are reported in source category 2A2 and were already discussed.

Non- $\text{CO}_2$  process emissions in the paper pulp and fertilizer industry are reported in other source categories, respectively 2B and 2C. Combustion emissions from these industrial activities are reported in source category 1A2.

##### METHODOLOGY

$\text{CO}_2$  emissions are estimated from the quantification of carbon in original raw materials, and making a mass balance for the quantities of  $\text{CO}_2$  that are liberated in the conversion process. Therefore emissions are estimated from consumption of carbonate materials:

---

<sup>60</sup> Or any other process not resulting in decarbonisation.

<sup>61</sup> Determined from composition of Blast Furnace Gas given by industry.

$$\text{Emi}_{\text{CO}_2 (y)} = 44/12 * \text{Mat}_{\text{Carb (m,y)}} * \text{C}_{\text{content (m)}} * 10^{-3}$$

where

$\text{Emi}_{\text{CO}_2 (y)}$  - emission of carbon dioxide in year y (kton/yr);

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

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

## EMISSION FACTORS

Carbon content of materials consumed in Portugal was set from molecular stoichiometry<sup>62</sup>:

Table 4.4 - Carbon content of carbonate materials

Material	Ccontent
Sodium Carbonate	0.42
Limestone*	0.44
Magnesium Carbonate	0.52
Coal (Electrodes) to be removed	3.67

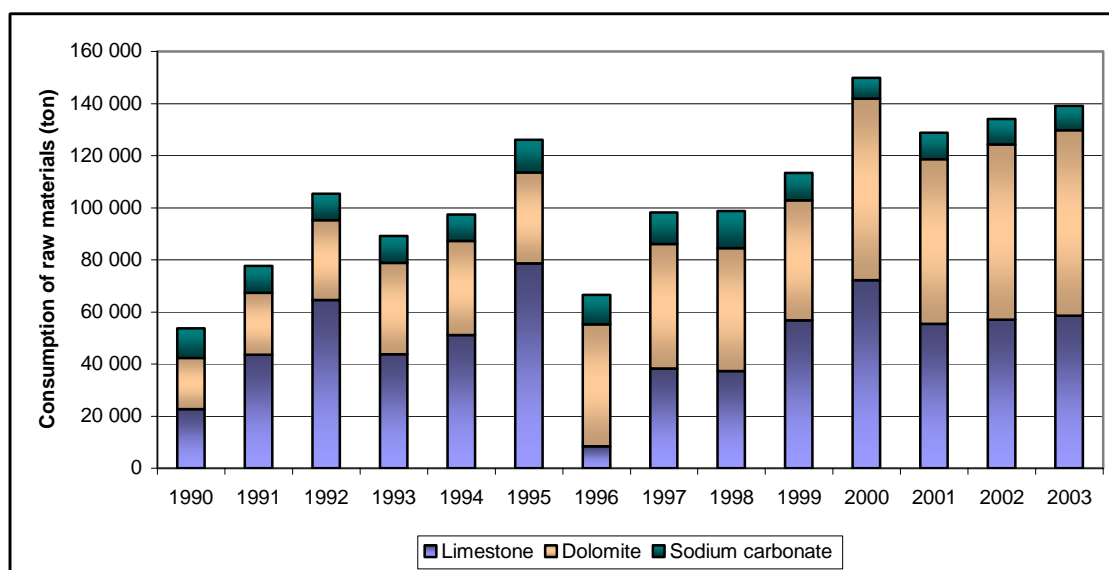
\* assumed pure calcium carbonate

## ACTIVITY DATA

Consumption of sodium carbonate in the paper and pulp industry were set from statistical information from INE from 1990 to 2000 and thereafter forecasted. Due to the unavailability of statistical information concerning consumption of carbonaceous materials in the fertilizer industry – for the production of calcium and magnesium nitrates – they had to be estimated from fertilizer production data and considering that stoichiometrically two moles of nitrogen require one mole of either  $\text{CaCO}_3$  or  $\text{MgCO}_3$ . Fertilizer production per fertilizer type was also available from INE database from 1990 to 2000 and thereafter forecasted. Final total consumption of carbonaceous materials is presented in Figure 4.7 below. Total carbonate consumption has increase 59% since year 1990.

<sup>62</sup> It was assumed that limestone was totally pure, which causes over-estimated emissions.

Figure 4.7 - Consumption of carbonate materials in industry (1990-2003)



## UNCERTAINTY ASSESSMENT

There are no proposed values in GPG for the consideration of uncertainty values for CO<sub>2</sub> emission factor from consumption of carbonate materials. The same uncertainty values that are proposed for lime production (non hydrated lime) were therefore assumed (2%), considering that the conversion is only a stoichiometric mass balance and that error results only from uncertainty in Calcium and Magnesium content of raw materials. The uncertainty value of activity data, also not referred to in GPG, was assumed also equal to the uncertainty set for lime production.

## RECALCULATIONS

The estimate of carbon dioxide emissions that are reported under this source category have suffered substantial changes in consequence of:

- inclusion of emission estimates from limestone and dolomite consumption in the fertilizer industry. Emissions from this source were not estimated in last submission due to unavailability of activity data;
- emissions of consumption of carbon electrodes in mechanical industry were moved to source category Iron and steel production (2C1);
- according to what was planned in last submission as further developments, emissions from limestone use in paper pulp plants were moved to source category 2A2 and are now discussed in chapter 4.2.A.2. Only emissions from the use of sodium carbonate still remain reported in this sub-source activity.

All the recalculations that were done had been planned as further developments in last submission.

## FURTHER IMPROVEMENTS

More efforts to obtain necessary statistical information or alternative methodologies will be envisaged to estimate emissions from emissions from carbonate use in the production of synthetic fertilizers (nitrates of calcium and magnesium and ammonium nitrate with calcium and magnesium).



Emissions of CO<sub>2</sub> from use of sodium carbonate (soda ash) will be moved to category 2A4 in next submissions. Finally care must be made to avoid double counting of emissions that may be already included in other industrial sectors.

#### 4.3.A.4 ROAD PAVING WITH ASPHALT (CRF 2A6)

##### OVERVIEW

Emission estimates reported in this source category include emissions occurring from paving road surfaces with asphalt materials as well as emissions occurring during operation of hot mix asphalt plants. Emissions from production of asphalt emulsions and cold asphalt mixtures are not included in the inventory estimates, being assumed that they are negligible.

Roads pavement with asphalt is done by the application of several layers over road bed. In volume, the majority of pavement is composed of layers of a compact aggregate and an asphalt binder (asphalt concrete). Asphalt concretes are classified either as hotmix or as coldmixes: cutback and emulsified asphalts. Liquefied asphalts – cutbacks and emulsions - are also used directly in seal and priming roadbed operations, sometimes in intermediate layers between applications of asphalt cement layers. Aggregate materials incorporated in asphalt concrete are usually composed of coarse unconsolidated rock fragments, either obtained from rock crushing, natural alluvial deposits or by products from metal ore refining.

Hot mix asphalts are made by mixing the aggregate material together with the asphalt cement using high temperatures (150<sup>o</sup>-160<sup>o</sup>)<sup>63</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<sup>o</sup>).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers<sup>64</sup>. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphtha (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12% of solvents. Hot mix asphalts in the other hand, result in minimum NMVOC emissions during application, because the organic component has high molecular weight and low vapour pressure (USEPA,2001 – EIIP Volume III Chapter 17).

Asphalt pavements dominate road paving activity in Portugal, whereas rigid cement pavements are only about 5% of total paved areas (APORBET).

Emissions during fabrication of asphalt concretes are estimated only for hot mix asphalt and comprehend NMVOC and Particulate Material that escape mostly from the drier. Other pollutants are also emitted but they result mostly from combustion of fuels and are considered in chapter Energy (1A2)<sup>65</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

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<sup>63</sup> That are needed to fluidize the asphalt cement.

<sup>64</sup> And also a solvent in several emulsion types.

<sup>65</sup> To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity<sup>66</sup>.

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible<sup>67</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,1997; USEPA,2001):

$$Emi_{NMVOC(y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Emi_{NMVOC(y)}$  - Emissions of NMVOC from asphalt application during year y (ton/yr);

$Binder_{(y)}$  – Total quantity of asphalt binder used in road paving during year y (ton/yr);

$SLV_{Fac}$  - Fraction of distillate (solvent) in asphalt ( $m^3/m^3$ );

$d_{SLV}$  - density of solvent added to liquefied asphalt (kg/l);

$d_{BIN}$  - density of bitumen binder mixture (kg/l);

$Cure_{FC}$  - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100% composed of VOC (USEPA,2001) and that emitted VOC have on average 85% of carbon:

$$Emi_{CO2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

<sup>66</sup> It is not possible to distinguish fuel combustion in hot mix production activity.

<sup>67</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.

**Hot Mix Asphalt Production**

For calculation of hot mix production emissions, emission calculation is based on total product:

$$Emi_{(p,y)} = Hotmix_{Batch(y)} * EF_{(p)} + Hotmix_{Drum(y)} * EF_{(p)}$$

Where,

$Emi_{(p,y)}$  – Total emissions for pollutant p occurring in year y from Hot mix asphalt production (ton);

$Hotmix_{Batch(y)}$  and  $Hotmix_{Drum(y)}$  – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

$EF_{(p)}$  and  $EF_{(p)}$  – Emission Factors for pollutant p used respectively in discontinuous (batch) and continuous (drum) plants (ton/yr);

Although available methodologies allow the calculation of emissions of several other pollutants from Hot mix asphalt production, in order to avoid double counting – and because fuel consumption in this activity could not be individualized from total fuel use in construction and building – only emissions of NMVOC and PM were estimated here. Although double counting could nevertheless be made for these pollutants, it was considered that the production process results in specific emissions of these two pollutants, that would be under-estimated if they would be estimated solely from fuel combustion. Particulate matter is enhanced by manipulation of aggregate materials and some NMVOC result not from incomplete combustion of fuel but also from partial evaporation of bitumen components.

**EMISSION FACTORS AND PARAMETERS**

The following parameters were chosen to determine emission factors for application of emulsified and cutback asphalts. These values were chosen according to recommendations in AP-42, EMEP/CORINAIR or industrial expert guess.

Table 4.5 - Emission Parameters for road paving with asphalt

Parameter	Cutback	Emulsions
$SLV_{Fac}$	25 %	3 %
$d_{SLV}$	0.85 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 4.6 - Emission Parameters for Hot Mix asphalt production

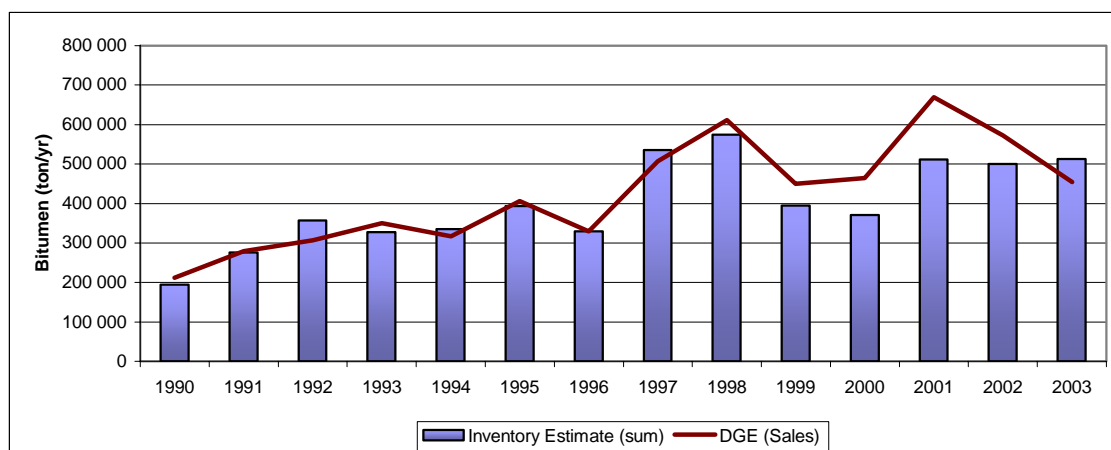
Pollutant	Continuous	Batch	Unit EF
PM	14	16	kg/ton
PM10	23	14	%
PM2.5	5.5	1	%
NMVOC	32.0	22.1	g/ton
CH4	12.0	7.4	g/ton

Source: USEPA (2000)

## ACTIVITY DATA

The total quantity of bitumen sold to construction and building economic sector is available from the Energy Balance and was collected by the General Directorate of Geology and Energy (DGGE) based on surveys<sup>68</sup>, and it is presented in Figure 4.8. 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 4.8 - Total consumption of bitumen in the construction sector according to sales from DGGE and sum of values of asphalt used, according to the inventory (1990-2003)



Cutback asphalt is seldom used in Portugal and it is sold only by two companies, according to information gathered at APORBET, the Portuguese Association of Producers of Bitumen Materials. Annual sales were assumed equal to annual consumption and may be seen in Table 4.7 and Figure 4.9. Total emulsions applied are available from EAPA for 1997 and beyond. For previous years use of emulsions was estimated from the total quantity of asphalt materials applied as road pavement, also from EAPA, and considering a percentage of that bitumen that is emulsions. It was also assumed that this percentage was zero in 1990 and has increased to 19% in 1996. Data for Hot mix concrete asphalt production is from EAPA for 1991-2001 and forecasted for the remaining years. Bitumen in hot mix asphalt was estimated considering that it equals 5% of hot mix asphalt. Although this last figure is not necessary for the inventory it was nevertheless estimated in order to verify if total bitumen sales, from DGGE, match the sum of individual estimates, and both values agree reasonably well as may be seen from Figure 4.8 above. Total production of Hot mix concrete asphalts is presented in Figure 4.9.

Table 4.7 – 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	2003
Cutback	1 232	933	162	576	824	501	340
Emulsified	110 000	130 000	95 000	86 000	107 000	116 000	116 000

<sup>68</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

Figure 4.9 - Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (1990-2003)

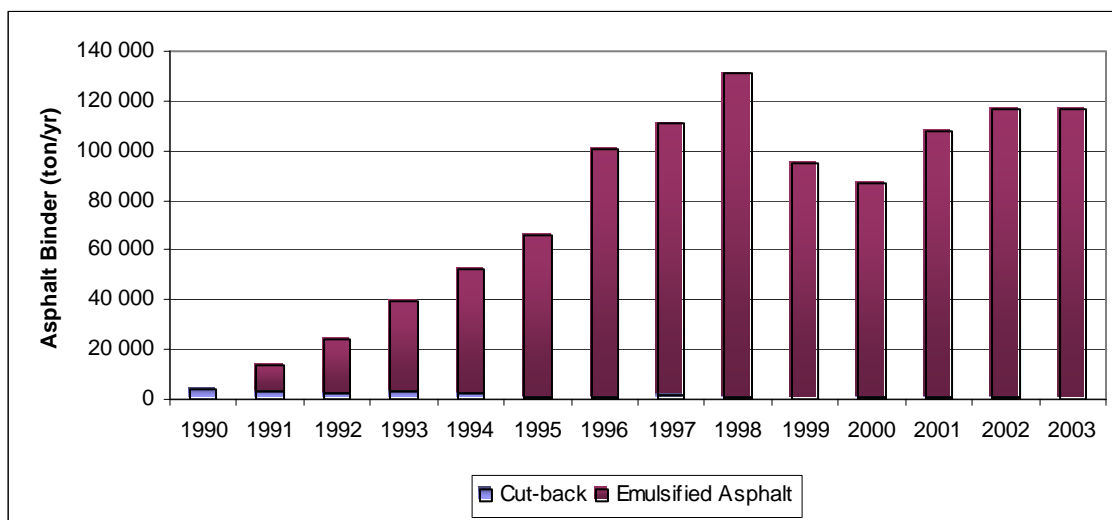
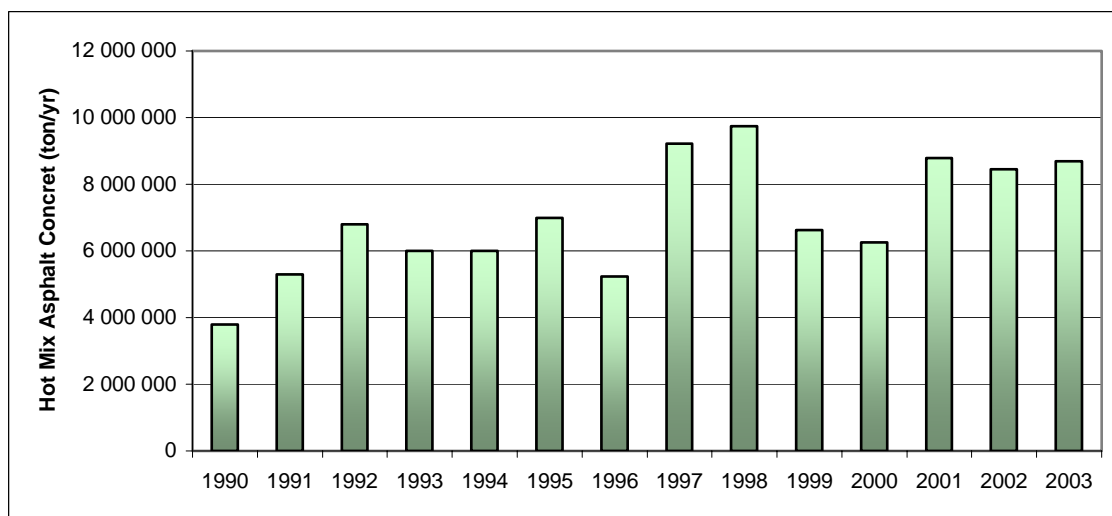


Figure 4.10 – Total Production of Hot Mix Asphalt (1990-2003)



Emissions of Hot Mix Production depend if the equipment is batch or continuous. Desegregation of Hot Mix production per equipment was done assuming a constant proportion of 46% continuous equipment and 54% batch, which is an expert guess (PTEN,2002).

### UNCERTAINTY ASSESSMENT

There is no specific information in the GPG concerning uncertainty values for this source sector. Uncertainty in activity data was estimated as the maximum difference between the total bitumen quantities estimated by the inventory and reported in the DGGE energy balance: 31 %.

The uncertainty in the emission factor for NMVOC/CO<sub>2</sub> is higher and mostly associated with the uncertainty in the share of asphalt that is applied as cut-back, emulsion of as hot mix. Because of the very variable emission factor according to which asphalt type is being considered two orders of magnitude was considered for the uncertainty value of the emission factors for NMVOC and CO<sub>2</sub>.

## RECALCULATIONS

Following the extensive improvements that were done last year (between submissions 2003 and 2004) in the emission estimates for this source sector, only minor details improved this year's submission estimates: correction of a formula error for solvent content in cut-back in the spreadsheets and correction of the values of binder density for emulsions.

## FURTHER IMPROVEMENTS

Interest in GHG emissions for this source sector have diminished since the revision made between submission 2003 and 2004 that result in a substantial downward revision of NMVOC emission estimates from this source sector. Some actions are however planned for this year and it is expected that they will result in the improvement of emission estimates. Focus will be made on a better knowledge of the quantities of cut-back that are used, the quantification of emulsification solutions and hence a better division between the three types of asphalt materials. Work is on the way in close contact with the department of industry of the Economy Ministry and APORBET, the Portuguese Association of Producers of Bitumen Materials, under SNIERPA development.

A special inquiry is also being made concerning the share of each type of hot mix equipments in use: batch and continuous production plants.

It was still however not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation and asphalt roofing. Improvements in this separation are expected in following submissions.

### 4.3.A.5 GLASS PRODUCTION (CRF 2A7)

#### OVERVIEW

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. It is made submitting this materials to a high temperature which are thereafter made solid without crystallization (semi-solid state).

Glass involves carbon dioxide emissions, from decarbonising of limestone and carbonate materials under high temperature conditions. Carbonate materials vary with the desired product and comprehend typically limestone, dolomite, soda ash (sodium carbonate) and other carbonate compounds of potassium, barium or strontium.

Combustion emissions from glass production were already considered in source sector 1A2, estimated from fuel consumption data or production data. Some anthracite coal is used also as additive in glass production. However, because the consumption of this material is already considered in the energy balance, to avoid double counting of emissions emissions from coal use are not considered here<sup>69</sup>.

#### METHODOLOGY

Carbon dioxide emissions from glass production were estimated from:

$$\text{Emission}_{\text{CO2(t,y)}} = \text{EF}_{\text{CO2(t)}} * \text{ActivityRate}_{\text{(t,y)}} * 10^{-3}$$

where

<sup>69</sup> They were not used to derive the country specific emission factors for instance.

$Emission_{CO_2(t,y)}$  - annual emission of carbon dioxide from specific glass type t in year y (ton/yr);

$ActivityRate_{(t,y)}$  - Glass of type t produced in a given year y (ton/yr);

$EF_{CO_2(t)}$  - emission factor from production of glass of type t (kg/ton)

## EMISSION FACTORS

The following emission factors were considered:

Table 4.8 - Carbon Dioxide Emission Factors for Glass Production

Material	EF	Unit EF	Reference
Flat Glass	126	kg/ton	CS
Container Glass	130	kg/ton	CS
Lead Crystal Glass	239	kg/ton	EMEP/CORINAIR
Other Glass	239	kg/ton	

Country specific emission factors were calculated using data from 10 industrial plants in Portugal under the studies for the development of the Allocation Plan for the implementation of the European Union Emission Trading Scheme (EU-ETS). These units reported annual production quantities together with consumption of carbonate materials: limestone, dolomite, sodium, barium and potassium carbonates, from where average emission factors could be estimated.

## ACTIVITY DATA

There are some problems with the use of statistical information from INE because not all products are reported in weight, but instead are measured in area-units ( $m^2$ ) 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 ( $m^2$ ) but was not used because conversion to weight units would lead to high uncertainties. Production value for 2002 and 2003 were forecasted by IA;
- Container Glass. Also for this type of glass product the information available in INE databases (IAIT and IAPI industrial surveys) was not well suited to be used in the inventory because production was measured in produced object umbers units and not weight. Production of container glass was available from Technology Centre for Ceramics and Glass (CTCV) for the period 1994 to 2003. Production in the period 1990 to 1993 was estimated by IA extrapolating CTCV time series and using the full time series of INE as surrogate data;
- Lead Crystal Glass production from 1992 to 2000 was available from INE IAPI industrial survey and was extrapolated, from the available time series, for 1990-1991 and 2001-2003. Original data in INE time series had to be converted from number units to weight units assuming typical weight per object;

- Other glass. This category comprehends several parts such as blocks, bricks, tiles, kitchen-ware, medical and pharmaceutical equipment and decoration articles. Time series was set from INE statistical database (IAIT and IAPI industrial surveys).

For some products original units were only available in number and had to be converted to weight. The following conversion table was assumed:

Table 4.9 – Unit conversion factors for glass products in INE statistical databases

Product	Conversion Factor (kg/unit)
Glasses	0.2
Bottles	0.5
Small containers (Jars)	0.2
Large Containers	3
Medical equipment	0.01
Other objects	0.5

Production values for container glass, lead crystal glass and other glass is presented in Figure 4.11. Because of confidentiality concerns the production of flat glass may not be published in NIR.

Figure 4.11 - Glass production by glass type (excluding flat glass production)

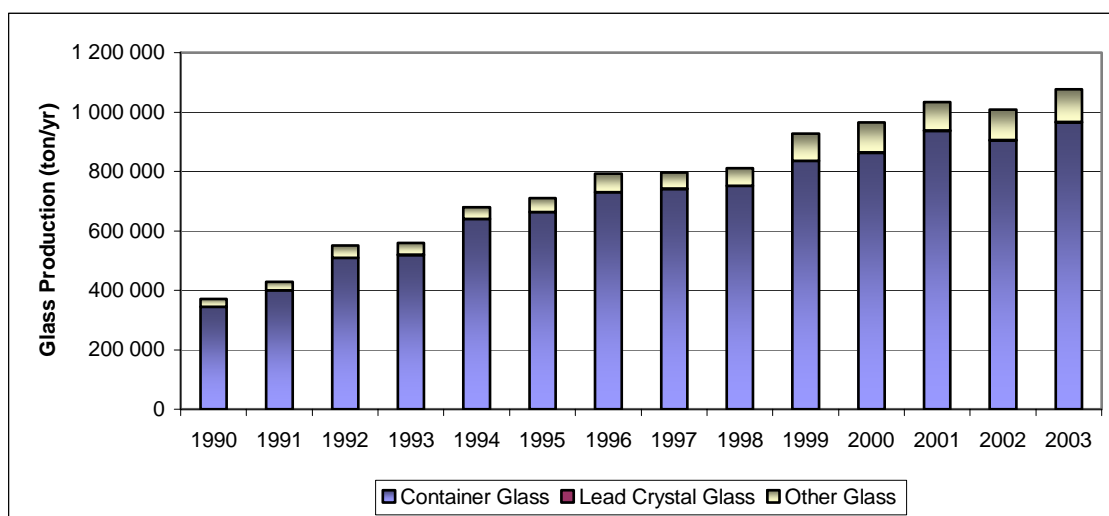


Table 4.10 - Glass production by glass type (excluding flat glass)

Type of Glass	1990	1991	1992	1993	1994	1995	1996
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	2003
Container Glass	741 392	751 333	835 451	863 502	936 471	904 433	965 279
Lead Crystal Glass	862	837	903	1 009	1 078	1 163	1 247
Other Glass	54 183	58 115	90 141	100 059	94 912	102 081	109 251



## UNCERTAINTY ASSESSMENT

A 100 % uncertainty value was set for activity data expressing the fact that for some glass types the activity data in statistical databases was expressed in non weight units, number of pieces or area. The double value of the standard deviation of the set of emission factors available for Portuguese units, and estimated from carbon market data, allows the consideration of an uncertainty value of 54%.

## RECALCULATIONS

The CO<sub>2</sub> emission factors were revised for flat glass production and container glass production after calculation of country-specific emission factors based on data collected under the Carbon Market Allocation Plan. The new emission factors resulted from the analysis of consumption of carbonaceous materials in the industrial sector. The following modification was done which resulted in downward revision of emission factors.

Table 4.11 – Revision of CO<sub>2</sub> emission factors for glass production from submission 2004 to submission 2005

Material	Sub 2004	Sub 2005	Unit EF
Flat Glass	210	126	kg/ton
Container Glass	200	130	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.

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

#### 4.3.B.1 AMMONIA PRODUCTION (CRF 2B1)

##### OVERVIEW

Presently only one fertilizer industrial plant manufactures ammonia in Portugal, using Vacuum Residual Fuel Oil (VRF) and source of hydrogen (feedstock). Ammonia is formed after reaction of hydrogen with nitrogen from air. In the start of year 1990 there was another unit operating in Portugal, but has stopped activity already in the beginning of that year. The conversion of feedstock to hydrogen results in the liberation of the associated carbon as ultimate CO<sub>2</sub> which is vented to atmosphere. Although actually some part of CO<sub>2</sub> liberated from VRF, during ammonia production, is in fact used in urea production 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.

Other pollutants result from the process, either from escape of ammonia (NH<sub>3</sub>) or either from release of products from feedstock: CO and NMVOC.

## METHODOLOGY

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

$$\text{Emi}_{\text{CO}_2(y)} = 44/12 * \text{Feedstock}_{(y)} * C_{\text{Feed}(y)} * 10^{-5}$$

where

$\text{Emi}_{\text{CO}_2(y)}$  - Emission of carbon dioxide (kton/yr);

$\text{FeedStock}_{(y)}$  - Annual consumption of feedstock (ton/yr)

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

Emissions estimates for the other pollutants are estimated by the use of emission factors multiplied by the quantity of material manufactured:

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

where

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

$\text{ActivityRate}_{(y)}$  - quantity of ammonia produced in year y (ton/yr);

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

A specific procedure applies to NMVOC emission estimate, whereas an additional fraction of methanol emissions were estimated from annual consumption of this compound in the industrial plant and assuming that this annual input was used to replenish annual losses to atmosphere. Emissions calculated that way are added to NMVOC emission estimates calculated from multiplication of ammonia production by an emission factor.

## EMISSION FACTORS

The following emissions factors were applied to production data for each substance. They were mostly set from emission factors in CORINAIR/EMEP and AP-42.

Table 4.12 - Emission Factors for ammonia production

Pollutant	EF kg/ton NH <sub>3</sub>
U <sub>CO<sub>2</sub></sub>	3.20 <sup>(a)</sup>
NM <sub>VOC</sub>	0.60 <sup>(b)(c)</sup>
CO	7.9 <sup>(c)</sup>
NH <sub>3</sub>	2.10 <sup>(c)</sup>

(a) expressed in ton CO<sub>2</sub>/ ton VFR. Carbon content in feedstock was assumed to be 86%

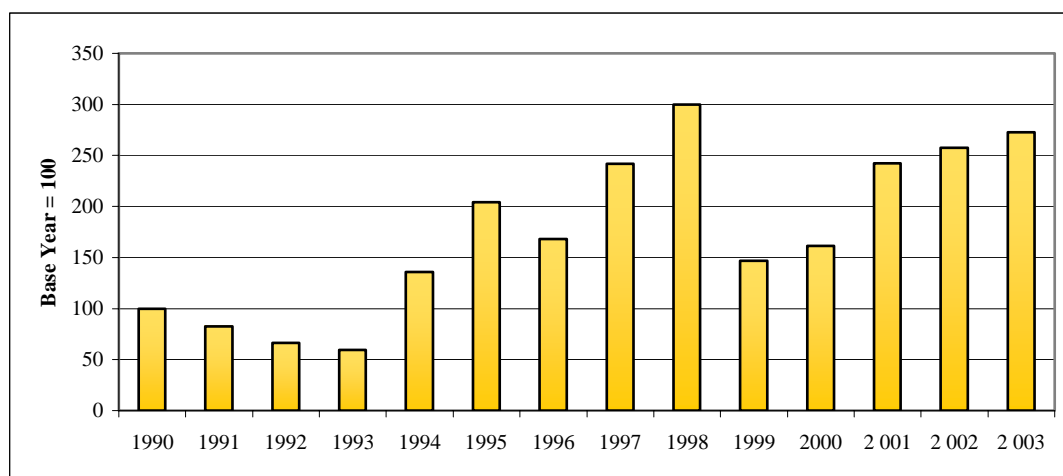
(b) USEPA (1993)

(c) Not including methanol emissions, estimated by mass balance

## ACTIVITY DATA

Because there is only one industrial plant in operation, it is not possible to present any absolute information concerning activity data for this source activity, neither ammonia production nor feedstock and methanol consumption. The overall trend in the quantity of ammonia produced in the period may be however depicted in Figure 4.12, from where it is evident the significant increase of production since 1990 but with substantial inter-annual changes.

Figure 4.12 - Trend in Ammonia production (1990-2003)



The following sources of information were used to construct the above full time-series.

- total production of ammonia in Portugal is available from INE for the period 1990-2000, resulting from the IAIT survey for 1990 and 1991, and from the IAPI survey thereafter. These correspond to a methodological change done by INE in what concerns industrial surveys. The IAIT industrial survey is available for years 1990-91 and IAPI industrial survey was used thereafter. Changes from IAIT to IAPI include modification in questionnaire, classification of economic activities, product and materials codification. Spatial allocation of economic data has also changed between these two survey processes;

- consumption of VRF feedstock could not however be determined from INE statistical database, because differentiation of residual fuel oil for feedstock and energy source was not clarified for this economic activity. Therefore, as explained before,

consumption of feedstock VRF was estimated from limited information and relying on a linear correlations: the quantity of VRF that was use was set from data collected at the only industrial plant in Portugal for a limited number of years – 1990 till 1994 – and a strong linear relation between feedstock consumption and ammonia production could be established from available data;

- use of methanol was also estimated for the full time period from a linear regression which was determined from available information for a limited number of years.

## UNCERTAINTY ASSESSMENT

No specific guidelines exist in GPG (IPPC,2000) to estimate the uncertainty of this source sector. The greatest uncertainty of emission estimates for this source sector results from the uncertainty in knowledge of activity data (Feedstock consumption). Because the ratio of feedstock consumption over ammonia production was used to estimate feedstock consumption, the standard deviation of these ratios was used to estimate the error and then doubled to include an additional factor of conservativeness<sup>70</sup>. The final uncertainty value for activity data was set as 31 %.

With the methodology that was used the uncertainty in the emission factor refers only to the uncertainty in the carbon content of feedstock: 5 %.

## RECALCULATIONS

No changes were made in inventory estimates for this source sector either in methodology, emission factors or activity data, apart from forecasting activity data to year 2003.

## FUTURE IMPROVEMENTS

The importance of emissions from this source category, particularly in the Industrial Process sector where it only seconds emissions from cement production, implies that better knowledge of activity data is necessary, and particularly for base year. Collection of this information is already planed under: the Methodology Development Plan that is being in the National System; and through cooperation with other entities such as Regional Environment Departments doing regional air emission inventories, the General-Directorate of Industry, Industry Associations, EPER registry and the industrial plant itself.

Information from Regional inventory surveys, EPER, E-PRTR and monitoring under *Autocontrolo* program may also allow better insight of technologies of this sector and may possibly improve methodologies and emission factors for gases other than CO<sub>2</sub>.

### 4.3.B.2 NITRIC ACID (CRF 2B2)

#### OVERVIEW

Only three industrial plants did produced nitric acid in Portugal between 1990 and 2003, located in Estarreja, Alverca and Lavradio. In all weak nitric acid (60%) is produced from ammonia, using catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to 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

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<sup>70</sup> A further doubling was used to convert from standart deviation to 95% confidence interval.

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.

## METHODOLOGY

For all pollutants emissions are estimated using the following equation:

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

where

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

ActivityRate<sub>(y)</sub> – production of Nitric Acid in year y (ton/yr);

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

## EMISSION FACTORS

The emission factors that were used are presented in Table 4.13, with a short explanation of their origin. All emissions were estimated using monitoring data for industrial plants in Portugal and used for the overall production.

Table 4.13 – Emission Factors for emission estimate for Nitric Acid Production

Pollutant	EF kg/ton HNO <sub>3</sub>
N <sub>2</sub> O	7.52 <sup>(a)</sup>
NO <sub>x</sub>	1.2 – 1.3 <sup>(b)</sup>
NH <sub>3</sub>	NE <sup>(c)</sup>

(a) From plant specific monitoring data at one (of a total of three industrial plants)

(b) From plant specific monitoring data at two (of a total of three industrial plants)

(c) Emission Factor not available from bibliography reference or emission monitoring

## ACTIVITY DATA

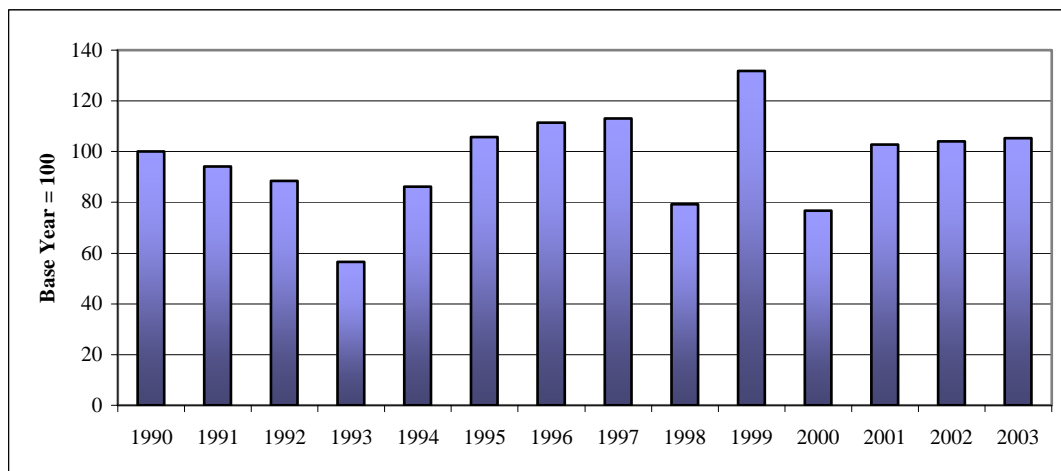
The activity data that was used to estimate emissions from this sub-source sector is subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends). The sources of information that were used to establish activity data time series are discussed below in Figure 4.13, together with the presentation of time trend. Albeit inter-annual variations the average annual production did not show a sustained trends in the period.

The time series was determined according to the following mode:

- Quantities of Nitric acid for year 1990 are available from a specific questionnaire that had been sent to industrial units by IA under Corinair90 project;

- From 1992 to 2000, total national production of Nitric Acid was set from INE statistical database (IAPI survey);
- For 1989-1991 statistical information of Nitric Acid Production is available from the IAIT survey.

Figure 4.13 - Trend in Nitric Acid production (1990-2003)



#### UNCERTAINTY ANALYSIS

The uncertainty value for activity data is 3%, considering that the restricted number of units allows a good knowledge of production data. The uncertainty value of the emission factor of Nitrous Oxide a value of 10 % was chosen, which is in accordance with references to uncertainty ranges in GPG and also in accordance with the difference between the country specific emission factor determined from monitoring data and the proposed emission factor.

#### RECALCULATIONS

Emission estimates for this source did not suffer modifications in either in methodology, emission factors or activity data, apart from forecasting activity data to year 2003.

#### FUTURE IMPROVEMENTS

Efforts will be made in order that the emission factors that are used, and which are country specific, may be improve in quality by incorporation of monitoring data from more years and for all units. In general better information must be obtained at plant level allowing the consideration of plant specific emission factors. Estimate of air emissions from Nitric Acid Manufacture should be extended to include other pollutants such as ammonia, and preferably also using estimates from plant monitoring.

#### 4.3.B.3 NON GHG EMISSIONS FROM INORGANIC CHEMISTRY AND FERTILIZER INDUSTRY

##### OVERVIEW

Discussed here are the air emissions, excluding greenhouse gases, resulting from sulphuric acid production, sulphur recovery and fertilizer industry. GHG emissions from chemical industry are discussed in previous chapters: Ammonia production and Nitric Acid production. Emissions of greenhouse gases and other pollutants from the organic chemistry are discussed in next chapter.

***Sulphuric Acid Production***

In 1990 in Portugal there were two industrial units producing sulphuric acid from mineral processing and more two additional industrial plants producing  $\text{H}_2\text{SO}_4$  by recovery of sulphur. In 1990 and 1991 both industrial plants producing sulphuric acid from pyrites were closed and thereafter only sulphur recovery process remained active. Presently, emissions of  $\text{SO}_x$  from sulphuric acid production result from recovery of sulphur - and abatement of air emission - in an ammonia industrial plant that uses a high sulphur content raw material, Vacuum Residual Fuel oil (VRF), as feedstock.

Production of sulphuric acid (Contact Process) comprehends a first step, where  $\text{SO}_2$  is formed from oxidation of elemental sulphur with air, followed by conversion to  $\text{SO}_3$ , in a catalytic converter, and finally the absorption of this gas in a strong acid solution.

In the case of sulphur recovery units, a flux of hydrogen sulphide, coming from the partial oxidation of the feedstock, is converted into  $\text{H}_2\text{SO}_4$ , also by air oxidation, but without previous conversion to elemental sulphur. The process then proceeds in a similar fashion to sulphuric acid production. Although emissions of  $\text{SO}_x$  from recovery of sulphur occur in the Claus unit and in the flare, all are reported in the same source category (2B5-Other Chemical Industry) in CRF tables. For reporting of acidification emissions, in NFR reporting format, only emissions in the Claus unit are reported in 2B5, while emissions in the flare – a lesser source however – are reported in 1AC – Flaring in chemical industries.

***Other Emission Sources in Chemical Industry and Fertilizer industry***

Other industrial inorganic chemical activities that contribute to air emissions and which are included in the inventory comprehend the manufacturing of:

- urea;
- ammonium sulphate;
- ammonium nitrate;
- calcium nitrate;
- other nitrogen inorganic fertilizers: calcium ammonium nitrate (CAN), Ammonium Sulphate Nitrate (ASN); Calcium Nitrate (CN); Calcium-magnesium nitrate (CMN)
- super phosphates, normal (NSS) and triple (TSS);
- di-ammonium phosphate;
- NPK fertilizers.

Production of some of these materials involve chemical reactions, such as ammonium nitrate neutralization, calcium nitrate, ammonium sulphate, super-phosphate production, but others, such as production of NPK fertilizers, merely include composing, mixing, granulation or prilling, cooling and drying.

**METHODOLOGY**

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

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

where

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

$\text{ActivityRate}_{(y)}$  - 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)

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>71</sup>:

$$\text{EmiSO}_{x(y)} = 2 * \text{Feedstock}_{(y)} * \text{S}_{\text{Feed}(y)} * 10^{-2} - 32/98 * \text{Prod}_{\text{H}_2\text{SO}_4(y)}$$

where

$\text{EmiSO}_{x(y)}$  - Emission of sulphur oxides<sup>72</sup> (ton/yr);

$\text{FeedStock}_{(y)}$  - Annual consumption of feedstock (ton/yr)

$\text{S}_{\text{Feed}(y)}$  - Sulphur content of feedstock (%);

$\text{Prod}_{\text{H}_2\text{SO}_4(y)}$  - production of sulphuric acid from sulphur recovery in year y (ton/yr).

## EMISSION FACTORS

The following emissions factors were applied to production data for each substance. They were mostly set from emission factors in CORINAIR/EMEP and AP-42.

Table 4.14 - Emission Factors for inorganic chemical industry processes (1/2)

Pollutant	Sulphuric Acid kg/ton H <sub>2</sub> SO <sub>4</sub>	Urea kg/ton Urea	Ammonium Sulphate kg/ton (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	Ammonium Nitrate kg/ton NH <sub>4</sub> O <sub>3</sub>
SO <sub>x</sub>	16.4-30.7 <sup>(a)</sup>			
NM VOC			1.04 <sup>(f)</sup>	
NH <sub>3</sub>		9.66 <sup>(d)</sup>		2.0 <sup>(g)</sup> + 1.4 <sup>(b)</sup>
PM		2.01 <sup>(d)</sup>	0.02 <sup>(f)</sup>	2.4 <sup>(h)</sup> + 2.5 <sup>(b+h)</sup>
PM <sub>10</sub>		1.82 <sup>(d)</sup>	0.02	2.4 + 2.0 <sup>(h)</sup>
PM <sub>2.5</sub>		1.61 <sup>(d)</sup>	0.02	2.4 + 2.0 <sup>(h)</sup>
PM <sub>1.0</sub>		1.61	0.02	2.4 + 2.0

<sup>71</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>72</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.



Table 4.15 - 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>(i)</sup>	1.0 <sup>(g)</sup>
PM	4.2 <sup>(c+h)</sup>	0.6 <sup>(b)</sup>	4.09 <sup>(c)</sup>	0.73 <sup>(i)</sup>	0.3 <sup>(g)</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 US-EPA (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) USEPA (1993)

(f) USEPA (1993). Rotary driers controlled (wet scrubber)

(g) UNEP/UNIDO/IFA (1998)

(h) USEPA (1993)

(i) USEPA (1993) Controlled

Sulphur content of feedstock used in the ammonia plant can not be made explicit in NIR due to confidential constraints.

## ACTIVITY DATA

All activity data that was used to estimate emissions from these sources are subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends). The information sources that were used to establish activity data time series are discussed below, together with the presentation of time trends.

### General

- National Statistical Information. IAIT industrial survey was available for years 1990-91 and IAPI industrial survey was used thereafter. Change from IAIT to IAPI represents a methodological shift made by INE, involving change in questionnaire, classification of economic activities, product and materials codification. Spatial allocation of economic data has also changed between these two survey processes;

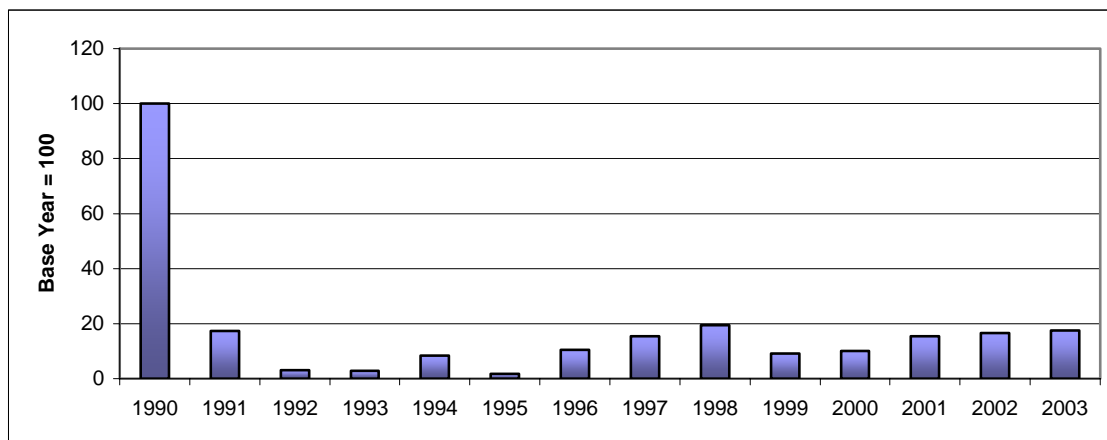
- Quantities of sulphuric acid production in year 1990 are available from a specific questionnaire that had been sent to industrial units by IA under Corinair90 project;

- some information is available for particular years for several fertilizer industrial plants, and as result of questionnaires made under regional air emission inventory surveys;

- production figures for 2001 and 2002 are estimated from IA, forecasted from previous time series.

### Sulphuric Acid

Figure 4.14 – Trend in total sulphuric acid production, including sulphur recovery (1990-2003)



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>73</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.

### Urea manufacturing

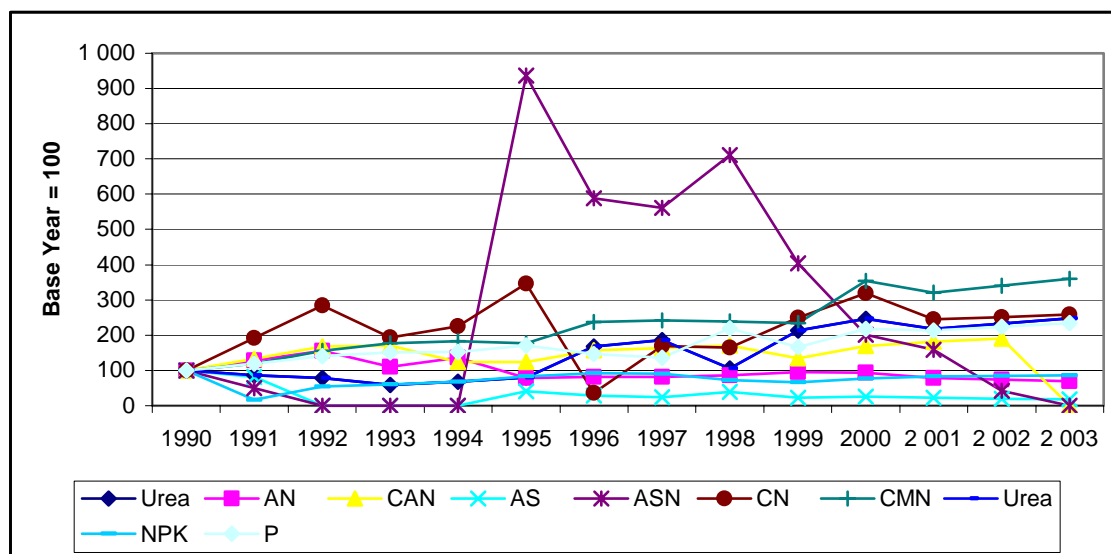
For the same reason that was explained for ammonia manufacturing, the existence of only one industrial plant producing urea in Portugal, prohibits the publication of any activity data.

### Fertilizer production

Production data for ammonium sulphate (AS), ammonium nitrate (AN) (liquid and solid), calcium ammonium nitrate (CAN), ammonium sulphate nitrate (ASN), Calcium Nitrate (CN), Calcium Magnesium Nitrate (CMN), normal and triple superphosphates, and Di-ammonium phosphate (DAP) are from INE's statistical database (IAIT and IAPI surveys according to year). Due to confidential issues it may not be reported here, and only trend evolution is presented in Figure 4.15.

<sup>73</sup> For confidentiality reasons original data and relation may not be reported in NIR

Figure 4.15 – Trend evolution in fertilizer production (1990-2003)



## RECALCULATIONS

Emission estimates for these sources did not suffer modifications in either in methodology, emission factors or activity data, apart from forecasting activity data to year 2003.

## FURTHER IMPROVEMENTS

Although country-specific emission factors are now used more extensively, more work is necessary in order to improve emission factors and their documentation. This work is already planned under: the Methodology Development Plan that is being developed for the development of the National System; and through cooperation with other entities such as Regional Environment Departments doing regional air emission inventories, the General-Directorate of Industry, Industry Associations and EPER registry. Best Available Technologies (BAT) should be considered also in the determination of future emission factors. In general, information from Regional inventory surveys, EPER, E-PRTR and monitoring under *Autocontrolo* program may also allow better insight of technologies of this sector and may possibly improve methodologies and emission factors.

For some fertilizers, FAO database has statistical information concerning production, but which do not agree with national statistical databases. Efforts will be made to explain differences, and compatibilize both information sources if possible. Also, efforts must be done to clarify incorporation of some basic fertilizer in mixtures, obtained by granulation, in order to avoid double counting. Preferably information should be collected directly from industrial plants.

Specific issues to improve comprehend the revision of the different reporting placement for SO<sub>x</sub> emissions from flaring in sulphur recovery.

### 4.3.B.4 ORGANIC CHEMICAL INDUSTRY

#### OVERVIEW

The organic chemical industry is responsible for greenhouse gas emissions in consequence of the release of carbon compounds that are transformed in carbon dioxide in the atmosphere. These emissions are mostly part of the carbon that is release from feedstocks.

For this source sector emissions for some industrial units were estimated at individual unit plants – Large Point Sources (LPS) - and using detailed characterization of the plants and their industrial activities. Chemical organic industry in Portugal is not very extensive, however. The major organic chemical plant in Portugal is BOREALIS unit, a petrochemical unit situated in the southern part of the country, near Sines. The basic process in this unit is Ethylene production by Thermal Steam Cracking of petroleum feedstock. From ethylene this unit produces Low Density Poly Ethylene (LDPE) and High Density Poly Ethylene (HDPE). As by product of ethylene production other organic compounds are produced, such as propylene, butadiene and C4 fraction, aromatics and a residual fuel oil used in the unit as energy source.

The second chemical industry LPS is the sole Carbon Black plant in Portugal. It is also situated in the southern part of the country, near Sines. CARBOGAL unit produces Carbon Black by the Oil Furnace Process, a partial combustion process where feedstock with a high content of aromatic material is converted by incomplete combustion, thermal cracking and dehydrogenation to carbon black. Emissions result from Gas Vent, combined dryer vent and fugitive emission in the vacuum system vent.

Finally the last individualized unit (LPS) is an industrial plant located in Lisbon producing Phthalic Anhydride from aromatic compounds.

Apart from those individualized industrial plants other chemical industrial activities were included as area sources in this sub-source sector<sup>74</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);

<sup>74</sup> This list is not extensive to chemical production in Portugal, but comprehends only those products for which there are emission estimate methodologies and emission factors

EF<sub>(p)</sub> - emission factor (kg/ ton)

In the case of carbon black, where CO<sub>2</sub> emissions result from liberation of carbon in tail gas to atmosphere, emissions were estimated using a simple mass balance:

$$44 / 12 * C_{\text{TailGas}} = C_{\text{Feedstock}} + C_{\text{AuxFuels}} - C_{\text{CarbonBlack}}$$

Where,

C<sub>TailGas</sub> – carbon emitted in tail gas (ton C/yr);

C<sub>Feedstock</sub> – Carbon entered in feedstock (ton C/yr);

C<sub>AuxFuels</sub> – additional carbon entered into system in fuels (ton C/yr);

C<sub>CarbonBlack</sub> – carbon stored in carbon black and not emitted to atmosphere (ton C/yr);

## EMISSION FACTORS

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994<sup>75</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>76</sup>. Emissions from flares and flue gas combustor were included in the emission factors.

Table 4.16 – Emission Factors for determination of process emissions in Borealis (kg/ton)

Fábrica	NM VOC	CH <sub>4</sub>
Ethylene	0.8	1.2
Butadiene	1.2	-
HDPE	9.6	-
LDPE	4.8	-
PP	8.0	-

In the same way, the carbon black industrial unit was subjected, also for period 1993-94, to a detailed survey and inventory exercise. Consequently 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.

<sup>75</sup> Unpublished.

<sup>76</sup> This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Table 4.17 – 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)
SO <sub>x</sub>	0.20	0.20	-
NO <sub>x</sub>	0.01	0.36 <sup>(a)</sup>	-
COVNM	33.3 <sup>(a)</sup>	2.50 <sup>(b)</sup>	-
CH <sub>4</sub>	0.80	0.8 + 1.4 <sup>(b)</sup>	-
CO	104	100 + 17 <sup>(b)</sup>	-
N <sub>2</sub> O	-	1.40 <sup>(b)</sup>	-
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

Emission factors for the Phthalic Anhydride Plant are from US-EPA (1983) and are presented in table 4.8:

Table 4.18 - Emission Factors for the production of Phthalic Anhydride

Pollutant	kg/ton
SO <sub>x</sub>	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 4.19 - Emission Factors for Nitrocellulose production (explosives)

FE (Kg/ton)	SO <sub>x</sub>	NO <sub>x</sub>
<b>TOTAL</b>	34.7	14
Nitration reactors	0.7	7
Nitric acid concentrator	-	7
Sulphuric acid concentrator	34	-

Source: USEPA (1983)

- it was assumed that the production of nitroglycerin is similar, in what concerns emissions, to nitrocellulose production, and the same emission factors were used;
- Black powder is made from carbon, sulphur and saltpetre (KNO<sub>3</sub>) mixed together. There are no reference to emissions from it production. It was assumed that the production process is basically physical and that no relevant atmospheric emissions occur;

- Emission factors for the production of TNT are also from AP-42 chapter 6.3 (USEPA, 1995):

Table 4.20 - Emission Factors for TNT production (explosives)

kg/ton	SO <sub>x</sub>	NO <sub>x</sub>
<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 (US-EPA).

Table 4.21 - Emission factors for chemical organic industrial processes

Compound	EF (kg/ton)	
	NMVOC	PM
VCM	2.5 <sup>(a)</sup>	-
LDPE	10.0 <sup>(b)</sup>	-
PVC	3.0 <sup>(c)</sup>	17.5 <sup>(d)</sup>
PP	8.0 <sup>(b)</sup>	1.5 <sup>(e)</sup>
PS	1.0 <sup>(d)</sup>	-
Formaldehyde	5.0	-

(a) ;(b) UN-ECE (1990). Old Plants

(c) TNO (1987). Emulsion; (d) USEPA (1991). Controlled (Fabric Filter)

(e) USEPA (1991); (f) USEPA (1991)

## ACTIVITY DATA

Activity data used to estimate emissions may not be reported in NIR, due to confidentiality issues that result from the limited number of units concerned for each individual compound.

For BOREALIS Petrochemical Plant in Sines - produced quantities are available from 1990 to 1997 and were forecasted thereafter. Production of carbon black and explosives is available from 1990 to 2000 from INE Statistical Database (IAIT and IAPI surveys).

Statistical information for all emissions sources other than Sines industrial Plants were obtained from the National Statistical Institute (INE) 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.

## UNCERTAINTY ASSESSMENT

The uncertainty of activity data received from Large Point Sources was set as 10%. For area sources it depends if the data set is updated for the all time series or not. If it is not updated the uncertainty value was set as 100% and 20% if it is updated. The high uncertainty in the choice of emission factors from international references, which are themselves based in limited information and which conditions of determination are most of the time different from specific

national conditions, lead to the choice of an uncertainty value of an order or magnitude for area sources and 100% for Large Point Sources<sup>77</sup>.

## 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.

## 4.3.C Metal Production (CRF 2C)

### 4.3.C.1 IRON AND STEEL PRODUCTION (CRF 2C1)

#### OVERVIEW

Iron results from reduction of the iron element present in mineral ores by contact with coke - reducing agent - at high temperatures in the blast furnace. The resulting material, pig iron – and also scrap in some steel plants - is transformed into steel into subsequent furnaces which may be a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF). Coke, sinter and lime are intermediate materials necessary for iron and steel production.

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

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<sup>77</sup> The uncertainty of emission factors refers to uncertainty of NMVOC determination. Uncertainty for conversion from NMVOC to CO<sub>2</sub> is comparatively irrelevant.



combustion process with contact, are reported under 1.A.2, although the emission factors are reported in this chapter.

Coke is produced by destructive distillation of imported fossil coal in coke ovens, where coal is subjected to heat in an oxygen-free atmosphere until all volatile components in the coal evaporate, forming a fuel used in industry, the Coke Gas. Process heat comes from the combustion of gases between the coke chambers. Excluding emissions associated with coke production resulting from use of fuels in under-fired heating furnaces (which are accounted in Energy source sector 1A1), air emissions from the coquerie result from coal preparation, coal charging, oven leakage during the coking period, coke removal and hot coke quenching. Leaks may also occur from poorly sealed doors, charge lids, off take caps, collecting main and from cracks that may develop in oven brickwork (USEPA, 2000)

Coke and sinter are added to the Blast Furnace where iron oxides, coke and fluxes react with blast air to form molten reduced iron, carbon monoxide (CO), and slag. Emissions occur during casting and in the blast furnace top. However the gas resulting from process in the blast furnace, which has a high CO content, is normally not emitted to atmosphere but used as fuel in integrated units (Blast Furnace Gas). Emissions from its combustion are also quantified and discussed under chapter 1A2 – Combustion in Manufacturing Industries and Construction. The emissions that are quantified here, in source 2.C, are only those resulting from casting operations and seal leaks at top of furnace.

In Basic Oxygen Furnace original material are re-melted with the addition of substantial source of oxygen which is lanced (injected) and oxidizes part of the carbon associated with iron: This carbon is emitted mostly as CO (contributing nevertheless to ultimate CO<sub>2</sub> emissions). Other emissions from BOF are iron oxides, oxides of other metals and sulphur and particulate matter. In EAF the original material, which is basically scrap, is subjected to an electric discharge that also reduces carbon content. Emissions in furnaces may also result from carbon additives such as limestone and coke.

Steel is finally finished in rolling mills. Emissions from this finishing process are mostly particulate matter besides combustion pollutants which is already included in emissions from the 1.A.2 sector.

Lime is necessary for the blast furnace charging and EAF mixtures. Production of lime from limestone in this unit results in CO<sub>2</sub> emissions from 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 from these two emission sources are reported however in source category Lime Production (2A2).

To avoid double counting, carbon dioxide emissions in coquerie and blast furnace, from oxidation of the carbon that was used as a reducing agent were not estimated from steel or coke production data but simply from use of coke derivative fuels (coke gas and blast furnace gas) in all combustion equipments. Methodology to estimate emissions from combustion of coke gas and blast furnace gas were already discussed in chapter 3.2A – Energy Industries and emissions are included in source sector 1A.2 - manufacturing industries and construction - and 1A.1.c.1 - Manufacture of Solid Fuels. Although in EAF there is a further reduction in carbon content that is accounted as 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 were set mostly from CORINAIR/EMEP also with contributions from IPCC96 and US-EPA AP42. Emission factors in kg/ton are present in next table.

Table 4.22 - Emission Factors for Iron and Steel Production

	Coke Oven	Sintering	Blast Furnace	BOF	EAF
Pollutant	(kg/ton coke)	(kg/ton sinter)	(kg/ton steel)	(kg ton/steel)	(kg/ton steel)
SOx	0.01 <sup>(a)</sup>	1	2	0.01	
NOx	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>	14.2-21.5 <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> <sup>#</sup>	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> <sup>#</sup>	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> <sup>#</sup>	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; (b) USEPA (2000) chapter c12s02; (c) USEPA (1986) c12s05; (d) carbon reduction from 4.25 to 2%; (e) Plant Specific Emission Factors (Carbon Market)

The CO<sub>2</sub> emission factors for Electric Arc Furnace, and that were used for each one of the two iron and steel plants that are included in the European Union Emission Trading Scheme (EU-ETS), were determined from consumption of carbon bearing materials in these units: limestone, calcium carbide and coke for years 2002 and 2003. It was assumed that the same carbon content exists in both scrap and final steel produced in EAF furnaces and consequently no additional emissions are estimated apart from carbon in additives.

## ACTIVITY DATA

Activity data for estimation of emissions from iron and steel production comprehend coke, sinter, pig iron and steel production and also scrap consumption, and time series for each product may be seen in Figure 4.16. The following sources of information were used to establish activity data time series:

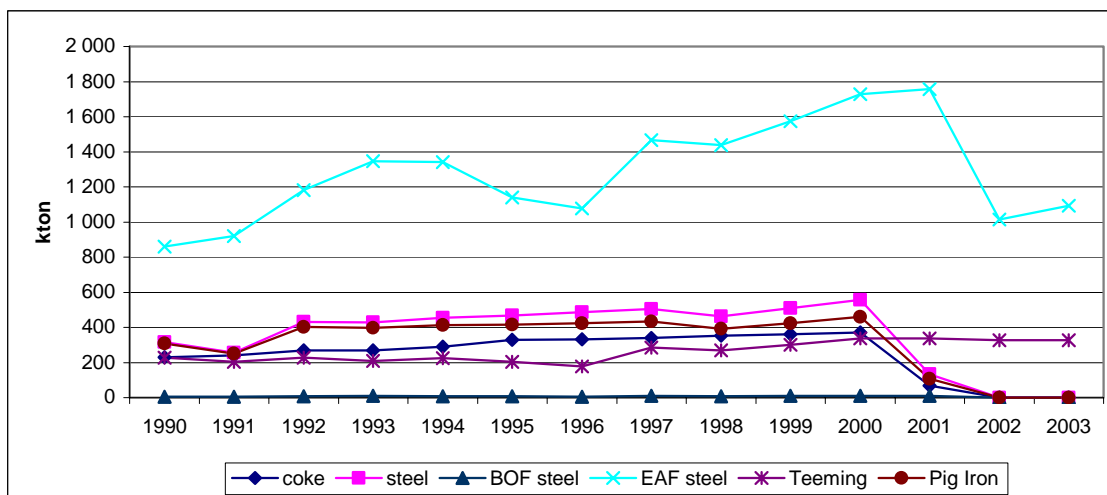
- coke production is available from DGGE (Coquerie Balance) annually from 1990 to 2001. After 2002 the production of coke has stopped;
- production time series for sinter, pig iron and steel production in blast furnace are available from industrial plant from 1990 to 1994 (IA direct survey). Thereafter annual values were estimated using coke production as surrogate data;
- steel resulting from BOF and EAF in Seixal Iron and Steel Plant were estimated from production data in both ovens types in 1990 and forecasted thereafter using fuel consumption in the electric power plant<sup>78</sup> as surrogate data<sup>79</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;
- steel production and scrap use in the EAF oven in Maia steel plant was available for 1990, 2002 and 2003 and interpolated in between.

<sup>78</sup> Power plant that is part of the iron and steel plant

<sup>79</sup> They may result not from iron produced at this industrial plant

Production of total steel and intermediate products as they are presently considered may be seen in next figure. Details about specific products and origin by furnace technology (BOF and EAF) can not be reported due to confidentiality constraints.

Figure 4.16 - Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2003)



## UNCERTAINTY ASSESSMENT

The great majority of CO<sub>2</sub> emissions result from EAF and BOF furnaces with only a small contribution from coke oven and blast furnace, and hence furnaces data is what basically determines overall uncertainty. For year 1990 data information was collected directly from industrial plants and it is mostly probably of good quality. The same situation applies to years 2002 and 2003 after the development of carbon market (EU-ETS). In the intermediate period information had to be collected from statistical information from National Statistical Institute (INE), General Directorate of Geology and Energy (DGGE) or even estimated from surrogate data. Quality of activity data for this period decreased substantially but does not affect overall trend of the inventory. The uncertainty in activity data was set as 10% the major value in the range proposed in GPG. The uncertainty value for the emission factor was determined considering an uncertainty of 25% in the carbon content of both raw materials and final steel and additional 5% in the quantity of reducing agent for EAF.

## RECALCULATIONS

The only modification resulted from the expressive downward revision of the emission factors that are used to estimate CO<sub>2</sub> emissions from steel production in EAF: from 199 kg CO<sub>2</sub>/ton steel to 14.2-21.5 kg CO<sub>2</sub>/ton steel. The explanation for this change is that it was realized that the emissions that were used in previous submission, and which were obtained from EMEP/CORINAIR Emission Factor Handbook, did include carbon dioxide emissions from fuel consumption<sup>80</sup>, and therefore those emissions were doubled counted because emissions from fuel consumption were already estimated from fuel consumption.

Activity data was revised for the all time series using information obtained directly from industrial plants for the carbon market (EU-ETS) allocation plan, and incorporating better information data for EAF steel production in one of the steel factories (Maia).

<sup>80</sup> Although this is not clearly stated in original document in EMEP/CORINAIR, in fact if fuel consumption in the two steel plants is also included in EF determination an emission factor very next to EMEP/CORINAIR is obtained.

CO<sub>2</sub> emissions from lime production, which were placed, in last submission, in combustion sector 1.A.2, should be individualized and reported in industrial production sources, under 2.A.2.

## FURTHER IMPROVEMENTS

Lack of information concerning activity data and possible double counting in steel production activities may be a problem to emission estimates for this source sector. Although this sector is undergoing deep changes with closure of main source activities (coquerie, blast furnace and sintering) an effort has to be made to clarify the situation and increase the quality of emission estimates for the base year. Because 2002 is a year with substantial changes for this source sector, care must be made to update appropriately the inventory thereafter.

Possible double counting of emissions of CO, NMVOC and SO<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.

Finally open dust sources of particulate matter are still not included in the inventory.

### 4.3.C.2 FERROALLOYS PRODUCTION (CRF 2C2)

#### OVERVIEW

Iron is smelted with other elements, such as silicon, manganese, chromium, molybdenum, vanadium or tungsten, forming alloys that have specific material characteristics requirements.

Usually alloy formation occurs in Electric Arc Furnaces (EAF) and, like the situation described in steel factoring, carbon monoxide and carbon dioxide emissions occur from oxidation of carbon still present in coke - used as raw material - and from consumption of the graphite electrodes.

#### METHODOLOGY

Emissions are estimated by multiplication of emission factors, because no data is available to estimate oxidation of coke and electrodes:

$$\text{Emission}_{\text{CO}_2(y)} = \text{EF}_{\text{CO}_2} * \text{ActivityRate}_{(y)}$$

where

$\text{Emission}_{\text{CO}_2(y)}$  - annual emission of carbon dioxide in year y (ton/yr);

$\text{ActivityRate}_{(y)}$  - Indicator of activity in the production process, the quantity of ferro-alloy produced in a given year y (ton/yr);

$\text{EF}_{\text{CO}_2}$  - carbon dioxide emission factor (ton/ton)

#### EMISSION FACTORS

The emission factor, 2.5 ton/ton, was set from emission factors proposed by IPCC96 and CITEPA (Draft contribution for Corinair90 Default Emission Factor Handbook).

#### ACTIVITY DATA

Quantity of ferro-alloy produced is only available for 1990 from National Statistical Institute (INE) and a constant production was temporarily assumed for the whole period: 1 049 ton/yr.

## UNCERTAINTY ANALYSIS

The uncertainty of emissions from this source is substantial, not only because there is lack of information concerning production data but also because there is a high level of uncertainty in the specific alloy that is being considered. Therefore the uncertainty value for activity data was set at 100% while uncertainty in emission factor was estimated from the range of emission factors proposed in IPCC (1997) i.e. 0 – 6.5.

## RECALCULATIONS

No changes have been made in emission estimates from this source category.

## FURTHER IMPROVEMENTS

Although this is a less important emission source, improvement of emissions estimates will have to be made in future, concerning:

- update of time series since 1990;
- individualization of each ferro-alloys by alloy, and application of specific emission sources.

### 4.3.C.3 ALUMINIUM PRODUCTION (CRF 2C3)

#### OVERVIEW AND RECALCULATIONS

Aluminium production will result in carbon dioxide emissions when it is reduced using carbon electrodes in smelting pots and ultimate 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.

### 4.3.D Other Production (CRF 2D)

#### 4.3.D.1 WOOD CHIPBOARD PRODUCTION

##### OVERVIEW

Chipboard manufacturing involves solvent emission but it included in this source sector.

##### METHODOLOGY

Emissions were estimated by the use of emission factors multiplied by the quantity of material produced:

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

where

Emission<sub>NM<sub>VOC</sub></sub> - annual emission of NMVOC in year y (ton/yr);

ActivityRate - Indicator of activity in the production process (ton/yr);

EF<sub>NMVO</sub>C - 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:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVO}C$$

### EMISSION FACTORS

Emission factor is 0.9 kg/ton, from Corinair90 Default Emission Factor Handbook.

### ACTIVITY DATA

Information about activity data for this sector is still scarce and limited to 1990, from National Statistics Institute (INE). In 1990 571 kilo-tons of chipboard were produced in Portugal.

### RECALCULATIONS

No changes have been made since last submission.

### FURTHER IMPROVEMENTS

The place where emissions from chipboard manufacture are located in the inventory should be subjected to revision and possibly moved to category "Solvent Use". Also, NMVOC emissions from this activity should be estimated according to methodologies for these source sector avoiding double counting of emissions that result in fact from solvent use.

Time series of chipboard production needs to be updated from statistical information from INE.

## 4.3.D.2 FOOD AND BEVERAGES

### OVERVIEW

Food and Beverage industrial processes are responsible for some NMVOC emissions resulting mostly from alcohol generation by microbial fermentation and consequent evaporation, and from evaporation of other organic compounds during processing.

The National Inventory Report includes emissions estimates for NMVOC from:

- Bread backing;
- Wine preparation;
- Beer production;
- Spirituous beverages distillation;
- Meat and fish processing;
- Sugar processing;

- Margarine and other fat production<sup>81</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, IPCC96 and US-EPA AP42:

Table 4.23 - 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	

<sup>81</sup> Emissions of NMVOC from edible oil extractions are included in "Use of Solvents".



Table 4.24 – Particulate Matter Emission Factors for Grain Milling and Rice Processing

Parameter	EF	Unit
PM	11	Kg/ton (a)
PM10	49	% PM
PM2.5	49	% PM
PM1	49	% PM

Source: USEPA (1998)

(a) Implied Emission Factor, comprehending grain milling, rice processing, animal feeds milling and manufacturing and flaking.

## ACTIVITY DATA

Activity data was available, for most activities only for years 1990 and 1991, from INE. Information about break backing, animal feed, coffee roasting and sugar include also information about years 1996 and 1997. Information lacking for the other years were estimated, using extrapolations and interpolations from the available time series, or else kept constant during all period. Annual activity levels that were considered in the inventory from 1990 to 2001 are presented in Table 4.25 and Table 4.26 below.

Table 4.25 – Annual production in the Food and Beverage Industry (1990-1996)

Product	1990	1991	1992	1993	1994	1995	1996
White wine	454	409	322	202	277	313	427
Red Wine	655	574	439	268	358	393	521
Beer	687	689	690	692	693	694	696
Spirits	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 4.26 - Production in the Food and Beverage Industry (cont: 1997-2003)

Product	1997	1998	1999	2000	2001	2002	2003
White wine	266	161	342	291	339	291	319
Red Wine	325	197	418	355	414	354	389
Beer	677	687	687	687	687	687	687
Spirits	14	14	14	14	14	14	14
Wheat Bread	172	187	172	158	143	129	114
Other Bread	16	17	16	14	13	11	10
Cakes	38	38	38	38	38	38	38
Fish	238	238	238	238	238	238	238
Sugar	348	323	328	334	339	344	349
Margarine	67	67	67	67	67	67	67
Animal Feed	3 809	3 761	3 761	3 761	3 761	3 761	3 761
Coffee							
Roasting	27	28	28	28	28	28	28
Milling	4 741	4 882	4 678	4 645	4 735	4 748	4 748

\* (a) Beverages expressed in million liters; food products in kton.

## RECALCULATIONS

The only modification made to this sector was the revision of the time series for wine production, using new data from Statistics of Agriculture (INE). Nevertheless the GHG inventory was not modified by these changes. Emissions from grain milling and rice processing were moved to another category of NFR.

## FURTHER IMPROVEMENTS

No improvements are expected for this source, which is responsible for minor emission quantities, besides update of activity data for the all time series using statistical information from National Statistical Institute (INE).

### 4.3.D.3 PAPER PULP PRODUCTION

#### OVERVIEW

In Portugal there were in 1990 six paper pulp plants using the kraft process and two units using the acid sulphide process. Later, in 1993, one of the smaller of the acid sulphide plants was decommissioned and nowadays only 6 plants remain in operation.

Kraft pulping is essentially a digestion process of wood by a solution of sodium sulphide ( $\text{Na}_2\text{S}$ ) 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 US-EPA AP42 and other sources and include emissions realized in:

- Kraft process: Digester, Brown Stock Washers, Black Liquor Evaporators, Non condensable gases, Smelt dissolving tank, Fluid Bed Calciner and Bleaching;
- Acid sulphide: Digester and Blow Pit.

Table 4.27 - Emission Factors for paper pulp production (non combustion)

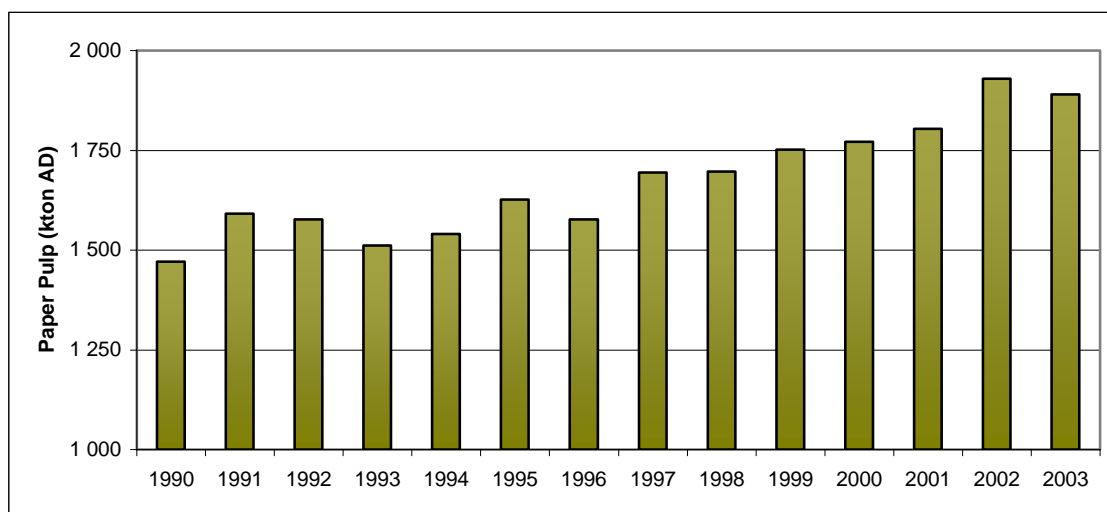
Process	SO <sub>x</sub>	NO <sub>x</sub>	NMVOC	TSP	PM <sub>10</sub> (%)	PM <sub>2.5</sub> (%)	PM <sub>1</sub> (%)
Kraft	0.31	1.95	2.74	3.5	88.5	73	40
Sulphide	35.5	NA					

## ACTIVITY DATA

Production of paper pulp expressed in air dried weight was collected directly from paper pulp plants from a direct survey, from information collected under LCP directive and from information published or delivered by CELPA, the Portuguese Paper Industry Association. Acid Sulphide production is only a minor component of total production<sup>82</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, and was in 2003 twenty eight per cent higher than in 1990.

<sup>82</sup> Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

Figure 4.17 - Total production of paper pulp - Kraft and semi-sulphide (1990-2003)



## RECALCULATIONS

No modifications were made for this source sector since last submission.

## 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).

## 4.3.E Consumption of Halocarbons and Sulphur Hexafluoride (CRF 2F)

### 4.3.E.1 OVERVIEW

Several simple halogenated organic compounds have high warming potentials and long atmospheric residence times. These include predominantly synthetic substances that have been used mostly as inert gases in such diverse applications as refrigeration gas, aerosols propellants, foam fillers, gas insulation and fire suppressants. Chlorofluorocarbons (CFC), Hydrochlorofluorocarbons (HCFC), Perfluorinated hydrocarbons (PFC) and sulphur hexafluoride (SF<sub>6</sub>)<sup>83</sup> are the most important among those compounds. CFC and HCFC are already under control and being phased out under the Montreal Protocol, as consequence of their role as Ozone Depleting Substances (ODS). Therefore, under the United Nations Convention on Climate Change it was decided to consider in the GHG inventory those substances not included in the Montreal Protocol: HFC, PFC and SF<sub>6</sub>.

Some emission sources are still not included in the inventory:

- Aerosols. According to information from 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

<sup>83</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.

because F gases are not reported explicitly at customs services and consequent emission cannot be estimated;

- Solvents. According from information from national importers in Portugal there is no reference of the use of HFC as solvents, but only of HCFC (Carreira, 2002). Use of HFC as a solvent represents probably a minor source in global terms;
- 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 covered in the inventory, mainly as result of lack of adequate basic activity data, although there is a strong believe that they are minor sources not decisively affecting total emissions:

- 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)

#### 4.3.E.2 GENERAL METHODOLOGY

For those sources for which sufficient data was available, actual emissions where estimated with a Tier 2 (advanced or actual method) approach which is considered Good Practice in accordance with GPG. This approach allows the quantification of emissions in the year in which they actually occurred accounting for the time lag between consumption and emissions. On the contrary the Tier 1, or potential approach, allocates emissions in the year that the chemical is sold into a particular end-user.

As a general rule bottom-up methodologies were used, and in fact overall methodology should be classified as Tier 2a. This approach departs from the knowledge of the number of equipments using HFC compounds and estimates emissions to atmosphere from charge (amount of chemical used in the equipment), service life, emission rate during the various periods of the equipment life and possible recovery of emissions.

Whenever possible emission estimates include:

- assembly emissions, when equipment is first filled<sup>84</sup>;

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<sup>84</sup> Assembly emissions could include also emissions during refilling but no data was available to make this distinction

- 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.

#### 4.3.E.3 RECALCULATION

No significant changes have been made since last year submission.

#### 4.3.E.4 FURTHER IMPROVEMENT

It is expected that emission estimates will improve as a consequence of the inclusion of non quantified sources and the improvement in methodologies and parameters for the already quantified sources. Main aspects that will be subjected to future improvements comprehend:

- Estimate of potential emissions, from statistical information on importations. The collection of this data poses difficult problems however;
- 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, coaches and vessels. And a better knowledge of the time series of light vehicles with AC should also be followed;
- It is known that SF<sub>6</sub> was used in Portugal as a tracer in scientific studies, even in the development of air emission methodologies (VOC from forest). But the quantities used in this activity remain unknown;
- 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;
- Emissions from certain source sectors rely in less accurate activity data, which was estimated from surrogate data and assumptions. Efforts will be made to reduce uncertainty on activity data and parameters.

## 4.3.E.5 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.

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 table 3.22.

Table 4.28 - 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*.

## 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).

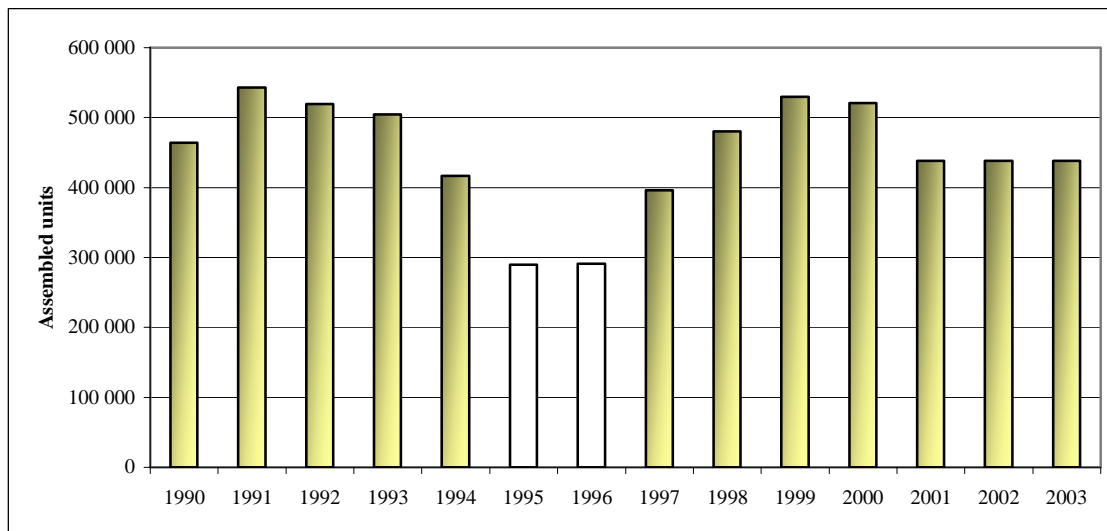
Table 4.29 - Percentage of households in Portugal provided with refrigeration equipments

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>85</sup>. Values for 2001 to 2003 were forecasted by IA.

Figure 4.18 – Number of assembled refrigeration units (1990-2002)



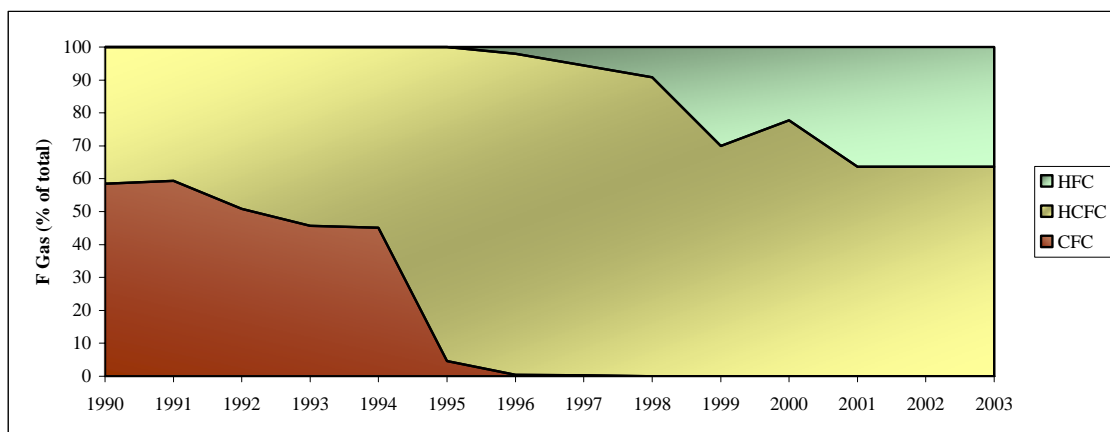
Number of disposed units (scrap rate) is not available in Portugal. It was assumed that 10% of the stock is removed every year.

#### 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>85</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 4.19 - Percentage of imported fluorine gases in Portugal by gas type (1990-2003)



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>86</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.

The quantity of refrigeration gas charged into the equipment was assumed at an average value of 100 g/equipment unit (GASA, 2000 after information from APIRAC) which is well within the range set in GPG table 3.22.

#### UNCERTAINTY ASSESSMENT

An uncertainty of 10% was considered for the number of assembled units by year, and 15% was assumed for the number of equipments in existence. The number of disposed units was estimated from expert guess and a higher uncertainty of 25% was considered. Uncertainty values for emission factors, or F gas liberation, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime – and each value was determined in accordance with the range of default emission factors in GPG. Individual uncertainty values are presented in next table.

Table 4.30 – Uncertainty of Emission Factors for HFC emissions from Domestic Refrigeration

Origin	Uncertainty (%)			
	Initial Charge	Emission	Time of Release	Combined
Assembly	225	67	5	235
Operation	225	67	13	235
Disposal	225	6	13	227

<sup>86</sup> In consequence no emissions of HFC from disposal are estimated for the reported period.

## 4.3.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.

Lifetime and disposal emissions<sup>87</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

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

HFC emissions for each particular compound were estimated from total refrigeration gas emissions and considering the percentage of HFC use in total refrigeration gas use in each particular year, according to the following equations:

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * HFC_{\% (j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\% (t,y)} * HFC_{\% (j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} * [Equip_{\% (t,t-lifetime)} * HFC_{\% (j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$ ,  $Oper_{Emi(t)}$ ,  $Disp_{Emi(t)}$  - total HFC emissions in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

<sup>87</sup> Assembly emissions are included in domestic refrigeration because the discrimination of equipment usage it is not feasible for all years

$Ass_{Emi(t,j)}$ ,  $Oper_{Emi(t,j)}$ ,  $Disp_{Emi(t,j)}$  - HFC emissions of compound j in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$  - Equipments assembled in year t;

$Equip_{Stock(t)}$  - Existing stock of equipment in year t;

$Equip_{Disposal(t)}$  - Number of equipments disposed at year t;

$Initial_{Charge(t)}$  - Initial charge of refrigeration gas filled in year t;

$Equip_{\%(t,y)}$  - Percentage of equipments assembled in year y in the existing stock in year t;

$HFC_{\%(j,t)}$  - Percentage of use of HFC compound j in year t;

X - annual emissions rate as a percentage of total initial charge;

Y - percentage of initial charge remaining in equipment at the time of disposal;

Z - the recovery efficiency at the time of disposal.

## EMISSION FACTORS

In a similar way to domestic equipments, emission factors were set as the average values from the proposed range in IPCC GPG table 3.22.

Table 4.31 - 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,1997).

## 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 4.32 - 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:

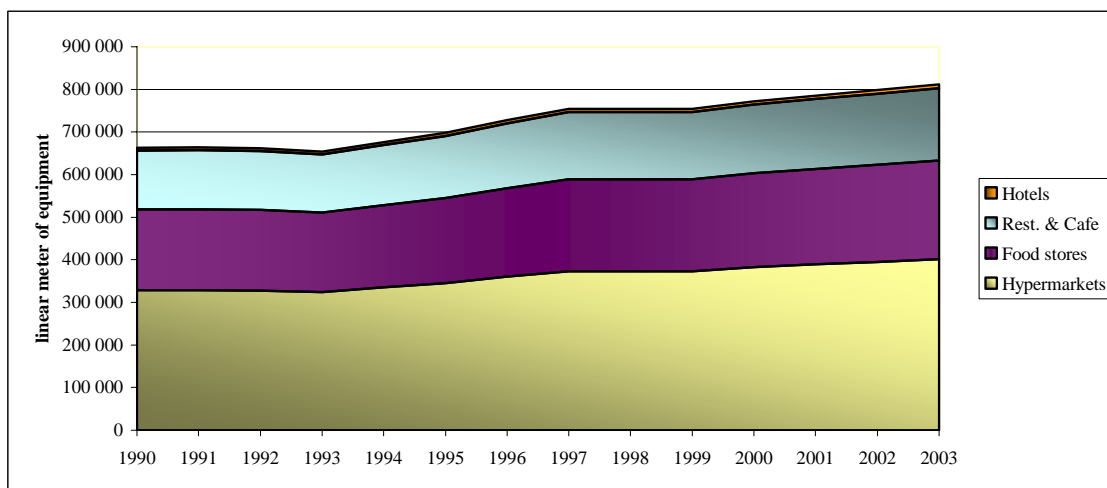
Table 4.33 - Number of refrigeration equipments per commercial unit in Portugal

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

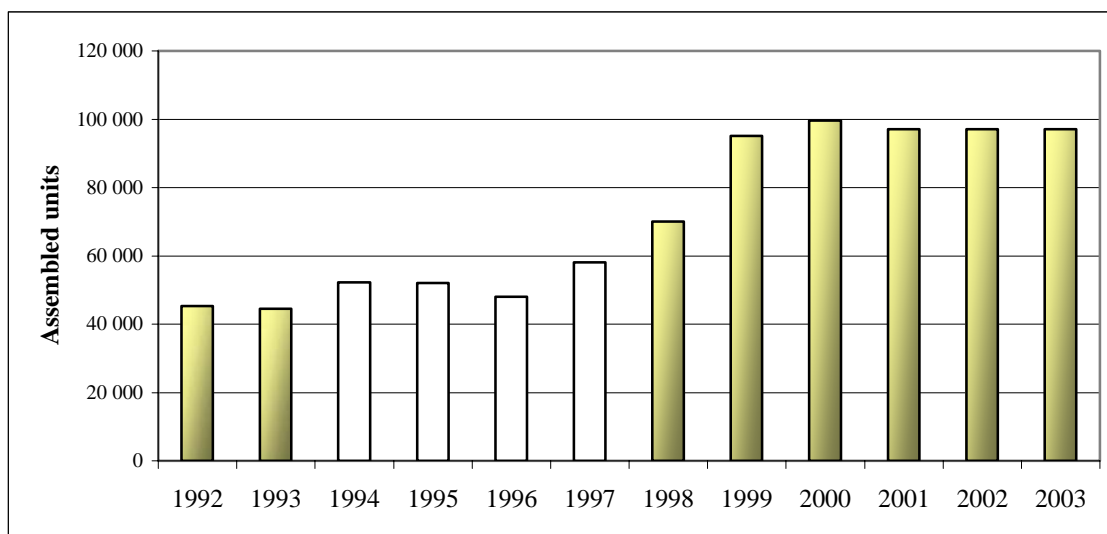
- the activity data time trend was assumed to follow Gross National Product (GNP) in the period 1990-2003.

Figure 4.20 - Refrigeration Equipments in commercial activity in Portugal (1990-2003)



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 after 2001 were forecasted by IA.

Figure 4.21 - Assemblage of commercial and industrial refrigeration units in Portugal (1992-2003)



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 GPG 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.

#### UNCERTAINTY ASSESSMENT

The uncertainty in the refrigeration equipment stock is much higher than that of domestic refrigeration. Using the same arguments that were used to derive activity data numbers, the actual values could be up to five times higher. The uncertainty of the number of disposed units per year is probably in the same order. When in comparison to domestic refrigeration there is also a somehow higher degree of error in the determination of the number of new units, and a value of 20% was considered appropriate.

Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime – and each value was determined in accordance with the range of default emission factors in GPG. Individual uncertainty values are presented in next table.

Table 4.34 – Uncertainty of Emission Factors for HFC emissions from Commercial Refrigeration

Origin	Uncertainty (%)			
	Initial Charge	Emission	Time of Release	Combined
Assembly	5 533	69	5	5 534
Operation	5 533	264	21	5 540
Disposal	5 533	11	21	5 533

#### 4.3.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. Lifetime and disposal emissions<sup>88</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

$$\text{Oper}_{\text{Emi}(t,j)} = \text{Oper}_{\text{Emi}(t)} \sum_{y=t}^{t-\text{Lifetime}} [\text{Equip}_{\%(t,y)} * \text{HFC}_{\%(j,y)}]$$

Disposal

$$\text{Disp}_{\text{Emi}(t,j)} = \text{Disp}_{\text{Emi}(t)} [\text{Equip}_{\%(t,t-\text{lifetime})} * \text{HFC}_{\%(j,t-\text{lifetime})}]$$

Where

$\text{Oper}_{\text{Emi}(t)}$ ,  $\text{Disp}_{\text{Emi}(t)}$  - total HFC emissions in year t from during Operation (Oper) and Disposal (Disp);

<sup>88</sup> Assembly emissions are not estimated and they are included in assemblage of other refrigeration equipments

$Oper_{Emi(t,j)}$ ,  $Disp_{Emi(t,j)}$  - HFC emissions of compound  $j$  in year  $t$  from during Operation (Oper) and Disposal (Disp);

$Equip_{Stock(t)}$  - Existing stock of equipment in year  $t$ ;

$Equip_{Disposal(t)}$  - Number of equipments disposed at year  $t$ ;

$Initial_{Charge(t)}$  - Initial charge of refrigeration gas filled in year  $t$ ;

$Equip_{\%(t,y)}$  - Percentage of equipments assembled in year  $y$  in the existing stock in year  $t$ ;

$HFC_{\%(j,t)}$  - Percentage of use of HFC compound  $j$  in year  $t$ ;

$X$  - annual emissions rate as a percentage of total initial charge;

$Y$  - percentage of initial charge remaining in equipment at the time of disposal;

$Z$  - the recovery efficiency at the time of disposal.

## EMISSION FACTORS

Lifetime emissions are supposed to occur with a yearly rate of 32.5 % of initial charge per year in accordance with the average rate proposed in table 3.22 of the GPG. The emitted quantity to the atmosphere is the residual product remaining in equipment (variable  $y$ ) which was set at 90% from *1996 IPCC Revised Guidelines* and no recovery is assumed at disposal.

## ACTIVITY DATA 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. Lifetime was set at 8 years also the average value from table 3.22 of IPCC GPG.

## UNCERTAINTY ASSESSMENT

Also for this sub-source there is a high level of uncertainty in the determination of refrigeration equipment stock and it was assumed that the actual values could be up to two times higher. The uncertainty of the number of disposed units per year is probably in the same order. Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime – and each value was determined in accordance with the range of default emission factors in GPG. Individual uncertainty values are presented in next table.

Table 4.35 – Uncertainty of Emission Factors for HFC emissions from Transport Refrigeration

Origin	Uncertainty (%)			
	Initial Charge	Emission	Time of Release	Combined
Operation	45	54	19	73
Disposal	45	6	19	49



## 4.3.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.

Emissions were estimated according to the following set of equations after GPG:

Assembly/First fill

$$Ass_{Emi(t)} = Equip_{Assembly(t)} * Initial_{Charge(t)} * (k/100)$$

Operation/Lifetime

$$Oper_{Emi(t)} = Equip_{Stock(t)} * Initial_{Charge(t)} * (x/100)$$

Disposal

$$Disp_{Emi(t)} = Equip_{Disposal(t)} * Initial_{Charge(t-lifetime)} * (y/100) * (1-z/100)$$

Assembly

$$Ass_{Emi(t,j)} = Ass_{Emi(t)} * HFC_{\% (j,t)}$$

Operation/ Lifetime

$$Oper_{Emi(t,j)} = Oper_{Emi(t)} \sum_{y=t}^{t-Lifetime} [Equip_{\% (t,y)} * HFC_{\% (j,y)}]$$

Disposal

$$Disp_{Emi(t,j)} = Disp_{Emi(t)} * [Equip_{\% (t,t-lifetime)} * HFC_{\% (j,t-lifetime)}]$$

where

$Ass_{Emi(t)}$ ,  $Oper_{Emi(t)}$ ,  $Disp_{Emi(t)}$  - total HFC emissions in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Ass_{Emi(t,j)}$ ,  $Oper_{Emi(t,j)}$ ,  $Disp_{Emi(t,j)}$  - HFC emissions of compound j in year t from during assembly (Ass), Operation (Oper) and Disposal (Disp);

$Equip_{Assembly(t)}$  - Equipments assembled in year t;

$Equip_{Stock(t)}$  - Existing stock of equipment in year t;

$Equip_{Disposal(t)}$  - Number of equipments disposed at year t;

$\text{Initial}_{\text{Charge}}(t)$  - Initial charge of refrigeration gas filled in year  $t$ ;

$\text{Equip}_{\%(t,y)}$  - Percentage of equipments assembled in year  $y$  in the existing stock in year  $t$ ;

$\text{HFC}_{\%(j,t)}$  - Percentage of use of HFC compound  $j$  in year  $t$ ;

$K$  - percentage of initial charge that it is released during assembly;

$X$  - annual emissions rate as a percentage of total initial charge;

$Y$  - percentage of initial charge remaining in equipment at the time of disposal;

$Z$  - the recovery efficiency at the time of disposal.

### EMISSION FACTORS

Lifetime emission factor was set as 3 per cent of initial charge per year, which is the average value from the proposed range in IPCC GPG table 3.22.

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.

### ACTIVITY DATA SOURCES

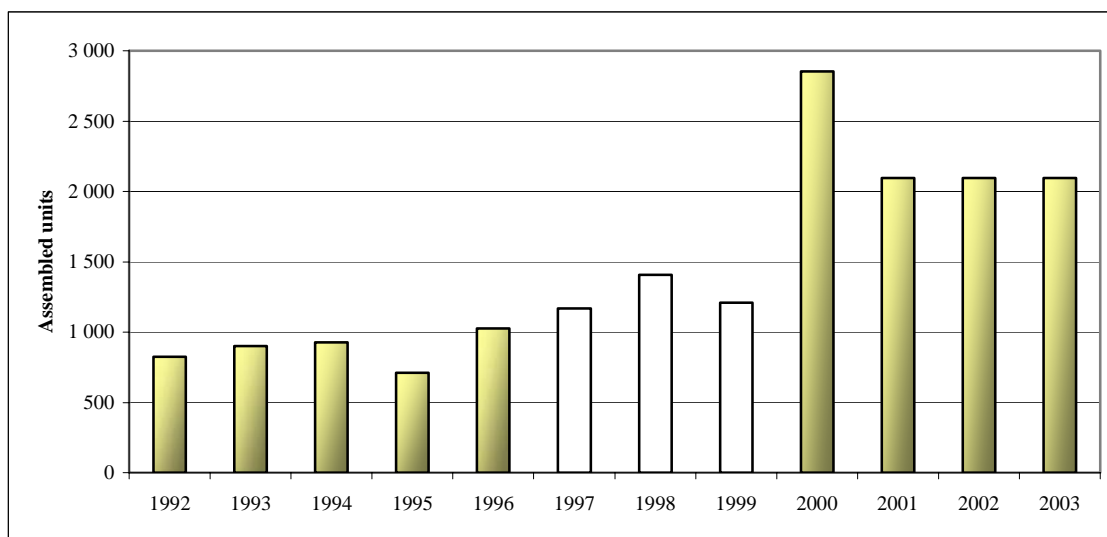
From available data on industry statistics it is not possible to have a clear view of the time trend affecting the number of assembled units, as consequence of the change that occurred in the industrial survey in 1992, when IAIT was replaced by IAPI that uses different products categories. IAIT survey 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 4.22), from 1992 to 2003, 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>89</sup>.

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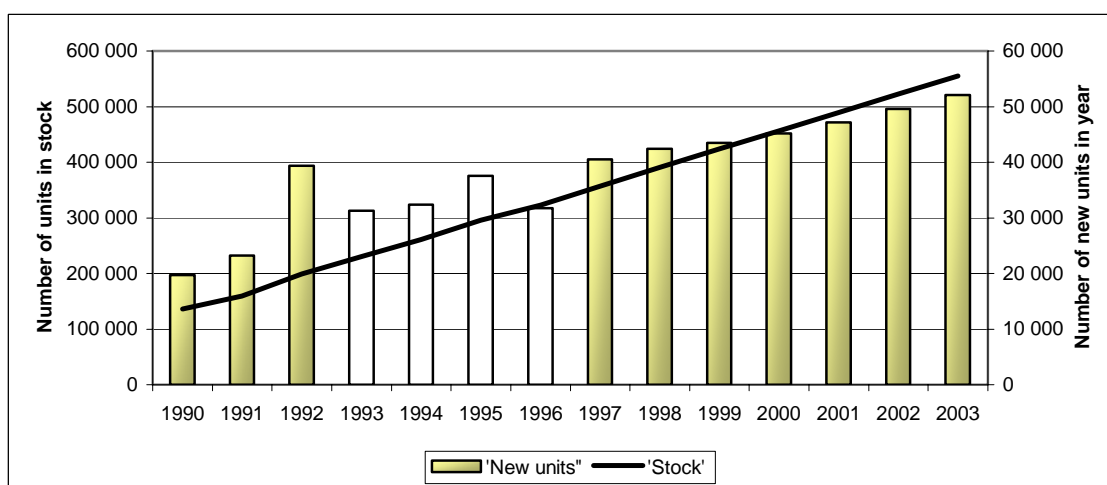
<sup>89</sup> Due to difference in magnitude order these values from IAIT are not shown in the graph

Figure 4.22 - Number of stationary air-conditioning assembled in Portugal in the period 1990-2003



The stock in existence and yearly disposed units is available from unpublished information received from IST-UTL. The time series from 1990 to 2003 is presented in next figure.

Figure 4.23 - Stationary air-conditioning: Annual new equipment units installed and annual stock of equipments in Portugal (1990 to 2003)



## 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.

## UNCERTAINTY ASSESSMENT

The uncertainty in the number of newly assembled AC units is higher than the value that was considered for domestic refrigeration due to the incompleteness in time series. An uncertainty value of 25 % was assumed. An uncertainty of 50% was considered for stock in existence and this same value was considered for disposal.

Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime – and each value was determined in accordance with the range of default emission factors in GPG. Individual uncertainty values are presented in next table.

Table 4.36 – Uncertainty of Emission Factors for HFC emissions from A/C stationary equipments

Origin	Uncertainty (%)			
	Initial Charge	Emission	Time of Release	Combined
Assembly	1 583	67	5	235
Operation	1 583	67	19	1 585
Disposal	1 583	6	19	1 585

#### 4.3.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. Due to lack of information it was not possible to estimate emissions by vehicle class and age. Emissions refer only to light vehicles<sup>90</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:

Operation/ Lifetime

$$\text{Oper}_{\text{Emi}(t,j)} = \text{Oper}_{\text{Emi}(t)} \sum_{y=t}^{t-\text{Lifetime}} [\text{Equip}_{\%(t,y)} \cdot \text{HFC}_{\%(j,y)}]$$

<sup>90</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

## 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). Lifetime was set at 12 years also the default value both in IPCC 96 and IPCC GPG.

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.

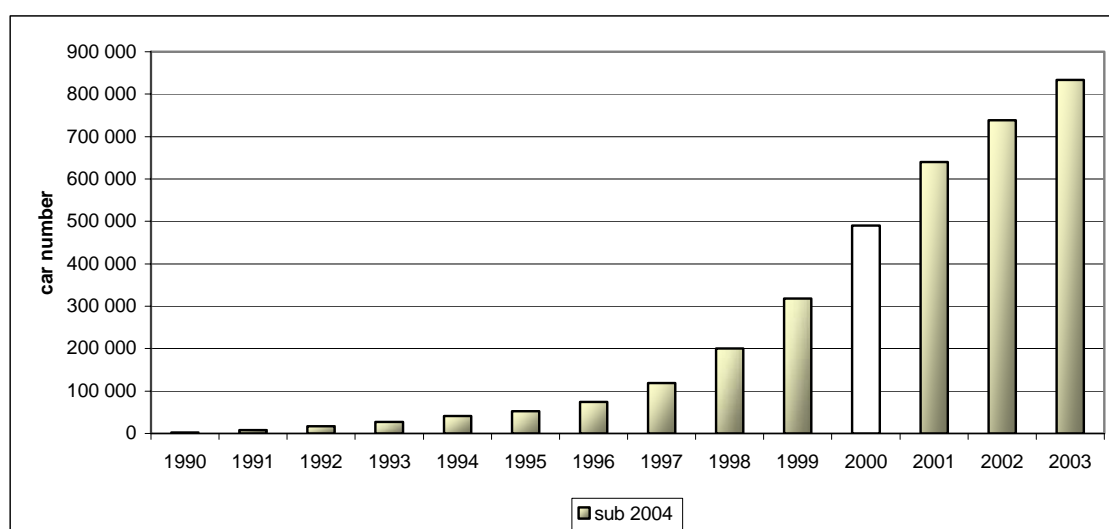
## ACTIVITY DATA SOURCES

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 4.37, according to information collected in Seixas et al (2000). Total number of vehicles equipped with MAC is presented in Figure 4.24. 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 4.37 - 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 and beyond	50	Figure for most important passenger car

Figure 4.24 - Estimated number of Light Vehicles equipped with MAC systems (1990-2003)



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 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* refers 1.2 kg/MAC as adequate for cars<sup>91</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.

## UNCERTAINTY ASSESSMENT

Also for this sub-source there is a high level of uncertainty in the determination of MAC units and it was assumed that the actual values could be up to three times higher or lower. The uncertainty of the number of disposed units per year is probably in the same order. Uncertainty values for emission factors, in a similar mode that was done for domestic refrigeration, incorporate the uncertainty in initial charge, emission factor and also a component for time of discharge – expressing the uncertainty in lifetime – and each value was determined in

<sup>91</sup> According to UNEP Technical Options Report (UNEP, 1989)

accordance with the range of default emission factors in GPG. Individual uncertainty values are presented in next table.

Table 4.38 – Uncertainty of Emission Factors for HFC emissions from MAC

Origin	Uncertainty (%)			
	Initial Charge	Emission	Time of Release	Combined
Operation	17	33	19	42
Disposal	17	44	19	51

#### 4.3.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

$$F_{Gas_{Emi(t,j)}} = Fill_{Gas_{Consumption(t)}} * HFC_{\%(j,t)} * (k/100)$$

Annual losses.

$$F_{Gas_{Emi(t)}} = F_{Gas_{inFoam(t)}} * (x/100)$$

$$F_{Gas_{inFoam(t,j)}} = \sum_{y=t}^{t-Lifetime} [Fill_{Gas_{Consumption(y)}} * HFC_{\%(j,y)}]$$

Where:

$FGas_{E_{mi}(t,j)}$  - 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>92</sup>;

K - first year loss emission factor;

X - annual loss emission factor.

This formulation is similar to equation 3.38 of the GPG.

Emissions due to decommissioning of foams 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>93</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 4.39 - 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 4.40 – 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

<sup>92</sup> For the time being the stock is restricted to foam filled in Portugal;

<sup>93</sup> Good Practice Guidebook sets the default product lifetime as 20 years (table 3.17)



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 deducted 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.

## UNCERTAINTY ASSESSMENT

There is a great uncertainty of the activity data for this source, with very scarce information, particularly in what concerns annual losses. The uncertainty in fill gas consumption was set at 50%, according to recommendations of GPG for country-specific top-down information. But the main uncertainty results from annual stock of foams, for which there is no information and an order of magnitude of error was considered. The uncertainties in emission factors express the variation in the range of the default rates and are documented in next table.

Table 4.41 – Uncertainty of Emission Factors for HFC emissions Foams

Origin	Uncertainty (%)		
	Emission	Time of Release	Combined
Blowing	438	5	438
Leakage	44	19	48

### 4.3.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 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*. The GPG 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.

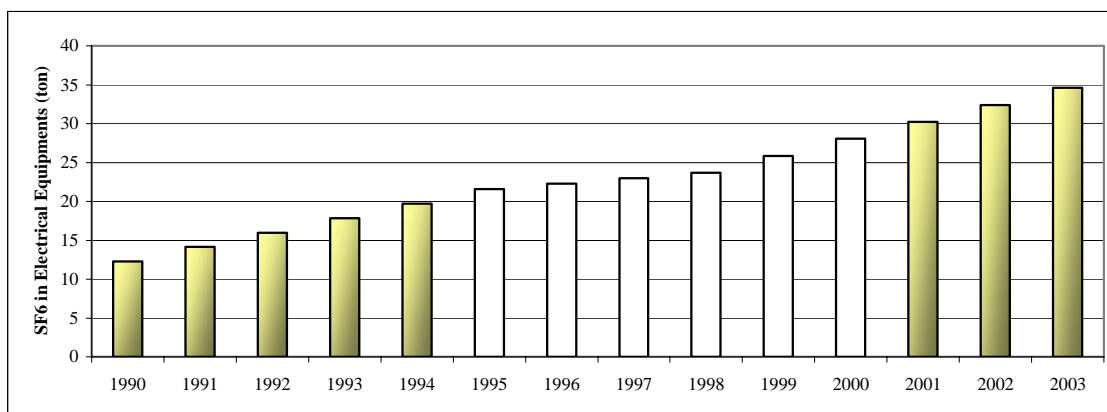
## ACTIVITY DATA SOURCES

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 4.25.

Table 4.42 - Quantity of Sulphur hexafluoride stock in Electric Equipments in Portugal

SF <sub>6</sub> (tons)	1990	1995	1998	2010
Switch Breakers	12.3	16.5	18.0	38.0
Sub-stations	0.0	5.1	5.7	11.9
Total	12.3	21.6	23.7	49.9

Figure 4.25 - Total SF6 in stock in electric equipments in Portugal (1990-2002)



## UNCERTAINTY ASSESSMENT

The uncertainty in the emission factor is 15%, obtained from statistical analysis of the emission factors determined for 1995, 1998, 1999 and 2000. The uncertainty in activity data was set at 25%.

## 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.

## CHAPTER: 5 : SOLVENT AND OTHER PRODUCT USE (CRF 3)

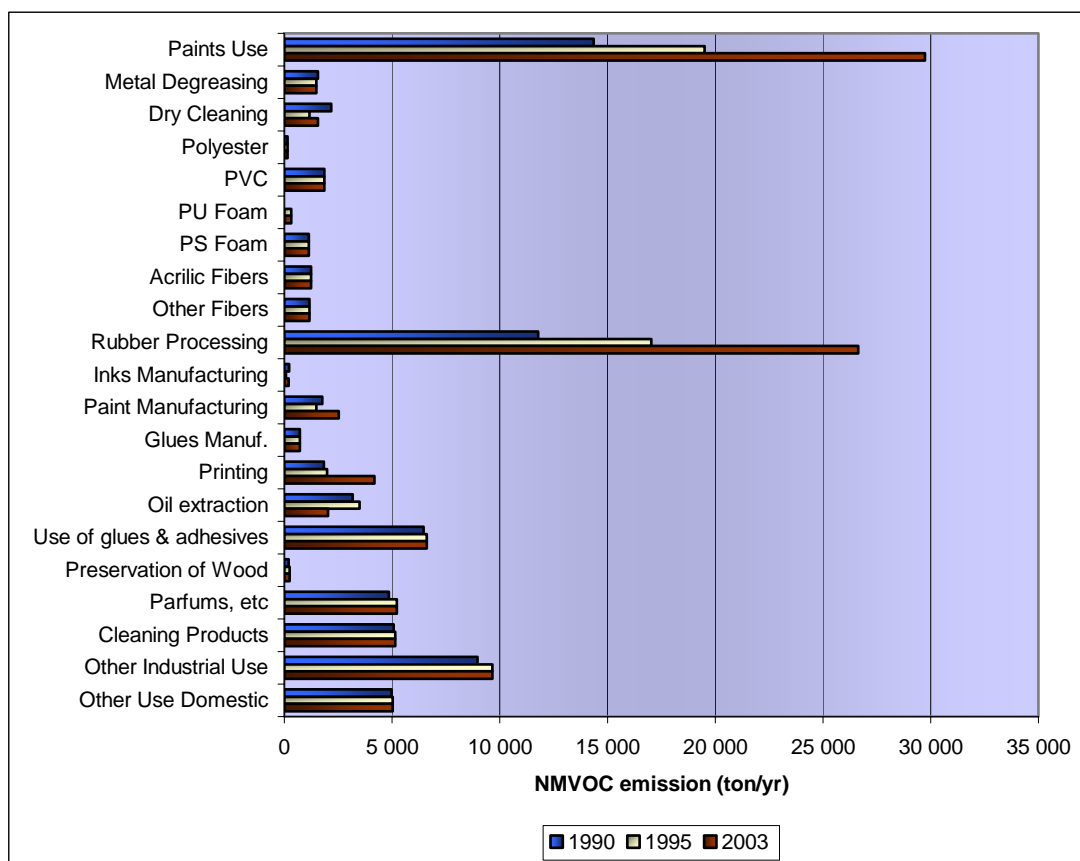
### 5.1 Overview

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 should also be included in this source, if resulting from use of this compound as component in specific applications, estimate for these sources are still un-available for Portugal. No emissions of methane are included in this source sector.

Some peculiarities apply to this source sector. In first place not all emissions occur directly to atmosphere when the production or use action takes place, as some solvents remain in product or are conveyed into wastewater. However, because eventually sooner or later these solvent fractions are liberated to atmosphere, all solvent losses may be assumed to contribute to air emissions. On the other hand, emissions of solvent may occur in three phases: during production of products containing solvents, during actual use of products containing solvent and during disposal.

The dominant sources of NMVOC from this sector in Portugal during the period 1990-2003 were Paint Application, Chemical Products Manufacture and Processing and other solvent use, while Degreasing and Dry Cleaning also contribute to emissions at a smaller scale. This may be seen in Figure 5.1, where the importance of emissions of NMVOC is shown in detail for years 1990, 1995 and 2003. From there it is evident the prevalence of emissions from paint use, rubber processing and other use of solvent products, and the substantial increase in emissions that was observable for use of paints and rubber processing.

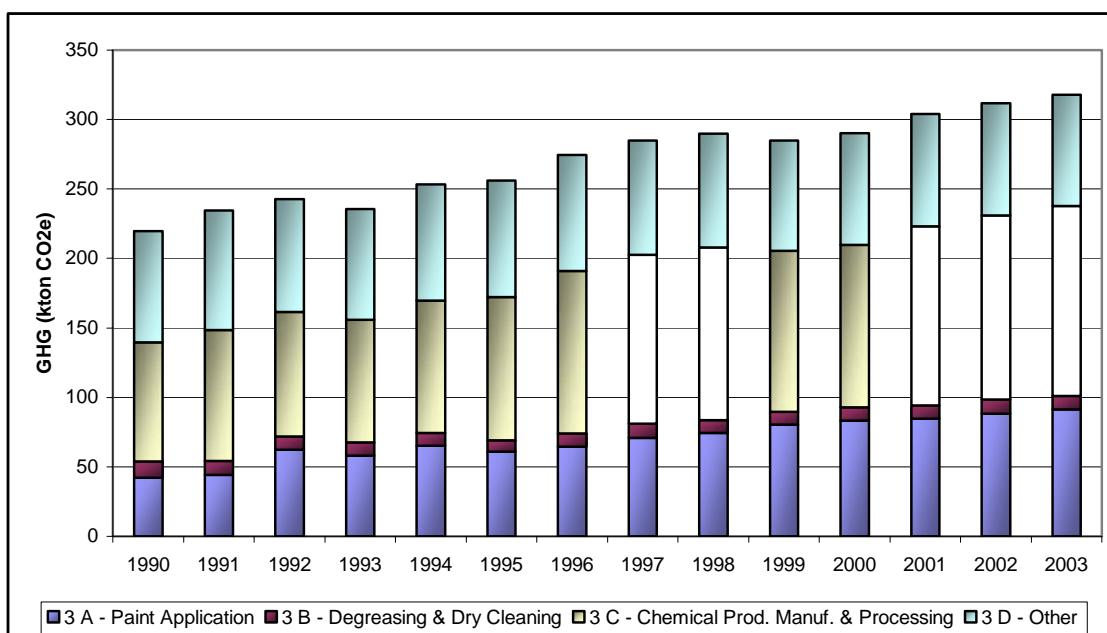
Figure 5.1 - NMVOC emissions from Solvent Use per individual source category in 1990, 1995 and 2003



NMVOC emissions estimates must be converted in CO<sub>2</sub> emissions whenever the carbon that is present in organic compounds has fossil fuel origin (originated from feedstocks from petroleum, coal or natural gas), and being assumed that NMVOC compounds are fully oxidized in air to carbon dioxide contributing thence to the atmospheric pool.

Total GHG emissions from this source sector have increased steadily in the period from 1990 to 2003, from 220 kton of CO<sub>2</sub> in 1990 (which is only 0.5 % of total CO<sub>2</sub> emissions or 0.37% of total GWP CO<sub>2</sub>e) to 318 kton CO<sub>2</sub> eq. in 2003 (0.38% of total GHG emissions in CO<sub>2</sub>e). All emissions, quantified as carbon dioxide, are presented in Figure 5.2 per sub-source sector.

Figure 5.2 - GHG emissions from Solvent Use per source sub-sector (1990-2003)



## 5.2 Recalculations

This source sector has only subjected to minor improvements, which reflects in small changes in emissions (Figure 5.3).

Figure 5.3 - Differences between 2003 and 2004 submissions for CO<sub>2</sub> emissions from solvent use

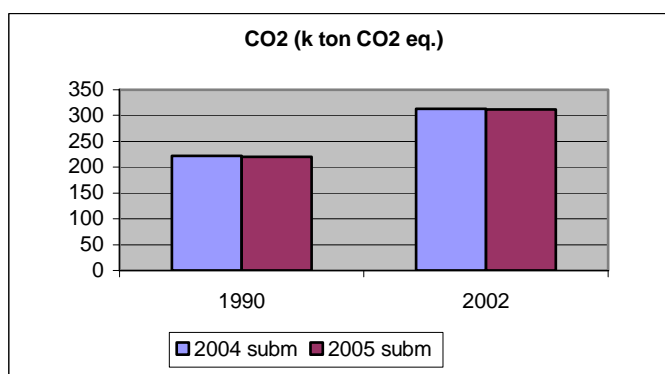


Table 5.1 - Recalculations of emissions from solvent use: differences between 2003 and 2004 submissions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2004 subm.	2005 subm.	Difference (1)	2004 subm.	2005 subm.	Difference (1)	2004 subm.	2005 subm.	Difference (1)
	CO <sub>2</sub> equivalent (Gg)	CO <sub>2</sub> equivalent (Gg)	(%)	CO <sub>2</sub> equivalent (Gg)	CO <sub>2</sub> equivalent (Gg)	(%)	CO <sub>2</sub> equivalent (Gg)	CO <sub>2</sub> equivalent (Gg)	(%)
1990									
3. Solvent and Other Product Use	222.26	219.71	-1.14		0.00		0.00	0.00	0.00
2002									
3. Solvent and Other Product Use	312.89	311.62	-0.41		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.

## 5.3 Category Sectors

### 5.3.A Paint Application (CRF 3A)

#### 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>94</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 those arising from car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities and domestic use.

The distinction between coating operations in construction and building and domestic use is not very relevant, however, because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

#### 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

<sup>94</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.

$Emi_{NMVOC(y)}$  – 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>2e</sub>.

$$U_{CO_2} = 44/12 * NMVOC * 0.85$$

where:

$U_{CO_2}$  - Ultimate CO<sub>2</sub> (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

### EMISSION 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>95</sup>.

Table 5.2 - Solvent content of paints consumed in Portugal

Paint Type	Resin/ polymer	Solvent (%)
Water Based	Acrylic & Vinyl	1.5
	Alkyd & Other	1.5
Solvent Based	Acrylic & Vinyl	90
	Acrylic & Vinyl low solvent content	47
	Polyester	39
	Alkyd, celulosic & Other	51
Oil Paints, Powder Paints		0
Other Paints		29

These specific emission factors were applied to the total consumption of paint, irrespective of the application where it is used, and average emission factors were hence determined for water based paint, solvent based paint and other paints. The resulting emission factors, that were in fact used to estimate emissions for each economic activity, are presented in next table.

<sup>95</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 5.3 – Average NMVOC emission factors from use of Paints

Paint Type	NMVOC EF (kg/ton Paint)
Water Based	1.5
Solvent Based	51
Oil and Powder Paints	0
Other Paints	29

there are small annual variations, although smaller than 1 kg/ton

### 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>96</sup>, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 5.4 and Table 5.5.

<sup>96</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 5.4 – Paint Production in Portugal by Paint Type in ton/yr (1990-1996)

Type	Polimer	1990	1991	1992	1993	1994	1995	1996
Water	Acrylic & Vinyl	0	0	76	64	72		
	Alkyd & Other	0	0	811	714	375	66 924	80 693
	Other		81	32	22	20	17	14
Solvent	Other	78 380	619	211	118	98	102	1 181
	Acrylic & Vinyl	0	0	248	48	23	76	134
	Acrylic & Vinyl Low solvent	0	0	0	0	0	63	439
	Alkydic	0	0	13	10	10		
	Celulosic	7 579	7 215	013	622	946	10 956	12 941
	Poliester	0	0	5 663	5 552	5 242	3 679	4 343
Oil	Other	13 981	13	2 155	1 688	1 315	890	1 810
			367	10	937	8 659	8 639	9 865
				8 659	8 639	9 865	12 028	
Powder		14 789	14	800	318	364	353	392
		2 069	789	2 542	2 896	2 889	3 269	3 747
	Other	1 164	1 164	1 357	37	2 181	2 133	2 363

Source: INE;  
# included as other

Table 5.5 – Paint Production in Portugal by Paint Type in ton/yr (1997-2003)

Type	Polimer	1997	1998	1999	2000	2001	2002	2003
Water	Acrylic & Vinyl	89	103		102		113	118
	Alkyd & Other	371	585	99 909	718	108 629	530	431
	Other	3	0	41	0	6	4	2
Solvent	Other	1 397	1 639	671	1 883	1 872	2 084	2 296
	Acrylic & Vinyl	136	562	535	546	572	635	698
	Acrylic & Vinyl Low solvent	743	2 089	2 476	2 335	2 707	3 068	3 428
	Alkydic	12						
	Celulosic	984	12 131	11 050	13 269	12 549	12 661	12 772
	Poliester	4 367	4 401	3 971	3 144	3 167	2 903	2 640
Oil	Other	1 849	2 873	3 620	4 247	3 792	4 096	4 400
		13						
		171	13 515	14 840	12 953	14 928	15 589	16 250
Powder		430	423	539	556	588	612	647
		3 618	3 843	4 706	5 846	5 759	6 004	6 392
	Other	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 5.6 and Table 5.7, respectively for imports and exports.

Table 5.6 – Import of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Water	Acrylic & Vinyl	538	957	1 705	907	2 760	3 411	3 262	2 696	3 081	2 240	1 983
	Alkyd & Other	1 204	1 731	1 789	2 151	3 357	6 493	7 924	8 661	9 066	8 751	10 104
Solvent	Other	78	78	80	102	1 365	440	568	424	359	462	383
	Acrylic & Vinyl	1 036	920	970	3 007	4 129	4 597	5 948	4 526	6 339	5 331	6 031
	Acrylic & Vinyl Low solvent	890	1 302	1 695	2 298	3 010	3 560	3 274	4 235	4 956	5 059	6 301
	Polyester	3 813	5 098	5 523	5 509	7 169	6 345	6 638	8 165	7 796	9 966	10 229
Oil	Alkyd, celulosic & other	91	141	326	199	148	223	216	264	291	234	157
	Other	31	111	123	257	48	15	17	11	24	186	247

Source: INE;

Table 5.7 – Export of Paints in Portugal by Paint Type in ton/yr (1990-2000)

Paint	Polymer	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Water	Acrylic & Vinyl	387	519	858	424	519	103	435	492	183	419	503
	Alkyd & Other	783	963	1 206	980	1 439	2 020	1 717	2 547	2 082	3 396	4 649
Solvent	Other	0	1	3	2	1	1	1	2	3	0	4
	Acrylic & Vinyl	2 084	2 289	1 659	1 579	1 399	806	1 343	1 126	1 606	1 089	856
	Acrylic & Vinyl Low solvent	908	1 085	761	705	2 658	3 228	5 342	4 439	8 464	7 055	6 755
	Polyester	499	395	663	840	808	1 707	3 538	2 829	1 972	1 482	794
Oil	Alkyd, celulosic & other	91	516	341	523	610	468	157	213	140	316	91
	Other	31	158	32	113	275	242	107	266	39	45	90

Source: INE;

Hence, total consumption of paints was calculated from 1990 and 2000, and the resultant time series is presented in Table 5.8, Table 5.9 and in Figure 5.4. Values for 2001 to 2003 result from forecasts made at IA from the available time series of paint consumption.

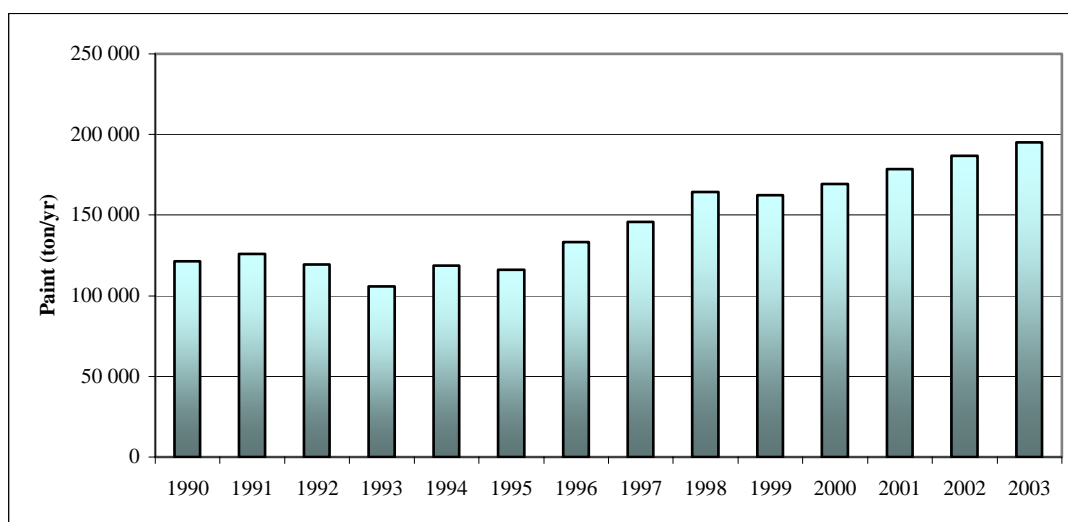
Table 5.8 –Estimated total consumption of Paints in Portugal by Paint Type (1990-1996)

Type	Polymer	1990	1991	1992	1993	1994	1995	1996
Water	Acrylic & Vinyl	151	438	77 658	65 196	74 616	70 233	83 520
	Alkyd & Other	78 800	82 388	826	1 311	2 036	4 593	7 401
Solvent	Acrylic & Vinyl	78	77	326	149	1 388	514	701
	Acrylic & Vinyl Low solvent	0	0	0	1 428	2 730	3 853	5 043
	Polyester	0	217	3 090	3 280	1 667	1 222	0
	Alkyd, celulosic & other	24 873	25 286	34 473	29 503	31 187	29 138	32 412
Oil	-	14 363	13 601	122	0	33	457	433
Powder	-	2 069	2 542	2 896	2 889	3 269	3 747	3 618
Other	-	1 037	1 436	48	2 164	1 939	2 271	0
Total	-	121 371	125 984	119 438	105 920	118 866	116 029	133 129

Table 5.9 –Estimated total consumption of Paints in Portugal by Paint Type (1997-2003)

Type	Polymer	1997	1998	1999	2000	2001	2002	2003
Water	Acrylic & Vinyl	91 575	106 483	101 730	104 198	111 204	116 218	121 232
	Alkyd & Other	7 514	8 624	6 067	7 337	9 780	10 720	11 660
Solvent	Acrylic & Vinyl	558	918	996	925	1 057	1 124	1 191
	Acrylic & Vinyl Low solvent	4 142	6 821	6 718	7 510	8 781	9 688	10 594
	Polyester	1 646	0	1 624	3 794	1 392	1 307	1 223
	Alkyd, celulosic & other	35 857	35 871	38 345	38 801	38 948	39 946	40 945
Oil	-	547	514	699	554	780	861	942
Powder	-	3 843	4 706	5 846	5 759	6 004	6 392	6 781
Other	-	39	343	406	576	576	576	576
Total	-	145 721	164 281	162 433	169 453	178 521	186 833	195 145

Figure 5.4 - Total consumption of Paints in Portugal (1990-2003)



Finally total consumption of paint was disaggregated by the economic activity where the paint is used. In first place, from IAIT and IAIP industrial surveys, it was possible to determine consumption of coating materials per economic activity but only for the industry sector: results

from IAIT and IAPI are presented in Table 5.10 and Table 5.11. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction<sup>97</sup>, as well as all use of oil and powder paints.

Table 5.10 - Paint and varnish consumption in industrial activities (1990-1996)

Economic Activity	Paint type	1990	1991	1992	1993	1994	1995	1996
Wood	Water	15	13	97	182	266	681	783
Plastic, cables		8	19	1 026	2 033	3 040	2 449	2 881
Glass and Ceramics		31	33	22	11	0	0	0
Metalic Equipment and furniture		0	0	0	0	0	0	0
Vehicles		0	0	0	0	0	0	0
Other machinery		35	33	22	11	0	2	46
Domestic, Serv. and Construction		78 862	82 728	77 317	64 271	73 347	71 694	87 211
Wood	Solvent	0	0	0	0	0	0	0
Plastic, cables		0	0	0	0	0	0	0
Glass and Ceramics		0	0	0	0	0	0	0
Metalic Equipment and furniture		838	996	664	332	0	0	1
Vehicles		1 581	1 242	836	430	24	28	630
Other machinery		476	444	1 936	3 428	4 920	5	12
		22 056	22 898	34 453	30 170	32 029	34 695	37 514
Domestic, Services and Construction	Oil	14 363	13 601	122	0	33	457	433
	Powder	2 069	2 542	2 896	2 889	3 269	3 747	3 618
	Other Paints	1 037	1 436	48	2 164	1 939	2 271	0

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by IA

Table 5.11 - Paint and varnish consumption in industrial activities (1997-2003)

Economic Activity	Paint type	1996	1997	1998	1999	2000	2001	2002	2003
Wood	Water	783	887	794	887	1 047	1 205	1 321	1 436
Plastic, cables		2 881	230	337	597	625	1 180	1 176	1 172
Glass and Ceramics		0	0	64	61	161	82	90	98
Metalic Equipment and furniture		0	0	0	0	0	0	0	0
Vehicles		0	0	0	0	0	0	0	0
Other machinery		46	53	84	92	93	89	97	104
Domestic, Serv. and Construction		87 211	97 920	828	106 161	609	118 428	124 255	130 082
Wood	Solvent	0	0	0	0	0	0	0	0
Plastic, cables		0	0	0	0	0	0	0	0
Glass and Ceramics		0	0	0	0	0	0	0	0
Metalic Equipment and furniture		1	1	3	36	34	34	34	34
Vehicles		630	690	735	685	1 874	799	800	800
Other machinery		12	11	16	16	23	23	23	23
		37 514	41 501	42 857	46 946	49 099	49 321	51 209	53 096
Domestic, Services and Construction	Oil	433	547	514	699	554	780	861	942
	Powder	3 618	3 843	4 706	5 846	5 759	6 004	6 392	6 781
	Other Paints	0	39	343	406	576	576	576	576

Source: consumption in industrial activities from INE; Consumption in domestic, services and construction estimated by IA

## UNCERTAINTY ASSESSMENT

The uncertainty factor of the emission factor for NMVOC and CO<sub>2</sub> expresses the uncertainty of the solvent content of paints. From the information that was collected from national suppliers of paint the error for water based paints was estimated to be 350% and the error for solvent based paints is 67%. The overall uncertainty value for CO<sub>2</sub>/NMVOC emission factor is therefore calculated to be 261% for all uses of paint.

<sup>97</sup> No further desegregation by this uses is possible from available statistical information

There is a great uncertainty associated with the activity data due to the fact that was estimated at IA from production data and importation and exportation. An overall uncertainty value of 30% may be assumed.

## RECALCULATIONS

No substantial modifications have been made in emission estimates from this source sector since last year's submission.

## FURTHER IMPROVEMENTS

In future, particularly after 2007, emissions factors must take account of the procedures set in each economic sector for the reduction of NMVOC emissions from paint use, including the control of the solvent content of paint and varnishes. In fact nowadays some control measures and low solvent content paints are already being applied in some economic activities - for instance in the car building industry – but no comprehensive information allows introduction of this level of detail in emission estimates. Therefore, efforts will be done in order that more detailed information from these sectors is collected and incorporated in the emission inventory.

### 5.3.B Degreasing and dry cleaning (CRF 3B)

#### 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>98</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.

#### METHODOLOGY

Assuming that all solvents consumed during degreasing and dry-cleaning evaporate, NMVOC emission will be equal to the amount of solvents used. If it is considered that annual consumption of solvents in an economic activity is used to replenish the quantity of solvent that was lost, then annual NMVOC emissions may be estimated from the annual consumption of solvent. This methodology overcomes the need of being aware of the portion of solvent that is recovered.

In the case of the dry-cleaning activity it was assumed that either the solvent is lost directly to atmosphere, or if it is conveyed to water or retained in clothes, but it will eventually reach atmosphere by evaporation.

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several authors (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

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<sup>98</sup> Emissions from degreasing in this industry are included under rubber processing

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).

### ACTIVITY DATA

Statistical information concerning total solvent use, from the National Statistics Institute (INE), was used to estimate VOC emissions. Consumption of solvents, presented in Table 5.12, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT statistical survey.

Table 5.12 - Solvent use in degreasing operations in metal and plastic industries (ton)

Sub-Sector / Year	1990	1991	1992-2003
Metal Degreasing	1 552	1 415	1 484

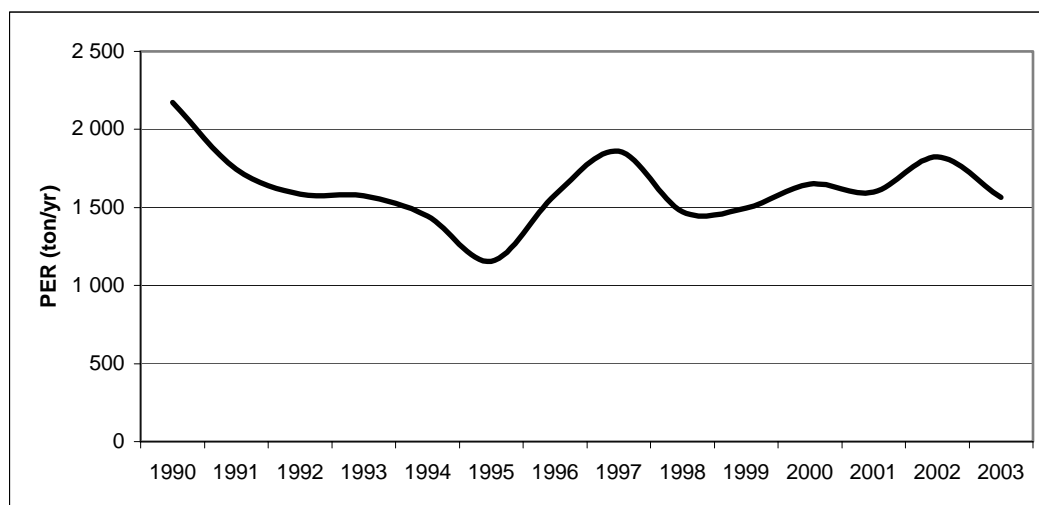
Source:IAIT industrial survey (INE)

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>99</sup> imported to Portugal is used in dry-cleaning<sup>100</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 2003, was therefore assumed as equal to solvent use. The full time series is presented in Figure 5.5.

<sup>99</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>100</sup> There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

Figure 5.5 – Annual importation/ consumption of PER (Tetra-chloro-ethylene) in Portugal (ton/yr) 1990-2003



Source: INE;

## UNCERTAINTY ASSESSMENT

The time trend of activity data for metal degreasing is very incomplete and an uncertainty of 100% was considered. Because emissions from PER use in dry cleaning were established from importation of this product the error is mostly due to incorrect allocation of emission, i.e. considering in dry cleaning a fraction of PER emissions that were realized in fact in other industrial activity. The final effect in inventory totals is therefore not significant and an error of 10% was used (USEPA,1981). The uncertainty of emissions from both sectors are fully considered under activity data.

## RECALCULATIONS

No changes were made in emission estimates from this source sector since last submission.

## FURTHER IMPROVEMENTS

A better knowledge of this sector should be achieved, namely to verify if other solvents are also used and in which quantities. Alternative methodologies, based on washed cloths and type of cleaning equipment should be also done, and results compared to the estimates that are now reported.

## 5.3.C Chemical products, manufacture and processing (CRF 3C)

### 5.3.C.1 OVERVIEW

This source sub-category comprehends several emission sources that are related to industrial processes involving manipulation of polymer. Although emissions for this source result mostly from the use of solvents, which are used as diluters or cleaning agents, some emissions result also from monomers leakage from the polymer, which means that these emissions should in fact be quantified under Production Processes. Nevertheless it was decided to include all those emissions here for simplicity in reporting and because it is not always possible to distinguish the part that is solvent from the part that has resulted from evaporation of monomers or from the degradation process of materials.

### 5.3.C.2 METHODOLOGY

Emissions were estimated by the use of emission factors that are multiplied by the quantity of material produced:

$$Emi_{NMVOC} = EF * Activity_{Rate} * 10^{-3}$$

where

$Emi_{NMVOC}$  - annual emission of NMVOC (ton/yr);

$Activity_{Rate}$  - Indicator of activity in the production process. Quantity of product produced per year as a general rule for this emission source sector (ton/yr);

EF - emission factor (kg/ ton)

It was assumed that NMVOC result mostly from solvents and that they have fossil origin, therefore contributing fully to ultimate carbon dioxide emissions. Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 85% of carbon:

$$Emi_{CO_2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

### 5.3.C.3 POLYMER PROCESSING

Processing of polymers to produce plastic materials involve organic compounds emission to atmosphere resulting from leakage of some monomers still present in the polymer mass, some polymer decomposing, evaporation of additives - such as phthalic anhydride - but mostly from solvents used in the production process.

Synthetic fiber production emits non-methane volatile organic compounds that result from solvent use, for example to dissolve the polymer prior to extrusion.

Emissions from foam blowing result from the application of hydrocarbons as blowing agents which are used as CFC substitutes.

#### ACTIVITY DATA

Information about activity data for this sector is scarce and limited to year 1990, from National Statistics Institute (INE). However, because some polymers and fibers are produced in a restricted number of industrial units, confidentiality constraints avoid their publication in NIR.

#### EMISSION FACTORS

Emission factors applied to polymer processing and fiber production were set from AP42 (US-EPA), and from CORINAIR/EMEP, and are presented in next table:

Table 5.13 – Emission factors of NMVOC from Polymer Processing

Material	Polymer	NMVOC
Synthetic Fibers	Rayon	0.8 <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>
	Vynion	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) c06s09; (b) Rentz et al, 1993 in EMEP/CORINAIR 3<sup>rd</sup> ed (File B633); (c) Achermann, 1992 in EMEP/CORINAIR 3<sup>rd</sup> ed (File B633)

## UNCERTAINTY ASSESSMENT

The uncertainty in activity data was considered high, 100%, expressing the reduced number of available years. Although an uncertainty of 50% could be considered for NMVOC/CO<sub>2</sub> emission factors, considering that quality rate is mostly C in original bibliographic references, the double of that value was assumed using a conservative approach and reflecting the difficulties in making a direct match between the conditions that emission factors apply and the conditions that prevail in national industry.

### 5.3.C.4 RUBBER PROCESSING

#### METHODOLOGY

Assuming that all solvents consumed during rubber processing evaporate, NMVOC emission will be equal to the amount of solvents used. This procedure could be used to estimate emissions for years 1990 and 1991. However, because statistical data on solvent consumption in this sector is not available beyond year 1992, NMVOC emissions had to be estimated from quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = \text{Solvent (y)} = \sum_p [S_{Fac(p)} * ProC_{RUBBER(p,y)}] * 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$  – NMVOC total emissions from rubber processing (ton/yr);

$\text{Solvent (y)}$  – 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;

$ProC_{RUBBER(p,y)}$  – Production of rubber product p in year y. Units vary according to product either number/yr to ton/yr.

#### EMISSION FACTORS

The emission factor, or solvent use factor, that was used to estimate solvent consumption after 1992 was derived from the statistical information available from IAIT for this sector for years



1989 to 1991, which is reproduced in Table 5.14. From the several materials that were consumed in this activity only Benzene and Gasoline were considered solvents and prone to evaporation.

Table 5.14 – Statistical information used to establish solvent use factors in the rubber processing industry, in Portugal

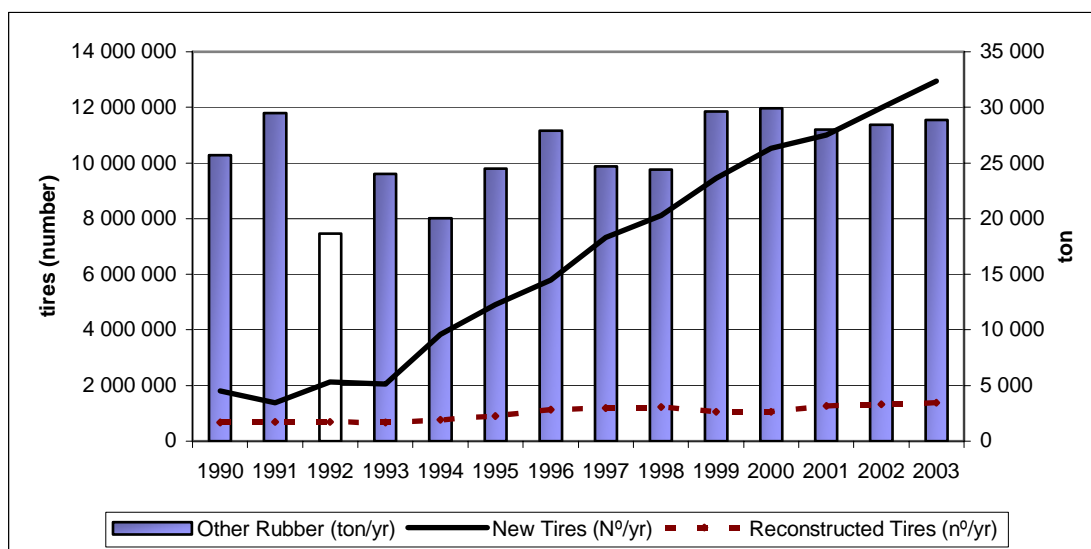
Product	Unit	1989	1990	1991	SFac
New Tires	nº	4 201 941	1 796 201	1 378 575	
Reconstructed Tires		969 972	663 772	689 342	
Other rubber products	ton	19 272	25 687	29 502	
New Tires	ton of	615	312	155	
Reconstructed Tires	solvent	11 579	11 180	12 851	
Other rubber products		766	285	244	
New Tires	kg/Tire	0.146	0.174	0.112	0.143
Reconstructed Tires		12	17	19	18
Other rubber products	kg/ton	40	11	8	10

Source: Production and use of solvent from INE – IAIT industrial survey.

## ACTIVITY DATA

Production data of rubber artefacts, including tires and tire reconstruction, was available from the IAIT and IAPI industrial surveys from INE. The aggregated values, collected from original INE's database, are reported in Figure 5.6.

Figure 5.6 - Processed rubber products in Portugal (1990-2003)



Source: INE (1990-2000); IA's forecasts thereafter

## UNCERTAINTY ASSESSMENT

The uncertainty in activity data seems comparatively small and a value of was used. There is however a great uncertainty in the country-specific emission factors, particularly the high levels of consumption of solvent for each tyre reconstructed. Consequently an order of magnitude was attributed to uncertainty of emission factors.

## RECALCULATIONS

No modifications were made in this source sector since last submission.

### 5.3.C.5 PAINTS MANUFACTURING

#### ACTIVITY DATA

Production of paints and varnish in Portugal was already presented in chapter 5.2 – Paint Application.

#### EMISSION FACTORS

The USEPA (1983) emission factor was used - 15 kg for each tone of paint or varnish manufactured, that includes emissions during cleaning of installations and applies to production of all coating materials. This emission factor was applied to the total value of paint and varnish produced in Portugal irrespective of type.

#### UNCERTAINTY ASSESSMENT

An uncertainty of 10% was considered for the activity data, a higher accuracy for production when in comparison to consumption. In the original document the emission factors are reported to have a C rate quality, which translated in uncertainty value represents 50 %.

## RECALCULATIONS

No modifications were made in this source sector since last submission.

### 5.3.C.6 INKS MANUFACTURING

#### ACTIVITY DATA

Statistical data of annual production of inks in Portugal is available from IAIT and IAPI industrial surveys (INE), for years 1990 though 2000. Linear forecast values were considered for subsequent years. Production of inks is presented in Table 5.15 and Table 5.16 by ink type.

Table 5.15 – Production of inks in Portugal, by type of ink (ton/yr) (1990-1996)

Ink	1990	1991	1992	1993	1994	1995	1996
Lithographic	1 122	1 064	135	45	69	60	448
Newspaper ink	318	185	0	0	0	0	0
Rotogravure	654	406	0	0	0	0	0
Flexography	880	999	119	119	907	084	025
Serigraphy	31	26	0	0	0	0	0
Drying by physical reaction	482	462	0	0	0	0	0
Other	40	51	99	47	50	22	109
<b>Total</b>	<b>3 528</b>	<b>3 193</b>	<b>353</b>	<b>212</b>	<b>027</b>	<b>166</b>	<b>582</b>

Source: INE (1990-2000); Forecast by IA (2001-2002)

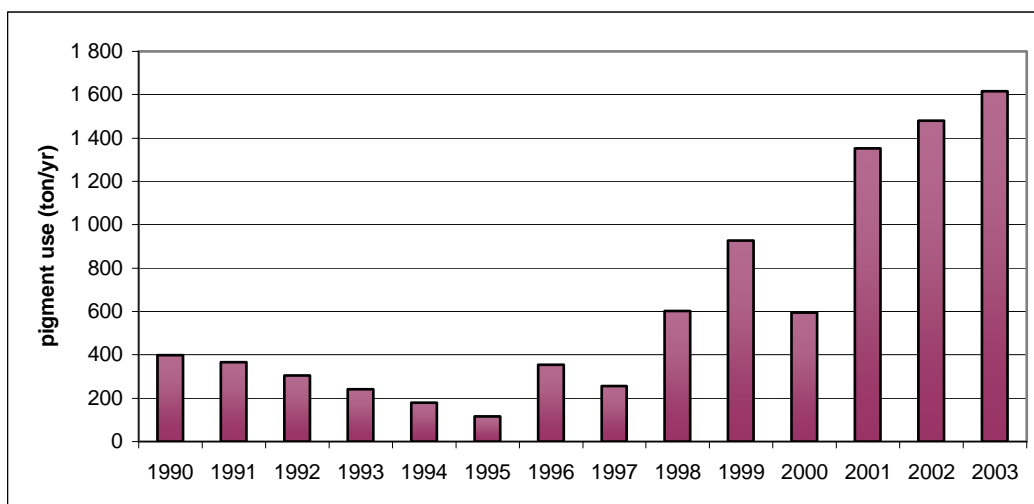
Table 5.16 – Production of inks in Portugal, by type of ink (ton/yr) (1997-2003)

Ink	1997	1998	1999	2000	2001	2002	2003
Lithographic	272	266	213	175	175	175	175
Newspaper ink	0	0	0	0	0	0	0
Rotogravure	0	0	0	0	0	0	0
	1	2	1	3	2	2	3
Flexography	928	039	663	008	640	857	073
Serigraphy	0	0	0	1	1	1	1
Drying by physical reaction	0	0	0	0	0	0	0
Other	17	11	0	82	82	82	82
	2	2	1	3	2	3	3
<b>Total</b>	<b>216</b>	<b>316</b>	<b>875</b>	<b>266</b>	<b>899</b>	<b>115</b>	<b>331</b>

Source: INE (1990-2000); Forecast by IA (2001-2002)

Use of pigments in ink production was also available from INE's database. Total pigment consumption is presented in Figure 5.7.

Figure 5.7 – Total pigment consumed in ink manufacturing in Portugal from 1990 to 2003



Source: INE

## EMISSION FACTORS

The NMVOC emission factor that was used, 60 kg for each tone of ink manufactured, refers to vehicle coking and applies to general ink type, is from USEPA (1983).

Particulate emissions during ink manufacturing were also estimated using an emission factor of 1 kg/ton pigment used (USEPA,1983).

## UNCERTAINTY ASSESSMENT

An uncertainty of 10% was considered for the activity data. In the original document the emission factors are reported to have a E rate quality, which translated in uncertainty value represents 1000 %.

## RECALCULATIONS

No modifications were made in this source sector since last submission.

### 5.3.C.7 GLUES MANUFACTURING

#### ACTIVITY DATA

Production of glues and adhesives in Portugal is available in Portugal for years 1990 and 1991 from INE. Average values were considered for subsequent years. Production of glues and adhesives is reported in chapter 5.5.

#### EMISSION FACTORS

The CORINAIR emission factor was adopted - 20 kg for each tone of glues and adhesives manufactured, which is applied to all kind of glues and adhesives, with or without solvents in their composition, and includes the cleaning of industrial installations.

#### UNCERTAINTY ASSESSMENT

An uncertainty of 100% was considered for the activity data, considering the lack of information, only available to some restricted years, to build a reliable time-series.

A high uncertainty in the emission factor lead, in similarity to what was done for inks manufacturing, to the choice of a uncertainty value of 1000 %.

## RECALCULATIONS

No modifications were made in this source sector since last submission.

### 5.3.D Other use of solvents and related activities (CRF 3D)

#### 5.3.D.1 OVERVIEW

In this chapter are included emission calculations for different activities, such as:

- 1) printing;
- 2) edible and non edible oil extraction;
- 3) use of glue and adhesives;
- 4) preservation of wood;
- 5) other solvents use;
- 6) use of perfume;
- 7) use of waxes and polishing products;
- 8) use of soaps and detergents.

### 5.3.D.2 PRINTING

#### OVERVIEW

Printing involves the application of an ink to several materials by presses, the most common of which is paper, but also cardboard, wood, plastics and metallic artifacts are subjected to this process. Emissions are very dependent of the printing technology because it (i.e., the type of press equipment) dictates the types of inks and coatings – and its solvent content - that can be used and defines, to a large extent, the emissions and the control techniques that are applicable (USEPA,1985). The following technologies are available:

- Lithography: the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellent to ink, by action of a dampener. In offset lithography the image is applied to a rubber-covered blanket cylinder and then transferred onto the substrate. This technique dominates the production of books and pamphlets and has been used increasing in newspapers;
- rotogravure: uses cylindrical image carrier, where the printing area is below the non printing area. The low relive is filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder. Used mostly in packaging, advertising, greeting cards, art books, catalogues, and directories;
- flexography: the image carrier, made of rubber or elastic photopolymers on which the printing areas are above the non printing areas. Used mostly in packaging, advertising newspapers, books, magazines, financial and legal document and directories;
- letterpress: similar to flexography, it uses a relief printing plate, but these plates differ from flexographic plates in that they have a rigid backing and are not "flexible." Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to non-heatset web offset;
- screen: the ink is passed onto the surface to be printed by forcing it through a porous image carrier (stencil), in which the printing area is open and the non-printing area is sealed off. It is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles;
- plateless: Images printed on paper by laser printers, photo copiers, fax machines, and ink jets

NMVOC emissions from printing result from the evaporation of solvents that are components of the ink or that are added (dilution) just prior to printing activities. Emissions may also result from the use of cleaning products and dampeners. Emissions may occur during drying at air or at ovens (heat set).

#### METHODOLOGY

$$Emi_{NMVOC(a,p,y)} = \sum_p \sum_t \sum_i [EF_{(i)} * INK_{CONS(p,i,t,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(y)}$  – NMVOC emissions resulting from printing activities during year y (ton/yr);

$\text{Ink}_{\text{CONS}(p,i,t,y)}$  – Use of ink  $i$  for printing product  $p$  using technology  $t$  during year  $y$  (ton coater/yr);

$\text{EF}_{(p)}$  – Emission Factor (solvent content) of ink  $i$  (kg/ton).

Ultimate  $\text{CO}_2$  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  $\text{CO}_2$  emissions are included in the inventory.

$$U_{\text{CO}_2} = 44/12 * \text{NMVOC} * 0.85$$

where:

$U_{\text{CO}_2}$  - Ultimate  $\text{CO}_2$  (ton/yr);

NMVOC - Global emissions of NMVOC (ton/yr).

### EMISSION FACTORS

NMVOC emission factors reflect solvent content of ink, assuming that all solvents contribute to volatile organic compounds, and that control equipment for emissions are not widespread and representative. Solvent content of ink are from USEPA (1981) and are presented in Table 5.17<sup>101</sup>.

Table 5.17 – Solvent content and emission factors used in Printing Industry (kg/ton ink consumed)

Product	Technology	Solvent Content ok ink (%)	density of solvent (kg/l)	EF kg/ton ink
Newspaper	Web Offset Lithography	5	0.74	37
	Letterpress	0		0
Books	Web Offset Lithography	40		297
Publications	Rotogravure	75		557
Packaging	Flexography	75		557
Artifacts	Flexography	75		557
Other		-		334

Source: USEPA (1981)

### ACTIVITY DATA

Consumption of inks in printing industry according to printing product is available from IAPI industrial survey, for years 1995 to 2000, from the INE's statistical database, which is summarized in Table 5.18.

<sup>101</sup> USEPA (1981) differentiates emissions during printing from those remaining in product. In the Portuguese inventory all solvents are assumed to emit NMVOC

Table 5.18 – Consumption of inks in industry by press product (ton/yr)

Industry	Product	1995	1996	1997	1998	1999	2000
Press	Newspaper	908	662	566	514	568	567
	Books	105	139	171	256	191	146
	Magazines & Other	19	24	16	57	109	146
	Packaging	1 062	1 228	1 280	1 234	1 350	1 646
	Other	2 513	3 113	3 312	3 548	3 822	4 003
Textile industry		0	0	0	0	0	58
Other	Artefacts	766	1 522	1 685	1 877	1 965	2 330

Source: IAPI, INE

Original data allows that total consumption of inks – but not its type – be divided by printing products. Data printing activities in other economic activities – metallic industry, plastic industry, ceramic and - is also included. Some assumptions were made concerning what technology was used for each press product, i.e.:

- newspapers are printed using web letterpress or web offset lithography, according to national sales of ink;
- books printing uses lithography;
- Magazines and other publications use rotogravure;
- Packages and metallic, plastic and other artefacts use flexography;
- serigraphy technology is used in textile processes.

For years in the period from 1990 to 1994, consumption of inks had to be estimated from national production and external trade, which is presented in Table 5.19, and according to:

$$\text{Total}_{\text{Cons}(y)} = \text{Production}_{(y)} + \text{Imports}_{(y)} - \text{Exports}_{(y)}$$

where:

$\text{Total}_{\text{Cons}(y)}$  - Total consumption of inks in year y (ton/yr);

$\text{Production}_{(y,p)}$  - National Produced inks in year y (ton/yr);

$\text{Imports}_{(y,p)}$  - Imported inks in year y (ton/yr);

$\text{Exports}_{(y,p)}$  - Exported quantity of inks in year y (ton/yr).

Because external trade classifies inks in a single class, the more detailed desegregation of inks, available for production of inks (Chapter 5.2.3), could not be used, and only total ink consumption could be assessed. The same proportion of technologies/products in 1995 was used to separate total inks consumption for the years between 1990 and 1994.

Table 5.19 - Production and External Trade of inks in 1990-1994 (ton)

Year	1990	1991	1992	1993	1994
National Production	3 528	3 193	353	212	1 027
Importation	1 481	1 745	2 705	2 720	3 051
Exportation	65	71	58	34	35
Consumption	4 944	4 868	3 000	2 898	4 044

Source: INE

Final consumption of inks per technology type is synthesized in Table 5.20 and Table 5.21. Values for 2001 and 2002 are forecasts made by IA from the previous time series.

Table 5.20 – Consumption of inks by printing technology and press product (1990-1996)

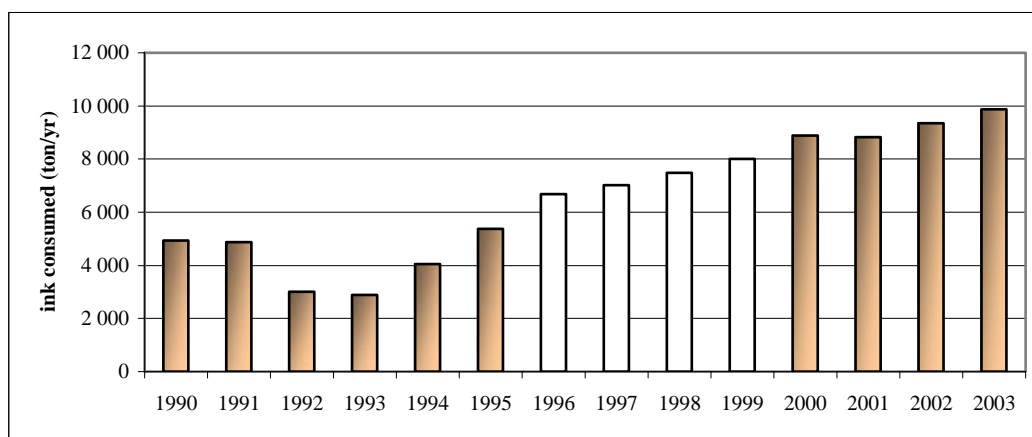
Technology	Product	1990	1991	1992	1993	1994	1995	1996
Web Offset Lithography	Newspaper	701	691	426	411	574	762	548
Letterpress		3	3	2	2	3	4	5
Web Offset Lithography	Books	100	98	60	58	81	108	141
Rotogravure	Publications	18	18	11	11	15	20	24
Flexography	Packages	1 008	993	612	591	825	095	250
Flexography	Artifacts	727	716	441	426	595	790	550
Serigraphy	Fabric	0	0	0	0	0	0	0
Total		4 944	2 386	2 350	1 448	1 399	1 952	2 593

Table 5.21 – Consumption of inks by printing technology and press product (1997-2003)

Technology	Product	1997	1998	1999	2000	2001	2002	2003
Web Offset Lithography	Newspaper	467	422	466	465	430	412	394
Letterpress		3	11	21	27	20	22	24
Web Offset Lithography	Books	174	259	193	147	211	225	239
Rotogravure	Publications	16	58	110	147	105	115	126
Flexography	Packages	1 299	1 249	1 364	1 661	1 550	1 627	1 704
Flexography	Artifacts	710	899	986	351	350	541	733
Serigraphy	Fabric	0	0	0	59	21	24	27
Total		3 170	3 361	3 589	3 864	4 039	4 153	4 388



Figure 5.8 – Total inks consumption in Portugal (1990-2003)



### UNCERTAINTY ASSESSMENT

It was considered that the activity data time trend have a medium quality due to the use of different sources of information for its determination. An overall uncertainty of 25% was considered. Concerning the emission factor for CO<sub>2</sub>, or NMVOC, the original emission factors had quality rates that varied from B to C and, therefore, the worst case uncertainty of 50% was considered, in conservative way.

### RECALCULATIONS

No modifications were made to estimates of this source sector.

### FURTHER IMPROVEMENTS

Although this source sector has suffered extensive modifications, efforts must continue in order to ameliorate emission estimates for this sub-source category. Key aspects are the improvement in consistency in the activity data time series and a better knowledge of printing processes that are used for each press product.

### 5.3.D.3 EDIBLE AND NON EDIBLE OIL EXTRACTION

#### OVERVIEW

This sub-source comprehends emissions of NMVOC from extraction of edible and non-edible oils from seeds.

Extraction of oil in Portugal may be made using mechanical processes or solvent based processes. Mechanical processes, using presses, are used to extract first olive oil from olives<sup>102</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.

<sup>102</sup> Classified as virgin olive oil

Particulate mater is emitted as result of grain handling, cracking, dehuling 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>103</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 mater emissions are estimated from consumption of grain:

$$Emi_{PM}(y) = EF * Cons_{GRAIN}(y) * 10^{-3}$$

where:

$Emi_{PM}(y)$  - Emissions of PM (ton/yr);

$Cons_{GRAIN}(y)$  - 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

<sup>103</sup> Hexane chemical formula

manufactured. However, from the available data from INE, this emission factor could be only estimated from IAIT industrial survey, i.e. from 1989 to 1991, because solvent consumption is not available from IAPI survey. Statistical information used in actual calculations of annual emission factor are presented in Table 5.22, together with the average emission factor in 1989-1991, value that was used to estimate annual NMVOC emissions for the whole 1990-2002 time period. Because in IAPI survey (1992-2000) it was not possible to distinguish production of edible oils from production of non-edible oils, it was decided just to use a global emission factor.

Table 5.22 – Calculation of the National emission factor for edible and non-edible oils extraction (kg/ton).

Oil Type	Parameter	1989	1990	1991	Average
Edible non-edible sum	Oil refined (ton)	93 401	90 686	107 163	
		113 749	110 883	113 509	
		207 150	201 569	220 672	
Edible non-edible sum	Solvent Use (ton)	2 328	1 763	1 697	
		1 394	1 257	1 408	
		3 722	3 020	3 106	
Edible non-edible sum	Emission Factor NMVOC (kg/ton)	24.9	19.4	15.8	20.1
		12.3	11.3	12.4	12.0
		18.0	15.0	14.1	<b>15.7</b>

The emission factor for Particulate Material, 1.34 g/kg grain handled is from USEPA (1995).

## ACTIVITY DATA

Oil production data was available from INE's industrial surveys: IAIT for 1990 and 1991 and IAPI thereafter until 2000. Production data for 2001, 2002 and 2003 was forecasted at IA from previous years. All annual values are reported in Table 5.23, together with olive oil production, although that product does not cause NMVOC emissions. Total grain processed is also reported in Table 5.23 and Table 5.24. Total extraction of edible and non-edible oil is also shown in Figure 5.9.

Table 5.23 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1990-1996)

Parameter	1990	1991	1992	1993	1994	1995	1996
Olive Oil Production	10 253	9 883	8 368	16 948	25 269	27 691	36 404
Oil refining	201 569	220 672	184 406	161 998	222 430	223 330	208 116
Grain processed	672 382	668 734	662 759	691 625	791 687	1 042 605	969 983

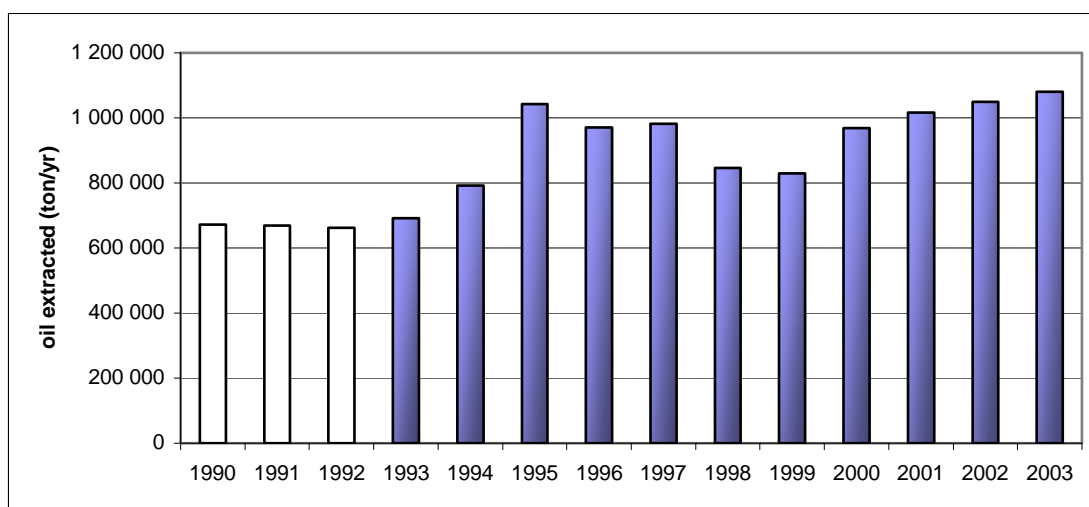
Source: National Statistics Institute (INE)

Table 5.24 - Refining of edible and non-edible oils in Portugal, and consumption of grain (ton) (1997-2003)

Parameter	1997	1998	1999	2000	2001	2002	2003
Olive Oil Production	31 839 174	41 190	46 673	41 912	38 796	NA	NA
Oil refining	686 982	168 580	122 263	136 230	142 748	135 869	128 989
Grain processed	574	846 161	829 526	968 898	1 017 147	1 048 385	1 079 623

Source: National Statistics Institute (INE)

Figure 5.9 – Total edible and non-edible oil extraction in Portugal (ton/yr)



### UNCERTAINTY ANALYSIS

The activity data time trend is reasonably complete and an uncertainty of 10% was considered. The uncertainty of NMVOC/CO<sub>2</sub> emission factor was established by comparison of the emission factors determined from the several available years: 26 %.

### RECALCULATIONS

No modifications were made to estimates of emissions from this source since last submission.

#### 5.3.D.4 GLUES AND ADHESIVES

##### Methodology

$$\text{NMVOC} = \text{Cons}_{\text{Nat}} \times \text{FE}_{\text{Nat}} + \text{Imp} \times \text{FE}_{\text{imp}}$$

where:

NMVOC = Global emissions of NMVOC (ton)

Cons<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:

Cons<sub>Nat</sub> = Consumed Glues and Adhesives produced in Portugal (ton)

Prod<sub>Nat</sub> = National Produced Glues and Adhesives (ton)

Exp = Exported Glues and Adhesives (ton)

### Emission Factors

To estimate the emission factor applied for the use of national glues and adhesives, the ratio of the amount of solvents consumed (Table 5.25 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 5.26). The emission factor for VOC emission from the manufacture of glue and adhesives was subtracted from this value to obtain the emission factors for use of national produced glue and adhesives.

Table 5.25 - Solvents consumption in glue and adhesives manufacture (ton).

	1989	1990	1991
Methyl ketone	361	328	328
Dibutyl phthalate	97	134	143
Ethyl Acetate	373	351	355
Hexane	1 567	1 357	1 277
Benzene	295	354	335
Toluene	1 839	1 690	1 799
Other solvents	1 876	2 010	2 003
<b>Total</b>	<b>6 408</b>	<b>6 224</b>	<b>6 240</b>

Table 5.26 - National emission factors (kg/ton).

	1989	1990	1991	Average
For production and use of glue and adhesives	190	172	175	179
Only for use of glue and adhesives	170	152	155	159

For non-natural imported glues and adhesives the CORINAIR90 Default Emission Factor was used: 600 kg/ton. It is considered that natural based glue does not contribute to NMVOC emission.

**Activity Data**

Table 5.27 - Activity Data for non natural glues and adhesives (ton)

Year	1990	1991	1992 - 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)

**Uncertainty Assessment**

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

**Recalculations**

No recalculations were made for this source sector.

**5.3.D.5 WOOD PRESERVATION****OVERVIEW**

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts and building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

**METHODOLOGY**

$$Emi_{NMVOC(y)} = Consumption(y) * FE_{Consumption}$$

where:

$Emi_{NMVOC(y)}$  - Emissions of NMVOC associated to consumption of wood preservation products (ton)

$Consumption(y)$  - Consumption of wood preservation products (ton)

$FE_{Consumption}$  - Emission factor associated to the consumption of wood preservation products.

**EMISSION FACTORS**

CORINAIR90 Emission Factor Handbook proposes three emission factors for VOC emission from wood preservation, depending on the type of product used. The emission factor is 100 kg/ton of product applied for creosote; 900 kg/ton for solvent based products and 0 for water

based products. The available data do not discriminate the share of the several types of preservation products, therefore, it was assumed that the main product used in Portugal is creosote.

### ACTIVITY DATA

Table 5.28 - Wood preservation products consumption (ton)

Year	1990	1991	1992 - 2002
Wood Preservation products Consumption (ton)	2083	2900	2491

Source: National Statistics Institute (INE)

### UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

### RECALCULATIONS

No recalculations were made for this source sector.

## 5.3.D.6 PERFUMES AND COSMETICS USE

### METHODOLOGY

Perfumes, personal hygiene and cosmetic products. Lipsticks, brilliantine, beauty creams and milks, depilatories, deodorants, hair sprays, sun lotions, tanner products, shampoos, tooth-cleaning, hair coloration and nail varnishes, among others, were considered in perfume, personal hygiene or cosmetic product. Emissions are estimated from:

$$\text{NMVOC} = \text{Use} * \text{FE}_{\text{Prod+use}}$$

where:

NMVOC - Emissions of NMVOC associated to the production and use of perfumes (ton)

Use - Use of perfumes (ton);

$\text{FE}_{\text{Prod+use}}$  - Emission factor associated to the production and use of perfumes (ton)

### EMISSION FACTORS

Since there are no available VOC emission factor for this activity an emission factor for VOC emission during the production and the use of these products was calculated. It was estimated by the ratio of the amount of solvents consumed during the manufacture process with the amount of perfumes, personal hygiene and cosmetic products manufactured.

$$\text{FE}_{\text{Prod+use}} = \text{Solvents} / \text{National Production}$$

where:

$FE_{\text{Prod+use}}$  = Emissions of NMVOC associated to consumption of perfume and cosmetics use (ton)

Solvents = Solvent content of perfumes (ton)

National Production = National production values of perfumes (ton)

Table 5.29 - Calculated emission factor (kg/ton).

1989	1990	1991	Average
162	170	184	172

## ACTIVITY DATA

Table 5.30 - Activity data associated to Perfumes Use (ton)

Year	1990	1991	1992-2002
<b>National Production (ton)</b>	21 587	19 540	20 957
<b>Imports (ton)</b>	10 830	15 210	13 020
<b>Exports (ton)</b>	3 829	4 201	4 015
<b>Solvents (ton)</b>	3 665	3 590	3 595

Source: National Statistics Institute (INE)

## UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

## RECALCULATIONS

No recalculations were made for this source sector.

### 5.3.D.7 WAXES AND POLISHING PRODUCTS

#### METHODOLOGY

The Methodology is similar to the one that was used for Perfume Use.

#### EMISSION FACTORS

The national emission factor, obtained in the same mode, was (kg/ton):

Table 5.31 – Emission factors

1989	1990	1991	Average
525	299	293	372



**ACTIVITY DATA**

Table 5.32- Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2002
<b>National Production (ton)</b>	3 963	3 781	3 312
<b>Imports (ton)</b>	12 390	12 429	12 410
<b>Exports (ton)</b>	983	403	693
<b>Solvents (ton)</b>	1 185	1 106	1 147

Source: National Statistics Institute (INE)

**UNCERTAINTY ASSESSMENT**

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

**RECALCULATIONS**

No recalculations were made for this source sector.

**5.3.D.8 SOAPS AND DETERGENTS****METHODOLOGY**

The Methodology is similar to the one that was used for Perfume Use.

**EMISSION FACTORS**

The national emission factor (kg/ton), obtained in the same mode kg/ton is:

Table 5.33 – Emission factors

1990	1991	Average
2	2	2

**ACTIVITY DATA**

Table 5.34 - Activity data associated to Waxes and polishing products use (ton)

Year	1990	1991	1992 - 2002
<b>National Production (ton)</b>	209 575	185 681	197 628
<b>Imports (ton)</b>	57 488	59 831	58 660
<b>Exports (ton)</b>	34 710	23 972	29 341
<b>Solvents (ton)</b>	461	426	437

Source: National Statistics Institute (INE)

## UNCERTAINTY ASSESSMENT

But activity data and emission factors have a high level of uncertainty and errors were assumed to be 100% in both cases.

## RECALCULATIONS

No recalculations were made for this source sector.

### 5.3.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 5.35, which may be considered, neglecting foreign trades, equal to the consumption of alcohol. Industrial consumption of alcohol in 1989 is shown in Table 5.36 by use. Statistical data is from INE in both cases.

Table 5.35 - Industrial production of ethanol (ton).

1989	1990	1991
7 754	9 941	8 027

Table 5.36 - Industrial consumption of alcohol in 1989 (ton).

Use	ton
Food and beverage industry	2 185
Manufacture of perfumes, personal hygiene and cosmetic products	1 913
Manufacture of waxes and polishing products	235
<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 5.37 and foreign trades values in Table 5.38. Statistical information is from the National Statistical Institute (INE).

Table 5.37- Rosin derivatives production (ton).

1989	1990	1991
13 362	12 145	11 299

Table 5.38 - Foreign trades of rosin derivatives (ton).

<i>Imports (ton)</i>		<i>Exports (ton)</i>	
1990	1991	1990	1991
722	700	11 558	13 692

#### 5.3.D.10 OTHER USES OF SYNTHETIC SOLVENTS FROM FOSSIL FUELS

##### METHODOLOGY

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 5.39 - 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 (DGGE)

**UNCERTAINTY ASSESSMENT**

Activity data is very scarce and doubtful and the overall uncertainty was assumed to be 1000%.

**RECALCULATIONS**

No recalculations were made for this source sector.

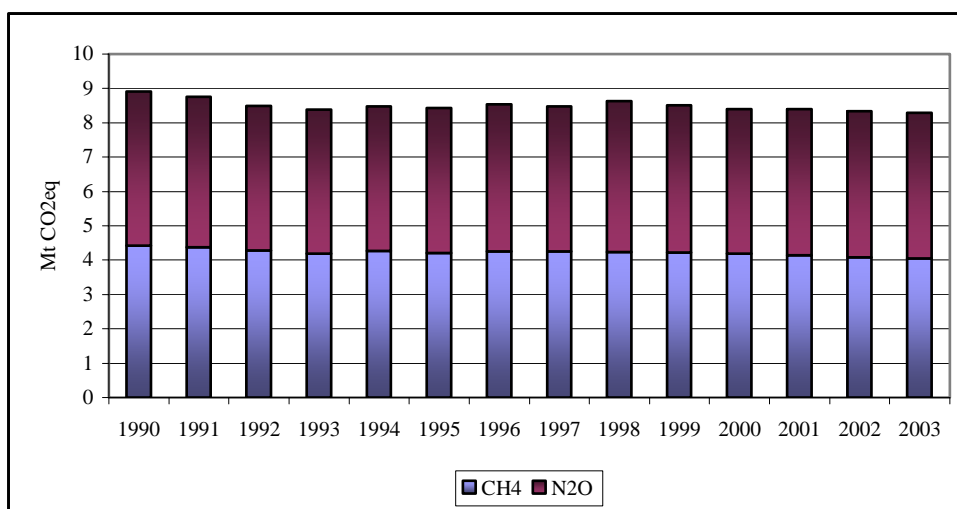
## CHAPTER: 6 AGRICULTURE (CRF 4)

### 6.1 Overview

Agriculture activities generate emissions of GHG from a variety of different sources. This section includes the quantification of: 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 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 sector Energy: Other Sectors (CRF 1A4). Presently there are no estimates for CO<sub>2</sub> release or uptake from soil in cultivated lands.

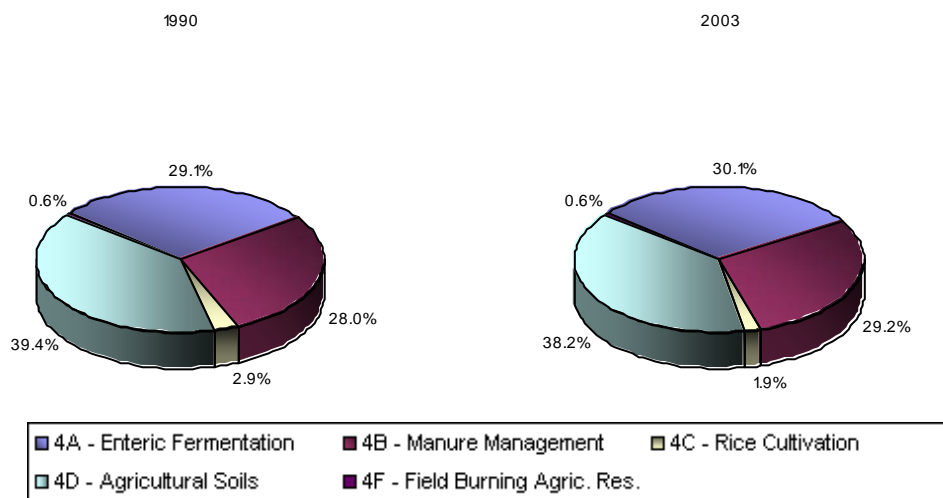
The importance of GHG agriculture emissions to total national emissions (excluding LULUCF and international bunkers) has decreased from 14.9% in 1990 to 10.0 % in 2003. This trend reflects not only a relative decrease but also the occurrence of an absolute reduction in emissions such that emissions from agriculture in 2003 are 7 % lower than emissions from agriculture in 1990: 8.9 Mton of CO<sub>2</sub>eq in 1990 and 8.3 Mton CO<sub>2</sub>eq in 2002 (Figure 6.1). Total GHG emissions show an approximately equal share of methane and nitrous oxide emissions: in 2003 methane emissions were about 49% of total GHG emissions from agriculture.

Figure 6.1 – Total Greenhouse Gas Emissions from Agriculture. Trends by GHG



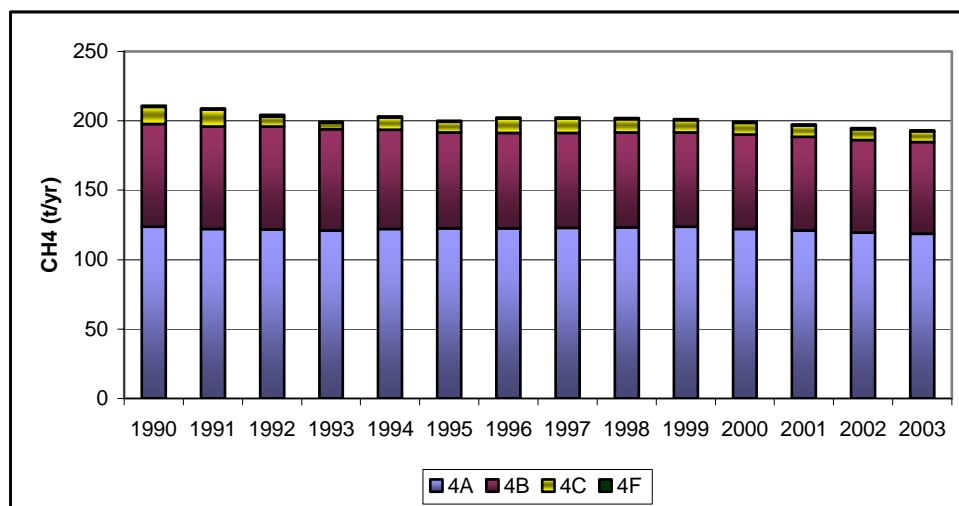
The major part of emissions from agriculture result only from 3 sub-source sectors, approximately with a similar share: Agriculture Soils, Enteric Fermentation and Manure Management (Figure 6.2).

Figure 6.2 - Greenhouse Gas Emissions from Agriculture. Importance of agriculture sub-sectors in 1990 and 2003



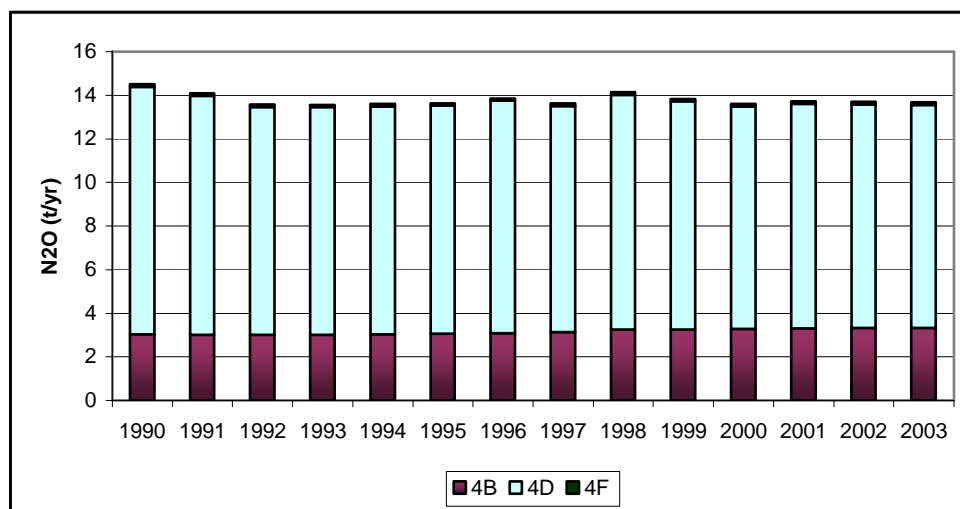
Emissions of CH<sub>4</sub> from agriculture have decreased (8.3 %) from 1990 to 2003 (Figure 6.3). Enteric Fermentation represents, on average in the 1990-2003 period, 60.5 % of the sectoral emissions and Manure Management accounts on average for 34.7 % of the sectoral emissions in the same period. The remaining 4.8 % of emissions result mostly from rice cultivation, with a very small contribution from field burning of residues, which represents only 0.4% of total emissions in the same average period.

Figure 6.3 - Methane emissions from agriculture



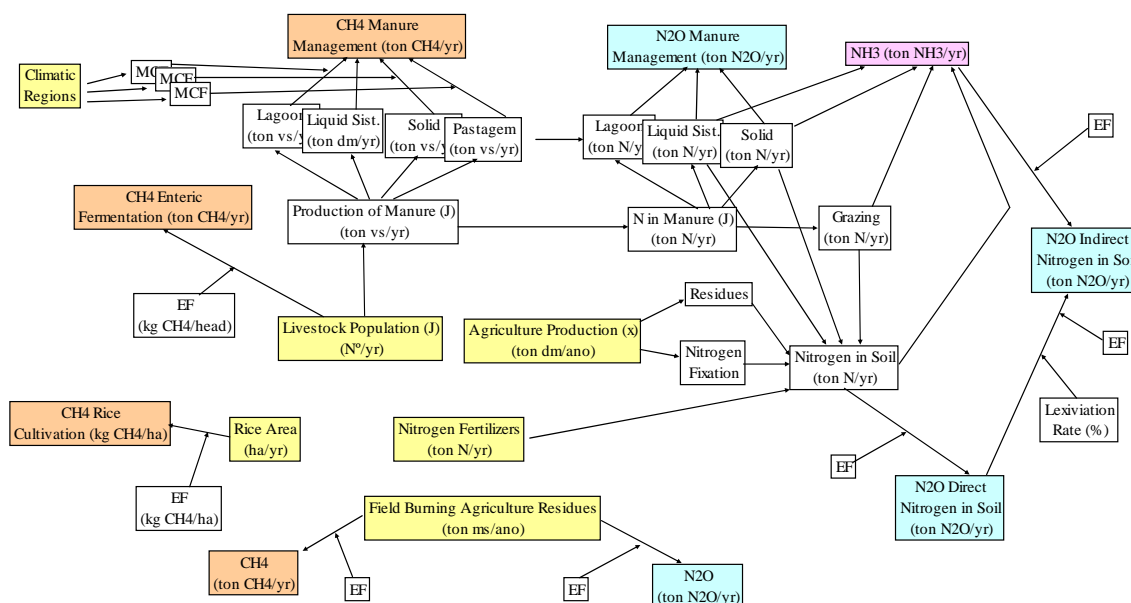
N<sub>2</sub>O emissions were also affected by a similar decrease (5.7%) during the 1990-2003 period (Figure 6.4). The great majority of emissions are associated with direct and indirect emissions from agricultural soils (76.3%), manure management is responsible for 22.9% of emissions, while the small remaining fraction results from field burning of agricultural residues (0.8%).

Figure 6.4 - Nitrous Oxide emissions from Agriculture



Emissions are estimated following as far as possible the methodology recommended by IPCC (1996 Revised IPCC Guidelines and Good Practice Guidebook) and are done in a consistent way: the same activity data is used and balanced for all source categories. A general overview of methodology is presented in Figure 6.5.

Figure 6.5 - Overview of Methodology



It must be emphasized that changes from submission 2004 to submission 2005 were done also in a consistent and coherent way among the several source sectors.

## 6.2 Recalculations

Total GHG emissions have suffered expressive changes since last submission, and efforts have been made, as much as possible, to follow the recommendations of the in-country review and the efforts that are being done under the Methodology Development Plan of the national inventory. Major modification resulted from the use of three year average as activity data for both livestock and crop production. Other significant modifications occurred for CH<sub>4</sub> emissions from manure Management (4B), where climate regions are now considered, and N<sub>2</sub>O from

agricultural soils (4D) (Figure 6.6). More detailed explanation of recalculations will be presented during explanation of each sub-source category.

Figure 6.6 - Differences between submission 2003 and submission 2004 for CH<sub>4</sub> and N<sub>2</sub>O emissions from agriculture REVER

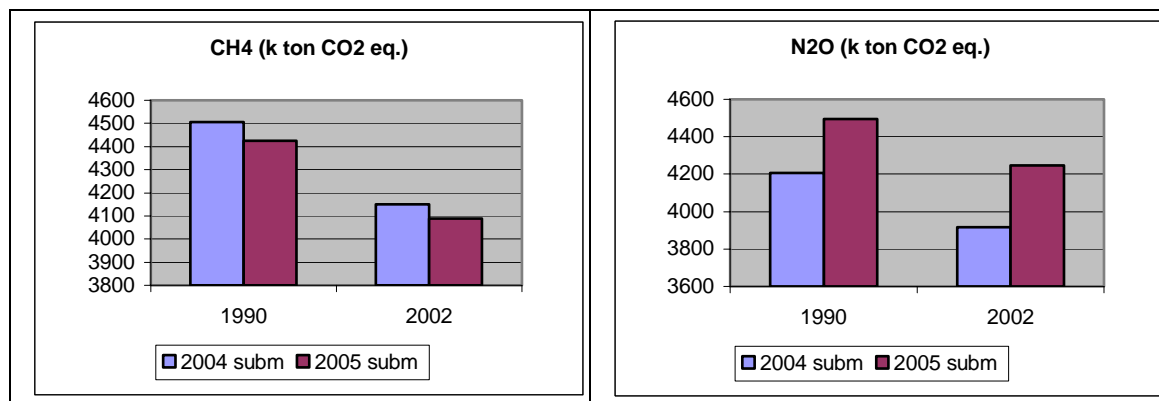


Table 6.1 – Recalculations. Differences between submission 2004 and submission 2005 for the agriculture sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2004 subm.	2005 subm.	Difference (1)	2004 subm.	2005 subm.	Difference (1)	2004 subm.	2005 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>4. Agriculture</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>4 504.86</b>	<b>4 425.76</b>	<b>-1.76</b>	<b>4 206.27</b>	<b>4 494.41</b>	<b>6.85</b>
4.A. Enteric Fermentation	0.00	0.00		2 605.55	2 594.08	-0.44		0.00	
4.B. Manure Management	0.00	0.00		1 625.83	1 558.21	-4.16	945.72	942.95	-0.29
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	3 223.59	3 514.53	9.03
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	17.76	-0.06	36.96	36.93	-0.07
4.G. Other	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
<b>2002</b>									
<b>4. Agriculture</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>4 151.57</b>	<b>4 088.11</b>	<b>-1.53</b>	<b>3 916.47</b>	<b>4 245.87</b>	<b>8.41</b>
4.A. Enteric Fermentation	0.00	0.00		2 515.45	2 504.05	-0.45		0.00	
4.B. Manure Management	0.00	0.00		1 456.88	1 405.46	-3.53	1 038.65	1 034.10	-0.44
4.C. Rice Cultivation	0.00	0.00		161.78	161.78	0.00		0.00	
4.D. Agricultural Soils <sup>(2)</sup>	0.00	NE	0.00	0.00	0.00	0.00	2 841.53	3 176.75	11.80
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		17.45	16.82	-3.64	36.28	35.02	-3.49
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.

## 6.3 Source categories

### 6.3.A CH<sub>4</sub> Emissions from Enteric Fermentation in Domestic Livestock (CRF 4A)

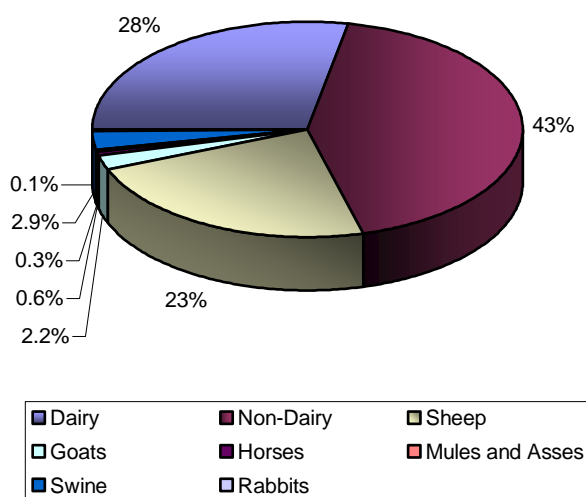
#### OVERVIEW

Methane emissions from enteric fermentation in animals result from this gas being produced as a by-product during the digestive process of carbohydrates by micro-organisms in the digestive system. This process occurs specially in ruminant animals, due to the 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. The share of each animal type is observable in Figure 6.7. Dairy cattle and non-dairy cattle are significant sources: dairy cattle represents 31% to 28% of total CH<sub>4</sub> emissions from Enteric Fermentation, while non-dairy cattle represents about 38% to 43% 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.

Figure 6.7 - Relative Importance of emissions of CH<sub>4</sub> from Enteric Fermentation per each animal specie in 2003



Sheep are also an important source of methane, for which emissions have oscillated between 22% and 23% of total CH<sub>4</sub> from Enteric Fermentation. Emissions from goats were 3.3-2.2% of total enteric fermentation and swine represented 3.2-2.9% of emissions. Total emissions of methane for all other species decreased from 1.6% to 1.0% along 1990 to 2003 and are therefore less important.

## 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<sub>CH<sub>4</sub></sub> - 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.

## EMISSION FACTORS

Emission factors may be seen in Table 6.2. For most species they are the default emission factors proposed by IPCC96 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 GP:

$$EF_{\text{Rabbit}} = [( \text{rabbit weight} )^{0.75} / ( \text{horse weight} )^{0.75} ] \cdot EF_{\text{Horse}}$$

Table 6.2 - 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 IPCC96 for broilers, laying hens, turkeys, ducks, geese, guinea fowl and other poultry, emissions from these classes were not estimated and were assumed as negligible. There are no livestock populations of Buffalo, Camels and Llamas in Portugal.

## ACTIVITY DATA

Annual livestock numbers are available from the statistical databases of the National Statistics Institute (INE) from 1989 to 2003. For cattle, sheep, goats and swine the value that was considered as activity data is the central three year average, i.e: the activity data reported for year n (1990 given as example) is the average of livestock numbers for n-1, n and n+1 (1989, 1990 and 1991). The exception is for last inventory year, where the average value refers only to n-1 and n (2002 and 2003).

However not all statistical information is available for all species and years and interpolations were done for the missing years. The number of rabbits, turkeys, ducks, geese and guinea-fowl, is only available for 1999 – from the national agriculture census that is done every ten years - and extrapolations were done for the other years using the available time series from FAO database as surrogate indicator of trend. For these species three year averages were not determined because they represent approximate estimates.

All original figures in statistical database 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 6.3 - Livestock Numbers (Thousands): 1990-1996

k head	1990	1991	1992	1993	1994	1995	1996
Dairy Cows \$	388	381	383	382	383	380	379
Other Cattle \$	998	986	978	967	983	1 000	1 008
Ewes \$	2 241	2 257	2 268	2 303	2 339	2 376	2 368
Other sheep \$	1 121	1 109	1 094	1 090	1 095	1 105	1 099
Female goats \$	579	556	538	528	517	509	498
Other goats \$	230	221	215	208	200	192	187
Sows \$	350	353	357	350	343	331	332
Other swine \$	2 277	2 260	2 261	2 219	2 178	2 085	2 067
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	30 605	8 123	8 093	8 048	16 921	17 527	17 195

Table 6.4 - Livestock Numbers (Thousands): 1997-2003

k head	1997	1998	1999	2000	2001	2002	2003
Dairy Cows \$	375	369	361	350	344	336	335
Other Cattle \$	1 020	1 037	1 054	1 063	1 060	1 060	1 057
Ewes \$	2 367	2 388	2 417	2 403	2 350	2 304	2 289
Other sheep \$	1 135	1 147	1 167	1 138	1 149	1 120	1 117
Female goats \$	485	472	461	441	419	393	384
Other goats \$	191	187	182	164	155	140	136
Sows \$	330	328	325	324	321	315	311
Other swine \$	2 055	2 048	2 033	2 035	2 036	2 012	1 986
Horses	38 *	40 *	41	40 *	40 *	41 *	41 *
Mules & asses	65 *	60 *	55	45 *	38 *	32 *	32 *
Rabbits	338 *	338 *	338	338 *	338 *	338 *	338 *
Broilers & male breeders	25 115 *	25 522 *	25 928	26 770	26 741 *	27 147 *	27 147 *
Hens	10 192	12 321	11 980	12 392	13 544 *	14 251 *	14 251 *
Turkeys	1 263 *	1 263 *	1 263	1 263 *	1 263 *	1 263 *	1 263 *
Ducks, geese, Guinea-fowl, etc	719 #	719 #	771	771 #	719 #	719 #	719 #
Total	18 150	20 297	48 376	47 079	7 834	7 681	7 615

\$ three year average

\* 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 (annual livestock numbers) agree quite well with FAO data on cattle numbers, particularly toward the end of the period, as may be seen from Table 6.5. 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 includes or does not include this situation<sup>104</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.

Table 6.5 – 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	1 375	1 398	1 336	1 348	1 363	1 386	1 389	1 386	1 409	1 421	1 414	1 399
	(-2.3%)	(-1.6%)	(4.6%)	(-0.9%)	(-1.1%)	(-1.7%)	(-0.2%)	(0.2%)	(-1.7%)	(-0.9%)	(0.5%)	(0.7%)	(0.3%)
Sheep	5 567	5 673	5 640	6 125	5 991	5 900	5 800	6 300	5 800	5 850	5 584	5 578	5 478
	(65.7%)	(67.8%)	(67.9%)	(83.1%)	(72.4%)	(69.4%)	(66.4%)	(83.6%)	(61.6%)	(63.2%)	(56.0%)	(61.2%)	(58.5%)
Goats	857	857	862	858	836	819	799	781	785	750	630	623	565
	(7.5%)	(11.0%)	(13.1%)	(18.3%)	(16.0%)	(16.3%)	(18.0%)	(16.0%)	(16.1%)	(19.1%)	(1.2%)	(11.0%)	(5.0%)
Pigs	2 598	2 664	2 574	2 690	2 444	2 430	2 375	2 394	2 385	2 350	2 338	2 338	2 389
	(-2.9%)	(2.9%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(-2.1%)	(1.9%)
Horses	26	26	25	25	25	23	25	22	24	19	17	17	17
	(-27.8%)	(-27.3%)	(-29.5%)	(-29.0%)	(-28.5%)	(-33.7%)	(-31.3%)	(-42.2%)	(-39.7%)	(-54.2%)	(-57.4%)	(-58.0%)	(-58.6%)
Mulas e B	250	250	250	230	230	230	210	210	190	185	180	175	175
	(119.3%)	(135.8%)	(155.0%)	(155.4%)	(180.2%)	(210.4%)	(202.9%)	(225.3%)	(217.9%)	(236.4%)	(301.0%)	(357.3%)	(453.0%)
Chickens	20 000	21 000	22 000	25 000	26 000	26 000	27 000	34 000	36 000	34 000	35 000	35 000	35 000
	(-35.8%)	(-33.5%)	(-31.2%)	(-22.8%)	(-20.7%)	(-23.2%)	(-20.5%)	(-3.7%)	(-4.9%)	(-10.3%)	(-10.6%)	(-13.1%)	(-15.5%)
Turkeys	5 250	5 250	5 250	5 400	5 400	5 400	6 500	7 000	7 000	7 500	7 500	7 000	7 000
	(315.7%)	(315.7%)	(315.7%)	(327.5%)	(327.5%)	(327.5%)	(414.6%)	(454.2%)	(454.2%)	(493.8%)	(493.8%)	(454.2%)	(454.2%)
Total	35 883	37 095	37 999	41 664	42 274	42 165	44 095	52 096	53 570	52 063	52 670	52 145	52 023
	(-12.0%)	(-9.8%)	(-8.2%)	(-0.5%)	(0.3%)	(-2.5%)	(1.9%)	(16.9%)	(13.3%)	(10.2%)	(8.7%)	(5.5%)	(3.1%)

The number of horses, mules, asses and turkeys<sup>105</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.

## UNCERTAINTY ASSESSMENT

The uncertainty associated with activity data (Livestock numbers) is not available from IPCC Guidelines and Good Practice Guidebook and was instead set equal to maximum difference, for all species, between annual values<sup>106</sup> in the national statistics and the time series available from FAO, which are presented in table Table 6.6.

<sup>104</sup> Seasonal variation of sheep numbers.

<sup>105</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>106</sup> Not the actual annual activity data that was used because they refer to 3 year averages which are not comparable to FAO statistical database.

Table 6.6 - Uncertainty for livestock population.

Animal Type	U (%)
Cattle	5
Sheep	84
Goats	19
Pigs	3
Horses	59
Mules and Asses	453
Chickens	36
Turkeys	494
General	17

Because a tier 1 methodology was used to estimate methane emissions from enteric fermentation the uncertainty associated with the emission factor was set at 50% for most species, the value in the higher range of the uncertainty values proposed in Good Practice. For rabbits, because the emission factor was estimated from scaling from other animals a higher 100% uncertainty was used<sup>107</sup>.

## RECALCULATIONS

Following the revision of the livestock time series made by INE, made after the final results of the 1999 Agriculture Census, changes occurred for the major animal types. However, the major change in the inventory arose for cattle, sheep, goats and swine, where the livestock numbers used as activity data are, for the first time, 3 year averages centered in the reporting year. This change was made in accordance with the recommendations of the in-country review of 2004.

No changes in methodology or emission factors were made since last year's submission.

## FURTHER IMPROVEMENTS

Because CH<sub>4</sub> from enteric fermentation is a key source<sup>108</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, non-dairy cattle and sheep<sup>109</sup>, which together sum about 94% of total CH<sub>4</sub> emissions from enteric fermentation. It is expected that this update will be implemented in following submissions for cattle, sheep and swine, as result of the efforts that are being made together with the Agriculture Ministry, under the program for the development of National System, and that 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. From the available recommendations the consideration of age and sex sub-groups will be necessary.

However, 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

<sup>107</sup> Assuming higher uncertainty values would lead to emission factors as high as those that were used for swine which would be rather unrealistic.

<sup>108</sup> According to the rule of thumb in note 2 of page 4.24 of GPG

<sup>109</sup> The strict use of the Good Practice rule of thumb would not result in the consideration of sheep as a significant source (below 25%). However the importance of emissions from sheep, its similar importance to emissions from other cattle and the uncertainty in Livestock numbers – which are probably underestimated – lead to the inclusion of this specie also as an significant source category.

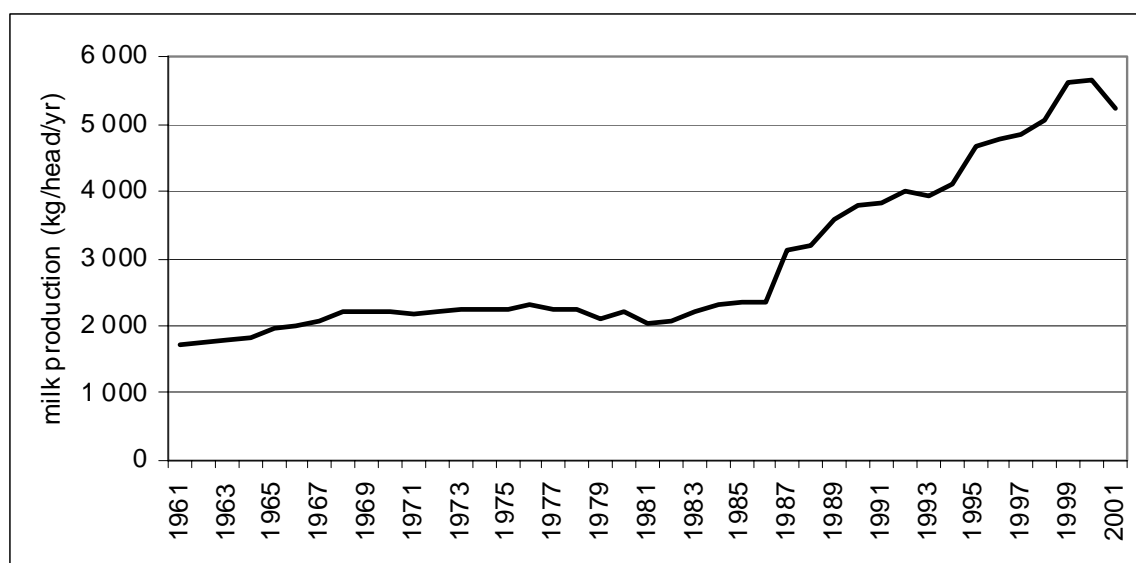
would result in emission factors different from IPCC defaults but that would not be actually representative of country-specific circumstances.

Also, statistical information that is available only for more recent years, will allow a better disaggregation per age and sex classes at least for cattle 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 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. 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.

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 6.8. 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 1996 when default emission factors for Western Europe were derived (4 200 kg/head/yr in IPCC 96 table 4-4). No attempt was yet 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.

Figure 6.8 - Milk production per cow (kg milk/head/year): 1961 to 2001



Source: FAO Statistical Database

### 6.3.B CH<sub>4</sub> Emissions from Manure Management (CRF 4B)

#### OVERVIEW

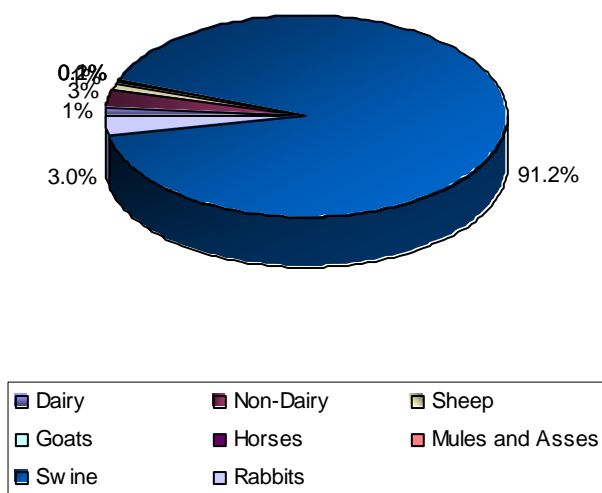
Methane emissions from manure occur when the organic material it contains, either solid or dung or liquid as urine, decomposes, during storage or treatment, in anaerobic environments by the action of methanogenic bacteria. The quantity that is emitted depends mostly of the existence of anaerobic conditions during storage of manure that promotes the activity of

methanogenic microorganisms. Methane formation is therefore particularly important in highly anaerobic Manure Management Systems (MMS) such as anaerobic lagoons, anaerobic digesters, accumulation in tanks in liquid or slurry state or where manure remains for a long time residence on stall floor. Methane emissions resulting from manure deposited directly in soil during grazing and pasture, although in small quantities, are also included in this source category<sup>110</sup>.

In some systems, such as anaerobic lagoons and digesters, the emitted gas may be collected and burned for energy use or simply flared. In these cases, methane emissions to the atmosphere may be significantly reduced.

Methane emission from Manure Management in Portugal is a key source. According to origin of manure by specie, most emissions result from swine manure, with 91.2 % of emissions in 2003, as may be seen in Figure 6.9, and according to the Good Practice rule of thumb this specie is the only significant source.

Figure 6.9 - Relative Importance of emissions of CH<sub>4</sub> from Enteric Fermentation per each animal specie in 2003



## METHODOLOGY

Following the 1996 IPCC Revised Guidelines and the Good Practice Handbook, emission estimates are calculated by the following simple equation (following equation 4.15 of GPG) applied for each animal type and considering emission factors dependent on animal type and climatic conditions. By this procedure both the quantity of manure produced per animal and the storage conditions are included in the determination of the emission factor, and will be discussed thereafter.

$$Emi_{CH_4} = \sum_t \sum_c [EF_{(i,k)} * N_{(i,k)}]$$

where, for each specie:

<sup>110</sup> Nitrous oxide emissions from manure deposited in soil during grazing and pasture are nevertheless included in source category N<sub>2</sub>O from agricultural soil: Animal production, in accordance with UNFCCC reporting guidelines.

$Emi_{CH_4}$  = methane emissions from manure management, kg CH<sub>4</sub>/year;

$EF_{(i,k)}$  = emission factor for the specific population of animal type i, living in climate region k, kg/head/year;

$N_{(i,k)}$  = total number of animals of type i, living in climate region k, head.

## EMISSION FACTORS

Emissions Factors for each animal type were established according to the tier 2 methodology proposed in GPG (equation 4.17), which considers the use of country specific information concerning the quantity of manure produce per animal and the share of each Manure Management System that is used for each animal type. The equation used for the calculation of the EF for each animal species is therefore:

$$EF_{(i)} = VS_{(i)} * 365 * Bo_{(i)} * 0.67 * \sum_{jk} MCF_{(jk)} * MMS_{(jk)}$$

$EF_{(i)}$  - annual emission factor for a defined livestock animal specie i (kg/year);

$VS_{(i)}$  - Amount of excretion, expressed in Volatile Solids (VS) for an average animal i in the livestock population (kg VS /day);

$Bo_{(i)}$  - Maximum methane production capacity from manure (m<sup>3</sup>/kg VS) for animal specie i. 0.67 kg/m<sup>3</sup> is methane density;

$MCF_{(jk)}$  - methane conversion factor for each Manure Management System j and for each climate region k;

$MMS_{(jk)}$  - fraction of total manure from animal specie i handled with Manure Management System j and for each climate region k.

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 previous reported 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 IPCC96. 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 IPCC96 for Western Europe or developed countries.



Table 6.7 – Production of Manure per animal type and manure characterization: dry mater content (dm) and maximum methane production capacity (Bo)

Class	Manure Production per Capita			IPCC96	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

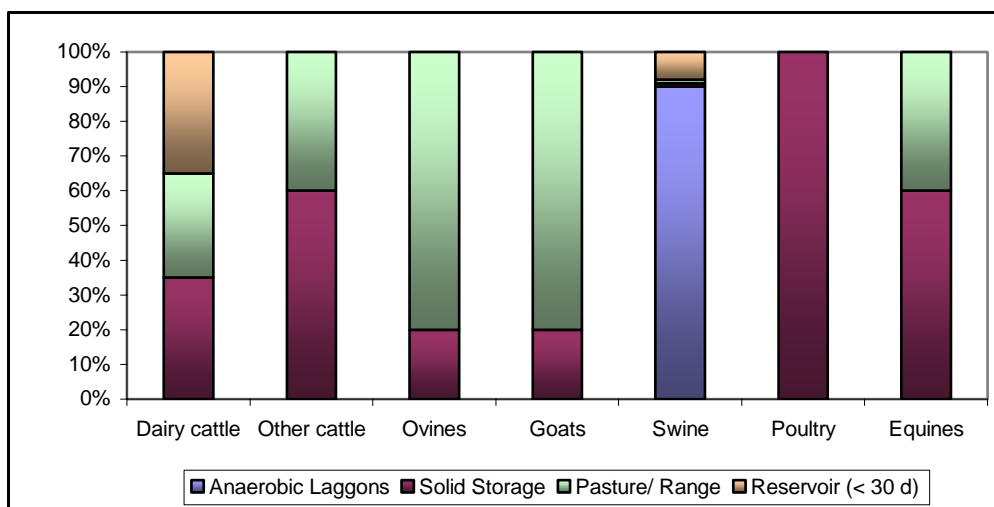
The major difference between the Portuguese country-specific emission factors (CS) and IPCC defaults arises mostly, however, from the use of a different share of Management Systems for Manure, which are presented in Table 6.8 and also in Figure 6.10. The country-specific percentages used in Portugal 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 in anaerobic lagoons, which have the highest MCF among MMS;
- the management of wastes from dairy cows kept in stall is split among solid storage and short retention time pits;
- dairy cows in pasture are more common in Portugal than the default assumption in IPCC;
- Solid storage is still the prevalent method of treatment for wastes from other cattle;
- Daily spread and usage as fuel are practically unknown in Portugal;
- there is a small percentage of traditional swine kept outdoors and foraging in pasture range;
- there are no substantial seasonal variations in the share of management system.

Table 6.8 – Methane emissions from Manure Management: Share of each Manure Management System per animal type and MCF per climate region

MMS	MCF		Dairy Cows		Other Cattle		Swine		Sheep	Goats	Poul.	Equ.
	temp	cool	CS	IPCC	CS	IPCC	CS	IPCC	CS (Country Specific)	CS (Country Specific)	CS (Country Specific)	CS (Country Specific)
Lagoon	39	45					90					
Liquid/Slurry	39	45		40		50						
Solid Storage	1	1.5	35	18	60		1	21	20	20	100	60
Drylot	1	1.5				2		2				
Pasture/ Range	1	1.5	30	19	40	38	1		80	80		40
Pit <1 month	0	0	35				8	3				
Pit >1 month	39	45						73				
Daily Spread	0.1	0.5		20								
Digester	10	10										
Burned for fuel	10	10		2		2						
River	1	1.5										
Other	1	1		1		8		1				
Total	-	-	100	100	100	100	100	100	100	100	100	100
MCF cool	-	-	0.65	16.2	1.0	20.2	35.12	28.7	1.0	1.0	1.0	1.0
MCF temperate	-	-	0.98	18.9	1.5	23.4	40.53	33.2	1.5	1.5	1.5	1.5

Figure 6.10 - Percentage of manure handled by each Manure Management System, by animal type



Two climate regions occur in Portugal, in accordance with IPCC definition (IPCC,1997): temperate (annual average temperature between 15°C and 25°C) and cool (annual average temperature below 15°C). Livestock populations living in each climate region were determined according to the following mode:

- the percentage of livestock numbers at each climate region was determined for each *concelho* territorial unit<sup>111</sup>. Within each *concelho* a homogenous distribution of animals was assumed;

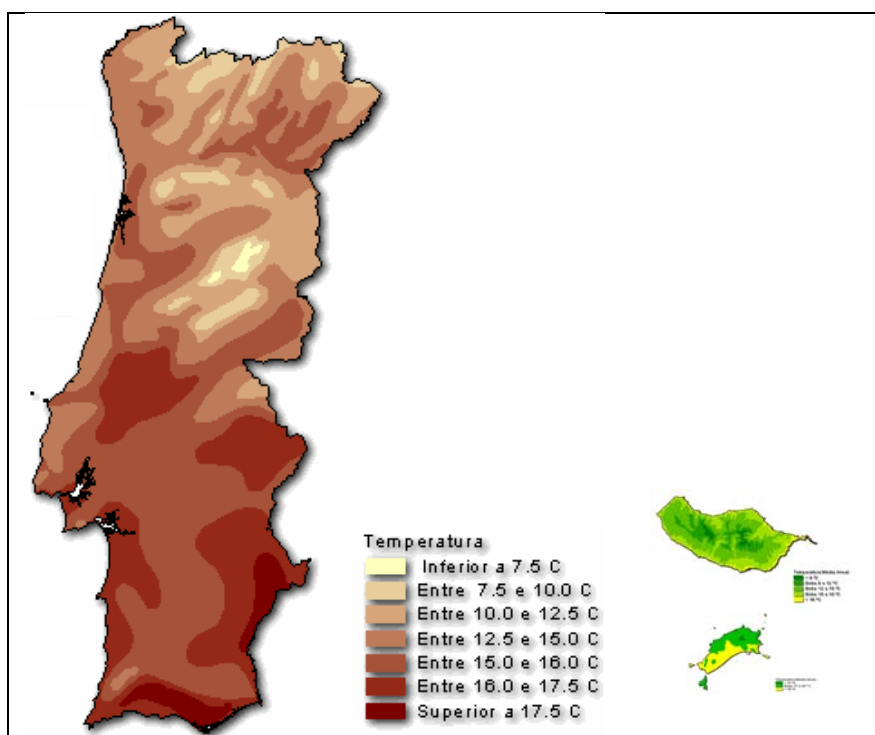
<sup>111</sup> Concelho territorial unit in Portugal is the designation to land areas associated with one municipal administrative authority. There are 306 *concelhos* in Portugal with an average area of km<sup>2</sup>. A nut III level territorial unit is defined as a set of *Concelhos*.

- for each Concelho in mainland Portugal and Madeira archipelago the percentage of land area above and below 15°C was determined using the annual average air temperature map, which is presented in Figure 6.11. All area in Azores islands were considered to be in temperate region;

- Livestock numbers per animal type were available at Concelho level from two detailed agriculture surveys: RGA89 and RGA99<sup>112</sup>. Data for 1999 was available for all animal types and for 1989 only for dairy cattle, other cattle, ewes, other sheep, female goats and other goats, sows and other swine;

- Livestock numbers in each Concelho area were allocated to each climate region, for years 1989 and 1999, according to the land area percentage, and always assuming an homogeneous distribution of animals in the Concelho territorial area. Interpolation was done for intermediate years and 1999 distribution was maintained for year 2000 and beyond<sup>113</sup>.

Figure 6.11 – Isothermal map for continental Portugal and Madeira archipelago (IA,1974) (Madeira island not to scale with mainland Portugal)



The percentage of livestock population living in cool climate regions for each animal type in 1989 and 1999, obtained in accordance with the above explained procedure, is presented in Table 6.10.

<sup>112</sup> Recenseamento Geral da Agricultura 1989 and Recenseamento Geral da Agricultura 1999, extensive agriculture census made by INE each 10 years.

<sup>113</sup> For horses, mules, asses, rabbits and poultry distribution for 1999 was used for the entire time series due to lack of appropriate data for 1989.

Table 6.9 – Percentage of livestock population living in climate cool regions in Portugal in years 1989 and 1999.

Animal Type	1989	1999
Dairy Cows	49.1	48.7
Other Cattle	39.4	33.9
Ewes	29.6	32.8
Other sheep	24.0	27.9
Female goats	53.1	51.8
Other goats	47.7	52.6
Sows	23.1	19.8
Other swine	23.5	20.6
Horses	39.8	39.8
Mules & asses	69.8	69.8
Rabbits	64.9	64.9
Broilers & male breeders	44.3	44.3
Hens	46.1	46.1
Turkeys	22.5	22.5
Ducks, geese, Guinea-fowl, etc	32.0	32.0

Final emissions factors are therefore those presented in next table, where is also done a comparison with the IPCC96 defaults for temperate regions of Western Europe and developed countries:

Table 6.10 - Final emission factors for determination of CH<sub>4</sub> emissions from Manure Management

Animal Type	EF (kg CH <sub>4</sub> /hd/yr)		
	Country Specific		IPCC
	Cool	Temperate	
Dairy Cows	2.3	3.4	44.0
Other Cattle	1.3	1.9	20.0
Ewes	0.18	0.27	0.28
Other sheep	0.18	0.27	0.28
Female goats	0.11	0.17	0.18
Other goats	0.11	0.17	0.18
Sows	41.2	47.6	10.0
Other swine	20.6	23.8	10.0
Horses	2.5	3.8	2.1
Mules & asses	2.5	3.8	1.14
Rabbits	0.07	0.10	-
Broilers & male breeders	0.02	0.03	0.117
Hens	0.05	0.07	0.117
Turkeys	0.10	0.15	0.117
Ducks, geese, Guinea-fowl, etc	0.05	0.07	0.117

Emission factors for each climate region were kept constant from 1990 to 2003 in accordance with the fact that 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. However, due

to a small change in livestock repartition in the territory the overall emission factor, considering both climate regions temperate and cool, changes along the reported period.

## 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 6.3 and

Table 6.4.

## UNCERTAINTY ASSESSMENT

Livestock numbers are considered to be the activity data of this source category and uncertainty values were equal to uncertainty values discussed for CH<sub>4</sub> emissions from Enteric Fermentation.

Information about uncertainty levels of emission factors is nevertheless absent from the Good Practice Handbook. Uncertainty values were set in the following mode:

- total uncertainty in the emission factor was determined using error propagation in the equation that was presented before for Emission Factor Determination and incorporating an additional factor for the consideration of errors in climate region determination;
- uncertainty for the quantity excreted, VS parameter, was made equal to the maximum value that is proposed in GP for Nitrogen Excretion rates: 50%;
- considering that the emissions from this source category are mostly the result of emissions from anaerobic lagoons treating pig manure, and that there is a high uncertainty in the MCF for this particular Manure Management System (according to GP MCF may range from 0 to 100%) the uncertainty in MCF parameter was set at 100%;
- the error associated with parameters Bo and biogas density are probably less important and not determinant of overall uncertainty value;
- uncertainty resulting from wrong determination of the share of each MMS was determined as the major difference between the share that is used in the National Inventory and the default share considered in IPCC Guidelines, whereas MMS have different MCF values. The uncertainty value was determined to be 22%;
- from observation of the climate maps it is evident that, from the particular conditions that affect Portuguese climate, small annual variations in average air temperatures and also mapping techniques could exert a profound modification in the percentage of livestock numbers that are classified as either cool or temperate. Territorial units under each climate class could easily change as much as 30% in either direction, value that was assumed as representative of uncertainty for this factor.

The overall uncertainty for the emission factor was determined to be 118%, according to the equation 6.4 in Good Practice Handbook for combining uncertainties. The same uncertainty value was assumed for all animal types, which reflects a conservative approach.

## RECALCULATIONS

The time series of livestock numbers were revised in a consistent way to what was done for Enteric Fermentation emissions, and was already discussed in the previous chapter. Activity data for cattle, sheep, goats and swine are now reported as three year averages.

The major modification resulted however from the division of total livestock population according to climate region, as was explained before. This has result in a decrease in total emissions and weighted average national emission factors per specie.

A small correction was made to pigs because in submission 2004 the percentage of pigs in pasture was also considered under solid storage leading to a small duplication of emissions.

## 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.

### 6.3.C CH<sub>4</sub> Emissions from Rice Cultivation (CRF 4C)

#### OVERVIEW

Methane production is enhanced in rice cultivation areas (rice paddies) due to the prevalence of anaerobic conditions which result from flooding and high levels of organic material in soil surface. The methane that is formed in soil underwater escapes to atmosphere as greenhouse gas emission, as visible bobbles or trough transport inside plant stems.

#### METHODOLOGY

Methane emissions from rice production were estimated following the equation 4.41 of GPG, but simplified because there are no appreciable differentiation in Portugal in what concerns water management regimes or any other conditions that are known to affect emissions from this source sector. Original formula was therefore simplified to:

$$E_{\text{Rice}_{\text{CH}_4(y)}} = EF * \text{Rice}_{\text{Area}(y)} * 10^{-2}$$

where

$E_{\text{Rice}_{\text{CH}_4(y)}}$  - Emission from rice production estimated for year y (ton/yr);

EF - Final emission factor, seasonally integrated and adjusted for management practices (g/m<sup>2</sup>/yr);

$\text{Rice}_{\text{Area}(y)}$  - Area under rice cultivation in year y (ha).

#### EMISSION FACTORS

According to GPG formulation, the final value for the emission factor results from the multiplication of several factors:

$$EF = E_{fc} * SF_w * SF_o * SF_s$$

where

EF - Final emission factor, seasonally integrated and adjusted for management practices ( $\text{g/m}^2/\text{yr}$ );

$E_{fc}$  - Seasonally integrated emission factor for continuously flooded fields without organic amendments ( $\text{g/m}^2/\text{yr}$ );

$SF_w$  - Scaling factor for water management regime and ecosystem hydrologic conditions;

$SF_o$  - Scaling factor reflecting organic amendments (rice straw, manure, compost, wastes), because easily decomposable carbon increase methane formation;

$SF_s$  - Scaling factor for soil type.

The default  $E_{fc}$  proposed in GPG ( $20 \text{ g/m}^2/\text{yr}$ ) was not used, but  $36 \text{ g/m}^2/\text{yr}$  was used instead, which is the value proposed by IPCC96 in table 4-13 for Italy. In accordance with opinion expressed by the Portuguese Agriculture Ministry it was considered that this later value, determined for a European country with environmental conditions similar to Portugal was better suited than the use of the GPG default.

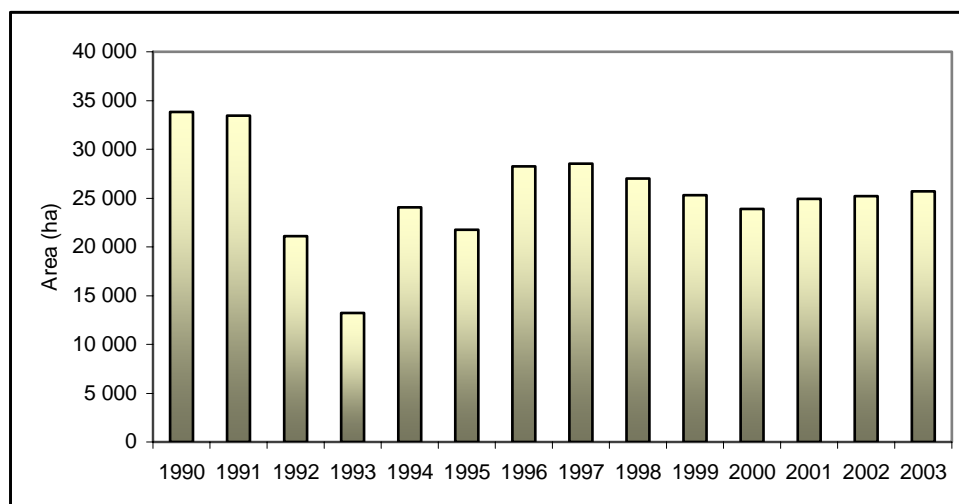
Rice culture in Portugal is almost homogeneous, in what concerns hydrologic management regime and characterized by cultivation being done under irrigated continuous flooded areas, where water regime is controlled by human activity (water diversion, irrigation and dikes). Rice fields are in standing water throughout all rice growing season and are only dried for harvest. All areas under rice cultivation are situated close to river banks almost at sea level. Accordingly the parameter  $SF_w$  was set as 1.0.

No statistical information exists concerning the use of organic amendments in rice fields but according to the Ministry of Agriculture these are not representative in Portuguese oriziculture, and the most appropriate value for  $SF_o$  is 1. In a similar way no information is available to establish influence of soil type and  $SF_s$  was also set to one.

## ACTIVITY DATA

Rice cultivated area is available from annual statistics from National Statistical Institute, which time series is presented in Figure 6.12. 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 6.12 – Area under rice cultivation in Portugal (1990-2003)



Relevant characteristics of rice cultivated areas, such as water management regime, organic amendments and soil type are included already in emission factor setting.

## UNCERTAINTY ASSESSMENT

The uncertainty in the adjusted seasonally integrated emission factor was set at 40%, according to the range proposed in table 4.22 of the GPG. For activity data, the standard deviation of inter-annual area under rice cultivation was considered, 40%.

## RECALCULATIONS

No changes have occurred since last submission, besides the replacement of the provisional value for rice cultivated area for year 2002.

## FURTHER IMPROVEMENTS

No improvements in methodology are expected in near future. The establishing of a national integrated emission factor would be welcomed but there are no current plans or studies to achieve that goal.

## 6.3.D N<sub>2</sub>O Emissions from Manure Management (CRF 4B)

### OVERVIEW

Part of the Nitrogen that is in manure, either in faeces or urine, is emitted as N<sub>2</sub>O during management or during storage of manure, before application to soil, as consequence of the nitrification-denitrification processes affecting ammonia nitrogen.

Emissions of N<sub>2</sub>O that occur after manure is deposited in soil, either as a way for disposal or as a fertilizer process, are estimated in the category N<sub>2</sub>O from agricultural soils and are discussed later. According to UNFCCC reporting guidelines, emissions of N<sub>2</sub>O from dung and urine that are deposited directly into soil during grazing, pasture and in paddocks, are also included in category N<sub>2</sub>O from agricultural soils.

In a short description this is a biological based process where emission of N<sub>2</sub>O from manure require the previous oxidation of organic nitrogen in ammonia form, which results from bacterial mineralization of organic nitrogen, into nitrites and nitrates (nitrification, a biological process mediated by bacteria such as *Nitrobacter* and *Nitrosomomas*) in an aerobic environment and thereafter the reduction of this compounds in an anaerobic environment (the denitrification process where nitrate is converted to N<sub>2</sub> and nitrous oxide). Although there is no extensive information concerning the factors that affect this process it is believed that N<sub>2</sub>O emissions increase with aeration, at least to finalize the process, and hence increase under opposite conditions that determine methane emissions from solid storage or deposition during grazing and dry lot, which means that are lesser emissions in fully anaerobic systems like liquid systems and anaerobic lagoons.

In terms of the importance of each Manure Management System, the great majority of emissions result from solid storage and dry-lot, totalizing on average in the 1990-2003 period 97.3 % of N<sub>2</sub>O emissions in each year. The rest comprehends 1.9 % of emissions from anaerobic lagoons and 0.9% of total emissions from liquid systems. In terms of origin by animal type<sup>114</sup>, emissions are dominated by poultry, non dairy cattle and dairy cattle, which together comprehend about 88% of total emissions, as may be seen in **Error! Reference source not**

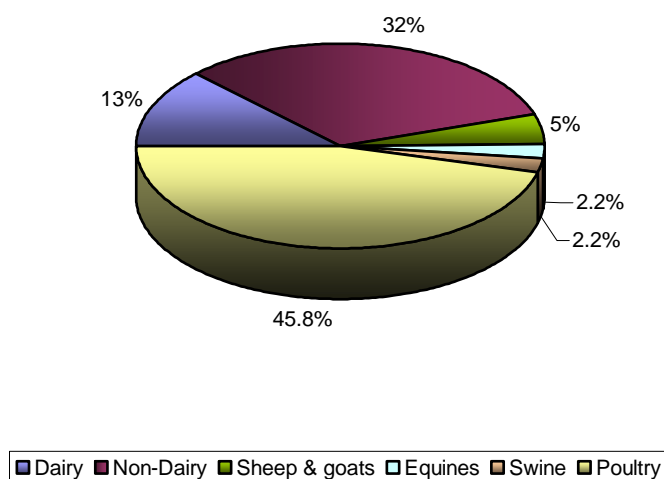
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<sup>114</sup> Division of emissions per animal type or specie is not required according to CRF reporting format, but it is nevertheless relevant to understand the origin of emissions and the relevance of each specie.



**found.** for year 2003. Emissions from non-dairy cattle and poultry may be considered significant sources<sup>115</sup>.

Figure 6.13 – Distribution of total N<sub>2</sub>O emissions from Manure Management per animal specie as origin of manure in year 2003



## METHODOLOGY

Emissions of N<sub>2</sub>O from manure for each Manure Management Systems *s* were estimated with the following formula:

$$EN_{2O(s)} = 44/28 * \sum_i [N_{(i)} * Nex_{(i)} * MS_{(i,s)}] * EF3_{(s)}$$

where,

EN<sub>2O(s)</sub> - N<sub>2</sub>O emissions from manure in Manure Management System *s*;

*S* - Manure Management System;

*i* - Animal/species category of livestock;

N<sub>(i)</sub> - Number (head) of individuals from livestock category *i* in the country;

Nex<sub>(i)</sub> - Annual country average N excretion per head of animal species/category *i*;

MS<sub>(i,s)</sub> - Fraction of Manure/Nitrogen from livestock category *i* that is managed in Manure Management System *s*;

<sup>115</sup> According to the IPCC rule of thumb in figure 4.4 of IPCC (2000), although in strict terms sub-categories for this source category are management systems and not animal species.

$EF3_{(s)}$  -  $N_2O$  emission factor for Manure Management System S (kg  $N_2O$ -N/kg N).

This formulation follows the one proposed in GPG (equation 4.18).

The following Manure Management Systems were considered to estimate total  $N_2O$  emissions from manure management:

- Anaerobic Lagoons;
- Liquid Systems;
- Solid Storage;
- Used as Fuel;
- Other MMS

This same methodology was used to assess Direct  $N_2O$  soil emissions from manure deposited in soil during grazing (Pasture Range and Paddock) and also Direct  $N_2O$  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".

## EMISSION FACTORS

$N_2O$  emission factors are presented in next table for all MMS (although the uses of daily spread, use for fuel and other systems are not considered in the Portuguese inventory). These emission factors are the default IPCC96 emission factors (table 4-22 which were maintained in GPG table 4.12) because there are no country-specific emission factors.

Table 6.11 –  $N_2O$  from Manure Management: Emission factors per Manure Management System

MMS	EF3 (kg $N_2O$ -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

## ACTIVITY DATA

Livestock populations used to estimate total nitrogen excretion are the same that are also used to estimate emissions of  $CH_4$  from Enteric Fermentation and  $CH_4$  from Manure Management, and are therefore referenced back to Table 6.3 and

Table 6.4.

The quantity of nitrogen excreted per head was estimated from the dry weight of manure emitted per head, already presented in the chapter concerning  $CH_4$  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 IPCC96).

There is an acceptable agreement between country-specific values and IPCC defaults for all species other than sheep, goats and equines. Albeit the nitrogen excretion rate for sheep appearing now too low, when in comparison to IPCC default (7 against 20), it has similarities to those used by other parties: Canada (4.1), NZ (11.8), Spain (9.82), Sweden (5.6), United Kingdom (6.73) and USA (4.14).

Table 6.12 – 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) IPCC96 does not set N excretion rate for goats. Comparison is with value for sheep; (2) IPCC96 default value for other animals; (3) IPCC96 reports only for poultry in general

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to year 2003, is presented in Table 6.13 and Table 6.14.

Table 6.13 – Total Nitrogen in Manure produced by livestock in Portugal 1990-1996 (ton N/yr)

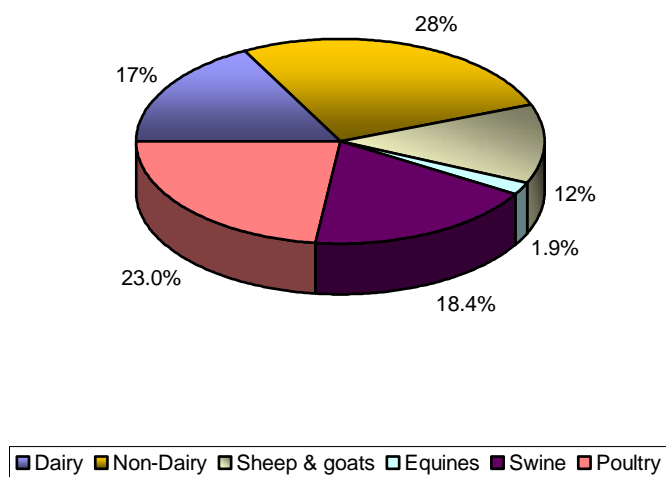
Animal Type	1990	1991	1992	1993	1994	1995	1996
Dairy Cows	41 930	41 173	41 389	41 281	41 389	41 029	40 957
Other Cattle	53 907	53 277	52 834	52 265	53 119	54 037	54 488
Ewes	15 464	15 574	15 648	15 891	16 135	16 395	16 335
Other sheep	7 734	7 651	7 546	7 518	7 557	7 621	7 582
Female goats	2 851	2 738	2 653	2 602	2 548	2 508	2 453
Other goats	1 134	1 091	1 058	1 025	984	945	922
Sows	10 432	10 501	10 621	10 422	10 214	9 856	9 896
Other swine	33 896	33 643	33 658	33 043	32 432	31 048	30 780
Horses	1 945	1 931	1 917	1 903	1 889	1 875	1 966
Mules & asses	6 160	5 729	5 297	4 866	4 435	4 004	3 746
Rabbits	507	507	507	507	507	507	507
Broilers & male breeders	16 569	16 872	17 174	17 476	17 779	18 081	18 383
Hens	14 025	14 025	14 025	14 025	14 025	15 077	14 615
Turkeys	4 162	4 162	4 162	4 162	4 162	4 162	4 162
Ducks, geese, Guinea-fowl, etc	852	852	852	876	876	876	1 054
total	211 568	209 726	209 340	207 863	208 051	208 022	207 847

Table 6.14 – Total Nitrogen in Manure produced by livestock in Portugal 1997-2003 (ton N/yr)

Animal Type	1997	1998	1999	2000	2001	2002	2003
Dairy Cows	40 525	39 831	39 028	37 792	37 219	36 274	36 165
Other Cattle	55 118	56 038	56 933	57 457	57 273	57 296	57 130
Ewes	16 333	16 477	16 674	16 577	16 211	15 898	15 796
Other sheep	7 833	7 913	8 053	7 850	7 925	7 725	7 705
Female goats	2 388	2 328	2 272	2 173	2 063	1 938	1 892
Other goats	940	922	896	806	766	692	671
Sows	9 817	9 780	9 673	9 658	9 558	9 382	9 257
Other swine	30 596	30 490	30 264	30 292	30 311	29 959	29 561
Horses	2 058	2 149	2 241	2 156	2 187	2 218	2 218
Mules & asses	3 488	3 230	2 972	2 425	2 068	1 710	1 710
Rabbits	507	507	507	507	507	507	507
Broilers & male breeders	18 685	18 988	19 290	19 916	19 895	20 197	20 197
Hens	16 093	19 453	18 916	19 566	21 385	22 501	22 501
Turkeys	4 162	4 162	4 162	4 162	4 162	4 162	4 162
Ducks, geese, Guinea-fowl, etc	1 135	1 135	1 217	1 217	1 135	1 135	1 135
total	209 679	213 404	213 098	212 554	212 665	211 595	210 608

The major contributors to total nitrogen from livestock in Portugal in 2003 are cattle, poultry and swine, as may be seen in Figure 6.14.

Figure 6.14 – Origin of nitrogen in manure from livestock production in Portugal in 2003, per animal type



The percentage of manure that is attributed to each Manure Management System was set in coherence to 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>116</sup>.

<sup>116</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.

Table 6.15 – Percentage of manure handled by each manure management system for each animal type.

Animal	Anaerobic Lagoons		Liquid Systems		Daily Spread		Solid Storage and Dry-lot		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			1	23	1			
Other swine	90		8	77			1	23	1			
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 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 recommends a higher level of solid storage systems than it is considered according to the experts of the Portuguese Ministry of Agriculture. There is a small number of animals kept feeding by grazing in range.

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.

## UNCERTAINTY ASSESSMENT

Uncertainty in activity data is the result of the combined uncertainties in livestock number, n-excretion rates and the distribution by each manure management system. Livestock uncertainty are equal to the values considered for sector CH<sub>4</sub> emissions from enteric fermentation. The uncertainty in N-excretion rate was set at 50%, according to the recommended value in the GPG. Uncertainty in MMS share was determined using the same procedure used in sector CH<sub>4</sub> emissions from Manure Management, where uncertainty was determined as the maximum difference in overall weighted emission factor considering both the MMS country specific share and the MMS share proposed by IPCC as default. The overall uncertainty values was determined to be 47%.

The uncertainty in N<sub>2</sub>O emission factors was set in accordance with the maximum values proposed in table 4.12 of the Good Practice Handbook (IPCC,2000), 100 % for all MMS.

## RECALCULATIONS

The time series of nitrogen excretion was revised only as consequence of revision of livestock numbers for the all time series, as already explained for CH<sub>4</sub> emissions from enteric fermentation, and as result of the adoption of three year intervals for activity data. No other changes were made, either in methodology, excretion rates, allocation per MMS or emission factors.

## FURTHER IMPROVEMENTS

Nitrogen excretion rates are being revised, particularly for sheep, goats, swine and non-dairy cattle, under the Methodology Development Program that is being implemented with the collaboration of the Agriculture Ministry. This revision will use country specific data for nitrogen excretion. Preliminary results indicate that a more detailed analysis by sex and age will be necessary to improve the quality of the inventory, particularly in what concerns distinction of dairy cows and beef mother cows.

Also, 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.

## 6.3.E Direct N<sub>2</sub>O Emissions from Agricultural Soil (CRF 4D1)

### 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 make estimates of this source fully consistent in what concerns:

- whole time series. All activity data for each sub-source was obtained from the same data source for all inventory years;
- methodology is the same applied to all inventory years;
- coherence with activity data for other source activities. Because activity data for this source is also used - or results from - emission estimates of other sources: N<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.

Considering climate conditions and the long period since when soils have been subjected to agriculture in Portugal, histosols represent at most a negligible emission quantity in Portugal, and they are reported as not occurring for all practical purposes. Emissions due to application of sewage sludge as a soil amendment is also not included in the inventory, as there are no reliable statistics for this activity, which is considered nevertheless negligible.

It is worth mentioning that N fixed by crops includes both annual crops and a permanent crop, carob production.

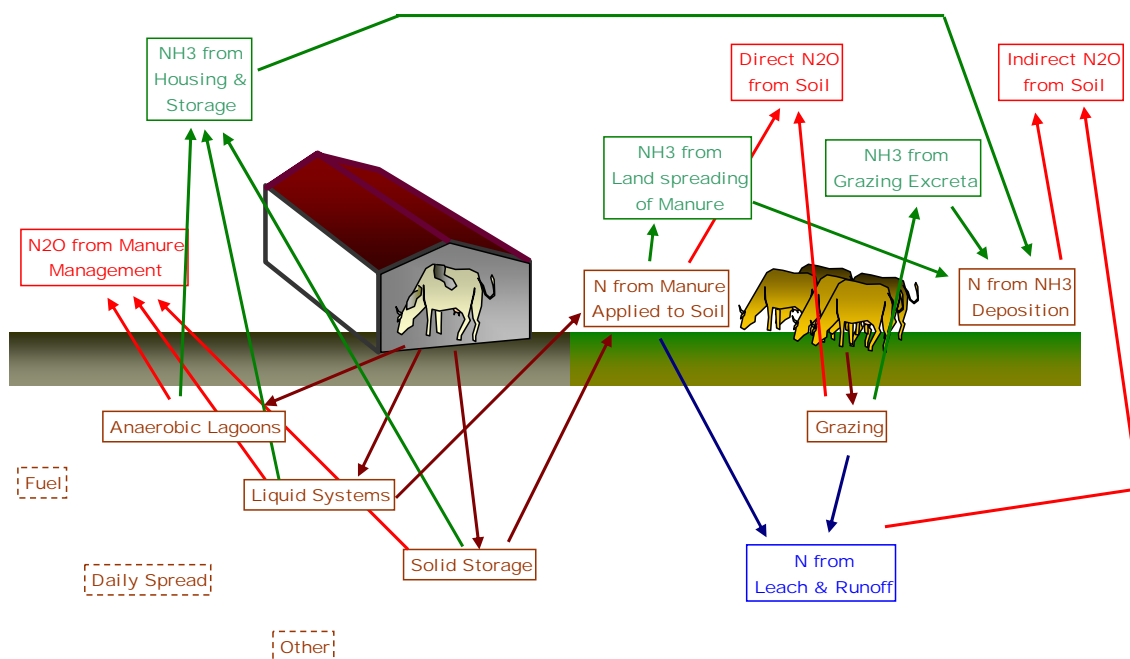
The situation concerning N<sub>2</sub>O emissions from manure is somehow complex because nitrogen originally in manure may give origin to N<sub>2</sub>O emissions that are considered in different IPCC categories:

- 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 still remaining in manure managed as liquid systems and solid storage and, 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.

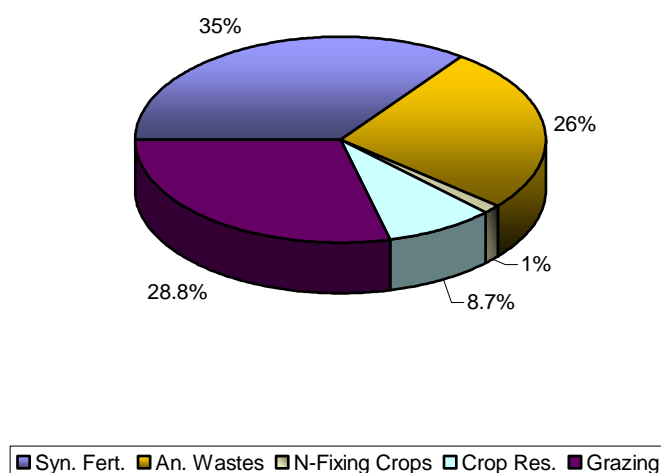


Figure 6.15 – Nitrogen fluxes from livestock system



The comparative importance of the several sub-source activities is shown in Figure 6.16, from where it is evident the major contribution from animal wastes, either from manure used as fertilizer (An. Wastes 26 % of total emissions) or direct deposition (Grazing 28.8%) and synthetic fertilizers (Syn. Fert with 35%), and this set represents the significant sources according to the IPCC rule of thumb. N2O from nitrogen fixing crops contribute with a less representative part of emissions from this source sector.

Figure 6.16– Contribution of the various sub-sources to total N2O emissions from Direct agricultural soil emissions



## 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>117</sup>.

Final N<sub>2</sub>O emissions are estimated with a formulation derived from equation 4.20 of GPG:

$$EN_{2O_{Direct}} = 44/28 * (FSN + FAM + FBN + FCR) * EF_1$$

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

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:

$$FAM = \sum_i \{ N_{(i)} * N_{ex(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * (1 - EF_{NH3SD(i)}) \}$$

where

<sup>117</sup> However in the calculation software (spreadsheets in excel) it is in fact possible to define different emission factors for each individual nitrogen source.

FAM - total amount of nitrogen in manure from Manure Management System that is applied to soil as fertilizer;

$N_{(i)}$  - Number (head) of individuals from livestock category  $i$  in the country;

$N_{ex(i)}$  - Annual country average N excretion per head of animal species/category  $i$ ;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  that is managed in Manure Management System  $s$ , except grazing;

$MSSD_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category  $i$  treated in Manure Management System  $S$  that is used as fertilizer in agriculture soils;

$EF_{NH3(i,s)}$  - Fraction of nitrogen in Manure Management System  $S$  from livestock category  $i$  that is lost to atmosphere as ammonia during housing and manure storage;

$EF_{NH3SD(i)}$  - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

This equation is equivalent to equation 4.23 of GPG if one considers that  $Frac_{GASM}$  equals the sum of  $EF_{NH3(i,s)}$  and  $EF_{NH3SD}$  and being aware that  $Frac_{PRP}$  is represented by parameter  $MSSD$ . Emissions of  $N_2O$  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) which means that crop-specific residue to product ratio and dry matter content are used:

$$FBN = \sum_i \{Crop_{BF(i)} * (1 + Res_{BF}/Crop_{BF(i)}) * Frac_{DM(i)} * Frac_{NCRBF(i)}\}$$

where

$i$  - Crop type

$Crop_{BF(i)}$  - Crop production of nitrogen fixing crops (ton/yr)

$Res_{BF}/Crop_{BF(i)}$  - Residue to crop product mass ratio for nitrogen fixing crop  $i$  (ton/ton)

$Frac_{DM(i)}$  - Fraction of dry matter in the aboveground biomass of crop type  $i$

$Frac_{NCRBF(i)}$  - nitrogen fraction in crop dry biomass (ton/ton)

Finally FCR, nitrogen input to soil in crop residues returned to soil, is estimated for all crops, whether they are nitrogen fixing crops or not, with the GPG tier 1b approach, which can be represented to the following equation, a similar simplification of equation 4.29 of the GPG:

$$FCR = \sum_i \{ [Crop_{(i)} * Res/Crop_{(i)} * Frac_{DM(i)} * Frac_{NCR(i)}] * [1 - Frac_{BURN(i)} - Frac_{FUEL(i)} - Frac_{CNST(i)} - Frac_{FOD(i)}] \}$$

where

$i$  - Crop type

$Crop_{(i)}$  - Crop production (ton/yr)

Res/Crop<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. Emissions were therefore estimated with the following formula:

$$Emi_{N_2O} = 44/28 * FGR * EF_3$$

where,

Emi<sub>N<sub>2</sub>O</sub> - N<sub>2</sub>O emissions from manure in Pasture, range and paddock;

EF<sub>3</sub> - N<sub>2</sub>O emission factor (kg N<sub>2</sub>O-N/kg N);

FGR - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture. This variable is determined from equation:

$$FGR = \sum_i [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)}]$$

where:

i - Animal/species category of livestock;

N<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>GRAZ(i)</sub> - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock.

### EMISSION FACTORS

EF<sub>1</sub>, the emission factor relating N input to soil with N<sub>2</sub>O emissions, was set equal to the IPCC default value of 0.0125 kg N<sub>2</sub>O-N/kg N input (table 4.17 of GPG and table 4.18 of IPCC96)<sup>118</sup>.

<sup>118</sup> Which is the same as stating that 1.25% of nitrogen input to soil is emitted as N<sub>2</sub>O

The emission factor of N<sub>2</sub>O for Pasture, Range and Paddock (EF<sub>3</sub>) was set at 0.02 kg N<sub>2</sub>O-N/kg N which is the default IPCC96 emission factor (table 4-22) that is also maintained in GPG (table 4.12).

## ACTIVITY DATA

The estimated quantities of nitrogen added to agricultural soils from each specific source are shown in Table 6.16 and Table 6.17 below and the percent contribution of each one in year 2003 is also represented graphically in

Figure 6.17. In this last year the majority (40 %) of nitrogen added to soil results from synthetic fertilizers, followed by nitrogen in manure applied as fertilizer (29 %) and as direct droppings during grazing in Pasture (20 %). Smaller quantities came from nitrogen returning to soil as crop residues (9.1 %) and from nitrogen fixed by leguminous plants (1.7 %). Total nitrogen added to agricultural soils in Portugal has been decreasing steadily and is in 2003 about 11 % lower than in 1990.

Table 6.16 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1990-1996<sup>119</sup>

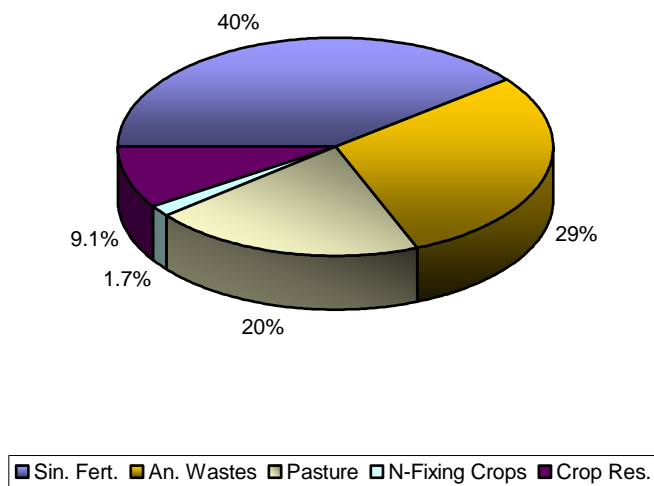
ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizer	142 260	133 444	119 804	122 813	120 572	117 982	124 229
Animal Manure	77 412	76 733	76 617	76 298	76 667	77 480	77 519
Pasture Range	59 574	58 812	58 402	58 062	58 400	58 660	58 607
Fixed by Crops	8 140	7 588	6 872	6 261	5 976	6 036	5 996
Crop Residues Returned to Soil	26 358	25 136	23 454	23 263	24 330	26 294	26 212
Total	313 744	301 714	285 149	286 697	285 944	286 452	292 563

Table 6.17 - Total quantities of Nitrogen Added to Agricultural Soils (after ammonia volatilisation): 1997-2003

ton N/yr	1997	1998	1999	2000	2001	2002	2003
Synthetic Fertilizer	113 396	122 640	112 777	106 523	109 889	109 805	109 721
Animal Manure	78 728	81 109	80 932	80 998	81 531	81 703	81 519
Pasture Range	58 822	59 032	59 282	58 478	57 747	56 768	56 512
Fixed by Crops	5 771	5 365	5 031	4 799	4 742	4 712	4 693
Crop Residues Returned to Soil	26 856	27 378	27 649	27 115	26 039	25 401	25 394
Total	283 573	295 525	285 672	277 913	279 948	278 388	277 838

<sup>119</sup> To be in accordance with CRF table 4.D nitrogen is expressed after subtraction of ammonia volatilization for synthetic fertilization and animal manure. In the case of Pasture Range/ Animal Production the values refer to nitrogen deposited in soil before NH<sub>3</sub> subtraction

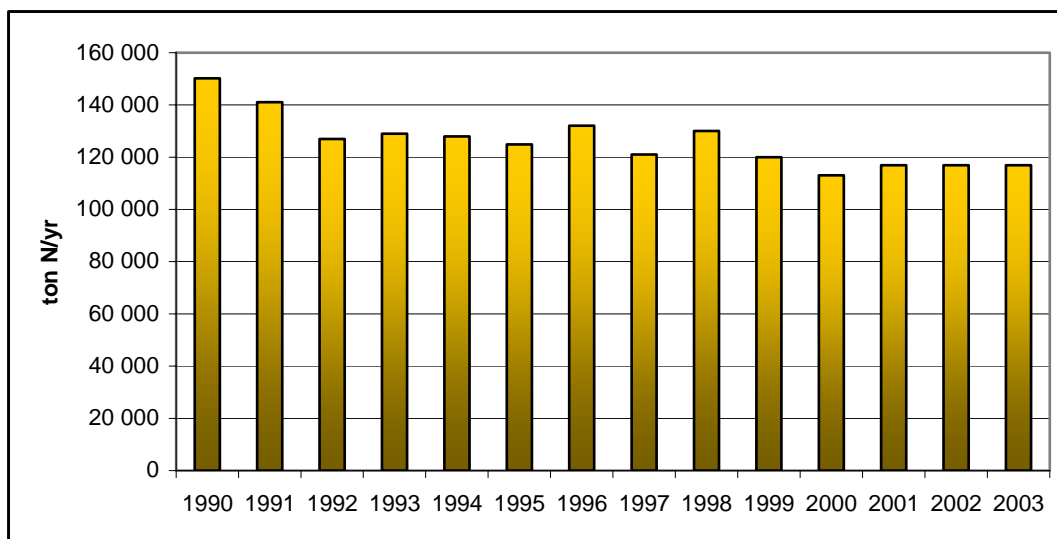
Figure 6.17 – Sources of direct input of Nitrogen to agricultural soil (average 1990-2003)



The time series of the quantity of nitrogen used as synthetic fertilizers, presented in Figure 6.18, was obtained from FAO statistical database (<http://www.apps.fao.org>) which itself results from information gathered in Portugal. The values for 2002 and 2003 are still provisional and equals the 2001 value, in agreement with the observed trend in time series. This time series shows an abrupt decrease until 1992 and thereafter a lighter reduction: total synthetic nitrogen fertilizer use in 2003 is 22% less than in 1990. 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 6.17.

Figure 6.18 - Use of Nitrogen Fertilizers in Portugal (ton N/yr)



Losses of nitrogen from volatilisation of  $\text{NH}_3$  and  $\text{NO}_x$  were estimated using a time variable and country-specific fraction  $\text{Frac}_{\text{GASF}}$ , which varies between 0.053 and 0.062 kg  $\text{NH}_3\text{-N/kg N}$ , and

which are almost half the default value from table 4-19 of IPCC96 (0.1 kg NH<sub>3</sub>-N/kg N). In what concerns acidification emissions it was assumed that these emissions are fully ammonia. A more detailed explanation of the methodology and assumptions used to derive these country-specific volatilization fractions is presented in chapter NH<sub>3</sub> Emissions from Agriculture (Chapter 6.2.8)

The quantity of nitrogen in manure that is applied to soil as fertilizer resulting in N<sub>2</sub>O emissions is estimated from the same data that was used to estimate nitrogen excreted in N<sub>2</sub>O from Manure Management and assuming that only the manure that is treated under Solid Storage or liquid systems is used as soil fertilizer, i.e. MSSD<sub>(i,s)</sub> equals 1 only for Solid Storage and Liquid Systems and is zero for all other Manure Management Systems. Quantities applied each year were also presented in Figure 6.18 and Table 6.17 above, where is shown that manure is the second main source of nitrogen applied to soil. Ammonia volatilisation factors, EF<sub>NH3(i,s)</sub> and EF<sub>NH3SD</sub>, are presented and discussed in more detail in chapter NH<sub>3</sub> Emissions from Agriculture (Chapter 6.2.8) and they result from EMEP/UNECE Guidebook 3rd ed (table 3A in chapter B1050). These volatilisation fractions depend only on animal class and not on the specific Manure Management System.

Table 6.18 – Emission factors used for calculation of NH<sub>3</sub> volatilisation emissions from land spreading of manure as fertilizer

Animal Type	Losses after land spreading (kg NH <sub>3</sub> -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 (chapter B1010 version 4.0 (Sutton, 2003)) and are presented in Table 6.19 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 6.19 – Emission factors used for calculation of NH<sub>3</sub> volatilisation from animal droppings during grazing (Pasture Range and Paddock)

Animal Type	Grazing in Pasture
Dairy Cows	0.08
Other Cattle	0.08
Sheep	0.04
Goats	0.04
Swine	0.08
Equines	0.08

The use of emission factors of ammonia volatilisation from EMEP/UNECE results, therefore, in obtaining a value for Frac<sub>GASM</sub> that is different and lower than the default value for Frac<sub>GASM</sub> (0.2 kg N-NH<sub>3</sub> + N-NO<sub>x</sub>/ kg of N excreted, in table 4-19 of IPCC96). The resultant implied Frac<sub>GASM</sub> 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 6.20 and Table 6.21 for leguminous crops and Table 6.22 to Table 6.25 for non leguminous crops. For each year a three year average centered in the reporting year was used<sup>120</sup>. 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 6.20 – Annual (three year average) production of Leguminous Crops (metric tons) (1/2)

Crop	1990	1991	1992	1993	1994	1995	1996
Peanut	29	32	29	26	20	17	20
Broad Beans <sup>(1)</sup>	15 486	15 402	15 285	15 182	14 766	15 050	14 829
Broad Beans, green	32 000	30 000	30 000	30 000	30 000	30 000	30 000
Beans	31 243	27 426	21 926	17 070	13 553	12 679	11 722
Chick-Peas	3 563	3 081	2 583	2 101	1 937	1 899	1 815
Lupins	48	43	35	37	34	34	34
Peas Green <sup>(1)</sup>	5 867	5 867	5 433	5 533	5 867	6 533	7 210
Carobs <sup>(1)</sup>	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green <sup>(1)</sup>	25 000	25 000	25 000	25 000	32 200	37 433	40 308
Total	133 236	126 850	120 292	114 949	118 377	123 646	125 939

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.21 - – Annual (three year average) production of Leguminous Crops (metric tons) (2/2)

Crop	1997	1998	1999	2000	2001	2002	2003
Peanut	23	27	25	25	25	25	25
Broad Beans <sup>(1)</sup>	15 162	14 829	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
Beans	10 756	8 951	7 456	6 157	5 883	5 478	5 297
Chick-Peas	1 810	1 478	1 198	968	1 012	1 167	1 254
Lupins	34	34	34	34	34	34	34
Peas Green <sup>(1)</sup>	7 417	7 390	6 947	6 974	7 000	7 000	7 000
Carobs <sup>(1)</sup>	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Beans Green <sup>(1)</sup>	33 461	26 844	21 002	18 107	16 679	16 833	16 563
Total	118 663	109 552	101 662	97 264	95 633	95 537	95 173

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

<sup>120</sup> For year n the value reported as production crop is the average of n-1, n and n+1, except for last year of the inventory where only n-1 and n are used.



Table 6.22 - Annual Production of non-leguminous Crops (metric tons) (1/4)

Crop	1990	1991	1992	1993	1994	1995	1996
Wheat	510 519	425 761	467 499	415 445	414 741	409 403	364 982
Triticale	61 983	61 350	67 167	74 463	70 552	63 141	47 680
Maize	666 832	666 596	667 567	685 982	698 177	738 450	789 109
Barley	95 691	88 545	95 201	85 904	82 590	73 074	50 600
Rye	98 612	82 120	72 195	66 673	55 594	51 326	43 625
Oats	91 718	64 436	65 868	66 907	71 084	65 778	54 137
Rice Paddy	156 939	145 418	116 394	103 482	108 432	142 842	153 658
Sunflower	46 954	48 644	43 418	45 355	37 061	34 806	30 466
Hops	194	112	68	45	88	129	131
Tomatoes	714 563	657 940	552 343	612 691	742 308	877 383	848 629
Tobacco	5 072	4 901	4 108	3 855	4 059	5 283	5 665
Tea	170	127	73	43	48	62	57
Chicory	2 203	2 533	2 761	3 035	2 855	2 644	2 391
Potatoes	1 374 093	1 448 989	1 445 498	1 428 786	1 374 603	1 329 139	1 159 229
Sugar Beet	12 225	14 627	21 051	33 769	46 346	46 492	79 635
Yams <sup>(1)</sup> after 1994	1 294	1 438	1 369	1 314	1 182	1 176	1 535
Sugar Cane <sup>(1)</sup> after 1991	3 760	3 878	3 996	4 000	4 000	4 000	4 000
Sweet Potatoes <sup>(1)</sup>	27 000	26 667	28 000	27 333	26 333	23 667	22 667
Maize for Forage <sup>(1)</sup>	3 398 333	3 545 000	3 883 333	4 228 333	4 511 667	4 633 333	4 766 667
Sorghum for Forage <sup>(1)</sup>	331 667	363 333	361 667	356 667	341 667	346 667	360 000
Roots Fodder <sup>(1)</sup>	378 333	383 333	388 333	393 333	386 667	395 000	401 667
Forage <sup>(1)</sup>	6 300 000	6 033 333	5 833 333	6 033 333	6 433 333	6 866 667	6 933 333
Pumpkins <sup>(1)</sup>	4 200	4 200	4 033	3 867	6 600	9 700	12 600
Lettuce <sup>(1)</sup> until 1996	32 000	32 000	34 667	40 000	49 267	56 367	62 761
Garlic <sup>(1)</sup>	1 667	1 667	1 533	1 467	1 467	1 467	1 433
Eggplants <sup>(1)</sup>	6 667	6 667	6 100	5 833	5 833	5 833	5 667
Onions <sup>(1)</sup> until 1996	57 200	57 200	68 133	82 400	101 933	107 900	109 540
Carrots <sup>(1)</sup> until 1996	82 667	83 000	83 000	83 000	97 700	128 133	139 062
Cauliflower <sup>(1)</sup> until 1996	19 667	20 000	20 000	20 000	23 300	26 700	29 441
Cabbages <sup>(1)</sup> until 1996	166 667	166 667	153 333	146 667	150 000	150 000	195 705
Spinach <sup>(1)</sup>	16 667	16 667	15 333	14 667	14 667	14 667	14 333
Watermelons <sup>(1)</sup> until 1996	2 333	2 000	2 000	2 000	2 000	2 000	19 278
Melons <sup>(1)</sup> until 1996	20 000	20 000	20 000	20 000	20 000	20 000	52 131
Cucumbers <sup>(1)</sup>	8 333	8 333	7 667	7 333	7 333	7 333	7 167
Chillies <sup>(1)</sup> until 1996	1 000	1 000	1 000	1 000	1 000	1 000	15 870
Mushrooms <sup>(1)</sup>	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 6.23 - Annual Production of non-leguminous Crops (metric tons) (2/4)

Crop	1997	1998	1999	2000	2001	2002	2003
Wheat	295 345	277 452	285 933	286 823	307 120	238 743	281 310
Triticale	37 354	29 787	30 216	29 849	27 295	17 622	18 339
Maize	877 874	926 044	930 023	905 264	859 531	833 755	797 311
Barley	41 648	28 096	30 613	26 075	22 982	15 208	16 518
Rye	42 367	42 930	44 851	42 086	34 980	28 481	30 626
Oats	44 496	57 578	80 278	83 605	70 852	46 394	50 243
Rice Paddy	166 064	159 204	152 012	146 731	144 816	146 546	146 854
Sunflower	34 319	27 399	27 928	23 242	24 443	20 926	19 577
Hops	107	72	52	51	50	48	46
Tomatoes	931 862	963 897	996 516	937 512	889 848	891 044	880 799
Tobacco	6 310	6 170	6 267	5 895	5 834	5 700	5 669
Tea	37	25	26	27	27	27	27
Chicory	2 290	2 342	2 220	2 633	2 967	3 300	3 300
Potatoes	996 255	913 913	874 442	795 252	739 309	737 055	758 558
Sugar Beet	123 188	280 829	384 902	415 982	462 161	469 632	564 004
Yams <sup>(1)</sup> after 1994	1 770	2 091	2 100	2 100	2 100	2 100	2 100
Sugar Cane <sup>(1)</sup> after 1991	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Sweet Potatoes <sup>(1)</sup>	22 000	22 000	22 000	22 000	22 000	22 000	22 000
Maize for Forage <sup>(1)</sup>	4 926 667	4 966 667	5 000 000	5 000 000	5 000 000	5 000 000	5 000 000
Sorghum for Forage <sup>(1)</sup>	360 000	360 000	360 000	360 000	360 000	360 000	360 000
Roots Fodder <sup>(1)</sup>	418 333	420 000	420 000	420 000	420 000	420 000	420 000
Forage <sup>(1)</sup>	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000	7 200 000
Pumpkins <sup>(1)</sup>	12 600	12 167	12 000	12 000	12 000	12 000	12 000
Lettuce <sup>(1)</sup> until 1996	74 069	84 876	79 469	66 190	54 680	57 424	59 192
Garlic <sup>(1)</sup>	1 400	1 400	1 400	1 400	1 400	1 400	1 400
Eggplants <sup>(1)</sup>	5 500	5 500	5 500	5 500	5 500	5 500	5 500
Onions <sup>(1)</sup> until 1996	104 479	108 760	85 286	62 362	34 474	35 335	37 079
Carrots <sup>(1)</sup> until 1996	144 900	144 646	123 294	90 898	49 775	49 255	50 170
Cauliflower <sup>(1)</sup> until 1996	29 823	31 140	26 201	20 378	14 715	15 966	17 161
Cabbages <sup>(1)</sup> until 1996	248 032	316 469	268 789	209 110	153 837	165 642	179 489
Spinach <sup>(1)</sup>	14 000	14 000	14 000	14 000	14 000	14 000	14 000
Watermelons <sup>(1)</sup> until 1996	37 345	55 412	43 959	32 427	22 478	24 772	26 355
Melons <sup>(1)</sup> until 1996	87 599	127 281	109 970	91 754	73 780	80 667	85 122
Cucumbers <sup>(1)</sup>	7 000	7 000	7 000	7 000	7 000	7 000	7 000
Chillies <sup>(1)</sup> until 1996	33 766	51 662	48 786	45 088	44 346	49 506	52 461
Mushrooms <sup>(1)</sup>	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 6.24 - Annual Production of non-leguminous Crops (metric tons) (3/4)

Crop	1990	1991	1992	1993	1994	1995	1996
Quinces	4 567	4 067	3 560	3 793	3 148	2 647	1 916
Loquat	1 528	1 594	1 527	1 622	1 606	1 666	1 552
Pomegranate	1 803	1 803	1 770	1 737	1 667	1 636	1 422
Pineapples <sup>(1)</sup> after 1992	1 476	1 760	1 927	2 093	2 000	2 000	2 000
Bananas <sup>(1)</sup> after 1991	43 648	41 156	38 300	37 667	35 000	32 667	31 667
Peach	90 123	94 948	97 090	95 860	90 813	85 731	83 124
Apples	270 551	275 635	269 502	252 390	237 011	234 541	259 108
Kiwi	3 406	5 863	8 403	9 808	9 412	9 554	9 960
Pears	93 580	96 660	97 790	110 070	104 094	108 363	127 956
Sour Cherries	642	682	713	677	630	606	444
Fig	15 100	14 683	13 583	10 809	8 330	6 656	5 548
Kaki	4 650	4 633	4 460	4 393	3 633	2 785	1 582
Apricots	4 543	4 610	4 480	4 695	4 812	4 956	4 904
Cherry	11 795	13 333	13 940	13 291	11 425	10 892	10 841
Plum	16 332	16 639	15 935	16 747	17 162	17 757	17 812
Avocados <sup>(1)</sup>	20 967	20 333	18 667	16 233	14 100	13 000	13 000
Strawberries <sup>(1)</sup>	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Raspberries <sup>(1)</sup>	100	100	100	100	100	100	100
Berries nes <sup>(1)</sup>	100	133	133	133	100	100	100
Tangerine	25 125	25 623	26 741	29 525	32 194	34 769	34 906
Lemon	10 117	10 438	10 518	10 791	10 906	10 402	9 981
Orange	169 155	174 974	173 802	179 825	190 173	191 883	199 290
Pomelo	4 950	5 267	5 550	5 909	6 320	6 769	6 863
Grapefruit	832	800	760	852	924	996	964
Walnut	5 610	5 283	4 508	3 550	3 105	3 053	3 245
Chestnuts	19 052	17 358	15 266	17 174	19 602	23 316	24 956
Hazelnuts	1 993	1 900	1 690	1 435	1 116	976	865
Almonds	50 377	48 375	47 548	38 783	31 320	26 406	31 049
Olives (Oil)	302 638	246 248	266 260	200 115	256 993	269 537	298 497
Olives (fruit)	21 400	19 900	16 821	12 491	9 823	9 156	9 248
Wine grapes	1 285 581	1 285 582	997 133	826 044	834 841	1 036 179	1 015 820
Grapes <sup>(1)</sup>	52 752	54 418	52 867	52 112	53 445	55 401	58 131
Total	17 235 220	16 986 779	16 752 885	17 063 206	17 893 790	18 849 561	19 055 200

Source: All data From National Statistical Institute except: (1) - FAO Statistical Database (<http://www.fao.org>)

Table 6.25 - Annual Production of non-leguminous Crops (metric tons) (4/4)

Crop	1997	1998	1999	2000	2001	2002	2003
Quinces	1 819	1 990	2 110	2 203	2 090	2 061	2 064
Loquat	1 388	1 142	948	888	903	885	878
Pomegranate	1 142	743	527	411	411	403	399
Pineapples <sup>(1)</sup> after 1992	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Bananas <sup>(1)</sup> after 1991	31 667	33 333	35 000	35 000	33 333	30 000	30 000
Peach	71 005	69 346	62 671	53 891	50 153	47 930	58 516
Apples	234 168	246 816	227 159	261 999	263 940	284 190	293 987
Kiwi	8 711	8 822	8 315	9 148	9 237	9 774	10 856
Pears	140 384	147 176	131 057	138 305	136 302	118 911	107 479
Sour Cherries	268	110	95	91	64	42	42
Fig	4 700	3 952	3 840	3 790	3 632	3 634	3 642
Kaki	994	1 240	1 799	2 591	2 810	3 030	3 128
Apricots	4 507	4 956	5 148	4 742	4 242	3 907	4 540
Cherry	9 044	10 786	9 506	12 123	13 201	15 368	17 062
Plum	16 743	16 975	16 214	15 108	14 478	14 893	16 613
Avocados <sup>(1)</sup>	13 000	13 000	13 000	13 000	13 000	13 000	13 000
Strawberries <sup>(1)</sup>	2 500	2 500	2 500	2 500	2 500	2 500	2 500
Raspberries <sup>(1)</sup>	100	100	100	100	100	100	100
Berries nes <sup>(1)</sup>	100	100	100	100	100	100	100
Tangerine	35 814	39 763	42 052	44 924	48 097	53 997	57 834
Lemon	9 301	9 864	10 516	11 260	11 447	12 019	12 328
Orange	219 960	231 015	245 725	229 659	251 633	258 756	277 106
Pomelo	6 868	5 816	4 788	3 774	4 021	4 140	4 306
Grapefruit	880	657	471	306	287	255	249
Walnut	3 331	3 740	3 880	4 322	4 323	4 530	4 572
Chestnuts	26 981	28 880	31 200	30 135	30 273	30 257	32 326
Hazelnuts	802	752	668	641	614	596	608
Almonds	31 464	33 263	28 821	25 804	24 539	23 470	27 333
Olives (Oil)	269 950	285 190	237 880	235 516	199 086	221 014	222 260
Olives (fruit)	9 275	10 160	9 253	10 947	10 952	12 199	11 468
Wine grapes	818 094	733 423	763 925	940 712	893 026	891 428	841 885
Grapes <sup>(1)</sup>	52 392	52 370	49 675	53 888	54 641	54 338	55 265
Total	19 363 152	19 651 790	19 631 974	19 518 112	19 174 732	19 101 776	19 243 651

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 ( $\text{Res}_{\text{BF}}/\text{Crop}_{\text{BF}}$ ), the fraction of dry matter in product ( $\text{Frac}_{\text{DM}}$ ) and the fraction of dry biomass in the whole plant that is nitrogen ( $\text{Frac}_{\text{NCRBF}}$ ). These parameters were established for each leguminous plant using the default IPCC 1996 Revised Guidelines which was latter replaced by table 4.16 of Good Practice Handbook) when available, and from other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in Table 6.26

Table 6.26 – 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 6.26). The values for other non-leguminous crops were determined from IPCC defaults (IPCC96 and GP) and other sources (Jarrige, 1988; INRA, AFRC). The considered values are presented in next table.

Table 6.27 - 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
Roots Fodder	0.30	10.0	2.28
Forage	0.09	20.0	1.08
Pumpkins	1.00	15.0	1.50
Lettuce	0.10	10.0	1.36
Garlic	0.10	10.0	1.36
Eggplants	1.00	15.0	1.50
Onions	0.10	10.0	1.36
Carrots	0.10	12.5	1.36
Cauliflower	0.10	13.5	2.70
Cabbages	0.10	13.5	2.70
Spinach	0.10	10.0	1.36
Fresh Fruit <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.

## UNCERTAINTY ASSESSMENT

The Good Practice Guidebook has no information concerning the uncertainty in activity data. The expected error in the quantity of synthetic fertilizers added to soil is expected to be high due to the lack of a suitable monitoring program. Other studies (Seixas et al, 1999; PNAC) made annual estimates that are up to 33% different from the inventory estimate. The double of this value (66%) was assumed to be a very conservative guess of the uncertainty factor. For nitrogen in animal manure applied to soil and animal production the same uncertainty value that was used for activity data in N<sub>2</sub>O from Manure Management was used and increased, in the case of animal manure applied to soil, by 100% due to the uncertainty in the percentage of manure that ends up in soil. Errors due to determination of nitrogen volatilization have an overall lesser importance and the global effect is difficult to access because the interconnections with indirect emissions. An uncertainty error of 25% in crop production was considered in accordance with GPG considerations about overall error for the all source sector.

GPG presents a possible variation from one-fifth to 5 times the default emission factor of 1.25%. From that range an uncertainty of 500% was assumed in uncertainty analysis for nitrogen applied as synthetic fertilizers, manure, crop residues and nitrogen fixed by n-fixing crops. Considering that in the cases of nitrogen added to soil from n-fixing crops and crop residues, an additional 100% uncertainty was added to take into account errors in the determination of nitrogen content of crops and residues from production, although this does not affect the final uncertainty factor<sup>121</sup>. In the case of animal production a lower uncertainty of 100% was used, following table 4.12 of the GPG.

## RECALCULATIONS

Substantial changes were made for this source sector, resulting from:

- use of three year average for activity data, both livestock numbers – and consequent animal manure production and nitrogen excretion – and crop production;
- consideration of the contribution of nitrogen in manure managed in liquid systems to agricultural soil, in order to avoid under-estimation of this nitrogen source;
- Emissions of N<sub>2</sub>O from Animal Production are now estimated applying the emission factor before ammonia volatilization subtraction, in a consistent way to N<sub>2</sub>O emissions estimate from Manure Management;
- 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;
- downward revision of the ammonia volatilization fraction FracGASM, which is now calculated using fertilizer specific data. Fraction values are now time dependent;
- revision of crop production data, according to the revised production time series from INE and correction of errors for some intermediate years;

## 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.

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<sup>121</sup> According to CRF table formats activity data is expressed as dry matter production and not nitrogen added to soil.

Major efforts will be placed in the improvement of activity data for the most important nitrogen contributor to soil: synthetic fertilizers. After agreement between the National Institute of Statistics (INE), the Ministry of Agriculture and the Institute for the Environment, INE is producing a time series of total use of nitrogen in synthetic fertilizers applied to soil, using statistical information such as production, import and export data of nitrogen fertilizers as well as cross-checking with estimates based on nitrogen input using agricultural area and nitrogen input rates per hectare. It was however still not possible to use this new time-series for this year inventory, which is expecting finalization and verification for the first years in the 1990 decade.

The share of each nitrogen fertilizer, particularly the importance of urea use, is also under study by INE and will be used to improve the preliminary estimate that was made by IA and that is temporarily being used in this year report.

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  $\text{Frac}_{\text{FOD}}$  parameter.

Efforts will be made to quantify the nitrogen in sewage sludge that is used as soil fertilizer.

### 6.3.F Indirect N<sub>2</sub>O Emissions from Agriculture (CRF 4D2)

#### OVERVIEW

Emissions of N<sub>2</sub>O from agriculture are considered indirect emissions from agriculture when they result from nitrogen that was not emitted when was applied the first time into soil but that has first suffered a path through 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<sub>2</sub>O indirect emissions result from the same microbial process associated to nitrification and denitrification that causes direct emissions. The only difference results from the fact that direct emissions occur solely in agricultural soils whether indirect emissions will occur in whenever conditions are adequate: in agricultural soils, non agricultural soils and even aquatic, Benthic and wetland systems.

Also, all NO<sub>x</sub> and NH<sub>3</sub> emissions from other emissions sources may settle in soil and water and result in similar N<sub>2</sub>O 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 where 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>122</sup>.

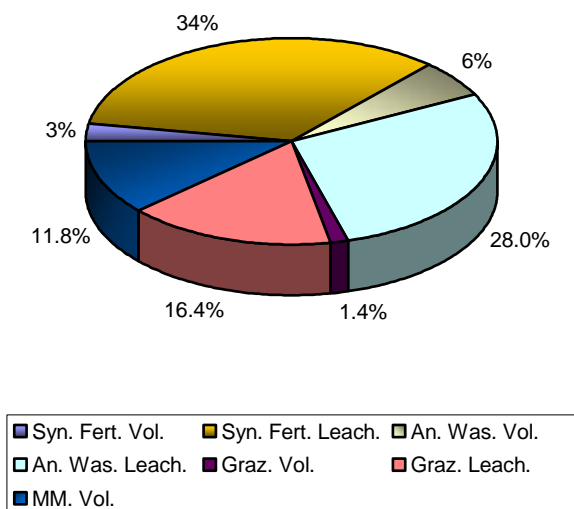
As may be seen from Figure 6.24, where the percent importance of each sub-source is represented for year 2003, indirect emissions from runoff and leaching from animal wastes applied to soil and from synthetic fertilizers are the two significant sources. Also representative are emissions from lixiviation from pasture range and volatilization from Manure Management systems. Indirect emissions from volatilization of ammonia applied to soil, either synthetic fertilizers or animal wastes and manure, have lesser importance.

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<sup>122</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.



Figure 6.19 – Relative importance of Indirect emissions of N<sub>2</sub>O from agriculture in year 2003



## METHODOLOGY

Different methodologies were used to estimate emissions for:

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>123</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).

<sup>123</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.

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 occurs predominantly in ammonia form.

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, that is proposed in GPG (equation 4.35 or 4.37):

$$N_2O_{(L)} = 44/28 * (N_{Fert} + N_{AM} + N_{GR}) * Frac_{LEACH} * EF_5$$

where,

$N_{Fert}$  - Annual amount of synthetic fertilizer nitrogen applied to soils (ton N/yr);

$N_{AM}$  - Annual amount of animal manure nitrogen intentionally applied to soils (ton N/yr), calculated from:

$$N_{AM} = \sum_i \{N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})]\}$$

$N_{(i)}$  - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category i;

$MS_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category i that is managed in Manure Management System s, except grazing;

$MSSD_{(i,s)}$  - Fraction of Manure/Nitrogen from livestock category i treated in Manure Management System S that is used as fertilizer in agriculture soils;

$EF_{NH3(i,s)}$  - Fraction of nitrogen in Manure Management System S from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$N_{GR}$  - Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture;

$Frac_{LEACH}$  - Fraction of N input that is lost through leaching and runoff

$EF_5$  - Emission factor for leaching/runoff (Kg N<sub>2</sub>O / kg NH<sub>3</sub>-N + NO<sub>x</sub>-N)

## EMISSION FACTORS

Default IPCC emission factors where used for  $EF_4$  and  $EF_5$  (table 4-23 of the 1996 IPCC and table 4.18 of the GPG):

Table 6.28 – Emission factors for N<sub>2</sub>O indirect emissions from agricultural soil

Emission Factor	Kg N <sub>2</sub> O / kg NH <sub>3</sub> -N + NO <sub>x</sub> -N
EF4 (Deposited nitrogen from volatilization)	0.010
EF5 (Leaching and Runoff)	0.025

GPG recommends strongly the use of the default IPCC emission factor for deposited nitrogen after volatilisation (EF<sub>4</sub>). According to GPG the default value for EF<sub>5</sub> will be probably revised in the near future.

## ACTIVITY DATA

Emissions of N<sub>2</sub>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 6.29 and Table 6.30 and which contribution of sub-sources in year 2003 is presented in Figure 6.20. Nitrogen from NH<sub>3</sub> volatilisation from Manure Management Systems was the major contributor to indirect emissions with about 59% of total deposition in 2003. The following most important components are nitrogen in manure applied to soil as fertilizer (26 %) and nitrogen volatilised from synthetic fertilizers (13 %). Nitrogen in droppings during grazing is a less important source with 6 % of emissions in 2003. Total ammonia emissions and deposition has grown about 1.8 % from base year to 2003.

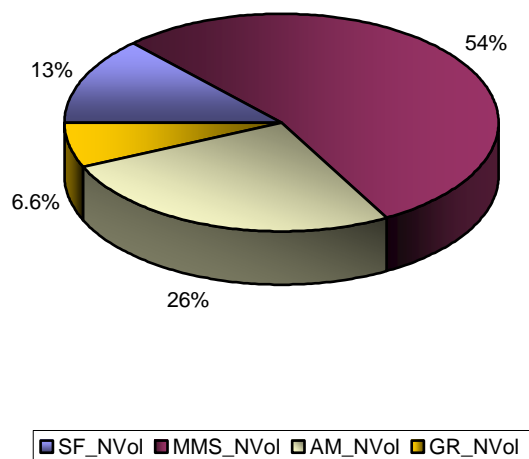
Table 6.29 – Nitrogen added to soil indirectly from Ammonia volatilisation, by emission source/component (1990-1996)

ton NH <sub>3</sub> /yr	1990	1991	1992	1993	1994	1995	1996
SF_NVol	7 940	7 556	7 196	6 187	7 428	7 018	7 771
MMS_NVol	29 524	29 360	29 402	29 197	29 160	29 108	29 085
AM_NVol	13 932	13 824	13 828	13 786	13 880	14 051	14 073
GR_NVol	3 896	3 839	3 811	3 780	3 801	3 814	3 815
Total	55 292	54 579	54 237	52 950	54 268	53 992	54 745

Table 6.30 – 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	2003
SF_NVol	7 604	7 360	7 223	6 477	7 111	7 195	7 279
MMS_NVol	29 450	30 242	30 124	30 262	30 508	30 561	30 414
AM_NVol	14 301	14 745	14 717	14 765	14 883	14 938	14 906
GR_NVol	3 826	3 838	3 850	3 801	3 757	3 701	3 687
Total	55 181	56 185	55 913	55 305	56 260	56 396	56 286

Figure 6.20 – Percent importance of nitrogen added to soil from volatilization of ammonia applied to agricultural soils, by emission source/component (2003)



The fraction of nitrogen input to soil that is lost through leaching and runoff ( $Frac_{LEACH}$ ) was set as 0.3 kg N/kg N, the default value in IPCC96. The losses of nitrogen from application of nitrogen in synthetic fertilizers and manure to agricultural soil are presented in tables Table 6.31 and Table 6.32 and in Figure 6.21, 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 2003 nitrogen deposited into soil has decreased by 10 %.

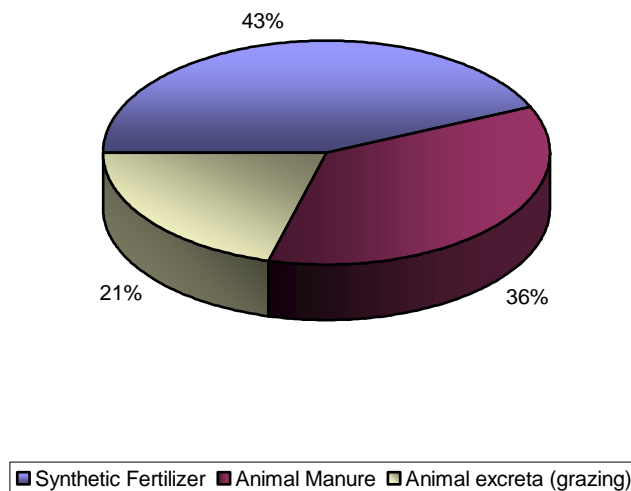
Table 6.31 – Nitrogen Lost from soil from lixiviation and runoff (1990-1996)

ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizer	45 060	42 300	38 100	38 700	38 400	37 500	39 600
Animal Manure	27 403	27 167	27 133	27 025	27 164	27 459	27 478
Animal excreta (grazing)	17 872	17 644	17 521	17 419	17 520	17 598	17 582
Total	90 335	87 111	82 754	83 144	83 084	82 557	84 660

Table 6.32 – Nitrogen Lost from soil from lixiviation and runoff (1990-1996)

ton N/yr	1997	1998	1999	2000	2001	2001	2002
Synthetic Fertilizer	36 300	39 000	36 000	33 900	35 100	35 100	35 100
Animal Manure	27 909	28 756	28 695	28 729	28 924	28 992	28 928
Animal excreta (grazing)	17 647	17 710	17 785	17 543	17 324	17 030	16 954
Total	81 855	85 466	82 479	80 172	81 348	81 123	80 981

Figure 6.21 – percent importance of sub-sources of Nitrogen Lost from soil from lixiviation and runoff in 2003



## UNCERTAINTY ASSESSMENT

The uncertainty in emission factors was set at an order of magnitude, in accordance with the considerations in GPG (IPCC,2000). In what concerns the uncertainty associated with activity data an additional 50% error was applied to activity data reported in N<sub>2</sub>O Direct emissions, in order to incorporate the error of the volatilization and leaching fractions, also in accordance with GPG (IPCC,2000).

## RECALCULATIONS

The main modification in the methodology has resulted from the fact that now the quantity of nitrogen that is lixiviated is estimated prior to subtraction of ammonia from synthetic fertilizers and animal manure that are added to soil as nitrogen sources. The methodology that is now used follows more closely the proposed methodology in IPCC (1997) and IPCC (2000).

Changes in emission estimates of N<sub>2</sub>O Indirect emissions resulted also indirectly from changes in the quantity of manure that is produced and applied to soil, crop production (discussed in chapter 6.2.3) and mainly from the revision of the volatilization factor for synthetic fertilizers applied to soil.

## 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.

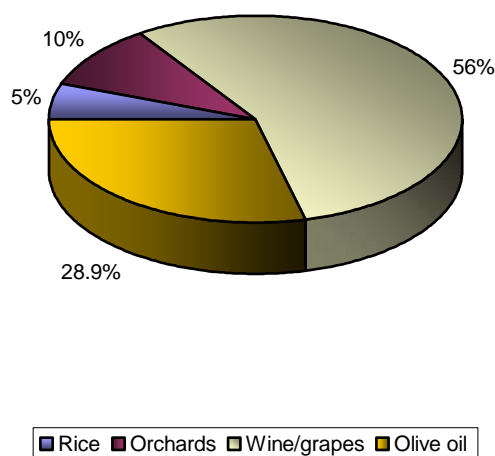
### 6.3.G Field Burning of Agriculture Residues (CRF 4F)

#### OVERVIEW

In-site burning of agricultural residues is still practiced nowadays in Portugal, being however forbidden by law-decree during the Forest Fire Season from May to September. This burning, results in emissions of trace gases as in other combustion processes, including methane, nitrous oxide, carbon monoxide, nitrous oxides and volatile organic compounds. Carbon dioxide is of course also emitted in this process but because it has biomass origin and it is in principle re-absorbed during next growing season, it is not considered in GHG emission inventory.

Considering equivalent carbon dioxide emissions (Figure 6.22), burning of residues from vineyards and olive oil are the most significant sources of this non-key source.

Figure 6.22 – Importance of GHG emissions from field burning of agriculture residues by crop in 2003



#### METHODOLOGY

Emissions of in-site burning of agriculture residues were estimated from the following equation:

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

where

$\text{Emission}_{(p, \text{crop}, y)}$  - Emission estimate of pollutant p from field burning of residues from a specific crop in year y (ton/year);

$\text{Crop}_{\text{BURN}(\text{crop}, y)}$  - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{EF}_{(p, \text{crop})}$  - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm).

Other methodology formulations could be used that would result in equal results. However activity data definition in dry matter terms was chosen in order that emission factors would be expressed in the same units that are presented in Implied Emission Factors (IEF) of table 4.F of CRF format. Consequently part of methodology that is in fact used to determine emissions, is included in emission factor determination and part also in activity data determination and they are subsequently described in the appropriate chapters. But for all relevant aspects, the methodology that it is used, follow the same methodology proposed in IPCC96 except for the fact that residue biomass is not estimated from crop production but from residue production quantities by cultivated area.

## 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 IPCC96 - assumes that some fixed part of carbon and nitrogen that are submitted to burning are emitted as specific compounds.

For carbon containing pollutants the equation is:

$$EF_{(pol,crop)} = C_{Fraction (Crop)} * Frac_{RESOXI (crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

For nitrogen containing compounds the equation is:

$$EF_{(pol,crop)} = C_{Fraction (Crop)} * Frac_{RESOXI (crop)} * NC_{Ratio (crop)} * ER_{(crop,pol)} * MWC_{(Pol)}$$

where

$EF_{(pol,crop)}$  - Emission factor from field burning of agriculture residues of a specific crop (kg/ton dm);

$C_{Fraction (Crop)}$  - Ratio of carbon content in dry biomass matter (kg C/kg dm);

$Frac_{RESOXI (crop)}$  - Fraction or ratio of carbon that it is oxidized during the active burning period (kg C/kg C);

$NC_{Ratio (crop)}$  - Ratio of nitrogen to carbon in crop residue (kg N/kg C);

$ER_{(crop,pol)}$  - Emission ratio, the fraction of total carbon/nitrogen content that it is emitted as pollutant pol (kg C/kg C or kg N/kg N);

$MWC_{(Pol)}$  - Stechiometric correction fraction to convert emissions in carbon/nitrogen units to total molecular weight emissions (kg/kg C or kg/kg N respectively for carbon compounds or nitrogen compounds).

The parameters used to establish emission factors for each crop are presented in next table.

Table 6.33 – 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 IPCC96 and which were still not updated in GPG (Annex 4.A.2).

Table 6.34 – 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 6.35, together with final emission factors for all other pollutants and all crops.

Table 6.35 – 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	PM <sub>10</sub> -PM <sub>1</sub>
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%

## 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>124</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 established the quantity of residues that is generated annually by each crop and what percentage is actually burnt in site. Activity data in suitable units is estimated from:

$$\text{Crop}_{\text{BURN (crop,y)}} = \text{Crop}_{\text{AREA(crop,y)}} * \text{Resid}_{\text{PROD (crop)}} * \text{Dm}_{\text{Content(crop)}} * \text{Frac}_{\text{RESBURN (crop)}} * 10^{-7}$$

where

$\text{Crop}_{\text{BURN (crop,y)}}$  - Biomass of residue of a specific crop in year y that it is burned in site expressed in biomass dry matter (t dm/yr);

$\text{Crop}_{\text{AREA (crop,y)}}$  - Cultivated area for each specific crop in year y (ha/yr);

<sup>124</sup> Comprehending fresh fruit, citrines and dry fruits (nuts)



$\text{Resid}_{\text{PROD (crop)}}$  - 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 6.36. Final activity data expressed in crop area dry matter content may be seen in Table 6.36 and Table 6.37, and in Table 6.38 – Estimated quantities of burnt crop area per crop (ha) (1997-2003)

Crop	1997	1998	1999	2000	2001	2002	2003
Rice	28 540	27 020	25 307	23 859	24 936	25 216	25 657
Orchards	162 336	161 382	157 122	157 698	157 909	157 985	158 139
Wine/grapes	232 226	226 497	219 444	220 356	222 569	222 620	222 446
Olive oil	338 414	347 271	368 974	369 162	369 314	369 858	374 154
Total	761 516	762 169	770 847	771 075	774 728	775 679	780 396

Figure 6.23.

Table 6.36 – Parameters used for the estimation of the quantity of burnt crop residues

Crop	$\text{Resid}_{\text{PROD}}$ kg live weight/ha	$\text{Frac}_{\text{RESBURN}}$ %	$\text{DMContent}$ %
Rice	3 900	50	30
Orchards	800	30	50
Wine/Grapes	2 500	40	50
Olive oil	375	100	50

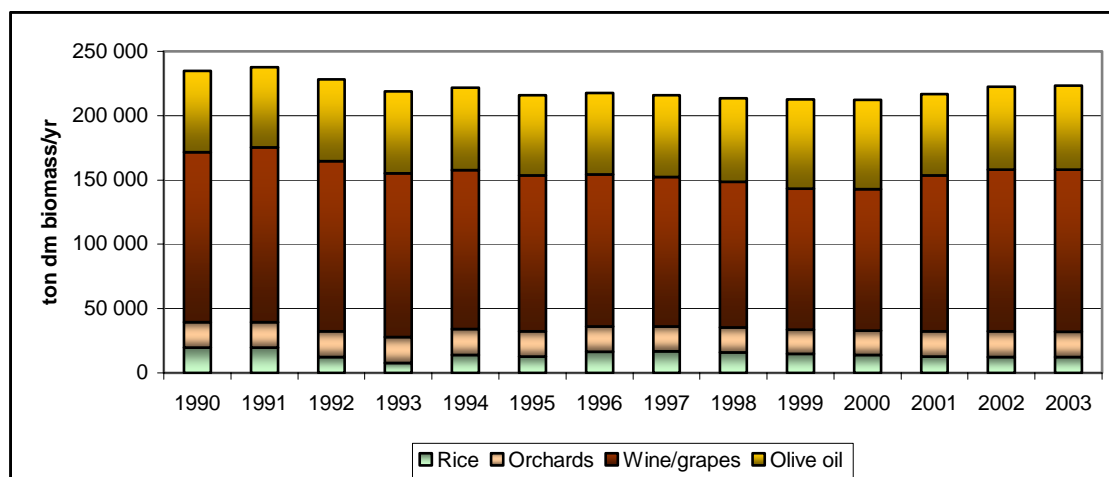
Table 6.37 – Estimated quantities of burnt crop area per crop (ha) (1990-1996)

Crop	1990	1991	1992	1993	1994	1995	1996
Rice	33 824	33 466	21 118	13 200	24 051	21 726	28 278
Orchards	164 147	166 120	168 101	166 838	165 690	164 748	163 842
Wine/grapes	264 359	271 160	264 062	254 528	247 615	241 964	236 654
Olive oil	337 189	333 757	338 947	340 579	340 672	333 144	336 621
Total	799 519	804 503	792 228	775 145	778 028	761 582	765 395

Table 6.38 – Estimated quantities of burnt crop area per crop (ha) (1997-2003)

Crop	1997	1998	1999	2000	2001	2002	2003
Rice	28 540	27 020	25 307	23 859	24 936	25 216	25 657
Orchards	162 336	161 382	157 122	157 698	157 909	157 985	158 139
Wine/grapes	232 226	226 497	219 444	220 356	222 569	222 620	222 446
Olive oil	338 414	347 271	368 974	369 162	369 314	369 858	374 154
Total	761 516	762 169	770 847	771 075	774 728	775 679	780 396

Figure 6.23 – Estimated total quantities of burnt crop residues per crop (1990-2003)



## UNCERTAINTY ASSESSMENT

The uncertainty in activity data is higher than the error associated with crop area determination, because there is a higher uncertainty in the percentage of crop areas that are subjected to burning and in which crops field burning is practiced. An uncertainty value of 100% was therefore considered.

The uncertainty range in emission factors was set at 20% in accordance with recommendations from GPG (IPCC,2000).

## RECALCULATIONS

In what concerns the other pollutants no modifications were made either in methodology or emission factors, and changes resulted only indirectly from the revision in crop area time series. However the use of three year average for activity data and emission estimates was not adopted for this source.

## FURTHER IMPROVEMENTS

Associated with agriculture activities, the burning of hedge rows and some infestants is still practice in Portugal. There is still no data concerning this activity and a better insight on this subject will have to be developed in next inventories.

The adoption of three year average for crop area and emissions will be discussed under Methodology Development Plan, which is not use yet for consistent with determination of emissions from forest fires.

## 6.3.H NH<sub>3</sub> Emissions from Volatilization of Fertilizers

### 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:

$$SN_{NH3} = N_{Fert} * Frac_{GASF}$$

where,

$N_{Fert}$  - total amount of nitrogen in synthetic fertilizers consumed annually

$Frac_{GASF}$  - fraction of nitrogen in synthetic fertilizers applied to soil that volatilises as  $NH_3$  or  $NO_x$

Ammonia emission from manure may occur in 4 different places in the life cycle of manure, with differentiated emission factors according to EMEP/CORINAIR Emission Factor Handbook:

- Emission in housing;
- Emission in outside storage;
- Emissions from land spreading of manure collected in each Manure Management Systems;
- Emissions of ammonia volatilised from droppings deposited directly in soil during grazing.

Emissions from manure during housing and storage ( $MMS_{NH3}$ ) are not differentiated and are estimated according to equation:

$$MMS_{NH3} = \sum_i [N_{(i)} * Nex_{(i)} * (1 - MS_{GRAZ(i)}) * EF_{NH3(i)}]$$

where

$N_{(i)}$  - Number (head) of individuals from livestock category i in the country;

$Nex_{(i)}$  - Annual country average N excretion per head of animal species/category i;

$EF_{NH3(i)}$  - Fraction of nitrogen from livestock category i that is lost to atmosphere as ammonia during housing and manure storage;

$MS_{GRAZ(i)}$  - Fraction of Manure/Nitrogen from livestock category i that is managed in Pasture Range and Paddock;

For the time being the emission factors are only dependent on animal type and not on the manure management system, except in what concerns the differentiation of ammonia volatilisation in grazing.

Emissions from manure collected in Manure Management Systems and that is later deposited in agricultural soil as fertilizer ( $AM_{NH3}$ ) is calculated from:

$$AM_{NH3} = \sum_i \{ N_{(i)} * Nex_{(i)} * \sum_s [MS_{(i,s)} * MSSD_{(i,s)} * (1 - EF_{NH3(i,s)})] * EF_{NH3SD(i)} \}$$

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;

$EF_{NH3SD(t)}$  - Fraction of nitrogen in manure that is lost to atmosphere as ammonia after application to soil as fertilizer.

Emissions from volatilisation of nitrogen added to soil during grazing (GZ\_NH3) was estimated by:

$$GZ\_NH3 = \sum_t [N_{(i)} * Nex_{(i)} * MS_{GRAZ(i)} * EF_{NH3(i)}]$$

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.

## EMISSION FACTORS

### AMMONIA VOLATILIZATION FROM SYNTHETIC FERTILIZERS

The volatilization ratio from synthetic fertilizers,  $Frac_{GASF}$ , was determined from a preliminary estimate of the share of nitrogen synthetic fertilizers used in Portugal. It must be stressed that this is a tentative first approach made by IA and it is expected that it will be replaced in next submissions with more accurate and founded data that is being analysed by INE, IA and the Ministry of Agriculture. Nevertheless it was felt that was better to use this factor than to rely in the use of the default IPCC approach that is recognized to be too high and not representative of the national conditions of fertilization, particularly when the results of the inventory are being used to discuss capes under the European CAFÉ program and Emissions Ceiling (NEC). The following approach was used:

- Data information concerning national production of nitrogen synthetic fertilizers was available from INE from 1992 till 2000, from the IAPI industrial survey and using PRODCOM product classification. This statistical information has confidential constraints and may not be published in the present report;

- Statistical information about foreign trade is available also from INE concerning importation and exportation of nitrogen fertilizers. Products are classified according to NC codes. The same confidential constraints apply to this data;

- annual consumption of nitrogen fertilizers per fertilizer type was hence estimated by IA for the years from 1992 to 2000, using the following equation<sup>125</sup>. In Figure 6.24 the share of consumption of each nitrogen fertilizer, as estimated by IA, is presented as an average situation in the 1992-2000 period, where it may be seen that Calcium Ammonium Nitrate is the main fertilizer in use and urea, the fertilizer more prone to nitrogen volatilization, represented about 17% of nitrogen added as fertilizer to soils.

$$\text{Consumption}_{(f)} = \text{Production}_{(f)} + \text{Import}_{(f)} - \text{Export}_{(f)}$$

where,

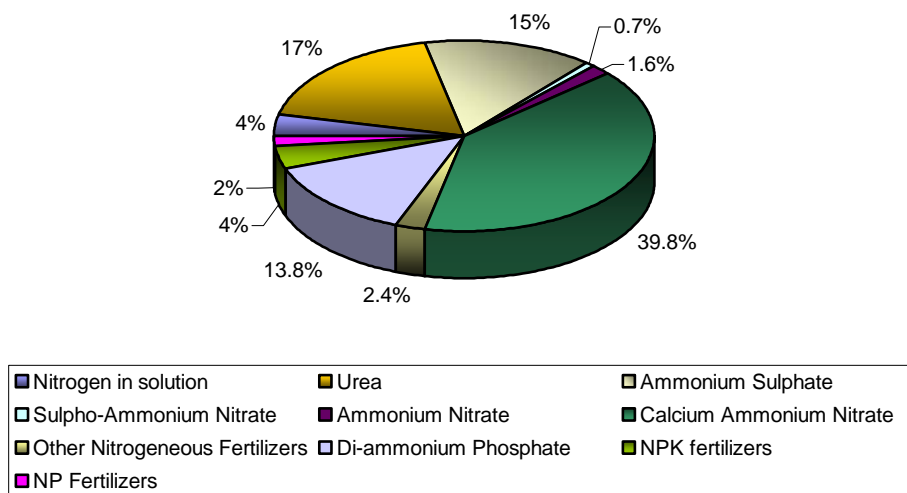
Consumption<sub>(f)</sub> – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

Production<sub>(f)</sub> – Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

Import<sub>(f)</sub> – Annual importation in Portugal of nitrogen fertilizer f (ton N/yr);

Export<sub>(f)</sub> – Annual exportation in Portugal of nitrogen fertilizer f (ton N/yr);

Figure 6.24 – Relative Importance of the use of various nitrogen fertilizers in Portugal, as estimated by IA from production and foreign trade



- product specific volatilization rates from EMEP/CORINAIR (EEA,2003) were used for each nitrogen fertilizer type according to Table 6.39.

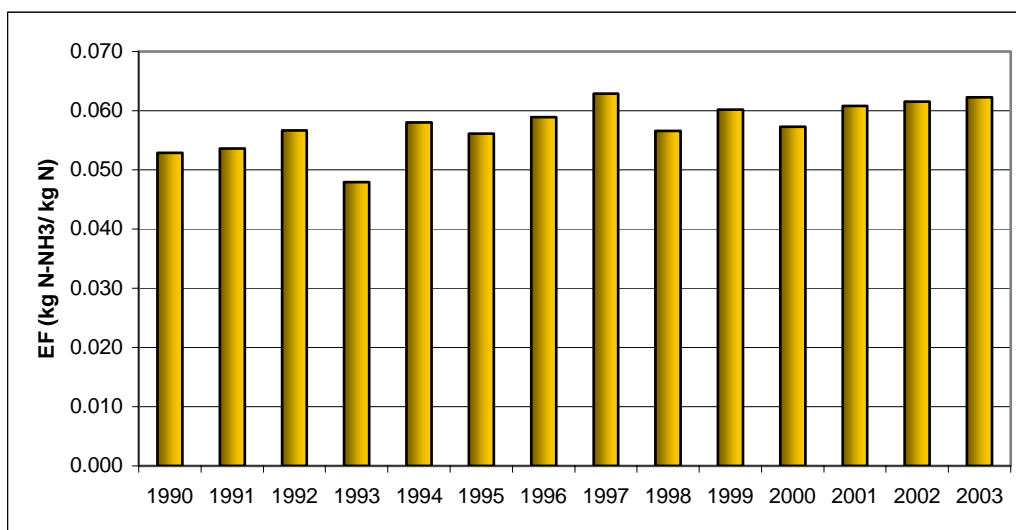
<sup>125</sup> This estimates are only preliminary guesses and are being revised together with INE and the Ministry of Agriculture.

Table 6.39 – Volatilization rates for each nitrogen fertilizer (Source: EMEP/CORINAIR file B1010vs4 - Revision of 3rd ed in Jan2003)

Acronym	Product	EF (kg NH <sub>3</sub> /kg N)
UAN	Nitrogen in solution	0.08
UREA	Urea	0.15
AS	Ammonium Sulphate	0.08
SAN	Sulpho-Ammonium Nitrate	0.05
AN	Ammonium Nitrate	0.02
CAN	Calcium Ammonium Nitrate	0.02
N	Other Nitr.Fertilizers	0.053
DAP	Di-ammonium Phosphate	0.05
NPK	NPK fertilizers	0.02
NP	NP Fertilizers	0.02

- finally, the weighted average ammonia volatilization rate was estimated for each year from 1992 to 2000 and back-extrapolated to 1990 and extrapolated to 2003. The final volatilization rates appear in Figure 6.25.

Figure 6.25 – Final volatilization rate of ammonia from the application of synthetic fertilizer in agricultural soils



## AMMONIA VOLATILIZATION FROM ANIMAL EXCRETA

The emission factors that were used to estimate ammonia emissions from manure from domestic livestock were already presented in source categories N<sub>2</sub>O emissions from Manure Management and Direct nitrous Oxide Emissions from Agricultural Soils and are present again in Table 6.40. These emission factors result from EMEP/UNECE 3rd edition in annex A of chapter B1050 and version 4.0 of chapter B1010 and are not dependent on the Manure Management System that is used. Final emission factors per animal class are presented in next table.

Table 6.40 - 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/UNECE 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 IPCC96).

#### ACTIVITY DATA

The quantity of nitrogen that is subjected to volatilisation is presented in Table 6.41 and Table 6.42 and Figure 6.26.

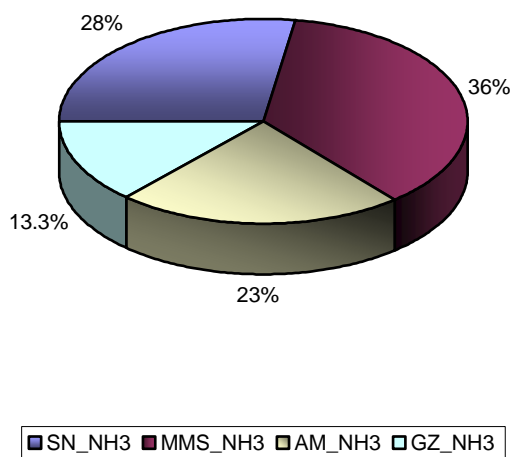
Table 6.41 – Nitrogen subjected to volatilization from each emission source/component (1990-1996)

Source	ton N/yr	1990	1991	1992	1993	1994	1995	1996
Synthetic Fertilizers	SN_NH3	150 200	141 000	127 000	129 000	128 000	125 000	132 000
M.M.S.	MMS_NH3	151 995	150 915	150 938	149 801	149 651	149 362	149 239
Animal Manure	AM_NH3	91 344	90 557	90 444	90 084	90 546	91 531	91 592
Grazing/ Pasture	GZ_NH3	59 574	58 812	58 402	58 062	58 400	58 660	58 607
Total		453 112	441 283	426 784	426 947	426 597	424 553	431 439

Table 6.42 – Nitrogen subjected to volatilization from each emission source/component (1997-2003)

ton N/yr	1997	1998	1999	2000	2001	2002	2003
SN_NH3	121 000	130 000	120 000	113 000	117 000	117 000	117 000
MMS_NH3	150 856	154 372	153 815	154 076	154 918	154 827	154 096
AM_NH3	93 029	95 854	95 649	95 763	96 414	96 641	96 425
GZ_NH3	58 822	59 032	59 282	58 478	57 747	56 768	56 512
Total	423 707	439 259	428 746	421 317	426 079	425 236	424 033

Figure 6.26 – Sources of nitrogen applied to soil by source/component and that contribute to ammonia volatilisation in 2003



## RECALCULATIONS

The major change in the inventory resulted from the downward revision of the ammonia volatilisation from the soil application of synthetic fertilizers, that now use product specific emission factors from EMEP/CORINAIR and a detailed pattern of nitrogen fertilizers consumption in Portugal, by product. In previous submission the IPCC default value for  $Frac_{GASF}$  was used.

Changes in the quantity of manure produced per animal, which was already discussed in chapter 6.2.4, made indirect changes in ammonia emissions.

## FURTHER IMPROVEMENTS

The importance of the Manure Management System in ammonia emissions needs to be included in the methodology, but that depends on the existence of appropriate emission factors.

It is expected that efforts will continue to ameliorate the volatilisation rates from the application of synthetic fertilizers, following a future better knowledge of the nitrogen fertilizer types used in Portuguese agricultural soils.



## CHAPTER: 7 LAND-USE 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 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 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 in forest fires 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). There is no prescribed burning of forest areas in Portugal.

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 whole national forest. All forests in Portugal are assumed to be, or to have been, affected by human intervention, and consequently considered as non-natural/ managed. Part of the Portuguese forest is characterised by having an undergrowth cover, which could also be considered as a potential sink source. However, as data available for harvest do not include these materials, and to avoid overestimation, the carbon sequester in this pool has not been quantified. Other wooded land (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

= area of forest (ha) \* annual growth rate (m<sup>3</sup>/ha/y) \*  
volume stem conversion factor into biomass above ground (t dm/m<sup>3</sup>) \*  
C-fraction of dry matter

##### 2. BIOMASS LOSS

= total harvest (m<sup>3</sup>) \* expansion factor \* volume stem conversion factor into  
biomass above ground (t dm/m<sup>3</sup>) \* C-fraction of dry matter

##### 3. NET ANNUAL CO<sub>2</sub> CHANGE (emission or removal)

= [ INCREMENT – BIOMASS LOSS ] \* 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 consider to be affected, or to have been affected in the past, 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 the 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>126</sup>). Forest area data for 1990 were estimated by the General Direction for Forestry Resources based on NFIs. Figures for 2002 (and 2003) 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 area for 2003 are equal to 2002 figures due to unavailability of data for new forest areas.

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	1990	1995	2002
	(NFI 2nd rev.)	(DGF estimates)	(NFI 3rd rev.)	(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.

<sup>126</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.

Table 7.2 – Area of plantations (1000 ha)

	1982-89	1990-94	1995-2002
<i>Pinus pinaster</i>	58	24	16
<i>other softwood</i>	20	17	34
<i>Eucalyptus</i>	15	36	35
<i>Quercus suber</i>	12	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>	9	19	22
Total	116	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 (ISA – Instituto Superior de Agronomia) 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

The amount of biomass lost in forest land due to biomass harvest or other losses (e.g. wildfires) has been quantified in previous submissions on the basis of tree harvesting data. These data is based on annual statistical data of wood consumption and refer mainly to the species - *pinus pinaster* and *eucalyptus*, which was obtained from FAO database. The analysis of data for the last 30 years 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.

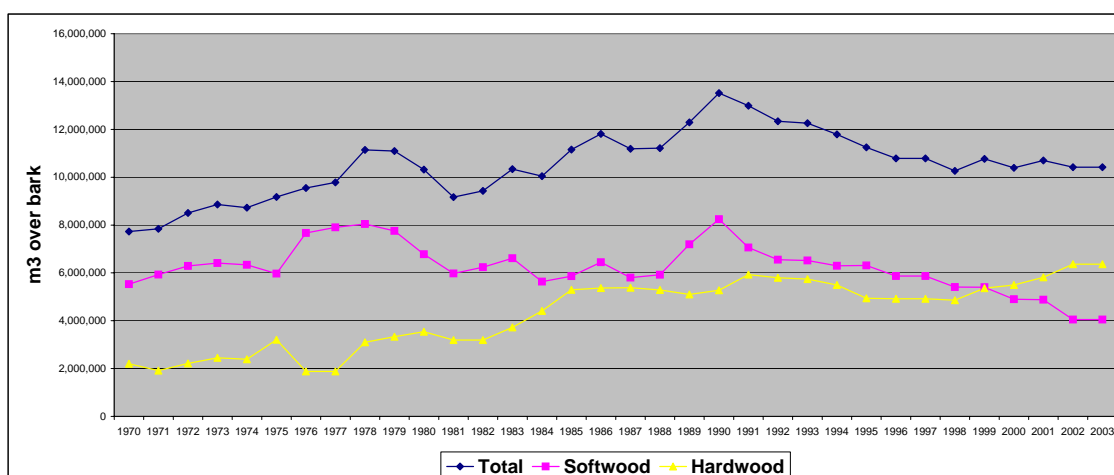
Values for tree feelings refer to roundwood over bark and do not include residues from exploration, i.e. branches, etc. To account for the whole tree volume, the expansion factors used were: for softwood 1.24; hardwood 1.2. The conversion to dry matter was done using the same parameters used for increment growth estimates.

Table 7.5 – Volumes of harvested wood (1000 m<sup>3</sup> over bark) (1990-2003)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
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	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	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	10,416

Note: 2003 are provisional figures.

Source: FAO, DGRF

Figure 7.1 – Volumes of harvested wood (1000 m<sup>3</sup> over bark) (1970-2003)

Note: 2003 are provisional figures.

Source: DGRI; FAO

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 considered 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).

The report from last year's in-depth review raised the issue of the potential underestimation of CO<sub>2</sub> emissions from forest fires. In the 2004 submission, these emissions were in fact quantified by the removal of salvaged wood volumes, based on the fact that these quantities are largely used in industry. It was assumed that all biomass burnt was removed as salvaged wood volumes, and were considered to be fully included in the harvest volumes which refer to wood consumption. However, in reality, due to scarcity of information (e.g. the % of salvaged volumes within harvest), it is difficult to determine exactly if all salvaged volumes are considered in the harvest volumes, or if part of the burnt trees are not included, which would generate emissions from dead wood, non-harvested fallen logs, and snags remaining in the forest.

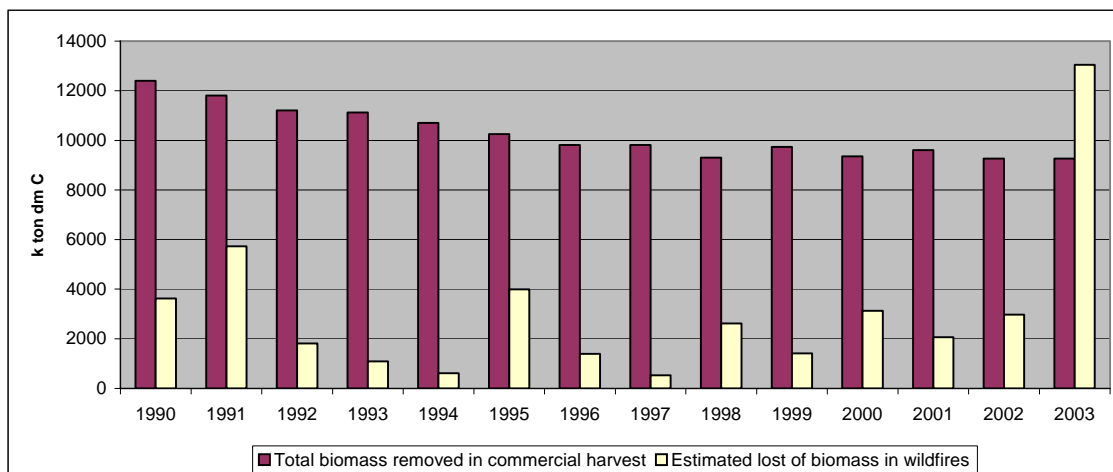
Forest wildfires have a substantial impact on Portuguese forest, unknown for most other parties. In its causes it is generally acknowledged the inadequate forestry and forest management, specific forestland structure conditions (land tenure, size of forest holdings) and socio-demographic factors (private owners old age, low literacy or absenteeism), constitute severe constraints and contribute to the high magnitude of yearly burned areas. Nevertheless, yearly fluctuations of burned areas are a consequence of climatic factors.

In order to assess this issue, the totals of biomass removed in commercial harvest were compared to the estimated lost of biomass in wildfires, converted in quantities of dry matter of carbon. These last were calculated based on the yearly burnt forest surface multiplied by the estimated average forest biomass above ground (45.61 t dm/ha; please see Table 7.6). The results, presented in the next figure, show that for most of the years -1990 to 2002 – the total biomass removed in commercial harvest is significantly higher than the estimated lost of biomass in wildfires.

For the time being, and without further information to treat the issue differently, biomass loss in forest land was calculated on the basis of the harvest volumes, and only under exceptional circumstances, such as the case of year 2003 in terms of the extent of forest wildfires whereas the estimated burnt biomass in wildfires was well above the available harvest figure, the estimate of biomass loss was considered differently, taking the estimated value of biomass lost

in wildfires as the amount of biomass lost in forest land for the year 2003, and assuming that the whole biomass in the burnt forest areas were lost.

Figure 7.2 – Comparison of total biomass removed in commercial harvest and biomass lost in wildfires (1990-2003)

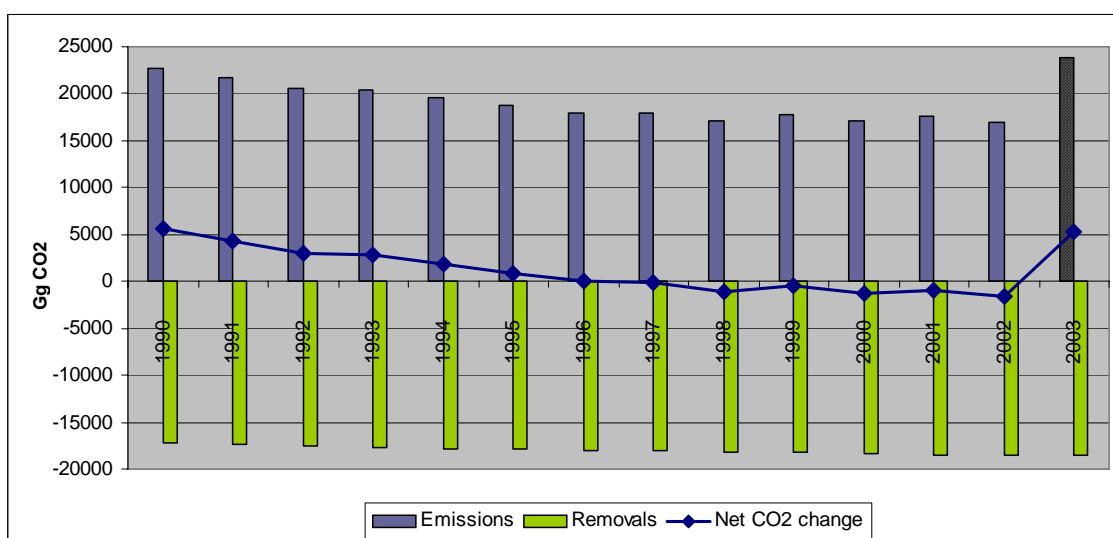


### NET ANNUAL CO<sub>2</sub> CHANGE

As said previously, biomass loss for the period 1990-2002, was based on harvest quantities, which have been registering a decrease since 1990. On the side of the removals, 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.

Concerning 2003, the situation is different, due to the extreme wildfires events. For that year, the amount of biomass loss was accounted as the lost of biomass provoked by wildfires, considering that the whole biomass in the burnt forest areas were lost. The estimates for 2003, which are still provisional, points to a net source of CO<sub>2</sub> emissions.

Figure 7.2 – Emissions, Removals and Net Annual CO<sub>2</sub> Change from Forest (Gg CO<sub>2</sub>) 1990-2003



## 7.2.B Other: Forest Fires (CRF 5 E)

IPCC (2003) 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

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.

#### CO<sub>2</sub> emissions

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, for the period 1990-2002, 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. Due to the exceptional characteristics of the year 2003, CO<sub>2</sub> emissions from wildfires, were calculated on the basis of the estimated lost of biomass in the forest burned land, assuming that the whole biomass in the burnt forest areas was consumed and lost during the fires. These emissions are reported under category 5.A.

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 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.

#### Non-CO<sub>2</sub> emissions

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 NMVOC) 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

= burnt area (ha) \* burnt biomass (t dm/ha) \* 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 -NMVOC: 0.0068

## 3. Emission estimation

Emissions CH<sub>4</sub> = C released \* emission ratio \* 16/12

Emissions NMVOC (expressed as CH<sub>4</sub>) = C released \* emission ratio \* 16/12

Emissions CO = C released \* emission ratio \* 28/12

Emissions N<sub>2</sub>O = C released \* ratio N/C (0.01) \* emission ratio \* 44/28

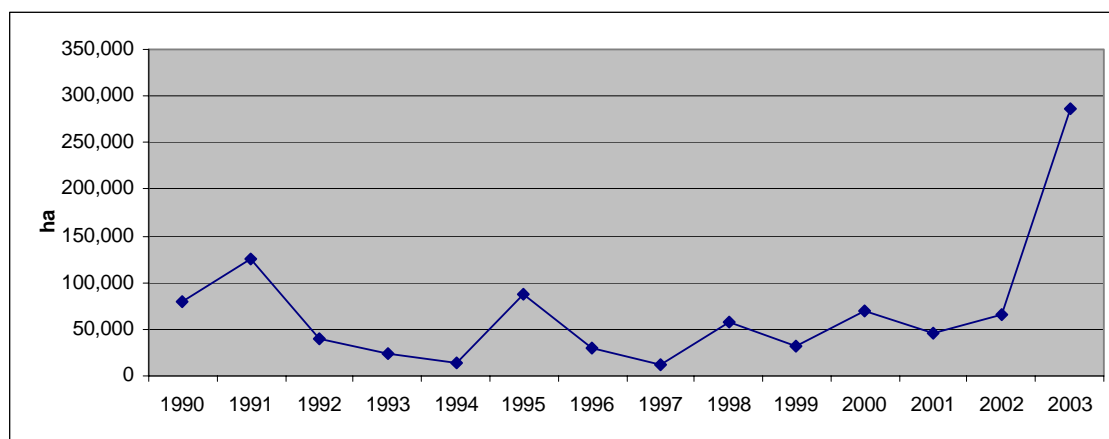
Emissions NO<sub>x</sub> = C released \* ratio N/C (0.01) \* emission ratio \* 46/14

## 7.2.B.2 ACTIVITY DATA AND PARAMETERS

Yearly data on burnt area is 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, being considered that it is non-managed land.

In the year 2003, Mainland Portugal was overwhelmed with a wave of forest wildfires induced by an exceptionally hot Summer, characterised by high temperatures, very low relative humidity, and instable winds. Furthermore, the country had registered long rainfall periods during the previous Winter and Spring time, which favored the vegetative growth and the substantial increase of biomass. The year registered the most destructive fires that were ever recorded, with a total of 286051 ha of forest burnt (bush land and shrubs, which are mostly non-managed areas, are not accounted in the estimates), representing approximately 5.5 times more than the average burned surface in the period 1990-2002.

Figure 7.3 – Forest fires: human and natural origin (1990-2003)



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>

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>127</sup> applied to the herbal-volume for each type of coverage, as presented in the next table.

<sup>127</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.

Table 7.7 – Biomass for undergrowth cover

	Area 1990 (ha)	Volume of under- -growth cover (m3/m2)	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

a) Estimates based on the relation biomass/ phyto-volume 3.24 kg/m3 (Tiago Oliveira, 1998).

b) Weighted average based on area.

Not all biomass in forest areas is liberated during a fire episode however. The degree of combustion of wood materials depends on the temperature gradient, the oxygen supply, and the burning time. In average, it is considered that 90% of the forest biomass corresponds to the stem and main parts of the trees, which are estimated to burn 50% during a fire. Concerning the fine materials (branches and leaves), it is considered that they represent 10% of forest biomass, and it has been assumed that 80% of these materials burn during a fire. In which refers to undergrowth cover it is considered, in average, that 80% of biomass are consumed in a fire. (PNAC, 2003)<sup>128</sup>

Taking the quantification of forest land biomass in above ground in trees and in undergrowth cover presented previously (Table 7.6 and Table 7.7), and the assumptions referred in the previous paragraph, the estimated biomass combusted considered is for forest trees - 24.2 t dm/ha - and undergrowth cover - 8.8 t dm/ha.

### 7.3 Recalculations

Due to specific conditions from forest fires in 2003, for the first time the harvest removal was corrected for the total biomass loss in forest fires. No other changes have been made since 2004 submission.

### 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 some effort should be done to improve their quality, as they are in fact based on models from other countries (USA, France).

Up to now, the biomass from under-storey woody vegetation in forests has only been considered for the estimates of non-CO<sub>2</sub> gases emissions from biomass burning in wildfires. One of the areas for improvement identified by the in-depth review ERT, is the estimation of CO<sub>2</sub> emissions from the undergrowth stratum of forests, if it is found that it is occurring. This quantification would need however the development of average growth rates for this vegetation.

<sup>128</sup> PNAC (Julho 2003), Floresta e Produtos Florestais – Cenário de Referência, Volume 8.

Another issue pointed out in the in-depth review report, is the potential underestimation of CO<sub>2</sub> emissions from the combustion of forest biomass during wildfires. With the exception of the year 2003, these emissions have been estimated by the removal of salvaged wood volumes, which have been considered to be fully included in the harvest volumes. However, some potential emissions may not have been considered, if tree material that could be used in industry is not removed and remain in the forests decomposing. Efforts are being done to solve the knowledge of the percentage of salvage material that is not used in industry.

Another improvement concerning future estimation of emissions from wildfires, could be to consider the characterisation of the burnt species, taking into account data on the share of burnt area by species for each year.

The application of the IPCC 2003 GPG for LULUCF, also in development, will imply a big national effort that should be accomplished under the context of the National System implementation. This effort comprises the major task of the quantification of CO<sub>2</sub> emissions from land-use conversions, using remote sensing data together with other available data sources, and the CO<sub>2</sub> Emissions and Removals from Soils.

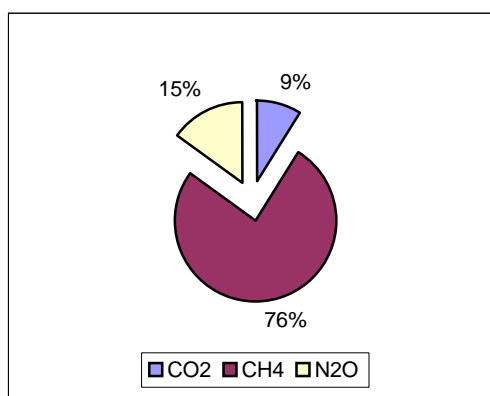
## CHAPTER: 8 WASTE (CRF 6)

### 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>, gas that results 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 (2003)



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 over time. 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 of untreated wastewater occurring under anaerobic conditions. CH<sub>4</sub> produced, usually during deliberate anaerobic wastewater treatment processes, can be collected and flared or combusted for energy, thereby reducing GHG emissions.

CH<sub>4</sub> emissions are affected by:

- Wastewater characteristics. Determines how much organic compounds degrades. 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 methane emissions depend on several factors,

increasing with temperature, BOD (Biochemical Oxygen Demand) or COD (Chemical Oxygen Demand) concentrations and the absence of biological inhibitors;

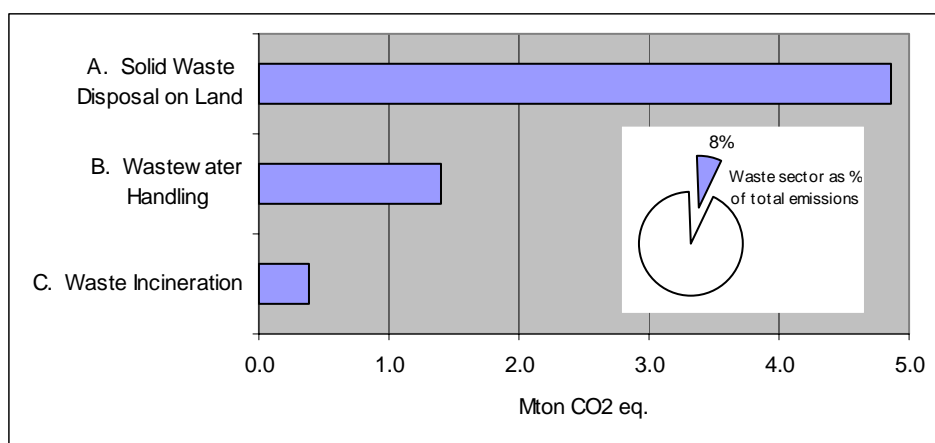
- Handling Systems – anaerobic versus aerobic conditions in system design and operation. The management conditions of collection and wastewater treatment systems determines the potential of CH<sub>4</sub> generation; systems providing anaerobic conditions will generally produce higher CH<sub>4</sub> 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, NH<sub>3</sub> and N<sub>2</sub>O. N<sub>2</sub>O emission estimate from human sewage were calculated using a simple approach, and indicative NMVOC emission 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 accounted 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 Particulate Matter and Heavy Metals emissions from the incineration of municipal solid wastes (MSW) and hospital hazardous wastes.

Emissions generated from waste activities represented in 2003 8% of total GHG emissions (excluding CO<sub>2</sub> from LULUCF). The major sub-category within this sector is solid waste disposed on land – 4.86 Mton CO<sub>2</sub> eq. - corresponding to more than two thirds of the sector emissions. Emission estimated for this category has been revised in this 2005 submission, to take account of some of the recommendations proposed by the in-depth review ERT, and a refinement in the calculation formula to consider variances of annual acceptance rates of waste landfilled.

Figure 8.2 – Sources of GHG in waste sector (2003)



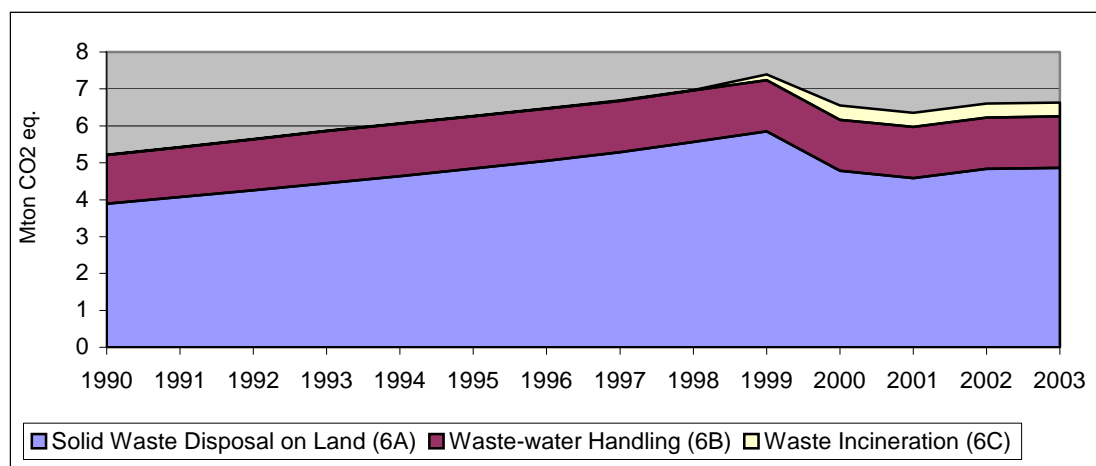
Note: Category 6D (Open burning of industrial waste) is not represented as it represents less than 0.02% of the emissions of the sector in 2003.

In the period 1990-2003 GHG emissions from waste activities have grown 27%, having reached a peak in 1999. The increase in emissions from the sector is strongly related to the change of consumption patterns registered in Portugal in the last decades, associated with new commercial structures. The opening of the first supermarket occurred in 1961. By the end of that decade/ beginning of the next one, several distribution companies appeared. The late 70s/ beginning of the 80s registered another increase of these commercial units, with the number of supermarkets rising from 196 in 1974 to 375 in 1985. The following years, which recorded a steady economic growth in particular since the Portuguese accession to the EU in 1986, have led to the reduction of customs barriers and the revival of domestic demand, and have definitively changed the consumption habits of the Portuguese population. Since 1985, year of the opening of the first hypermarket in Portugal, until 1997, they were settled 40 hypermarkets and 943 supermarkets in the country (APED)<sup>129</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.

<sup>129</sup> APED, Anuário da Distribuição Portuguesa 1999.

Figure 8.3 – Emission trends of GHG from waste



The emissions from incineration, as presented in Figure 8.3, have grown significantly since 1999, corresponding to the start of operation of the two incineration units dedicated to MSW incineration. This was 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 decline since 1999, which is in part due to the flaring of biogas collected in landfills, where have been installed biogas burners.

## 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):

$$Q_{T,x} = k R_x L_0 e^{-k(t-x)} \quad (1)$$

where:

$Q_{T,x}$  - methane generated in current year  $t$  by the waste quantity deposited in year  $x$  -  $R_x$  (Mg CH<sub>4</sub>/yr);

$k$  - methane generation rate constant (1/yr);

$R_x$  - quantity of waste disposed in year  $x$  (Mg/yr);

$L_0$  - methane generation potential (Mg CH<sub>4</sub>/Mg waste).

$$\text{CH}_4 \text{ emitted in year } t \text{ (Gg/yr)} = [\text{CH}_4 \text{ generated in year } t - R_{ec(t)}] * (1 - \text{OX}) \quad (2)$$

where:



$R_{ec(t)}$  - CH<sub>4</sub> recovered in year T (Gg/yr);

OX - oxidation factor (fraction).

CH<sub>4</sub> recovery ( $R_{ec(t)}$ ) is the amount of CH<sub>4</sub> generated at SWDS that is recovered and combusted (e.g. flared or used for energy) and not emitted as CH<sub>4</sub> but as CO<sub>2</sub><sup>130</sup>. On the other hand, the CH<sub>4</sub> that is recovered but subsequently vented to atmosphere is not subtracted from emissions.

The oxidation factor (OX) reflects the portion of CH<sub>4</sub> from SWDS that is oxidised to CO<sub>2</sub> in the soil or other material covering the waste. If the OX is zero, no oxidation takes place, and if OX is 1 then 100% of CH<sub>4</sub> is oxidised. Well-managed disposal sites tend to have higher oxidation results than unmanaged dump sites with no cover or where large amounts of CH<sub>4</sub> can escape through cracks in the cover.

The methane generation potential ( $L_0$ ) depends upon the composition of waste, waste disposal practices and of the physical characteristics of the SWDS. It is estimated by the formula:

$$L_0 = MCF * DOC * DOC_F * F * 16/12$$

where:

MCF - CH<sub>4</sub> correction factor (fraction);

DOC - degradable organic carbon (fraction) (Mg C/Mg waste);

DOC<sub>F</sub> - fraction DOC dissimilated;

F – volume fraction 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 (IPCC, 1997):

$$DOC = (0.4 * A) + (0.17 * B) + (0.15 * C) + (0.3 * D)$$

where:

A = fraction of waste that is paper and textiles;

B = fraction of waste that is garden waste, park waste or other non-food organic putrescibles;

C = fraction of waste that is food waste;

D = fraction of waste that is wood or straw.

<sup>130</sup> Although not ultimate CO<sub>2</sub>.

Fraction of degradable organic carbon dissimilated ( $DOC_F$ ) is an estimate of the fraction of carbon that is ultimately degraded and converted into landfill gas, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS. Theoretically it is assumed that it varies mainly with the temperature (T) in the anaerobic zone of a landfill:

$$DOC_F = 0.014T + 0.28 \text{ (Tabasaran, 1981).}$$

Fraction of  $CH_4$  in landfill gas landfill gas is usually considered to be composed dominantly by half of  $CO_2$  and half of  $CH_4$ <sup>131</sup>.

## ACTIVITY DATA AND PARAMETERS

SWDS include solid municipal or urban waste (household, garden, commercial-services wastes) and industrial wastes.

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 of USA, based on the emissions model from EPA(1993), and it was considered that landfill waste production should consider a period of 30 years after disposal.

### Urban waste

#### Quantities of waste landfilled

In 2003, 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, characterization data on MSW is available for the majority of these systems, including production amounts, final disposal and, to a less extent, waste composition.

For years before 1999 information on urban waste was not collected on a regular basis, and information had to be collected from several sources:

- 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;
- 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, a portuguese NGO, 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.

<sup>131</sup> Other gases exist in lesser quantities however.

- 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.

Whenever necessary, municipal solid wastes production were estimated for each municipality according to:

$$[\text{Population (inhabitants)} * \text{Annual per capita generation rate (ton/inhabitants/year)}]$$

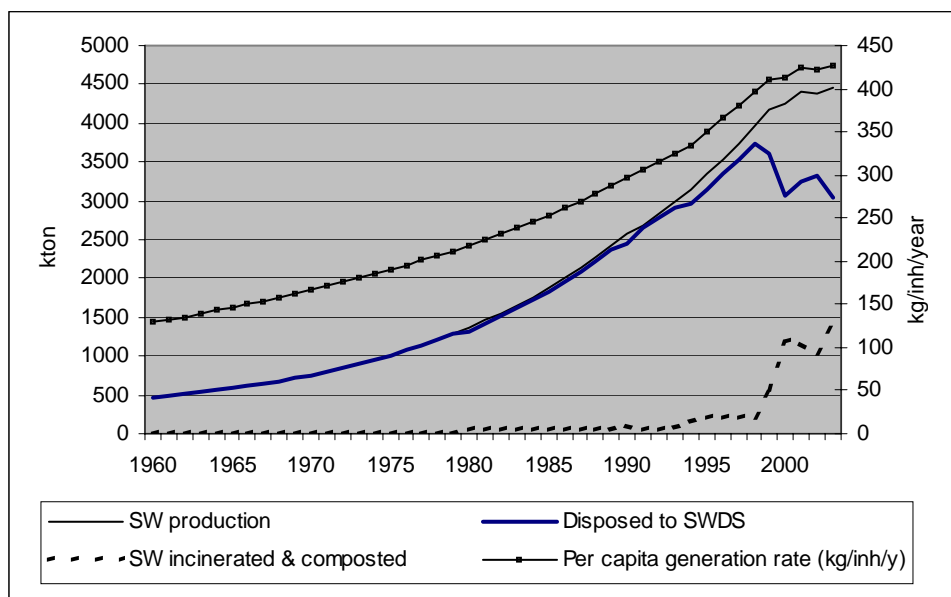
Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991 e 2001. Data for intermediate years were estimated, by interpolation, for each municipality. Figures for 2003 were calculated by data 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:

$$\begin{aligned} \text{Waste disposed to SWDS} = & [\text{Population} * \text{Annual per capita generation rate} * \\ & \text{Percentage of Population served by waste collection}] \\ & - \text{Quantity of incinerated waste} - \text{Quantity of composted waste} \end{aligned}$$

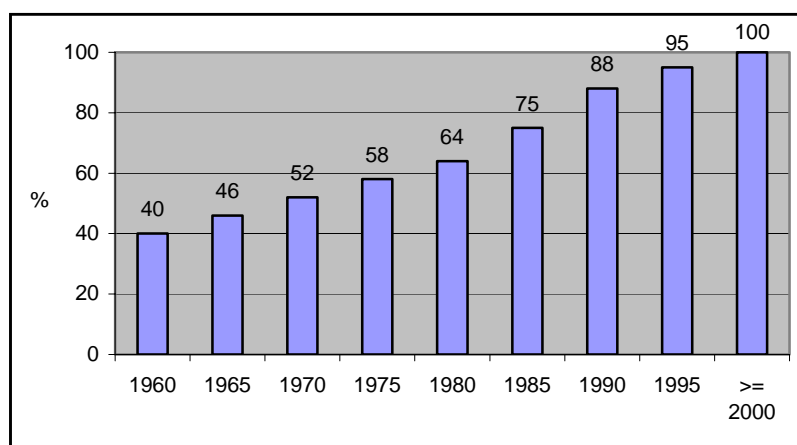
The next figure presents trends for per capita generation rates, SW generation amounts and quantities incinerated and composted, which refer to estimates based in the previously mentioned assumptions for the historical time series. For the more recent years (for 1994, and since 1999) the information refers to data effectively collected. As presented in the graph, waste disposed to SWDS start being reduced in 1999 which corresponds to the beginning of operation of the two MSW incineration units.

Figure 8.4 – Urban waste in the period 1960-2003



Source: IA estimates; INR; Quercus study

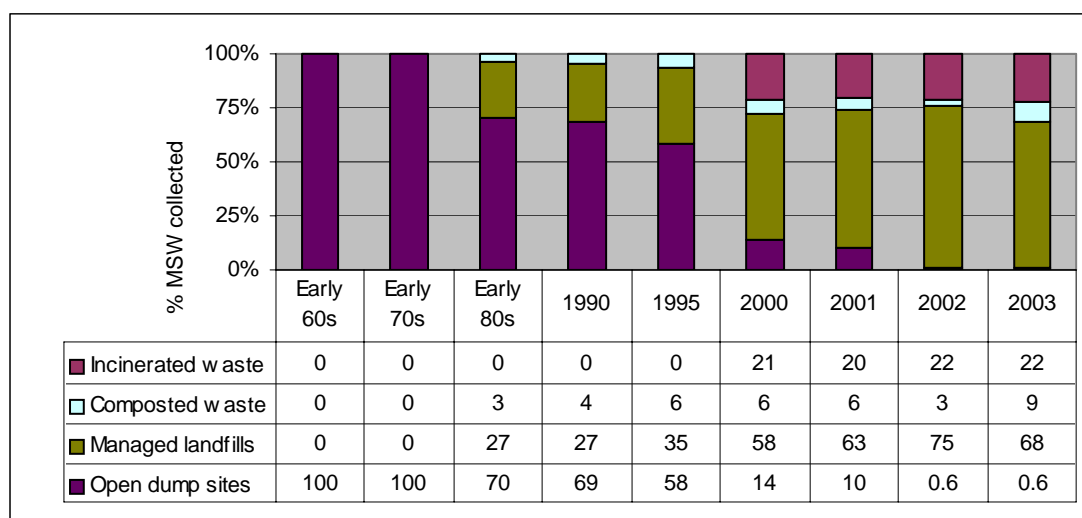
Figure 8.5 - Population served by solid waste collection systems



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 close 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 2003 this figure fell to approximately 68%, and the percentage of waste incinerated grew to 22%).

Figure 8.6 – Final disposal of waste (% of municipal solid waste collected)

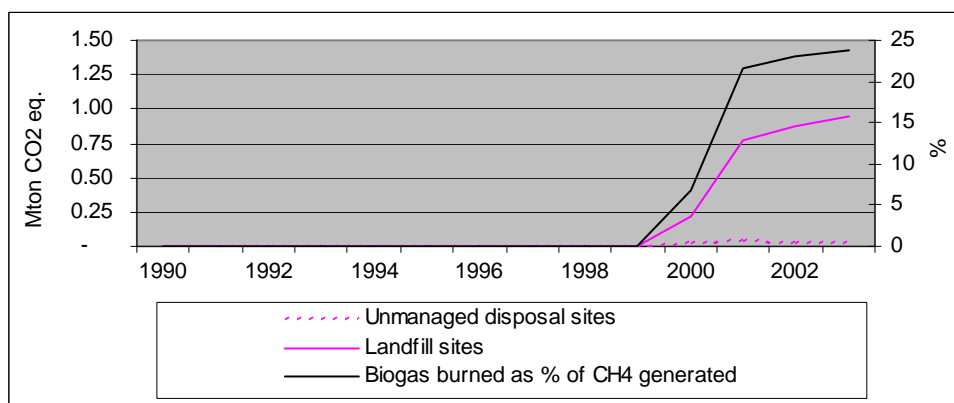


Note: 2002 and 2003 - disposal on open dump sites refer to disposal on controlled dump sites.

Source:IA estimates; Quercus; INR

#### Recovery of Landfill gas

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 the 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.

#### CH<sub>4</sub> generation potential (Lo)

The parameters used in the calculation are mainly IPCC default values.

Table 8.1 – Parameters used in Lo calculation

Parameter	Explanation	Value considered
MCF	IPCC defaults	Managed landfills = 1.0 Open dump sites = 0.6
DOC	National estimate	Variable on waste composition
DOCF	IPCC default (considering T = 35°)	0.77
F	IPCC default	0.5

The estimation of Degradable Organic Carbon (DOC), presented in the following table, was based on information on the waste composition from several sources.

Table 8.2 - Composition of waste disposed to SWDS (fermentable fractions)

Fermentable fractions	Early 60s	Early 70s	Early 80s	Early 90s	Mid-90s	2000
	Percentage of weight					
Paper and textiles (fraction A)	22.5	22.5	22.5	24.9	25.8	27.1
Non-food fermentable materials (fraction B)	0.0	0.0	0.0	13.4	18.7	11.9
Food waste (fraction C)	59.9	59.9	59.9	42.0	34.8	35.9
Wood or straw (fraction D)	0.0	0.0	0.0	0.2	0.3	0.3
DOC	18.0	18.0	18.0	18.6	18.8	18.3

Notes: Early 60s, 70s and 80s data refer to Fernandes, A Pastor (1982), "RSU do Continente - um Guia para Orientação e Inform. Das Autarquias", LNETI. Early 90s: estimates from interpolation. Mid 90s: data refer to 1994; DGA. 2000: INR

#### Methane Generation Rate Constant (k)

The value set for the CH<sub>4</sub> generation rate constant (k) should be dependent on several factors as the composition of the waste and the conditions of the SWDS. In the absence of national studies to determine this parameter, and following the recommendations of the in-depth review, the values used in the previous submissions were revised in order to apply the guidance from IPCC 2000.

This parameter is related to the time taken for the DOC in waste to decay to half its initial mass ('half life' or  $t_{1/2}$ ) as follows:  $k = \ln 2 / t_{1/2}$ . The k value considered now is 0.07 (half life of about 10 years), which represents a higher decay rate compared to the k default value proposed by the IPCC 2000 (0.05 - half life of about 14 years).

#### **Industrial waste**

##### Quantities of waste landfilled

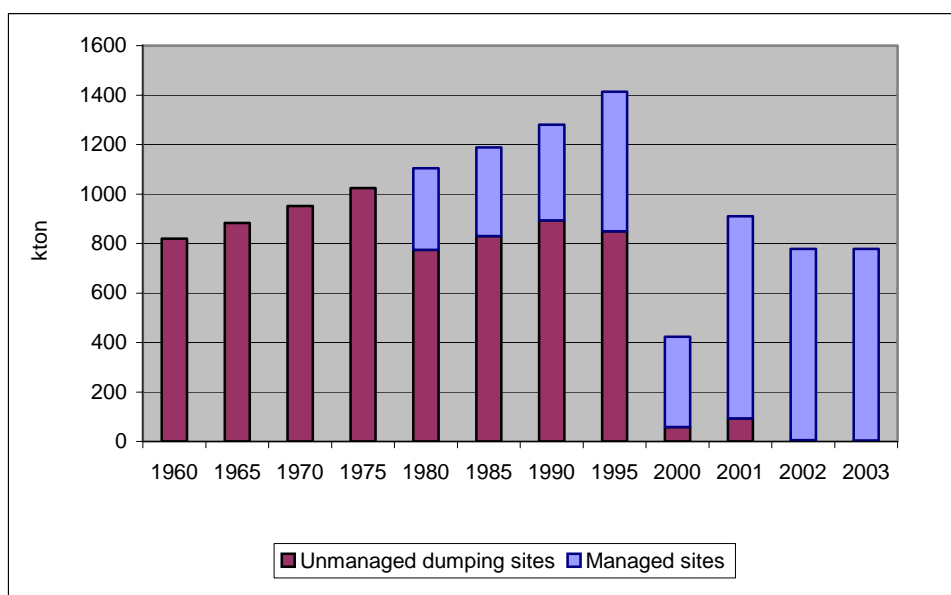
Industrial wastes considered in the inventory must refer only to the fermentable part of industrial waste. Although it is a fact that all industrial waste generated was usually disposed in SWDS together with urban waste, but it is clear that the urban wastes volume, previously discussed, does not incorporate the industrial fraction and hence no double counting is occurring.

It was considerably harder to get information about the quantitative of industrial wastes that are produced and deposited in Landfills in Portugal, when in comparison to urban wastes. Historical time series were back-casted based only on information data for 1999 and after, when annual registries relating to industrial units declarations were began to be sent to the regional environment directorates (CCDR). Data for the years 2000 and 2002 refer also to annual registries. Available data on industrial waste production results from information from INR (Waste Institute) and refer to annual registries from industrial units declarations. These information are classified according to the European Waste Catalogue list (EWC) and are disaggregated by disposal type. From this database the IA selected (by expert judgement) the EWC categories referring to organic origin.

Time trends had to incorporate therefore substantial expert judgement. For the period 1960-1990 it was considered a growth rate of 1.5% per year, and for the following years (1990-1998) 2% per year. The deposited quantities in years 2001 and 2003 are also estimates based on interpolation (2001) and last available data (2003 refer to 2002 data).

As there is no available information concerning final industrial waste disposal in the period, it was assumed that all estimated waste produced have followed the urban disposal pattern between uncontrolled and controlled SWDS.

Figure 8.8 – Quantities of fermentable industrial waste disposed to SWDS



Source: IA estimates; INR

#### *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 varies according to the available information on industrial waste composition: 0.28 (1960 – 1999), 0.20 for 2000, 0.26 (average of available data) and 0.29 for 2002 and 2003 (2002 data).

Available data on industrial waste production results from information from INR (Waste Institute) and refer to annual registries from industrial units declarations. These information are classified according to the European Waste Catalogue list (EWC) and are disaggregated by disposal type. From this database the IA selected (by expert judgement) the EWC categories referring to organic origin. Each one of these categories were classified according to a group and were assigned with a DOC value, also defined by expert guess.

The referred DOC values resulted from weighted averages based on the quantities reported for each EWC considered category and the respective assigned DOC, and refer to disposal on land.

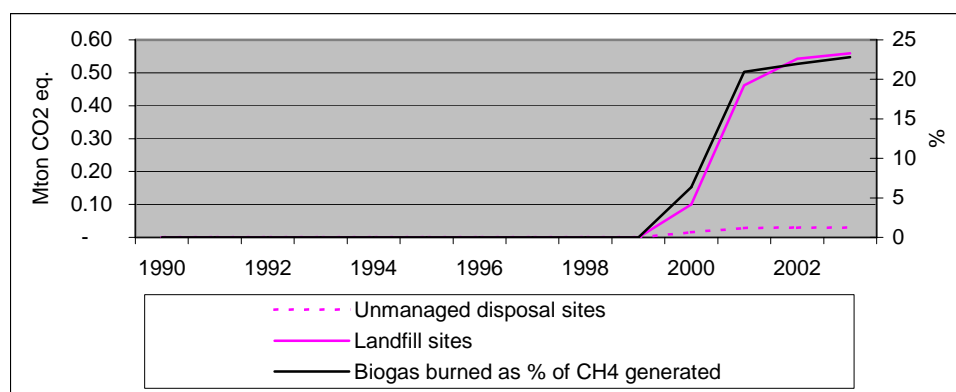
Table 8.3– Base table for industrial waste C content estimation

Groups	C Total (0..1)	DOC (0..1)	% C Biogenic
Paper and textiles	0.40	0.40	100
Garden waste, park waste or other non-food organic putrescibles	0.17	0.17	100
Food waste	0.15	0.15	100
Wood or straw	0.30	0.30	100
Fuels	0.85	0	0
Plastics	0.85	0	0
Sludge from natural origin	0.14	0.14	100
Sludge from non-natural origin or hydrocarbons	0.43	0	0
Synthetic fibres	0.85	0	0
Non-natural organic substances	0.85	0	0

#### Other parameters

Data on quantities of 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 NMVOC EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

NMVOC emissions are calculated using a similar methodology that was used 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 NMVOC 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 a similar methodology that was used 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 the difference that 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

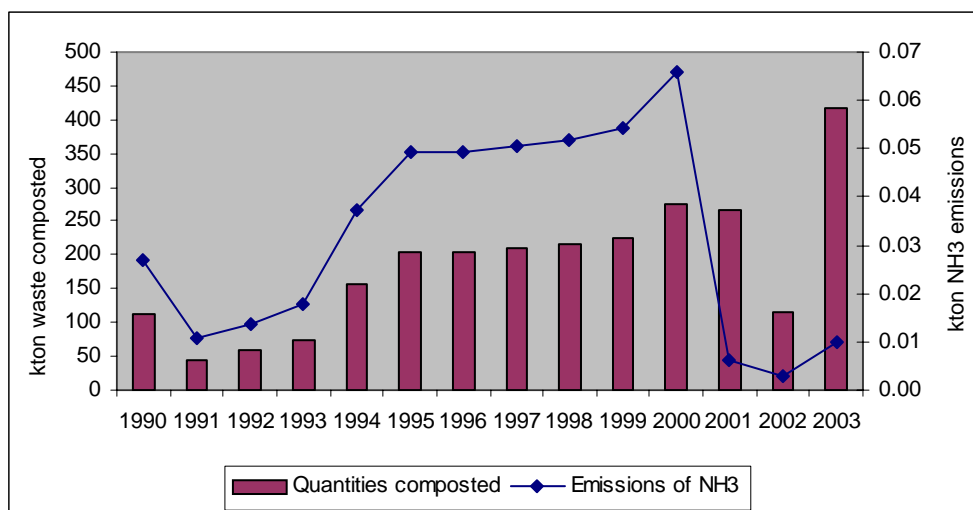
Emission estimates follow a simpler methodology indicated in Corinair 3<sup>rd</sup> rev. (EEA,2002), which is based on the quantities of composted waste and the application of an emission factor, as follows:

$$\text{NH}_3 \text{ emitted (ton/y)} = \text{Quantity of composted waste} * \text{EF (g NH}_3\text{/ton RSU)} / 10^6$$

##### ACTIVITY DATA

The activity level for years in the beginning of the time trend are based on the Quercus survey (1995). Data for recent years refer to data collected from management systems.

Figure 8.10 – Quantities of urban waste composted and related NH<sub>3</sub> emissions



Source:INR; IA

##### EMISSION FACTORS

Emission factors reflect change in treatment technology. Until 1999 NH<sub>3</sub> emissions from composting domestic organic waste were estimated to be without control; after 2000 it was assumed the existence of emission control with bio-filters.

Table 8.4 – Ammonia emission factors for compost production

	EF g NH <sub>3</sub> /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

#### CH<sub>4</sub> EMISSIONS FROM WASTEWATER HANDLING (WWH)

##### *Methodology*

CH<sub>4</sub> 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 CH<sub>4</sub> generation potential of waste is the amount of degradable organic component (DC) of the wastewater stream, which is expressed in terms of either BOD (recommended for domestic wastewater and sludge), or COD (more appropriate for industrial waste streams). Total organic waste (TOW) is a function of human population and the amount of waste generated per person.

$$TOW_{dom} = P * D_{dom} * 365 * 10^{-3}$$

where:

TOW<sub>dom</sub> - total domestic/commercial organic waste in kg BOD/yr;

P - population (inhabitants);

D<sub>dom</sub> - domestic/commercial degradable organic component in g BOD/ inhabitant/day.

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 of methane 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. Finally CH<sub>4</sub> that is recovered and flared or used for energy was subtracted from total emissions, as it is not emitted into the atmosphere.

$$M = \sum_i (TOW_i * EF_i - MR_i)$$

where:

M - Total CH<sub>4</sub> emissions from wastewater and sludge handling in kg CH<sub>4</sub>

TOW<sub>i</sub> - total organic waste for waste type i in kg DC/yr. (Step 1)

EF<sub>i</sub> - emission factor for waste type i in kg CH<sub>4</sub>/kg DC (Step 2)

MR<sub>i</sub> - total amount of methane recovered or flared from wastewater type i in kg CH<sub>4</sub>.

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<sub>dom</sub>) was determined multiplying the total population for each year by a per capita wastewater BOD<sub>5</sub> production rate. National population data is from the census from National Statistical Office (INE) for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation. The BOD<sub>5</sub> factor considered was 60 g BOD<sub>5</sub>/cap/day, which is the figure considered in the Council Directive 91/271/CEE, 21<sup>st</sup> Mai, referring to urban waste water treatment.

Data for population served by wastewater treatment systems at regional level was established from Environmental State Reports, which include 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.

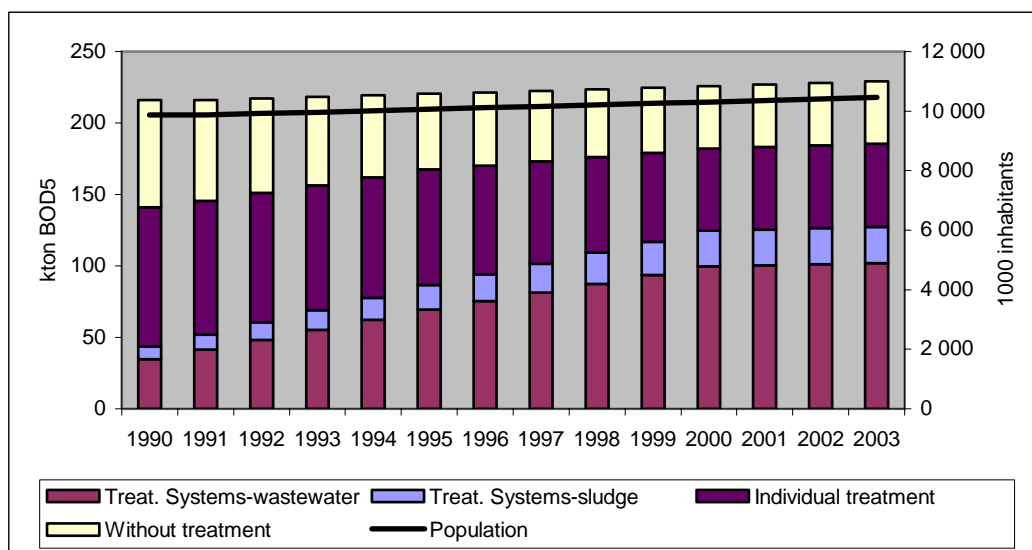
Figure 8.11 – Wastewater BOD produced according to handling systems (ton BOD<sub>5</sub>) and national population trends

Table 8.5 - 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)

Source: Environmental State Reports; INAG.

**Parameters: Bo and MCF** - The default IPCC (2000) value for B<sub>0</sub> 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 8.6). 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.

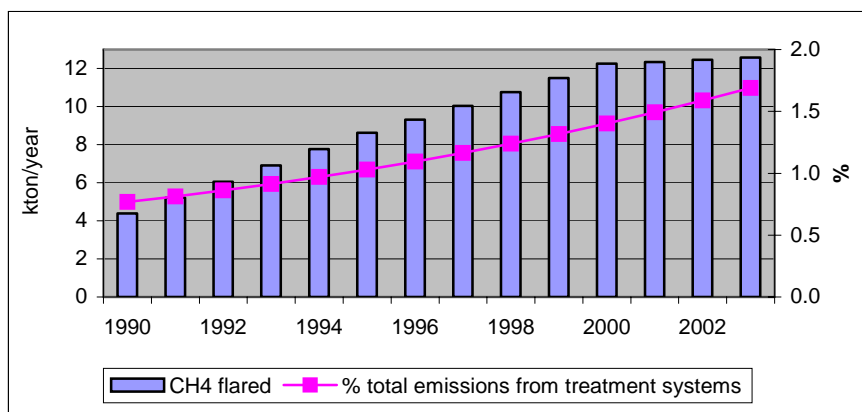
Table 8.6 - Wastewater treated by type of treatment system (%) and associated Methane Conversion Factors (MCF)

Region	Anaerobic digestion	Imhof 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
<b>MCF</b>	<b>1.00</b>	<b>0.50</b>	<b>0.10</b>	<b>0.18</b>	

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.

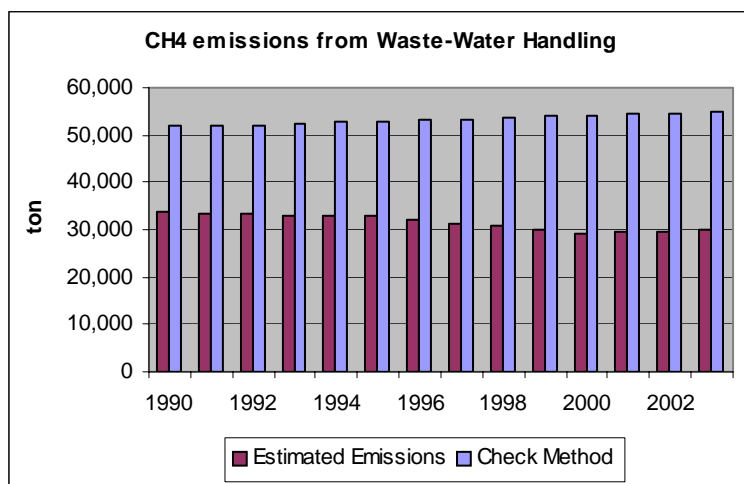
Figure 8.12 - Estimated quantities of CH<sub>4</sub> flared

#### COMPARISON BETWEEN ESTIMATES FOR CH<sub>4</sub> EMISSIONS FROM WASTE-WATER HANDLING AND IPCC "CHECK METHOD"

Following the in-depth review recommendations, the domestic CH<sub>4</sub> estimated emissions were compared with the "check method" proposed in the IPCC GPG. The comparison shows a big discrepancy between the reported emissions and the results from this method: the results of the application of the "check method" are for all the period well above the reported emissions. "Check method" values for 1990 (51.8 kton) was about 35% higher than estimated emissions (33.6 kton) and this percent difference increased up to 46% in 2003 (see table W-8 in the attachment).

Also, the 1990-2003 trend shows some contradiction between the two methodologies. The check method shows a positive variation of 6% between 1990-2003, and the reported emissions show a decrease of about 11% in the same period.

Figure 8.13– Comparison between estimated CH<sub>4</sub> domestic emissions and “check method”



### Methodology

IPCC check method is presented in the following equation. Default parameter values used refer to IPCC GPG.

$$WM = P \times D \times SBF \times EF \times FTA \times 365 \times 10^{-6}$$

where:

WM = Annual CH<sub>4</sub> emission per country, from domestic wastewater (ton)

P = Population of country or urban population for some developing countries (inhabitants)

D = Organic load in biochemical oxygen demand per person (g BOD/inhab./day), overall default = 60 g BOD/inhab./day

SBF = Fraction of BOD that readily settles, default = 0.5

EF = Emission factor (g CH<sub>4</sub>/g BOD), default = 0.6

FTA = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

### Discussion of the results

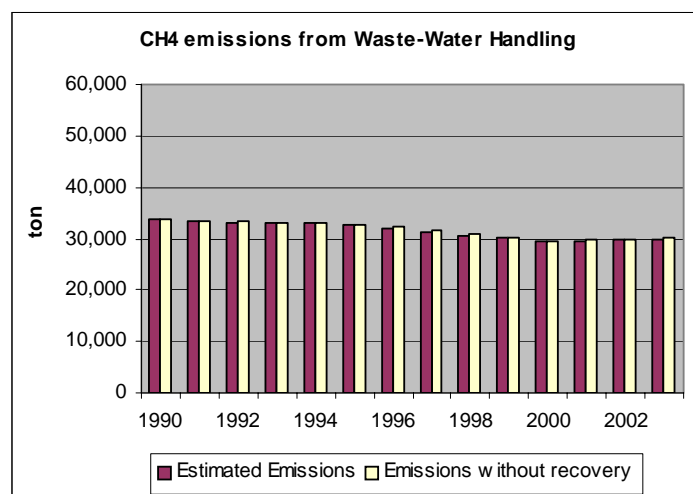
As previously mentioned, the results of the application of the “check method” are for the whole period well above the reported emissions. Also the trend variation during the 1990-2003 is not consistent with the one obtained from the national method. The 1990-2003 percentage change for the estimated emissions decrease around 11%, while the “check method” accounts for a 6% increase.

The variables Population (P), Organic load in biochemical oxygen demand per person (D), and the EF (g CH<sub>4</sub>/g BOD, default = 0.6) are the same in both approaches. Consequently the differences result from other parameters, i.e., the fraction of BOD that degrades anaerobically, and the consideration of CH<sub>4</sub> recovery in the case of the reported emissions.

The estimated emissions in the national inventory were based on average MCF factors for wastewater treatment systems which were weighted by the percentage of each type of treatment for each region. Despite the fact that MCF values considered are based on expert judgement (Table 8.5), it is considered that they represent a better approximation of the real national circumstances than the defaults suggested by the “check method”.

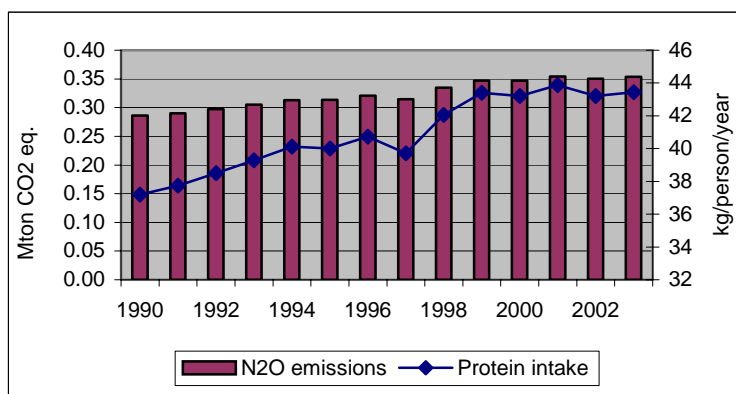
The influence of the CH<sub>4</sub> recovery is not significant as the percentage of the estimated recovery amount represent only a small part of the total emissions generated in treatment systems (in 2003 they represented 1.7% of emissions from treatment systems). Next figure shows that emissions with and without CH<sub>4</sub> recovery are very close and do not explain the difference between the report emissions and the “check method”.

Figure 8.14– Comparison between CH<sub>4</sub> domestic emissions with and without recovery



### 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 8.15 – N<sub>2</sub>O emissions from human sewage and per capita protein intake

Source: Protein intake: FAO database (August 2004); 2003 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.

$$N_2O_{(s)} = \text{Protein} * \text{Fra}_{\text{CNPR}} * \text{Pop} * \text{EF} * 44/28$$

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 8.7), multiplied by total population, from the National Statistical Office (INE) Census for the years 1981, 1991 and 2001; intermediate years have been estimated by interpolation.

Other parameters considered for the estimations are based on IPCC (1997) defaults.



Table 8.7 - Data and parameters used calculation of N<sub>2</sub>O emissions from wastewater

Parameter	Explanation	Values considered	
		Year	Value (kg/person/year)
Annual per capita protein intake	FAO data (August 2004)	1990	37.2
		1991	37.7
		1992	38.5
		1993	39.3
		1994	40.1
		1995	40.0
		1996	40.7
		1997	39.7
		1998	42.0
		1999	43.4
		2000	43.2
		2001	43.9
		2002	43.2
		2003	43.4
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: 2003 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 NMVOC/inhabitant/year, which results from the following emission factor from CORINAIR90 Default Emission Factor:

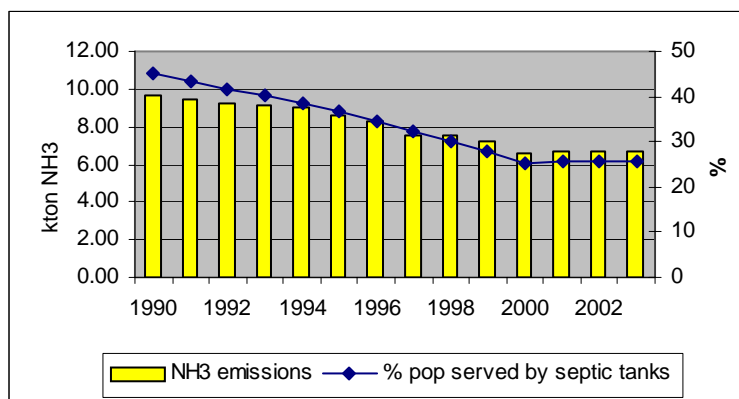
$$EF = 0.36 \text{ kg/106 l wastewater} * 125 \text{ l/inhabitant/year} * 365$$

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*”.

## NH<sub>3</sub> EMISSIONS FROM WASTEWATER HANDLING (WWH)

NH<sub>3</sub> emissions result mainly from the decomposition of urea and uric acid contained in human excreta. The estimates in the National Inventory considered the population served by individual private treatment facilities (e.g. septic tanks).

Figure 8.16 – NH<sub>3</sub> 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:

NH<sub>3(s)</sub> - NH<sub>3</sub> emissions from human sewage (kg NH<sub>3</sub>-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 NH<sub>3</sub>-N/kg sewage-N produced);

Pop - number of inhabitants in country;

Stor - % population served by individual private treatment (septic tanks).

### Activity data

Underlying data were already presented in sub-chapter N<sub>2</sub>O emissions from wastewater.

### Emission factors

The EF proposed by EMEP/CORINAIR (EEA,2002) was used: 0.3 kg NH<sub>3</sub>-N/kg sewage-N produced, which is based on the assumption that during storage for one year approximately 30% of nitrogen is emitted as NH<sub>3</sub> in an evaporation process.

## 8.2.B.2 INDUSTRIAL WASTEWATER

### METHODOLOGY

Emissions from industrial wastewater are based on national estimates for industry wastewater organic content, which are still very uncertainty, and default emission factors from the EMEP/CORINAIR Guidebook (EEA,2002) (CH<sub>4</sub> and N<sub>2</sub>O) and national data for domestic

wastewater (NMVOC). 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 8.8 - 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 8.9 - Emissions factors

Pollutant	Unit	EF	Source
CH <sub>4</sub>	Kg/ inh.eq.	0.30	EMEP/CORINAIR (3rd edition), chp
N <sub>2</sub> O	Kg/ inh.eq.	0.02	B9101 (EEA,2002)
NMVOC	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):

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \sum_i (IW_i * CCW_i * FCF_i * EF_i * 44 / 12)$$

where:

i - waste type;

IW<sub>i</sub> - Amount of incinerated waste of type i (Gg/yr);

CCW<sub>i</sub> - Fraction of carbon content in waste of type i;

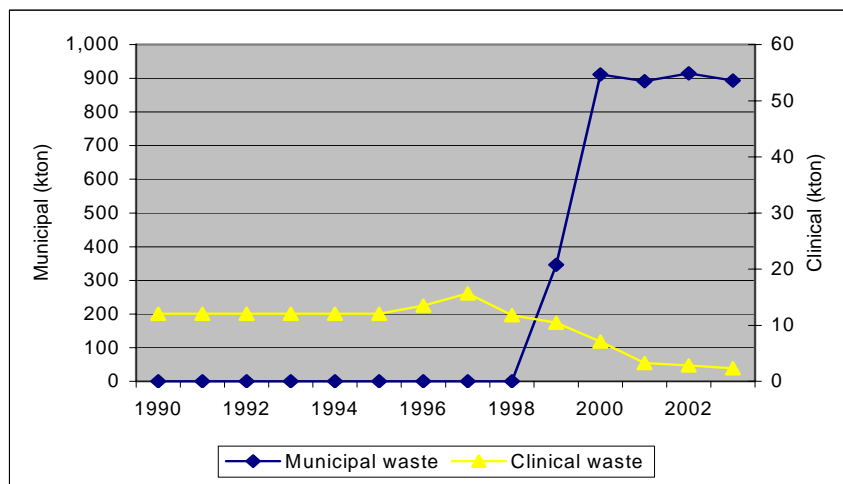
FCF<sub>i</sub> - Fraction of fossil carbon in waste of type i;

EF<sub>i</sub> - Burn out efficiency of combustion of incinerators for waste of type i (fraction).

## ACTIVITY DATA AND PARAMETERS

Until 1999, incineration of solid wastes refers exclusively to incineration of hospital hazardous wastes. The figure for 1995 was used as an estimated for the former years.

Figure 8.17 – Quantities of municipal and clinical wastes incinerated (1990-2003)



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 began 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 fibbers, and synthetic rubber – are to be accounted in the estimates.

Data on clinical waste incinerated refers only to Mainland Portugal and correspond to data declared in registry maps of public hospital units (there is no incineration in private units). The quantities of clinical waste incinerated decreased strongly in recent years as shown in previous figure. 25 incinerators were closed in recent years in Mainland Portugal, remaining at present 2 hospital incinerators. Nowadays the other clinical wastes receive alternative treatment or are treated abroad.

The non-biogenic components fractions are considered to be different for MSW, and clinical waste. Data are presented in the following table.

Table 8.10 - Parameters considered

	Unit	MSW	Clinical waste
C content of waste	%	30 a)	60 b)
Fraction of fossil carbon in waste	% total C	37 a)	40 b)
Efficiency of combustion	%	95 b)	

a) National figure; b) IPCC default.

The parameters presented in the previous table for MSW were kept constant in the all period and refer to national estimates based on waste composition for 1994. The fossil C content in MSW was calculated from the weighted average of the C content in plastics and textiles (fossil carbon) and the respective fractions of waste weight. The total C content of MSW, which includes the biogenic and non-biogenic (fossil) components, results from the weighted average of the different waste fractions and the respective total C content. The % of fossil carbon in waste was then obtained dividing the fossil C component by the total C content in MSW.

Information used for the calculation are presented in the next table.

Table 8.11– Base table for MSW C content estimation

	% of weight	Non-biogenic C content	Total C content
Paper/ Card	22.7	0	40
Glass	5.1	0	0
Plastics	11.7	85	85
Metals	2.7	0	0
Food waste	34.8	0	15
Textiles	3.1	40	80
Non-food fermentable materials	18.7	0	17
Wood	0.3	0	30
Other	0.8	0	0
C content in Plastics and Textiles (1)	11.2		
<b>Total C of waste (2)</b>	<b>30.0</b>		
<b>% non-biogenic C in waste (1)/(2) * 100</b>	<b>37.3</b>		

## 8.2.C.2 NON-CO<sub>2</sub> 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 8.12 - Emissions factors of GHG and precursors gases from incineration of MSW

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH <sub>4</sub>	g/GJ	6.500	CORINAIR 94
N <sub>2</sub> O	kg/ton MSW	0.100	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton MSW	0.022	Country measured data
NO <sub>x</sub>	kg/ton MSW	0.724	Country measured data
COVNM	kg/ton MSW	0.020	Corinair 3rd version. Activity 090201. Uncontrolled
CO	kg/ton MSW	0.036	Country measured data

Table 8.13- Emissions factors of CLRTAP gases from incineration of MSW

Pollutants	Unit	EF	Source
NH <sub>3</sub>	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 8.14 - Emissions factors of GHG and precursors gases from incineration of clinical wastes

Pollutants	Unit	EF	Source
LHV	MJ/kg	7.820	PROET study
CH <sub>4</sub>	g/GJ	6.500	CORINAIR 94
N <sub>2</sub> O	kg/ton	0.100	Corinair 3rd version. Activity 090201. No NO <sub>x</sub> abatement
SO <sub>x</sub>	kg/ton	1.090	AP-42 Uncontrolled
NO <sub>x</sub>	kg/ton	1.780	AP-42 Uncontrolled
COVNM	kg/ton CW	7.400	Corinair 3rd version. Activity 090202. Particle abatement
CO	kg/ton	1.480	AP-42 Uncontrolled

Table 8.15- Emissions factors of CLRTAP gases from incineration of clinical wastes

Pollutants	Unit	EF	Source
NH <sub>3</sub>	kg/ton MSW	0.0043	Country measured data
Pb	kg/ton MSW	0.0364	AP-42 Uncontrolled
PST	kg/ton MSW	2.3300	AP-42 Uncontrolled
PM10	% PST	65	AP-42 Uncontrolled
Cd	kg/ton MSW	0.0027	AP-42 Uncontrolled
Hg	kg/ton MSW	0.0537	AP-42 Uncontrolled
Ar	kg/ton MSW	0.0001	AP-42 Uncontrolled
Cr	kg/ton MSW	0.0004	AP-42 Uncontrolled
Cu	kg/ton MSW	0.0062	AP-42 Uncontrolled
Ni	kg/ton MSW	0.0003	AP-42 Uncontrolled

## 8.2.D Other (CRF 6 D)

This category includes emissions from the open burning of industrial solid waste on land which was previously reported in the category 6C. This change relates to the in-depth review recommendation to report these emissions under category 6.A Solid Waste Disposal on Land –

Other. These emissions have however been reported under 6.D in order to to report more pollutants (SO<sub>2</sub>) in CRF tables than was possible in category 6.A.

### 8.2.D.1 CO<sub>2</sub> EMISSIONS

#### METHODOLOGY

The same methodology as for category 6.C Waste incineration was used, which refers to IPCC Guidelines (IPCC,1997). Ultimate CO<sub>2</sub> emissions estimation from open combustion of industrial waste on land were calculated as follows:

$$\text{CO}_2 \text{ emissions (Gg/yr)} = \text{IW} * \text{CCW} * \text{FCF} * \text{EF} * 44 / 12$$

where:

IW - Amount of burned waste (Gg/yr);

CCW - Fraction of carbon content in waste;

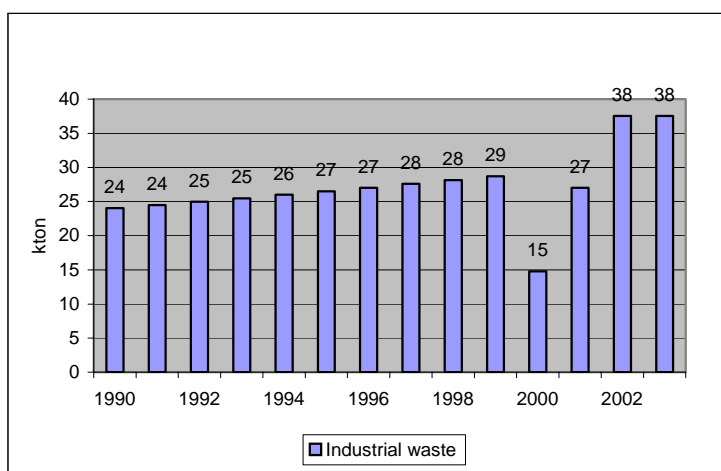
FCF - Fraction of fossil carbon in waste;

EF - Burn out efficiency of combustion of incinerators for waste (fraction).

#### ACTIVITY DATA AND PARAMETERS

Data refer to uncontrolled combustion of industrial solid waste on land which were collected from INR. Data for the years 2000 and 2002 refer to industrial units declarations. The years 2001 and 2003 are estimates based on interpolation (2001) and on the last available data (2003 refer to 2002 data). Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%.

Figure 8.18– Quantities of open combusted industrial waste (1990-2003)



Source: INR; IA estimates.

Table 8.16- Parameters considered

	Unit	Industrial Solid Waste
C content of waste	%	14-18 a)
Fraction of fossil carbon in waste	% total C	20.5-0.3 a) c)
Efficiency of combustion	%	95 b)

a) C content of waste: until 1999 - 14; 2000 - 18; 2002 - 17.

b) IPCC default.

c) % total C: until 1999 - 20.5; 2000 - 0.3; 2002 - 1.0.

The parameters presented in the previous table (C content and % total C) are national estimates based on the background data on industrial waste production received from INR. As mentioned in the previous sub-section 6.C, these information are classified according to the European Waste Catalogue list (EWC) and are disaggregated by disposal type. Each one of the EWC categories were classified according to a group and were assigned with an estimated fraction of C content and a fraction of fossil carbon in waste, which has been defined by expert judgement (please see Table 8.16). The values considered resulted from weighted averages based on quantities reported for each of the EWC categories and the respective assigned C content and fraction of fossil C, and refer to disposal type "incineration on land".

## 8.2.D.2 NON-CO2 EMISSIONS

### METHODOLOGY

Emissions were estimated as the product of the mass of total waste combusted, and an emission factor for the pollutant emitted per unit mass of waste incinerated.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \text{IW} * \text{EF} * 10^{-6}$$

where:

IW = Amount of combusted waste (Gg/yr);

EF = Pollutant emission factor (kg pollutant/Gg)

### ACTIVITY DATA AND PARAMETERS

Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR (EEA,2002).

Table 8.17 - Emissions factors of GHG and precursors gases from open burning of Industrial Solid Wastes

Pollutants	Unit	EF	Source
CH <sub>4</sub>	kg/ton MSW	6.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
N <sub>2</sub> O	kg/ton MSW	0.1	Corinair 3rd version. Activity 090201. No NOx abatement
SO <sub>x</sub>	kg/ton MSW	0.5	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
NO <sub>x</sub>	kg/ton MSW	3.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
COV	kg/ton MSW	15.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
CO	kg/ton MSW	42.0	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)



Table 8.18 - Emissions factors of Particulate Matter and Heavy Metals from open burning of Industrial Solid Wastes

Pollutants	Unit	EF	Source
PST	kg/ton MSW	8.0000	AP-42. 5th ed. Chp 2.5 (Open Burning of municipal refuse)
PM10	% PST	100	Conservative EF
Pb	g/ton MSW	0.4580	AP-42. Chp 2.1 (Refuse Combustion) a)
HCl	kg/ton MSW	0.0790	AP-42. Chp 2.1 (Refuse Combustion) a)
As	g/ton MSW	0.0069	AP-42. Chp 2.1 (Refuse Combustion) a)
Cd	g/ton MSW	0.0038	AP-42. Chp 2.1 (Refuse Combustion) a)
Cr	g/ton MSW	0.1300	AP-42. Chp 2.1 (Refuse Combustion) a)
Hg	g/ton MSW	1.6300	AP-42. Chp 2.1 (Refuse Combustion) a)
Ni	g/ton MSW	0.1350	AP-42. Chp 2.1 (Refuse Combustion) a)

a) Mass Burn Waterwall Combustor (MW/WW) with Electrostatic Prec. And Semi-wet scrubber (same as Spray Dryer) SD/ESP

## 8.3 Uncertainty Assessment

### 8.3.A Solid Waste Disposal on Land

The uncertainty of activity data for Municipal Solid Wastes must be considered high not only because it is estimated in most years from population and per capita waste production ratio but mostly because of the low accuracy in the back-cast establishment of a time series (since 1960) of solid wastes disposed in landfills. An uncertainty of 25% was therefore considered as representative of the accuracy of the present time series for production of Municipal Solid Wastes.

The activity data for the calculation of emissions from Industrial Waste Production has an even lower accuracy than Municipal Solid Wastes, because the time trend since 1960 was established with information only collected after 1999. Comparison of the production of industrial solid wastes from 1999 till 2002 show unexpected expressive annual variations, which indicate that annual production could have an uncertainty of about 68%. An uncertainty the double of this value was considered (136%), to incorporate the error in backward forecasts till 1960, which is of the order that IPCC (2000) recommends for countries with low quality data was considered: 100%.

Uncertainty in the determination of the emission factor follows the rules of error propagation and were set from the default values proposed in the GPG for DOC (50%),  $DOC_F$  (50%), MCF (10% for Managed systems and 60% for unmanaged) and F (20%) and 300% for k, the methane generation rate constant<sup>132</sup>. An overall error of 62 %, for managed systems and 86 % for unmanaged systems, was therefore obtained and used for both urban and industrial wastes.

### 8.3.B Wastewater Handling

For urban waste water treatment the activity data, expressed in organic load to wastewater systems, was estimated from population and per capita production and the error associated with both variables needs to be incorporated in the determination of the final uncertainty value. Assuming the default uncertainties proposed in GPG, 5% for human population and 30% for BOD per capita, a final 30.4 % error was set for this activity. In the case of industrial wastewater systems the available information is much more scarce and limited to a few years and,

<sup>132</sup> The uncertainty for this variable affects nevertheless when emissions occur and not how much and affects emission estimates exponentially.

although the consideration of the default GPG uncertainties results in an overall 103% error, a conservative doubling of that value was considered.

Concerning the methane emission factor, the uncertainty of this parameter includes an error in the Maximum Methane Producing Capacity (Bo), for which the GPG default of 30% was used, and the error determination in the fraction of water treated anaerobically. For urban water the uncertainty in this last fraction was estimated as 22 %, considering the percentage of individual septic tanks and the lack of knowledge of in which conditions they operate, and the maximum value of 50% was considered for industrial wastewater in which case there is less information. The overall uncertainty in the CH<sub>4</sub> emission from urban wastewater handling is 38 %, and 58 % for industrial wastewater handling.

### 8.3.C Waste Incineration and Other

The uncertainty of the quantity of urban wastes was assumed to be 5%, considering that they are obtained directly from the incineration plants. For hospital wastes an uncertainty of 48% was calculated from comparison of annual variation in the quantities reported as incinerated, and also considering the fact that there is a fair lack of information of the production time series, particularly before 1995. In a way similar to what was done for determination of the uncertainty of production of industrial solid wastes, the comparison of the incineration of industrial solid wastes from 1999 till 2002 and its annual variations, allowed the estimation of an annual uncertainty of about 45%.

The uncertainty of CO<sub>2</sub> emission factors was set as 25% for urban and industrial wastes and 50% for hospital wastes, which expresses the uncertainty in carbon content and the additional uncertainty in the fraction of the incinerated carbon that has fossil origin. For N<sub>2</sub>O and CH<sub>4</sub> emission factors a 100% uncertainty was considered.

## 8.4 Recalculations

The revisions that have been done in the 2005 inventory submission refers to: updates in background data time series, refinement in calculation formulas and parameters revision to take account of in-depth review recommendations. Synthesis of changes may be observed in Figure 8.19 and Table 8.19.

Figure 8.19 – Differences between 2004 and 2005 submissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O)

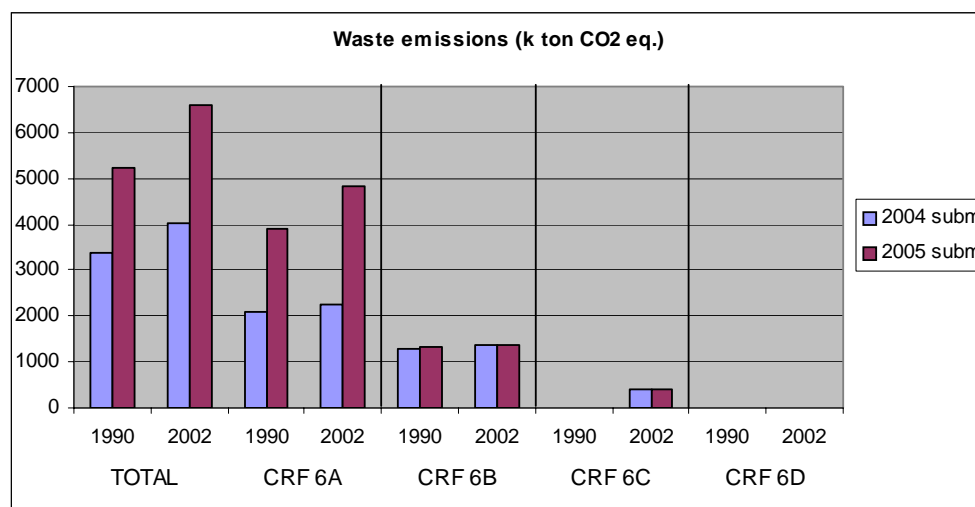


Table 8.19 – Recalculations (differences between 2004 to 2005 submissions)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
		2004	2005	Difference	2004	2005	Difference	2004	2005	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>6. Waste</b>		<b>10.10</b>	<b>10.10</b>	<b>0.00</b>	<b>2,911.82</b>	<b>4,761.38</b>	<b>63.52</b>	<b>448.83</b>	<b>448.26</b>	<b>-0.13</b>
6.A.	Solid Waste Disposal on Land	0.00	0.00	0.00	2,089.29	3,891.80	86.27			
6.B.	Wastewater Handling				822.49	869.54	5.72	447.71	447.15	-0.13
6.C.	Waste Incineration	10.10	10.08	-0.24	0.04	0.01	-66.57	1.12	0.37	-66.57
6.D.	Other	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.74	0.00
<b>2002</b>										
<b>6. Waste</b>		<b>379.83</b>	<b>358.76</b>	<b>-5.55</b>	<b>3,031.43</b>	<b>5,664.80</b>	<b>86.87</b>	<b>591.87</b>	<b>584.69</b>	<b>-1.21</b>
6.A.	Solid Waste Disposal on Land	0.00	0.00	0.00	2,241.10	4,832.99	115.65			
6.B.	Wastewater Handling				789.27	830.79	5.26	560.80	555.08	-1.02
6.C.	Waste Incineration	379.83	358.76	-5.55	1.07	0.98	-8.44	31.07	28.44	-8.44
6.D.	Other	0.00	0.00	0.00	0.00	0.04	0.00	0.00	1.16	0.00

Notes:(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100% x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission.

### 8.4.A Solid Waste Disposal on Land

Data on MSW for 2002 and 2003 were updated with data collected by municipal management systems, and remembering that data used in 2004 submission for 2002 was a provisional estimate.

According to in-depth review recommendations, new estimates on the composition of municipal wastes were used, which enable the use of different DOC values reflecting the evolution in the composition of solid waste.

A refinement has been implemented concerning the calculation formula used in the estimates of this category. Previously used First Order Decay model - equation 3 IPCC 1996 – was changed to equation 4, which is a derivative of Eq. 3 that allows a better consideration of variances in annual SW disposed into land. Furthermore, as pointed out in sub-section 5.1.1.2 of IPCC GPG, equation 4 is suitable for national (and regional) estimates; previous equation used (eq. 3) is to be used for an individual landfill, or possibly a group of specific landfills.

In accordance with the in-country review recommendations, the k parameter (methane generation rate) was changed to 0.07 (previous value was 0.05).

Data on fermentable industrial waste disposed on land have been updated for the period 2000-2002 with data supplied by INR, and refer to annual registries from industrial units declarations.

### 8.4.B Wastewater Handling

Minor changes were done since last submission:

- the BOD<sub>5</sub> factor was changed to 60 g BOD<sub>5</sub>/cap/day (instead of 56 g BOD<sub>5</sub>/cap/day); the new figure refers to the Council Directive 91/271/CEE, 21<sup>st</sup> Mai, on urban waste water treatment;
- revision of protein intake data (update from FAO database in August 2004).

### 8.4.C Waste Incineration and Other

The in-depth review ERT recommended emissions on “open burning of industrial solid waste on land”, which were previously included in category 6.C, to be reported under category 6.A. These emissions have however been reported under 6.D Other, in order to report more pollutants (SO<sub>2</sub>) in CRF tables than was possible in category 6.A.

## 8.5 Further improvements

One of the issues that still needs to be improved in the near future is the better quantification of the amount of CH<sub>4</sub> recovered and flared. 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).

An improvement has been done in this submission concerning the variation of waste composition along the time series. However estimates for the early years (1960s and 1970s) are not available, and the data for the most recent years from waste management systems are also not collected.

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). Furthermore, as pointed out in the in-depth review report, CH<sub>4</sub> emissions from sludge handling and recovery of CH<sub>4</sub> in the category Industrial Waste-Water Handling should be estimated and reported in the near future.

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.

The issue of energy recovery in waste incineration has not yet been considered and should be addressed.

## 8.6 Annex WASTE: Background Data Tables

Table W-1 – National population, per capita generation rates, and urban waste production: 1960-2003

Year	Population	Annual per capita generation rate	Pop. served by waste collection syst.	Urban waste production				
				Total	Open dump sites	Managed landfills	Composted waste	Incinerated waste
	inhabitants	kg/inh/year	% pop.	kton				
1960	8 889 197	128.8	40	457.8	457.8	0.0	0.0	0.0
1961	8 861 388	132.1	41	482.4	482.4	0.0	0.0	0.0
1962	8 833 580	135.6	42	507.8	507.8	0.0	0.0	0.0
1963	8 805 771	139.1	44	534.1	534.1	0.0	0.0	0.0
1964	8 777 962	142.8	45	561.4	561.4	0.0	0.0	0.0
1965	8 750 154	146.5	46	589.6	589.6	0.0	0.0	0.0
1966	8 722 345	150.3	47	618.8	618.8	0.0	0.0	0.0
1967	8 694 536	154.2	48	649.1	649.1	0.0	0.0	0.0
1968	8 666 727	158.3	50	680.4	680.4	0.0	0.0	0.0
1969	8 638 919	162.4	51	712.8	712.8	0.0	0.0	0.0
1970	8 611 110	166.7	52	746.3	746.3	0.0	0.0	0.0
1971	8 722 192	171.2	53	794.5	794.5	0.0	0.0	0.0
1972	8 833 274	175.9	54	845.2	845.2	0.0	0.0	0.0
1973	8 944 357	180.7	56	898.5	898.5	0.0	0.0	0.0
1974	9 055 439	185.6	57	954.5	954.5	0.0	0.0	0.0
1975	9 166 521	190.6	58	1 013.4	1 013.4	0.0	0.0	0.0
1976	9 277 603	195.8	59	1 075.1	1 075.1	0.0	0.0	0.0
1977	9 388 685	201.0	60	1 140.0	1 140.0	0.0	0.0	0.0
1978	9 499 767	206.4	62	1 208.1	1 208.1	0.0	0.0	0.0
1979	9 610 850	212.0	63	1 279.5	1 279.5	0.0	0.0	0.0
1980	9 721 932	217.7	64	1 354.4	949.2	360.5	44.7	0.0
1981	9 833 014	224.6	66	1 462.0	1 021.1	396.2	44.7	0.0
1982	9 836 427	231.6	68	1 558.2	1 088.1	425.4	44.7	0.0
1983	9 839 841	238.8	71	1 658.9	1 158.2	456.0	44.7	0.0
1984	9 843 254	246.2	73	1 764.5	1 231.7	488.1	44.7	0.0
1985	9 846 667	253.9	75	1 875.0	1 308.6	521.7	44.7	0.0
1986	9 850 081	261.8	78	2 001.1	1 396.3	560.1	44.7	0.0
1987	9 853 494	269.9	80	2 133.2	1 488.2	600.3	44.7	0.0
1988	9 856 907	278.3	83	2 271.7	1 584.5	642.5	44.7	0.0
1989	9 860 320	287.0	85	2 416.8	1 685.4	686.7	44.7	0.0
1990	9 863 734	295.9	88	2 568.7	1 764.9	692.1	111.7	0.0
1991	9 867 147	305.1	89	2 690.9	1 731.9	913.5	45.5	0.0
1992	9 916 044	314.7	91	2 831.4	1 821.8	951.7	57.8	0.0
1993	9 964 941	324.5	92	2 978.4	1 915.3	989.4	73.7	0.0
1994	10 013 838	334.6	93	3 132.3	1 839.0	1 137.2	156.2	0.0
1995	10 062 735	350.0	95	3 341.2	1 951.7	1 184.4	205.1	0.0
1996	10 111 632	365.4	96	3 542.8	2 027.8	1 310.3	204.7	0.0
1997	10 160 529	380.7	97	3 748.6	2 007.1	1 531.4	210.1	0.0
1998	10 209 426	395.9	98	3 958.7	1 507.5	2 236.0	215.2	0.0
1999	10 258 323	411.0	99	4 173.3	974.1	2 626.6	226.2	346.4
2000	10 307 220	412.1	100	4 247.9	588.3	2 473.6	274.8	911.1
2001	10 356 117	425.2	100	4 403.1	451.9	2 792.9	266.6	891.7
2002	10 405 014	421.2	100	4 382.7	27.8	3 294.7	116.2	943.9
2003	10 453 911	427.1	100	4 464.6	25.9	3 019.2	416.1	1 003.4

Sources:INE; IA estimates; INR; Quercus Study

Table W - 2 – Fermentable industrial waste disposal: 1960-2003

Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills	Year	Open dump sites	Managed landfills
kton			kton			ton		
1960	819	0	1975	1 024	0	1990	893	388
1961	832	0	1976	1 040	0	1991	843	463
1962	844	0	1977	1 055	0	1992	860	473
1963	857	0	1978	1 071	0	1993	876	483
1964	870	0	1979	1 087	0	1994	835	551
1965	883	0	1980	773	330	1995	850	565
1966	896	0	1981	782	338	1996	848	594
1967	909	0	1982	794	343	1997	810	661
1968	923	0	1983	806	348	1998	594	907
1969	937	0	1984	818	354	1999	358	1 173
1970	951	0	1985	830	359	2000	59	365
1971	965	0	1986	842	365	2001	94	817
1972	980	0	1987	854	370	2002	5	773
1973	994	0	1988	867	376	2003	5	773
1974	1 009	0	1989	880	382			

Notes:

Share between open dump and managed landfills based on disposal of municipal solid wastes.

2002 and 2003: disposal on open dump sites refer to disposal on controlled dump sites.

Source: IA estimates; INR

Table W - 3 – Quantities of CH<sub>4</sub> recovered and combusted (Urban waste): 1990-2003

	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	1.17	10.64	0.02	0.22	7
2001	1.75	37.07	0.04	0.78	22
2002	1.62	41.84	0.03	0.88	23
2003	1.69	44.81	0.04	0.94	24

Source: IA estimates

Table W - 4 – Quantities of CH<sub>4</sub> recovered and combusted (Fermentable industrial waste): 1990-2003

	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	0.72	4.75	0.02	0.10	6
2001	1.33	22.00	0.03	0.46	21
2002	1.38	25.82	0.03	0.54	22
2003	1.40	26.61	0.03	0.56	23

Source: IA estimates

Table W - 5 – National population and wastewater BOD produced by handling systems: 1990-2003

	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	216	35	9	98	75
1991	9 867	216	41	10	94	70
1992	9 916	217	48	12	91	66
1993	9 965	218	55	14	87	62
1994	10 014	219	62	16	84	57
1995	10 063	220	69	17	81	53
1996	10 112	221	75	19	76	51
1997	10 161	223	81	20	72	49
1998	10 209	224	87	22	67	47
1999	10 258	225	94	23	62	46
2000	10 307	226	100	25	57	44
2001	10 356	227	100	25	58	44
2002	10 405	228	101	25	58	44
2003	10 454	229	102	25	58	43

Source: IA estimates

Table W - 6 – Estimated quantities of CH<sub>4</sub> flared: 1990-2003

Year	Wastewater treatment systems		Sludge treatment systems	
	kton/year	% emissions of wastw. treat.	kton/year	% emissions of sludge treat.
1990	0.02	0.5	0.02	2.0
1991	0.02	0.5	0.02	2.1
1992	0.03	0.5	0.03	2.2
1993	0.03	0.6	0.03	2.2
1994	0.04	0.6	0.04	2.3
1995	0.04	0.6	0.05	2.4
1996	0.04	0.6	0.06	2.5
1997	0.05	0.7	0.07	2.6
1998	0.05	0.7	0.08	2.7
1999	0.06	0.7	0.09	2.8
2000	0.06	0.7	0.11	3.0
2001	0.07	0.8	0.12	3.1
2002	0.07	0.8	0.13	3.2
2003	0.07	0.8	0.14	3.3

Source: IA estimates

Table W - 7 – Quantities of waste incinerated: 1990-2003

Year	MSW quantities incinerated	Clinical waste quantities incinerated
	kton	
1990	-	12
1991	-	12
1992	-	12
1993	-	12
1994	-	12
1995	-	12
1996	-	13
1997	-	16
1998	-	12
1999	346	10
2000	911	7
2001	892	3
2002	915	3
2003	893	2

Note: Estimates in italics

Sources: INR; DGS; IA estimates



Table W - 7 – Quantities of industrial waste open burned: 1990-2003

Year	Industrial solid waste incinerated
	kton
1990	24
1991	24
1992	25
1993	25
1994	26
1995	27
1996	27
1997	28
1998	28
1999	29
2000	15
2001	27
2002	38
2003	38

Note: Estimates in italics  
Sources: INR; IA estimates.

Table W - 8 – Comparison between estimates for CH<sub>4</sub> emissions from waste-water handling and IPCC check-method

Year	CH <sub>4</sub> emissions			National CH <sub>4</sub> emissions	
	Check method	National estimates	% difference	w without recovery	recovered
	ton	ton	%	ton	ton
1990	51 844	33 607	35.2	33 640	34
1991	51 862	33 331	35.7	33 373	42
1992	52 119	33 201	36.3	33 253	52
1993	52 376	33 063	36.9	33 126	63
1994	52 633	32 919	37.5	32 994	75
1995	52 890	32 771	38.0	32 859	89
1996	53 147	32 088	39.6	32 190	102
1997	53 404	31 398	41.2	31 515	117
1998	53 661	30 704	42.8	30 837	133
1999	53 918	30 006	44.3	30 158	152
2000	54 175	29 308	45.9	29 480	172
2001	54 432	29 479	45.8	29 663	184
2002	54 689	29 662	45.8	29 859	198
2003	54 946	29 857	45.7	30 069	213
% variation 1990-2003	6.0	-11.2	-	-	-

## 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

#### 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.

## 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.

### 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>133</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		D kd dm/m2		Vegetation Period	$\varepsilon$ µgC/g dm/h @standart L,T					
					µgC/g dm/h @standart L,T			Isoprene	Monoterpenes	OVOC
Maritime pine	Pinus pinaster	700	Veldt (1989); Guenther et al (1994); Nunes (1996)	Evergreen	0	-	2.25	Pio et al, 1999	1.5	Guenther et al, 1994
Umbrella pine	P. Pinea	400	same as Other Coniferous	Evergreen	0	-	6	EMEP/CORINAIR-B1101 (EEA,2002)	1.5	
Other coniferous	-	400	(Ortiz and Dory, 1990 in Simpson,1995)	Evergreen	0	-	1.08	Simpson et al 1998. Average for Cupressus, halepensis, Pseudotsuga, P. sylvestris	1.5	
Gum tree	Eucalyptus sp.	300	(Nunes,1996); Nunes & Pio (1999)	Evergreen	32	Nunes & Pio (1999)	1.5	Nunes & Pio (1999)	1.5	
Cork oak	Quercus suber	200	Intermediate value between Forest area Mediterranean Oak (300) Simpson et al (1995) and Monte Hueco (100) from Ortiz and Dory (1990)	Evergreen	0	-	varies along year according to Table 9.2		1.5	
Holm oak	Quercus rotundifolia	200	Intermediate value between Forest area Mediterranean Oak (300) Simpson et al (1995) and Monte Hueco (100) from Ortiz and Dory (1990)	Evergreen	0	-	17	Luchetta, Simon and Torres (Average value)	1.5	
Oaks	Quercus sp.	400	Guenther et al (1994)	Apr-Sept	40	Guenther et al (1994)	0.35	Luchetta et al, 1999(Average Q. robur and Q. petrae)	1.5	
Chetnut	Castanea sativa	375	Guenther et al (1994)	Apr-Sept	0	-	8.71	(Luchetta et al,1999)	1.5	
Other broadleaves	-	418	Guenther et al (1994) in Geron, Guenther et Pierce (1994). Average: Acacia, Betula, Celtis, Fraxinus, Juniperus, Platanus, Populus, Prunus, Salix, Ulmus and Olea)	Mixed Evergreen and Deciduous	12.8	Guenther et al (1994) in Geron, Guenther et Pierce (1994). Average: Acacia, Betula, Celtis, Fraxinus, Juniperus, Platanus, Populus, Prunus, Salix, Ulmus and Olea)	0.6	Guenther et al (1994) in Geron, Guenther et Pierce (1994). Average: Acacia, Betula, Celtis, Fraxinus, Juniperus, Platanus, Populus, Prunus, Salix, Ulmus and Olea)	1.5	
Mixed broadleaves/ coniferous	-	380	Average other species	Mixed Evergreen and Deciduous	-	Average other species	-	Average other species	1.5	
Bush (Matos)	-	200	Ortiz & Dory (1990) in Simpson et al, 1999 (Garrigue)	Evergreen	8	Ortiz & Dory (1990) in Simpson et al, 1999 (Garrigue)	0.65	Ortiz & Dory (1990) in Simpson et al, 1999 (Garrigue)	1.5	
Olive Tree	Olea europaea	200	(Ortiz and Dory, 1990 in Simpson,1995)	Evergreen	0	-	1.6	(Ortiz and Dory, 1990 in Simpson,1995)	1.5	
Orchards/ Vine	-	200		Mixed Evergreen and Deciduous	0	-	1.6		1.5	

<sup>133</sup> During this period emissions from foliage are obviously zero.

Values for  $\gamma$  are estimated according to empirical equations that are functions of both VOC compound and vegetation specie. For Isoprene emissions the general set of equations were used, function of light and temperature, following Guenther et al (1993).

$$\gamma = C_L * C_T$$

$C_L$ , the light dependence factor is determined from:

$$C_T = \frac{0.0027 * 1.066 * Q}{\sqrt{1 + (0.027 * Q)}}$$

where Q is the flux of PAR (mmol/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)

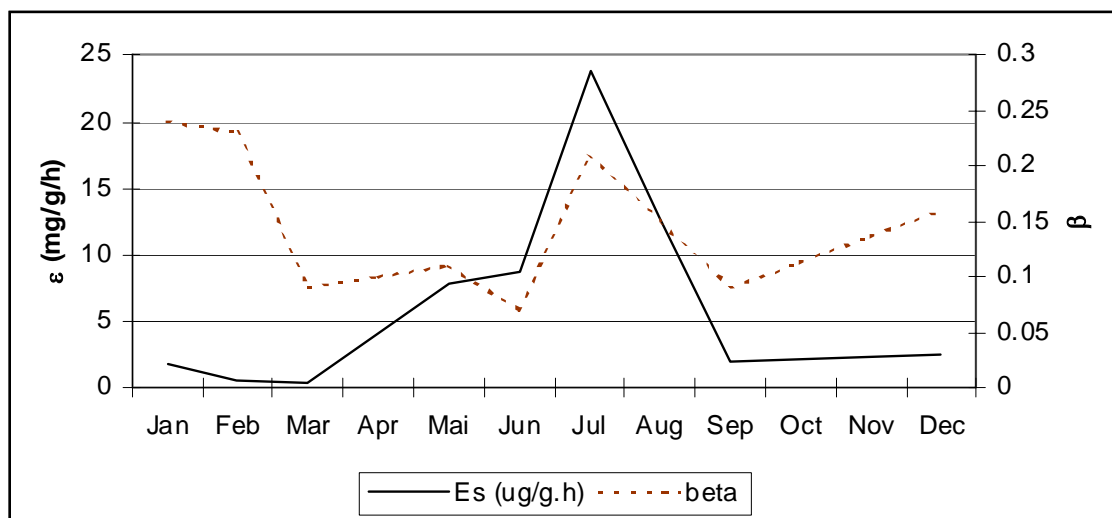
This same equation was used for OVOC following recommendations in Geron et al (1999) and in the EMEP/CORINAIR (Chapter B1101) (EEA,2002).

For some species however, this general formulation was not used but it is replaced by country specific equations. This is particularly the case for cork and Holm oaks, where monoterpene emissions are also function of light<sup>134</sup>. These equations are summarized in table 9.2.

<sup>134</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  $\gamma$ 

Specie	Compound	Equation	Reference
P. Pinaster	Monoterpernes	$\gamma = \exp[0.138 * (T-30)]$	Pio et al (1999)
Eucapypus	Monoterpenes	$\gamma = \exp[0.07 * (T-30)]$	Nunes (1996)
Cork Oak	Isoprene	$\gamma = \{CL*CT + \exp[\beta * (T-T_s)]\}$	Silva et al (1999); CL*CT is Guenther's model. B parameter changes during the year, and the considered variation is in Figure 9.2
Holm Oak	Isoprene	$\gamma = \{CL*CT + \exp[0.09 * (T-T_s)]\}$	

Figure 9.1 - Time variable  $\varepsilon$  for Cork Oak (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.

### 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
	$\mu\text{gC}/\text{m}^2/\text{h}$			$\mu\text{g}/\text{m}^2/\text{h}$
Arable Land	8	20	12	45
Rice	8	20	12	45
Grassland	8	20	12	45
Market Gardening	8	20	12	45

Source: Veldt, 1991 ; Veldt, 1998

## Resin-tapping

The emission factor for resin-tapping, per tree in extraction, follows the equation proposed by Pio & Valente (1998), for each particular condition:

$$\log_{10}[\text{EF\_tapping}_{(m,h)}] = 0.631 + 0.06 * T$$

where,

$\text{EF\_tapping}_{(m,h)}$  - VOC emission rate from resin-tapping (mg VOC/hr/tree) for a specific time;

T - Air temperature ( $^{\circ}\text{C}$ ).

The annual emission factor for each territorial unit was obtained by the addition of the emission factors for each hourly period in a year:

$$\text{EF\_tapping}_{(n)} = \sum_{m,h} \{\text{EF\_Tapping}_{(m,h)}\}$$

## 9.4 Activity Data

Basic activity data is the area for each crop or plant species. This information was available from DGRF for years 1990 and 1995 and was interpolated and extrapolated<sup>135</sup> for the remaining time-series. Foliage areas for each tree species were obtained according to the following equation:

$$\text{Foliage\_Area}_{(n,s)} = \text{Pure}_{(n,s)} + 0.75 * \text{Dominant}_{(n,s)} + 0.25 * \text{Dominated}_{(n,s)} + \text{Dispersed}_{(n,s)}$$

where,

$\text{Foliage\_Area}_{(n,s)}$  - total area covered by foliage of tree specie s in territorial unit n (ha);

$\text{Pure}_{(n,s)}$  - Land area occupied by pure strands of specie s in territorial unit n (ha);

<sup>135</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	1 069 000	1 076 142	1 082 374	1 087 696	1 092 107	976 069	975 141
P. pinea	35 000	44 607	54 637	65 088	75 962	77 650	80 560
Other coniferous	69 000	62 737	55 907	48 510	40 546	27 358	28 383
Quercus suber	693 000	703 675	714 427	725 254	736 158	712 813	720 675
Quercus rotundifolia	462 000	473 572	485 139	496 702	508 261	461 577	463 442
Other oaks	123 000	131 024	139 212	147 563	156 077	130 899	130 506
Castanea sativa	37 000	39 064	41 179	43 346	45 563	40 579	40 457
Eucalyptus sp.	554 000	598 135	643 947	691 437	740 604	672 149	674 508
Other broadleaves	98 000	103 688	109 455	115 302	121 229	102 037	104 481
Other mixed	0	0	0	0	0	0	0
Bush (Matos)	1 734 822	1 798 772	1 862 722	1 926 671	1 990 621	2 054 571	2 054 571
Olive	322 093	324 236	325 523	321 664	317 805	307 077	303 218
Orchards and Vine	421 501	424 306	425 989	420 940	415 890	401 851	396 801
Arable Land	2 340 754	2 363 534	2 292 882	2 298 800	2 302 868	2 131 628	2 166 240
Rice	33 246	33 466	21 118	13 200	23 132	21 646	22 389
Grassland	858 000	859 000	860 000	862 000	862 000	1 052 798	1 052 798
Market Gardening	32 000	32 000	31 000	31 000	31 000	30 127	29 951
Resin-tapping (Million tree)	35	35	35	35	35	35	35



Table 9.5 - Forest Area per tree specie (ha) (1997-2003)

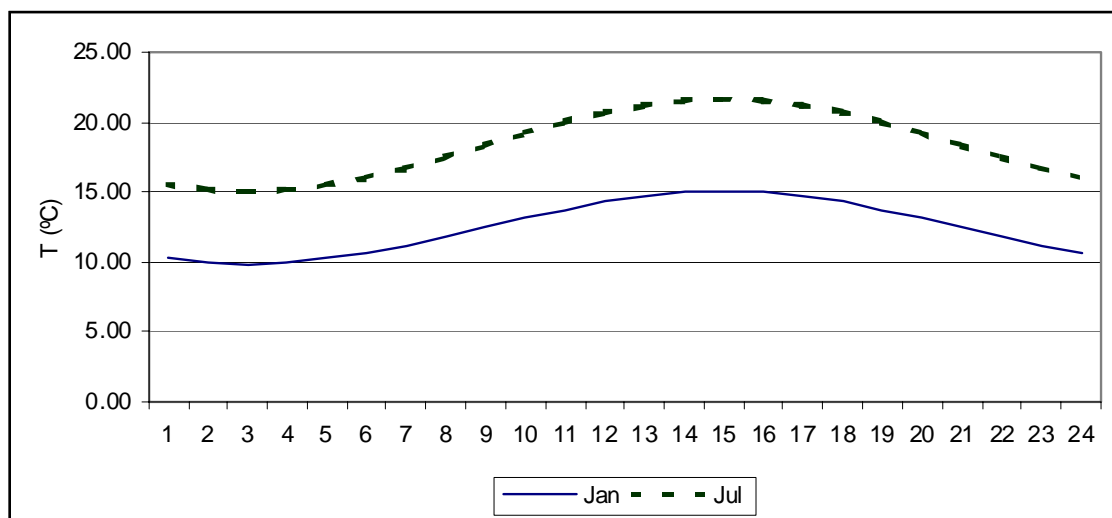
Specie	1997	1998	1999	2000	2001	2002	2003
Pinus pinaster	974 213	973 284	972 356	971 428	970 500	969 572	969 572
P. pinea	83 470	86 379	89 289	92 199	92 266	92 222	91 547
Other coniferous	29 408	30 434	31 459	32 484	36 667	40 961	41 635
Quercus suber	728 536	736 398	744 259	752 121	759 982	767 844	767 844
Quercus rotundifolia	465 308	467 173	469 038	470 903	472 769	474 634	474 634
Other oaks	130 114	129 721	129 328	128 936	128 543	128 150	128 150
Castanea sativa	40 336	40 214	40 092	39 970	39 849	39 727	39 727
Eucalyptus sp.	676 866	679 225	681 583	683 942	686 300	688 659	688 659
Other broadleaves	106 925	109 369	111 813	114 256	116 700	119 144	119 144
Other mixed	0	0	0	0	0	0	0
Bush (Matos)	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571	2 054 571
Olive	297 299	291 379	285 460	279 540	279 540	279 540	279 540
Orchards and Vine	389 055	381 308	373 562	365 815	365 815	365 815	365 815
Arable Land	2 131 334	2 096 428	2 061 522	2 026 616	2 026 616	2 026 616	2 026 616
Rice	22 389	22 389	22 389	22 389	22 389	22 389	22 389
Grassland	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798	1 052 798
Market Gardening	29 598	29 245	28 891	28 538	28 538	28 538	28 538
Resin-tapping (Million Tree)	35	35	35	35	35	35	35

For the determination of emissions from resin-tapping the number of pine trees under extraction must be known. Pio & Valente (1998) estimated that this number is about 35 million trees in the 1980-1990 period. After 1990 the same authors believe that there has been a decrease in the number of trees explored, but no statistical information is available

The calculation of the emission factors it is necessary, as mentioned before, the knowledge of PAR and leaf temperature. These were set for each hour of the day and each month according to the following information.

A time series of 30 years (1951-1980) of average minimum and maximum air temperature, for each month and territorial unit, were used to establish a typical evolution of daily temperature, for each month of the year and each territorial unit. A cosine function was considered with a peak of air temperature occurring at 15.00 (2 PM). In the following figure there is an example for the daily evolution of air temperatures in January and July for Madeira Island.

Figure 9.2 - Cosine modelling of daily evolution of air temperatures in January and July in Madeira Island region. Obtained for average minimum and maximum monthly temperatures in 1951-1980 (INMG)

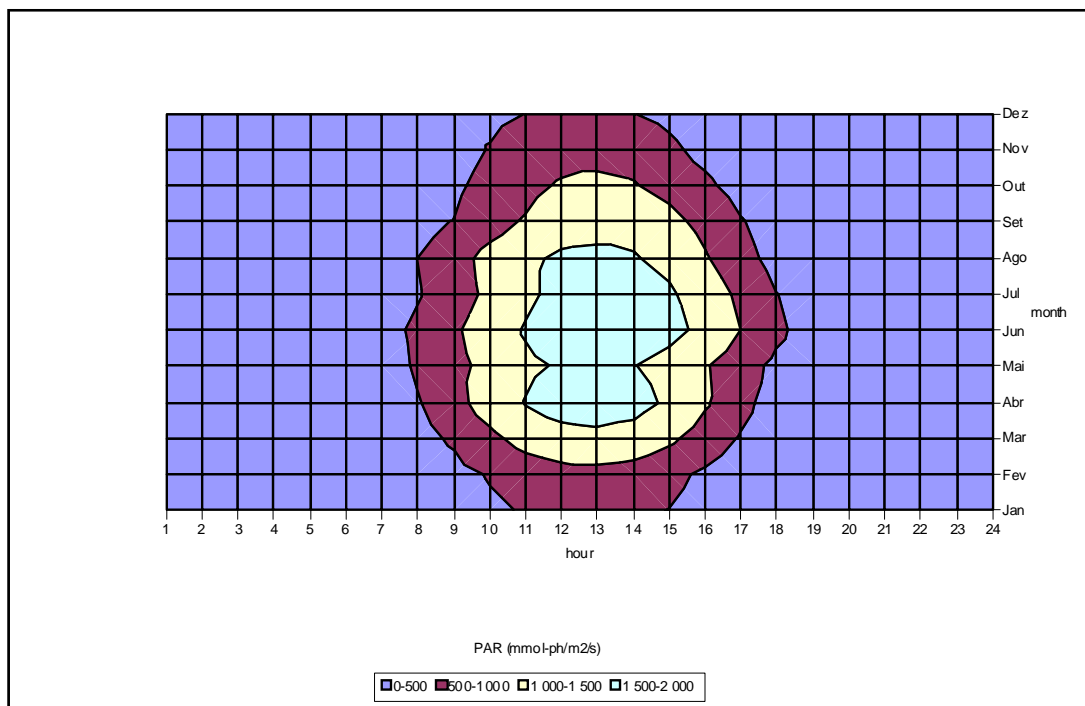


Source: INMG

However the information concerning PAR is scarce and some simplifications and assumptions had to be made. The pattern of monthly and daily variation of PAR was set by UA (Nunes, 1996) in Aveiro region, in central coastal Portugal, from a full year of measurements of total radiation ( $W/m^2$ ) in the meteorology monitoring station of Cacia. Average hourly total radiation was converted in PAR ( $mmol\text{-photons}/m^2/s$ ) by multiplication of 0.45, the local conversion factor (Pinho, 1995 in Nunes, 1996) and assuming an average wavelength of 550 nm. The annual monthly-hourly pattern of PAR in Cacia is presented in Figure 9.4.

PAR values for Cacia were corrected for each territorial unit proportionally to the relation of insolation in each specific region and in original Cacia station.

Figure 9.3 - Pattern of evolution of PAR (mmol/m<sup>2</sup>/s) according to month and hour of day (Nunes,1996)



## 9.5 Recalculations

The activity data (area covered for each species) was revised in order to improve consistency with the activity data used to estimate emissions from source category 5A

## 9.6 Further Improvements

The existence and importance of NMVOC emissions from non-tree crops is much subject to debate, as for example in EMEP/CORINAIR (Chapter B1010 and B1104) (EEA,2002). It is expected that further improvements in methodology may lead to changes in emission estimates for this source sector.

It is expected that efforts will be made during next year to revise and improve the methodology and emission factors for the estimate of NMVOC from agriculture and forestry.

The emission factors could be estimated for each specific year using meteorological data.

The possible inclusion emissions of foliage under-canopy or dominated trees should be addressed, at least for some types of ecosystems.

An improvement in information concerning resin extraction may ameliorate the estimates of VOC emissions from resin-tapping in Maritime pine.

## CHAPTER: 10 RECALCULATIONS AND IMPROVEMENTS

This section presents an overview of recalculations and improvements made in the 2005 submission. The detailed explanation of the recalculations and the foreseen improvements are included in each sectoral chapter.

In general, changes in methodology, source coverage or scope of the data have been reflected in the recalculation of the entire time series (from 1990 to 2002), in order to make the inventory internally consistent.

### 10.1 Implications for emissions levels

The implications of recalculations for emission levels by category and for the national totals by gas are presented in the following tables.

In a resumed way, the tables show that: CO<sub>2</sub> emissions recalculations are mostly related to the energy sector, in particular energy industries and transport; CH<sub>4</sub> emissions changes refer in majority to the waste sector and more specically to the 6.A category, i.e. Solid Waste Disposal on Land; and N<sub>2</sub>O emissions revisions are mainly related to Agriculture (Agriculture Soils).

The related explanations are included in the sector specific sections of the report.

Table 10.1 – Recalculation difference of CO2 emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		kton CO2 eq.												
<b>Total National Emissions and Removals</b>		-519	-594	-622	-424	-536	-342	-284	-80	154	334	-235	322	1 381
<b>1. Energy</b>		-650	-743	-764	-595	-707	-542	-481	-297	-85	84	-515	0	283
1.A.	Fuel Combustion Activities	-650	-743	-764	-595	-692	-513	-456	-265	-55	112	-490	32	321
1.A.1.	Energy Industries	-242	-260	-289	-280	-270	-308	-260	-270	-282	-353	-644	-314	-376
1.A.2.	Manufacturing Industries and Construction	-55	-108	-75	85	-24	192	199	382	587	826	548	713	1 078
1.A.3.	Transport	-323	-343	-367	-368	-363	-363	-359	-240	31	105	280	-289	-292
1.A.4.	Other Sectors	-30	-32	-32	-33	-35	-34	-36	-136	-391	-464	-674	-79	-89
1.A.5.	Other	0	0	0	0	0								
1.B.	Fugitive Emissions from Fuels					-15	-28	-25	-32	-29	-29	-25	-31	-38
1.B.1.	Solid fuel													
1.B.2.	Oil and Natural Gas					-15	-28	-25	-32	-29	-29	-25	-31	-38
<b>2. Industrial Processes</b>		134	151	143	172	171	200	198	218	240	251	283	323	1 120
2.A.	Mineral Products	156	173	167	196	196	229	225	246	268	280	312	320	1 104
2.B.	Chemical Industry	0	0	0	0	0	0	0	0	0	0	0	0	0
2.C.	Metal Production	-21	-22	-24	-23	-25	-28	-28	-28	-28	-29	-29	3	16
2.D.	Other Production													
2.G.	Other													
<b>3. Solvent and Other Product Use</b>		-3	-2	-1	-1	0	0	-1	-1	-1	-1	-3	-1	-1
<b>4. Agriculture</b>														
4.A.	Enteric Fermentation													
4.B.	Manure Management													
4.C.	Rice Cultivation													
4.D.	Agricultural Soils <sup>(2)</sup>													
4.E.	Prescribed Burning of Savannas													
4.F.	Field Burning of Agricultural Res.													
4.G.	Other													
<b>5. Land-Use Change and Forestry (net)</b>		0	0	0		0	0	0	0	0	0	0	0	0
5.A.	Changes in Forest and Other Woody Biomass Stocks	0	0	0		0	0	0	0	0	0	0	0	0
5.B.	Forest and Grassland Conversion													
5.C.	Abandonment of Managed Lands													
5.D.	CO <sub>2</sub> Emis. and Removals from Soil													
5.E.	Other													
<b>6. Waste</b>								0				0	0	-21
6.A.	Solid Waste Disposal on Land													
6.B.	Wastewater Handling													
6.C.	Waste Incineration	0	0	0	0	0	0	0	0	0	0	0	0	-21
6.D.	Other	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Memo Items:</b>														
<b>International Bunkers</b>		-20	-20	-21	-17	-17	-18	-19	-20	-21	-26	-27	-20	-22
<b>Multilateral Operations</b>														
<b>CO<sub>2</sub> Emissions from Biomass</b>		-811	-934	-948	-902	-879	-899	-895	-992	-988	-1 016	-1 058	-1 200	-1 138

Table 10.2 - Recalculation difference of CH4 emissions

GHG SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	kton CO2 eq.												
<b>Total National Emissions and Removals</b>	1 734	1 761	1 934	2 192	2 234	2 268	2 419	2 542	2 738	2 755	2 238	2 259	2 465
<b>1. Energy</b>	-36	-65	-94	-58	-57	-65	-71	-72	-83	-93	-99	-100	-105
1.A. Fuel Combustion Activities	-36	-65	-94	-58	-57	-65	-71	-71	-81	-88	-91	-86	-87
1.A.1. Energy Industries	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.2. Manufacturing Industries and Construction	-35	-65	-95	-57	-56	-63	-67	-66	-74	-80	-80	-76	-75
1.A.3. Transport	-1	0	1	0	-2	-2	-4	-5	-7	-8	-9	-10	-12
1.A.4. Other Sectors	0	0	0	0	0	0	0	0	-1	-1	-1	0	0
1.A.5. Other													
1.B. Fugitive Emissions from Fuels	0	0			0		0	0	-2	-5	-8	-13	-18
1.B.1. Solid fuel		0											
1.B.2. Oil and Natural Gas					0		0	0	-2	-5	-8	-13	-18
<b>2. Industrial Processes</b>					0	0							0
2.A. Mineral Products													
2.B. Chemical Industry						0							
2.C. Metal Production													
2.D. Other Production													
2.G. Other													
<b>3. Solvent and Other Product Use</b>													
<b>4. Agriculture</b>	-79	-106	10	145	88	35	89	97	124	-40	-47	-45	-63
4.A. Enteric Fermentation	-11	-86	12	48	75	72	102	129	144	0	-14	14	-11
4.B. Manure Management	-68	-20	-2	98	14	-37	-12	-32	-19	-40	-32	-59	-51
4.C. Rice Cultivation										0	0		
4.D. Agricultural Soils <sup>(2)</sup>													
4.E. Prescribed Burning of Savannas													
4.F. Field Burning of Agricultural Res.	0	0	0	0	-1	-1	-1	-1	-1	0	-1	-1	-1
4.G. Other													
<b>5. Land-Use Change and Forestry (net)</b>													
5.A. Changes in Forest and Other Woody Biomass Stocks													
5.B. Forest and Grassland Conversion													
5.C. Abandonment of Managed Lands													
5.D. CO <sub>2</sub> Emiss. and Removals from Soil													
5.E. Other													
<b>6. Waste</b>	1 850	1 933	2 018	2 105	2 203	2 298	2 401	2 517	2 698	2 888	2 384	2 404	2 633
6.A. Solid Waste Disposal on Land	1 803	1 886	1 971	2 059	2 157	2 252	2 356	2 473	2 655	2 846	2 343	2 363	2 592
6.B. Wastewater Handling	47	47	46	46	46	46	45	44	43	42	41	41	42
6.C. Waste Incineration	0	0	0	0	0	0	0	0	0	0	0	0	0
6.D. Other	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Memo Items:</b>													
International Bunkers	0								0	0			0
Multilateral Operations													
CO <sub>2</sub> Emissions from Biomass													

Table 10.3 - Recalculation difference of N2O emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		kton CO2 eq.												
<b>Total National Emissions and Removals</b>		282	212	297	321	305	323	323	345	330	179	237	303	277
<b>1. Energy</b>		-5	-7	-8	-9	-11	-12	-15	-28	-61	-74	-97	-43	-45
1.A.	Fuel Combustion Activities	-5	-7	-8	-9	-11	-12	-15	-28	-61	-74	-97	-43	-45
1.A.1.	Energy Industries	0	0	0	0	0	0	0	0	0	0	-1	0	0
1.A.2.	Manufacturing Industries and	0	0	0	0	0	1	1	1	1	1	0	-2	0
1.A.3.	Transport	-5	-8	-8	-10	-11	-13	-15	-17	-16	-21	-22	-41	-45
1.A.4.	Other Sectors	0	0	0	0	0	0	0	-12	-46	-54	-75	0	0
1.A.5.	Other													
1.B.	Fugitive Emissions from Fuels													
1.B.1.	Solid fuel													
1.B.2.	Oil and Natural Gas													
<b>2. Industrial Processes</b>						0	0						0	
2.A.	Mineral Products													
2.B.	Chemical Industry					0	0						0	
2.C.	Metal Production													
2.D.	Other Production													
2.G.	Other													
<b>3. Solvent and Other Product Use</b>														
<b>4. Agriculture</b>		288	220	301	328	314	331	335	375	391	254	339	345	329
4.A.	Enteric Fermentation													
4.B.	Manure Management	-3	-22	1	8	14	15	22	32	40	-5	-5	-3	-5
4.C.	Rice Cultivation													
4.D.	Agricultural Soils <sup>(2)</sup>	291	242	300	321	301	318	314	345	353	259	346	349	335
4.E.	Prescribed Burning of Savannas													
4.F.	Field Burning of Agricultural Res.	0	0	-1	-1	-1	-1	-1	-2	-2	0	-2	-1	-1
4.G.	Other													
<b>5. Land-Use Change and Forestry (net)</b>														
5.A.	Changes in Forest and Other Woody Biomass Stocks													
5.B.	Forest and Grassland Conversion													
5.C.	Abandonment of Managed Lands													
5.D.	CO <sub>2</sub> Emiss. and Removals from Soil													
5.E.	Other													
<b>6. Waste</b>		-1	-1	4	2	3	4	2	-2	0	-1	-5	1	-7
6.A.	Solid Waste Disposal on Land													
6.B.	Wastewater Handling	-1	-1	4	2	3	4	2	-2	0	-1	-4	1	-6
6.C.	Waste Incineration	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-3
6.D.	Other	1	1	1	1	1	1	1	1	1	1	0	1	1
<b>Memo Items:</b>														
<b>International Bunkers</b>			0						0	0	0		0	
<b>Multilateral Operations</b>														
<b>CO<sub>2</sub> Emissions from Biomass</b>														

Table 10.4 - Recalculation difference of F-gases emissions

GHG SOURCE AND SINK CATEGORIES		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		kton CO2 eq.												
<b>Total Actual Emissions</b>									0	0		0	0	0
HFCs									0	0		0	0	0
PFCs														
SF6									0					

Table 10.5 – Recalculation of total CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions

Year	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	2004 Subm. (kton CO <sub>2</sub> eq.)	2005 Subm. (kton CO <sub>2</sub> eq.)	Difference (%)	2004 Subm. (kton CO <sub>2</sub> eq.)	2005 Subm. (kton CO <sub>2</sub> eq.)	Difference (%)	2004 Subm. (kton CO <sub>2</sub> eq.)	2005 Subm. (kton CO <sub>2</sub> eq.)	Difference (%)
1990	49 703	49 185	-1.0	8 450	10 184	20.5	5 782	6 064	4.9
1991	50 332	49 738	-1.2	8 812	10 573	20.0	5 755	5 966	3.7
1992	53 186	52 563	-1.2	8 262	10 196	23.4	5 469	5 765	5.4
1993	51 313	50 890	-0.8	8 005	10 198	27.4	5 312	5 633	6.0
1994	51 626	51 090	-1.0	8 170	10 404	27.3	5 542	5 847	5.5
1995	54 392	54 051	-0.6	8 645	10 914	26.2	5 727	6 050	5.6
1996	50 545	50 260	-0.6	8 420	10 839	28.7	5 841	6 163	5.5
1997	53 424	53 344	-0.1	8 421	10 963	30.2	5 744	6 090	6.0
1998	56 795	56 948	0.3	8 789	11 527	31.2	5 782	6 112	5.7
1999	63 999	64 332	0.5	9 016	11 771	30.6	6 224	6 403	2.9
2000	62 593	62 358	-0.4	8 584	10 821	26.1	5 870	6 107	4.0
2001	63 484	63 806	0.5	8 226	10 485	27.5	6 012	6 315	5.0
2002	65 858	67 239	2.1	8 365	10 830	29.5	6 097	6 374	4.6

## 10.2 Implications for emissions trends

The comparison of total GHG emissions of 2005 with the previous 2004 submission shows an increase of the national total GHG emissions, with higher estimated levels for both the base year (1990: 2.6%) and 2002: 5.0%. The recalculations resulted in an accentuation of the growing trend from 40.5% (2004 submission) to 43.8% (2005 submission) for the 1990-2002 period.

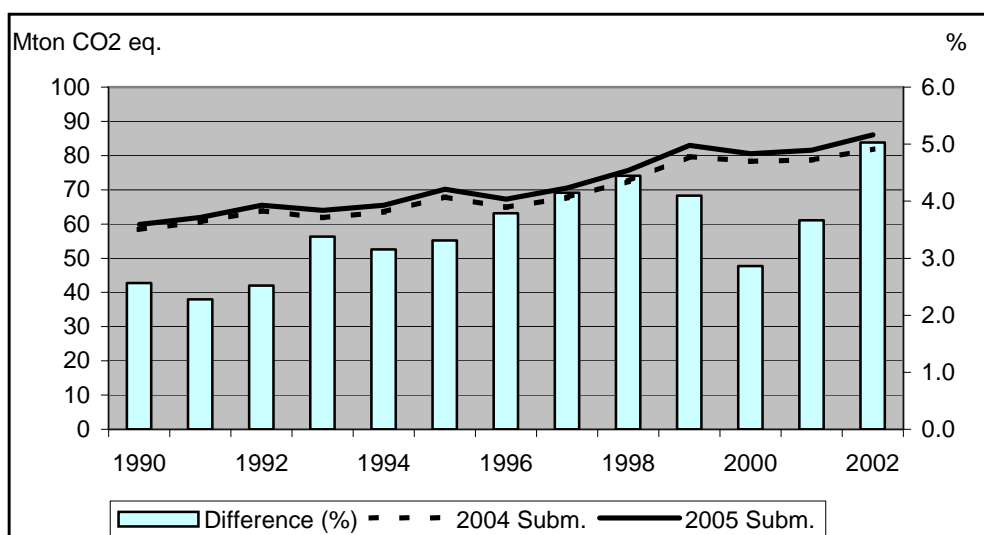
Figure 10.1 – Recalculation of total emissions trends (CO<sub>2</sub> from LUCFs excl.)



Table 10.6 – Recalculation of total emissions trends (CO<sub>2</sub> from LUCFs excl.)

Year	2004 Submission (kton CO <sub>2</sub> eq.)	2005 Submission (kton CO <sub>2</sub> eq.)	Difference (%)
1990	58 362	59 860	2.6
1991	60 576	61 955	2.3
1992	63 870	65 478	2.5
1993	61 863	63 953	3.4
1994	63 504	65 507	3.2
1995	67 895	70 144	3.3
1996	64 830	67 287	3.8
1997	67 702	70 510	4.1
1998	72 483	75 704	4.4
1999	79 692	82 959	4.1
2000	78 327	80 567	2.9
2001	78 646	81 530	3.7
2002	81 982	86 105	5.0

### 10.3 Future improvements

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

Source specific planned improvements are included in the respective sectoral sections or sub sections.

## LIST OF ACRONYMS

ABS	Acrylonitrile Butadiene Styrene	Acrilo Nitrilo Butadieno Estireno
AC	Air Conditioning	Ar condicionado
ACAP	Portuguese Association of Automobile Business	Associação do Comércio Automóvel de Portugal
AG	Aviation Gasoline	Gasolina de Aviação
AN	Ammonium Nitrate	Nitrato de Amónio
ANA	Airports and Air Navigation	Aeroportos e Navegação Aérea
ANAM	Madeira Island Airports and Air Navigation	Aeroportos e Navegação Aérea da Madeira
ANECRA	National Association of Companies of Automobile Business and Reparation	Associação Nacional das Empresas do Comércio e da Reparação Automóvel
APED	Portuguese Association of Distribution Companies	Associação Portuguesa de Empresas de Distribuição
APIRAC	National Association of Industry of Refrigeration and Air Conditioning	Associação Portuguesa dos Industriais da Refrigeração e Ar Condicionado
APORBET	Portuguese Association of Bituminous Mixes Producers	Associação Portuguesa de Fabricantes de Misturas Betuminosas
AS	Ammonium Sulphate	Sulfato de Amónia
ASN	Ammonium Sulphate Nitrate	Sulfonitrato de Amónia
BAT	Best Available Technologies	-
BOD	Biochemical Oxygen Demand	Carência Bioquímica de Oxigénio
BOF	Basic Oxygen Furnace	-
CAFE	Clean Air For Europe	-
CAN	Calcium Ammonium Nitrate	Nitrato de Cálcio-amónio
CDDR-LVT	Lisbon and Tagus Valley Coordination and Regional Development Commission	Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
CELPA	Portuguese Paper Industry Association	Associação da Indústria Papeleira
CFC	Chlorofluorocarbons	Clorofluorcarbonetos
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 (ex DGE)	General Directorate for Geology and Energy	Direcção Geral de Geologia e Energia
DGE (ex DGI)	Enterprises General Directorate	Direcção Geral das Empresas
DGRF	General Directorate for Forestry Resources	Direcção Geral dos Recursos Florestais
DGTT	General Directorate of Terrestrial Transportation	Direcção Geral dos Transportes Terrestres
DGV	National Entity responsible for road traffic	Direcção Geral de Viação
Distrito	Portuguese territorial unit comprehending several concelhos but not coincident with a region which is NUT II.	-
DOC	Degradable Organic Carbon	Carbono Orgânico Degradável
DOCF	Degradable Organic Carbon Dissimilated	-
DRAOT	Regional Directorate of Environment and Land Use Planning	Direcção Regional do Ambiente e Ordenamento do Território
EAF	Electric Arc Furnace	Forno Arco Eléctrico
EAPA	European Asphalt Pavement Association	-
EF	Emission Factors	Factores de Emissão
EMEP	Cooperative Programme for Monitoring and Evaluation of the Longrange Transmission of Air Pollutants in Europe	-
EPER	European Pollutant Emission Register	Registo Europeu de Emissões Poluentes
E-PRTR	European Pollutant Release and Transfer Register	-
FAEED	Federal Aviation Administration Aircraft Engine Emission Database	-
FAM	Animal Manure Nitrogen Applied to Soils	-
FAO	Food and Agriculture Organization of the United Nations	-
FCC	Fluidized-bed Catalytic Cracking	Cracking catalítico de leito fluidizado
FCR	Fixation in Crop Residues	-
FCT-UNL	Faculty of Science and Technology of New University of Lisbon	Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
FGR	Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that	-

	volatilises as 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	Hydrochlorofluorocarbons	-
HDPE	High Density Poly Ethylene	-
HDV	Heavy Duty Vehicles	Veículos Pesados de Mercadorias
HFC	Hydrofluorocarbons	-
IA	Institute for The Environment	Instituto do Ambiente
IAIT	Annual Survey to Manufacturing Industry	Inquérito Anual à Indústria Transformadora
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	Poliuição 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 traffic	Navegação Aérea
NCV	Net Calorific Value	-
NFI	National Forestry Inventories	Inventário Florestal Nacional
NFR	New Format Reporting	-
NH <sub>3</sub>	Ammoniac	Amoníaco
NM VOC	Non Methane Volatile Organic Compounds	Compostos Orgânicos Voláteis Não Metânicos (COVNM)
NO <sub>x</sub>	Nitrogen Oxides (NO + NO <sub>2</sub> )	Óxidos de Azoto (NO+NO <sub>2</sub> )
NPK	Nitrogen, Phosphorus and Potassium	Nitrogénio, Fósforo e Potássio
NSS	Normal Super Phosphates	Superfosfatos simples
NUTS (0..III)	Nomenclature of Territorial Units for Statistics	Nomenclatura de Unidades Territoriais para fins estatísticos
OD	Origin - Destiny	Origem - Destino
ODS	Ozone Depleting Substances	-
OECD	Organization for Economic Co-operation and Development	Organização para a Cooperação e Desenvolvimento Económico (OCDE)
OX	Oxidation Factor	Factor de Oxidação
PAF	Florestal Action Program	Programa de Acção Florestal
PAH	Polycyclic Aromatic Hydrocarbons	Hidrocarbonetos Aromáticos Policíclicos
PCI	Low Heating Value (LHV)	Poder Calorífico Inferior
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

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## 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.
- EDP-Electricidade de Portugal, 2004. Relatório de Ambiente 2003 - 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 Ferreira, 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, "Ferrous Alloy 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 Pulp", 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

## ANNEX A: KEY SOURCE CATEGORY ANALYSIS

### 10.4 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.

### 10.5 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 2005 Portuguese inventory estimates (1990-2003). The Tier 2 method could not yet been used, as the results from the uncertainty estimates study were not available in time to be considered. This method is however more sophisticated, as it incorporates source category uncertainty estimates, and should be applied in next submission.

#### 10.5.A 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 (1990-2003), according to the following equation:

Source Category Level Assessment = Source Category estimate / Total estimate

$$L_{x,t} = E_{x,t} / E_t$$

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>136</sup>.

### 10.5.B 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:

$$\text{Source Category Trend Assessment} = (\text{Source Category Level assessment}) \bullet |(\text{Source Category Trend} - \text{Total trend})|$$

$$T_{x,t} = L_{x,t} \bullet | [((E_{x,t} - E_{x,0}) / E_{x,t}) - ((E_t - E_0) / E_t)] |$$

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)

### 10.5.C 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.

## 10.6 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.

<sup>136</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.



In last submission, a very detailed split of source categories was performed. As recommended by the 2004 in-country review report, the level of disaggregation was revised for the 2005 submission in order to enhance the usefulness of the analysis. In a general way, the source categories have been split into (sub)categories that have been estimated using the same methodology and emission factors.

The analysis resulted in the identification of 45 key sources that are listed in the table A-1, which cover 97.3% of total GHG emissions in 2003.

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-2.15 contain data for each inventory year's level assessment and trend assessment for 1990-2003.

The most important sources for all year's level assessment are CO<sub>2</sub> emissions from combustion of fossil fuels in Road Transportation (1A3b) (diesel and gasoline together) and Public Electricity and Heat Production (1A1a) (solid fuels – coal and liquid fuels – Oil (in 2003 liq. fuels are relatively less important)). CO<sub>2</sub> emissions from combustion in Manufacturing Industries and Construction – Other (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 have probably been considered as non-key sources if considered separately. Another important source is CO<sub>2</sub> emissions from Cement production (2A1), which appear among the sixth most important.

Other main large contributors to the level assessment for each year are: N<sub>2</sub>O emissions from Agricultural Soils (4D), CH<sub>4</sub> emissions from Municipal Solid Waste Disposal (6A) and Industrial Waste (6A3), and Enteric Fermentation (4A); CO<sub>2</sub> emissions from Petroleum refining (1A1b) (liquid fuels); CO<sub>2</sub> emissions from Commercial/Institutional and residential categories (1A4a and 1A4b) (liquid fuels); CO<sub>2</sub> emissions from Ammonia Production (2B1); CH<sub>4</sub> and N<sub>2</sub>O emissions from Manure Management (4B).

Among other main emissions are: CO<sub>2</sub> emissions from combustion in Chemical industry (1A2c) (liquid fuels), Food Processing, Beverages and Tobacco (1A2e) (liquid fuels) and Paper, Pulp and Print industries (1A2d) (liquid fuels); CH<sub>4</sub> emissions from Domestic and Commercial Wastewater Handling (6B2); N<sub>2</sub>O emissions from processes in Nitric Acid Production (2B2). Lime production (2A2) is also a key source identified by its CO<sub>2</sub> emissions contribution to the level assessment since 1997 (this subcategory was not identified previously as it was not assessed separately).

The importance of CH<sub>4</sub> emissions from Wildfires (5E) depends on the yearly burnt area which relies on variable conditions (mostly climatic). 2003 is the year that registered the greatest extent of burnt areas and where the level assessment of the category is the most significant.

CO<sub>2</sub> emissions from road transports appear as the biggest contributor to the trend 1990-2003. 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 the sectors that contribute the most to the overall trend is: Public Electricity and Heat Production (1A1a) (liquid and gaseous 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 – Other (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. N<sub>2</sub>O emissions from Agricultural Soils (4D) is

another sector identified by the trend analysis, which appears as a decline due to the decrease on fertilizer consumption.

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 (1990-2003) based on Tier 1 approach (1/2)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Key source Category Flag	Criteria for Identification	Comments	2003 emissions estimate (kton CO2 eq.)
1 A 3 b Road Transportation	Liquid Fuels	CO2	√	Level Trend	All years	18747
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	√	Level Trend	All years	11648
1 A 2 f Other	Liquid Fuels	CO2	√	Level Trend	All years	3991
2 A 1 Cement Production	Production Quantities	CO2	√	Level Trend	All years	3538
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	√	Level Trend	All years	3190
4 D AGRICULTURAL SOILS	Input to Soils	N2O	√	Level Trend	All years	3170
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	√	Level Trend	All years	2969
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	√	Level Trend	All years	2890
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	√	Level Trend	1998, 1999, 2000, 2001, 2002, 2003	2674
1 A 1 b Petroleum refining	Liquid Fuels	CO2	√	Level	All years	2497
4 A ENTERIC FERMENTATION	Population size	CH4	√	Level Trend	All years	2493
1 A 2 f Other	Gaseous Fuels	CO2	√	Level Trend	1998, 1999, 2000, 2001, 2002, 2003	2177
1 A 4 b Residential	Liquid Fuels	CO2	√	Level Trend	All years	1903
6 A 3 Other	Industrial W. Disposal on Land	CH4	√	Level Trend	All years	1892
2 B 1 Ammonia Production	Production Quantities	CO2	√	Level Trend	All years	1622
5 E OTHER	Wildfires	CH4	√	Level Trend	1990, 1991, 1995, 2000, 2001, 2002, 2003	1585
4 B MANURE MANAGEMENT	Animal Excretion	CH4	√	Level Trend	All years	1388
1 A 2 c Chemicals	Liquid Fuels	CO2	√	Level Trend	All years	1231
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	√	Level Trend	All years	1068
4 B MANURE MANAGEMENT	Animal Excretion	N2O	√	Level Trend	All years	1032
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	√	Level Trend	All years	893
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	√	Level Trend	All years	632
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	√	Level Trend	All years	627
2 B 2 Nitric Acid Production	Production Quantities	N2O	√	Level Trend	All years	597
1 A 2 f Other	Solid Fuels	CO2	√	Level Trend	All years	539
1 A 3 b Road Transportation	Liquid Fuels	N2O	√	Level Trend	1997, 1998, 1999, 2000, 2001, 2002, 2003	518
1 B 2 a Oil	Liquid Fuels	CO2	√	Level Trend	1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003	503
2 A 2 Lime Production	Production Quantities	CO2	√	Level	1997, 1998, 1999, 2000, 2001, 2002, 2003	503
1 A 3 a ii Domestic	Liquid Fuels	CO2	√	Level	1992, 1993, 1994, 1996, 1998, 1999, 2000, 2001, 2002, 2003	394
1 A 4 b Residential	Gaseous Fuels	CO2	√	Level Trend	2001, 2002, 2003	371

Table A-1 – Portuguese key source categories (1990-2003) based on Tier 1 approach (2/2)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Key source Category Flag	Criteria for Identification	Comments	2003 emissions estimate (kton CO2 eq.)
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	√	Level Trend	2003	356
1 A 2 c Chemicals	Gaseous Fuels	CO2	√	Level Trend	2003	354
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	√	Level	All years	354
6 C WASTE INCINERATION	Waste Incinerated	CO2	√	Level Trend	2000, 2001, 2002, 2003	350
1 A 3 d ii National navigation	Liquid Fuels	CO2	√	Level Trend	1990, 1991, 1992, 1993, 1994, 1995, 1996, 2000, 2003	347
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	√	Trend		334
1 A 4 b Residential	Biomass	CH4	√	Level	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 2000, 2001, 2002	307
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	√	Trend		257
1 B 2 b Natural gas	Gaseous Fuels	CH4	√	Trend		244
1 B 2 d Other (Geothermal)	Energy Production	CO2	√	Trend		209
4 C RICE CULTIVATION	Culture Surface	CH4	√	Trend		159
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	√	Qual		40
2 F 2 Foam Blowing	Consumption	HFCs	√	Qual		22
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, 2001	0
<b>Sub-Total</b>		All gases				<b>80624</b>
<b>% of Total</b>		All gases				<b>97.3</b>
<b>TOTAL EMISSIONS</b>		All gases				<b>82903</b>

Tables A-2.1 to A.2-14 – Tier 1 Level assessment: 1990 to 2003

## Tier 1 Level Assessment (1990)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1990	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	9249	0.15	0.15
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	7659	0.13	0.28
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6301	0.11	0.39
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3515	0.06	0.45
1 A 2 f Other	Liquid Fuels	CO2	3368	3368	0.06	0.50
2 A 1 Cement Production	Production Quantities	CO2	3107	3107	0.05	0.55
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2594	0.04	0.60
1 A 2 f Other	Solid Fuels	CO2	2103	2103	0.04	0.63
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2052	0.03	0.67
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1910	0.03	0.70
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	1839	0.03	0.73
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1660	0.03	0.76
1 A 4 b Residential	Liquid Fuels	CO2	1621	1621	0.03	0.78
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1558	0.03	0.81
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1317	0.02	0.83
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	943	0.02	0.85
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	820	0.01	0.86
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	744	0.01	0.87
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	743	0.01	0.89
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	706	0.01	0.90
2 B 1 Ammonia Production	Production Quantities	CO2	569	569	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	567	0.01	0.92
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	470	0.01	0.93
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	466	0.01	0.93
5 E OTHER	Wildfires	CH4	441	441	0.01	0.94
1 A 4 b Residential	Biomass	CH4	343	343	0.01	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	286	0.00	0.95
4 C RICE CULTIVATION	Culture Surface	CH4	256	256	0.00	0.96
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	245	0.00	0.96
2 A 2 Lime Production	Production Quantities	CO2	178	178	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	173	173	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	CH4	164	164	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	161	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	154	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	151	0.00	0.98
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	128	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	73	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CO2	67	67	0.00	0.98
1 B 1 a Coal Mining	Solid Fuels	CH4	66	66	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	64	0.00	0.99
2 B 5 Other	Production Quantities	CO2	64	64	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	63	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	56	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	49	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	49	0.00	0.99
5 E OTHER	Wildfires	N2O	45	45	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	44	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	42	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	37	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	36	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	35	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	27	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	25	0.00	1.00
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	24	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	19	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	18	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	15	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	12	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	11	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CO2	9	9	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	8	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	4	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	2	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	2	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	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
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	1.00

1 A 2 c Chemicals	Biomass	N2O	1	1	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 3 d ii National navigation	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 a ii Domestic	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (1991)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1991	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	9871	0.16	0.16
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	8123	0.13	0.29
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6655	0.11	0.40
1 A 2 f Other	Liquid Fuels	CO2	3368	3448	0.06	0.45
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3396	0.05	0.51
2 A 1 Cement Production	Production Quantities	CO2	3107	3200	0.05	0.56
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2563	0.04	0.60
1 A 2 f Other	Solid Fuels	CO2	2103	2245	0.04	0.64
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2098	0.03	0.67
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	1972	0.03	0.70
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1752	0.03	0.73
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1718	0.03	0.76
1 A 4 b Residential	Liquid Fuels	CO2	1621	1700	0.03	0.79
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1552	0.03	0.81
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1376	0.02	0.83
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	937	0.02	0.85
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	894	0.01	0.86
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	830	0.01	0.88
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	810	0.01	0.89
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	700	0.01	0.90
5 E OTHER	Wildfires	CH4	441	695	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	534	0.01	0.92
2 B 1 Ammonia Production	Production Quantities	CO2	569	447	0.01	0.93
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	438	0.01	0.94
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	414	0.01	0.94
1 A 4 b Residential	Biomass	CH4	343	328	0.01	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	290	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	256	0.00	0.96
4 C RICE CULTIVATION	Culture Surface	CH4	256	253	0.00	0.96
2 A 2 Lime Production	Production Quantities	CO2	178	188	0.00	0.96
1 A 3 c Railways	Liquid Fuels	CO2	173	181	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	CH4	164	179	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	176	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	158	0.00	0.97
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	134	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	94	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	86	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	84	0.00	0.98
5 E OTHER	Wildfires	N2O	45	71	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	70	0.00	0.98
1 A 4 b Residential	Biomass	N2O	73	69	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CO2	67	65	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CH4	66	64	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	62	0.00	0.99
2 B 5 Other	Production Quantities	CO2	64	62	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	61	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	52	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	48	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	46	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	44	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	38	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	37	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	35	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	32	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	30	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	28	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	18	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	18	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	13	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
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
1 B 1 a Coal Mining	Solid Fuels	CO2	9	8	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	8	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	7	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	7	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	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
1 A 2 f Other	Solid Fuels	N2O	5	5	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	3	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	3	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	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
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	Liquid Fuels	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
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
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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 3 d ii National navigation	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 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00



## Tier 1 Level Assessment (1992)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1992	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	10743	0.16	0.16
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	9294	0.14	0.31
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	8344	0.13	0.43
1 A 2 f Other	Liquid Fuels	CO2	3368	3453	0.05	0.49
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3235	0.05	0.54
2 A 1 Cement Production	Production Quantities	CO2	3107	3067	0.05	0.58
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2554	0.04	0.62
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2145	0.03	0.65
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2110	0.03	0.69
1 A 2 f Other	Solid Fuels	CO2	2103	2088	0.03	0.72
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1914	0.03	0.75
1 A 4 b Residential	Liquid Fuels	CO2	1621	1800	0.03	0.78
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1681	0.03	0.80
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1556	0.02	0.82
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1351	0.02	0.85
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	935	0.01	0.86
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	934	0.01	0.87
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	909	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	888	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	697	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	673	0.01	0.92
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	502	0.01	0.93
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	410	0.01	0.94
2 B 1 Ammonia Production	Production Quantities	CO2	569	335	0.01	0.94
1 A 4 b Residential	Biomass	CH4	343	317	0.00	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	298	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	265	0.00	0.95
5 E OTHER	Wildfires	CH4	441	220	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	193	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	190	0.00	0.96
2 A 2 Lime Production	Production Quantities	CO2	178	187	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	181	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	160	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	160	0.00	0.97
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	145	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	98	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	92	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	90	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	86	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	81	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CO2	67	75	0.00	0.98
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	68	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	68	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	67	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	63	0.00	0.99
2 B 5 Other	Production Quantities	CO2	64	63	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	62	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CH4	66	60	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	47	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	47	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	42	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	39	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	38	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	36	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	34	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	23	0.00	1.00
5 E OTHER	Wildfires	N2O	45	22	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	20	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	15	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
1 A 3 c Railways	Liquid Fuels	N2O	11	12	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
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	8	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	8	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CO2	9	8	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	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 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	4	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	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	N2O	2	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	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
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 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

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
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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	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 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CO2	1	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00
2 A 7 Other	Production Quantities	CH4	0	0	0.00	1.00
2 B 1 Ammonia Production	Production Quantities	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (1993)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1993	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	11192	0.17	0.17
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	9187	0.14	0.32
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6443	0.10	0.42
1 A 2 f Other	Liquid Fuels	CO2	3368	3726	0.06	0.48
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3239	0.05	0.53
2 A 1 Cement Production	Production Quantities	CO2	3107	3125	0.05	0.58
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2541	0.04	0.62
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2251	0.04	0.65
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2192	0.03	0.69
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	1906	0.03	0.72
1 A 4 b Residential	Liquid Fuels	CO2	1621	1890	0.03	0.75
1 A 2 f Other	Solid Fuels	CO2	2103	1888	0.03	0.78
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1703	0.03	0.80
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1530	0.02	0.83
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1188	0.02	0.84
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	978	0.02	0.86
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	932	0.01	0.87
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	914	0.01	0.89
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	871	0.01	0.90
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	697	0.01	0.91
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	694	0.01	0.92
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	414	0.01	0.93
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	321	0.01	0.94
1 A 4 b Residential	Biomass	CH4	343	310	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	305	0.00	0.95
2 B 1 Ammonia Production	Production Quantities	CO2	569	281	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	257	0.00	0.95
2 A 2 Lime Production	Production Quantities	CO2	178	230	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.96
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	179	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	170	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	166	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	166	0.00	0.97
5 E OTHER	Wildfires	CH4	441	132	0.00	0.98
4 C RICE CULTIVATION	Culture Surface	CH4	256	100	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	90	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	88	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	83	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	82	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.98
1 B 2 a Oil	Liquid Fuels	CO2	67	74	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	70	0.00	0.99
2 B 5 Other	Production Quantities	CO2	64	68	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	67	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	66	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	58	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CH4	66	55	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	44	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	43	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	40	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	37	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	36	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	34	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	33	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	20	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	17	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00	1.00
5 E OTHER	Wildfires	N2O	45	13	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	13	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	13	0.00	1.00
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
1 A 2 f Other	Liquid Fuels	CH4	6	9	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	8	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CO2	9	7	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	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
1 A 2 f Other	Solid Fuels	N2O	5	4	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	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	N2O	2	3	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	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 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 B 2 d Other (Geothermal)	Energy Production	CO2	2	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid 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 f Other	Solid Fuels	CH4	2	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
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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 3 d ii National navigation	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	Liquid Fuels	N2O	1	1	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid 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 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00
2 A 7 Other	Production Quantities	CH4	0	0	0.00	1.00
2 B 1 Ammonia Production	Production Quantities	CH4	0	0	0.00	1.00
6 B 3 Other	Wastewater	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	0	0.00	1.00

## Tier 1 Level Assessment (1994)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1994	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	11782	0.18	0.18
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	9617	0.15	0.33
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	4675	0.07	0.40
1 A 2 f Other	Liquid Fuels	CO2	3368	3785	0.06	0.46
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3241	0.05	0.51
2 A 1 Cement Production	Production Quantities	CO2	3107	3220	0.05	0.55
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2561	0.04	0.59
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2396	0.04	0.63
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2386	0.04	0.67
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2244	0.03	0.70
1 A 2 f Other	Solid Fuels	CO2	2103	2055	0.03	0.73
1 A 4 b Residential	Liquid Fuels	CO2	1621	1910	0.03	0.76
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1773	0.03	0.79
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1504	0.02	0.81
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1268	0.02	0.83
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	1136	0.02	0.85
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	1052	0.02	0.86
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	937	0.01	0.88
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	885	0.01	0.89
2 B 1 Ammonia Production	Production Quantities	CO2	569	775	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	691	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	645	0.01	0.92
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	489	0.01	0.93
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	348	0.01	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	313	0.00	0.94
1 A 4 b Residential	Biomass	CH4	343	307	0.00	0.95
1 B 2 a Oil	Liquid Fuels	CO2	67	258	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	257	0.00	0.95
2 A 2 Lime Production	Production Quantities	CO2	178	248	0.00	0.96
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	214	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	182	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	168	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	165	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	145	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	109	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	102	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	96	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	83	0.00	0.98
5 E OTHER	Wildfires	CH4	441	75	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	74	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	72	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	67	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	65	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	48	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	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 2 a Oil	Liquid Fuels	CH4	35	45	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	44	0.00	0.99
1 B 1 a Coal Mining	Solid Fuels	CH4	66	41	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	38	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	35	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	28	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	27	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	20	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	14	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
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
1 A 2 f Other	Liquid Fuels	CH4	6	10	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	9	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
5 E OTHER	Wildfires	N2O	45	8	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CO2	9	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
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
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	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
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	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
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	1	0.00	1.00
1 A 5 Other	Solid Fuels	CO2	8	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	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
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 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
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00
2 A 7 Other	Production Quantities	CH4	0	0	0.00	1.00
2 B 1 Ammonia Production	Production Quantities	CH4	0	0	0.00	1.00
6 B 3 Other	Wastewater	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	0	0.00	1.00

## Tier 1 Level Assessment (1995)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1995	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	12406	0.18	0.18
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11031	0.16	0.33
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	5753	0.08	0.42
1 A 2 f Other	Liquid Fuels	CO2	3368	4181	0.06	0.48
2 A 1 Cement Production	Production Quantities	CO2	3107	3386	0.05	0.52
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3240	0.05	0.57
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2572	0.04	0.61
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2545	0.04	0.64
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2393	0.03	0.68
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2297	0.03	0.71
1 A 2 f Other	Solid Fuels	CO2	2103	1933	0.03	0.74
1 A 4 b Residential	Liquid Fuels	CO2	1621	1913	0.03	0.76
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1660	0.02	0.79
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1478	0.02	0.81
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1449	0.02	0.83
2 B 1 Ammonia Production	Production Quantities	CO2	569	1199	0.02	0.85
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	1108	0.02	0.86
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	951	0.01	0.88
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	927	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	886	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	688	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	600	0.01	0.92
5 E OTHER	Wildfires	CH4	441	485	0.01	0.93
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	445	0.01	0.93
1 B 2 a Oil	Liquid Fuels	CO2	67	415	0.01	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	314	0.00	0.94
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	309	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	307	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	282	0.00	0.96
2 A 2 Lime Production	Production Quantities	CO2	178	268	0.00	0.96
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	245	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	168	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	164	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	162	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	134	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	107	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	103	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	90	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	84	0.00	0.99
2 B 5 Other	Production Quantities	CO2	64	77	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	74	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	72	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	70	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	61	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	56	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	52	0.00	0.99
5 E OTHER	Wildfires	N2O	45	49	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	49	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	37	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	34	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	31	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	22	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	21	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	20	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	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
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	11	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	10	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
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	8	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	7	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
1 A 2 f Other	Solid Fuels	N2O	5	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
1 A 2 f Other	Biomass	CH4	2	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 3 d ii National navigation	Liquid Fuels	N2O	4	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
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	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 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	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
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
1 A 2 a Iron and Steel	Solid Fuels	N2O	1	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CH4	66	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00
2 A 7 Other	Production Quantities	CH4	0	0	0.00	1.00
2 B 1 Ammonia Production	Production Quantities	CH4	0	0	0.00	1.00
6 B 3 Other	Wastewater	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	0	0.00	1.00



## Tier 1 Level Assessment (1996)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1996	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	13055	0.19	0.19
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	10161	0.15	0.35
1 A 2 f Other	Liquid Fuels	CO2	3368	4586	0.07	0.41
2 A 1 Cement Production	Production Quantities	CO2	3107	3313	0.05	0.46
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3306	0.05	0.51
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	2811	0.04	0.55
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2704	0.04	0.59
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2574	0.04	0.63
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2351	0.03	0.67
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2326	0.03	0.70
1 A 4 b Residential	Liquid Fuels	CO2	1621	2055	0.03	0.73
1 A 2 f Other	Solid Fuels	CO2	2103	1862	0.03	0.76
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1794	0.03	0.79
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1443	0.02	0.81
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1344	0.02	0.83
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	1194	0.02	0.85
2 B 1 Ammonia Production	Production Quantities	CO2	569	975	0.01	0.86
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	963	0.01	0.87
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	952	0.01	0.89
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	947	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	674	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	632	0.01	0.92
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	440	0.01	0.93
1 B 2 a Oil	Liquid Fuels	CO2	67	367	0.01	0.93
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	321	0.00	0.94
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	308	0.00	0.94
1 A 4 b Residential	Biomass	CH4	343	308	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	298	0.00	0.95
2 A 2 Lime Production	Production Quantities	CO2	178	293	0.00	0.96
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	276	0.00	0.96
4 C RICE CULTIVATION	Culture Surface	CH4	256	214	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	179	0.00	0.97
5 E OTHER	Wildfires	CH4	441	169	0.00	0.98
1 A 3 c Railways	Liquid Fuels	CO2	173	153	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	129	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	117	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	110	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	84	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	80	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	80	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	75	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	75	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	74	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	65	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	44	47	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	39	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	37	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	37	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	34	0.00	1.00
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	31	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	21	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	18	0.00	1.00
5 E OTHER	Wildfires	N2O	45	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	16	0.00	1.00
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	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	14	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	12	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	11	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	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
2 B 5 Other	Production Quantities	CH4	8	8	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	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
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
1 A 2 f Other	Biomass	CH4	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 3 d ii National navigation	Liquid Fuels	N2O	4	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
1 A 3 a ii Domestic	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 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 2 f Other	Solid Fuels	CH4	2	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	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
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
6 D OTHER WASTE	Industrial Waste Open Burning	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 2 c Chemicals	Other Fuels	N2O	0	1	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	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
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	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
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Solid Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 5 Other	Biomass	CH4	0	0	0.00	1.00
1 A 5 Other	Other Fuels	CH4	0	0	0.00	1.00
1 B 1 a Coal Mining	Solid Fuels	CH4	66	0	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 d Other (Geothermal)	Energy Production	CH4	0	0	0.00	1.00
2 A 7 Other	Production Quantities	CH4	0	0	0.00	1.00
2 B 1 Ammonia Production	Production Quantities	CH4	0	0	0.00	1.00
6 B 3 Other	Wastewater	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (1997)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1997	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	13815	0.20	0.20
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	10470	0.15	0.34
1 A 2 f Other	Liquid Fuels	CO2	3368	5309	0.08	0.42
2 A 1 Cement Production	Production Quantities	CO2	3107	3483	0.05	0.47
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3218	0.05	0.51
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3083	0.04	0.56
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2878	0.04	0.60
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2582	0.04	0.64
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2410	0.03	0.67
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2395	0.03	0.70
1 A 4 b Residential	Liquid Fuels	CO2	1621	2016	0.03	0.73
1 A 2 f Other	Solid Fuels	CO2	2103	1621	0.02	0.76
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	1527	0.02	0.78
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1492	0.02	0.80
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1489	0.02	0.82
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1436	0.02	0.84
2 B 1 Ammonia Production	Production Quantities	CO2	569	1433	0.02	0.86
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	1098	0.02	0.88
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	987	0.01	0.89
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	972	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	659	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	641	0.01	0.92
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	542	0.01	0.93
1 B 2 a Oil	Liquid Fuels	CO2	67	454	0.01	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	314	0.00	0.94
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	310	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	309	0.00	0.95
2 A 2 Lime Production	Production Quantities	CO2	178	307	0.00	0.95
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	305	0.00	0.96
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	242	0.00	0.96
4 C RICE CULTIVATION	Culture Surface	CH4	256	216	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	147	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	141	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	123	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	122	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	109	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	102	0.00	0.98
1 A 2 f Other	Gaseous Fuels	CO2	0	91	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	89	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	82	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	77	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	71	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	70	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
5 E OTHER	Wildfires	CH4	441	64	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	56	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	50	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	50	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	45	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	43	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	41	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	40	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	40	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	34	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	22	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	19	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	17	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	14	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	13	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	12	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	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
2 B 5 Other	Production Quantities	CH4	8	9	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	1.00
1 A 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
5 E OTHER	Wildfires	N2O	45	6	0.00	1.00
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	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
1 A 2 f Other	Solid Fuels	N2O	5	4	0.00	1.00
1 A 2 f Other	Biomass	CH4	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 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	3	0.00	1.00
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
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	Liquid Fuels	N2O	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 3 d ii National navigation	Liquid Fuels	N2O	4	2	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CO2	0	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 2 c Chemicals	Biomass	N2O	1	1	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	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
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Other Fuels	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (1998)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1998	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	15526	0.21	0.21
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	9623	0.13	0.33
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	5577	0.07	0.41
1 A 2 f Other	Liquid Fuels	CO2	3368	5253	0.07	0.48
2 A 1 Cement Production	Production Quantities	CO2	3107	3458	0.05	0.52
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3339	0.04	0.57
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	3084	0.04	0.61
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2589	0.03	0.64
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2483	0.03	0.67
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2469	0.03	0.71
1 A 4 b Residential	Liquid Fuels	CO2	1621	2122	0.03	0.73
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	1967	0.03	0.76
2 B 1 Ammonia Production	Production Quantities	CO2	569	1789	0.02	0.78
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1521	0.02	0.80
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1435	0.02	0.82
1 A 2 f Other	Solid Fuels	CO2	2103	1166	0.02	0.84
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	1109	0.01	0.85
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1078	0.01	0.87
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1010	0.01	0.88
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	938	0.01	0.89
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	831	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	645	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	485	0.01	0.92
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	448	0.01	0.92
1 A 2 f Other	Gaseous Fuels	CO2	0	441	0.01	0.93
1 B 2 a Oil	Liquid Fuels	CO2	67	431	0.01	0.94
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	366	0.00	0.94
2 A 2 Lime Production	Production Quantities	CO2	178	341	0.00	0.94
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	338	0.00	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	335	0.00	0.95
5 E OTHER	Wildfires	CH4	441	318	0.00	0.96
1 A 4 b Residential	Biomass	CH4	343	306	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	204	0.00	0.97
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	200	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	137	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	129	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	124	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	117	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	102	0.00	0.98
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	99	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	87	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	85	0.00	0.98
3 D OTHER	Other Use of Chemicals	CO2	80	82	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	75	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	68	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	54	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	52	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 a Oil	Liquid Fuels	CH4	35	46	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	45	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	44	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	44	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	38	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	34	0.00	0.99
5 E OTHER	Wildfires	N2O	45	32	0.00	0.99
1 A 2 c Chemicals	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 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	28	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	22	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	21	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CO2	0	20	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	20	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CO2	49	19	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	16	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	16	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	15	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	15	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	14	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	14	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	12	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	10	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	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 c Railways	Liquid Fuels	N2O	11	9	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
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 F 2 Foam Blowing	Consumption	HFCs	0	4	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	4	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	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 4 a Commercial / Institutional	Liquid Fuels	CH4	1	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	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
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
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 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	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 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
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 2 f Other	Solid Fuels	CH4	2	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 f Other	Gaseous Fuels	CH4	0	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	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 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	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 c Chemicals	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	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 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	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 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (1999)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 1999	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	16357	0.20	0.20
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	12279	0.15	0.35
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	5656	0.07	0.41
1 A 2 f Other	Liquid Fuels	CO2	3368	4807	0.06	0.47
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3924	0.05	0.52
2 A 1 Cement Production	Production Quantities	CO2	3107	3742	0.05	0.56
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	3279	0.04	0.60
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3243	0.04	0.64
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2595	0.03	0.67
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	2573	0.03	0.70
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2563	0.03	0.74
1 A 4 b Residential	Liquid Fuels	CO2	1621	2229	0.03	0.76
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	2151	0.03	0.79
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1554	0.02	0.81
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1425	0.02	0.82
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1142	0.01	0.84
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	1062	0.01	0.85
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1010	0.01	0.86
1 A 2 f Other	Solid Fuels	CO2	2103	956	0.01	0.87
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	943	0.01	0.89
1 A 2 f Other	Gaseous Fuels	CO2	0	897	0.01	0.90
2 B 1 Ammonia Production	Production Quantities	CO2	569	843	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	747	0.01	0.92
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	630	0.01	0.92
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	504	0.01	0.93
1 B 2 a Oil	Liquid Fuels	CO2	67	416	0.01	0.93
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	402	0.00	0.94
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	369	0.00	0.94
2 A 2 Lime Production	Production Quantities	CO2	178	352	0.00	0.95
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	347	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	302	0.00	0.96
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	254	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	197	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	191	0.00	0.97
5 E OTHER	Wildfires	CH4	441	172	0.00	0.97
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	144	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	144	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	135	0.00	0.98
1 A 2 c Chemicals	Other Fuels	CO2	63	134	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	116	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	100	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	99	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	93	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	86	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	42	80	0.00	0.98
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	80	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	79	0.00	0.99
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	77	0.00	0.99
1 A 4 b Residential	Gaseous Fuels	CO2	0	76	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	65	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	60	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	58	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	52	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	51	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	46	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	45	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	42	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
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	40	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	33	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	31	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	23	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	23	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	19	0.00	1.00
5 E OTHER	Wildfires	N2O	45	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	15	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 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	14	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	11	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	11	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	10	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	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 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	8	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	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 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
1 A 2 f Other	Biomass	CH4	2	4	0.00	1.00

1 A 2 f Other	Gaseous Fuels	CH4	0	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 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00	1.00
1 A 3 a ii Domestic	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 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 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 3 d ii National navigation	Liquid Fuels	N2O	4	2	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	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 c Chemicals	Liquid Fuels	CH4	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	Liquid Fuels	CH4	1	2	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 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	1	0.00	1.00
1 A 2 c Chemicals	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 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	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 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00



## Tier 1 Level Assessment (2000)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2000	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	18072	0.22	0.22
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11895	0.15	0.37
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	4268	0.05	0.42
1 A 2 f Other	Liquid Fuels	CO2	3368	4106	0.05	0.48
2 A 1 Cement Production	Production Quantities	CO2	3107	3723	0.05	0.52
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	3182	0.04	0.56
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3164	0.04	0.60
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2567	0.03	0.63
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2240	0.03	0.66
1 A 4 b Residential	Liquid Fuels	CO2	1621	2203	0.03	0.69
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	2143	0.03	0.71
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	2067	0.03	0.74
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1606	0.02	0.76
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1583	0.02	0.78
1 A 2 f Other	Gaseous Fuels	CO2	0	1436	0.02	0.80
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1425	0.02	0.82
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1278	0.02	0.83
1 A 2 f Other	Solid Fuels	CO2	2103	1218	0.02	0.85
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1016	0.01	0.86
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	991	0.01	0.87
2 B 1 Ammonia Production	Production Quantities	CO2	569	935	0.01	0.88
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	931	0.01	0.89
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	615	0.01	0.90
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	596	0.01	0.91
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	461	0.01	0.92
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	435	0.01	0.92
2 A 2 Lime Production	Production Quantities	CO2	178	384	0.00	0.93
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	381	0.00	0.93
5 E OTHER	Wildfires	CH4	441	380	0.00	0.93
1 B 2 a Oil	Liquid Fuels	CO2	67	372	0.00	0.94
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	361	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	347	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	301	0.00	0.95
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	250	0.00	0.95
1 A 2 c Chemicals	Solid Fuels	CO2	44	214	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.96
4 C RICE CULTIVATION	Culture Surface	CH4	256	180	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	163	0.00	0.97
1 A 4 b Residential	Gaseous Fuels	CO2	0	161	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	152	0.00	0.97
1 A 2 c Chemicals	Other Fuels	CO2	63	136	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	132	0.00	0.97
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	132	0.00	0.98
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	120	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	117	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	117	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	116	0.00	0.98
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	111	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	103	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	95	0.00	0.99
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	91	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	83	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	68	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	63	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	56	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	52	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	49	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	43	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	39	0.00	0.99
5 E OTHER	Wildfires	N2O	45	39	0.00	0.99
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO2	0	36	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	33	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	28	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	23	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	23	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	19	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	18	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	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
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	12	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	11	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	11	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	11	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	10	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	9	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	9	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	9	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	8	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
1 A 2 f Other	Gaseous Fuels	CH4	0	6	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00

1 A 2 f Other	Biomass	CH4	2	4	0.00	1.00
1 A 3 a ii Domestic	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
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
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	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 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	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
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 2 f Other	Solid Fuels	CH4	2	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 a Commercial / Institutional	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	Other Fuels	N2O	0	1	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	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	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 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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	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	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	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 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (2001)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2001	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	18369	0.23	0.23
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11009	0.14	0.36
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	5178	0.06	0.42
1 A 2 f Other	Liquid Fuels	CO2	3368	4292	0.05	0.48
2 A 1 Cement Production	Production Quantities	CO2	3107	3545	0.04	0.52
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3192	0.04	0.56
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2818	0.03	0.59
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2541	0.03	0.62
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	2493	0.03	0.66
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	2392	0.03	0.68
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2380	0.03	0.71
1 A 4 b Residential	Liquid Fuels	CO2	1621	1958	0.02	0.74
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1769	0.02	0.76
1 A 2 f Other	Gaseous Fuels	CO2	0	1752	0.02	0.78
2 B 1 Ammonia Production	Production Quantities	CO2	569	1434	0.02	0.80
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1423	0.02	0.82
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1398	0.02	0.83
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1357	0.02	0.85
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1027	0.01	0.86
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	965	0.01	0.87
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	775	0.01	0.88
1 A 2 f Other	Solid Fuels	CO2	2103	755	0.01	0.89
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	619	0.01	0.90
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	582	0.01	0.91
1 A 2 a Iron and Steel	Solid Fuels	CO2	466	514	0.01	0.91
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	481	0.01	0.92
1 B 2 a Oil	Liquid Fuels	CO2	67	448	0.01	0.93
2 A 2 Lime Production	Production Quantities	CO2	178	404	0.00	0.93
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	373	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	354	0.00	0.94
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	350	0.00	0.94
1 A 4 b Residential	Biomass	CH4	343	302	0.00	0.95
5 E OTHER	Wildfires	CH4	441	251	0.00	0.95
1 A 4 b Residential	Gaseous Fuels	CO2	0	248	0.00	0.95
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	242	0.00	0.96
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	232	0.00	0.96
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	215	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.96
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	199	0.00	0.97
4 C RICE CULTIVATION	Culture Surface	CH4	256	164	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	160	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	145	0.00	0.98
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	132	0.00	0.98
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	129	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	129	0.00	0.98
1 A 3 c Railways	Liquid Fuels	CO2	173	118	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	110	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	106	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	102	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	85	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	81	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	78	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	59	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	58	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	56	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	55	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 Venting and flaring	Liquid Fuels	CO2	49	52	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	42	0.00	0.99
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	36	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	34	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	28	0.00	1.00
5 E OTHER	Wildfires	N2O	45	25	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	23	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	23	0.00	1.00
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	21	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CO2	0	20	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	19	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	19	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	16	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	15	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	14	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	14	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	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 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	11	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	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 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CO2	25	9	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	9	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
1 A 2 f Other	Gaseous Fuels	CH4	0	7	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00

1 A 2 f Other	Biomass	CH4	2	4	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	4	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	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	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 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
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
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	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 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	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 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 e Food Processing, Beverages and Tobacco	Biomass	CH4	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	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
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	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	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
1 A 2 c Chemicals	Other 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 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (2002)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2002	Level Assess.	Cumulative Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	18831	0.22	0.22
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	12199	0.14	0.36
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	6484	0.08	0.44
1 A 2 f Other	Liquid Fuels	CO2	3368	4376	0.05	0.49
2 A 1 Cement Production	Production Quantities	CO2	3107	3824	0.04	0.53
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	3237	0.04	0.57
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3177	0.04	0.61
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2897	0.03	0.64
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	2527	0.03	0.67
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2504	0.03	0.70
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2492	0.03	0.73
1 A 4 b Residential	Liquid Fuels	CO2	1621	1949	0.02	0.75
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1936	0.02	0.77
1 A 2 f Other	Gaseous Fuels	CO2	0	1917	0.02	0.79
2 B 1 Ammonia Production	Production Quantities	CO2	569	1528	0.02	0.81
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1405	0.02	0.83
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1343	0.02	0.84
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1321	0.02	0.86
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1034	0.01	0.87
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	941	0.01	0.88
1 A 2 f Other	Solid Fuels	CO2	2103	757	0.01	0.89
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	700	0.01	0.90
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	623	0.01	0.91
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	590	0.01	0.91
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	509	0.01	0.92
1 B 2 a Oil	Liquid Fuels	CO2	67	438	0.01	0.92
2 A 2 Lime Production	Production Quantities	CO2	178	396	0.00	0.93
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	375	0.00	0.93
5 E OTHER	Wildfires	CH4	441	361	0.00	0.94
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	359	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	350	0.00	0.95
1 A 4 b Residential	Gaseous Fuels	CO2	0	311	0.00	0.95
1 A 4 b Residential	Biomass	CH4	343	302	0.00	0.95
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	292	0.00	0.96
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	277	0.00	0.96
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	243	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	241	0.00	0.96
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	221	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	194	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	179	0.00	0.98
4 C RICE CULTIVATION	Culture Surface	CH4	256	162	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	157	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	133	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	110	0.00	0.98
1 A 3 c Railways	Liquid Fuels	CO2	173	110	0.00	0.98
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	108	0.00	0.99
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	107	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	88	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	81	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	64	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	61	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	58	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	58	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	55	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	55	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	53	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	46	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	39	0.00	0.99
5 E OTHER	Wildfires	N2O	45	37	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	35	0.00	0.99
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	31	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	28	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	25	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	24	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	23	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	21	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	20	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	19	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	17	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	16	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	15	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	15	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	12	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	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	CH4	6	8	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	8	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	8	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	7	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	7	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00

1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	3	0.00	1.00
1 A 3 a ii Domestic	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
2 C 2 Ferroalloys Production	Production Quantities	CO2	3	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	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	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid 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	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	2	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid 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 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 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
1 A 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 1 a Public Electricity and Heat Production	Biomass	N2O	0	1	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	1	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	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	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	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	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00

## Tier 1 Level Assessment (2003)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2003	Level Assess.	Cumulativ e Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	18747	0.23	0.23
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11648	0.14	0.37
1 A 2 f Other	Liquid Fuels	CO2	3368	3991	0.05	0.41
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.04	0.46
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3190	0.04	0.50
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3170	0.04	0.53
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2969	0.04	0.57
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	2890	0.03	0.60
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	2674	0.03	0.64
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2497	0.03	0.67
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2493	0.03	0.70
1 A 2 f Other	Gaseous Fuels	CO2	0	2177	0.03	0.72
1 A 4 b Residential	Liquid Fuels	CO2	1621	1903	0.02	0.75
6 A 3 Other	Industrial Waste Disposal on Land	CH4	2052	1892	0.02	0.77
2 B 1 Ammonia Production	Production Quantities	CO2	569	1622	0.02	0.79
5 E OTHER	Wildfires	CH4	441	1585	0.02	0.81
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1388	0.02	0.82
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1231	0.01	0.84
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1068	0.01	0.85
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1032	0.01	0.86
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	893	0.01	0.88
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	632	0.01	0.88
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	627	0.01	0.89
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	597	0.01	0.90
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.01	0.90
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	518	0.01	0.91
1 B 2 a Oil	Liquid Fuels	CO2	67	503	0.01	0.92
2 A 2 Lime Production	Production Quantities	CO2	178	417	0.01	0.92
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	394	0.00	0.93
1 A 4 b Residential	Gaseous Fuels	CO2	0	371	0.00	0.93
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	356	0.00	0.94
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	354	0.00	0.94
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	354	0.00	0.94
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	350	0.00	0.95
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	347	0.00	0.95
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.96
1 A 4 b Residential	Biomass	CH4	343	307	0.00	0.96
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	257	0.00	0.96
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	244	0.00	0.97
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	209	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	CH4	164	208	0.00	0.97
6 B 1 Industrial Wastewater	Wastewater	N2O	161	205	0.00	0.97
2 A 7 Other	Production Quantities	CO2	64	168	0.00	0.98
5 E OTHER	Wildfires	N2O	45	161	0.00	0.98
4 C RICE CULTIVATION	Culture Surface	CH4	256	159	0.00	0.98
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	137	0.00	0.98
2 B 5 Other	Production Quantities	CO2	64	115	0.00	0.98
1 A 3 c Railways	Liquid Fuels	CO2	173	95	0.00	0.98
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	93	0.00	0.98
3 A PAINT APPLICATION	Paint application	CO2	42	91	0.00	0.99
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	86	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.99
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	75	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	64	0.00	0.99
1 A 2 c Chemicals	Solid Fuels	CO2	44	58	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	57	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	55	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	52	0.00	0.99
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	0.99
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	HFCs	0	40	0.00	0.99
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	35	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	28	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	24	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	23	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	23	0.00	1.00
2 F 2 Foam Blowing	Consumption	HFCs	0	22	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	21	0.00	1.00
1 A 2 f Other	Gaseous Fuels	N2O	0	17	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	17	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	14	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	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 2 f Other	Gaseous Fuels	CH4	0	9	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	8	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	7	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	1.00

1 A 2 f Other	Biomass	CH4	2	5	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	2	3	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	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	Gaseous Fuels	N2O	0	3	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	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 2 c Chemicals	Liquid Fuels	CH4	1	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 f Other	Solid Fuels	N2O	5	1	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	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
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	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 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	1	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	1	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Liquid Fuels	CH4	0	0	0.00	1.00
Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Gaseous Fuels	CH4	0	0	0.00	1.00
Industries	Biomass	CH4	0	0	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Other Fuels	CH4	0	0	0.00	1.00
Industries	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	1.00



Tables A-2.15 – Tier 1 Trend assessment: 1990-2003

## Tier 1 Trend Assessment (1990-2003)

IPCC SOURCE CATEGORIES	ACTIVITY	GHG	Base year Estimate (kton CO2 eq.) 1990	Current year Estimate (kton CO2 eq.) 2003	Trend Assess.	Contributi on to Trend	Cumulati ve Total
1 A 3 b Road Transportation	Liquid Fuels	CO2	9249	18747	0.05	0.15	0.15
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CO2	6301	3190	0.05	0.14	0.29
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CO2	0	2674	0.02	0.07	0.36
1 A 2 f Other	Solid Fuels	CO2	2103	539	0.02	0.06	0.42
1 A 2 f Other	Gaseous Fuels	CO2	0	2177	0.02	0.06	0.48
1 A 4 a Commercial / Institutional	Liquid Fuels	CO2	744	2890	0.02	0.05	0.53
4 D AGRICULTURAL SOILS	Input to Soils	N2O	3515	3170	0.01	0.04	0.57
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CO2	1660	1068	0.01	0.03	0.60
4 A ENTERIC FERMENTATION	Population size	CH4	2594	2493	0.01	0.03	0.63
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CO2	7659	11648	0.01	0.03	0.66
5 E OTHER	Wildfires	CH4	441	1585	0.01	0.03	0.68
	Industrial Waste Disposal on Land						
6 A 3 Other	CH4	CH4	2052	1892	0.01	0.02	0.71
2 B 1 Ammonia Production	Production Quantities	CO2	569	1622	0.01	0.02	0.73
4 B MANURE MANAGEMENT	Animal Excretion	CH4	1558	1388	0.01	0.02	0.75
2 A 1 Cement Production	Production Quantities	CO2	3107	3538	0.01	0.02	0.77
1 A 2 f Other	Liquid Fuels	CO2	3368	3991	0.01	0.02	0.79
1 A 2 c Chemicals	Liquid Fuels	CO2	1317	1231	0.01	0.02	0.80
6 A MUNICIPAL SOLID WASTE DISPOSAL ON LAND	SW Disposal on Land	CH4	1839	2969	0.00	0.01	0.81
1 B 2 a Oil	Liquid Fuels	CO2	67	503	0.00	0.01	0.82
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CO2	743	632	0.00	0.01	0.83
1 A 4 b Residential	Gaseous Fuels	CO2	0	371	0.00	0.01	0.84
1 A 4 a Commercial / Institutional	Gaseous Fuels	CO2	0	356	0.00	0.01	0.85
1 A 2 c Chemicals	Gaseous Fuels	CO2	0	354	0.00	0.01	0.86
6 B 2 Domestic and Commercial wastewater	Wastewater	CH4	706	627	0.00	0.01	0.87
1 A 4 b Residential	Liquid Fuels	CO2	1621	1903	0.00	0.01	0.88
1 A 3 b Road Transportation	Liquid Fuels	N2O	128	518	0.00	0.01	0.89
6 C WASTE INCINERATION	Waste Incinerated	CO2	10	350	0.00	0.01	0.90
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CO2	0	334	0.00	0.01	0.90
1 A 3 d ii National navigation	Liquid Fuels	CO2	470	347	0.00	0.01	0.91
4 B MANURE MANAGEMENT	Animal Excretion	N2O	943	1032	0.00	0.01	0.92
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CO2	0	257	0.00	0.01	0.93
1 B 2 b Natural gas	Gaseous Fuels	CH4	0	244	0.00	0.01	0.93
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CO2	820	893	0.00	0.01	0.94
1 B 2 d Other (Geothermal)	Energy Production	CO2	2	209	0.00	0.01	0.94
4 C RICE CULTIVATION	Culture Surface	CH4	256	159	0.00	0.01	0.95
2 B 2 Nitric Acid Production	Production Quantities	N2O	567	597	0.00	0.00	0.95
2 A 2 Lime Production	Production Quantities	CO2	178	417	0.00	0.00	0.96
1 A 4 b Residential	Biomass	CH4	343	307	0.00	0.00	0.96
1 A 1 b Petroleum refining	Liquid Fuels	CO2	1910	2497	0.00	0.00	0.97
1 A 3 c Railways	Liquid Fuels	CO2	173	95	0.00	0.00	0.97
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	N2O	151	86	0.00	0.00	0.97
1 A 2 a Iron and Steel	Liquid Fuels	CO2	154	93	0.00	0.00	0.98
5 E OTHER	Wildfires	N2O	45	161	0.00	0.00	0.98
2 A 7 Other	Production Quantities	CO2	64	168	0.00	0.00	0.98
1 A 2 a Iron and Steel	Gaseous Fuels	CO2	0	75	0.00	0.00	0.98
1 A 3 a ii Domestic	Liquid Fuels	CO2	245	394	0.00	0.00	0.98
6 B 2 Domestic and Commercial wastewater	Wastewater	N2O	286	354	0.00	0.00	0.98
	HFC						
2 F 1 Refrigeration and Air Conditioning Equipment	Consumption	s	0	40	0.00	0.00	0.99
1 A 4 b Residential	Biomass	N2O	73	65	0.00	0.00	0.99
3 A PAINT APPLICATION	Paint application	CO2	42	91	0.00	0.00	0.99
3 D OTHER	Other Use of Chemicals	CO2	80	80	0.00	0.00	0.99
2 A 3 Limestone and Dolomite Use	Production Quantities	CO2	24	64	0.00	0.00	0.99
1 A 2 c Chemicals	Other Fuels	CO2	63	57	0.00	0.00	0.99
6 C WASTE INCINERATION	Waste Incinerated	N2O	0	28	0.00	0.00	0.99
2 B 5 Other	Production Quantities	CO2	64	115	0.00	0.00	0.99
1 A 3 b Road Transportation	Liquid Fuels	CH4	56	52	0.00	0.00	0.99
1 B 2 c Venting and flaring	Liquid Fuels	CO2	49	42	0.00	0.00	0.99
	HFC						
2 F 2 Foam Blowing	Consumption	s	0	22	0.00	0.00	0.99
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	N2O	0	21	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
3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	Chemical manufacture and processing	CO2	86	137	0.00	0.00	0.99
1 A 2 f Other	Gaseous Fuels	N2O	0	17	0.00	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	N2O	37	35	0.00	0.00	1.00
2 C 1 Iron and Steel Production	Production Quantities	CO2	27	23	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	N2O	15	8	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	N2O	11	6	0.00	0.00	1.00
1 A 2 f Other	Gaseous Fuels	CH4	0	9	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CO2	3	12	0.00	0.00	1.00
4 F FIELD BURNING OF AGRICULTURAL WASTES	Residues Burning	CH4	18	17	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CO2	0	8	0.00	0.00	1.00
2 F 7 Electrical Equipment	Consumption	SF6	0	7	0.00	0.00	1.00
3 B DEGREASING AND DRY CLEANING	Degreasing and Dry Cleaning	CO2	12	10	0.00	0.00	1.00
1 B 2 a Oil	Liquid Fuels	CH4	35	43	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	N2O	2	9	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	N2O	5	1	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	N2O	36	55	0.00	0.00	1.00
1 A 2 f Other	Biomass	N2O	21	24	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	N2O	11	11	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CO2	3	1	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CO2	44	58	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	N2O	6	6	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	CH4	19	23	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00

1 A 2 c Chemicals	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Liquid Fuels	CH4	1	4	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CO2	20	30	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	N2O	0	3	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	N2O	5	5	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	N2O	4	3	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	N2O	11	13	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Liquid Fuels	CH4	3	2	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	N2O	9	11	0.00	0.00	1.00
1 A 2 f Other	Liquid Fuels	CH4	6	7	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	N2O	0	2	0.00	0.00	1.00
1 A 2 f Other	Biomass	CH4	2	5	0.00	0.00	1.00
1 A 2 f Other	Solid Fuels	CH4	2	1	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Biomass	N2O	11	14	0.00	0.00	1.00
2 C Ferroalloys Production	Production Quantities	CO2	3	3	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	N2O	2	2	0.00	0.00	1.00
6 C WASTE INCINERATION	Waste Incinerated	CH4	0	1	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	N2O	0	1	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	N2O	2	3	0.00	0.00	1.00
2 A 6 Road Paving with Asphalt	Production Quantities	CH4	1	2	0.00	0.00	1.00
2 B 5 Other	Production Quantities	CH4	8	11	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Biomass	CH4	1	1	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	N2O	0	1	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	N2O	2	3	0.00	0.00	1.00
1 A 3 d ii National navigation	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 3 a ii Domestic	Liquid Fuels	CH4	1	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	N2O	1	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Liquid Fuels	CH4	2	2	0.00	0.00	1.00
1 A 4 b Residential	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Liquid Fuels	CH4	1	2	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 b Residential	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Liquid Fuels	CH4	1	1	0.00	0.00	1.00
1 A 2 c Chemicals	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CO2	0	0	0.00	0.00	1.00
2 D 2 Food and Drink	Production Quantities	CO2	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Liquid Fuels	CH4	2	2	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Solid Fuels	CH4	1	2	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	N2O	1	1	0.00	0.00	1.00
1 A 2 a Iron and Steel	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	N2O	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	N2O	1	2	0.00	0.00	1.00
1 A 2 a Iron and Steel	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CO2	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	N2O	0	0	0.00	0.00	1.00
2 B 5 Other	Production Quantities	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	N2O	0	0	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 f Other	Other Fuels	N2O	0	0	0.00	0.00	1.00
6 D OTHER WASTE	Industrial Waste Open Burning	CH4	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 c Chemicals	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 B 2 c Venting and flaring	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 3 c Railways	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 c Agriculture / Forestry / Fishing	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 1 a Public Electricity and Heat Production	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 1 b Petroleum refining	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
Industries	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
Industries	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 1 c Manufacture of Solid fuels and Other Energy	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 a Iron and Steel	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Biomass	CH4	0	0	0.00	0.00	1.00
1 A 2 b Non-ferrous Metals	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 d Pulp, Paper and Print	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 2 e Food Processing, Beverages and Tobacco	Other Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 e Other Transportation	Liquid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 e Other Transportation	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 3 e Other Transportation	Gaseous Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Solid Fuels	CH4	0	0	0.00	0.00	1.00
1 A 4 a Commercial / Institutional	Other Fuels	CH4	0	0	0.00	0.00	1.00

## ANNEX B: UNCERTAINTY ANALYSIS METHODOLOGY

### 10.7 B.1 Introduction

Uncertainty in results of the GHG inventory of emissions results from natural variability of emission processes, incomplete knowledge of emission sources and definition, errors and gaps in data collection and statistical information, incorrect determination and choice of emission factors and parameter due to errors in original monitoring data, reference studies and expert judgement.

Uncertainty values are defined as the range of 95% confidence interval (IPCC,1997; IPCC,2000), meaning that there is a 95% probability that the actual value of the quantity (activity data, emission factor or emission) is within the interval defined by the confidence limits.

The uncertainty analysis was performed only for the direct GHG: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC and SF<sub>6</sub>, considering all emissions in CO<sub>2</sub> equivalent (CO<sub>2</sub>e). The uncertainty of all source activities was determined, with the exception of the source category IPCC 5

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

### 10.8 B. 2 Methodology Issues

#### 10.8.A Level of Analysis

The level at which uncertainties are estimated was determined at the level at which different uncertainty values must be attributed. Therefore the following factors were considered:

- Origin of activity data. A different level was defined whenever activity data resulted from a different origin, including different classes in Energy Balance. In the case when Large Point Source (LPS) was used to estimate part of emissions from a given source sector the uncertainty analysis had to be done independently for that fraction, because error is different, and uncertainty level was independently made for emissions from LPS and from the remaining Area sources. This separation is also very important in agriculture where different animal types have very different levels of error in activity data;
- Emission Factor. A different class is used for sub-sources whenever different emission factors were used. For example, that has caused the detailed consideration of emissions for each product from organic chemical industry (PVC, Polypropylene, etc) because emission factors have different origins. In the same way fuels (e.g. biomass) were analyzed independently in situations where uncertainty values are different;
- For certain processes, if the emission estimate depends of different parts of the product life-time, uncertainty analysis was done at the lowest level also. That is the case of aviation, where separation is done for LTO and cruise emissions, and fluorine gas emissions from refrigeration equipment, where uncertainty analysis was performed independently for assembly, operation and disposal;

## 10.8.B Uncertainty Values

The uncertainty values that were used were set from:

- Good Practice Guidebook (IPCC,2000);
- references to emission factors, such as AP42<sup>137</sup>;
- comparison of several sources of information. For example, comparison to international sources such as FAO, IEA;
- inter-annual un expected variations of activity data;
- statistical variation in the determination of country-specific emission factors, for different units or different years.

The actual uncertainty values that were used for each activity source are reported in main text under methodological considerations for each source.

To avoid an excessive influence of expert judgement from the team that performs the inventory in uncertainty levels definition an exterior technician, not involved in inventory preparation, has helped the choice of uncertainty levels. Nevertheless insight into the inventory is only possible to be assessed from the inventory team for more complex sources (agriculture and wastes for example) and the desired independence was partly affected.

## 10.8.C Error propagation

Two different rules were used in error propagation (IPCC,2000):

Rule A: For the case when the quantities are to be combined by addition, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms;

$$U_{Total} = \frac{\{\sum_i [U_i * x_i]\}^{0.5}}{\sum_i [x_i]}$$

Where:

$U_{total}$  is the percentage uncertainty in the sum of the quantities expressed as a percentage;

<sup>137</sup> In this reference source quality codes are usually reported from A (good quality) to E (poor quality). The following conversion rules was used in uncertainty assessment:

A	5 %
B	10 %
C	50 %
D	100 %
E	1 000 %

$x_i$  and  $U_i$  are the uncertain quantities and the percentage uncertainties associated with them, respectively;

Rule B: quantities are to be combined by multiplication, a simpler rule applies:

$$U_{\text{Total}} = \sum_i [U_i^2]$$

-  $U_{\text{total}}$  is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

-  $U_i$  are the percentage uncertainties associated with each of the quantities.